Department of Energy
Carlsbad Area Office
P. O. Box 3090
Carlsbad, New Mexico 88221

June 17, 1996

RECEIVED
HAZARDOUS WASTE
PROGRAM

Mr. Elliot P. Laws
Assistant Administor
U.S. Environmental Protection Agency
401 M. Street, SW
Washington, D.C. 20460

Subject: No-Migration Variance Petition

Dear Mr. Laws:

I am pleased to submit for your review and approval, the Department of Energy's No-Migration Variance Petition (NMVP) for disposal operations at the Waste Isolation Pilot Plant (WIPP). We are providing the remaining copies requested by your staff to Dr. Matt Hale, Director of the Permits & State Programs Division in the Office of Solid Waste (OSW).

The process to begin development of this particular submittal for the disposal phase began in earnest in August 1994. We, the Carlsbad Area Office (CAO) and staff from the OSW, have been in regular contact since that date. In May 1995, we provided the OSW a draft NMVP that covered the operational time period of the WIPP facility. Subsequently, we received comments on the draft NMVP. Therefore, between discussions with the OSW staff and comments received, we believe that all concerns regarding the operational phase draft NMVP have been fully addressed. We now look forward to working with you and your staff during the review of the final NMVP.

If you have any questions or require further information, please do not hesitate to contact me at (505) 234-7300.

Sincerely,

George E. Dials

George E. Dials, Manager
Carlsbad Area Office

Enclosure

CAO:GED96-1446

960612

cc w/ enclosure:
M. Hale, EPA (6)
D. Neleigh, EPA (3)

cc wo/enclosure:
A. Alm, EM-1

DOE/CAO-96-2160

Final
No-Migration
Variance Petition

June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume I of VIII

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APPENDICES

AAC Active Access Controls AAC-1
ADM Air Dispersion Modeling ADM-1
BAD Background Air Data BAD-1
BECR Biennial Environmental Compliance Report BECR-1
BH Borehole Data BH-1
BRAGFLO Brine and Gas Flow BRAGFLO-1
BWQ Background Water Quality BWQ-1
CLI Climatology CLI-1
CLP Closure Plans CLP-1
CMP Confirmatory Monitoring Plan CMP-1
CONT Contingency Plan CONT-1
D&D Decontamination and Decommissioning ..... D&D-1
DEF Deformation DEF-1
DIF Diffusion DIF-1
GAS Gas-Generation GAS-1
GCR Geological Characterization Report GCR-1
LTHBL Long-Term Health-Based Level LTHBL-1
LTM Long-Term Monitoring LTM-1
MASS Modeling Assumptions MASS-1
OUTPUT Output OUTPUT-1
PAR Parameter Sheets PAR-1
PMR Permanent Marker Report PMR-1
QAPD Quality Assurance Program Description QAPD-1
REG Regulatory Interpretations REG-1
RA Risk Assessment RA-1
RM Rock Mechanics RM-1
SCR Screening SCR-1
SER Annual Site Environmental Report for Calendar Year 1993 ..... SER-1
SUM Summary of Site-Characterization Studies SUM-1
SURV Aerial Surveys SURV-1
VOC VOC Screening Methodology VOC-1
WAP Waste Analysis Plan WAP-1

EXECUTIVE SUMMARY

The United States Department of Energy (DOE) is responsible for the disposition of transuranic (TRU) waste generated by the production of nuclear weapons and other defense-related activities. Approximately 2.63 million ft^3 (74,500 m^3) of these wastes have been generated and are retrievably stored at government installations across the country. It is projected that additional volumes of this waste will be generated through decontamination and decommissioning activities in the future. The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico at a latitude of 32 degrees, 22 minutes, 11 seconds, north and a longitude of 103 degrees, 47 minutes, 30 seconds, west, was sited and constructed to meet the criteria established by the scientific and regulatory community for the safe, permanent disposal of TRU and TRU mixed wastes. The Environmental Protection Agency (EPA) Identification Number for the WIPP facility is NM4890139088.

TRU waste is defined as waste that contains more than 100 nanocuries of alpha-emitting TRU isotopes, with half-lives greater than 20 years, per gram of waste. TRU-mixed waste is waste that contains both hazardous waste and source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954 that is classified as TRU waste. In order to permanently dispose of TRU mixed waste, the DOE has elected to petition the EPA for a variance from the Land Disposal Restrictions (LDR) of the Resource Conservation and Recovery Act (RCRA), which are codified in Title 40 of the Code of Federal Regulations (CFR) Part 268. According to the provisions of 40 CFR §268.6, it may be demonstrated "to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit...for as long as the wastes remain hazardous." This document fulfills the requirements for the portions of a No-Migration Variance Petition (NMVP), as outlined in 40 CFR § 268.6, and provides a demonstration of no-migration for the operational time frame as well as after closure of the facility.

The NMVP contains the following information:

- Chapter 1 provides a brief discussion of the history of the WIPP project, a summary of the site selection process, and a discussion of how the NMVP is structured to demonstrate no migration for both the operational and post-closure periods.

- Chapter 2 provides geological and hydrological characteristics of the site and surrounding area. Geological descriptions include both regional and local geology including structure, subsurface geology, geomorphology, geologic stability, soils, and topography. Hydrological descriptions include groundwater and surface water and associated characteristics.

- Chapter 3 describes the facility systems with emphasis on those which prevent migration of hazardous constituents such as location, design, layout, and barriers.

- Chapter 4 describes the wastes to be managed and disposed of at the facility and incorporates the WIPP Waste Analysis Plan as submitted with the RCRA Part B permit application .

- Chapter 5 examines the potential environmental and human health impacts associated with the waste emplacement activities at the WIPP facility throughout its projected 25 years of operation, as well as potential impacts during the 10-year closure period.

- Chapter 6 details the monitoring activities planned at the WIPP facility.

- Chapter 7 describes quality assurance programs and plans for each of the activities to be completed in support of a no-migration variance.

- Chapter 8 examines the potential long-term environmental and human health impacts associated with disposed waste at the WIPP facility after closure.

- Chapter 9 provides an assessment of regulatory compliance with the no-migration standards.

- Chapter 10 contains the certification statement for this petition.

- Appendices should be considered part of this petition and detailed information in support of the main body of the text. This includes, for example, long-term model screening of features, events, and processes (FEPs).

The selected location of the WIPP facility was the result of extensive siting studies, which began in 1973. The study focused on salt beds and salt domes, because salt was recognized to be a good medium for a repository due to its low permeability and radiological shielding properties. The U.S. Geological Survey (USGS) and the Oak Ridge National Laboratory (ORNL) selected eastern New Mexico as the area which best satisfied the tentative selection criteria. After additional criteria were considered, the Los Medaños site was chosen as the location for the geologic repository.

The characterization of the WIPP site shows that the geology, hydrology, climatology, air quality, ecology, and cultural and natural resources are conducive to effective disposal of TRU mixed waste with no migration of hazardous constituents beyond the unit boundary.

The design and operation of the WIPP facility are protective of human health and the environment. Physical characteristics of the surface facilities, shafts and hoists, underground waste disposal and support facilities, emergency response, waste management support systems and engineered barriers combine to ensure that migration of hazardous constituents from the disposal unit is prevented. Site policies and procedures enhance the protection provided by the design of the facility through administrative controls.

The waste destined for disposal at the WIPP facility must meet a stringent set of criteria. These criteria were developed to address WIPP operational safety requirements, applicable Department of Transportation (DOT) requirements, applicable Nuclear Regulatory Commission (NRC) requirements, and applicable RCRA requirements. Waste analysis will be performed at the generator/storage sites, and these activities will be controlled through written operating procedures and verified through an audit program conducted by WIPP facility personnel. Through this program, sites are granted the authority to certify their waste as meeting the waste acceptance criteria and requirements. Certification makes waste eligible for disposal at the WIPP facility.

The DOE has interpreted "no migration" to mean that hazardous constituents shall not exceed agency-approved human health-based levels (HBLs) beyond the boundary of the disposal unit. Prior to final closure of the WIPP facility, the potential for migration of hazardous constituents exists because of the volatilization of organic compounds from waste containers through air. After closure, the potential exists for migration of contaminated gas and brine through the subsurface.

During waste emplacement, concentrations resulting from the release of volatile organic compounds (VOCs) from the repository will not exceed HBLs at the point of compliance. The point of compliance is 5.0 ft (1.5 m) above the ground surface within the WIPP site boundary near the Exhaust Shaft. The DOE has specified a point 5.0 ft (1.5 m) above the ground immediately adjacent to the underground ventilation exhaust duct as the no-migration boundary for emissions during operations and closure. This point has been selected, because it is the nearest point to the emission source where a hypothetical individual could be exposed to hazardous constituents from disposed waste. Calculations based on existing headspace VOC analyses and characteristics of the facility demonstrate that there will be no migration of hazardous constituents during waste emplacement activities above acceptable HBLs. In addition, during waste emplacement, the release of VOCs from the repository will not pose a significant health risk to the public outside the site boundary.

The long-term performance of the underground disposal unit has been modeled to demonstrate that there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous. For the post-closure period, the unit boundary used to demonstrate compliance for the Waste Isolation Pilot Plant (WIPP) facility is defined as the portion of the Salado Formation bounded laterally by the land-withdrawal area. Both gas flow and brine flow were examined using modeling techniques and bounding calculations, and the results show that the repository will be an effective disposal unit for TRU mixed waste for 10,000 years.

Various monitoring activities are conducted and will be conducted throughout the operational life of the facility. These activities include meteorological monitoring, air quality monitoring, water quality sampling, wildlife population monitoring, and aerial monitoring. VOC monitoring has been conducted since 1991. With more than four years

of data having been collected, a credible basis for determining the WIPP facility's background levels of the targeted VOCs has been established.

The concentrations of VOCs at the point of compliance during disposal operations and facility closure have been estimated to be one-third to five orders of magnitude below HBLs. Because these calculations were based on conservative assumptions, and because the DOE has collected more than four years of data to support the validity of background levels of VOCs in air, the DOE will implement confirmatory VOC monitoring activities into the disposal phase.

Quality assurance (QA) programs define the management systems to be employed to meet the requirements prescribed by the Carlsbad Area Office's (CAO's) Quality Assurance Program Document (QAPD). The purpose of specifying requirements for QA programs is to ensure that all participants develop and implement effective management systems to ensure that items, processes, and services meet or exceed applicable CAO QA requirements.

1.0 Introduction

Abstract

The United States Department of Energy (DOE) is responsible for the disposition of transuranic (TRU) waste generated by the production of nuclear weapons and other defense-related activities. Approximately 2.63 million ft^3 (74,500 m^3) of these wastes have been generated and are stored at government installations across the country. It is projected that additional volumes of this waste will be generated through decontamination and decommissioning activities in the future. The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, was sited and constructed to meet the criteria established by the scientific and regulatory community for the safe, permanent disposal of TRU and TRU-mixed wastes.

TRU waste is defined as waste that contains more than 100 nanocuries of alpha-emitting TRU isotopes, with half-lives greater than 20 years, per gram of waste. TRU-mixed waste is waste that contains both hazardous waste and source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954 that is classified as TRU waste. In order to permanently dispose of TRU-mixed waste, the DOE has elected to petition the Environmental Protection Agency (EPA) for a variance from the Land Disposal Restrictions (LDR) of the Resource Conservation and Recovery Act (RCRA), which are codified in Title 40 of the Code of Federal Regulations (CFR) Part 268. This document fulfills the requirements for the portions of a No-Migration Variance Petition (NMVP), as outlined in 40 CFR § 268.6, relevant to a demonstration of compliance.

Project Overview

The regulations require that the DOE demonstrate that the WIPP will isolate the wastes placed in it for 10,000 years. The DOE has developed a phased approach demonstrating the performance of the WIPP facility. The phased approach implemented by DOE provides the information needed to predict how the disposal system will perform during the 10,000-year period. The phases are as follows:

- *Siting Phase*
- *Site and Preliminary Design Validation Phase*
- *Construction Phase*
- *Disposal Phase*
- *Decommissioning Phase*
- *Post-Decommissioning Phase*

Site Selection

The site selection process for the WIPP began in 1973 with a review of information on potential disposal media. This work focused on salt beds and salt domes. The tentative selection criteria used in the initial stage of the process emphasized radiation and mine safety, hydrologic isolation, and ease of construction. The criteria specified the following conditions: 1,000–2,500 ft (305–762 m) depth to salt, 200 ft (61 m) minimum of salt thickness, lateral extent of salt sufficient to protect against dissolution, favorable tectonics (low historical seismicity and no salt-flow structures nearby), minimal groundwater, low resource potential, minimum number of existing boreholes, low population density, and maximum use of federal lands. The U.S. Geological Survey (USGS) and the Oak Ridge National Laboratory (ORNL) selected eastern New Mexico as the area which best satisfied the tentative selection criteria from the bedded salt regions surveyed.

The Delaware Basin site was determined to be the best area. Eight additional selection criteria were considered at this stage in the process:

1. The site should be at least 6 mi (10 km) from the Capitan Limestone, referred to as the "Capitan Reef," a major aquifer, to avoid any possible deformation hazard related to the nearness of the reef.

2. To minimize potential conflicts with exploration of mineral resources, the central 4 mi^2 (10 km^2) of the repository itself should not be in the Known Potash District, and as little as possible of the surrounding buffer zone should be in the district.

3. No part of the central area should be less than 1 mi (1.6 km) away from holes drilled through the Castile Formation into underlying rocks in order to avoid dissolution by water flowing upward through an inadequately plugged borehole.

4. Known oil and gas stratigraphic trends should be avoided.

5. The nearest dissolution front should be at least 1 mi (1.6 km) from the site.

6. The bedding of geological strata should be nearly flat as can be determined by surface geophysical investigations to ensure mine safety and ease of construction and to avoid the need for numerous exploratory holes that could pose a subsequent risk to the integrity of the repository.

7. Salt of high purity should be available at depths between 1,000 and 3,000 ft (305 and 914 m) to ensure mine safety and ease of construction. In addition, a salt thickness of 200 ft (61 m) or more is preferred to confine thermal and mechanical effects to the salt.

8. The use of state and private land should be minimized, especially in the central area, to simplify land acquisition and to avoid any relocation of residents.

Based on these additional criteria in the site selection process, the Los Medaños site was chosen for evaluation as the location for the geologic repository.

Regulatory Framework

In 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to the RCRA, which established, in § 3004(d)-(m), a stringent regulatory program to prohibit the land disposal of hazardous waste unless (1) the waste is treated to meet the standards or otherwise satisfy the requirements established by the EPA under § 3004 (m); or (2) the waste is disposed of in a land disposal unit that has been determined by the EPA to satisfy the statutory no-migration standard. In order to meet the second condition, it must be demonstrated "to a reasonable degree of certainty that there will be no migration of hazardous constituents from the disposal unit...for as long as the wastes remain hazardous." If such a demonstration can be made, an NMVP is submitted to the EPA by the operator of the facility. A no-migration variance may be granted if, upon review of the NMVP, the EPA determines that the operator of the facility has successfully demonstrated no-migration of hazardous constituents in accordance with the requirements of 40 CFR §268.6.

The WIPP facility qualifies as a land disposal unit under the following definition in 40 CFR §268.2:

> "Land disposal" means placement in or on the land and includes...placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, underground mine or cave, or concrete vault or bunker intended for disposal purposes. [emphasis added]

Pursuant to the provisions of 40 CFR § 268.6, the DOE submitted an NMVP for the WIPP test phase in March 1989 and a revision in 1990. A final test phase No-Migration Determination (NMD) was granted by the EPA in November 1990 (55 FR 47700). The NMD allows the DOE to emplace a limited quantity of untreated TRU-mixed waste in the WIPP facility for testing. Since the NMD is only applicable to test-phase activities, the DOE must seek another variance for permanent disposal of TRU-mixed waste in order to proceed with the disposal phase.

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1.0 INTRODUCTION

The United States Department of Energy (DOE) is responsible for the disposition of transuranic (TRU) waste generated by the production of nuclear weapons and other defense-related activities. Approximately 2.63 million ft^3 (74,500 m^3) of these wastes have been generated and are stored at government installations across the country. It is projected that additional wastes will be generated in the future. The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, was sited and constructed to meet the criteria established by the scientific and regulatory community for the safe, long-term disposal of TRU and TRU-mixed wastes.

TRU waste is defined as waste that contains more than 100 nanocuries of alpha-emitting TRU isotopes, with half-lives greater than 20 years, per gram of waste. TRU-mixed waste is waste that contains both hazardous waste and source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954 that is classified as TRU waste. In order to permanently dispose of TRU-mixed waste, the DOE has elected to petition the U.S. Environmental Protection Agency (EPA) for a variance from the Land Disposal Restrictions (LDR) of the Resource Conservation and Recovery Act (RCRA), which are codified in Title 40 of the Code of Federal Regulations (CFR) Part 268. This document fulfills the requirements for the portions of a No-Migration Variance Petition (NMVP), as outlined in 40 CFR § 268.6, relevant to a demonstration of compliance during disposal operations, the closure period, and post-closure period.

1.1 Project Overview

The DOE was authorized by the DOE National Security and Military Applications of the Nuclear Energy Authorization Act of 1980 (Public Law 96-164) and funded by Congress to provide a research and development facility to demonstrate the safe disposal of radioactive waste resulting from defense activities and programs of the United States. The WIPP facility near Carlsbad, New Mexico, was constructed to determine the efficacy of an underground repository for disposal of TRU and TRU-mixed wastes. The WIPP Land Withdrawal Act (LWA) of 1992 (Public Law 102-579) transferred jurisdiction of the land used for the WIPP project from the Secretary of the Department of Interior to the Secretary of the DOE and provided additional authorization to continue the activities initiated by Public Law 96-164. The LWA requirements relevant to this petition focus on compliance with the hazardous waste disposal regulations issued by the EPA. Once the DOE demonstrates compliance with the disposal regulations and a no-migration variance is obtained and other prerequisites in the LWA met, the WIPP facility will be used for the permanent disposal of TRU and TRU-mixed wastes.

It must be demonstrated, to a reasonable degree of certainty, that hazardous constituents will not migrate from the disposal unit for 10,000 years. The phased development of the WIPP facility that the DOE has chosen to follow is intended to provide adequate knowledge of how the disposal system will perform in this time frame.

Development of the WIPP facility began with a siting phase. During this phase, several sites were evaluated and the present site was selected on the basis of extensive geotechnical research, supplemented by testing (see Section 1.2). The results of these studies are reported in Powers et al. (1978), which is included as Appendix GCR. Based upon the favorable properties of the selected site, the repository was designed and safety analyses were prepared. Subsequent research has expanded the understanding of the geologic, hydrologic, geochemical, and mechanical properties of the host rock and surrounding strata of the site. The siting phase ended with the publication of a Final Environmental Impact Statement (FEIS) in 1980, which evaluated alternatives for the safe, long-term isolation of TRU waste. The Record of Decision (ROD) concluded that the phased development of the WIPP facility was the preferred alternative of those considered.

The site and preliminary design validation (SPDV) phase followed the siting phase. During this phase, two shafts were constructed, an underground testing area was excavated, and various geologic, hydrologic, and other geotechnical features were investigated, further expanding the knowledge of the site's characteristics. In addition, methods for assessing the long-term performance of the WIPP facility were evaluated. A series of geologic and hydrologic studies began in 1984 under an agreement between the DOE and the State of New Mexico. The majority of these studies are summarized in Lappin (1988) which, in effect, concluded the site characterization; however, limited geologic and hydrologic studies of the WIPP site continue. Lappin (1988) is included in this petition as Appendix SUM.

The construction phase followed the SPDV, during which surface structures for receiving waste were built and underground excavations were completed for waste emplacement. The DOE reached its decision to end the construction phase after all prerequisites for ending construction were met and documented. These documents used the data collected since 1980 to evaluate the potential short-term and long-term impacts of the WIPP facility. The Final Safety Analysis Report (FSAR) was then written, approved, and published.

At the conclusion of the construction phase, the DOE proposed to initiate a test phase that would include testing with TRU and TRU-mixed wastes at the WIPP facility. In October 1993, the DOE decided not to conduct these tests at the WIPP facility. Instead, the DOE implemented an accelerated regulatory compliance program, which focused on activities and experiments directly relevant to a demonstration of compliance with applicable long-term disposal regulations.

Once a successful demonstration of compliance with applicable federal and state laws and regulations is made, the DOE will proceed through three additional phases at the WIPP facility: a disposal phase, a decommissioning phase (closure), and a post-decommissioning (post-closure) phase. The disposal phase, projected to last 25 years, will consist of receiving, handling, and emplacing TRU and TRU-mixed wastes in the

repository and will end when the design capacity of the repository has been reached. Additional scientific studies may continue during the disposal phase.

The decommissioning phase will follow the disposal phase. The repository will be prepared for permanent closure during this phase. Surface facilities will be decontaminated and decommissioned, underground excavations will be prepared for closure, and shaft seals will be emplaced. This phase is projected to last for 10 years.

The post-decommissioning phase will consist of active and passive institutional controls. Active institutional controls will include activities such as control of access to the site. Such controls will be implemented consistent with applicable regulations and permit conditions and will continue for at least 100 years. The passive institutional control system is designed to provide "defense-in-depth" and includes notification devices such as permanent markers and records. These controls will be designed to ensure that the potential for future, inadvertent human intrusion is unlikely.

1.2 Site Selection Process

Salt deposits have been recognized as a medium well suited for radioactive waste disposal since the completion of a National Academy of Sciences–National Research Council (NAS-NRC) study in 1955 (NAS-NRC [1957][1]. Salt has a relatively high thermal conductivity, which serves to conduct heat away from the waste rapidly, and has favorable plastic (creep) properties that permit the absorption of significant pressure without fracturing. The existence of large salt deposits demonstrates isolation from circulating groundwaters for long periods of geologic time; moreover, the depositional nature and the preservation of large salt deposits demonstrate that the region has been stable for long periods of time.

The site selection process for the WIPP facility began in 1973 with a review of information on potential disposal media. This work focused on salt beds and salt domes. The tentative selection criteria used in the initial stage of the process emphasized radiation and mine safety, hydrologic isolation, and ease of construction. The criteria specified the following conditions: 1,000 to 2,500 ft (305 to 762 m) depth to salt, 200-ft (61-m) minimum of salt thickness, lateral extent of salt sufficient to protect against dissolution, favorable tectonics (low historical seismicity and no salt-flow structures nearby), minimal groundwater, low resource potential, minimum number of existing boreholes, low population density, and maximum use of federal lands. The United States Geological Survey (USGS) and the Oak Ridge National Laboratory (ORNL) selected eastern New Mexico as the area that best satisfied the initial selection criteria from the bedded salt regions surveyed.

[1]While endorsing salt as a favorable medium for the disposal of high-level liquid waste, the NAS-NRC acknowledged that it had not conducted sufficient research in this area. The NAS-NRC assumed that the necessary research would be completed prior to a decision to proceed with the construction and operation of such a disposal unit.

During the second stage of the selection process, two of three New Mexico locations were determined to be inadequate: the Clovis-Portales site, because shallow salt formations had a significant clay content and the purer salt formations were too deep; and the Mescalero Plains area, because of extensive oil field development. After shifting the potential site twice (in order to avoid borehole penetrations of the salt within 2 mi [3.2 km] of the repository border), the ORNL reduced the distance criterion to 1 mi (1.6 km) and selected a site in the Delaware Basin for extensive characterization.

In the final stage of the process, eight areas of the New Mexico portion of the Delaware Basin in Eddy and Lea counties were evaluated by the Energy Research Development Administration (ERDA). Eight additional selection criteria were considered at this stage in the process:

1. The site should be at least 6 mi (10 km) from the Capitan Limestone, a major aquifer referred to as the "Capitan Reef," to avoid any possible deformation hazard related to the proximity of the reef.

2. To minimize potential conflicts with exploration for mineral resources, the central 4 mi^2 (10 km^2) of the repository itself should not be in the Known Potash District, and as little as possible of the surrounding buffer zone should be in the district.

3. No part of the central area should be less than 1 mi (1.6 km) away from holes drilled through the Castile Formation into underlying rocks in order to avoid dissolution by water flowing upward through an inadequately plugged borehole.

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7. Salt of high purity should be available at depths between 1,000 and 3,000 ft (305 and 914 m) to ensure mine safety and ease of construction. In addition, a salt thickness of 200 ft (61 m) or more is preferred to confine thermal and mechanical effects to the salt.

8. The use of state and private land should be minimized, especially in the central area, to simplify land acquisition and to avoid any relocation of residents.

The Los Medaños site was found to best meet the additional selection criteria. The FEIS provided the basis for making the final decision regarding siting the WIPP facility at the

Los Medaños site. This decision weighed the numerous advantages of the location and its suitability against potential adverse environmental impacts. The WIPP site (Figure 1-1) was selected as the best of the available areas considered. The specific horizon in the bedded salt was selected because of its desirable stratigraphic features. The stratigraphy is continuous throughout a large geographic area, and clay seams and interbeds of anhydrite or polyhalite are removed from the repository horizon. The facility has been constructed at a horizon such that operational and rock-support problems are minimized.

Subsequent validation and construction activities have confirmed that the site's features are suitable for the long-term isolation of radioactive and hazardous wastes.

1.3 Regulatory Framework

In 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to the RCRA which established, in § 3004(d)-(m), a stringent regulatory program to prohibit the land disposal of hazardous waste unless (1) the waste is treated to meet the standards or otherwise satisfy the requirements established by the EPA under § 3004(m); or (2) the waste is disposed of in a land disposal unit that has been determined by the EPA to satisfy the statutory no-migration standard. In order to meet the second condition, it must be demonstrated "to a reasonable degree of certainty that there will be no migration of hazardous constituents from the disposal unit . . . for as long as the wastes remain hazardous." If such a demonstration can be made, an NMVP is submitted to the EPA by the operator of the facility. A no-migration variance may be granted if, upon review of the NMVP, the EPA determines that the operator of the facility has successfully demonstrated no migration of hazardous constituents in accordance with the requirements of 40 CFR § 268.6.

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The EPA draft guidance document, *"No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners* (EPA 1992), interprets

"no migration" as no movement of hazardous constituents beyond the unit boundary in concentrations exceeding EPA-approved health-based levels (HBLs). HBLs are media-specific levels of exposure believed by the EPA to be adequately protective of human health.

The unit boundary for the WIPP facility is defined as the portion of the Salado Formation (hereafter referred to as the Salado) bounded laterally by the land-withdrawal area. The unit boundary is used as the point of compliance for demonstrating no migration of hazardous constituents; the demonstration is made for a 10,000-year period.

During operations, the disposal unit is defined as the underground facility. The DOE has specified a point 5.0 ft (1.5 m) above the ground immediately adjacent to the underground ventilation exhaust duct as the no-migration boundary for emissions during operations. This point has been selected since it is the nearest point to the emission source where a hypothetical individual could be exposed to hazardous constituents from disposed waste.

Releases that exceed the following no-migration standards at the points of compliance will be considered migration:

- HBLs for air, based on an annual average
- HBLs for soil
- HBLs for water.

1.4 Application Synopsis

The purpose of this document is to demonstrate, according to the requirements of 40 CFR § 268.6, that there will be no migration of hazardous constituents from the WIPP facility during disposal operations, closure of the facility, and after closure.

Chapter 2 presents a thorough discussion of the WIPP facility's natural environment. The geology, hydrology, climatology, and meteorology of the site are described in detail along with any other environmental factors that could affect repository performance. Background environmental conditions are also described.

A description of the overall facility and its operations is presented in Chapter 3. Specifically, descriptions of surface waste-handling and support facilities, shafts and hoists, underground waste disposal and support facilities, emergency response, and waste management support systems are included. Preliminary discussions of engineered barriers are provided, as well as the facility closure and post-closure plans.

Chapter 4 includes a discussion and identification of the wastes the DOE intends to dispose of at the WIPP facility. The chapter includes specific information relative to waste types, the sources of the wastes, applicable RCRA hazardous waste codes, descriptions of waste-generating processes, anticipated waste quantities, and other relevant chemical and physical properties. Also included is a summary of the analytical

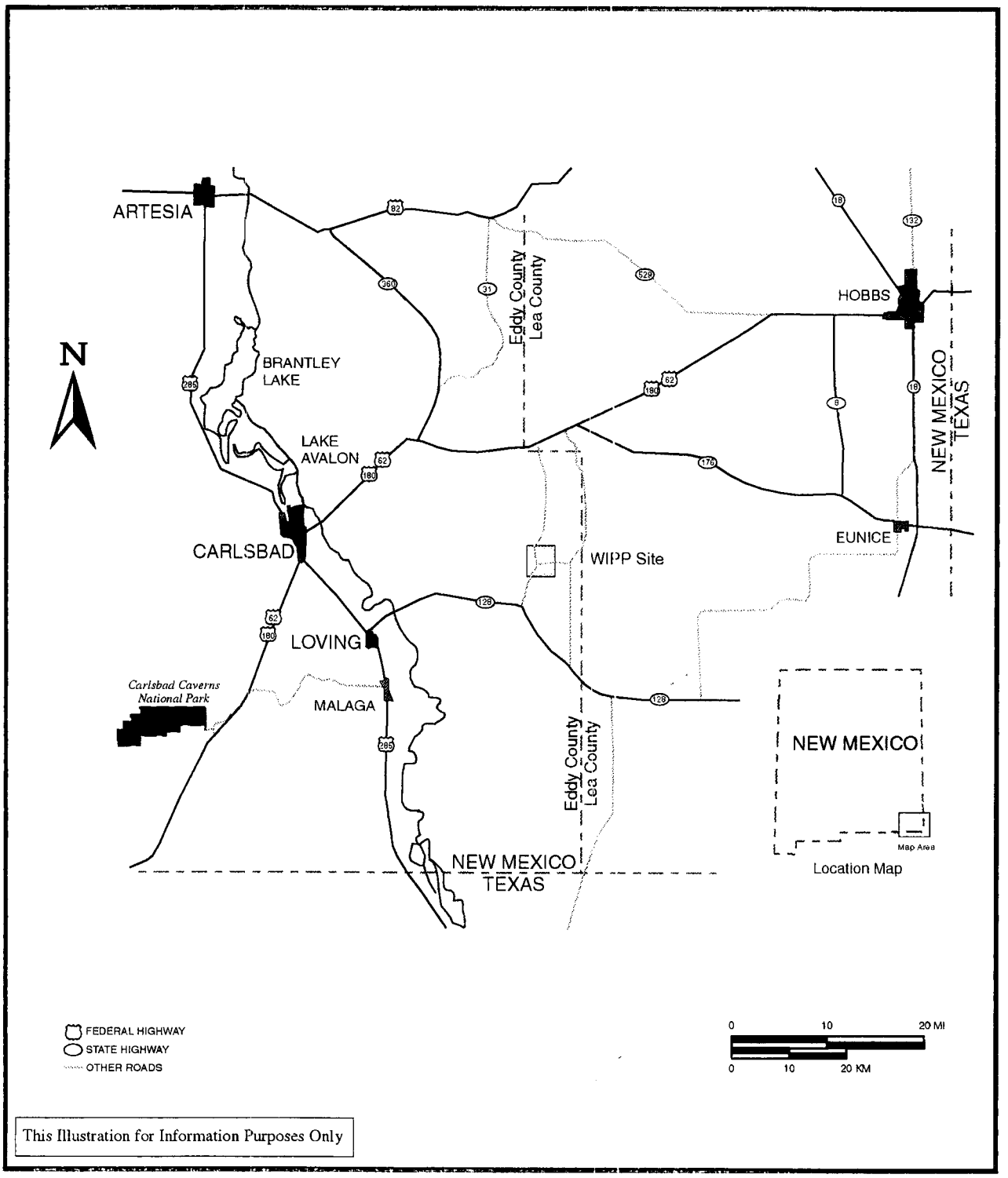

Figure 1-1. Location of the WIPP Facility

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methods to be used in waste characterization activities as well as a discussion of future plans for waste characterization activities.

Impacts to human health and the environment, as a result of the land disposal of TRU-mixed waste during disposal and closure, are defined in Chapter 5. An assessment of all viable release pathways is conducted to determine the criteria for demonstrating no migration during the operational and closure periods. The projected excess risk to the public is compared to acceptable levels of risk defined by the EPA. In addition, this chapter provides an analysis of infrequent events and processes that contribute to uncertainty in the no-migration demonstration for the operational and closure periods.

Chapter 6 provides a description of the monitoring programs at the WIPP facility. Monitoring activities will focus on the air pathway during disposal operations. The concept of long-term monitoring is introduced in this chapter and Appendix LTM.

Chapter 7 describes the minimum requirements pertaining to DOE quality assurance (QA) programs for the WIPP facility. QA programs for specific activities and the data quality objectives, established as appropriate for these programs, are also described throughout the document.

Chapter 8 provides an assessment of the long-term impacts to human health and the environment. The potential for migration of hazardous constituents in the brine and gas phase beyond the unit boundary is evaluated to identify all viable release pathways. Modeling techniques and bounding analyses are used to demonstrate compliance to HBLs for the applicable media. Also included is an analysis of features, events, and processes that contribute to uncertainty in the no-migration demonstration for the post-closure period.

An assessment of compliance with the no-migration standards is addressed in Chapter 9; the specific requirements of 40 CFR § 268.6 are addressed individually. Based on information and results presented in the previous chapters, a demonstration of compliance is made for disposal operations, closure operations, and post-closure periods.

Chapter 10 provides the mandatory certification statement specified in 40 CFR § 268.6. This certification statement is signed by a representative of the petitioner, the DOE, who is the owner and operator of the WIPP facility. DOE policy requires its facility management and operating contractor to also sign certifications as "co-operator." Therefore, the certification is also signed by a representative of the Westinghouse Electric Corporation, Waste Isolation Division.

Supporting documents, such as project plans, procedures, and data are included as appendices. In May 1995, the DOE submitted a draft version of this petition, which included all relevant information for the operational and closure periods. This final version of the petition includes Chapter 8 and other supporting documentation in

appendices demonstrating no migration for the post-closure period. It also includes updated information from the draft version.

This petition has been prepared in accordance with *"No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners (Draft)* (EPA 1992). Even though this guidance manual is draft, the EPA Office of Solid Waste has indicated that it is appropriate for use by the DOE in preparation of this NMVP submittal. The guidance manual includes a "Checklist of Information Needs" to assist the petitioner in providing a complete document. Table 1-1 provides this checklist and indicates where specific information may be found within the petition.

Table 1-1. Checklist of Information Needs

Information Need	Addressed in Section
Facility Description	
Name of facility	1.0
Address of facility	3.0
Name of owner/operator	3.0
Anticipated period of operation	3.0
Status of RCRA permit application	Appendix BECR
Location map	1.2
Detailed site plan	3.2
Aerial surveys	Appendix SURV
Advantages/disadvantages of location	1.2
Evaluation of storage/disposal unit	
Design objective	3.1
Design criteria	3.2
Design performance projection	3.2
Materials specifications	3.2
Detailed drawings and specifications	3.2
Documentation of unit construction	3.2
Documentation of unit operation	3.2.3, 3.2.4, 3.4.1
Closure plans	3.7, Appendix CLP
Post-closure plans	3.7, Appendix CLP
Cover design	3.7
Design QA/QC demonstration (testing and inspection)	3.1, 3.2
Facility operation QA/QC demonstration	3.2, 3.4
Waste Characteristics	
Waste type by name	4.1, 4.3, Appendix WAP
Processes that produced the waste	4.3.4.5, Appendix WAP
Hazardous properties	4.3.3, 3.1.1, Appendix WAP, Appendix LTHBL

Table 1-1. Checklist of Information Needs (continued)

Information Need	Addressed in Section
Physical characteristics	4.3.2, Appendix WAP, Appendix SCR
Chemical characteristics	4.3.3, Appendix WAP, Appendix SCR
Biological properties	4.3.3.3, 8.2.3.3, Appendix SCR
Constituents and percentages of constituents	4.3.6, 8.3.2, Appendix WAP
Analytical methods and results	4.3.4, Appendix WAP
Projection of waste volume to be disposed	4.1
Quantity of banned waste being disposed	4.1
Frequency of disposal	4.1
Period of time waste has been and will be disposed	4.1
Handling procedures	3.2
Waste treatment before, during, and after disposal	3.2, 3.4
Liquid phase mobility information	8.3.3, 8.4.1, Appendix SCR, Appendix PAR, Appendix BRAGFLO
Gas/particulate mobility	8.3.2, 8.4.1, Appendix SCR, Appendix PAR, Appendix BRAGFLO
Solid phase mobility	8.3.3, 8.4.1, Appendix SCR
Dust generation potential	N/A[a]
Gas-liquid phase interactions	8.3.1, 8.4.1, Appendix SCR, Appendix PAR, Appendix BRAGFLO
Persistence/degradation potential in unit and environment	4.3.3.3, 8.3.1, Appendix SCR
QA/QC demonstration	4.3.1, 7.3.5
Waste Transformation and Immobilization	
Estimation of quantity and quality of leachate formation	8.2.5, 8.4.1, Appendix SCR, Appendix OUTPUT
Waste/waste compatibility, interaction, reaction products	4.3.3.2, Appendix SCR
Waste liner compatibility	N/A[b]
Assessment of biodegradation potential	4.3.3.3, Appendix SCR
Assessment of oxidation/reduction potential	4.3.3.3, Appendix SCR
Assessment of immobilization due to insolubility	Appendix SCR

Table 1-1. Checklist of Information Needs (continued)

Information Need	Addressed in Section
Assessment of photodegradation potential	N/A[c]
Assessment of immobilization due to hydrolysis	Appendix SCR
Assessment of immobilization due to adsorptivity	Appendix SCR
Site Characterization	
Surficial geology and soils (regional and local)	
Topography	2.1.4.2, Appendix SCR
Soil types	2.1.3.10, Appendix SCR
Soil properties	2.1.3.10, Appendix SCR
Depth to bedrock	2.1.3, Appendix SCR
Bedrock geology (regional and local)	
Stratigraphy and lithology	2.1.3, Appendix SCR
Seismic activity of area	2.6, Appendix SCR
Assessment of ground motion potential and degree	2.6, Appendix SCR
Geologic cross-sections	2.1.3
Degree of bedrock faulting and fracturing	2.1.5, Appendix SCR
Rock characterization	2.1, Appendix SCR
Groundwater hydrology (regional and local)	
Water table map	2.2.1.5
Seasonal variations in the water table	N/A[d], Appendix SCR
Identification of all aquifers and aquitards	2.2.1, Appendix SCR
Characterization of all aquifers	2.2.1, Appendix SCR
Vertical and horizontal hydraulic conductivity	2.2.1, Appendix MASS
Aquifer interconnection	2.2.1, Appendix SCR
Description of groundwater monitoring program	6.1, 2.4.2, Appendix SER
Monitoring QA/QC documentation	7.3.6, Appendix SER
Surface-water hydrology[e]	
Location of all watersheds	2.2.2
Map of drainage patterns	2.2.2
Map of floodplain	2.2.2

Table 1-1. Checklist of Information Needs (continued)

Information Need	Addressed in Section
Flood analysis	2.2.2
Meteorology/climatology	
Wind rose	2.5, Appendix SER
Precipitation records	2.5, Appendix SER
Temperature records	2.5, Appendix SER
Relative humidity records	2.5, Appendix SER
Maps of storm tracks	2.5, Appendix SER
Monitoring Plan	
Media to be monitored	6.1, 2.4, Appendix SER
Type of monitoring to be conducted at the unit	6.1, 2.4, Appendix SER
Location of monitoring stations	6.1, 2.4, Appendix SER
Frequency of monitoring at each station	6.1, 2.4, Appendix SER
Specific hazardous chemicals to be monitored	6.1, 2.4
Implementation schedule for the monitoring program	6.1
Equipment used at the monitoring stations	6.1
Sampling and analytical techniques employed	6.1
Data recording/reporting procedures	6.1
Waste Mobility	
Unsaturated zone soils[f]	
Soil samplings	2.1.3.4, Appendix GCR, Appendix PAR
Soil testing	2.1.3.4, Appendix GCR, Appendix PAR
Unsaturated zone physical properties[f]	
Volumetric water content	2.2.1.3, 8.4, 8.4.1, Appendix MASS
Degree of water saturation	2.2.1.3, 8.4, 8.4.1, Appendix MASS
Bulk density	2.2.1.3, 8.4.2.1
Pressure potential	2.2.1.3, 8.2.8, 8.4.1, Appendix BRAGFLO, Appendix PAR, Appendix OUTPUT
Relative permeability	2.2.1.3, 8.2.3.2, 8.4.1, Appendix PAR, Appendix BRAGFLO

Table 1-1. Checklist of Information Needs (continued)

Information Need	Addressed in Section
Unsaturated hydraulic conductivity	2.2.1.3, Appendix PAR, Appendix MASS
Water capacity	2.2.1.3[g], Appendix PAR, Appendix BRAGFLO
Water diffusivity	N/A[h]
Leachate characteristics affecting mobility	
Leachate characterization	Appendix SCR
Leachate interactions	Appendix SCR
Secondary leachate evaluation	Appendix SCR
Evaluation of transport mechanisms	5.1.1, 8.2.7, 8.3, 8.4.1, Appendix SCR
Evaluation of fate of contaminants in unsaturated zone	Appendix SCR
Vapor concentration of constituents at the source	5.2.2, 8.3.2, Appendix SCR
Vapor pressure of constituents	8.3.2.1, Appendix SCR
Solubility data for constituents	8.3.3, Appendix SCR
Activity coefficients	N/A[i]
Henry's Law constant	8.3.3, Appendix SCR
Background measurements for air	2.4.3, Appendix BAD
Assessment of volatilization potential	4.3.3.3, Appendix SCR
Modeling Evaluation	
Model accounts for all transport mechanisms	5.2.5, 8.2, 8.3, Appendix SCR, Appendix ADM
Model appropriate for petitioned waste	5.2.5, 8.2, Appendix SCR, Appendix ADM
Data input accurate and verified	5.2.5, 8.2, Appendix PAR, Appendix ADM
Model tested under field conditions[j]	5.2.5, Appendix ADM
Model is accurate over long time periods	8.2, 8.4.1, Appendix SCR, Appendix PAR, Appendix OUTPUT
Limitations of model	5.2.5, 8.2, 8.4.1, 8.4.2, 8.3, Appendix ADM, Appendix MASS, Appendix OUTPUT, Appendix PAR, Appendix SCR
Model inputs adequately documented	5.2.5, 8.2, 8.4, Appendix ADM, Appendix PAR, Appendix SCR

Table 1-1. Checklist of Information Needs (continued)

Information Need	Addressed in Section
Model outputs appropriate and reasonable	5.2.5, 8.4.1, 8.4.2, Appendix ADM, Appendix OUTPUT
Assessment of Environmental Risk	
Identification of all exposure pathways and routes	5.1.1, 8.1.2, 8.2, 8.4.1, Appendix PAR, Appendix SCR
Identification of all potential receptors	
Wildlife	2.4.1
Vegetation	2.4.1.1
Identification of sensitive or endangered species	2.4.1.7
Assessment of bioaccumulation through the foodchain	Appendix SER
Uncertainty Analysis	
Natural events	
Climatic fluctuations	5.3, 8.4.3, Appendix SCR, Appendix CLI
Glaciation	5.3, 8.4.3, Appendix SCR
Stream erosion	5.3, 8.4.3, Appendix SCR
Magmatic activity	5.3, 8.4.3, Appendix SCR
Epeirogenic displacement	5.3, 8.4.3, Appendix SCR
Orogenic diastrophism	5.3, 8.4.3, Appendix SCR
Diagenesis	5.3, 8.4.3, Appendix SCR
Static fracturing	5.3, 8.4.3, Appendix SCR
Dissolution	5.3, 8.4.3, Appendix SCR
Sedimentation	5.3, 8.4.3, Appendix SCR
Flooding	5.3, 8.4.3, Appendix SCR
Undetected features (i.e., faults, lava tubes)	5.3, 8.4.3, Appendix SCR
Meteorites	5.3, 8.4.3, Appendix SCR
Fires	5.3, 8.4.3, Appendix SCR
Hurricanes	N/A[k]
Tornadoes	5.3, 8.4.3, Appendix SCR
Earthquakes	5.3, 8.4.3, Appendix SCR
Ground motion	5.3, 8.4.3, Appendix SCR

Table 1-1. Checklist of Information Needs (continued)

Information Need	Addressed in Section
Waste-induced or facility-induced events	
Thermal effects	5.3, 8.4.3, Appendix SCR
Chemical effects	5.3, 8.4.3, Appendix SCR
Mechanical effects	5.3, 8.4.3, Appendix SCR
Modification of hydrologic regime	5.3, 8.4.3, Appendix SCR
Human-induced events	
Improper design or operation	5.3, 8.4.3, Appendix SCR
Past intrusions	N/A[l]
Future intrusions	5.3, 8.4.3, Appendix SCR
Intentional intrusion	5.3, 8.4.3, Appendix SCR
Perturbation of groundwater system	5.3, 8.4.3, Appendix SCR
Biosphere alterations	5.3, 8.4.3, Appendix SCR

[a] The WIPP facility will only manage sealed containers of waste.
[b] The WIPP facility does not use an engineered liner for waste containment.
[c] The wastes emplaced in the WIPP facility will not be subject to ultraviolet light.
[d] During the operational phase, the WIPP facility will not be affected by seasonal variations in water table. For the long-term demonstration, water table variation caused by climatic changes is screened from the conceptual model in Appendix SCR.
[e] Surface water hydrology is also addressed in Appendix SCR.
[f] As applied to the WIPP, the DOE assumes "unsaturated zone soils" information requirements pertain to the Salado Formation; relevant hydraulic properties are addressed in the long-term demonstration as input parameters and/or model results representing material regions in the disposal unit (e.g., Salado Formation, Repository and Shaft).
[g] Water (or field) capacity is addressed indirectly in the NMVP long-term simulation: two-phase flow properties (e.g., residual brine saturation) and effective porosities used in the BRAGFLO model are related to the field capacity of porous media.
[h] Parameters used to define water diffusivity (hydraulic conductivity/transmissivity and specific storage/storativity) are employed directly in the demonstration analyses; water (or aquifer) diffusivity is not relevant.
[i] The rationale for not using activity coefficients is discussed in Section 8.3.3 (Liquid Phase Source Term)
[j] Due to compliance restrictions and for other practical considerations, BRAGFLO brine and gas modeling has not been directly tested under field conditions in the underground facility.
[k] The region in which the WIPP facility is located has no history of hurricanes.
[l] There have been no past intrusions into the underground structures at the WIPP facility.

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40 CFR Part 268. "Land Disposal Restrictions."

40 CFR Part 264. "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities."

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2.0 Site Characterization

Abstract

This chapter describes the site characterization information compiled by the Department of Energy (DOE) for the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. In particular, it addresses "the site's climatology, meteorology, geology and hydrology...in sufficient detail to permit assessment of the degree of waste isolation achievable." This chapter has been prepared to demonstrate compliance with the no-migration standards of 40 Code of Federal Regulations (CFR) § 268.6(a)(3).

The DOE has developed conceptual models of the significant natural processes that are working in the vicinity of the WIPP. These conceptual models are implemented through numerical modeling to demonstrate that the WIPP disposal system will meet the environmental performance standards of 40 CFR § 268.6. The information used in the long-term simulation includes field studies, laboratory evaluations, experiments, and, for those features not easily characterized, professional judgment. The Environmental Protection Agency (EPA) guidance specifies natural, waste- or facility-induced, and human-induced events that must be considered in the petition. In reality, the events specified in the EPA's guidance also include "features" of the site and "processes" acting on the site. This combination of features, events, and processes is commonly referred to in geologic repository programs as FEPs.

In this chapter, the DOE describes the WIPP site in terms of its geology, hydrology, climatology, air quality, ecology, and cultural and natural resources. This chapter provides information on the disposal system's natural FEPs that are relevant to the assessment of the WIPP site as a potential repository for transuranic (TRU) waste and establishes: (1) the favorable characteristics of the site, (2) background environmental quality, and (3) discusses features of the site that might be important for inclusion in a quantitative performance assessment.

Geology

Geological data have been collected from the WIPP site and surrounding area for use in evaluating the site's suitability as a mixed waste repository. These data have been collected principally by the DOE and its predecessor agencies, the United States Geological Survey (USGS), the New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and private organizations engaged in natural resource exploration and extraction. The DOE has analyzed the data provided in this chapter and believes it supports the DOE's position that the WIPP site is suitable for the long-term isolation of hazardous waste. Many issues have been discussed, investigated, and resolved in order for the DOE to reach the conclusion that the site is suitable.

Data Sources and Quality. Because of intense interest in both hydrocarbon and potash resources in the region, there exists a large volume of data as potential background for the

WIPP site, though some data are proprietary. Also, there is the geological information developed directly and indirectly by studies sponsored by WIPP; it ranges from raw data to interpretive reports.

Geologic History. In this chapter, the DOE summarizes the more important points of the geologic history within about 200 mi (320 km) of the WIPP site, with emphasis on more recent or nearby events.

The geologic history in this region can be subdivided into three general phases:

- A Precambrian period, represented by metamorphic and igneous rocks ranging in age from about 1.5 to 1.1 billion years old
- A period principally of erosion from about 1.1 to 0.6 billion years, as there is not known to be any rock record from this time
- An interval from 0.6 billion years to the present represented by a more complex set of mainly sedimentary rocks and shorter periods of erosion and dissolution.

This latter phase is the main subject of the DOE's detailed discussion of this text.

The Delaware Basin is part of the larger Permian Basin, located in the southwestern part of the central region of North America. During the Permian period, which came to a close about 225 million years ago, ancient seas covered the basin. Their evaporation resulted in the deposition of the salt and other marine materials in great abundance. Three major evaporite-bearing formations were created in this manner:

- The Castile Formation, formed through evaporation of the Permian Sea, which deposited carbonates, anhydrites, and halite (salt). Its upper boundary is at a depth of about 2,825 ft (861 m), and its thickness near the WIPP facility is about 1,500 ft (457 m).

- The Salado Formation, in which the repository is constructed, overlies the Castile and resulted from prolonged desiccation that produced cycles containing some carbonates and anhydrites, but predominantly halite. Its upper boundary is at a depth of about 850 ft (259 m) and it is about 2,000 ft (610 m) thick at the repository.

- The Rustler Formation, deposited in a lagoonal environment during a major freshening of the basin, consists of carbonates, anhydrites, and halites and contains small amounts of brine. The Rustler Formation's upper boundary is about 500 ft (152 m) below the surface and it ranges up to 560 ft (171 m) in thickness.

These evaporite-bearing formations lie between two other formations significant to the geology and hydrology of the WIPP site. The Dewey Lake Red Bed Formation overlying the Rustler Formation was formed through terrestrial, rather than marine, processes (such as the deposition of river sediments), and consists almost entirely of mudstone, claystone, siltstone, and interbedded sandstone. This formation forms a 650-ft (198-m) thick barrier

of fine-grained sediments which retard the downward percolation of water into the evaporite units below. The Bell Canyon Formation is the first water-bearing unit below the Salado. It is overlain by the thick evaporite sequences of the Castile Formation above. It consists of 1,500 ft (457 m) of interbedded sandstone, shales, and siltstones.

Stratigraphy and Lithology in the Vicinity of the WIPP Site. In this chapter, the DOE presents the stratigraphy and lithology of the Paleozoic and younger rocks underlying the WIPP site and vicinity, emphasizing the units nearer the surface. The principal stratigraphic data are the chronologic sequence, age, and extent of rock units, including some of the nearby relevant facies changes. Characteristics such as thickness and depth are summarized here from published sources for deeper rocks.

Physiography and Geomorphology. The WIPP site is in the Pecos Valley Section of the southern Great Plains Physiographic Province, a broad highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range Province to the Central Lowlands Province. The Pecos Valley Section itself is dominated by the Pecos River Valley, a long north-south trough that is from 5 to 30 mi (8.1 to 50 km) wide and as much as 1,000 ft (305 m) deep in the north. The Pecos River System has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched some time after the middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent, because of the semiarid climate. The local surface has a karst terrain containing superficial sinkholes, dolines, and solution-subsidence troughs from both surface erosion and subsurface dissolution. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, including such erosional features as scarps, cuestas, terraces, and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations range from more than 6,000 ft (1,829 m) in the northwest to about 2,000 ft (610 m) in the south.

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest, and is hummocky with sand ridges and dunes. A hard caliche layer (Mescalero caliche) is typically present beneath the sand blanket and on the surface of the underlying Gatuña Formation. Elevations at the site range from 3,570 ft (1,088 m) in the east to 3,250 ft (991 m) in the west. The average east-to-west slope is 50 ft per mi (9.5 m per km).

Tectonic Setting and Site Structural Features. Most broad-scale structural elements of the area around the WIPP developed during the late Paleozoic. There is little historical or geological evidence of significant tectonic activity in the vicinity. The entire region has tilted recently, and activity related to Basin and Range tectonics formed major structures southwest of the area. Seismic activity is specifically addressed in a separate chapter.

Fault zones are well known along the Central Basin Platform, east of WIPP, from extensive drilling for oil and gas. There are no known Quaternary or Holocene faults of

tectonic origin offsetting rocks at the surface nearer to the site than the western escarpment of the Guadalupe Mountains. A significant part of the tilt of basin rocks is attributed to a mid-Miocene to Pliocene uplift along the Guadalupe-Sacramento mountains trend, inferred on the basis of High Plains sediments of the Ogallala. Seismic activity is low and is commonly attributed to secondary oil recovery along the Central Basin Platform.

Within the Delaware Basin, only one feature of igneous origin is known to have formed since the Precambrian. An igneous dike or series of echelon dikes occurs along a linear trace about 75 mi (120 km) long from the Yeso Hills south of White's City to the northeast. The dike trend passes about 8 mi (13 km) northwest of the WIPP site center. Evidence of the extent of the dike ranges from outcroppings at Yeso Hills to subsurface intercepts in boreholes and mines to airborne magnetic responses.

The loading and unloading history of the site and surrounding areas may be considered a factor in the development of the hydrological system, including the Culebra, at the WIPP site. The depth to the base of the Culebra in the area indicates the current state of loading for the unit. This depth is a function of regional dip, erosion, and dissolution/subsidence.

Non-Tectonic Processes and Features. Non-tectonic processes and features, which include evaporite deformation and dissolution of strata, are known to be active in the Delaware Basin. These processes are of interest because they represent mechanisms that are potentially disruptive to the repository in the long term. Both processes have been investigated extensively.

Surface-Water and Groundwater Hydrology

The DOE believes the hydrological characteristics of the disposal system are important because contaminant transport via fluid flow could have great impact on the disposal system. At the WIPP site, one of the DOE's selection criteria was to choose a location that would minimize these impacts. This was accomplished when the DOE selected (1) a disposal medium that is essentially devoid of groundwater; (2) a location where the effects of groundwater circulation are minimal and predictable; (3) an area where groundwater use is virtually nonexistent; (4) an area where there are no surface-waters; (5) an area where future groundwater use is unlikely; and (6) a repository host rock that will not likely be affected by anticipated long-term climate changes within 10,000 years.

In order to provide a comprehensive understanding of the impact of groundwater and surface-water on the disposal system, the following factors have been evaluated:

Groundwater

- General flow direction
- Flow type
- Horizontal and vertical flow velocities
- Hydraulic interconnectivity between rock units

- General groundwater use
- Chemistry (including, but not limited to, salinity, mineralization, age, Eh, and pH).

Surface-Water

- Regional precipitation and evapotranspiration rates
- Location and size of surface-water bodies
- Water volume, flow rate, and direction
- Drainage network
- Hydraulic connection with groundwater
- Soil hydraulic properties (infiltration)
- General water chemistry and use.

The hydrological system is divided into three segments for the purposes of modeling and discussion. These are (1) the Salado, which contains the repository; (2) the non-Salado rock units, which are of interest to the extent they can affect the Salado and the demonstration of no-migration; and (3) the surface waters, which are impacted by the natural variability of the climate.

The WIPP site lies within the Pecos River drainage area. The climate is semiarid, with a mean annual precipitation of about 12 in. (0.3 m), a mean annual runoff from 0.1 to 0.2 in. (2.5 to 5 mm), and a mean annual pan evaporation of more than 100 in. (2.5 m). Surface waters (Section 2.2.2) typically have high TDS concentrations, particularly of chloride, sulfate, sodium, magnesium, and calcium.

At the WIPP site, the DOE obtains hydrologic data from conventional and special-purpose test configurations in multiple surface boreholes. Geophysical logging of the boreholes has provided hydrologic information on the rock strata intercepted. Pressure measurements, fluid samples, and ranges of rock permeability have been obtained for selected formations through standard and modified drill-stem tests.

Slug injection or withdrawal tests have provided additional data to aid in the estimation of transmissivity and storage. Also, the hydraulic head of groundwaters within many water-bearing zones in the region has been mapped from measured depths to water in the boreholes.

Resources

"Resources" is used to broadly define both economic (mineral and non-mineral) and cultural resources associated with the WIPP site. These resources are important because they (1) provide evidence of past uses of the area, (2) indicate potential future use of the area, and the possibility that such use could disrupt the closed repository, and (3) provide a basis for designing and implementing long-term passive controls to reduce the likelihood of human intrusion. Because of the depth of the disposal horizon, it is believed that only the mineral resources are significant in predicting the long-term performance of

the disposal system. However, the non-mineral and cultural resources are presented for completeness.

Background Environmental Conditions

The regulations in 40 CFR § 268.6 specifically require an assessment of background environmental conditions. Background environmental conditions are provided in this application as part of the complete description of the WIPP and its vicinity. Background environmental conditions form the baseline for determining if releases to the environment will occur during the operational period or during any post-operational monitoring period. Emphasis is placed on ecological conditions, water quality, and air quality and includes the following:

Ecological Conditions

- Vegetation
- Mammals
- Reptiles and amphibians
- Birds
- Arthropods
- Aquatic ecology
- Endangered species

Quality of Environmental Media

- Surface water
- Groundwater
- Air

Terrestrial and Aquatic Ecology. The WIPP site is in an area characterized by stabilized sand dunes. The vegetation is dominated by shinnery oak, mesquite, sand sage, dune yucca, smallhead snakeweed, three-awn, and numerous species of forbs and perennial grasses. The dominant shrubs are deep-rooted species with extensive root systems. The shrubs not only stabilize the dune sand, but serve as food, shelter, and nesting sites for many species of wildlife inhabiting the area.

The most conspicuous mammals at the site are the black-tailed jack rabbit and the desert cottontail. Common small mammals found at the WIPP site include the Ord's kangaroo rat, the plains pocket mouse, and the northern grasshopper mouse. Big-game species, such as the mule deer and the pronghorn antelope, and carnivores, such as the coyote, are present in small numbers.

Commonly observed reptiles in the study area are the side-blotched lizard, the western box turtle, the western whiptail lizard, and several species of snakes, including the bullsnake, the prairie rattlesnake, the western diamondback rattlesnake, the coachwhip, the western hognose, and the glossy snake. Of these, only the side-blotched lizard is

found in all habitats. The others are mainly restricted to one or two associations within the central dunes area, although the western whiptail lizard and the western diamondback rattlesnake are found in areas dominated by creosote bush as well. The yellow mud turtle is found only in the limited number of aquatic habitats in the study area (i.e., dirt stock ponds and metal stock tanks), but it is common in these locales.

Numerous birds inhabit the area either as transients or year-long residents. Loggerhead shrikes, pyrrhuloxias, and black-throated sparrows are examples of common residents. Migrating or breeding waterfowl species do not frequently reside in the area. Some raptors (e.g., Harris hawks) are residents. The density of large avian predators' nests has been documented as among the highest recorded in the scientific literature.

About 1,000 species of insects have been collected in the study area. Of special interest are subterranean termites. Vast colonies of these organisms are located across the study area. They are detritivores, and play an important part in the recycling of nutrients in the study area.

Aquatic habitats within a 5-mi (8-km) radius of the WIPP site are limited. Stock-watering ponds and tanks constitute the only permanent surface waters. Ephemeral surface-water puddles form after heavy thunderstorms. At greater distances, seasonally wet, shallow lakes (playas) and permanent salt lakes are found.

The DOE consulted with the U.S. Fish and Wildlife Service (FWS) in 1979 to determine the presence of threatened and endangered species at the WIPP site (included in Appendix I of the FEIS). At that time, the FWS listed the Lee pincushion cactus, the black-footed ferret, the American peregrine falcon, the bald eagle, and the Pecos gambusia as threatened or endangered and as occurring or having the potential to occur on lands within or outlying the WIPP site. The FWS advised the DOE that the list of species provided in 1979 is still valid, except that the black-footed ferret should now be deleted. The DOE believes that the actions described in the 1990 *Supplement Environmental Impact Statement* (SEIS) will have no impact on any threatened or endangered species, because these activities do not involve any ground disturbance that was not already evaluated in the FEIS. In addition, there is no critical habitat for terrestrial species identified as endangered by either the FWS or the New Mexico Department of Game and Fish (NMDG&F) at the site area.

Water Quality. Based on major solute compositions, four hydrochemical facies are delineated and described for the Culebra. Together, the variations in solutes and the distribution of halite in the Rustler exhibit a mutual interdependence. Concentrations of solutes are lowest where Rustler halite is less abundant, consistent with the hypothesis that solutes in Rustler groundwaters are derived locally by dissolution of minerals (e.g., halite, gypsum, and dolomite) in adjacent strata.

In general, the chemistry of Magenta water is variable. Groundwater types range from a predominantly sodium chloride type to a calcium-magnesium-sodium-sulfate type chemistry. In the WIPP area, the water quality of the Magenta is better than that of the

Culebra. However, water from the Magenta is not used anywhere in the vicinity of the WIPP.

The Pecos River is the nearest permanent water source to the WIPP site. Natural brine springs, representing outfalls of the brine aquifers in the Rustler, feed the Pecos River at Malaga Bend, 12 mi (19 km) southwest of the site. This natural saline inflow adds approximately 70 tons of chloride per day to the Pecos River. Return flow from irrigated areas above Malaga Bend further contributes to the salinity. The concentrations of potassium, mercury, nickel, silver, selenium, zinc, lead, manganese, cadmium, and barium also show significant elevations at Malaga Bend, but tend to decrease downstream. The metals are presumably rapidly adsorbed onto the river sediments. Natural levels of certain heavy metals in the Pecos River below Malaga Bend exceed the water quality standards of the World Health Organization (WHO), the EPA, and the State of New Mexico.

Air Quality. Measurement of selected air pollutants at the WIPP site began in 1976 and were reported by DOE in the FEIS. Since the preparation of that document, a more extensive air quality monitoring program has been established. Seven classes of atmospheric gases regulated by the EPA have been monitored at the WIPP site between August 27, 1986 and October 30, 1994. These gases are carbon monoxide (CO), hydrogen sulfide (H_2S), ozone (O_3), nitrogen oxides (NO, NO_2, NO_x), and sulfur dioxide (SO_2). The total suspended particulates (TSPs) are monitored in conjunction with the air-monitoring programs of the WIPP.

Climate and Meteorological Conditions

The long time periods involved in the isolation of radioactive waste are significant with respect to potential changes in climate. Climate changes are documented through studies of floral, faunal, and geological data and lead to fuller understanding of cyclic effects that may impact the long-term performance of the disposal system. The purpose of this chapter is to build the basis for the modeling of future climate change.

Historic Climatic Conditions. Prior to 18,000 years ago, radiometric dates are relatively scarce, and the record is incomplete. From 18,000 years ago to the present, however, the climatic record is relatively well constrained, as shown by floral, faunal, and lacustrine data. These data span the transition from the last full-glacial maximum to the present interglacial period; given the global consistency of glacial fluctuations, they are broadly representative of extremes for the entire Pleistocene.

Early and middle Pleistocene paleoclimatic data for the southwestern United States are incomplete and permit neither continuous reconstructions of paleoclimates nor direct correlations between climate and glaciation prior to the last glacial maximum, which occurred 22,000–18,000 years ago. Stratigraphic and soil data from several locations, however, indicate that cyclical alternation of wetter and drier climates in the southwest had begun by the early Pleistocene.

Global climate models indicate that the dominant glacial effect in the Southwestern U.S. was the disruption and southward displacement of the westerly jet stream by the physical mass of the ice sheet to the north. At the glacial peak, major Pacific storm systems followed the jet stream across New Mexico and the southern Rocky Mountains, and winters were wetter and longer than either at the present or during the previous interglacial period.

Gastropod assemblages at Lubbock Lake in western Texas suggest mean annual temperatures 41°F (5°C) below present values. Both floral and faunal evidence indicate that annual precipitation throughout the region was 1.6 to 2.0 times greater than today's values. Floral evidence also suggests that winters may have continued to be relatively mild, perhaps because the glacial mass blocked the southward movement of arctic air. Summers at the glacial maximum were cooler and drier than at present, without a strongly developed monsoon.

Three significant conclusions can be drawn from the climatic record of the American Southwest. First, maximum precipitation in the past coincided with the maximum advance of the North American ice sheet. Minimum precipitation occurred after the ice sheet had retreated to its present limits. Second, past maximum long-term average precipitation levels were roughly twice the present levels. Minimum levels may have been 90 percent of the present levels. Third, short-term fluctuations in precipitation have occurred during the present relatively dry, interglacial period, but they have not exceeded the upper limits of the glacial maximum.

Recent Climatic Conditions. Recent climatic conditions are provided to allow for the assessment of impacts of these factors on the disposal unit and the site. The WIPP facility does not rely on climatic conditions to control waste migration; however, meteorological information is used to evaluate the air pathway during operation of the facility.

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are mostly from the southeast and moderate. In late winter and spring, there are strong west winds and dust storms. During the winter, the weather is often dominated by a high-pressure system situated in the central portion of the western United States and a low-pressure system located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona.

Seismology

The seismic studies build a basis from which to predict ground motions that the WIPP repository may be subjected to in the near and distant future. The concern about seismic effects in the near future, during the operational period, pertains mainly to the design requirements for surface and underground structures providing containment during seismic events. The concern about effects occurring over the long term, after the repository has been decommissioned and sealed, pertains more to relative motions

(faulting) within the repository and possible effects of faulting on the integrity of the salt beds and/or shaft seals.

Seismic History. Seismic data are presented in two time frames, before and after the time when seismographic data for the region became available. The earthquake record in southern New Mexico dates back only to 1923, and seismic instruments have been in place in the state since 1961. Various records have been examined to determine the seismic history of the area within 180 mi (290 km) of the site. With the exception of a weak shock in 1926 at Hope, New Mexico, and shocks in 1936 and 1949 felt at Carlsbad, all known shocks before 1961 occurred to the west and southwest of the site more than 100 mi (160 km) away.

2.0 SITE CHARACTERIZATION

In Title 40 Code of Federal Regulations (CFR) § 268.6(a)(3), the U.S. Environmental Protection Agency (EPA) specifies that one component of the no-migration demonstration include a comprehensive characterization of the disposal unit site, including an analysis of background environmental conditions. The EPA (EPA 1992) has also provided guidance to assist an applicant in determining the information that is required to meet the specific requirements of 40 CFR § 268.6(a)(3). The EPA requires that "the site's climatology, meteorology, geology and hydrology must be described in sufficient detail to permit assessment of the degree of waste isolation achievable." In its detailed guidance, the EPA adds "background environmental quality" to the list of needed information. The purpose of Chapter 2 is to address these information needs.

The U.S. Department of Energy (DOE) uses the performance assessment simulation codes described in Chapter 8 to demonstrate that the Waste Isolation Pilot Plant (WIPP) disposal system will meet the environmental performance standards of Title 40 of the Code of Federal Regulations (CFR) §268.6. The information used in the long-term simulation includes field studies, laboratory evaluations, experiments, and, in the case of some features not amenable to direct characterization, professional judgment.

The DOE selected the Los Medaños region and present site for the WIPP based on certain defined siting criteria. The siting criteria were specified to emphasize favorable features over unfavorable features. This siting process is discussed in this petition in Appendix GCR.

In conducting the long-term demonstration, screening criteria for features, events, and processes (FEPs) have been formulated and applied to determine those site characteristics that affect disposal unit performance sufficiently to be included in the conceptual model underlying the simulation. The screening criteria are also used to minimize conceptual uncertainty (EPA 1992, 34-35).

Section 8.4.3 contains a comprehensive list of potential FEPs of interest (including many not considered sufficiently likely or important to warrant discussion in previous documents) and describes the methodology used to screen them. Appendix SCR contains screening arguments for those FEPs that have been excluded from the conceptual model.

The DOE's site screening, site selection, and subsequent characterization led to the identification of specific FEPs that required in-depth evaluation. The DOE dealt with these FEPs, for the most part, during the site characterization, and many were documented with studies identified in an agreement signed by the DOE and the State of New Mexico (DOE and State of New Mexico 1981). A list of FEPs related to the natural environment is presented in Table 2-1. The DOE's basis for retention or elimination of site-related FEPs in the development of the conceptual model, as discussed in Section 8.4.3 and Appendix SCR, includes information presented in this chapter.

In this chapter, the DOE describes the WIPP site geology, hydrology, climatology, air quality, ecology, and cultural and natural resources. This chapter's purpose is to explain (1) characteristics of the site, (2) background environmental quality, and (3) discuss features of the site that might be important for inclusion in a quantitative performance assessment. The DOE uses this information to implement the long-term simulation used to evaluate the efficacy of natural and engineered barriers in meeting environmental performance standards (Chapter 8). Results of these predictive models are used by the DOE to demonstrate that the DOE has a reasonable expectation that compliance with applicable regulations will be achieved.

The DOE located the WIPP site 26 mi (42 km) east of Carlsbad, New Mexico, in Eddy County (Figure 2-1). The latitude of the WIPP site center is 32°22'11" N and the longitude is 103°47' 30" W. The region surrounding the WIPP site has been studied for many years, and exploration of both potash and hydrocarbon deposits has provided extensive knowledge of the geology of the region. Two exploratory holes were drilled by the federal government in 1974 at a location northeast of the present site; that location was abandoned in 1975 as a possible repository site after U.S. Energy Research and Development Administration (ERDA)-6 was drilled and unacceptable structure and pressurized brine were encountered. The results of these investigations are reported in Powers et al. (1978, 2–6; included in this document as Appendix GCR). During late 1975 and early 1976, the ERDA identified the current site, and an initial exploratory hole (ERDA-9) was drilled. By the time an initial phase of site characterization was completed in August 1978, 47 holes had been or were being drilled for various hydrologic and geologic purposes. Geophysical techniques were applied to augment data collected from boreholes. Since 1978, the DOE has drilled additional holes to support hydrologic studies, geologic studies, and facility design. Geophysical logs, cores, basic data reports, geochemical sampling and testing, and hydrological testing and analyses are reported by the DOE and its scientific advisor, Sandia National Laboratories (SNL), in numerous public documents. Many of those documents form the basis for the DOE's assertions in this petition. As necessary, specific references from these documents are cited to reinforce the statements being made. Additional sources of information on the various topics in this section are listed in a bibliography at the end of the chapter.

Biological studies of the site began in 1975 to gather information for the Environmental Impact Statement. Meteorological studies began in 1976, and economic studies were initiated in 1977. Baseline environmental data were initially reported in 1977 and are now updated annually by the DOE.

The DOE located the WIPP disposal horizon within a rock salt deposit known as the Salado Formation (hereafter referred to as the Salado) at a depth of 2,150 ft (655 m) below the ground surface. The Salado is regionally extensive, includes continuous beds of salt without complicated structure, is deep with little potential for dissolution in the immediate vicinity of the WIPP, and is near enough to the surface to make access reasonable. Particular site selection criteria narrowed the choices when the present site was located during 1975 and 1976 as discussed in Appendix GCR (2-10 to 2-27) and summarized by Weart (1983).

Table 2-1. Issues Related to the Natural Environment That Were Evaluated for the WIPP Performance Assessment Scenario Screening

FEP Topical Heading		WIPP Issue	Discussion
Geological Processes or Events			
Stratigraphy		Stratigraphy	§ 2.1.3
Tectonics		Changes in regional stress	§ 2.1.5.1
		Regional tectonics	§ 2.1.5.1
		Regional uplift and subsidence	§ 2.1.5.1
Structural effects	Deformation	Salt deformation	§ 2.1.6.1
		Diapirism	§ 2.1.6.1
	Fracture development	Formation of fractures	§ 2.1.5.2
		Changes in fracture properties	§ 2.1.5.2
	Fault movement	Formation of new faults	§ 2.1.5.3
		Movement along faults	§ 2.1.5.3
	Seismic Activity	Earthquakes	§ 2.6
		Ground shaking	§ 2.6
Crustal processes	Igneous Activity	Volcanic activity	§ 2.1.5.4
		Magmatic activity	§ 2.1.5.4
	Metamorphism	Metamorphism	App. SCR
Geochemical effects	Dissolution	Shallow dissolution	§ 2.1.6.2
		Lateral dissolution	§ 2.1.6.2
		Deep dissolution	§ 2.1.6.2
		Solution chimneys	§ 2.1.6.2
		Breccia pipes	§ 2.1.6.2
		Collapse breccias	§ 2.1.6.2
	Mineralization	Fracture infilling	§ 2.1.3.5
		Hydrothermal alteration	
Subsurface Hydrological Processes			
Groundwater characteristics		Saturated groundwater flow	§ 2.2.1
		Unsaturated groundwater flow	§ 2.2.1
		Groundwater flow--fractures	§ 2.2.1
		Effects of preferential pathways	§ 2.2.1
Changes in groundwater flow		Thermal effects on groundwater flow	§ 2.2.1
		Saline groundwater intrusion	§ 2.2.1
		Fresh groundwater intrusion	§ 2.2.1
		Density effects on groundwater flow	§ 2.2.1
		Hydrological response to earthquakes	App. SCR
Subsurface Geochemical Processes			
Groundwater geochemistry		Groundwater geochemistry	§ 2.2.1
Changes in groundwater geochemistry		Saline groundwater intrusion	App. SCR
		Fresh groundwater intrusion	App. SCR
		Changes in groundwater Eh	App. SCR
		Changes in groundwater pH	App. SCR
		Effects of dissolution on groundwater chemistry	App. SCR
Geomorphological Processes			
Physiography		Physiography	§ 2.1.4
Meteorite impact		Meteorite impact	App. SCR

Table 2-1. Issues Related to the Natural Environment That Were Evaluated for the WIPP Performance Assessment Scenario Screening (Continued)

FEP Topical Heading		WIPP Issue	Discussion
Denudation	Weathering	Mechanical weathering	App. SCR
		Chemical weathering	App. SCR
	Erosion	Aeolian erosion	§ 2.1.4.2
		Fluvial erosion	§ 2.1.4.2
		Mass wasting	App. SCR
	Sedimentation	Aeolian deposition	§ 2.1.4.2
		Fluvial deposition	App. SCR
		Lacustrine deposition	App. SCR
		Mass wasting	App. SCR
Soil Development		Soil development	§ 2.1.3.10
Surface Hydrological Processes or Events			
Fluvial		Surface flow characteristics: stream/river flow	§ 2.2.2
Lacustrine		Surface water bodies	§ 2.2.2
Infiltration/recharge/discharge		Groundwater discharge	§ 2.2.1
		Groundwater recharge	§ 2.2.1
		Runoff	§ 2.2.2
		Infiltration	§ 2.5.2
Changes in surface hydrology		Changes in groundwater recharge/discharge	§ 2.2.1
		Lake formation/infilling	§ 2.2.2
		River flooding	§ 2.1.4.2, § 2.2.2
Climatic Processes			
Climate		Precipitation	§ 2.5.2.3
		Temperature	§ 2.5.2.1
		Wind	§ 2.5.2.4
Climate change	Meteorological	Climate change	§ 2.5.1
		Drought	§ 2.5.1
	Glaciation	Glaciation	§ 2.5.1
		Permafrost	§ 2.5.1
Marine Processes			
Seas		Coastal waters	App. SCR
		Ocean waters	App. SCR
		Estuaries	App. SCR
Marine sedimentology		Coastal erosion	App. SCR
		Marine sediment transport and deposition	App. SCR
Sea level change		Sea level change	App. SCR
Ecological Processes			
Flora & fauna		Plants	App. SCR
		Animals	App. SCR
		Microbes	App. SCR
Changes in flora & fauna		Natural ecological development	App. SCR

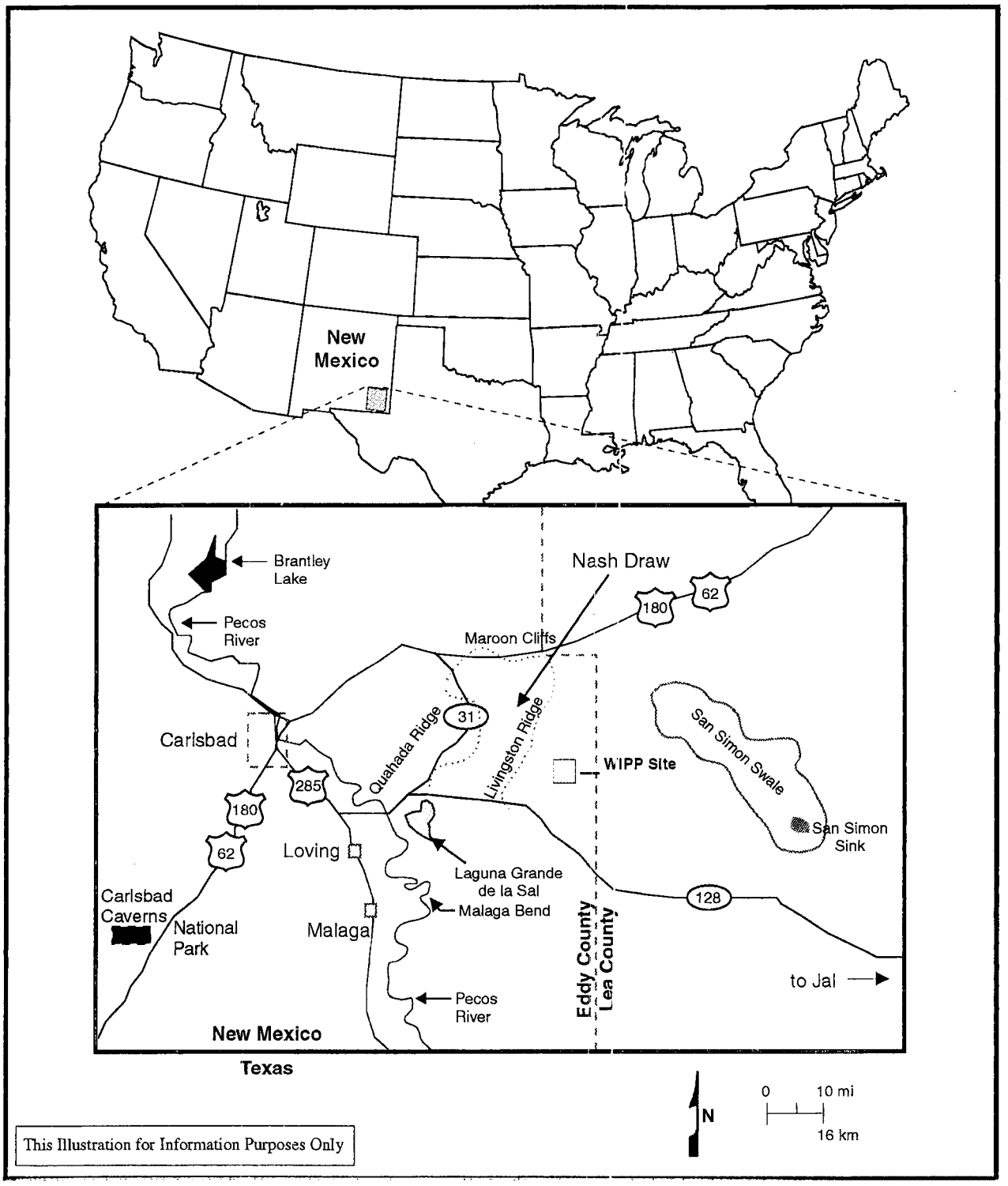

Figure 2-1. WIPP Site Location in Southeastern New Mexico

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The EPA has previously reviewed and commented on much of the information collected by the DOE during the site characterization program. This review was conducted in 1989 after the DOE submitted a no-migration variance petition to the EPA for Test Phase activities. The EPA issued a document titled "Background Document for the U.S. Environmental Protection Agency's proposed decision on the No Migration Variance for U.S. Department of Energy's Waste Isolation Pilot Plant," (EPA 1990a). In this document, the EPA reached conclusions regarding the adequacy of the DOE's site characterization program and the reasonableness of the DOE's interpretation of the results of the site characterization activities. These conclusions were reached after thorough review of the record by the EPA's geologists, hydrologists, and other scientists. The EPA's decision in 1990 to issue a variance was based on disposal system performance over a relatively short time frame. This notwithstanding, many of the conclusions the EPA reached apply equally for the long term. In the following sections, the EPA's previous comments and conclusions are presented as background.

2.1 Geology

A thorough description of the WIPP facility's natural environmental setting is considered crucial by the DOE for a demonstration of compliance with the disposal standards. The DOE is providing the detail necessary to assess the achievable degree of waste isolation. In this section, the DOE addresses environmental factors and long-term environmental changes that are important for assessing the waste isolation potential of the disposal system. The first of these environmental factors is geology.

Geological data have been collected from the WIPP site and surrounding area to evaluate the site's suitability as a radioactive waste repository. These data have been collected principally by the DOE, the DOE's predecessor agencies, the United States Geological Survey (USGS), the New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and private organizations engaged in natural resource exploration and extraction. The DOE has analyzed the data and has determined that the data support the DOE's position that the WIPP site is suitable for the long-term isolation of TRU-mixed waste.[1] Many issues have been discussed, investigated, and resolved in order for the DOE to conclude that the site is suitable. The DOE discusses these issues in the following sections. Most of the data collected have been reported or summarized in Appendices GCR and SUM.

[1]The EPA, in its background document on the WIPP for the April 1990 proposed no-migration determination (NMD), stated that "In general, the selected site has been shown to be geologically and seismically stable. The confining unit in which the WIPP has been constructed -- the Salado Formation -- is a promising geologic medium for mixed waste disposal." The EPA, however, went on to state that there are certain areas that require additional investigation, including brine inflow into the repository, far field permeability, and groundwater flow patterns in the formations that overlie the Salado. These latter topics have been the subject of intense investigation and modeling since the EPA prepared its assessment and are discussed in detail in this chapter.

2.1.1 Data Sources and Quality

The geology of southeastern New Mexico has been of great interest for more than a century. The Guadalupe Mountains have become a common visiting and research point for geologists because of the spectacular exposures of Permian-age reef rocks and related facies (see Shumard 1858, Crandall 1929, Newell et al. 1953, and Dunham 1972 in the bibliography). Because of intense interest in both hydrocarbon and potash resources in the region, a large volume of data exists as background information for the WIPP site, though some data are proprietary. Finally, there is the geological information developed directly and indirectly by studies sponsored by the DOE for the WIPP project; it ranges from raw data to interpretive reports.

Elements of the geology of southeastern New Mexico have been discussed or described in professional journals or technical documents from many different sources. These types of articles are an important source of information, and where there is no contradictory evidence, the information in these articles is referenced when subject material is relevant. Implicit rules of professional conduct of research and reporting have been applied, as have journal and editorial review. Elements of the geology presented in such sources have been deemed critical to the WIPP and have been the subject of specific DOE-sponsored WIPP studies.

The geological data that the DOE has developed explicitly for the WIPP project have been produced over a 20-year period by different organizations and contractors using applicable national standards for quality assurance (QA) and documentation. The EPA reviewed the DOE's various QA programs (including those of Sandia, Westinghouse, and International Technology Corporation [ITC]) at the time that the 1990 NMD was issued and concluded that these programs were adequate. In addition, during a rulemaking in 1988, the EPA addressed the use of older geological data in making a long-term demonstration of repository performance. In response to comments on a proposed rule regarding the permitting of underground injection wells, the EPA concluded that "[e]xcluding historical data or information which might have been gathered off-site by methods not consistent with certain prescribed procedures may be counterproductive." The EPA further stated that such data should be used as long as their limitations are accounted for. In the final rule, the EPA stipulated "that only measurements pertaining to the waste or that result from testing performed to gather data for the petition demonstration comply with prescribed procedures." Further, the EPA stated that "the concerns about the accuracy of geologic data are addressed more appropriately by requiring that the demonstration identify and account for the limits on data quality rather than by excluding data from consideration" (53 FR 28188).

As site characterization activities progressed, the DOE, along with independent review groups such as the National Academy of Sciences (NAS) and the State of New Mexico acting through the Environmental Evaluation Group (EEG), identified natural FEPs that required additional detailed investigation. Because these investigations, in many cases, were to gather data that would either be used in developing conceptual models or in the prediction of disposal system performance, the QA standards applied to these

investigations were more stringent, thereby assuring accuracy and repeatability to the extent possible for geologic investigations.

Geological data have been developed by the DOE through a variety of WIPP-sponsored studies using drilling, mapping or other direct observation, geophysical techniques, and laboratory work. Most of the techniques and statistics of data acquisition will be incorporated by specific discussion. Borehole investigations are a major source of geological data for the WIPP and surrounding area. Boreholes studies provide raw data (for example, depth measurements, amount of core, geophysical logs) that support point data and interpreted data sets. These data sets are used in computing other useful analysis tools such as structure maps for selected stratigraphic horizons or isopachs (thickness) of selected stratigraphic intervals.

The borehole data sets that were used specifically for obtaining WIPP geologic information are included as reference information in Appendix BH. A map of some borehole locations in the data set is provided in Figure 2-2. These boreholes are the ones used for most of the geological interpretations in this chapter. Other holes are not shown, because they were not of sufficient depth, were not cored, or were not drilled for purposes of site characterization.

2.1.2 Geologic History

In this section, the DOE summarizes the more important points of the area's geologic history within about 200 mi (320 km) of the WIPP site, with emphasis on more recent or nearby events. Figure 2-3 shows the major elements of the area's geological history from the end of the Precambrian Period.

The geologic time scale that the DOE uses for WIPP is based on the compilation by Palmer (1983, 503–504) for "The Decade of North American Geology" (DNAG). There are several compiled sources of chronologic data related to different reference sections or methods (see, for example, Harland et al. 1982 and Salvador 1985 in the bibliography). Although most of these sources show generally similar ages for chronostratigraphic boundaries, there is no consensus on either reference boundaries or most-representative ages. The DNAG scale is accepted by the DOE as a standard that is useful and sufficient for WIPP purposes, as no known critical parameters require more accurate or precise dates.

The geologic history in this region can conveniently be subdivided into three general phases:

- A Precambrian Period, represented by metamorphic and igneous rocks ranging in age from about 1.5 to 1.1 billion years.
- A period from about 1.1 to 0.6 billion years ago, for which no rocks are preserved. Erosion may have been the dominant process for much of this period.
- An interval from 0.6 billion years ago to the present represented by a more complex set of mainly sedimentary rocks and shorter periods of erosion and dissolution

This latter phase is the main subject of the DOE's detailed discussion of this text.

Only a few boreholes in the WIPP region have bored deep enough to penetrate Precambrian crystalline rocks, and therefore, relatively little petrological information is available. Foster (1974, Figure 3) extrapolated the elevation of the Precambrian surface under the area of WIPP as being between 14,500 ft (4,420 m) and 15,000 ft (4,570 m) below sea level; the site surface at WIPP is about 3,400 ft (1,036 m) above sea level. Keesey (1976, vol. I, exhibit no. 2) projected a depth of about 18,200 ft (5,550 m) to the top of Precambrian rocks in the vicinity of the WIPP. The depth projection is based on the geology of the nearby borehole in Section 15, T22S, R31E.

Precambrian rocks of several types crop out in the following locations: the Sacramento Mountains northwest of WIPP; around the Sierra Diablo and Baylor Mountains near Van Horn, Texas; west of the Guadalupe Mountains at Pump Station Hills; and in the Franklin Mountains near El Paso, Texas. East of the WIPP, a relatively large number of boreholes on the Central Basin Platform have penetrated the top of the Precambrian (Foster 1974, Figure 3). As summarized by Foster (1974, 10), Precambrian rocks in the area considered similar to those in the vicinity of the site range in age from about 1.14 to 1.35 billion years.

For about 500 million years (1.1 to 0.6 billion years ago), there is no certain rock record in the region around the WIPP. The most likely rock record for this period may be the Van Horn sandstone, but there is no conclusive evidence that it represents part of this time period. The region is generally thought to have been subject to erosion for much of the period until the Bliss sandstone began to accumulate during the Cambrian.

2.1.3 Stratigraphy and Lithology in the Vicinity of the WIPP Site

The FEP screening process has identified stratigraphy as a feature of the natural system to be included in the performance modeling. The conceptual models developed for this purpose are discussed in Chapter 8. Stratigraphic information provided in the following sections is used in the conceptual model and includes the thickness and lateral distribution of the various stratigraphic units; the lithology, including the presence of soluble or insoluble constituents and the distribution of fractures or vugs; and the presence of minerals of geochemical significance. This discussion has focused on the general properties of the various rock units as determined from field studies. Specific parameters used in the modeling described in Chapter 8 are summarized in Appendix PAR. These parameters include some of those that are of hydrological, tectonic, or geomorphological significance and are described in the subsequent sections.

This section describes the stratigraphy and lithology of the Paleozoic and younger rocks underlying the WIPP site and vicinity (Figure 2-4), emphasizing the units nearer the surface. Details begin with the Permian (Guadalupian) Bell Canyon Formation (hereafter referred to as the Bell Canyon)—the upper unit of the Delaware Mountain Group—because this is the uppermost transmissive formation below the evaporites. The

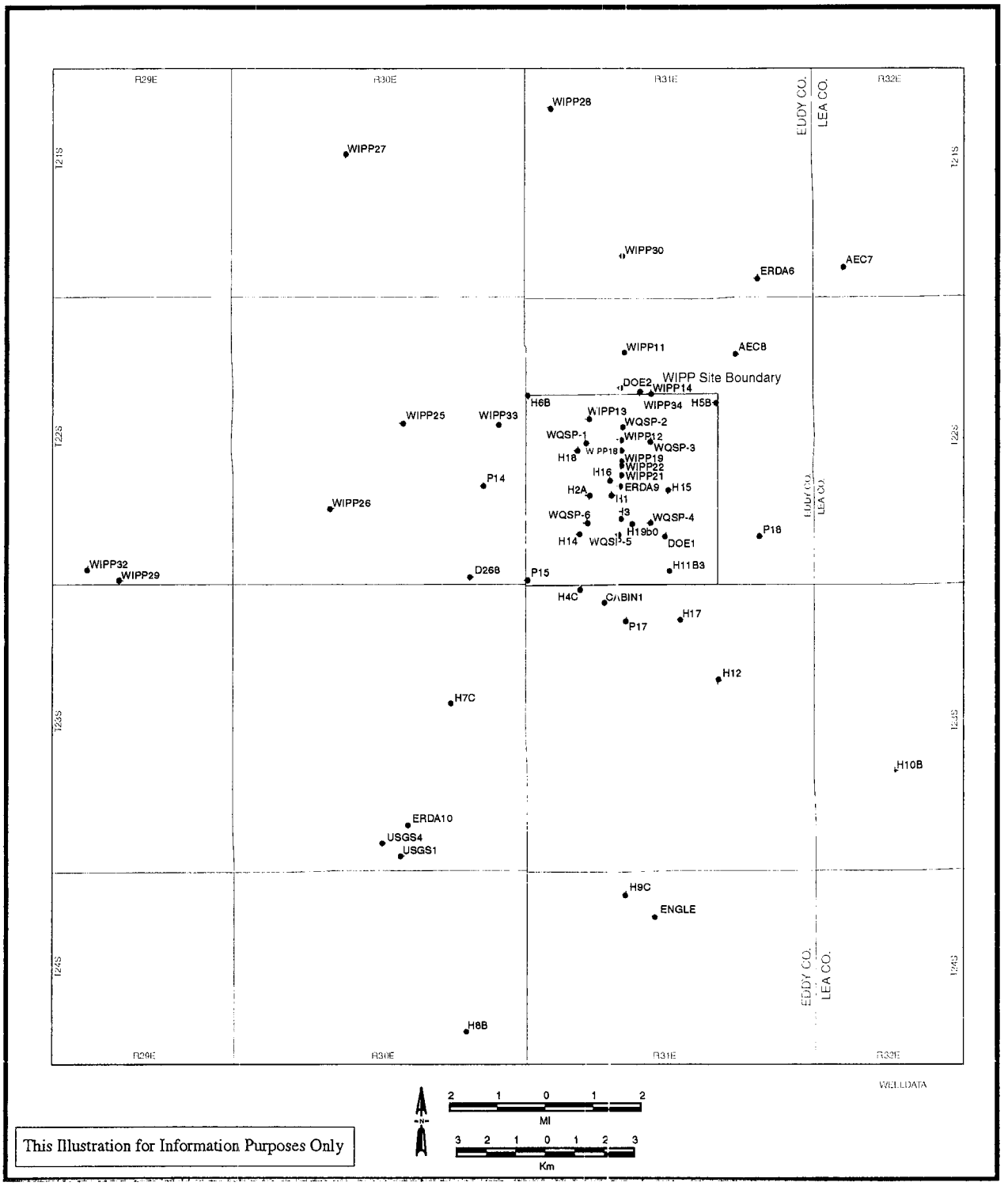

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Figure 2-2. WIPP Site and Vicinity Borehole Location Map

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ERA	PERIOD	EPOCH	YEARS		MAJOR GEOLOGIC EVENTS - SOUTHEAST NEW MEXICO REGION
			DURATION	BEFORE PRESENT	
CENOZOIC	Quaternary	Holocene	10,000		Eolian and erosion/solution activity. Development of present landscape.
		Pleistocene	1,590,000	1,600,000	Continued deposition of Gatuña sediments.
	Tertiary	Pliocene	3,700,000		Deposition of Gatuña sediments. Formation of caliche caprock. Regional uplift and east-southeastward tilting; Basin-Range uplift of Sacramento and Guadalupe-Delaware Mountains.
		Miocene	18,400,000		
		Oligocene	12,900,000		Erosion dominant. No Early to Mid-Tertiary rocks present.
		Eocene	21,200,000		Laramide "revolution." Uplift of Rocky Mountains. Mild tectonism and igneous activity to west and north.
		Paleocene	8,600,000	66,400,000	
MESOZOIC	Cretaceous		77,600,000	144,000,000	Submergence. Intermittent shallow seas. Thin limestone and clastics deposited.
	Jurassic		64,000,000	208,000,000	Emergent conditions. Erosion, formation of rolling terrain. Deposition of fluvial clastics.
	Triassic		37,000,000	245,000,000	Erosion. Broad floodplain develops.
PALEOZOIC	Permian		41,000,000	286,000,000	Deposition of evaporite sequence followed by continental redbeds. Sedimentation continuous in Delaware, Midland, Val Verde basins and shelf areas.
	Pennsylvanian		34,000,000	320,000,000	Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
	Mississippian		40,000,000	360,000,000	Regional tectonic activity accelerates, folding up Central Basin platform. Matador arch, ancestral Rockies. Regional erosion. Deep, broad basins to east and west of platform develop.
	Devonian		48,000,000	408,000,000	Renewed submergence. Shallow sea retreats from New Mexico; erosion. Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas Peninsula emergent until Middle Mississippian.
	Silurian		30,000,000	438,000,000	
	Ordovician		67,000,000	505,000,000	Marathon-Quachita geosyncline, to south, begins subsiding. Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform and carbonates.
	Cambrian		65,000,000	570,000,000	Clastic sedimentation - Bliss sandstone.
	PRECAMBRIAN				Erosion to a nearly level plain. Mountain building, igneous activity, metamorphism, erosional cycles.

Figure 2-3. Major Geologic Events - Southeast New Mexico Region

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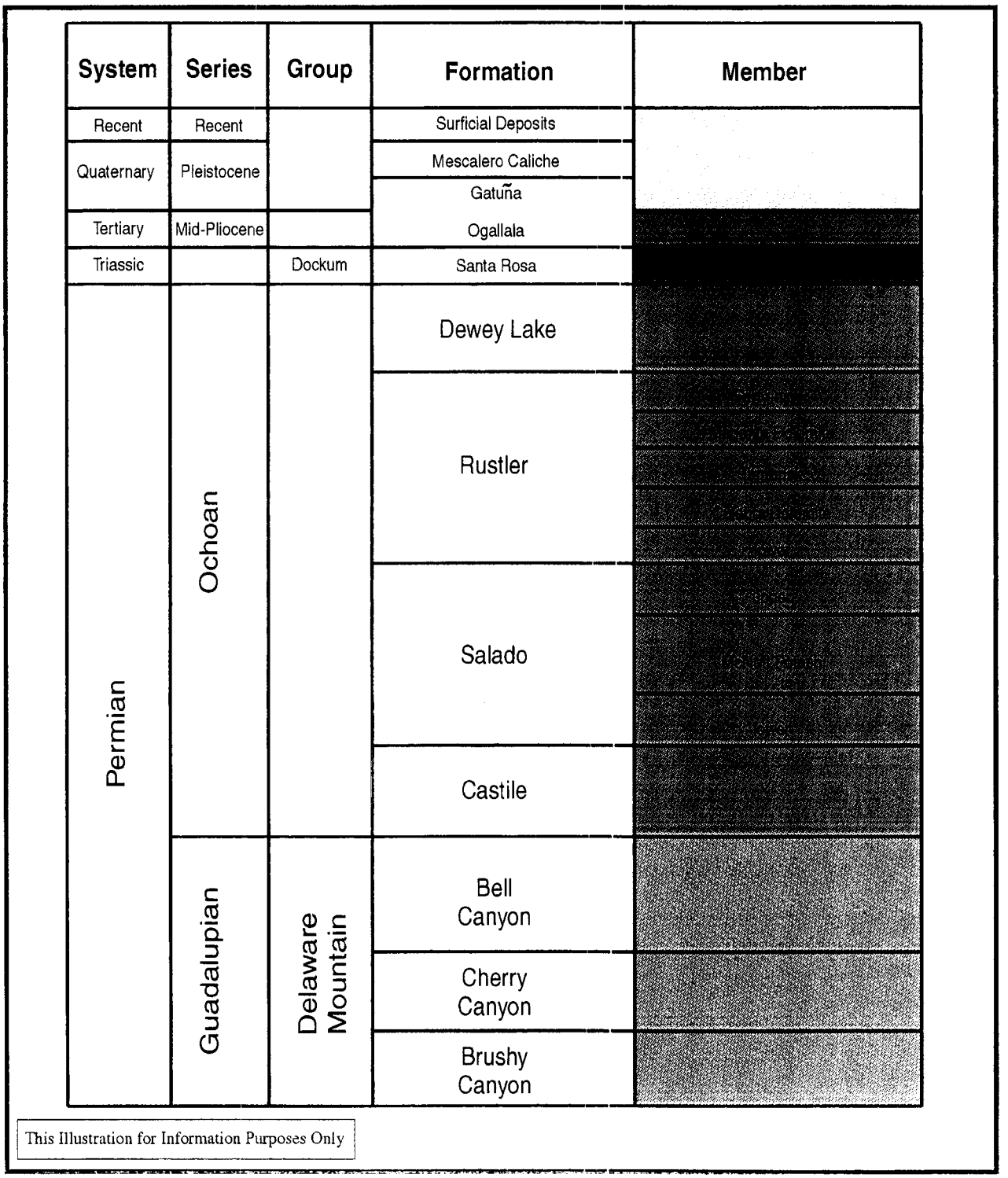

Figure 2-4. Site Geologic Column

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principal stratigraphic data are the chronologic sequence, age, and extent of rock units, including some of the nearby relevant facies changes. For deeper rocks, characteristics such as thickness and depth are summarized from published sources, and for shallower rocks they are mainly based on data sets presented in Appendix BH (above the Bell Canyon). The lithologies of upper formations and some formation members are described. A comprehensive discussion of stratigraphy in the WIPP area is presented in this application in Appendix GCR. Detailed referencing to original investigations by the United States Geological Society (USGS) and others is included.

2.1.3.1 General Stratigraphy and Lithology below the Bell Canyon

As stated previously, the Precambrian basement near the site is projected to be about 18,200 ft (5,550 m) below the surface (Keesey 1976, vol. II, exhibit no. 2), consistent with information presented by Foster in 1974. Ages of similar rock suites in the region range from about 1.14 to 1.35 billion years.

A detailed discussion of the distribution of Precambrian rocks in southeastern New Mexico and Texas can be found in this application in Appendix GCR, Section 3.3.1.

The basal units overlying Precambrian rocks are clastic rocks commonly attributed either to the Cambrian Bliss sandstone or the Ellenberger Group (Foster 1974, 10ff), considered most likely to be Ordovician in age in this area. The Ordovician System comprises the Ellenberger, Simpson, and Montoya Groups in the northern Delaware Basin. Carbonates are predominant in these groups, with sandstones and shales common in the Simpson Group. Foster (1974, Figure 4) reported 975 ft (297 m) of Ordovician-age rocks north of the site area and extrapolated a thicker section of about 1,300 ft (396 m) at the present site (1979, Figure 5). Keesey (1976, vol. II, exhibit no. 2) projected a thickness of 1,200 ft (366 m) for the Ordovician System within the site boundaries.

Silurian-Devonian rocks in the Delaware Basin are not stratigraphically well defined, and there are various notions for extending nomenclature into the basin. Common drilling practice is not to differentiate, though the Upper Devonian Woodford shale at the top of the sequence is frequently distinguished from the underlying dolomite and limestone (Foster 1974, 18). Foster (1974, Figure 6) showed a reference thickness of 1,260 and 160 ft (384 and 49 m) for the carbonates and the Woodford shale, respectively; he estimated thickness of these units at the present WIPP site of about 1,150 ft (351 m) and 170 ft (52 m), respectively. Keesey (1976, vol. II, exhibit no. 2) projected 1,250 ft (381 m) of carbonate and showed 82 ft (25 m) of the Woodford shale.

The Mississippian System in the northern Delaware Basin is commonly attributed to Mississippian limestone and the overlying Barnett shale (Foster 1974, 24), but the nomenclature is not consistently used. At the reference well used by Foster (1974, 25), the limestone is 540 ft (165 m) thick and the shale is 80 ft (24 m); isopachs at the WIPP are 480 ft (146 m) and less than 200 ft (61 m). Keesey (1976, vol. II, exhibit no. 2) indicates 511 ft (156 m) and 164 ft (50 m), respectively, within the site boundaries.

The nomenclature of the Pennsylvanian System applied within the Delaware Basin is both varied and commonly inconsistent with accepted stratigraphic rules. Chronostratigraphic, or time-stratigraphic, names are applied from base to top to these lithologic units: the Morrow, Atoka, and Strawn (Foster 1974, 31). Foster (1974, Figure 13) extrapolated thicknesses of about 2,200 ft (671 m) for the Pennsylvanian at the WIPP site. Keesey (1976, vol. II, exhibit no. 2) reports 2,088 ft (636 m) for these units. The Pennsylvanian rocks in this area are mixed clastics and carbonates, with carbonates more abundant in the upper half of the sequence.

The Permian is the thickest system in the northern Delaware Basin, and it is divided into four series from the base to top: Wolfcampian, Leonardian, Guadalupian, and Ochoan. According to Keesey (1976, vol. II, exhibit no. 2), the three lower series total 8,684 ft (2,647 m) near the site. Foster (1974, 35ff) indicates a total thickness for the lower three series of 7,665 ft (2,336 m) for a reference well north of WIPP. Foster's isopach maps of these series indicate about 8,500 ft (2,591 m) for the WIPP site area. The Ochoan Series at the top of the Permian is considered in more detail later because the formations host and surround the WIPP repository horizon. Its thickness at DOE-2, about 2 mi (3.2 km) north of the site center, is 3,938 ft (1,200 m) according to Mercer et al. (1987, 23 and 24).

The Wolfcampian Series is also referred to as the Wolfcamp Formation (hereafter referred to as the Wolfcamp) in the Delaware Basin. In the site area, the lower part of the Wolfcamp is dominantly shale with carbonate and some sandstone according to Foster (1974, 38); carbonate increases to the north. Clastics increase to the east toward the margin of the Central Basin Platform. Keesey (1976, vol. II, exhibit no. 2) reports the Wolfcamp to be 1,493 ft (455 m) thick at a well near the WIPP site.

The Leonardian Series is represented by the Bone Spring Limestone or Formation (hereafter referred to as the Bone Spring). According to Foster (1974, 39) the lower part of the formation is commonly interbedded carbonate, sandstone, and some shale, while the upper part is dominantly carbonate. Near the site, the Bone Spring is 3,247 ft (990 m) thick according to Keesey (1976, vol. II, exhibit no. 2).

The Guadalupian Series is represented in the general area of the site by a number of formations exhibiting complex facies relationships (Figure 2-5). The Guadalupian Series is known in considerable detail west of the site from outcrops in the Guadalupe Mountains, where numerous outcrops and subsurface studies have been undertaken. (See, for example, P.B. King 1948, Newell et al. 1953, and Dunham 1972 in the bibliography).

Within the Delaware Basin, the Guadalupian Series comprises three formations: Brushy Canyon, Cherry Canyon, and Bell Canyon, from base to top. These formations are dominated by submarine channel sandstones with interbedded limestone and some shale. The Lamar limestone generally tops the series, immediately underneath the Castile Formation (hereafter referred to as the Castile). Around the margin of the Delaware Basin, reefs developed when the Cherry Canyon and Bell Canyon formations were being deposited. These massive reef limestones, the Goat Seep and Capitan limestones, are

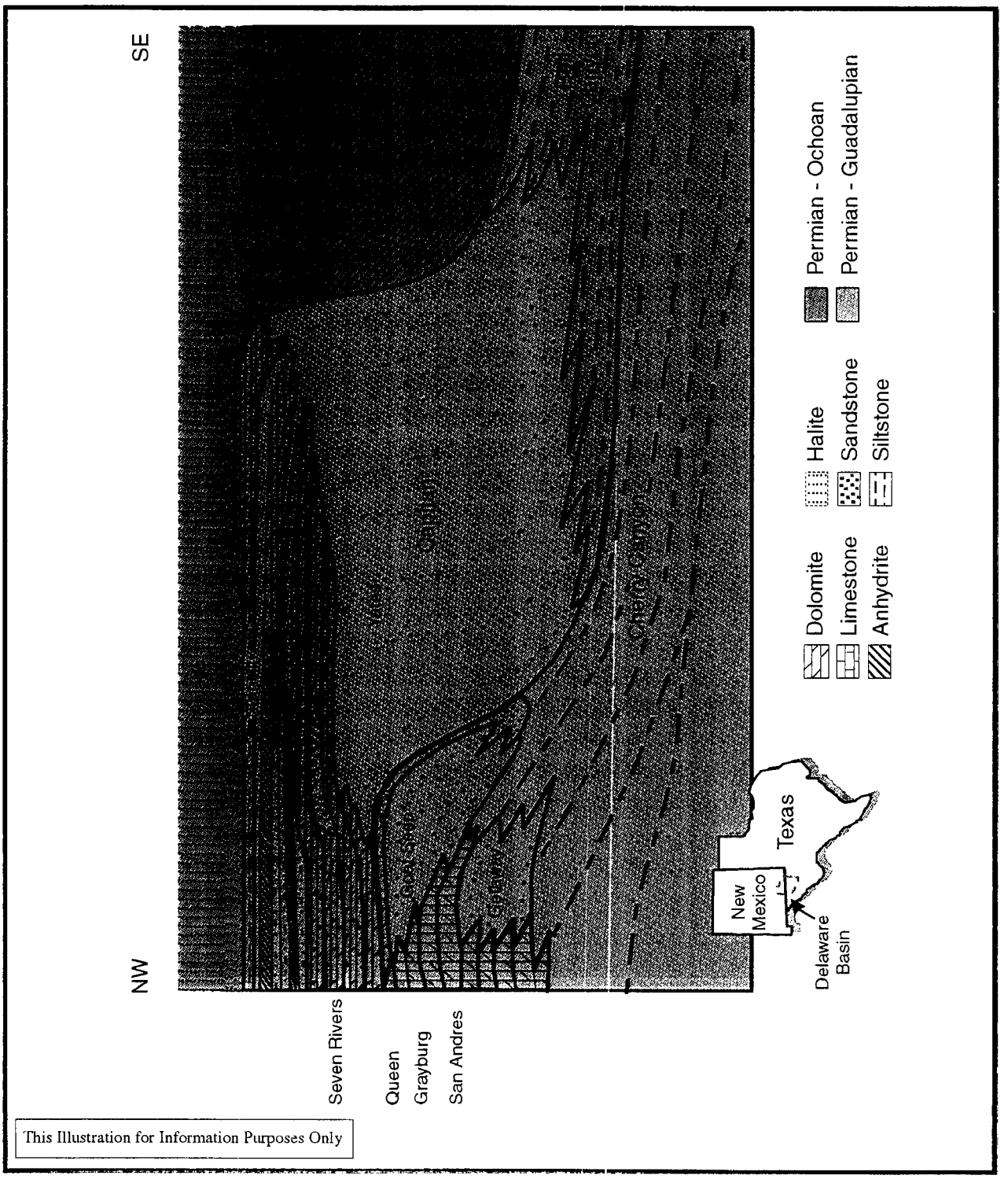

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Figure 2-5. Cross Section from Delaware Basin (southeast) through Marginal Reef Rocks to Back-Reef Facies

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equivalent in time to these basin sandstone formations but were developed topographically much higher around the basin margin. A complex set of limestone to sandstone and evaporite beds was deposited further away from the basin behind the reef limestones. The Capitan Reef and back-reef limestones are well known, because numerous caves, including the Carlsbad Caverns, are developed in these and adjacent rocks.

2.1.3.2 The Bell Canyon

The Bell Canyon is of interest, because it is the first laterally continuous transmissive unit below the WIPP repository. The significance of this unit is related to the potential for groundwater to migrate from the Bell Canyon into the repository and cause dissolution. The following discussion summarizes the basic understanding of the Bell Canyon lithology. Dissolution is discussed in Section 2.1.6. Bell Canyon hydrology is presented in Section 2.2.1.2.

The Bell Canyon is known from outcrops on the west side of the Delaware Basin and from subsurface intercepts for oil and gas drilling. Several informal lithologic units are commonly named during such drilling. Mercer et al. (1987, 28) stated that DOE-2 penetrated the Lamar limestone, the Ramsey sand, the Ford shale, the Olds sand, and the Hays sand. This informal nomenclature is used for the Bell Canyon in some other WIPP reports.

The Clayton Williams Badger Federal borehole near the WIPP (Section 15, T22S, R31E) intercepted 961 ft (293 m) of Bell Canyon, including the Lamar limestone, according to Keesey (1976, vol. II, exhibit no. 2). Reservoir sandstones of the Bell Canyon were deposited in channels that are straight to slightly sinuous. In their 1988 paper, Harms and Williamson proposed that density currents flowed from shelf regions, cutting channels and depositing the sands.

Within the basin, the Bell Canyon (Lamar limestone)–Castile contact is distinctive on geophysical logs because of the contrast in low natural gamma of the basal Castile anhydrite compared to the underlying limestone. Density or acoustic logs are also distinctive because of the massive and uniform lithology of the anhydrite compared to the underlying beds. In cores, the transition is sharp, as described by Mercer et al. (1987, 312) for DOE-2. A structure contour map of the top of the Bell Canyon in shown in Figure 2-6. According to Powers et al. 1978 (App. GCR p. 4-59), this structure does not reflect the structure of deeper formations suggesting different origins. The "rootless" character of at least some of the normal faulting in the lower Permian suggests there are shallow-seated features.

2.1.3.3 The Castile Formation

The Castile is the lowermost lithostratigraphic unit of the Late Permian Ochoan Series (Figure 2-7) and is part of the thick layer of evaporites within the WIPP disposal system. It was originally named by Richardson in 1904 for outcrops in Culberson County, Texas.

The Castile crops out along a lengthy area of the western side of the Delaware Basin. The two distinctive lithologic sequences now known as the Castile and the Salado were separated into the Upper and Lower Castile by Cartwright (1930). Lang in 1939 clarified the nomenclature by restricting the Castile to the lower unit and naming the upper unit the Salado. By defining an anhydrite resting on the marginal Capitan limestone as part of the Salado, Lang in 1939 effectively restricted the Castile to the Delaware Basin inside the reef rocks.

Through detailed studies of the Castile, Anderson et al. (1972, 59–86) introduced an informal system of names that is widely used and included in many WIPP reports. The units are named from the base as anhydrite 1 (A1), halite 1 (H1), anhydrite 2 (A2), etc. The informal nomenclature varies through the basin from A3 up because of complexity of the depositional system. The Castile consists almost entirely of thick beds of two lithologies: (1) interlaminated carbonate and anhydrite and (2) high-purity halite.

In the eastern part of the Delaware basin, the Castile is commonly 1,400–1,500 ft thick (427–457 m) (derived from Borns and Shaffer 1985, Figures 9, 11, 16). At DOE-2, the Castile is 989 ft (301 m) thick. The Castile is thinner in the western part of the Delaware Basin, and it lacks halite units. Anderson and Powers (1978, Figures 1, 3, 4, 5) correlated geophysical logs throughout the WIPP region, interpreting thin zones equivalent to halite units as dissolution residues. Anderson further attributed the lack of halite in the basin to its removal by dissolution.

For borehole DOE-2, a primary objective was to ascertain whether a series of depressions in the Salado 2 mi (3.2 km) north of the site was from dissolution in the Castile as proposed by Davies in his doctoral thesis (1984, 175). Studies have suggested that these depressions were not from dissolution but halokinesis in the Castile (see, for example, Borns 1987 and Chaturvedi 1987 in the bibliography). Robinson and Powers (1987, 69–79) interpreted one deformed zone in the Castile as partly caused by synsedimentary, gravity-driven, clastic deposition and suggested that the extent of dissolution may have been overestimated by previous workers. No Castile dissolution is known to be present in the immediate vicinity of the WIPP site. The process of dissolution and the resulting features are discussed later in this chapter.

In Culberson County, Texas, the Castile hosts major native sulfur deposits. The outcrops of Castile on the Gypsum Plain south of White's City, New Mexico, have been explored for native sulfur without success, and there is no reported indication of native sulfur anywhere in the vicinity of the WIPP.

In part of the area around the WIPP, the Castile has been significantly deformed and often there are pressurized brines associated with the deformed areas; borehole ERDA-6 encountered both. WIPP-12, 1 mi (1.6 km) north of the site center, revealed lesser Castile structure, but it also encountered a zone of pressurized brine within the Castile. Castile deformation is described and discussed in Section 2.1.6.1 and Appendix DEF, which details structural features, and pressurized brine are described in Section 2.2.1,

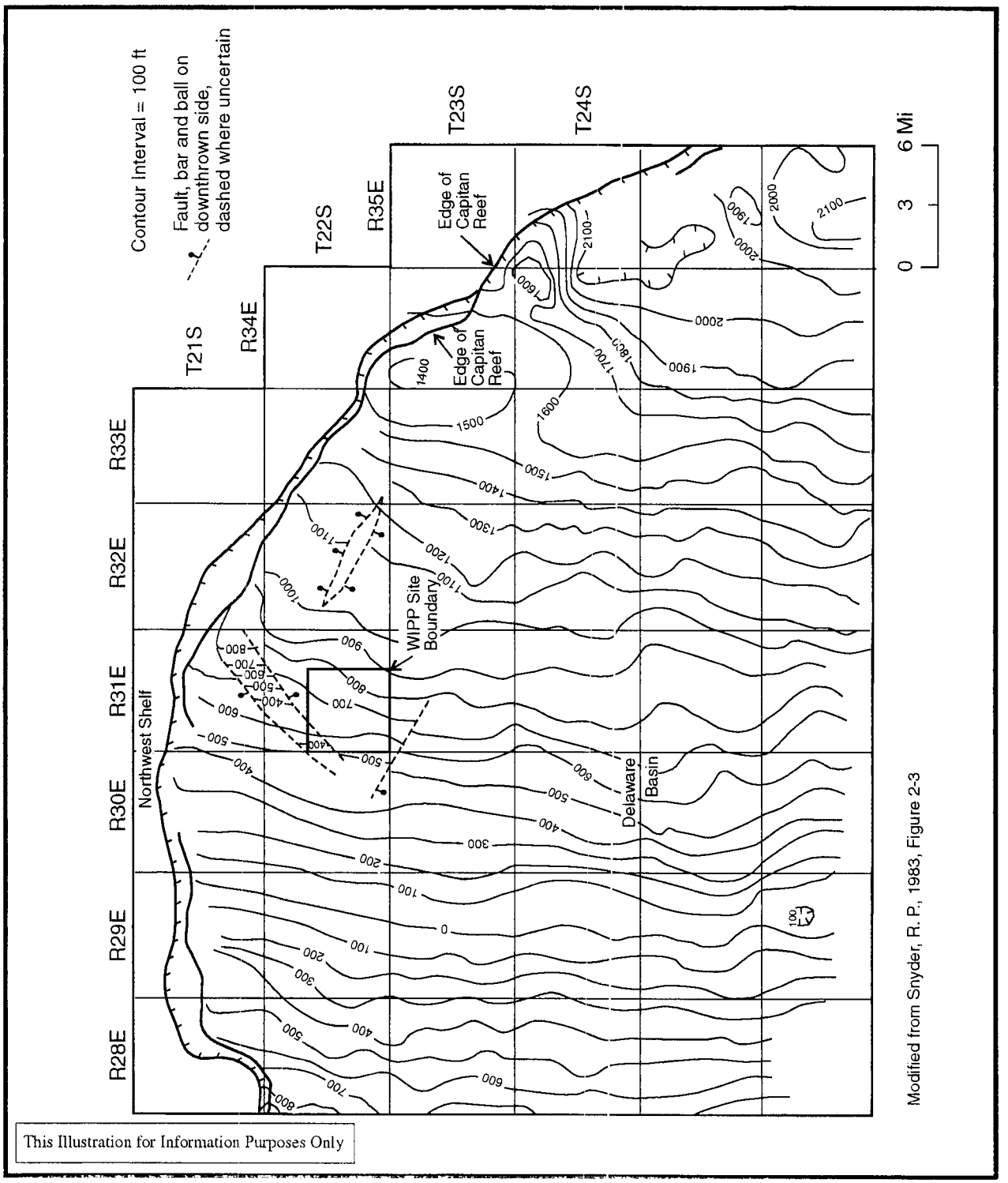

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Figure 2-6. Structure Contour Map of Top of Bell Canyon

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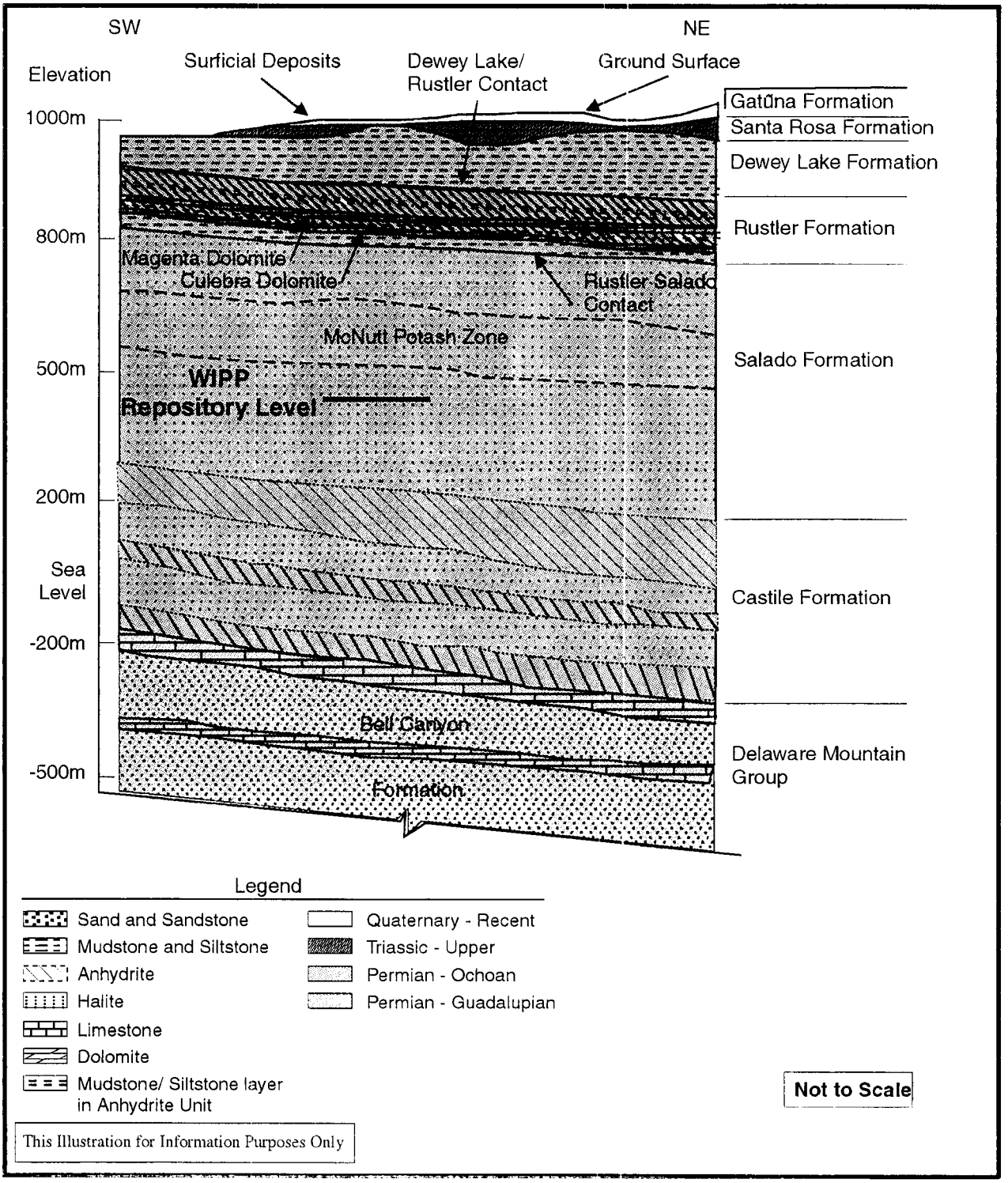

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Figure 2-7. Generalized Stratigraphic Cross Section above Bell Canyon Formation at WIPP Site

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which details the area's hydrology. Appendix GCR contains additional discussions of Castile brine.

The Castile continues to be an object of research interest unrelated to the WIPP program as an example of evaporites supposedly deposited in deep water. Anderson (1993, 12–13) discusses alternatives and contradictory evidence. Although these discussions and a resolution might eventually affect some concepts of Castile deposition and dissolution, this issue is largely of academic interest and bears no impact on the suitability of the Los Medaños region for the WIPP site. Additional discussion of Castile deformation and the associated WIPP studies appears in Section 2.1.6.1 and Appendix DEF.

2.1.3.4 The Salado

The Salado is of interest because it contains the repository horizon and provides the primary natural barrier for the long-term isolation of hazardous constituents. The following section provides basic information regarding the genesis and lithology of the Salado. Subsequent sections discuss Salado deformation, Salado dissolution, and Salado hydrology. Appendix GCR provides detailed information about the Salado.

The Salado is dominated by halite, in contrast to the underlying Castile. The Salado extends well beyond the Delaware Basin, and Lowenstein (1988, 592) has termed the Salado a "saline giant."

While the Fletcher Anhydrite Member, which is deposited on the Capitan Reef rocks, is defined by Lang (1939, 1569–1572; 1942, 63–79) as the base of the Salado, some investigators consider that the Fletcher Anhydrite Member may interfinger with anhydrites normally considered part of the Castile. The Castile-Salado contact is not uniform across the basin, and whether it is conformable is unresolved. Around the WIPP site, the Castile-Salado contact is commonly placed at the top of a thick anhydrite informally designated A3; the overlying halite is called the infra-Cowden salt and is included within the Salado. Bodine (1978, 28–29) suggests that the clay mineralogy of the infra-Cowden in ERDA-9 cores changes at about 15 ft (4.6 m) above the lowermost Salado and that the lowermost clays are more like Castile clays. At the WIPP site, the DOE recognizes the top of the thick anhydrite as the local contact for differentiating the Salado from the Castile and notes that the distinction is related only to nomenclature and has no relevance to the performance of the WIPP disposal system.

The Salado in the northern Delaware Basin is broadly divided into three informal members. The middle member is known locally as the McNutt Potash Zone (MPZ) or member, and it includes 11 defined potash zones, ten of which are of economic significance in the Carlsbad Potash District. The lower and upper members remain unnamed. The WIPP repository level is located below the MPZ in the lower member. Figure 2-8 shows details of the Salado stratigraphy near the excavated regions.

Within the Delaware Basin, a system is used for numbering the more significant sulfate beds within the Salado, designating these beds as marker beds (MB) from MB 100 (near

the top of the formation) to MB 144 (near the base). The system is generally used within the Carlsbad Potash District as well as at and around the WIPP site. The repository is located in the vicinity of MB 139 and MB 138.

In the central and eastern part of the Delaware Basin, the Salado is at its thickest, ranging up to about 2,000 ft (about 610 m) thick and consisting mainly of interbeds of sulfate minerals and halite, with halite dominating. The thinnest portions of the Salado consist of a brecciated residue of insoluble material a few tens-of-ft thick and is exposed in parts of the western Delaware Basin. The common sulfate minerals are anhydrite ($CaSO_4$), gypsum ($CaSO_4 \cdot 2H_2O$) near the surface, and polyhalite ($K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$). They form interbeds and are also found along halite grain boundaries.

In the vicinity of the repository, authigenic quartz (SiO_2) and magnesite ($MgCO_3$) are also present as accessory minerals. Marker beds in the salt are predominantly anhydrite with seams of clay. The clays within the Salado are enriched in magnesium and depleted in aluminum. The magnesium enrichment probably reflects the intimate contact of the clays with brines derived from evaporating sea water, which are relatively high in magnesium.

A partial list of minerals found in the Delaware Basin evaporites, together with their chemical formulas, is given in Table 2-2. The table also indicates the relative abundances of the minerals in the evaporite rocks of the Castile, Salado, and Rustler. Minerals found either only at depth, removed from influence of weathering, or only near the surface, as weathering products, are also identified.

Although the most common Delaware Basin evaporite mineral is halite, the presence of less soluble interbeds (dominantly anhydrite, polyhalite, and claystone) and more soluble admixtures (for example, sylvite, glauberite, kainite) has resulted in chemical and physical properties of the bulk Salado that are significantly different than those of pure halite layers contained within it. In particular, the MPZ, between MB 116 and MB 126, is locally explored and mined for potassium-bearing minerals of economic interest. Under differential stress, interbeds (anhydrite, polyhalite, magnesite, dolomite) may fracture while, under the same stress regime, pure halite would undergo plastic deformation. Fracturing of relatively brittle beds, for example, has locally enhanced the permeability, allowing otherwise nonporous rock to carry groundwater. Some soluble minerals incorporated in the rock salt can be radiometrically dated, and their dates indicate the time of the formation. The survival of such minerals is significant, in that such dating is impossible in pure halite or anhydrite.

Liquids were collected from fluid inclusions and from seeps and boreholes within the WIPP drifts. Analysis of these samples indicated that there is compositional variability of the fluids showing the effects of various phase transformations on brine composition. The fluid inclusions belong to a different chemical population than do the fluids emanating from the walls. It was concluded that much of the brine is completely immobilized within the salt and that the free liquid emanating from the walls is present as a fluid film along intergranular boundaries mainly in clays and in fractures in anhydrites. Additional information can be found in Appendix GCR.

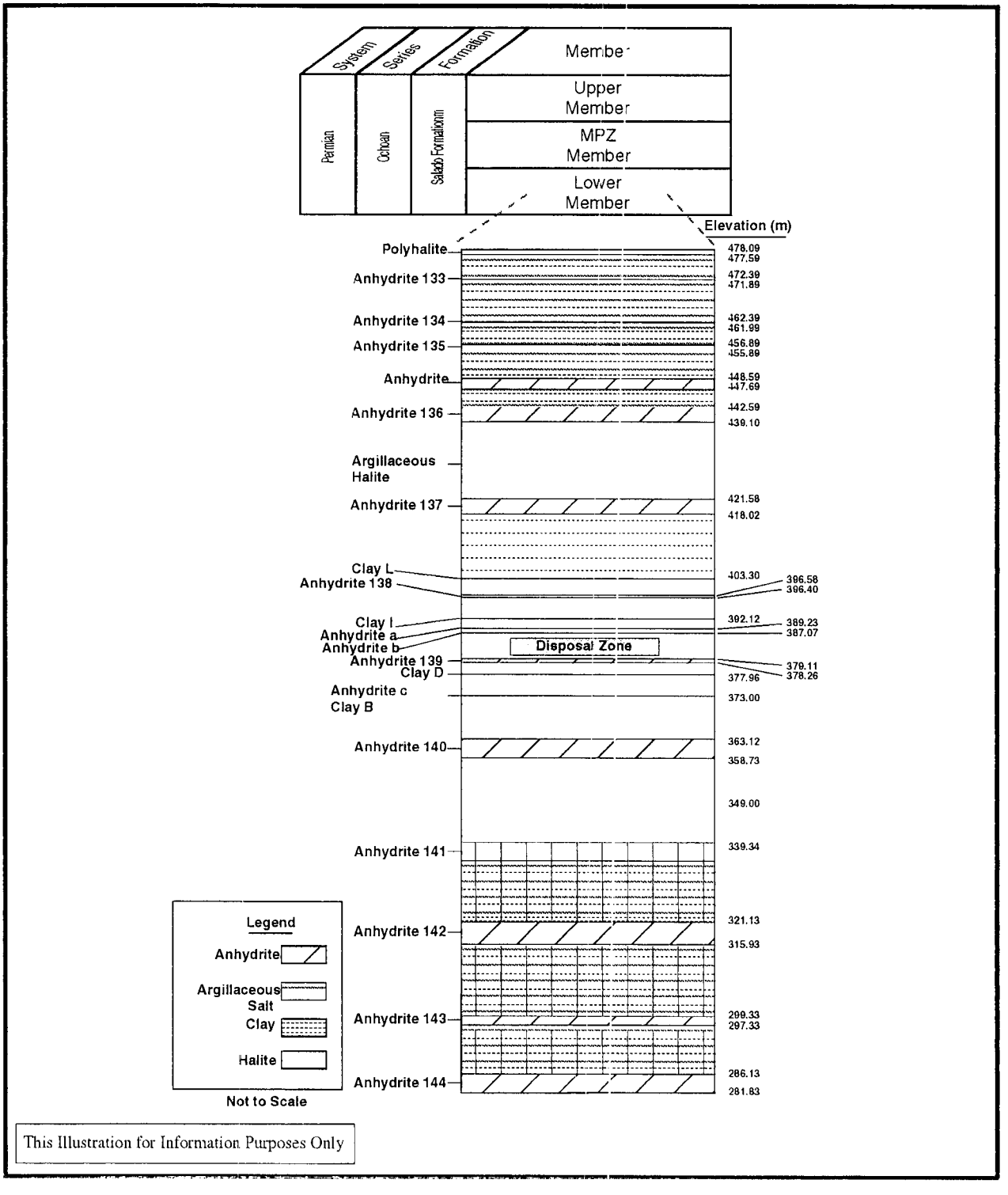

Figure 2-8. Salado Stratigraphy

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Table 2-2. Chemical Formulas, Distributions, and Relative Abundances of Minerals in the Castile, Salado, and Rustler Formations

Mineral	Formula	Occurrence/Abundance
Amesite	$(Mg_4Al_2)(Si_2Al_2)O_{10}(OH)_8$	S, R
Anhydrite	$CaSO_4$	CCC, SSS, RRR (rarely near surface)
Calcite	$CaCO_3$	S, RR
Carnallite	$KMgCl_3 \cdot 6H_2O$	SS
Chlorite	$(Mg,Al,Fe)_{12}(Si,Al)_8O_{20}(OH)_{16}$	S, R
Corrensite	mixed-layer chlorite and smectite	S, R
Dolomite	$CaMg(CO_3)_2$	RR
Feldspar	$(K,Na,Ca)(Si,Al)_4O_8$	C, S, R
Glauberite	$Na_2Ca(SO_4)_2$	C, S (never near surface)
Gypsum	$CaSO_4 \cdot 2H_2O$	CCC (only near surface), S, RRR
Halite	NaCl	CCC, SSS, RRR (rarely near surface)
Illite	$K_{1-1.5}Al_4[Si_{7-6.5}Al_{1-1.5}O_{20}](OH)_4$	S, R
Kainite	$KMgClSO_4 \cdot 3H_2O$	SS
Kieserite	$MgSO_4 \cdot H_2O$	SS
Langbeinite	$K_2Mg_2(SO_4)_3$	S
Magnesite	$MgCO_3$	C, S, R
Polyhalite	$K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$	SS, R (never near surface)
Pyrite	FeS_2	C, S, R
Quartz	SiO_2	C, S, R
Serpentine	$Mg_3Si_2O_5(OH)_4$	S, R
Smectite	$(Ca_{1/2},Na)_{0.7}(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH)_4 \cdot nH_2O$	S, R
Sylvite	KCl	SS

Legend: C = Castile; S = Salado; R = Rustler
3 letters = abundant; 2 letters = common; 1 letter = rare or accessory

In its previous review of Salado data in 1989, the EPA reached the conclusion that the characterization of the Salado "has provided a good understanding of the conditions in the area of WIPP" and that the "Salado is a laterally continuous, homogeneous rock unit that is thick, stable, and very low in permeability." The EPA also recognized further information needs that have been met since the review. These include the characteristics of the disturbed rock zone (DRZ) that forms around the excavation, hydrological factors (far field permeability and brine inflow), and rock mechanics factors (fractures in the marker beds) (EPA 1990a).

Early investigators of the Salado recognized a repetitious vertical succession or cycle of beds in the Salado: clay - anhydrite - polyhalite - halite and minor polyhalite - halite. Later investigators described the cyclical units as clay - magnesite - anhydrite or

polyhalite or glauberite - halite - argillaceous halite capped by mudstone. Lowenstein (1988, 592–608) defined a depositional cycle (Type I) consisting of (1) basal mixed siliciclastic and carbonate (magnesite) mudstone, (2) laminated to massive anhydrite or polyhalite, (3) halite, and (4) halite with mud. Lowenstein also recognized repetitious sequences of halite and halite with mud as incomplete Type I cycles and termed them Type II cycles. Lowenstein (1988, 592–608) interpreted the Type I cycles as having formed in a shallowing upward, desiccating basin beginning with a perennial lake or lagoon of marine origin and evaporating to saline lagoon and salt pan environments. Type II cycles are differentiated because they do not exhibit features of prolonged subaqueous deposition and also have more siliciclastic influx than do Type I cycles.

From detailed mapping of the Salado in the air intake shaft (AIS) at WIPP, Holt and Powers (1990a, 45–72) constructed a more detailed sedimentological analysis of Salado depositional cycles, similar in broad aspects to the Type I cycle of Lowenstein. Argillaceous halites and halitic mudstone at the top of many depositional cycles were interpreted by Holt and Powers (1990a, 45–78) in terms of modern features such as those at Devil's Golf Course at Death Valley National Monument, California. The evaporative basin was desiccated, and varying amounts of insoluble residues collected on the surface through surficial dissolution, eolian sedimentation, and some clastic sedimentation from temporary flooding caused from surrounding areas. The surface developed local relief that could be mapped in some cycles, while the action of continuing desiccation and exposure increasingly concentrated insoluble residues. Flooding, most commonly from marine sources, reset the sedimentary cycle by depositing a sulfate bed.

The details available from the shaft demonstrated the important role of syndepositional water level to water table changes that created solution pits and pipes within the halitic beds while they were at the surface. Holt and Powers (1990a, Appendix F, 3–26) concluded that passive halite cements filled the pits and pipes, as well as less dramatic voids, as the water table rose. Early diagenetic to synsedimentary cements filled the porosity early and rather completely with commonly clear and coarsely crystalline halite, reducing the porosity to a very small volume according to Casas and Lowenstein (1989).

Although Holt and Powers (1990a) found no evidence for post-depositional halite dissolution in the AIS, dissolution of the Upper Salado halite has occurred west of the WIPP. Effects of dissolution are visible in Nash Draw and at other localities where gypsum karst has formed, where units above the Salado such as the Rustler Formation (hereafter referred to as the Rustler), Dewey Lake Redbeds (hereafter referred to as the Dewey Lake), and post-Permian rocks have subsided.

Within Nash Draw, Robinson and Lang (1938, 87–88) recognized a zone equivalent to the Upper Salado but lacking halite. Test wells in southern Nash Draw produced brine from this interval, and it has become known as the brine aquifer. Robinson and Lang (1938) considered this zone a residuum from dissolution of Salado halite (see Section 2.1.6.2). Jones et al. (1960) remarked that the residuum should be considered part of the Salado, though in geophysical logs it may resemble the Lower Rustler. The approximate

eastern limit of the residuum and brine aquifer lies near Livingston Ridge (the eastward margin of Nash Draw) and is marked by a thickening of the Salado (see Section 2.1.6.2).

At the center of the site, Holt and Powers in their 1984 report recognized clasts of fossil fragments and mapped channeling in siltstones and mudstones above the halite; they considered these beds to be a normal part of the transition from shallow evaporative lagoons and desiccated salt pans of the Salado to the saline lagoon of the Lower Rustler. Although some Salado halite dissolution at the WIPP may have occurred prior to deposition of the Rustler clastics, this process was quite different from the subsurface removal of salt from the Salado in more recent time that caused the residuum and associated brine aquifer in Nash Draw. Where the Salado halite is buried at depths greater than about 1,000 ft (approximately 305 m), physical evidence for large-scale dissolution (for example, post-depositional accumulation of insoluble residues, brecciation from differential collapse, and mass removal) is not observed.

Given the susceptibility of evaporite minerals to dissolution by flowing groundwater, geochronological investigations provide a means to confirm the physical evidence indicating that little or no rock-water interactions have occurred in the Salado at the WIPP since the Late Permian Period. Radiometric techniques provide a means of determining the approximate time of the latest episode of regional recrystallization of evaporite minerals, which can be inferred to be the approximate time of the latest episode of freely circulating groundwater. Radiometric dates for minerals of the Salado are available from mines and boreholes in the vicinity of the WIPP (Register and Brookins 1980, 39–42; Brookins 1980, 29–31; Brookins et al. 1980, 635–637; Brookins 1981, 147–152; and Brookins and Lambert 1987, 771–780). The distribution of dates shows that rubidium-strontium (Rb-Sr) isochron determinations on evaporite minerals, largely sylvite (179 to 229 million years ago), are in good agreement with potassium-argon (K-Ar) determinations on pure polyhalites (195 to 216 million years ago). (Potassium-argon ages for sylvite are significantly younger than Rb-Sr ages for the same rocks because of the loss of radiogenic argon. Radiogenic strontium, as a solid, is less mobile than argon and therefore the Rb-Sr ischron method is preferred for sylvite.) Clay minerals have both Rb-Sr and K-Ar ages significantly older (390 plus or minus 77 million years) than the evaporite minerals, presumably reflecting the detrital origin of the clays.

One significantly younger recrystallization event has been identified in evaporites in the WIPP region and has been shown to be a contact phenomenon associated with the emplacement of an Oligocene igneous dike (see Section 2.1.5.4) Polyhalite near the dike yields a radiometric age of 21 million years, compared to the 32 to 34 million-year age determined for the dike (Calzia and Hiss 1978, 39–45). This exception notwithstanding, the results of radiometric determinations argue for the absence of pervasive recrystallization of the evaporites in the Salado in the last 200 million years. This conclusion is supported by the number of replicate determinations, the wide distribution of dated minerals throughout the Delaware Basin, and the concordance of dates obtained by various radiometric methods.

The DOE believes that the Salado is of primary importance to the containment of waste. As the principal natural barrier, many of the properties of the Salado have been characterized by the DOE and numerical codes were developed by the DOE to simulate the natural processes within the Salado that affect the disposal system performance. These properties fall into two categories: physical and hydrological. The physical properties of importance are summarized in Appendix RM. The hydrological properties are included in Section 2.2.1.

2.1.3.5 Rustler Formation

The Rustler is the youngest evaporite-bearing formation in the Delaware Basin. It was originally named by Richardson in 1904 for outcrops in the Rustler Hills of Culberson County, Texas. Adams (1944, 1614) first used the names Culebra Member and Magenta Member to describe the two carbonates in the formation, indicating that Lang favored the names, though Lang did not use these names in his 1942 publication. Vine (1963) extensively described the Rustler in Nash Draw and proposed the four formal names and one informal term for the stratigraphic subdivisions still used for the Rustler (from the base): unnamed lower member, Culebra Dolomite Member, Tamarisk Member, Magenta Dolomite Member, and Forty-niner Member (Figure 2-9). (The Culebra Dolomite Member, the Tamarisk Member, the Magenta Dolomite Member, and the Forty-niner Member are hereafter referred to as the Culebra, the Tamarisk, the Magenta, and the Forty-niner.) Though it has been noted by some investigators that the unnamed lower member might be named the Los Medaños Member, this nomenclature has not been formalized and is not adopted here.

Two studies of the Rustler since Vine's 1963 work contribute important information about the stratigraphy, sedimentology, and regional relationships while examining more local details as well. Eager (1983) published a report on relationships of the Rustler observed in the southern Delaware Basin as part of sulfur exploration in the area. Holt and Powers (1988, Chapter 5) reported the details of sedimentologic and stratigraphic studies of WIPP shafts and cores as well as of geophysical logs from about 600 boreholes in southeastern New Mexico. Their work resulted in the more detailed subdivisions of the Rustler indicated in the right column of Figure 2-9.

The Rustler is regionally extensive; a similar unit in the Texas Panhandle is also called the Rustler. Within the area around WIPP, evaporite units of the Rustler are interbedded with significant siliciclastic beds and the carbonates. Both the Magenta and the Culebra extend regionally beyond areas of direct interest to the WIPP. In the general area of the WIPP, both the Tamarisk and the Forty-niner have similar lithologies: lower and upper sulfate beds and a middle unit that varies principally from mudstone to halite from west to east (Figure 2-9).

In a general sense, halite in the unnamed lower member broadly persists to the west of the WIPP site, and halite is found east of the center of the WIPP in the Tamarisk and the Forty-niner (Figure 2-10). (Additional detail on the lithologies of these members follows.) Two different explanations have been used to account for the halite

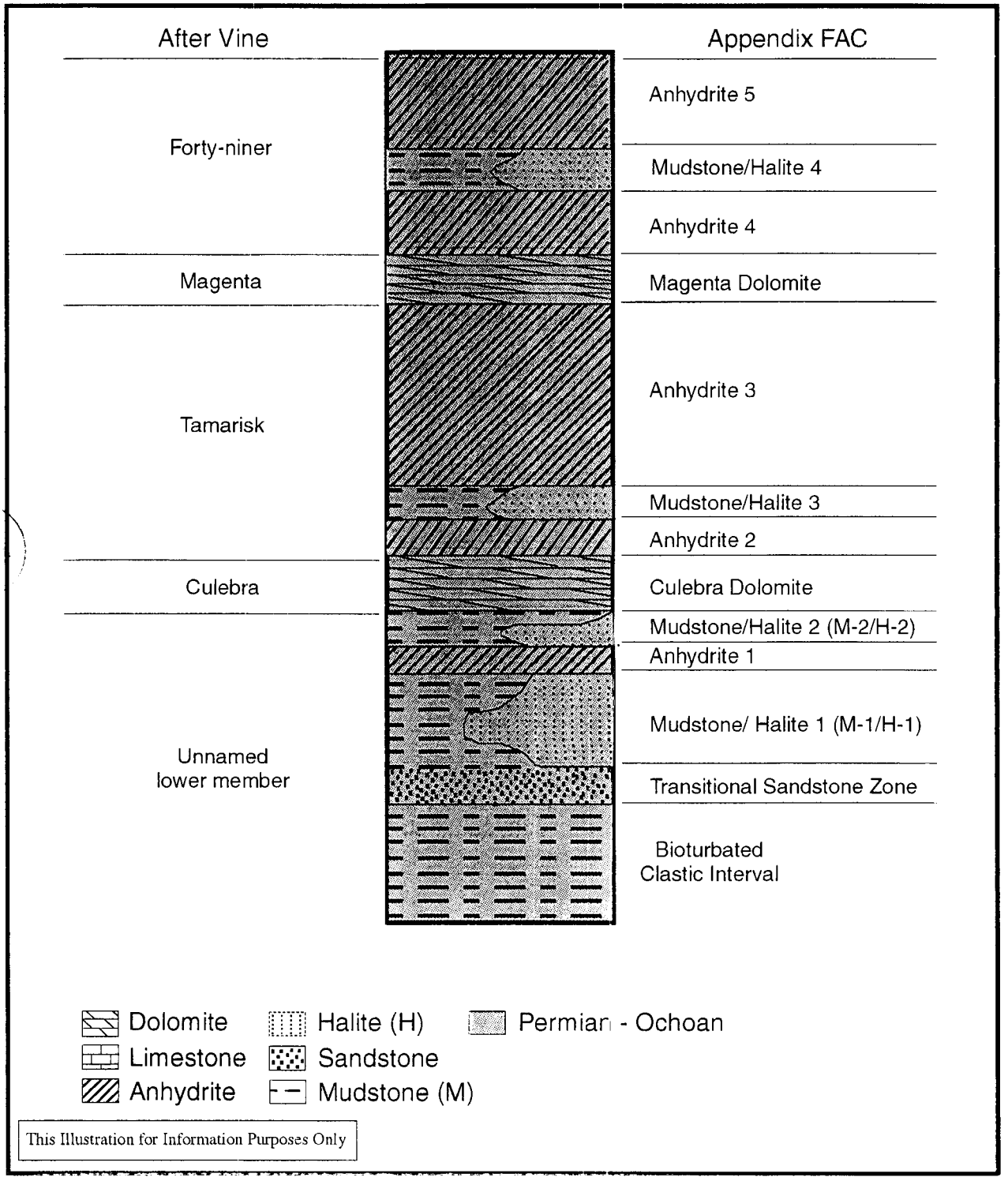

Figure 2-9. Rustler Stratigraphy

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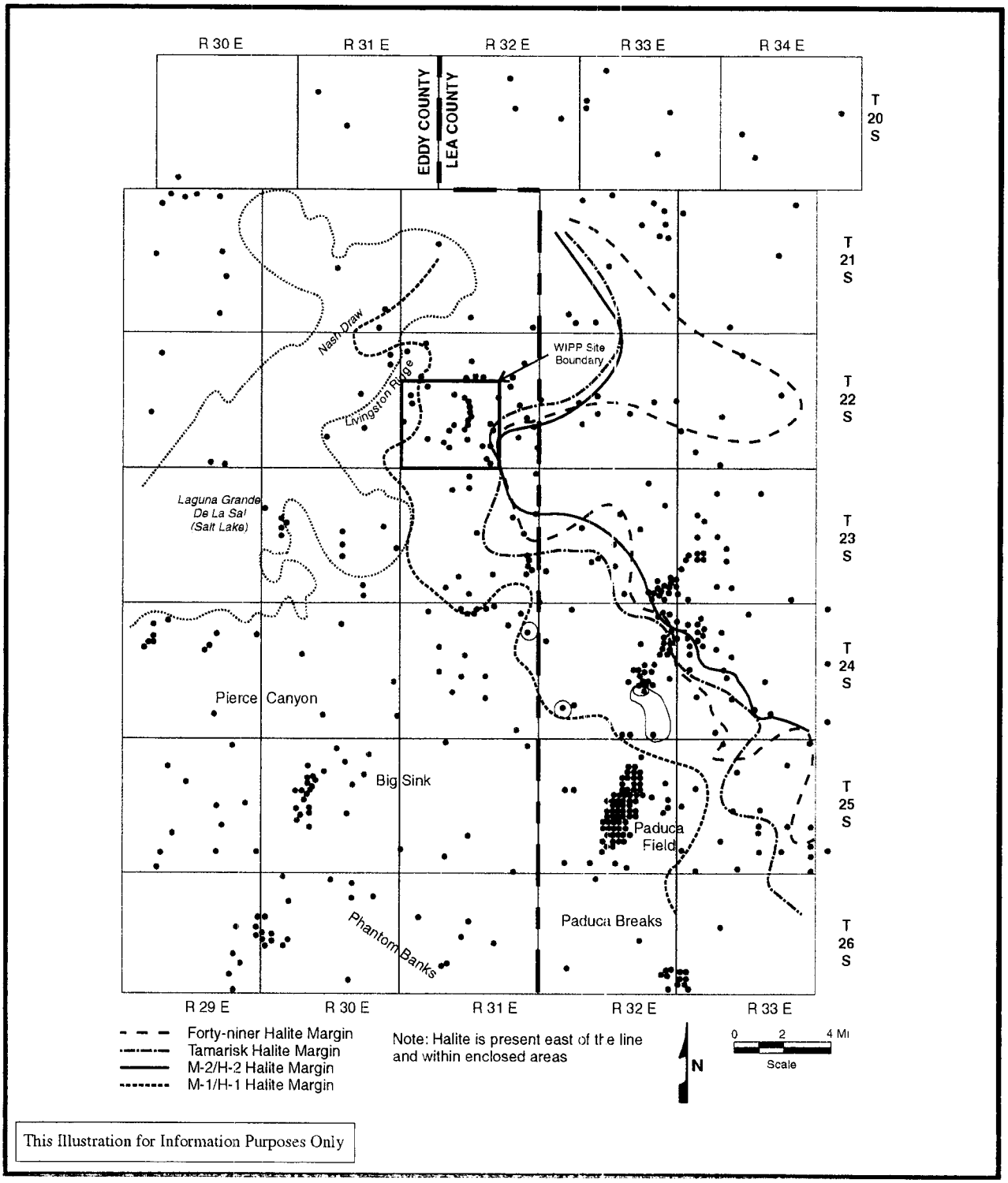

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Figure 2-10. Halite Margins in the Rustler

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distribution. A prominent interpretation in many documents is that halite was originally deposited relatively uniformly in the noncarbonate members across southeastern New Mexico, including the WIPP site. The modern distribution resulted from dissolution of Rustler halite to the west of the site. As shown by Holt and Powers (1988, 6-20 and 6-22), sedimentary features and textures within WIPP shafts and cores led them to propose an alternative interpretation of depositional facies for the mudstone-halite units; halite was dissolved syndepositionally from mudflat facies, especially to the west, and was redeposited in a halite pan to the east. As discussed in Section 2.2.1, Culebra transmissivity shows about six orders of magnitude variation across the area around the site. Although some investigators have called attention to the correlation between the distribution of halite in the Rustler and variations in Culebra transmissivity and have attributed the variation to fracturing resulting from post-depositional dissolution of Rustler halite (see, for example, Snyder 1985), Holt and Powers' (1988) work largely rules out this explanation. Variations in transmissivity of the Culebra have also been correlated qualitatively to the thickness of overburden above the Culebra, the amount of dissolution of the Upper Salado, and the distribution of gypsum fillings in fractures in the Culebra. The DOE believes that variations in Culebra transmissivity are primarily caused by the relative abundance of open fractures in the unit, which may be related to each of these factors.

In the region around the WIPP, the Rustler reaches a maximum thickness of more than 500 ft (152 m) (Figure 2-11), while it is about 300 to 350 ft (91 to 107 m) thick within most of the WIPP site. Much of the difference in Rustler thickness can be attributed to variations in the amount of halite contained in the formation. Variation in Tamarisk thickness accounts for a larger part of thickness changes than do variations in either the unnamed lower member or the Forty-niner. Details of the Rustler thickness can be found in Appendix GCR, 4-39 and Figure 4.3-8.

Much project-specific information about the Rustler is contained in Holt and Powers (1988). The WIPP shafts were a crucial element in Holt and Powers' 1988 study, exposing features not previously reported. Cores were available from several WIPP boreholes, and their lithologies were matched to geophysical log signatures to extend the interpretation throughout a larger area in southeastern New Mexico. These data are included in Appendix FAC.

Unnamed Lower Member

The unnamed lower member rests on the Salado with apparent conformity at the WIPP site. It consists of significant proportions of bedded and burrowed siliciclastic sedimentary rocks with cross-bedding and fossil remains. These beds record the transition from strongly evaporative environments of the Salado to saline lagoonal environments. The upper part of the unnamed lower member includes halitic and sulfatic beds within clastics. Holt and Powers (1988, 9-1ff) interpret these as facies changes within a saline playa environment and not dissolution residues from post-depositional dissolution.

According to Holt and Powers (1988, Figure 4.7), the unnamed lower member ranges in thickness from about 96 to 126 ft (29 to 38 m) within the site boundaries. The maximum thickness recorded during that study was 208 ft (63 m) southeast of the WIPP site.

Halite is present in this unit west of most of the site area (see Figure 2-10 for an illustration of the halite margins). Cross-sections based on geophysical log interpretations by Holt and Powers (1988, Figure 4.4) show that the unit is thicker to the east where the halite is more abundant.

The Culebra

The Culebra rests with apparent conformity on the unnamed lower member, though the underlying unit ranges from claystone to its lateral halitic equivalent in the site area. West of the WIPP site, in Nash Draw, the Culebra is disrupted from dissolution of underlying halite. Holt and Powers (1988, 6-12, 6-13, 8-14ff) principally attribute this to dissolution of Salado halite, while Snyder (1985, 6) indicates that salt was dissolved post-depositionally from the unnamed lower member. These alternative interpretations offer differing explanations of how the existing Rustler hydrologic system developed and might continue to develop. Culebra hydrology and its significance to disposal system performance are discussed in detail in Section 2.2.1.4.

The Culebra was described by Robinson and Lang (1938, 83) as a dolomite 35 ft (11 m) in thickness. The Culebra is generally brown, finely crystalline, locally argillaceous and arenaceous dolomite with rare to abundant vugs with variable gypsum and anhydrite filling; Adams (1944, 1614) noted that oölites are present in some outcrops as well. Holt and Powers (1988) describes the Culebra features in detail, noting that most of the Culebra is microlaminated to thinly laminated, while some zones display no depositional fabric. Holt and Powers (1984) described an upper interval of the Culebra consisting of waxy, golden-brown carbonate; dark organic claystone; and some coarser siltstone of probable algal origin. Because of the unique organic composition of this thin layer, Holt and Powers did not include it in the Culebra for thickness computations, and this will be factored into discussions of Culebra thickness. Based on core descriptions from the WIPP project, Holt and Powers (1988, 5-11) concluded that there is very little variation of depositional sedimentary features throughout the Culebra.

Vugs are an important part of Culebra porosity. They are commonly zoned parallel to bedding. In outcrop, vugs are commonly empty. In the subsurface, vugs range from open to partially filled or filled with anhydrite, gypsum, or clay (Holt and Powers 1990a, 318–320). Lowenstein (1988, 20–21) noted similar features. Holt and Powers (1988, 8-4) attributed vugs partly to syndepositional growth as nodules and partly as later replacive textures. Lowenstein (1988, 592–608) also described textures related to later replacement and alteration of sulfates. Vug or pore fillings vary across the WIPP site and contribute to the porosity structure of the Culebra. Natural fractures filled with gypsum are common east of the WIPP site center and in a smaller area west of the site center (Figure 2-12).

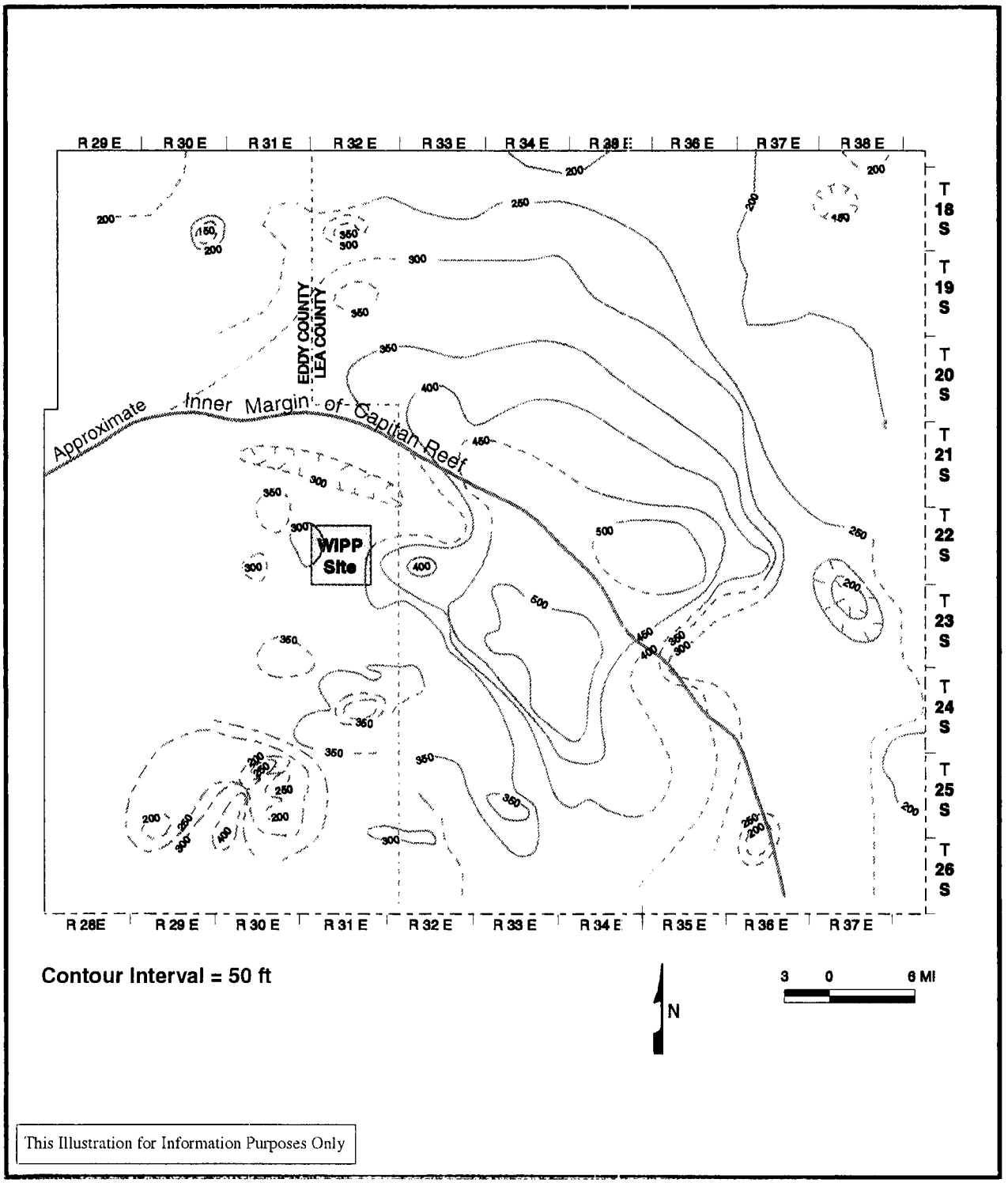

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Figure 2-11. Isopach Map of the Entire Rustler

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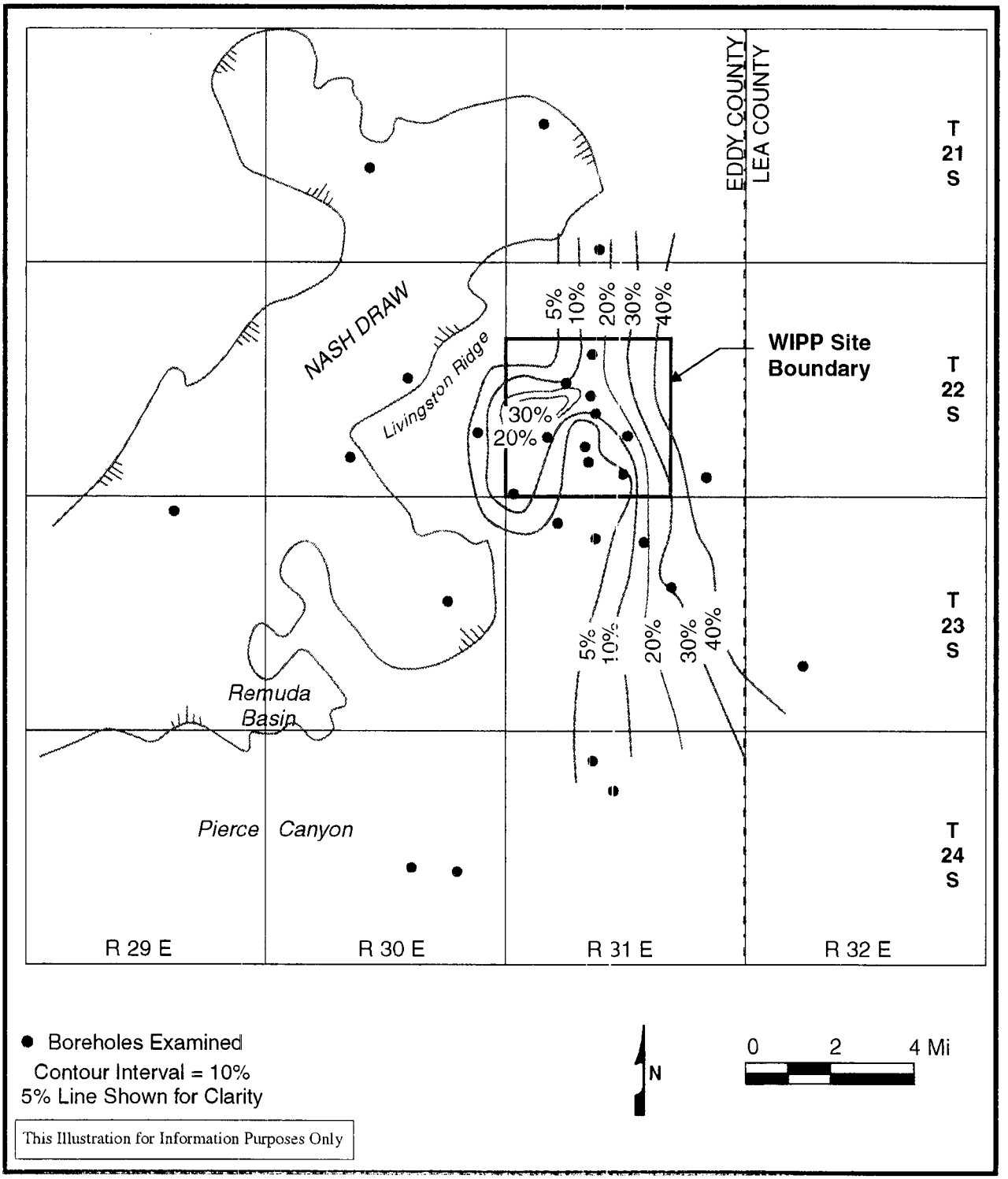

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Figure 2-12. Percentage of Natural Fractures in the Culebra Filled with Gypsum

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After dolomite, Sewards et al. (1991, IX-1) report that clay is the second most abundant mineral of the Culebra. Clay minerals include corrensite, illite, serpentine, and chlorite. Clay occurs in bulk rock and in fracture surfaces.

In the WIPP area, the Culebra varies in thickness. Depending on the area considered and the horizons chosen for the upper and lower boundaries of the Culebra, different data sources provide varying estimates (Table 2-3). Holt and Powers (1988, 4-7) considered the organic-rich layer at the Culebra-Tamarisk contact separately from the Culebra in interpreting geophysical logs.

Comparing data sets, Holt and Powers (1988) typically interpret the Culebra as being about 3 ft (about 1 m) thinner than other interpretations. In general, this reflects the difference between including or excluding the unit at the Culebra-Tamarisk contact.

LaVenue et al. (1988, Table B.1) calculated a mean thickness of 25 ft (7.6 m) for the Culebra within their model domain based on thicknesses measured in 78 boreholes. Mercer (1983, reproduced here as Appendix HYDRO, Table 1) reported a data set similar to LaVenue et al. The borehole database for the region of interest is provided in Appendix BH.

The Tamarisk

Vine (1963, B14) named the Tamarisk for outcrops near Tamarisk Flat in Nash Draw. Outcrops of the Tamarisk are distorted, and subsurface information was used to establish member characteristics. Vine reported two sulfate units separated by a siltstone, about 5 ft (1.5 m) thick, interpreted by Jones et al. in 1960 as a dissolution residue. The Tamarisk is generally conformable with the underlying Culebra. The transition is marked by an organic-rich unit interpreted as being present over most of southeastern New Mexico.

The Tamarisk around the WIPP site consists of lower and upper sulfate units separated by a unit that varies from mudstone (generally to the west) to mainly halite (to the east). Near the center of the WIPP site, the lower anhydrite was partially eroded during deposition of the middle mudstone unit, as observed in the WIPP waste-handling and Exhaust Shafts. The lower anhydrite was completely eroded at WIPP-19. Before shaft exposures were available, the lack of the Lower Tamarisk anhydrite at WIPP-19 was interpreted as the result of dissolution and the mudstone was considered a cave filling.

Jones interprets halite to be present east of the center of the WIPP site based on geophysical logs and drill cuttings. Based mainly on cores and cuttings records from the WIPP potash drilling program, Snyder prepared a map in 1985 showing the halitic areas of each of the noncarbonate Rustler Members. A very similar map based on geophysical log characteristics was prepared by Holt and Powers (1990a) (see Figure 2-10).

Holt and Powers (1988, 6–8) describe the mudstones and halitic facies in the middle of the Tamarisk and postulate that the unit formed in a salt pan to mudflat system. Holt and

Table 2-3. Culebra Thickness Data Sets

Source	Data Set Location								
	T22S, R31E			T21-23S, R30-32E			Entire Set		
	n	ave	std dev	n	ave	std dev	n	ave	std dev
Richey (1989)	7	7.5 m	1.04 m	115	7.9 m	1.45 m	633	7.7 m	1.65 m
Holt and Powers (1988)	35	6.4 m	0.59 m	122	7.0 m	1.26 m	508	6.5 m	1.89 m
LaVenue et al. (1988)							78	7.7 m	
Source	**WIPP Potash Drillholes**								
Jones (1978)				21	7.5 m	0.70 m			
Holt and Powers (1988)				21	6.3 m	0.50 m			

Legend: n = number of boreholes or data points
ave = average or mean
std dev = standard deviation
m = meters

Powers cited sedimentary features and the lateral relationships as evidence of syndepositional dissolution of halite in the marginal mudflat areas. In contrast, other investigators interpreted the lateral decrease in thickness and absence of halite to the west as evidence of post-depositional dissolution (see, for example, Jones et al. 1960, Jones 1978, and Snyder 1985). The differing concepts for halite distribution in the Rustler, and particularly the Tamarisk, have been used to explain the significant changes in hydrologic properties of the Culebra, as described in later sections.

The Tamarisk thickness varies greatly in southeastern New Mexico, principally as a function of the thickness of halite in the middle unit. Within T22S, R31E, Holt and Powers (1988, Figure 4.9) show a range from 84 to 184 ft (26 to 56 m) for the entire Tamarisk and a range from 6 to 110 ft (2 to 34 m) for the interval of mudstone-halite between lower and upper anhydrites. Expanded geophysical logs with corresponding lithology illustrate some of the lateral relationships for this interval (Figure 2-13).

The Magenta

Adams (1944, 1614) attributes the name Magenta Member to Lang, based on a feature named Magenta Point north of Laguna Grande de la Sal. According to Holt and Powers (1988, 5-22), the Magenta is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features. It does not vary greatly in sedimentary features across the site area.

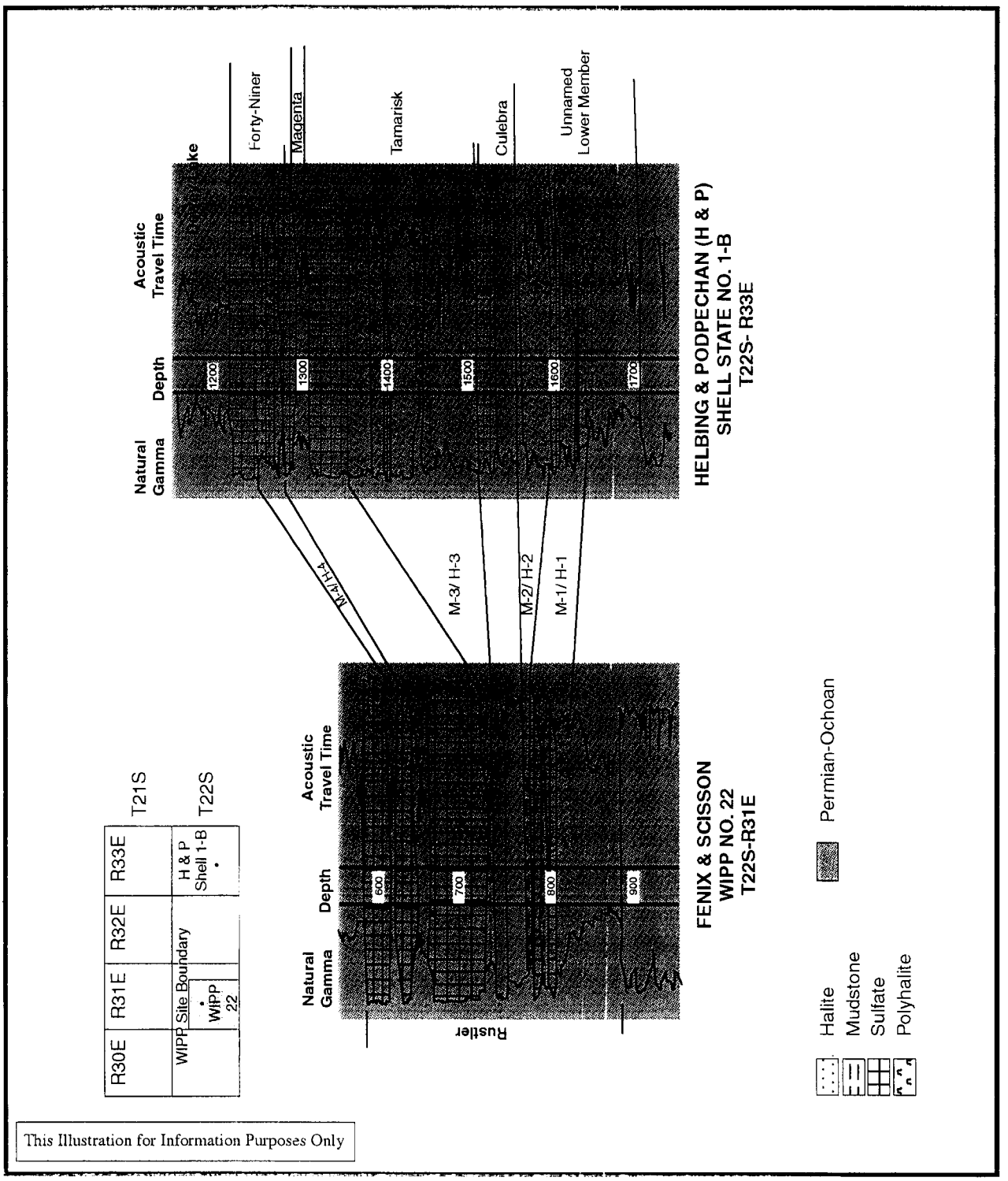

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Figure 2-13. Log Character of the Rustler Showing Mudstone-Halite Lateral Relationships

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Holt and Powers (1988, 5-22) reported that the Magenta varies from 23 to 28 ft (7.0 to 8.5 m) around the WIPP site. Additional detail on the Magenta can be found in Appendix GCR and Appendix FAC.

The Forty-niner

Vine named the Forty-niner for outcrops at Forty-niner Ridge in eastern Nash Draw, but the unit is poorly exposed there. In the subsurface around the WIPP, the Forty-niner consists of basal and upper sulfates separated by a mudstone. It is conformable with the underlying Magenta. As with other members of the Rustler, geophysical log characteristics can be correlated with core and shaft descriptions to extend geological inferences across a large area.

The Forty-niner varies from 43 to 77 ft (13 to 23 m) thick within T22S, R31E. East and southeast of the WIPP, the Forty-niner exceeds 80 ft (24 m), and some of the geophysical logs from this area indicate that halite is present in the beds between the sulfates.

Within the waste-handling shaft, the Forty-niner mudstone displayed sedimentary features and bedding relationships indicating sedimentary transport. The mudstone has been commonly interpreted as a residue from the dissolution of halitic beds because it is thinner where there is no halite. These beds are not known to have been described in detail prior to mapping in the waste-handling shaft at WIPP, and the features found there led Holt and Powers (1988, i and ii) to reexamine the available evidence for, and interpretations of, dissolution of halite in Rustler units.

2.1.3.6 Dewey Lake Redbeds

The nomenclature for rocks included in the Dewey Lake Redbeds Formation (hereafter referred to as the Dewey Lake) was introduced during the 1960s to clarify relationships between these rocks assigned to the Upper Permian and the Cenozoic Gatuña Formation (hereafter referred to as the Gatuña).

There are three main sources of data about the Dewey Lake in the area around WIPP. Miller reported the petrology of the unit in 1955 and 1966. Schiel (1988) described outcrops in the Nash Draw areas and interpreted geophysical logs of the unit in southeastern New Mexico and west Texas to infer the depositional environments and stratigraphic relationships in 1988 and 1994. Holt and Powers (1990a) were able to describe the Dewey Lake in detail at the AIS for WIPP in 1990, confirming much of Schiel's information and adding data regarding the Lower Dewey Lake.

The Dewey Lake overlies the Rustler conformably, though local examples of the contact (for example, the AIS described by Holt and Powers in 1990a) show minor disruption by dissolution of some of the Upper Rustler sulfate. The formation is predominantly reddish-brown fine sandstone to siltstone or silty claystone with greenish-gray reduction spots. Thin bedding, ripple cross-bedding, and larger channeling are common features in outcrops, and additional soft sediment deformation features and early fracturing from the

lower part of the formation are described by Holt and Powers. Schiel (1988; 1994, 9) attributed the Dewey Lake to deposition on "a large, arid fluvial plain subject to ephemeral flood events."

There is little direct faunal or radiometric evidence of the age of the Dewey Lake. It is assigned to the Ochoan Series of Late Permian age, and it is regionally correlated with units of similar lithology and stratigraphic position. Schiel (1988, 1994) reviewed the limited radiometric data from lithologically similar rocks (Quartermaster Formation) and concluded that much of the unit could be Early Triassic in age.

Near the center of the WIPP site, Holt and Powers (1990a, Figure 5) mapped 498 ft (152 m) of the Dewey Lake (Figure 2-14). The formation is thicker to the east (Schiel 1994, Figure 2) of the WIPP site, in part because western areas were eroded before the overlying Triassic rocks were deposited.

The Dewey Lake contains fractures, which are filled with minerals to varying degrees. Both cements and fracture fillings have been examined and used to infer groundwater infiltration. Holt and Powers (1990a, 3-8ff) described the Dewey Lake as cemented by carbonate above 164.5 ft (50 m) in the AIS; some fractures in the lower part of this interval were also filled with carbonate, and the entire interval surface was commonly moist. Below this point, the cement is harder, the shaft is dry, and fractures are filled with gypsum. Holt and Powers (1990a, 3-11, Figure 16) suggested the cement change might be related to infiltration of meteoric water. They also determined that some of the gypsum-filled fractures are syndepositional. Dewey Lake fractures include horizontal to subvertical trends, some of which were mapped in detail (Holt and Powers 1986, Figures 6, 7, and 8).

Lambert (1991, 5-65) analyzed the deuterium/hydrogen (D/H) ratios of gypsum in the Rustler and gypsum veins in the Dewey Lake. He suggests that none of the gypsum formed from evaporitic fluid such as Permian seawater but that the D/H ratios all show influence of meteoric water. Furthermore, Lambert (1991, 5-66) infers that the gypsum D/H ratio is not consistent with modern meteoric water; it may, however, be consistent with older meteoric fluids. There is no obvious correlation with depth indicating infiltration. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) indicate no intermixing or homogenization of fluids between the Rustler and the Dewey Lake, but there may have been lateral movement of water within the Dewey Lake. Dewey Lake carbonate-vein material shows a broader range of strontium ratios than does surface caliche, and the ratios barely overlap.

2.1.3.7 The Santa Rosa

There have been different approaches to the nomenclature of rocks of Triassic age in southeastern New Mexico. Bachman (1974) generally described the units as "Triassic, undivided" or as the Dockum Group, without dividing it. Vine (1963) used "Santa Rosa Sandstone," and Santa Rosa has become common usage. Lucas and Anderson (1993a) import other formation names that are unlikely to be useful for WIPP.

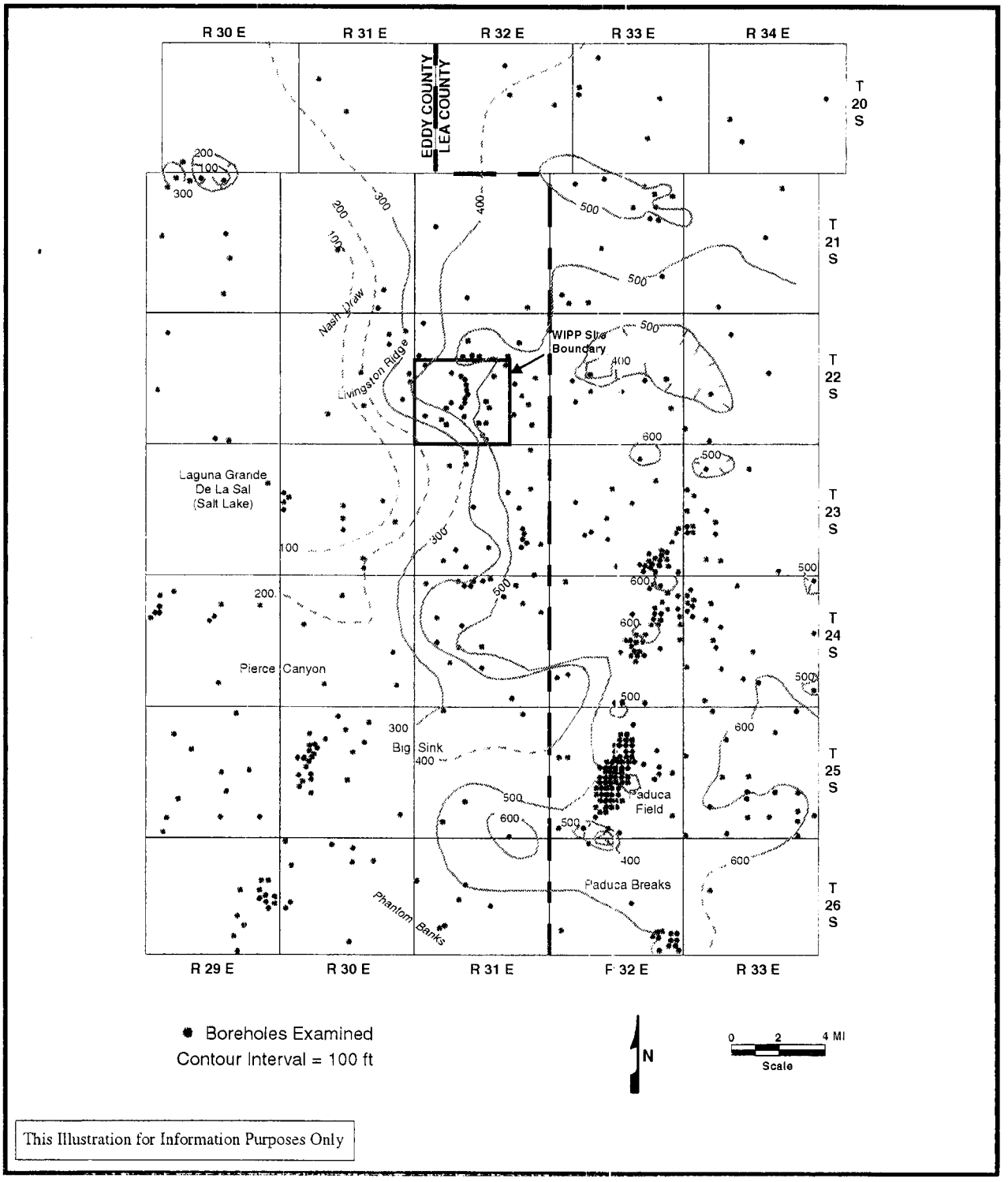

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Figure 2-14. Isopach of the Dewey Lake

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The Santa Rosa has been called disconformable over the Dewey Lake by Vine (1963, B25). These rocks have more variegated hues than the underlying uniformly colored Dewey Lake. Coarse-grained rocks, including conglomerates, are common, and the formation includes a variety of cross-bedding and sedimentary features (Lucas and Anderson 1993a, 231–235).

Within the WIPP site boundary, the Santa Rosa is relatively thin to absent (Figure 2-15). At the AIS, Holt and Powers (1990a, Figure 5) attributed about 2 ft (0.6 m) of rock to the Santa Rosa. The Santa Rosa is a maximum of 255 ft (78 m) thick in potash holes drilled for WIPP east of the site boundary. The Santa Rosa is thicker to the east.

2.1.3.8 The Gatuña Formation

Lang (in Robinson and Lang 1938, 84) named the Gatuña for outcrops in the vicinity of Gatuña Canyon in the Clayton Basin. Rocks now attributed to the Gatuña in Pierce Canyon were once included in the "Pierce Canyon Formation" with rocks now assigned to the Dewey Lake. The formation has been mapped from the Santa Rosa, New Mexico, area south to the vicinity of Pecos, Texas. It is unconformable with underlying units. Vine in 1963 and Bachman in 1974 provided some limited description of the Gatuña. The most comprehensive study of the Gatuña is based on WIPP investigations and landfill studies for the City of Carlsbad and Eddy County (Powers and Holt 1993). Much of the formation is colored light reddish-brown. It is broadly similar to the Dewey Lake and the Santa Rosa, though the older units have more intense hues. The formation is highly variable, ranging from coarse conglomerates to claystones with some highly gypsiferous sections. Sedimentary structures are abundant. Analysis of lithofacies indicates that the formation is dominantly fluvial in origin with areas of low-energy deposits and evaporitic minerals.

The thickness of the Gatuña is not very consistent regionally as shown in Figure 2-16. Thicknesses range up to about 300 ft (91 m) at Pierce Canyon, with thicker areas generally subparallel to the Pecos River. To the east, the Gatuña is thin or absent. Holt and Powers in 1990 reported about 9 ft (2.7 m) of undisturbed Gatuña in the AIS at WIPP.

The Gatuña has been considered Pleistocene in age based on a volcanic glass in the Upper Gatuña along the eastern margin of Nash Draw that has been identified as the Lava Creek B ash, dated at 0.6 million years by Izett and Wilcox (1982). This upper limit age is corroborated by the age determinations from the Mescalero caliche (hereafter referred to as the Mescalero) that overlies the Gatuña (see Section 2.1.3.9). An additional volcanic ash from the Gatuña in Texas yields consistent K-Ar and geochemical data, indicating that it is about 13 million years at that location (Powers and Holt 1993, 271). Thus, the Gatuña ranges in age over a period of time that may be greater than the Ogallala Formation (hereafter referred to as the Ogallala) on the High Plains east of WIPP.

2.1.3.9 Mescalero Caliche

The Mescalero caliche is an informal stratigraphic unit apparently first differentiated by Bachman in 1974, though Bachman (1973, 17) described the "caliche on the Mescalero Plain." He differentiated the Mescalero from the older, widespread Ogallala caliche or caprock on the basis of textures, noting that breccia and pisolitic textures are much more common in the Ogallala caliche. The Mescalero has been noted over significant areas in the Pecos drainage, including the WIPP area, and it has been formed over a variety of substrates. Bachman described the Mescalero as a two-part unit: (1) an upper dense laminar caprock and (2) a basal, earthy-to-firm, nodular calcareous deposit. Machette (1985, 5) classified the Mescalero as having Stage V morphologies of a calcic soil (the more mature Ogallala caprock reaches Stage VI).

Bachman (1976, Figure 8) provided structure contours on the Mescalero caliche for a large area of southeastern New Mexico, including the WIPP site. From the contours and Bachman's discussion of the Mescalero as a soil, it is clear that the Mescalero is expected to be continuous over large areas. Explicit WIPP data are limited mainly to boreholes, though some borehole reports do not mention the Mescalero. The unit may be as much as 10 ft (3 m) thick.

The Mescalero overlies the Gatuña and was interpreted by Bachman on basic stratigraphic grounds as having accumulated during the early-to-middle Pleistocene. Samples of the Mescalero from the vicinity of the WIPP were studied using uranium-trend methods. Based on early written communication from Rosholt, Bachman (1985, 20) reports that the basal Mescalero began to form about 510,000 years ago and the upper part began to form about 410,000 years ago; these ages are commonly cited in WIPP literature. The samples are interpreted by Rosholt and McKinney in 1980 in the formal report as indicating ages of 570,000 ± 110,000 years for the lower part of the Mescalero and 420,000 ± 60,000 years for the upper part.

According to Bachman (1985, 19), where the Mescalero is flat lying and not breached by erosion, it is an indicator of stability or integrity of the land surface over the last 500,000 years.

2.1.3.10 Surficial Sediments

Soils of the region have developed mainly from Quaternary and Permian parent material. Parent material from the Quaternary System is represented by alluvial deposits of major streams, dune sand, and other surface deposits. These are mostly loamy and sandy sediments containing some coarse fragments. Parent material from the Permian System is represented by limestone, dolomite, and gypsum bedrock. Soils of the region have developed in a semiarid, continental climate with abundant sunshine, low relative humidity, erratic and low rainfall, and a wide variation in daily and seasonal temperatures. Subsoil colors are normally light brown to reddish brown but are often mixed with lime accumulations (caliche) that result from limited, erratic rainfall and insufficient leaching.

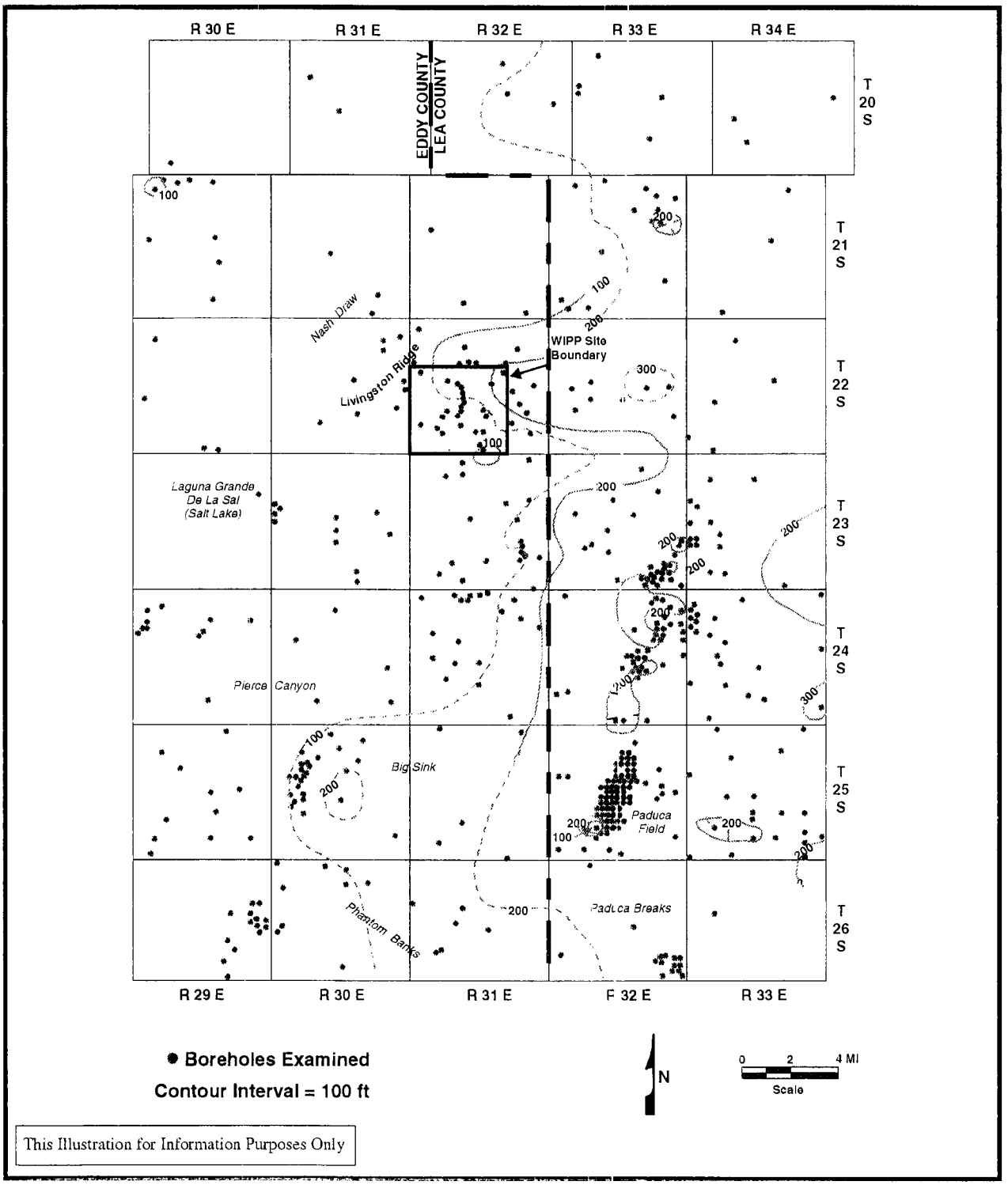

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Figure 2-15. Isopach of the Santa Rosa

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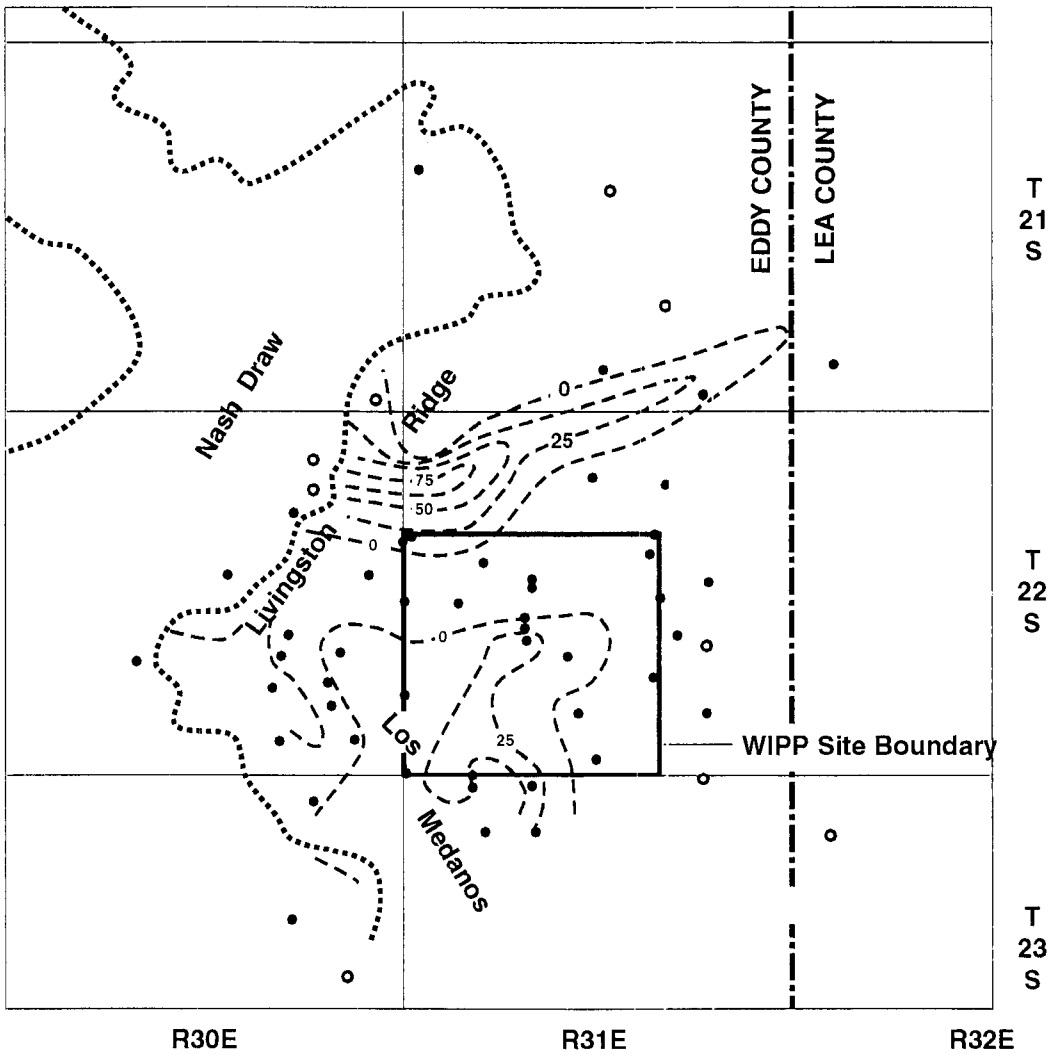

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Figure 2-16. Isopach of the Gatuña

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A soil association is a landscape with a distinctive pattern of soil types (series). It normally consists of one or more major soils and at least one minor soil. There are three soil associations within 5 mi (8.1 km) of the WIPP site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. Of these three associations, only the Kermit-Berino soil series have been mapped across the WIPP site by Chugg et al. (1952, Sheet No. 113). These are sandy soils developed on eolian material. The Kermit-Berino soils include active dune areas. The Berino soil has a sandy A horizon; the B horizons include more argillaceous material and weak-to-moderate soil structures. A and B horizons are described as noncalcareous, and the underlying C horizon is commonly caliche. Bachman (1980) interpreted the Berino soil as a paleosol that is a remnant B horizon of the underlying Mescalero. Rosholt and McKinney (1980) applied uranium-trend methods to samples of the Berino soil from the WIPP site area. They interpreted the age of formation of the Berino soil as 330,000 ± 75,000 years.

Generally, the Berino Series, which covers about 50 percent of the site, consists of deep, noncalcareous, yellow-red to red sandy soils that developed in wind-worked material of mixed origin. These soils are described as undulating to hummocky and gently sloping (0 percent to 3 percent slopes). The soils are the most extensive of the deep, sandy soils in the Eddy County area. Berino soils are subject to continuing wind and water erosion. If the vegetative cover is seriously depleted, the water-erosion potential is slight, but the wind-erosion potential is very high. These soils are particularly sensitive to wind erosion in the months of March, April, and May, when rainfall is minimal and winds are highest. These soil characteristics are a consideration for the design of long-term passive controls such as monuments and markers.

The Kermit Series consists of deep, light-colored, noncalcareous, excessively drained loose sands, typically yellowish-red fine sand. The surface is undulating to billowy (from 0 to 3 percent slopes) and consists mostly of stabilized sand dunes. Kermit soils are slightly to moderately eroded. Permeability is very high; and if vegetative cover is removed, the water-erosion potential is slight, but the wind-erosion potential is very high. The distribution of soils at the WIPP site is shown on a surface geological map which is Figure 4.2-4 in Appendix GCR.

2.1.4 Physiography and Geomorphology

In this section, the DOE presents a discussion of the physiography and geomorphology of the WIPP site and surrounding area. This information is taken from DOE (1980, 7-21 to 7-23). Geomorphology and physiography are discussed in this section and Appendix SCR. Physiography is considered in the demonstration to the extent that: (1) physiography determines the elevation of the regional water table, and (2) the elevation of the water table partially effects the potential for fluid flow within the shaft system. Information is presented in this section to support screening other geomorphological processes from the conceptual model, such as weathering, erosion, sedimentation, and soil development. In order to perform this screening, such factors as slopes, proximity to watercourses, dissection, and historic and existing processes are important. These are presented in this section in terms of the regional and local physiographic and

geomorphological characteristics. Tectonic processes that may alter the physiography of the region or site area are discussed in Section 2.1.5. In addition, Section 2.1.6 presents more specific details on nontectonic processes identified during site characterization as having the potential for affecting the repository over the longer term and which required detailed investigation. These include evaporite deformation and dissolution.

2.1.4.1 Regional Physiography and Geomorphology

The WIPP site is in the Pecos Valley section of the southern Great Plains physiographic province (Figure 2-17), a broad, highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range Province to the Central Lowlands Province. The Pecos Valley section itself is dominated by the Pecos River Valley, a long north-south trough that is from 5 to 30 mi (8.1 to 48 km) wide and as much as 1,000 ft (305 m) deep in the north. The Pecos River System has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched some time after the Middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent because of the semiarid climate. The surface locally has a karst terrain containing sinkholes, dolines, and solution-subsidence troughs from both surface erosion and subsurface dissolution. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying Upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, including such erosional features as scarps, cuestas, terraces, and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations vary from more than 6,000 ft (1,829 m) in the northwest to about 2,000 ft (610 m) in the south.

The Pecos Valley section is bordered on the east by the virtually uneroded plain of the Llano Estacado. The Llano Estacado is part of the High Plains section of the Great Plains physiographic province and is a poorly drained eastward-sloping surface covered by gravels, wind-blown sand, and caliche that has developed since early-to-middle Pleistocene time. Few and minor topographic features are present in the High Plains section, formed when more than 500 ft (152 m) of Tertiary silts, gravels, and sands were laid down in alluvial fans by streams draining the Rocky Mountains. In many areas, the nearly flat surface is cemented by a hard caliche layer.

To the west of the Pecos Valley section are the Sacramento Mountains and the Guadalupe Mountains, part of the Sacramento section of the Basin and Range Province. The Capitan escarpment along the southeastern side of the Guadalupe Mountains marks the boundary between the Basin and Range and the Great Plains provinces. The Sacramento section has large basinal areas and a series of intervening mountain ranges.

2.1.4.2 Site Physiography and Geomorphology

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest, and is hummocky with sand ridges and dunes. A hard caliche layer (Mescalero caliche) is typically present beneath the sand blanket and on the

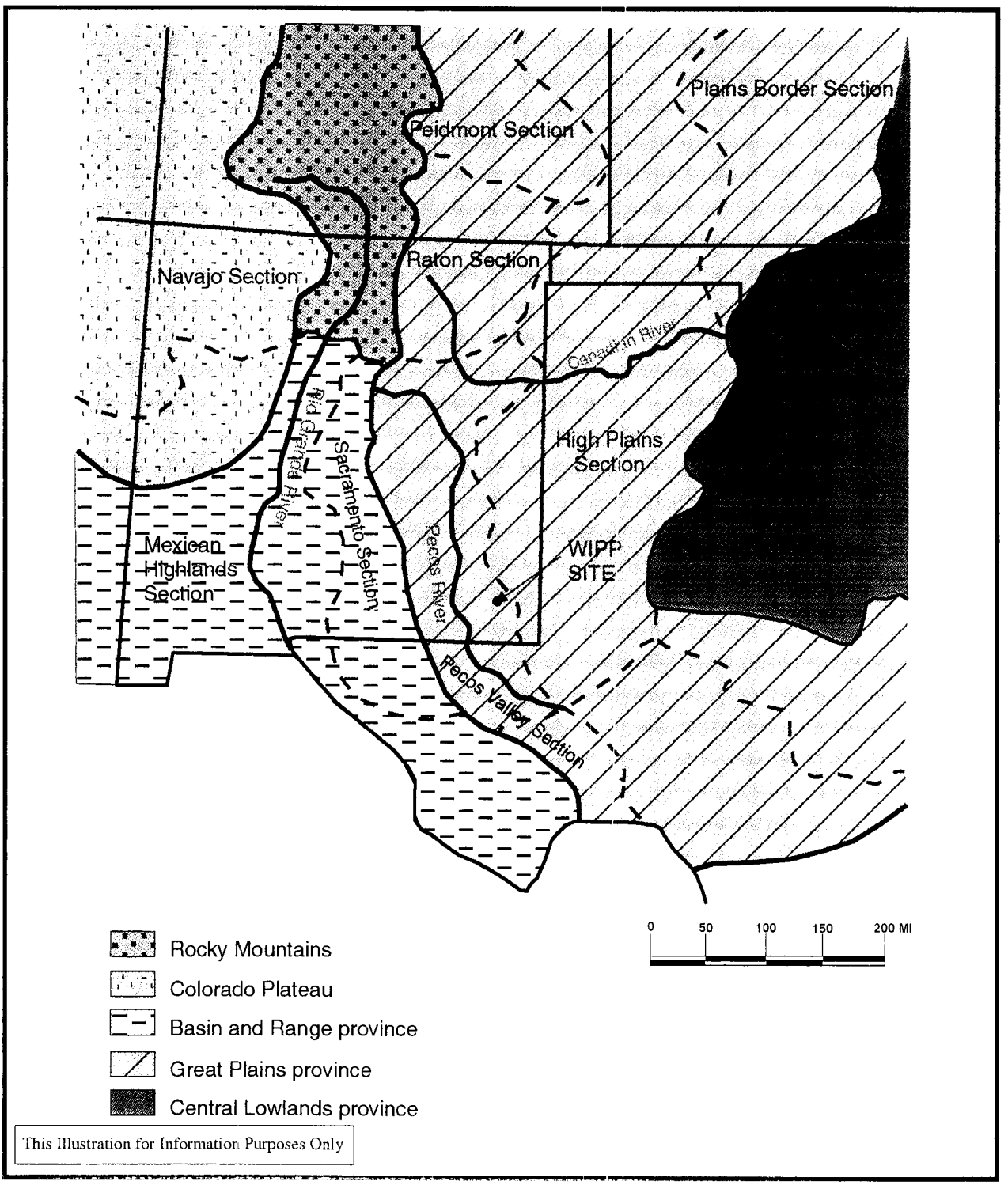

Figure 2-17. Physiographic Provinces and Sections

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surface of the underlying Gatuña. Figure 2-18 is a topographic map of the area. Elevations at the site range from 3,570 ft (1,088 m) in the east to 3,250 ft (990 m) in the west. The average east-to-west slope is 50 ft per mi (9.5 m per km).

Livingston Ridge is the most prominent physiographic feature near the site. It is a west-facing escarpment that has about 75 ft (23 m) of topographic relief and marks the eastern edge of Nash Draw, the drainage course nearest to the site (see Figure 2-1). Nash Draw is a shallow 5-mi-wide (8-km-wide) basin, 200 to 300 ft (61 to 91 m) deep and open to the southwest. It was caused, at least in part, by subsurface dissolution and the accompanying subsidence of overlying sediments. Livingston Ridge is the approximate boundary between terrain that has undergone erosion and/or solution collapse and terrain that has been little affected.

About 15 mi (24 km) east of the site is the southeast-trending San Simon Swale, a depression caused, at least in part, by subsurface dissolution. Between San Simon Swale and the site is a broad, low mesa named the Divide. Lying about 6 mi (9.7 km) east of the site and about 100 ft (30 m) above the surrounding terrain, it is a boundary between southwest drainage toward Nash Draw and southeast drainage toward San Simon Swale. The Divide is capped by the Ogallala and the overlying caliche, upon which have formed small, elongated depressions similar to those in the adjacent High Plains section to the east.

Surface drainage is intermittent; the nearest perennial stream is the Pecos River, 12 mi (19 km) southwest of the WIPP site boundary. The site's location near a natural divide protects it from flooding and serious erosion caused by heavy runoff. Should the climate become more humid, any perennial streams should follow the present basins, and Nash Draw and San Simon Swale would be the most eroded, leaving the area of the Divide relatively intact.

2.1.5 Tectonic Setting and Site Structural Features

The DOE has screened out, on the basis of either probability or consequence or both, all tectonic, magmatic and structural related processes. The screening discussions can be found in Appendix SCR. The information needed for this screening is included here and covers regional tectonic processes such as subsidence and uplift and basin tilting, magmatic processes such as igneous intrusion and events such as volcanism, and structural processes such as faulting and loading and unloading of the rocks because of long-term sedimentation or erosion. Discussions of structural events, such as earthquakes, are considered to the extent that they may create new faults or activate old faults. The seismicity of the area is considered in Section 2.6 for the purposes of determining seismic design parameters for the facility.

2.1.5.1 Tectonics

The processes and features included in this section are those more traditionally considered part of tectonics, processes that develop the broad-scale features of the earth.

Salt dissolution is a different process that can develop some features resembling those of tectonics.

Most broad-scale structural elements of the area around the WIPP developed during the Late Paleozoic. There is little historical or geological evidence of significant tectonic activity in the vicinity, and the level of stress in the region is low. The entire region tilted slightly during the Tertiary, and activity related to Basin and Range tectonics formed major structures southwest of the area. Seismic activity is specifically addressed in a separate section.

Broad subsidence began in the area as early as the Ordovician, developing a sag called the Tobosa Basin. By Late Pennsylvanian to Early Permian time, the Central Basin Platform developed (Figure 2-19), separating the Tobosa Basin into two parts: the Delaware Basin to the west and the Midland Basin to the east. The Permian Basin refers to the collective set of depositional basins in the area during the Permian Period. Southwest of the Delaware Basin, the Diablo Platform began developing either in the Late Pennsylvanian or Early Permian. The Marathon Uplift and Ouachita tectonic belt limited the southern extent of the Delaware Basin. Most of these broader scale features surrounding the Delaware Basin formed during the Late Paleozoic and have since remained relatively constant in their relationships.

According to Brokaw et al. (1972, 30), pre-Ochoan sedimentary rocks in the Delaware Basin show evidence of gentle downwarping during deposition, while Ochoan and younger rocks do not. A relatively uniform eastward tilt, generally from about 75 to 100 ft per mi (14 to 19 m per km), has been superimposed on the sedimentary sequence. P.B. King (1948, 108) generally attributes the uplift of the Guadalupe and Delaware mountains along the west side of the Delaware Basin to later Cenozoic, though he also notes that some faults along the west margin of the Guadalupe Mountains have displaced Quaternary gravels.

P.B. King (1948, 144) also infers the uplift from the Pliocene-age deposits of the Llano Estacado. Subsequent studies of the Ogallala of the Llano Estacado show that it varies in age from Miocene (about 12 million years before present) to Pliocene. This is the most likely range for uplift of the Guadalupe Mountains and broad tilting to the east of the Delaware Basin sequence.

Analysis of the present regional stress field indicates that the Delaware Basin lies within the Southern Great Plains stress province. This province is a transition zone between the extensional stress regime to the west and the region of compressive stress to the east. An interpretation by Zoback and Zoback (1991, 350) of the available data indicates that the level of stress in the Southern Great Plains stress province is low. Changes to the tectonic setting, such as the development of subduction zones and a consequent change in the driving forces, would take much longer than 10,000 years to occur.

To the west of the Southern Great Plains province is the Basin and Range province, or Cordilleran Extension province, where according to Zoback and Zoback (1991, 353)

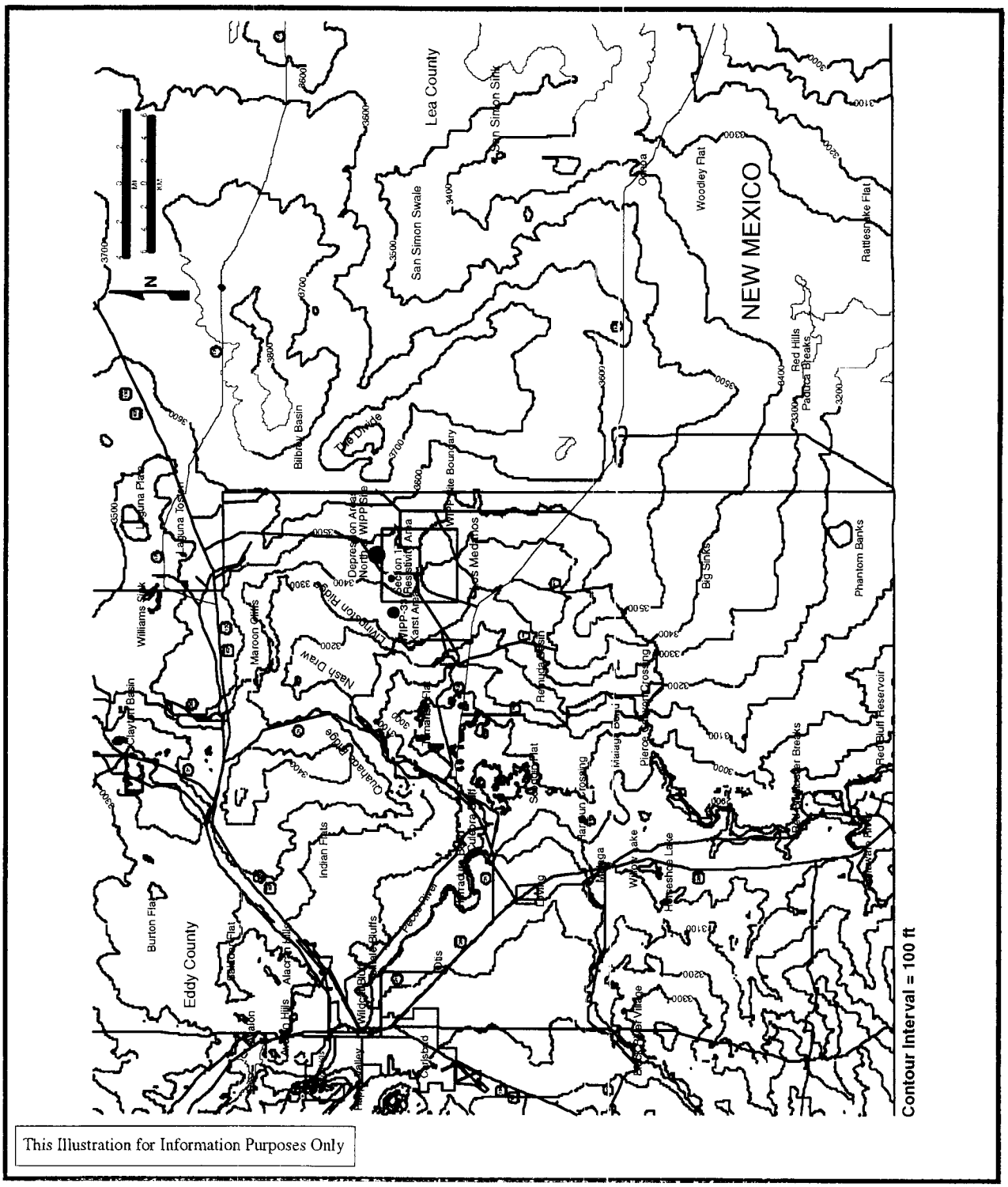

Figure 2-18. Topographic Map of Area Around the WIPP Site

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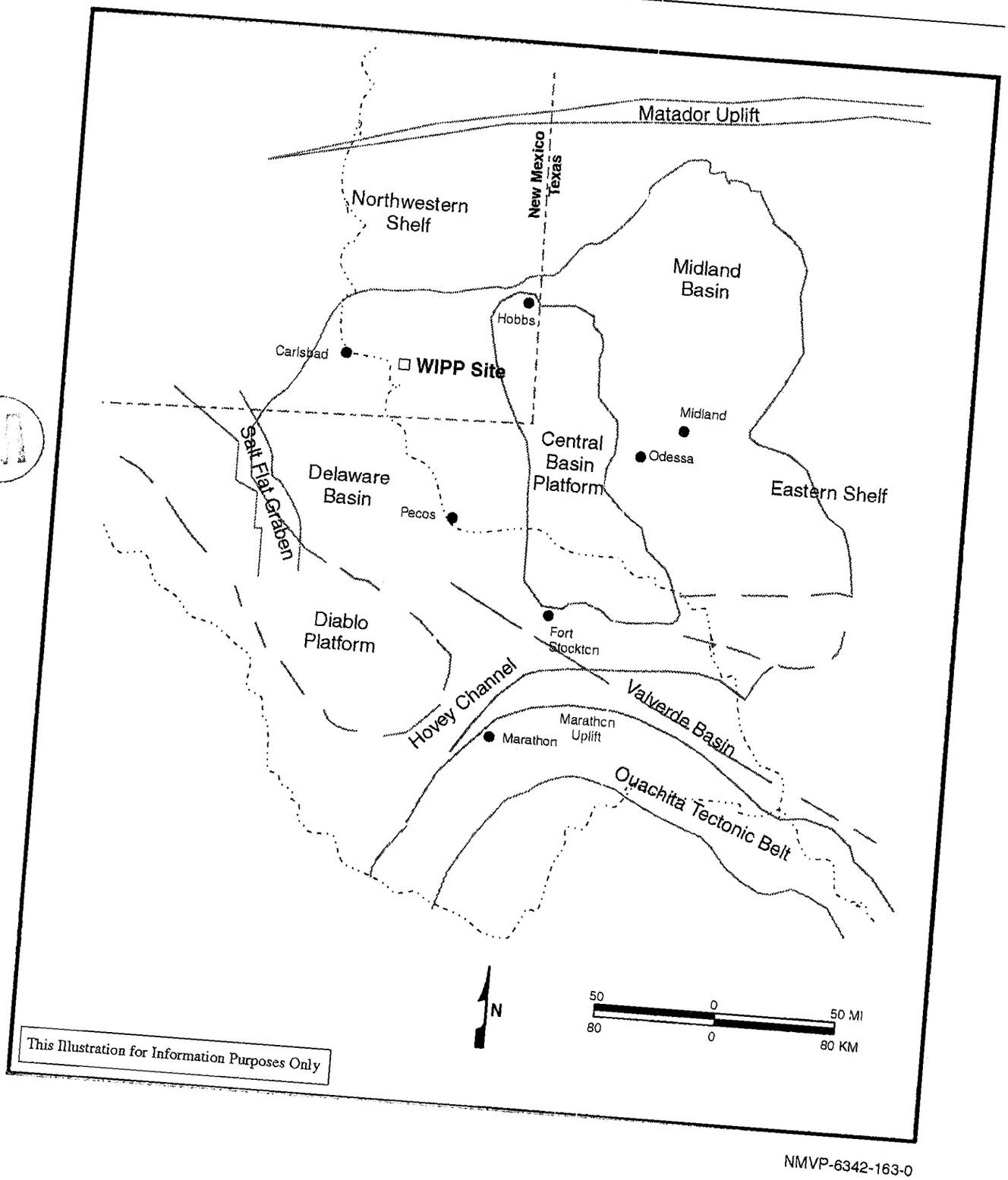

Figure 2-19. Structural Provinces of the Permian Basin Region

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normal faulting is the characteristic style of deformation. The eastern boundary of the Basin and Range province is marked by the Rio Grande Rift. Sanford et al. (1991, 230) note that, as a geological structure, the Rift extends beyond the relatively narrow geomorphological feature seen at the surface, with a magnetic anomaly at least 300 mi (480 km) wide. On this basis, the Rio Grande Rift can be regarded as a system of axial grabens along a major north-south trending structural uplift (a continuation of the Southern Rocky Mountains). The magnetic anomaly extends beneath the Southern Great Plains stress province, and regional-scale uplift of about 3,300 ft (1,000 m) over the past 10 million years also extends into eastern New Mexico.

To the east of the Southern Great Plains province is the large Mid-Plate province that encompasses central and eastern regions of the conterminous United States and the Atlantic basin west of the Mid-Atlantic Ridge. The Mid-Plate province is characterized by low levels of paleo- and historic seismicity. Where Quaternary faulting has occurred, it is generally strike-slip and appears to be associated with the reactivation of older structural elements.

Zoback and Zoback (1991) report no stress measurements from the Delaware Basin. The stress field in the Southern Great Plains stress province has been defined from borehole measurements in west Texas and from volcanic lineaments in northern New Mexico. These measurements were interpreted by Zoback and Zoback (1991, 353) to indicate that the least principal horizontal stress is oriented north northeast–south southwest and that most of the province is characterized by an extensional stress regime.

There is an abrupt change between the orientation of the least principal horizontal stress in the Southern Great Plains and the west–northwest orientation of the least principal horizontal stress characteristic of the Rio Grande Rift. In addition to the geological indications of a transition zone as described above, Zoback and Zoback (1980, 6134) point out that there is also evidence for a sharp boundary between these two provinces. This is reinforced by the change in crustal thickness from about 24 mi (40 km) beneath the Colorado Plateau to about 30 mi (50 km) or more beneath the Southern Great Plains east of the Rio Grande Rift. The base of the crust within the Rio Grande Rift is poorly defined but appears to be at a depth of about 21 mi (35 km) (Thompson and Zoback 1979, 158). There is also markedly lower heat flow in the Southern Great Plains (typically < 60 mWm^{-2}) reported by Blackwell et al. (1991, 428) compared with that in the Rio Grande Rift (typically > 80 mWm^{-2}) reported by Reiter et al. (1991, 463).

On the eastern boundary of the Southern Great Plains province, there is only a small rotation in the direction of the least principal horizontal stress. There is, however, a change from an extensional, normal faulting regime to a compressive, strike-slip faulting regime in the Mid-Plate province. According to Zoback and Zoback (1980, 6134), the available data indicate that this change is not abrupt and that the Southern Great Plains province can be viewed as a marginal part of the Mid-Plate province.

2.1.5.2 Loading and Unloading

Loading and unloading during the geological history since deposition is considered an influence on the hydrology of the Permian units because of its possible effect on the development of fractures.

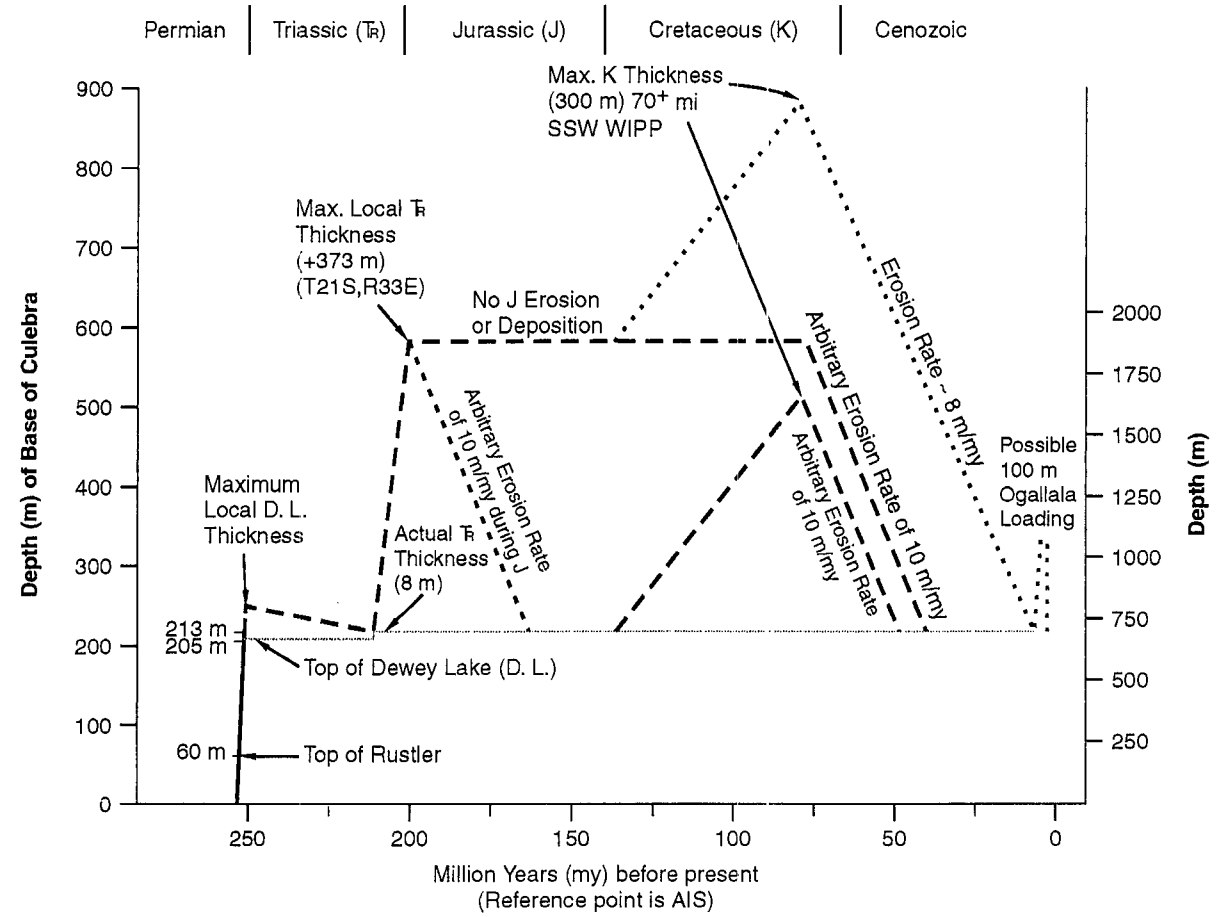
The sedimentary loading, depth of total burial, and erosion events combine in a complex history reconstructed here from regional geological trends and local data. The history is presented in Figure 2-20 with several alternatives, depending on the inferences that are drawn, ranging from minimal to upper bound estimates. The estimates are made with a reference point and depth to the Culebra at the AIS (Holt and Powers 1990a).

Given the maximum local thickness of the Dewey Lake, the maximum load at the end of the Permian was no more than approximately 787 ft (240 m). Given the present depth to the Culebra from the top of the Dewey Lake in the AIS, approximately 115 ft (35 m) of Dewey Lake might have been eroded during the Early Triassic before additional sediments were deposited. The Triassic thickness at the AIS is approximately 26 ft (8 m). Northeast of the WIPP site (T21S, R33E), Triassic rocks (Dockum Group) have a maximum local thickness of approximately 1,233 ft (375 m). This thickness is a reasonable estimate of the maximum thickness also attained at the WIPP site prior to the Jurassic Period. At the end of the Triassic, the total thickness at the WIPP site may have then attained approximately 1,863 ft (568 m) in two similar loading stages of a few million years each, over a period of approximately 50 million years.

The Jurassic outcrops nearest to the WIPP site are in the Malone Mountains of west Texas. There is no evidence that Jurassic rocks were deposited at or in the vicinity of the WIPP site. As a consequence, the Jurassic is considered a time of erosion or nondeposition at the site, though erosion is most likely. An arbitrary erosion rate averaging approximately 33 ft (10 m) per million years is sufficient to erode the inferred thickness of 1,198 ft (365 m) of additional Triassic rocks from the WIPP site. The Jurassic is the first possible period of significant unloading at the WIPP site.

This much erosion during the Jurassic obviously cannot be broadly inferred for the area or there would not be thick Triassic rocks still preserved. Triassic rocks of this thickness are preserved nearby, indicating either pre-Jurassic tilting or that erosion did not occur until later (but still after tilting to preserve the Triassic rocks near the WIPP site). It is also possible that the immediate site area had little Triassic deposition or erosion, but very limited Triassic deposition (that is, 26 ft [8 m]) at the WIPP site seems unlikely.

Lang (1947) reported fossils from Lower Cretaceous rocks in the Black River Valley southwest of the WIPP site. Bachman (1980) also reported similar patches of probable Cretaceous rocks near Carlsbad and south of White's City. From these reports, it is likely that some Cretaceous rocks were deposited at the WIPP site. Approximately 70 mi (110 km) south southwest of the WIPP site, significant Cretaceous outcrops of both Early and Late Cretaceous age have a total maximum thickness of approximately 1,000 ft (300 m). Southeast of the WIPP, the nearest Cretaceous outcrops are thinner and



Note: The estimates are made with a reference point and depth to the culebra at the AIS.

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Figure 2-20. Loading and Unloading History Estimated for Base of Culebra

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represent only the Lower Cretaceous. Based on outcrops, a maximum thickness of 1,000 ft (300 m) of Cretaceous rocks could be estimated for the WIPP site. Compared to the estimate of Triassic rock thickness, it is less likely that Cretaceous rocks were this thick at the site. The uppermost lines of Figure 2-20 summarize the assumptions of maximum thickness of these units.

A more likely alternative is that virtually no Cretaceous rocks were deposited, followed by erosion of remaining Triassic rocks during the Late Cretaceous to the Late Cenozoic. Such erosion may also have taken place over an even longer period, beginning with the Jurassic Period. Ewing (1993) favors Early Cretaceous uplift and erosion for the Trans-Pecos Texas area, but he does not analyze later uplift and erosional patterns.

In the general vicinity of the WIPP site, there are outcrops of Cenozoic rock from the Late Miocene (Gatuña and Ogallala Formations). There is little reason to infer any significant Early Cenozoic sediment accumulation at the WIPP site. Erosion is the main process inferred to have occurred during this period and an average erosion rate of approximately 36 ft (11 m) per million years is sufficient during the Cenozoic to erode the maximum inferred Triassic and Cretaceous thickness prior to Gatuña and Ogallala deposition. Significant thicknesses of Cretaceous rocks may not have been deposited, however, and average erosion rates could have been lower.

Maximum-known Gatuña thickness in the area around the WIPP is approximately 330 ft (100 m); at the WIPP site the Gatuña is very thin to absent. Ogallala deposits are known from the Divide east of the WIPP site, as well as from the High Plains further east and north. On the High Plains northeast of the WIPP, the Upper Ogallala surface slopes to the southeast at a rate of approximately 20 ft per mi (4 ms per km). A straight projection of the 4,100-ft (1250-m) contour line from this High Plains surface intersects the site area, which is at an elevation slightly above 3,400 ft (1,036 m). This difference in elevation of 700 ft (213 m) represents one estimate, probably near an upper bound, of possible unloading subsequent to deposition of the Ogallala Formation.

Alternatively, the loading and unloading of the Ogallala could have been closer to 330 ft (100 m). In any case, it would have occurred as a short-lived pulse over a few million years at most.

While the above inferences about greater unit thicknesses and probable occurrence are permissible, a realistic assessment suggests a more modest loading and unloading history. It is likely that the Dewey Lake accumulated to near local maximum thickness of approximately 787 ft (240 m) before being slightly eroded prior to the deposition of Triassic rocks. It also is most probable that the Triassic rocks accumulated at the site to near local maximum thickness. In two similar cycles of rapid loading, the Culebra was buried to a depth of approximately 2,132 ft (650 m) by the end of the Triassic.

It also seems unlikely that a significant thickness of Cretaceous rock accumulated at the WIPP site. Erosion probably began during the Jurassic, slowed or stopped during the Early Cretaceous as the area was nearer or at base level, and then accelerated during the

Cenozoic, especially in response to uplift as Basin and Range tectonics encroached on the area and the basin was tilted more. Erosional beveling of Dewey Lake and Santa Rosa suggest considerable erosion since tilting in the mid-Cenozoic. Erosion rates for this shorter period could have been relatively high, resulting in the greatest stress relief on the Culebra and surrounding units. Some filling occurred during the Late Cenozoic as the uplifted areas to the west formed an apron of Ogallala sediment across much of the area, but it is not clear how much Gatuña or Ogallala sediment was deposited in the site area. From general reconstruction of Gatuña history in the area (Powers and Holt 1993), the DOE infers that Gatuña or Ogallala deposits likely were not much thicker at the WIPP site than they are now. The loading and unloading spike (Figure 2-20) representing Ogallala thickness probably did not occur. Cutting and headward erosion by the Pecos River has created local relief and unloading by erosion.

At the WIPP site, this history is little complicated by dissolution, though locally (for example, Nash Draw) the effects of erosion and dissolution are more significant. The underlying evaporites have responded to foundering of anhydrite in less dense halite beds. These have caused local uplift of the Culebra (as at ERDA 6) but little change in the overburden at the WIPP. Areas east of the WIPP site are likely to have a similar history to the site. West of the site, the final unloading is more complicated by dissolution and additional erosion leading to exposure of the Culebra along stretches of the Pecos River Valley.

2.1.5.3 Faulting

Fault zones are well known along the Central Basin Platform, east of WIPP, from extensive drilling for oil and gas, as reported by Hills (1984). Holt and Powers performed a more recent analysis in 1986 of geophysical logs from oil and gas wells to examine the regional geology for the Rustler. This analysis showed that faults along the margin of the Central Basin Platform displaced Rustler rocks of at least Late Permian age. The overlying Dewey Lake shows marked thinning along the same trend according to Schiel (1988, Figure 21), but the structure contours of the top of the Dewey Lake are not clearly offset. Schiel concluded that the fault was probably reactivated during the Dewey Lake's deposition, but movement ceased at least by the time the Santa Rosa was deposited. No surface displacement or fault has been reported along this trend.

Muehlberger et al. (1978) have mapped Quaternary fault scarps along the Salt Basin graben west of both the Guadalupe and Delaware mountains. These are the nearest known Quaternary faults of tectonic origin to the WIPP. Kelley (1971) inferred the Carlsbad and Barrera faults along the eastern escarpment of the Guadalupe Mountains based mainly on vegetative lineaments. Hayes and Bachman reexamined the field evidence for these faults in 1979 and concluded that they were nonexistent. Figure 2-21 illustrates major regional structures, including faults.

On a national basis, Howard et al. (1971, sheets 1 and 2) assessed the location and potential for activity of young faults. For the region around the WIPP site, Howard et al. (1971, sheet 1) located faults along the western escarpment of the Delaware and

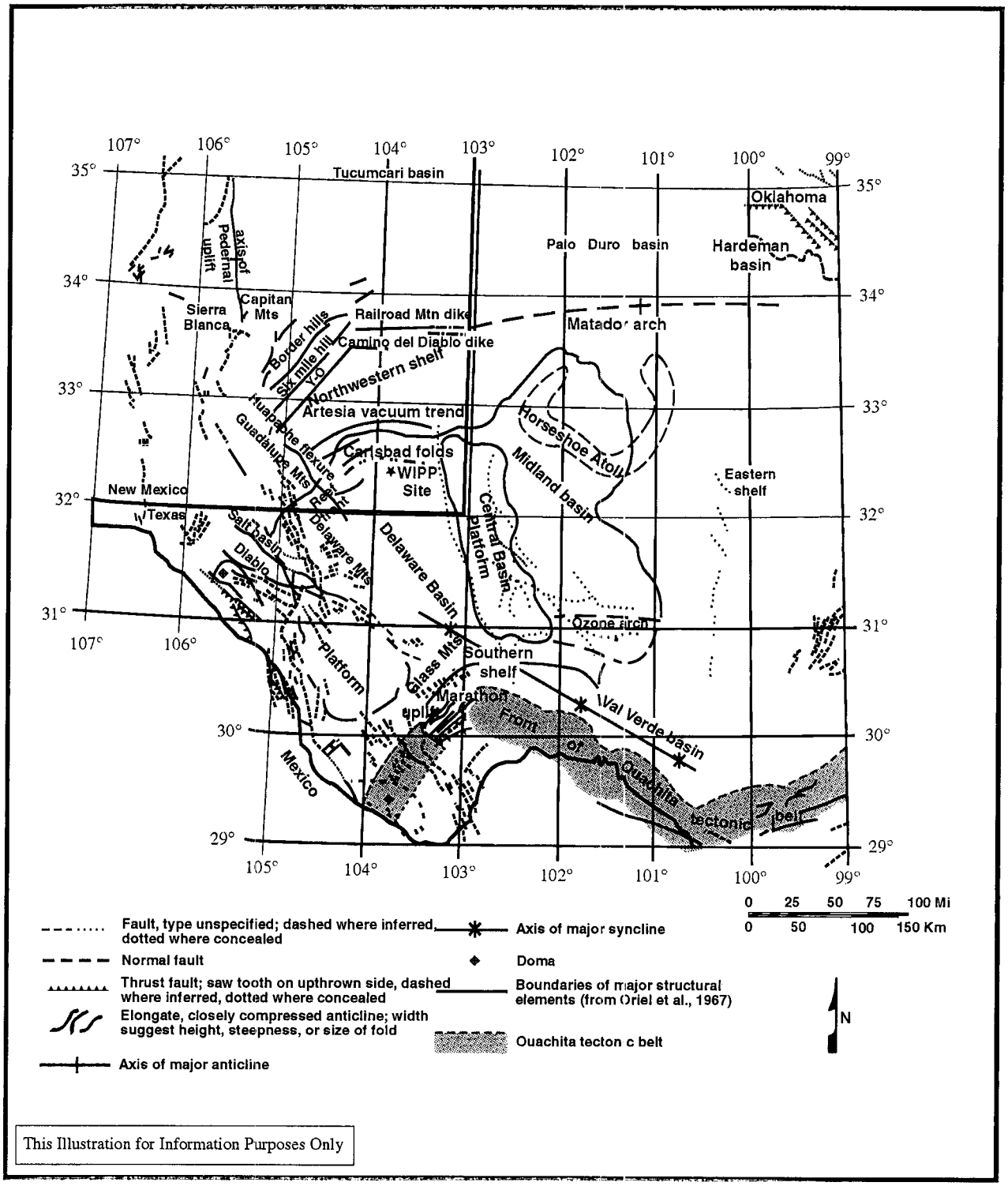

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Figure 2-21. Regional Structures of the Guadalupe Mountains

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Guadalupe mountains trend. These faults were judged to be Late Quaternary (approximately the last 500,000 years) or older.

In summary, there are no known Quaternary or Holocene faults of tectonic origin that offset rocks at the surface nearer to the site than the western escarpment of the Guadalupe Mountains. A significant part of the tilt of basin rocks is attributed to a mid-Miocene to Pliocene uplift trend along the Guadalupe-Sacramento mountains that is inferred on the basis of High Plains sediments of the Ogallala.

2.1.5.4 Igneous Activity

Within the Delaware Basin, only one feature of igneous origin is known to have formed since the Precambrian. An igneous lamprophyre dike or series of dikes occurs along a linear trace about 75 mi (120 km) long from the Yeso Hills south of White's City to the northeast of the WIPP site. At its closest, the dike trend passes about 8 mi (13 km) northwest of the WIPP site center as shown in Figure 2-22. Evidence for the extent of the dike includes outcroppings at Yeso Hills, subsurface intercepts in boreholes and mines, and airborne magnetic responses.

An early radiometric determination for the dike by Urry (1936) yielded an age of 30 ± 1.5 million years. More recent work on dike samples by Calzia and Hiss (1978) are consistent with early work, indicating an age of 34.8 ± 0.8 million years.[2] Work by Brookins (1980, 29–31) on polyhalite samples in contact with the dike indicated an age of about 21.4 million years.

Volcanic ashes found in the Gatuña (Section 2.1.3.8) were airborne from distant sources and do not represent volcanic activity at the WIPP site.

2.1.6 Nontectonic Processes and Features

Nontectonic processes and features, which include evaporite deformation and dissolution of strata, are known to be active in the Delaware Basin. These processes are of interest because they represent mechanisms that are potentially disruptive to the repository in the long term. Both processes have been investigated extensively. The conclusions from these investigations are summarized in this section.

Halite in evaporite sequences is relatively plastic, which can lead to the process of deformation; it is also highly soluble, which can lead to the process of dissolution. Both processes (deformation and dissolution) can produce structural features similar to those produced by tectonic processes. The features developed by dissolution and deformation can be distinguished from similar-looking tectonic features where the underlying units do not reflect the same feature as do the evaporites. As an example, the evaporite

[2] Calzia and Hiss reported 32.2 to 33.9 million years. However, Powers et al. 1978 reported a recalculated value of 34.8 ± 0.8 million years based on a change in measured decay constant.

deformation commonly does not affect the underlying Bell Canyon. The deformation also tends to die out in overlying units, and the Rustler or the Dewey Lake may show little, if any, effects from deformed evaporites. Beds underlying areas of dissolved salt are not affected, but overlying units to the surface may be affected.

2.1.6.1 Evaporite Deformation

The most recent review of evaporite deformation in the northern Delaware Basin and original work to evaluate deformation is summarized here. More detail is provided in Appendix DEF.

Basic WIPP History of Deformation Investigations

The Castile has been known for many years to be deformed in parts of the Delaware Basin, especially along the northern margin. Jones et al. (1973) clearly showed the Castile to be thicker from the northwestern to northern part of the basin margin, just inside the Capitan Reef (hereafter referred to as the Capitan). A dissertation by Snider (1966, Figures 11 and 14) and a paper by Anderson et al. (1972, Figure 10) also presented maps showing some evidence of thicker sections of Castile next to the Capitan. ERDA-6 was drilled during 1975 as part of the program to characterize an initial site for WIPP. The borehole penetrated increasingly deformed beds through the Salado into the Castile, and, at 2,711 ft (826 m) depth, the borehole began to produce pressurized brine and gas. Anderson and Powers (1978) and Jones (1981a) interpreted beds to have been displaced structurally by as much as 950 ft (290 m). Some of the lower beds may have pierced overlying beds. The beds were considered too structurally deformed to mine reasonably along single horizons for a repository. Therefore, the site was abandoned in 1975, and the current site was located in 1976 (Appendix GCR). The deformed beds around ERDA-6 were considered part of a deformed zone within about 6 mi (10 km) of the inner margin of the Capitan Reef. As a consequence, the preliminary selection criteria prohibited locating a new site within 6 mi (10 km) of the Capitan Reef margin.

General criteria for the present site for the WIPP appeared to be met based on initial data from drilling (ERDA-9) and geophysical surveys. Beginning in 1977, the new site was more intensively characterized through geophysical surveys, including seismic reflection and drilling. Extensive seismic reflection work revealed good reflector quality in the southern part of the site and poor quality or disturbed reflectors in a sector of the northern part of the site. The area of disturbed reflectors became known as the disturbed zone, the area of anomalous seismic reflectors, or zone of anomalous seismic reflection data. (The disturbed zone based on poor Castile seismic reflectors is completely different from the distrubed rock zone (DRZ) that describes the deformation around mined underground openings at the WIPP.)

Powers et al. 1978 in Appendix GCR (Figures 4.4, 4.5, and 4.6), generally shows the disturbed zone beginning about 1 mi (1.6 km) north of the WIPP site center. Borns et al., in 1983, included two areas south of the WIPP site as showing the same features of the disturbed zone. Neill et al., also in 1983, summarized the limits of the disturbed zone

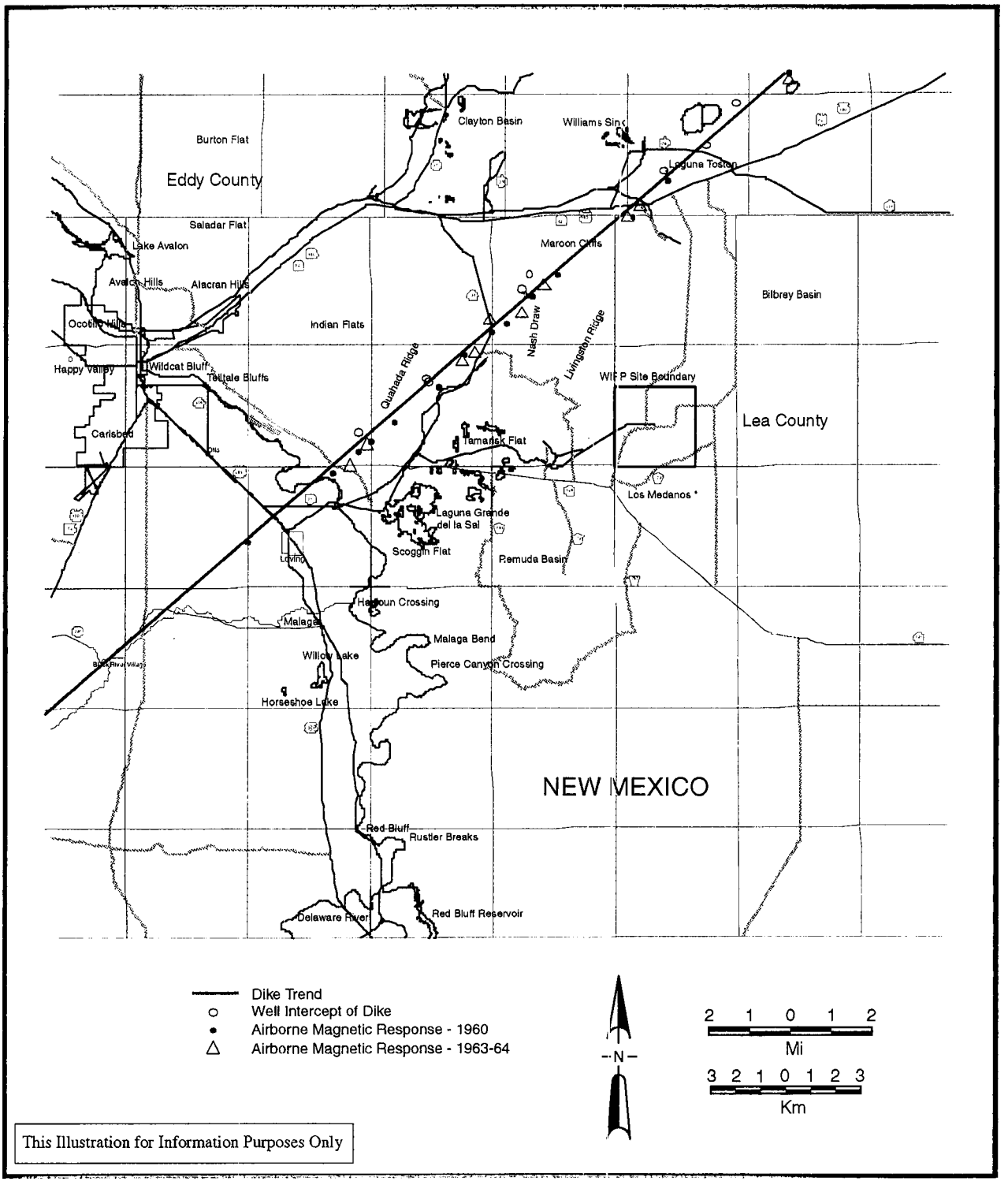

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Figure 2-22. Igneous Dike in the Vicinity of the WIPP Site

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based on differing interpretations and included the area less than 1 mi (1.6 km) north of the site center where the dip in the Castile begins to steepen. WIPP-11 was drilled early during 1978 about 3 mi (5 km) north of the site center over part of the disturbed zone where proprietary petroleum company data had also indicated significant seismic anomalies. The borehole encountered highly deformed beds within the Castile and altered thicknesses of halite units, but no pressurized brine and gas were found.

Less than 1 mi (1.6 km) north of the site center, seismic data indicated possible faulting of the Upper Salado and the Lower Rustler over the area of steepening Castile dips. Four boreholes (WIPP-18, -19, -21, -22) were drilled into the Upper Salado and demonstrated neither faulting nor significant deformation of the Rustler-Salado contact. Lateral changes in the seismic velocity of the upper sections contributed to the interpretation of a possible fault and thus complicate interpretations of deeper structure.

WIPP-12 was located about 1 mi (1.6 km) north of the center of the site and drilled during 1978 to a depth of 2,785 ft (850 m) in the Upper Castile to determine the significance of structure on possible repository horizons. The top of the Castile was encountered at an elevation about 160 ft (49 m) above the same contact in ERDA-9 at the site center.

WIPP-12 was deepened during late 1981 to a depth of 3,925 ft (1,200 m) to test for possible brine and gas in the deformed Castile. The probability of encountering brine and gas was considered low because ERDA-6 and other known brine reservoirs in the Castile occurred in areas with greater deformation. During drilling, fractured anhydrite in the Upper Castile (Lower A3) began to yield pressurized brine and gas. The borehole was deepened to the basal anhydrite (A1) of the Castile. Over a million gallons of brine were allowed to flow from the well before the hole was shut in. Subsequent reservoir testing was conducted to estimate reservoir size (see Section 2.2.1).

As a consequence of discovering pressurized brine and gas in WIPP-12, the Environmental Evaluation Group (EEG) recommended that the design of the facility be changed and that proposed waste disposal areas in the north be moved or reoriented to the south. After additional drilling of DOE-1, the DOE concluded that the design change had advantages, and the disposal facilities were placed south of the site center.

A microgravity survey of the site was designed to delineate further the structure within the disturbed zone based on the large density differences between halite and anhydrite. The gravity survey was unsuccessful in yielding any improved resolution of the Castile structure.

DOE-2 was the last WIPP borehole to examine structure within the Castile. Salado structure from potash data suggested a low point about 2 mi (3.2 km) north of the site center. It was proposed by Davies (1984, 175) that the Salado low might indicate deeper dissolution of Castile halite, somewhat similar to the dissolution causing breccia pipes (see Section 2.1.6.2 on evaporite dissolution). The borehole demonstrated considerable

Castile deformation, but there was no indication that halite had been removed by dissolution.

Extent of the Disturbed Zone at the Site

Nearby surface drilling, shafts, and underground drilling during early excavations at WIPP showed that the repository horizon varies modestly from the regional structure over the central part of the site; north of the site center, the beds dip gently to the south. Borns in 1987 suggested that the south dip is probably related to the dip on the underlying Castile.

The upper surface of MB 139, under the repository horizon, exhibited local relief in the exploratory salt-handling shaft. Jarolimek et al. (1983a, 4–6) interpreted the relief as mainly caused by syndepositional growth of gypsum at the water-sediment interface to form mounds and by subsequent partial crushing. Jarolimek et al. concluded that the MB relief was not due to deformation because the base of the MB showed no comparable relief. Based on concerns of the EEG, MB 139 was reevaluated. Borns and Shaffer in 1985 found less relief on the upper surface of the MB in the areas they examined; they also concluded that depositional processes were responsible for the relief. In either case, deformation is not thought to have caused the relief on MB 139.

Deformation Mechanisms

In analyzing Castile structure in the northern Delaware Basin, Borns et al. (1983) proposed five processes as the principal hypotheses to explain the structure: gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes. Gravity foundering is the most comprehensive and best-accepted hypothesis of the five. It is based on the fact that anhydrite is much more dense (about 2.9 grams per cm^3) than halite (about 2.15 grams per cm^3), and anhydrite beds therefore have a potential for sinking into underlying halite. Regardless of which mechanism causes the disturbed zone, the important coinsideration is what are the long-term future effects. To evaluate this, Borns et al. postulated that both gravity driven deformation mechanisms could be ongoing. The strain rates from such deformation are such that deformation would progress over the next 250,000 years and that such deformation would not directly jeopardize the disposal system. However, regardless of the mechanism invoked, rates of salt deformation are too slow to affect performance of the WIPP during the regulatory period.

Timing of Deformation of the Disturbed Zone at the Site

Jones estimated in 1981 that deformation of the Castile and overlying rocks took place before the Ogallala Formation was deposited, as he believes the unit is undeformed. Anderson and Powers (1978) inferred that data from ERDA-6 indicate that the Castile was deformed after the basin was tilted. Though these lines of evidence could be consistent with mid-Miocene deformation, there are other interpretations of tilting

consistent with older deformation (Madsen and Raup 1988). There is no known evidence of surface deformation or other features to indicate recent deformation.

In its 1989 study of the WIPP, the EPA reviewed the record regarding the deformation features in the Castile. While the EPA concluded that none of the features underlie the WIPP repository (with the possible exception of brine), the EPA considered it important to look at the origins of the deformations to consider whether they indicate general instability in the area or result in processes that might directly threaten the integrity of the WIPP.

The EPA concluded that the data indicate that Castile deformation was probably initiated millions of years ago in association with major tilting of the strata. The EPA also concluded that the region is relatively inactive at present, implying that new development of major Castile features probably will not occur. Furthermore, the EPA concluded that over one-half million years is likely to be required for the features to form, indicating that the formation of the features "is not catastrophic and will probably not affect the WIPP repository within the foreseeable future" (EPA 1990a).

2.1.6.2 Evaporite Dissolution

Because evaporites are much more soluble than most other rocks, project investigators have considered it important to understand the dissolution processes and rates that occur within the site being considered for long-term isolation. These dissolution processes and rates constitute the limiting factor in any evaluation of the site. Over the course of the WIPP project, extensive resources have been committed to identify and study a variety of features in southeastern New Mexico interpreted to have been caused by dissolution. The subsurface distribution of halite for various units has been mapped. Several different kinds of surface features have been attributed to dissolution of salt or karst formation. The processes proposed or identified include point-source (brecciation), deep dissolution, shallow dissolution, and karst. Screening arguments relative to dissolution are presented in Appendix SCR. These arguments are based principally on the observed rates and processes in the region. These are described below.

Brief History of Project Studies

Well before the WIPP project, several geologists recognized that dissolution is an important process in southeastern New Mexico and that it contributed to the subsurface distribution of halite and to the surficial features. Early studies include those by Lee (1925), Maley and Huffington (1953), and Olive (1957). Robinson and Lang (1938) identified an area under Nash Draw where brine occurred at about the stratigraphic position of the Upper Salado–basal Rustler and considered that salt had been dissolved to produce a dissolution residue. Vine (1963) mapped Nash Draw and surrounding areas, reporting on various dissolution features. Vine reported surficial domal structures, later called breccia pipes and identified as deep-seated dissolution and collapse features.

As the USGS and Oak Ridge National Laboratory (ORNL) began to survey southeastern New Mexico as an area in which to locate a repository site in salt, Brokaw et al. in 1972 prepared a summary of the geology that included solution and subsidence as significant processes in creating the features of southeastern New Mexico. Brokaw et al. also recognized a solution residue at the top of salt in the Salado in the Nash Draw area, and the unit commonly became known as the brine aquifer because it yielded brine. Brokaw et al. also interpreted the east–west decrease in thickness of the Rustler to be a consequence of removal by dissolution of halite and other soluble minerals.

During the early 1970s, the basic ideas about shallow dissolution of salt (generally from higher stratigraphic units and within a few hundred feet of the surface) were set out in a series of reports by Bachman, Jones, and collaborators, as discussed in the following sections. Piper (1973, 1974) independently evaluated the geological survey data for ORNL. Claiborne and Gera (1974) concluded that salt was being dissolved too slowly from the near-surface units to affect a repository for several million years, at least.

By 1978, shallower drilling around the WIPP site to evaluate potash resources was interpreted by Jones (1978, 9), and he felt that the Rustler included "dissolution debris, convergence of beds, and structural evidence for subsidence." Halite in the Rustler has been reevaluated by the DOE, but there are only minor differences in inferred distributions among the various investigators. These investigators do have different explanations about how this distribution occurred (see Section 2.1.3.5 on Rustler stratigraphy): (1) through extensive dissolution of the Rustler's halite after the Rustler was deposited or (2) through syndepositional dissolution of halite from saline mud flat environments during Rustler deposition.

Anderson (1978) reevaluated halite distribution in deeper units, especially the Castile and Salado formations. He identified local anomalies proposed as features developed after dissolution of halite by water flowing upward from the underlying Bell Canyon. Anderson mapped geophysical log signatures of the Castile and interpreted lateral thinning and change from halite to non-halite lithology as evidence of lateral dissolution of deeper units (part of deep dissolution), and he proposed that deep dissolution might threaten the WIPP site. In response to Anderson's developing concepts, ERDA-10 was drilled south of the WIPP area during the latter part of 1977. ERDA-10 intercepted a stratigraphic sequence without evidence of solution residues in the Upper Castile.

A set of annular or ring fractures is evident in the surface around San Simon Sink, about 18 mi (30 km) east of the WIPP site. Nicholson and Clebsch (1961, 14) suggested that San Simon Sink developed as a result of deep-seated collapse. WIPP-15 was drilled at about the center of the sink to a depth of 811 ft (247 m) to obtain samples for paleoclimatic data and stratigraphic data to interpret collapse. Anderson and Bachman both interpret San Simon Sink as dissolution and collapse features, and the annular fractures are not considered evidence of tectonic activity.

Following the work by Anderson, Bachman (1974) mapped surficial features in the Pecos Valley, especially at Nash Draw, and differentiated between those surface features in the

basin that were formed by karst and those that were formed by deep collapse features over the Capitan Reef. WIPP-32, WIPP-33, and two boreholes over the Capitan Reef were eventually drilled. Their data, which demonstrated the concepts proposed by Bachman, are documented in Snyder and Gard (1982, 65).

A final program concerning dissolution and karst was initiated following a microgravity survey of a portion of the site during 1980. Based on localized low-gravity anomalies, Barrows et al. (1983) interpreted several areas within the site as locations of karst. WIPP-14 was drilled during 1981 at a low-gravity anomaly. It revealed normal stratigraphy through the zones proposed to be affected by karst. As a followup, in 1985 Bachman also reexamined surface features around the WIPP and concluded that there was no evidence for active karst within the WIPP site. The nearest karst feature is northwest of the site boundaries at WIPP-33 and is considered inactive.

Extent of Dissolution

The margins of halite within the anhydrite and claystone members of the Rustler have been mapped by different methods, which were summarized by Beauheim (in 1987a, 131–134). There are few differences in interpretation, despite the different methods used (Figure 2-10). Lower members of the Rustler are halitic west of the site, and higher members generally show halite only further east. Snyder (1985) interprets these margins as a consequence of post-depositional dissolution of halite. Holt and Powers (1988, 6-8 and 6-9) interpret sedimentary structures within the Rustler mudstone as being equivalent to halite, indicating that most halite was removed during the depositional process and redeposited in a salt pan in the eastern part of the depositional basin.

Upper intervals of the Salado thin dramatically west and south of the WIPP site (Figure 2-23) compared to deeper Salado intervals. There are no cores for further consideration of possible depositional variations. As a consequence, this zone of thinning is interpreted by the DOE as the edge of dissolution of the Upper Salado.

Timing of Dissolution

The dissolution of Ochoan evaporites through the near-surface processes of weathering and groundwater recharge has been studied extensively (Anderson 1981, Lambert 1983a, Lambert 1983b, Bachman 1984, and see also Holt and Powers 1988). The work of Lambert (1983a) was specifically mandated by the agreement between the DOE and the State of New Mexico to evaluate in detail the conceptual models of evaporite dissolution proposed by Anderson (1981). There was no clear consensus of the volume of rock salt removed. Hence, estimates of the instantaneous rate of dissolution vary significantly. Dissolution may have taken place as early as the Ochoan, during or shortly after deposition. For the Delaware Basin as a whole, Anderson (1981) proposed that up to 40 percent of the rock salt in the Castile and Salado formations was dissolved during the past 600,000 years. Lambert (1983b) suggested that in many places the variations in salt-bed thicknesses inferred from borehole geophysical logs that were the basis for Anderson's calculation were depositional in origin, compensated by thickening of adjacent nonhalite

beds, and were not associated with the characteristic dissolution residues. Borns and Shaffer also suggested in 1985 a depositional origin for many apparent structural features attributed to dissolution.

Snyder (1985), as well as earlier workers (for example, Vine 1963, Lambert 1983b, and Bachman 1984), attributes the variations in thickness in the Rustler, which crops out in Nash Draw, to post-depositional evaporite dissolution. Holt and Powers (1988, 7-1 to 7-27) have challenged this view and attribute the east-to-west thinning of salt beds in the Rustler to depositional facies variability rather than post-depositional dissolution. Bachman (1974, 1976, and 1980) envisioned several episodes of dissolution since the Triassic, each dominated by greater degrees of evaporite exhumation and a wetter climate, interspersed with episodes of evaporite burial and/or a drier climate. Evidence for dissolution after deposition of the Salado and before deposition of the Rustler along the western part of the Basin was cited by Adams (1944). Others have argued that the evaporites in the Delaware Basin were above sea level and therefore potentially subject to dissolution, during the Triassic, Jurassic, Tertiary, and Quaternary periods. Because of discontinuous deposition, not all of these times are separable in the geological record of southeastern New Mexico. Bachman (1974) contends that dissolution was episodic during the past 225 million years as a function of regional base level, climate, and overburden.

There have been several attempts to estimate the rates of dissolution in the basin. Bachman (1974) provided initial estimates of dissolution rates based on a reconstruction of Nash Draw relationships, including the observation that portions of the Gatuña were deposited over areas of active dissolution and subsidence of the underlying evaporites.

Though these rates indicate no hazard to the WIPP related to Nash Draw dissolution, Bachman later reconsidered the Nash Draw relationships and concluded that pre-Cenozoic dissolution had also contributed to salt removal. Thus, the initial estimated rates were too high. Anderson concluded in 1978 that the integrity of the WIPP to isolate radioactive waste would not be jeopardized by dissolution within about 1 million years. Anderson and Kirkland (1980, 66–69) expanded on the concept of brine density flow proposed by Anderson (1978) as a means of dissolving evaporites at a point by circulating water from the underlying Bell Canyon. Wood et al. (1982) examined the mechanism and concluded that, while it was physically feasible, it would not be effective enough in removing salt to threaten the ability of the WIPP to isolate TRU waste.

The EPA conducted its own extensive review of dissolution literature and data and examined suspected dissolution features around the WIPP site. The EPA reached the following conclusion:

> Deep-seated dissolution probably occurs in portions of the Delaware Basin, but it is very unlikely that deep-seated dissolution is operating near or below the WIPP. Very little or no possibility exists for the formation of breccia pipes within the WIPP site boundary. There does appear to be a near-surface dissolution front along the Rustler/upper Salado contact, which is moving toward the WIPP site from Nash Draw. However, assuming current estimates of dissolution rates, it would take millions of years for this front to reach

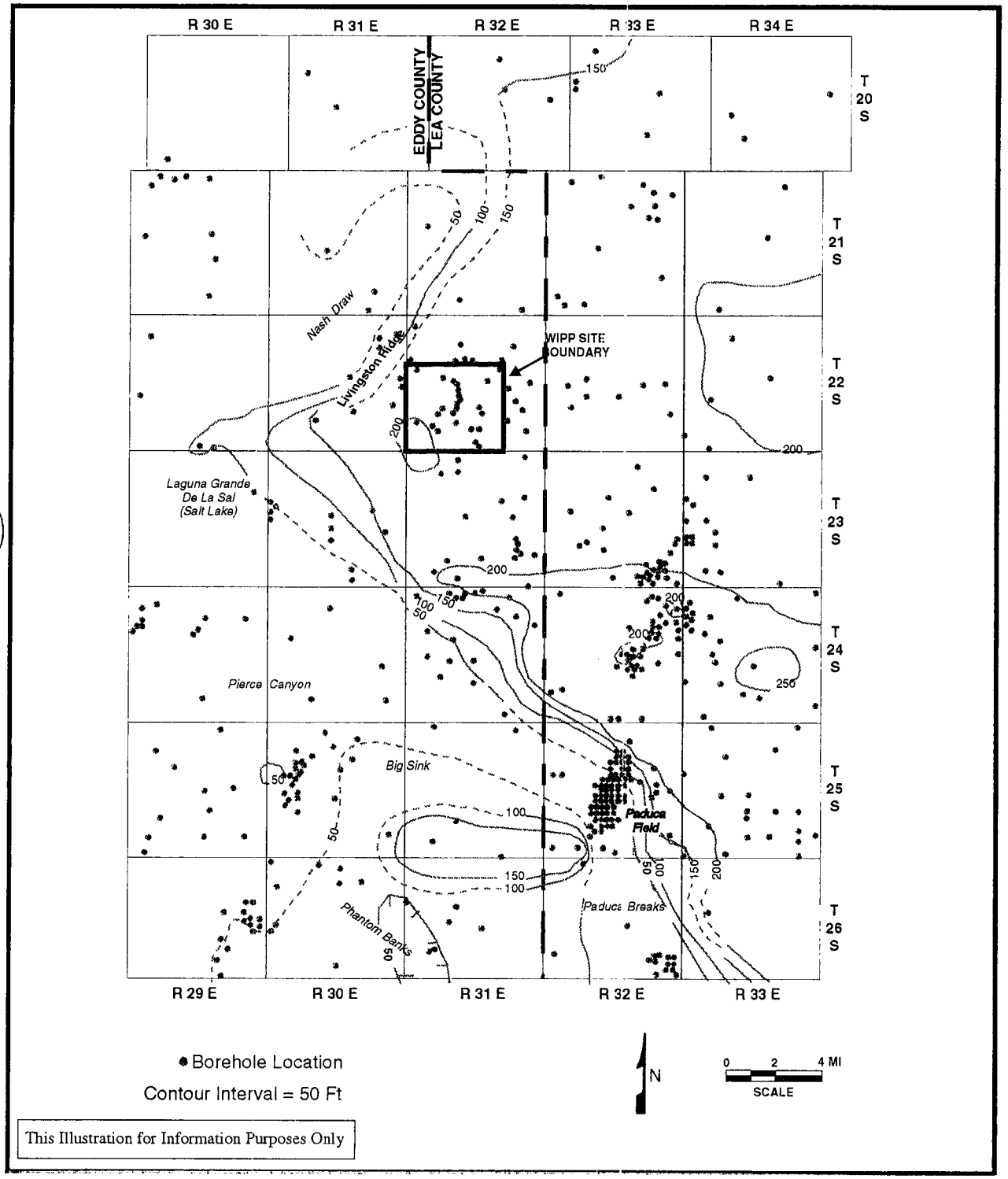

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Figure 2-23. Isopach from the Base of MB 103 to the Top of the Salado

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> the WIPP repository. Therefore, near surface dissolution along this front is not a mechanism that will affect the WIPP repository in the foreseeable future. Dissolution within the Upper Rustler Formation is apparent within southern parts of the WIPP site boundary. But is well outside of the unit boundaries and it is under further study. Regional geochemical studies are planned relative to dissolution considerations.
>
> Dissolution rates do not appear to be increasing under current climatic conditions, and available data indicate that the climate has probably been relatively dry for the last 500,000 years. (EPA 1990a)

Surface Features Related to Dissolution

Bachman (1980, 97) separated breccia pipes, formed over the Capitan Reef by dissolution and collapse of a cylindrical mass of rock, from evaporite karst features that appear similar to breccia pipes. There are surficial karst features, including sinks and caves, in large areas of the basin. Nash Draw is the result of combined dissolution and erosion. Within the site boundaries, there are no known surficial features caused by dissolution or karst.

The subsurface structure of the Culebra is shown in Figure 2-24. South of the WIPP site between Pierce Canyon and Paduca Breaks there is a relationship between this structure and dissolution. Salt has been removed from the underlying Salado to create a general anticline from near Laguna Grande de la Sal to the southeast of the WIPP site. Beds generally dip to the east, and salt removed to the west created the other limb of the structure. Units below the evaporites apparently do not show the same structure.

2.2 Surface Water and Groundwater Hydrology

The DOE has determined that the hydrological characteristics of the disposal system are important because contaminant transport via fluid flow has a potential to impact the performance of the disposal system. At the WIPP site, one of the DOE's selection criteria was to choose a location that would minimize this impact. This was accomplished when the DOE selected (1) a host formation that contains little groundwater and transmits it poorly, (2) a location where the effects of groundwater flow are minimal and predictable, (3) an area where groundwater use is low, (4) an area where there are no permanent surface waters, (5) an area where future groundwater use is unlikely, and (6) a repository host rock that will not likely be affected by anticipated possible long-term climate changes within 10,000 years.

The following discussion summarizes the characteristics of the groundwater and surface water at and around the WIPP site. This summary is based on data collection programs that were initiated with the WIPP program and that continue to some extent today. The purpose of these programs was to provide information sufficient for the development and use of predictive models of the groundwater movement at the WIPP site.

For a comprehensive understanding of the impact of groundwater and surface water on the disposal system, the following factors have been evaluated:

Groundwater

- Horizontal and vertical flow fluxes and velocities
- Hydraulic interconnectivity between rock units
- Hydraulic parameters (porosity, etc.)
- General groundwater use
- Chemistry (including, but not limited to, salinity, mineralization, age, Eh, and pH)

Surface Water

- Regional precipitation and evapotranspiration rates
- Location and size of surface-water bodies
- Water volume, flow rate, and direction
- Drainage network
- Hydraulic connection with groundwater
- Soil hydraulic properties (infiltration)
- General water chemistry and use

Changes to the hydrological system due to human activity are evaluated in Appendix SCR. The specifics of groundwater modeling are found in Chapter 8. The hydrological system is divided into four segments for the discussion in this chapter. These are (1) the rock units below the Salado; (2) the rock units above the Salado, which may affect the disposal unit; (3) the Salado; and (4) the surface waters. The groundwater regime is discussed in Section 2.2.1, and the surface-water regime in Section 2.2.2.

The WIPP site lies within the Pecos River drainage area (Figure 2-25, see also Figure 2-36). As discussed in the FEIS (DOE 1980), the climate is semiarid, with a mean annual precipitation of about 13 in. (0.33 m), a mean annual runoff of 0.1 to 0.2 in. (2.5 to 5 mm), and a mean annual pan evaporation of more than 100 in. (2.5 m). Additional information about climatic conditions at the WIPP is given in Section 2.5.2. Brackish water with total dissolved solids (TDS) concentrations of more than 3,000 parts per million is common in the shallow wells near the WIPP site. Surface waters typically have high TDS concentrations, particularly of chloride, sulfate, sodium, magnesium, and calcium. Additional information about water quality is given in Section 2.4.2.

2.2.1 Groundwater Hydrology

At the WIPP site, the DOE obtains groundwater hydrologic data from conventional and special-purpose test configurations in multiple surface boreholes. (Figure 2-2 is a map of borehole locations.) Geophysical logging of the boreholes has provided hydrologic information on the rock strata intercepted. Pressure measurements, fluid samples, and ranges of rock permeability have been obtained for selected formations through the use of standard and modified drill-stem tests. Slug injection or withdrawal tests and other flow-rate tests have provided data to aid in the estimation of transmissivity and storage. The hydraulic head of groundwaters within many water-bearing zones in the region has been mapped from measured depths to water in the boreholes.

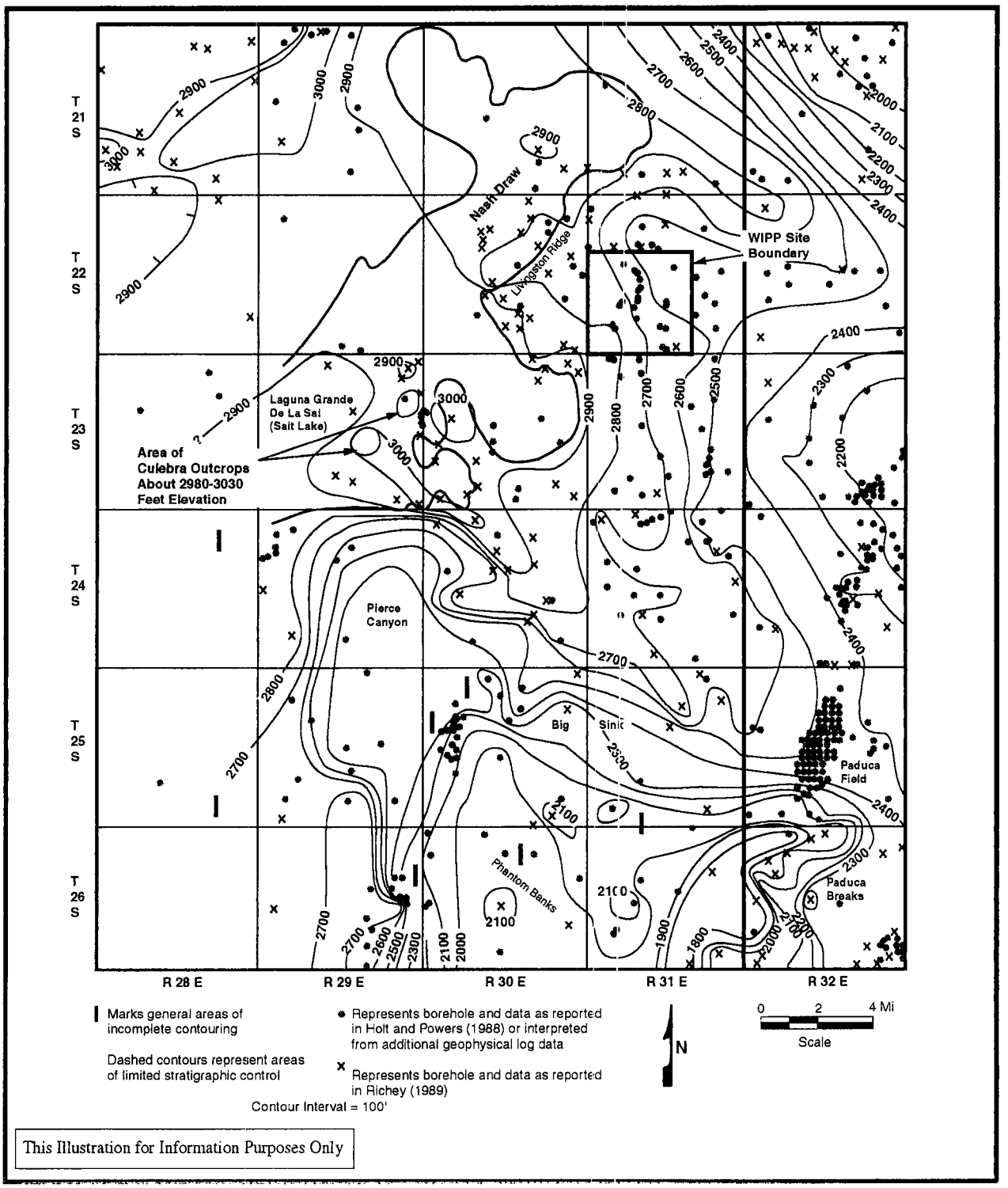

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Figure 2-24. Structure Contour Map of Culebra Dolomite Base

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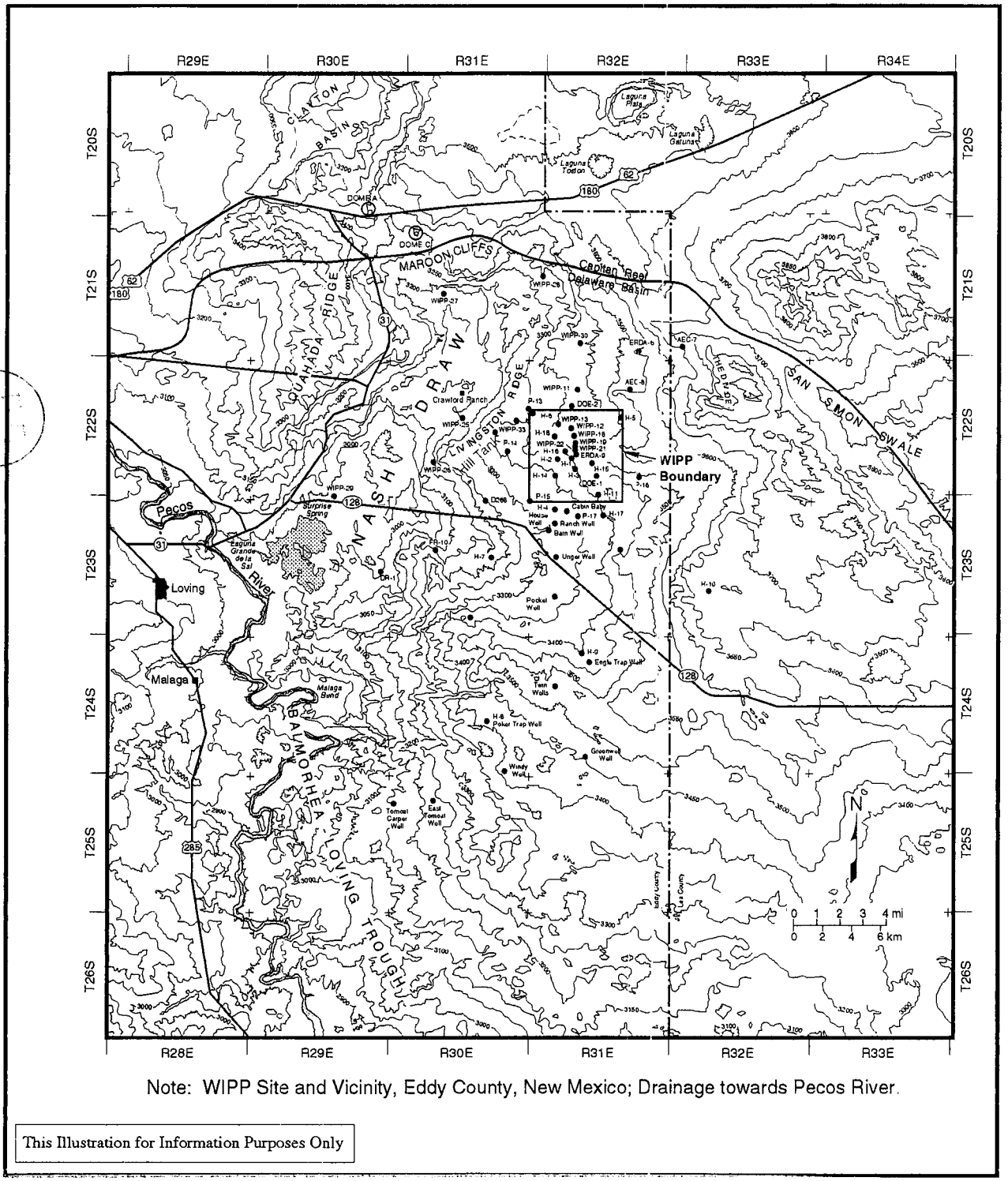

Note: WIPP Site and Vicinity, Eddy County, New Mexico; Drainage towards Pecos River.

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Figure 2-25. Drainage Pattern in the Vicinity of the WIPP Facility

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Rock units that are important to WIPP hydrology are the Bell Canyon, the Castile, the Salado, the Rustler, the Dewey Lake, and the Santa Rosa (Figures 2-26 and 2-27). Even though absent at the WIPP site, the Capitan Limestone and the Rustler-Salado contact zone in Nash Draw will be discussed because they are important features of the groundwater characteristics of the WIPP region.

The Bell Canyon is of interest to the DOE because it is the first regionally continuous water-bearing unit beneath the WIPP. The halite and anhydrite layers of the Castile provide a hydrologic barrier between the Salado and the underlying Bell Canyon. The Castile is of interest to performance assessment because it contains isolated high-permeability zones containing pressurized brine. As discussed in Section 2.1.6.1, several such zones of pressurized brine have been intercepted by boreholes near the WIPP site, and one or more may exist at the WIPP site.

The Salado is comprised of low-permeability beds of variable composition. The low permeability of the Salado provides a hydrologic barrier in all directions between the repository and the accessible environment or more transmissive beds.

The Rustler contains two laterally transmissive members. The Culebra is the first laterally continuous unit located above the WIPP underground facility to display hydraulic conductivity and transmissivity sufficient for mass transport. The hydrology and fluid geochemistry of the Culebra are important to regulations involving radionuclide transport and, as a result, have received a great deal of study (see, for example, LaVenue et al. 1988, 1990; Haug et al. 1987; and Siegel et al. 1991 in the bibliography). The Magenta, although more transmissive than the anhydrite and claystone members of the Rustler, has lower transmissivity than the Culebra, and is unfractured.

The Dewey Lake does not produce water into the WIPP shafts, indicating unsaturated conditions or low transmissivity. Flow from a fractured zone has been observed at Water Quality Sampling Program (WQSP)-6a. The Santa Rosa is shallow and unsaturated at the site, and the only flow through it is infiltration, which likely occurs at low rates because of the evaporative climate.

For the no-migration demonstration, the DOE recognizes the Salado as the most significant hydrostratigraphic unit. Other units are considered to have less important roles; however, their hydrology is discussed for background information.

2.2.1.1 Conceptual Models of Groundwater Flow

The DOE addresses issues related to groundwater flow within the context of a conceptual model of how the natural hydrologic system works on a large scale. The conceptual model of regional flow around the WIPP that is presented here is based on widely accepted concepts of regional groundwater flow in groundwater basins (see, for example, Hubbert 1940, Tóth 1963, and Freeze and Witherspoon 1967 in the bibliography).

An idealized groundwater basin is a three-dimensional closed hydrologic unit bounded on the bottom by an impermeable rock unit (units with much smaller permeability than the units above), on the top by the ground surface, and on the sides by groundwater divides. The water table is the upper boundary of the region of saturated liquid flow. All rocks in the basin are expected to have finite permeability; in other words, hydraulic continuity exists throughout the basin. This means that the potential for liquid flow from any unit to any other units exists, although the existence of any particular flow path is dependent on a number of conditions related to gradients and permeabilities. All recharge to the basin is by infiltration of precipitation to the water table and all discharge from the basin is by flow across the water table to the land surface.

Differences in elevation of the water table across an idealized basin provide the driving force for groundwater flow. The pattern of groundwater flow depends on the lateral extent of the basin, the shape of the water table, and the heterogeneity of the permeability of the rocks in the basin. Water flows along gradients of hydraulic head from regions of high head to regions of low head. The highest and lowest heads in the basin occur at the water table at its highest and lowest points, respectively. Therefore, groundwater flows from the elevated regions of the water table, downward across confining layers (layers with relatively small permeability), then laterally along more conductive layers, and finally upward to exit the basin in regions where the water table (and by association, the land surface) is at low elevations. Recharge is necessary to maintain relief on the water table, without which flow does not occur.

Groundwater divides are boundaries across which it is assumed that no groundwater flow occurs. In general, these are located in areas where groundwater flow is dominantly downward (recharge areas) or where groundwater flow is upward (discharge areas). Topography and surface-water drainage patterns provide clues to the location of groundwater divides. Ridges between creeks and valleys may serve as recharge-type divides, and rivers, lakes, or topographic depressions may serve as discharge-type divides.

In the groundwater basin model, rocks can be classified into hydrostratigraphic units. A hydrostratigraphic unit is a continuous region of rock across which hydraulic properties are similar or vary within described or stated limits. The definition of hydrostratigraphic units is a practical exercise to separate rock regions with similar hydrologic characteristics from rock regions with dissimilar hydrologic characteristics. Although hydrostratigraphic units often are defined to be similar to stratigraphic units, this need not be the case. Hydrostratigraphic unit boundaries can reflect changes in hydraulic properties related to differences in composition, fracturing, dissolution, or a variety of other factors that may not be reflected in the definition of stratigraphic formations.

Confining layers in a groundwater basin model can be characterized as allowing vertical flow only. The amount of vertical flow occurring in a confining layer generally decreases in relation to the depth of the layer. Flow in conductive units is more complicated. In general, flow will be lateral through conductive units. The magnitude (in other words, volume flux) of lateral flow is related to the thickness, conductivity, and gradient present in the unit. Gradients generally decrease in deeper units. The direction of flow is

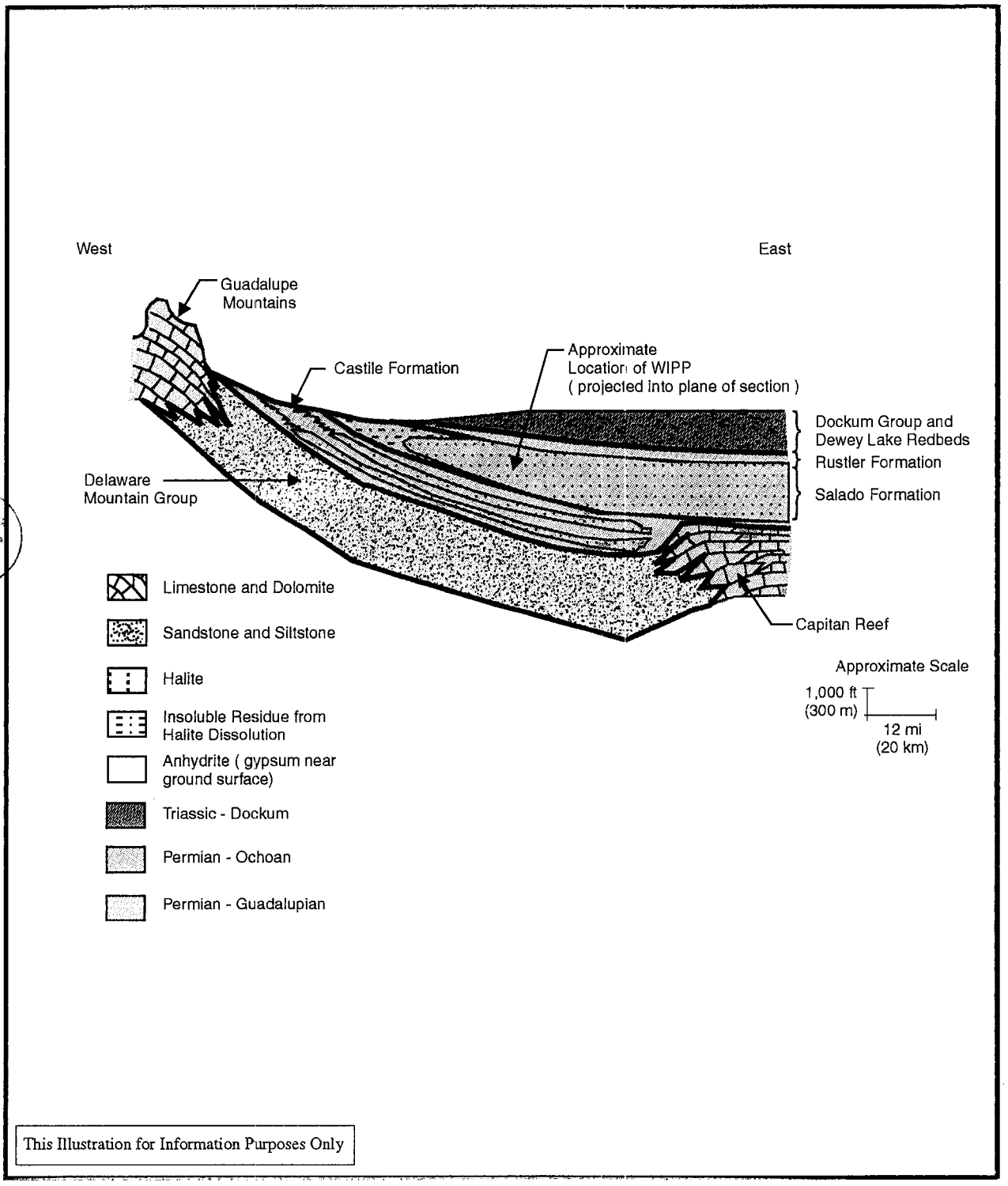

Figure 2-26. Schematic West-East Cross Section through the North Delaware Basin

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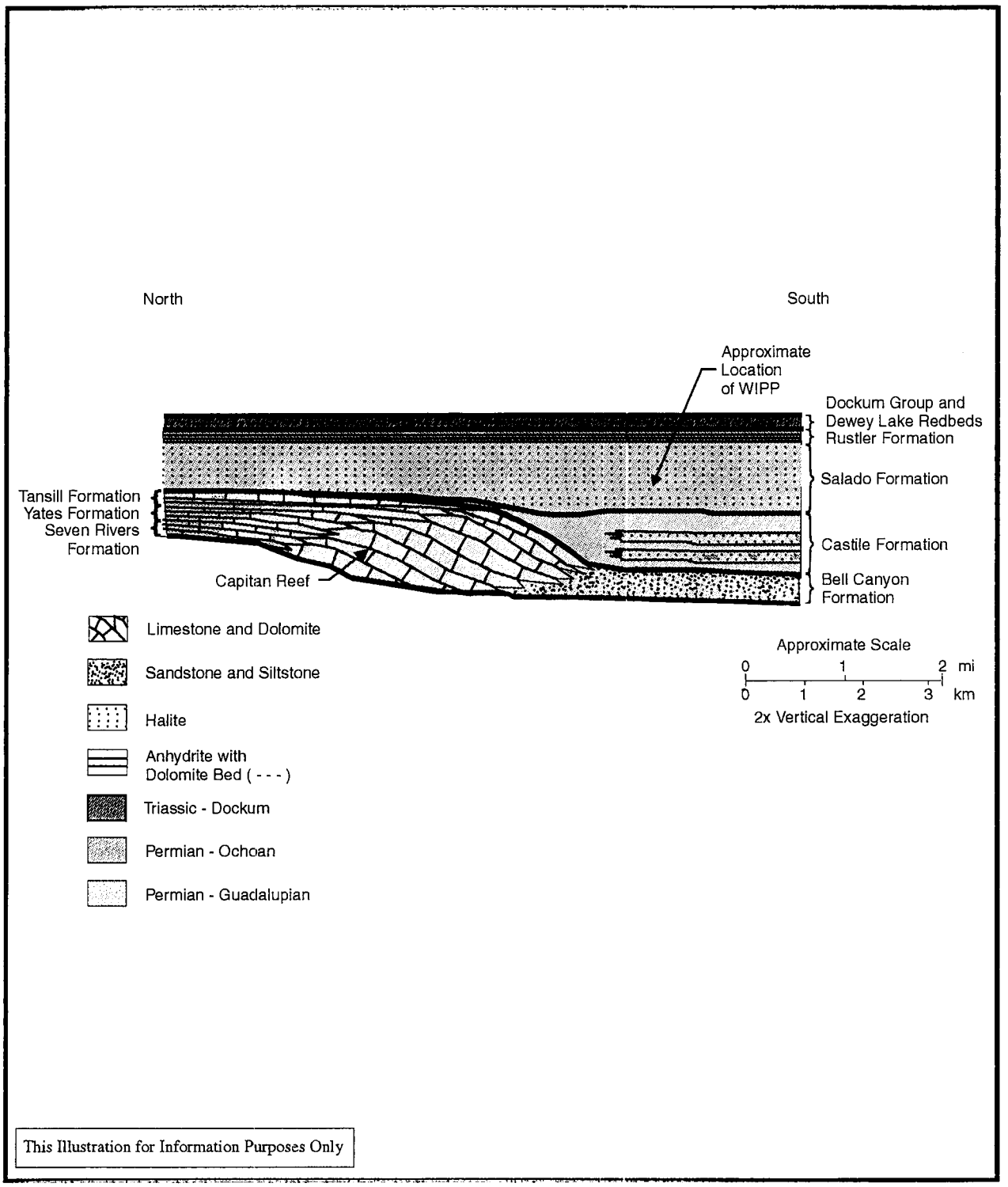

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Figure 2-27. Schematic North-South Cross Section through the North Delaware Basin

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generally related to the distance the unit is from the land surface. Near the land surface, flow directions are influenced primarily by the local slope of the land surface. In deeper conductive units, flow directions are generally oriented parallel to the direction between the highest and lowest points in a groundwater basin. Thus, flow rates, volumes, and directions in conductive units in a groundwater basin are generally not expected to be the same.

In the WIPP region, the Salado provides an extremely low-permeability layer that forms the base for a regional groundwater-flow basin in the overlying rocks of the Rustler, Dewey Lake, and Santa Rosa. The Castile and Salado together form their own groundwater system, and they separate flow in units above them from that in units below. Because of the plastic nature of halite and the resulting low permeability, fluid pressures in the evaporites are more related to lithostatic stress than to the shape of the water table in the overlying units, and regionally neither vertical nor horizontal flow will occur as a result of natural pressure gradients in time scales relevant to the disposal system. (On a repository scale, however, the excavations themselves create pressure gradients that may induce flow near the excavated region.) Consistent with the recognition of the Salado as the base of the groundwater basin of interest, the following discussion is divided into three sections: hydrology of units below the Salado, hydrology of the Salado, and hydrology of the units above the Salado.

2.2.1.2 Units Below the Salado

Units of interest to the WIPP project below the Salado are the Bell Canyon and the Castile. These units have quite different hydrologic characteristics.

Hydrology of the Bell Canyon Formation

The Bell Canyon is considered for the purposes of regional groundwater flow to form a single hydrostratigraphic unit about 1,000 ft (300 m) thick. Tests at five boreholes (AEC-7, AEC-8, ERDA-10, DOE-2, and Cabin Baby) indicate a range of hydraulic conductivities for the Bell Canyon from 5×10^{-2} ft per day to 1×10^{-6} ft per day (1.7×10^{-7} to 3.5×10^{-12} m per second). The pressure measured in the Bell Canyon at the DOE-2 and Cabin Baby boreholes ranges from 12.6 to 13.3 megapascals (Appendix HYDRO, 29–31; DOE 1983, 4-9 to 4-12; Beauheim 1986, 61–71). Fluid flow in the Bell Canyon is markedly influenced by the presence of the extremely low-permeability Castile and Salado above it, which effectively isolate it from interaction with overlying units except where the Castile is absent because of erosion or nondeposition, such as in the Guadalupe Mountains, or where the Capitan Reef is the overlying unit (Figures 2-26 and 2-27). Because of the isolating nature of the Castile and Salado, fluid flow directions in the Bell Canyon are sensitive only to gradients established over very long distances. At the WIPP, the brines in the Bell Canyon flow northeasterly under an estimated hydraulic gradient of 25 to 40 ft per mi (4.7 to 7.6 m per km) and discharge into the Capitan aquifer. Velocities are on the order of tenths of ft per year, and groundwater yields from wells in the Bell Canyon are 0.6 to 1.5 gal (2.3 to 5.7 l) per minute. The fact that flow directions in the Bell Canyon under the WIPP are inferred to be almost opposite to the flow directions in

units above the Salado (see Section 2.2.1.4) is not of concern because, as discussed above, the presence of the Castile and Salado makes the flow in the Bell Canyon sensitive to gradients established over long distances, whereas flow in the units above the Salado is sensitive to gradients established by more local variations in water table elevation.

Castile Hydrology

As described in Sections 2.1.3.3, the Castile is dominated by low permeability anhydrite and halite zones. However, fracturing in the upper anhydrite has generated isolated regions with much greater permeability than the surrounding intact anhydrite. These regions are located in the area of structural deformation as discussed in Section 2.1.6.1. The higher permeability regions of the Castile contain brine at pressures greater than hydrostatic and have been referred to as brine reservoirs (see Figure 2-28). The fluid pressure measured by Popielak et al. in 1983 in the WIPP-12 borehole (12.7 MPa) is greater than the nominal hydrostatic pressure for a column of equivalent brine at that depth (11.1 MPa). Therefore, under open-hole conditions, brine could flow upward to the surface through a borehole.

Results of hydraulic tests performed in the ERDA-6 and WIPP-12 boreholes suggest that the extent of the highly permeable portions of the Castile is limited. The vast majority of brine is thought to be stored in low-permeability microfractures; about 5 percent of the overall brine volume is stored in large open fractures. The volumes of the ERDA-6 and WIPP-12 brine reservoirs were estimated by Popielak et al. in 1983 to be 3.5×10^6 ft^3 (100,000 m^3) and 9.5×10^6 ft^3 (270,000 m^3), respectively.

A geophysical survey using time domain electromagnetic (TDEM) methods was completed over the WIPP-12 brine reservoir and the waste disposal panels (The Earth Technology Corporation 1988). The TDEM measurements detected a conductor interpreted to be the WIPP-12 brine reservoir and also indicated that similar brine occurrences may be present within the Castile under a portion of the waste disposal panels.

The origin of brine in the Castile has been investigated geochemically. Popielak et al. (1983, 5) concluded that the ratios of major and minor element concentrations in the brines indicate that these fluids originated from ancient seawater and that no evidence for fluid contribution from present meteoric waters. The Castile brine chemistry from the ERDA-6 and WIPP-12 reservoirs are distinctly different from each other and from local groundwaters. These geochemical data indicate that brine in reservoirs to any significant extent has not mixed with other waters and has not circulated. The brines are saturated, or nearly so, with respect to halite and, consequently, have little potential to dissolve halite.

2.2.1.3 Hydrology of the Salado

As described in Sections 2.1.3, the Salado consists mainly of halite and anhydrite. A considerable amount of information about the hydraulic properties of these rocks has

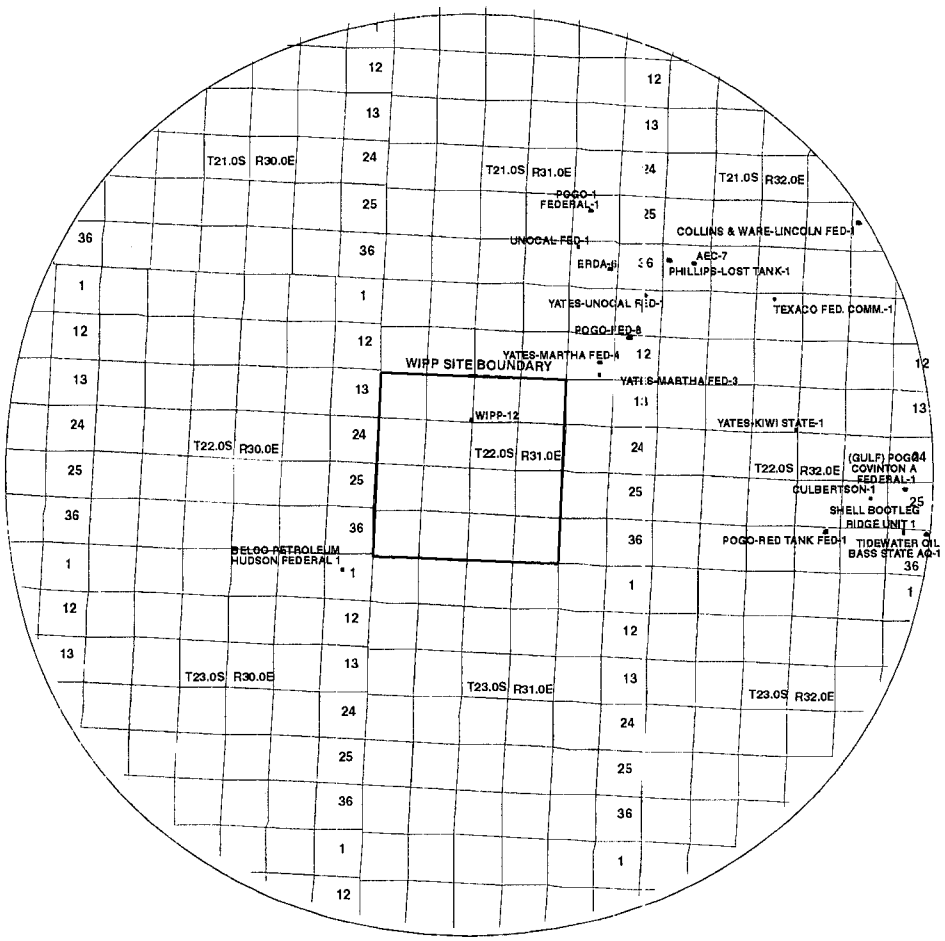

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Figure 2-28. Recent Occurrences of Pressurized Brine in the Castile Formation

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been collected through field and laboratory experiments. Appendix PAR summarizes this information.

Hydraulic testing in the Salado in the WIPP underground provided quantitative estimates of the hydraulic properties controlling brine flow through the Salado. The tests are interpreted by Beauheim et al. in 1991 and 1993 using models based on potentiometric flow. The tests influence rock as far as 33 ft (10 m) distant from the test zone and are not thought to significantly alter the pre-test conditions of the rock. The stratigraphic intervals tested include both pure and impure halite. Because tests close to the repository are within the DRZ that surrounds the excavated regions (see Section 3.7.1), it is reasonable to use the results of the tests farthest from the repository as most representative of undisturbed conditions.

Twenty-two hydraulic tests have been performed in impure halite, and two in pure halite. Interpreted permeabilities using a Darcy-flow model vary from 1×10^{-23} to 4×10^{-18} m^2 for impure halite intervals. Interpreted formation pore pressures vary from 0.3 to 9.7 MPa for impure halite, with the lower pressures believed to show effects of the DRZ. Tests in pure halite show no observable response, indicating either extremely low permeability ($<10^{-23}$ m^2), or no flow whatsoever, even though appreciable pressures are applied to the test interval. Appendix PAR contains a summary of the results of field permeability tests to date.

Fourteen hydraulic tests have been performed in anhydrite. Interpreted permeabilities using a Darcy-flow model vary from 2×10^{-20} to 7×10^{-18} m^2 for anhydrite intervals. Interpreted formation pore pressures vary from atmospheric to 12.5 megapascals for anhydrite intervals. Lower values are caused by depressurization near the excavation.

The properties of anhydrite interbeds have also been investigated in the laboratory. Tests were performed on three groups of core samples from MB 139 as part of the Salado Two-Phase Flow Laboratory Program. The laboratory experiments provided porosity, intrinsic permeability, and capillary pressure data. Preliminary analysis of capillary pressure test results indicate a threshold pressure of less than 1 megapascal. The laboratory-measured effective porosity and intrinsic permeability data are shown in Appendix PAR.

Fluid pressure above hydrostatic is a hydrologic characteristic of the Salado (and the Castile) that plays a potentially important role in the repository behavior. It is difficult to accurately measure natural pressures in these formations because the boreholes or repository excavations required to access the rocks decrease the stress in the region measured. Stress released instantaneously decreases fluid pressure in the pores of the rock, so measured pressures must be considered as a lower bound of the natural pressures. Stress effects related to test location and the difficulty of making long-duration tests in lower permeability rocks result in higher pore pressures observed to date in anhydrites. The highest observed pore pressure in halite-rich units, near Room Q, is on the order of 9 megapascals, whereas the highest pore pressures observed in anhydrite are 12.5 megapascals. It is expected that the far-field pore pressures in halite-rich and anhydrite beds in the Salado at the repository level are similar because the anhydrites are

too thin and of too low permeabilities to have liquid pressures much different than those of the surrounding salt. For comparison, the hydrostatic pressure for a column of brine at the depth of the repository is about 7 megapascals, and the lithostatic pressure calculated from density measurements in ERDA-9 is about 15 megapascals.

Fluid pressure in sedimentary basins that are much higher or much lower than hydrostatic are referred to as abnormal pressures in the literature of the petroleum industry, where they have received considerable attention. In the case of the Delaware Basin evaporites, the high pressures are almost certainly maintained because of the large compressibility and plastic nature of the halite and, to a lesser extent, the anhydrite. The lithostatic pressure at a particular horizon must be supported by a combination of the stress felt by the rock matrix and the pore fluid. In highly deformable rocks, the portion of the stress that must be borne by the fluid exceeds hydrostatic pressure but cannot exceed lithostatic pressure.

Brine content within the Salado is estimated at 1 to 2 percent by weight, although the thin clay seams have been observed by Deal et al. (1993) to contain up to 25 percent brine by weight. Brine in the Salado is likely Late Permian. This brine may move toward areas of low pressure, such as a borehole or mined section of the Salado.

Observation of the response of pore fluids in the Salado to changes in pressure boundary conditions at walls in the repository, in boreholes without packers, in packer-sealed boreholes, or in laboratory experiments is complicated by low permeability and low porosity. Qualitative data on brine flow to underground workings and exploratory boreholes have been collected routinely since 1985 under the Brine Sampling and Evaluation Program (BSEP) and have been documented in a series of reports (Deal and Case 1987; Deal et al. 1987, 1989, 1991a, b, and 1993). Additional data on brine inflow are available from the Large-Scale Brine Inflow Test (Room Q). Flow has been observed to move to walls in the repository, to boreholes without packers, and to packer-sealed boreholes. In certain cases, evidence for flow is no longer observed where it once was; in others, flow has begun where it once was not observed. In many cases, observations and experiments must last for months or years to obtain useful results. In part because of design requirements such as duration (the experimental period is short relative to the time required for the geological materials to fully respond), few quantitative data have been obtained for brine flow into the excavated region at atmospheric pressure. For performance assessment modeling, brine flow is a calculated term dependent on local pressure gradients and hydraulic properties of the Salado units. Data on pore pressure and permeability of halite and anhydrite layers are available from the Room Q test and other borehole tests, and these data form the basis for the quantification of the material properties used in the performance assessment. See Section 8.2 and Appendix PAR for additional discussions of the properties of the Salado.

2.2.1.4 Units Above the Salado

In evaluating groundwater flow above the Salado, the DOE considers the Rustler, Dewey Lake, Santa Rosa, and overlying units to form a groundwater basin with boundaries

coinciding with selected groundwater divides as discussed in Section 2.2.1.1. The boundary follows Nash Draw and the Pecos River valley to the west and south and the San Simon Swale to the east (Figure 2-29). The boundary continues up drainages and dissects topographic highs along its northern part. It is assumed that these boundaries represent groundwater divides whose positions remain fixed over the past several thousand years and 10,000 years into the future. For reasons described in Section 2.2.1.2, the lower boundary of the groundwater basin is the upper surface of the Salado.

Nash Draw and the Pecos River are areas where discharge to the surface occurs. Hunter (1985) described discharge at Surprise Spring and into saline lakes in Nash Draw. She reported groundwater discharge into the Pecos River between Avalon Dam north of Carlsbad and a point south of Malaga Bend as approximately 32.5 ft^3 per second (0.92 m^3 per second), mostly in the region near Malaga Bend.

Within this groundwater basin, hydrostratigraphic units with relatively high permeability are called conductive units, and those with relatively low permeability are called confining layers. The confining layers consist of halite and anhydrite and are perhaps five orders of magnitude less permeable than conductive units.

In a groundwater basin, the position of the water table moves up and down in response to changes in recharge. The amount of recharge is generally a very small fraction of the amount of rainfall; this condition is expected for the WIPP. The water table would stabilize at a particular position if the pattern of recharge remained constant for a long time. The equilibrated position depends, in part, on the distribution of hydraulic conductivity in all hydrostratigraphic units in the groundwater basin. However, the position of the water table depends mainly on the topography and geometry of the groundwater basin and the hydraulic conductivity of the uppermost strata. The position of the water table can adjust slowly to changes in recharge. Consequently, the water table can be at a position that is very much different from its equilibrium position at any given time. Generally, the water table drops very slowly in response to decreasing recharge but might rise rapidly in times of increasing recharge.

The asymmetry of response occurs because the rate at which the water table drops is limited by the rate at which water flows through the entire basin. In contrast, the rate at which the water table rises depends mainly on the recharge rate and the porosity of the uppermost strata. From groundwater basin modeling, the head distribution in the groundwater basin appears to equilibrate rapidly with the position of the water table.

In general, vertical leakage through confining layers is directed downward over all of the site. This downward leakage uniformly over the WIPP site is the result of a well-developed discharge area, Nash Draw and the Pecos River, along the western and southern boundaries of the groundwater basin. This area acts as a drain for the laterally conductive units in the groundwater basin, causing most vertical leakage in the groundwater basin to occur in a downward direction.

Hydrology of the Rustler Formation

The Rustler contains the most transmissive units above the repository. Fluid flow in the Rustler is characterized by very slow rates of vertical leakage through confining layers and faster lateral flow in conductive units. To illustrate this point, regional modeling with the groundwater basin model indicates that lateral specific discharges in the Culebra, for example, are perhaps two to three orders of magnitude greater than the vertical specific discharges across the top of the Culebra.

Unnamed Lower Member

The unnamed lower member makes up a single hydrostratigraphic unit in WIPP models of the Rustler, although its composition varies somewhat. Overall, it acts as a confining layer. The basal interval of the unnamed lower member, approximately 64 ft (20 m) thick, is composed of siltstone, mudstone, and claystone and confines the water-producing zones of the lowermost Rustler. Transmissivities of 2.7×10^{-4} ft^2 per day (2.9×10^{-10} m^2 per second) and 2.2×10^{-4} ft^2 per day (2.4×10^{-10} m^2 per second) were reported by Beauheim (1987a, 50) from tests at well H-16 that included this interval. These transmissivity values correspond to hydraulic conductivities of 4.2×10^{-6} ft per day (1.5×10^{-11} m per second) and 3.4×10^{-6} ft per day (1.2×10^{-11} m per second). The porosity of the unnamed lower member was measured in 1995 as part of testing at the H-19 hydropad. Two claystone samples had effective porosities of 26.8 and 27.3 percent. One anhydrite sample had an effective porosity of 0.2 percent. Hydraulic conductivity in the lower portion of the unnamed lower member is believed by the DOE to increase to the west in and near Nash Draw, where dissolution at the underlying Rustler-Salado contact has caused subsidence and fracturing of the sandstone and siltstone.

The remainder of the unnamed lower member contains mudstones, anhydrite, and variable amounts of halite. The hydraulic conductivity of these lithologies is extremely low; tests of mudstones and claystones in the waste-handling shaft gave hydraulic conductivity values varying from 2×10^{-9} ft per day (7×10^{-15} m per second) to 3×10^{-8} ft per day (1×10^{-13} m per second) according to Saulnier and Avis (1988, 6-11).

The Culebra

The Culebra is of interest because it is the most transmissive unit at the WIPP site. Hydrologic research has been concentrated on the unit for over a decade. Although it is relatively thin, it is an entire hydrostratigraphic unit in the WIPP hydrological conceptual model, and it is the most important conductive unit in this model.

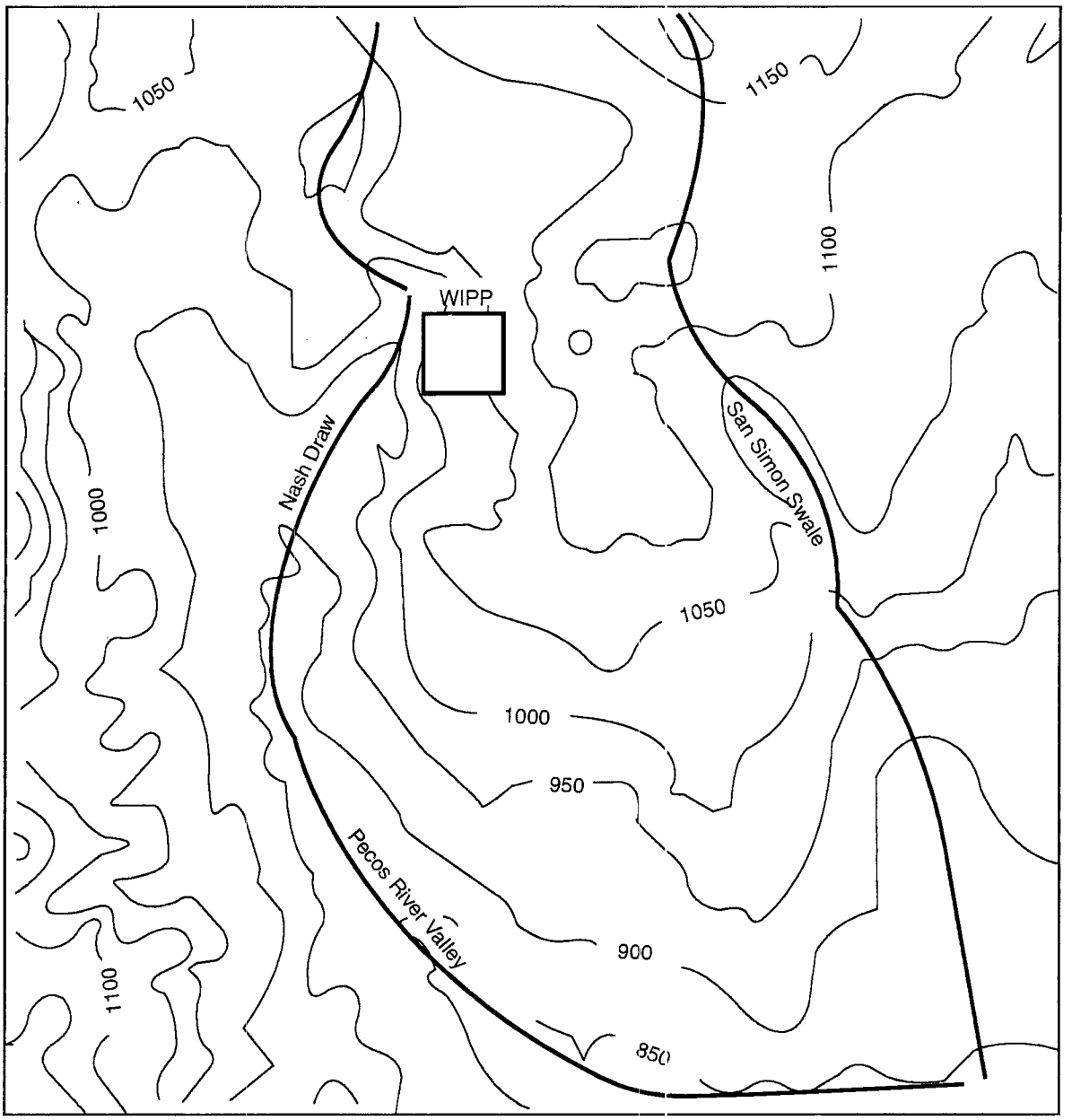

Figure 2-29. Outline of the Groundwater Basin Model Domain on a Topographic Map

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The two primary types of field tests that are being used to characterize the Culebra are hydraulic tests and tracer tests.

The hydraulic testing consists of pumping, injection, and slug testing of wells across the study area (e.g., Beauheim 1987a). The most detailed hydraulic test data exist for the WIPP hydropads (e.g., H-19). The hydropads generally comprise a network of three or more wells located within a few tens of meters of each other. Long-term pumping tests have been conducted at hydropads H-3, H-11, and H-19 and at well WIPP-13 (Beauheim 1987b, 1987c, 1989; Beauheim et al. 1995). These pumping tests provided transient pressure data at the hydropad and over a much larger area. Tests often included use of automated data-acquisition systems, providing high resolution (in both space and time) data sets. In addition to long-term pumping tests, slug tests and short-term pumping tests have been conducted at individual wells to provide pressure data that can be used to interpret the transmissivity at that well (Beauheim 1987a). (Additional short-term pumping tests have been conducted in the WQSP wells [Stensrud 1995]). Detailed cross-hole hydraulic testing has recently been conducted at the H-19 hydropad (Kloska et al. 1995).

The hydraulic tests are designed to yield pressure data for the interpretation of such characteristics as transmissivity, permeability, and storativity. The pressure data from long-term pumping tests and the interpreted transmissivity values for individual wells are used for the generation of transmissivity fields in PA flow modeling.

The DOE has conducted numerous tests to evaluate transport properties of the Culebra, including a series of tracer tests at six locations (the H-2, H-3, H-4, H-6, H-11, and H-19 hydropads) near the WIPP site. These tests are not discussed here since transport in the Culebra will not occur as long as the no-migration standard is met. For details on the results of those tests, Jones et al. (1992) should be consulted.

The Culebra is a fractured dolomite with nonuniform properties both horizontally and vertically. There are multiple scales or porosity (and permeability) within the Culebra including fractures ranging from microscale to potentially large, vuggy zones, and inter- and intragranular porosity. Flow occurs within fractures, vuggy zones and probably to some extent in intergranular porosity. (In other words, flow occurs in response to hydraulic gradients in all places that are permeable).

Fluid flow in the Culebra is dominantly lateral and southward except in discharge areas along the west or south boundaries of the basin. Where transmissive fractures exist, flow is dominated by fractures but may also occur in vuggy zones and to some extent in intergranular porous regions. Regions where flow is dominantly through vuggy zones or intergranular porosity have been inferred from pumping tests and tracer tests. Flow in the Culebra may be concentrated along zones that are thinner than the total thickness of the Culebra. In general, the upper portion of the Culebra is massive dolomite with a few fractures and vugs, and appears to have low permeability. The lower portion of the Culebra appears to have many more vuggy and fractured zones and to have a significantly higher permeability.

There is strong evidence that the permeability of the Culebra varies spatially and varies sufficiently that it cannot be characterized with a uniform value or range over the region of interest to the WIPP. The transmissivity of the Culebra varies spatially over six orders of magnitude from east to west in the vicinity of the WIPP (Figure 2-30). Over the site, Culebra transmissivity varies over three to four orders of magnitude. Transmissivities are from 1×10^{-3} ft^2 per day (1×10^{-9} m^2 per second) at well P-18 east of the WIPP site to 1×10^{3} ft^2 per day (1×10^{-3} m^2 per second) at well H-7 in Nash Draw (see Figure 2-2 for the locations of these wells).

Transmissivity variations in the Culebra are believed to be controlled by the relative abundance of open fractures rather than by primary (that is, depositional) features of the unit. Lateral variations in depositional environments were small within the mapped region, and primary features of the Culebra show little map-scale spatial variability according to Holt and Powers (1988). Direct measurements of the density of open fractures are not available from core samples because of incomplete recovery and fracturing during drilling, but observation of the relatively unfractured exposures in the WIPP shafts suggests that the density of open fractures in the Culebra decreases to the east. Qualitative correlations have been noted between transmissivity and several geologic features possibly related to open-fracture density, including (1) the distribution of overburden above the Culebra, (2) the distribution of halite in other members of the Rustler, (3) the dissolution of halite in the upper portion of the Salado, and (4) the distribution of gypsum fillings in fractures in the Culebra (see Section 2.1.3.5 and Figure 2-12).

Measured matrix porosities of the Culebra vary from 0.03 to 0.30. Fracture porosity values have not been measured directly, but interpreted values from tracer tests at the H-3, H-6, and H-11 hydropads vary from 5×10^{-4} to 3×10^{-3}. Data are insufficient to determine whether the average porosity of the matrix and fractures varies significantly on a regional scale.

Geochemical and radioisotope characteristics of the Culebra have been studied. There is considerable variation in groundwater geochemistry in the Culebra. The variation has been described in terms of different hydrogeochemical facies that can be mapped in the Culebra (see Section 2.4.2). A halite-rich hydrogeochemical facies exists in the region of the WIPP site and to the east, approximately corresponding to the regions in which halite exists in units above and below the Culebra (Figure 2-10), and in which a large portion of the Culebra fractures are gypsum filled (Figure 2-12). An anhydrite-rich hydrogeochemical facies exists west and south of the WIPP site, where there is relatively less halite in adjacent strata and where there are fewer gypsum-filled fractures. Radiogenic isotopic signatures suggest that the age of the groundwater in the Culebra is on the order of 10,000 years or more (see, for example, Lambert 1987, Lambert and Carter 1987, Lambert and Harvey 1987 in the bibliography).The radiogenic ages of the Culebra groundwater and the geochemical differences provide information potentially relevant to the groundwater flow directions and groundwater interaction with other units and are important constraints on conceptual models of groundwater flow. Previous conceptual models of the Culebra (see for example, Chapman 1986, Chapman 1988,

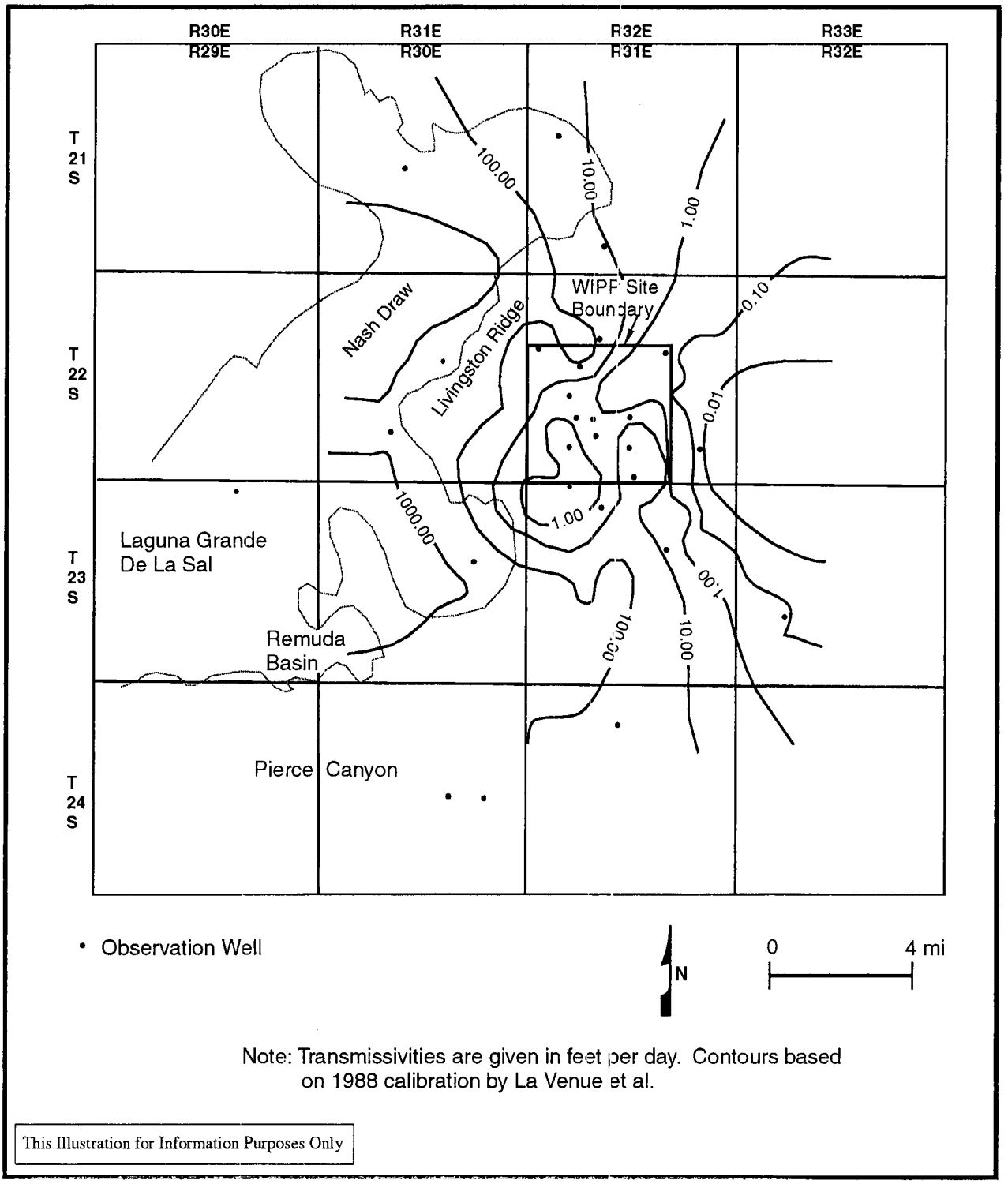

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Figure 2-30. The Transient Calibrated Culebra Transmissivities

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LaVenue et al. 1990, Siegel et al. 1991 in the bibliography), have not been able to consistently relate the hydrogeochemical facies, radiogenic ages, and flow constraints (that is, transmissivity, boundary conditions, etc.) in the Culebra.

The groundwater basin modeling that has been conducted provides flow fields that reasonably explain observed hydrogeochemical facies and radiogenic ages. The groundwater basin model combines and tests three fundamental processes: (1) it calculates vertical leakage, which may carry solutes into the Culebra; (2) it calculates lateral fluxes in the Culebra (directions as well as rates); and (3) it calculates a range of possible effects of climate change. The presence of the halite facies is explained by vertical leakage of solutes into the Culebra from the overlying halite-containing Tamarisk by advective or diffusive processes. Because lateral flow rates here are low, even slow rates of solute transport into the Culebra can result in high solute concentration. Vertical leakage occurs slowly over the entire model region, and thus the age of groundwater in the Culebra is old, consistent with radiogenic information. Lateral fluxes within the anhydrite zone are larger because of higher transmissivity, and where the halite and anhydrite facies regions converge, the halite facies signature is lost by dilution with relatively large quantities of anhydrite facies groundwater.

Groundwater levels in the Culebra in the WIPP region have been measured continuously for several decades. Water-level rises have been observed in the WIPP region and are placed into three categories: those caused by WIPP-related activities, those caused by potash mining activities, and those that are unexplained. The extent of water-level rise observed at a particular well depends on several factors, but the proximity of the observation point to the cause of the water-level rise appears to be a primary factor.

In the vicinity of the WIPP site, water-level rises are unquestionably caused by recovery from drainage into the shafts. Drainage into shafts has been reduced by a number of grouting programs over the years, most recently in 1993 around the AIS. Northwest of the site, in and near Nash Draw, water levels appear to fluctuate in response to effluent discharge from potash mines. Correlation of water-level fluctuation with potash mine discharge cannot be proven because sufficient data on the timing and volumes of discharge are not available. Head distribution in the Culebra (Figure 2-31) is consistent with groundwater basin modeling results indicating that the generalized directional flow of groundwater is north to south (see Figure 2-29). However, caution should be used when making assumptions based on groundwater-level data alone. Studies in the Culebra have shown that fluid density variations in the Culebra can affect flow direction. One should also be aware that the fractured nature of the Culebra, coupled with variable fluid densities, can also cause localized flow patterns to differ from general flow patterns.

Water level rises in the vicinity of the H-9 hydropad, about 6.5 mi (11 km) south of the WIPP site, are not thought to be caused by either WIPP-related activities or potash mining discharge. They remain unexplained.

The DOE continues to monitor groundwater levels throughout the region, but only water level changes at or near the site have the potential to affect performance.

Inferences about vertical flow directions in the Culebra have been made from well data collected by the DOE. Beauheim (1987a) reported flow directions towards the Culebra from both the unnamed lower member and the Magenta over the WIPP site, indicating that the Culebra acts as a drain for the units around it. This indication is consistent with results of groundwater basin modeling.

The Tamarisk

The Tamarisk acts as a confining layer in the groundwater basin model. Attempts were made in two wells, H-14 and H-16, to test a 7.9-ft (2.4-m) sequence of the Tamarisk that consists of claystone, mudstone, and siltstone overlain and underlain by anhydrite. Permeability was too low to measure in either well within the time allowed for testing; consequently, Beauheim (1987a, 108–110) estimated the transmissivity of the claystone sequence to be one or more orders of magnitude less than that of the tested interval in the unnamed lower member (that is, less than approximately 2.5×10^{-5} ft^2 per day [2.7×10^{-11} m^2 per second]). The porosity of the Tamarisk was measured in 1995 as part of testing at the H-19 hydropad. Two claystone samples had an effective porosity of 21.3 to 21.7 percent. Five anhydrite samples had effective porosities of 0.2 to 1.0 percent.

The Magenta

The Magenta is a conductive hydrostratigraphic unit about 19 ft (6 m) thick at the WIPP. The Magenta is saturated except near outcrops along Nash Draw, and hydraulic data are available from 15 wells. According to Mercer (1983), transmissivity ranges over five orders of magnitude from 1×10^{-3} to 4×10^{2} ft^2 per day (1×10^{-9} to 4×10^{-4} m^2 per second). The porosity of the Magenta was measured in 1995 as part of testing at the H-19 hydropad. Four samples had effective porosities ranging from 2.7 to 25.2 percent. See Appendix PAR for additional discussion of Magenta permeability measurements.

The hydraulic transmissivities of the Magenta, based on sparse data, show a decrease in conductivity from west to east, with slight indentations of the contours north and south of the WIPP that correspond to the topographic expression of Nash Draw. In most locations, the hydraulic conductivity of the Magenta is one to two orders of magnitude less than that of the Culebra. The Magenta does not have hydraulically significant fractures in the vicinity of the WIPP.

The hydraulic gradient across the site varies from 16 to 20 ft per mi (3 to 4 m per km) on the eastern side, steepening to about 32 ft per mi (6 m per km) along the western side near Nash Draw (Figure 2-32).

Regional modeling using the groundwater basin model indicates that leakage occurs into the Magenta from the overlying Forty-niner and out of the Magenta downwards into the Tamarisk. Regional modeling also indicates that flow directions in the Magenta are dominantly westward, similar to the slope of the land surface in the immediate area of the WIPP. This flow direction is different than the dominant flow direction in the next underlying conductive unit, the Culebra. This difference is consistent with the

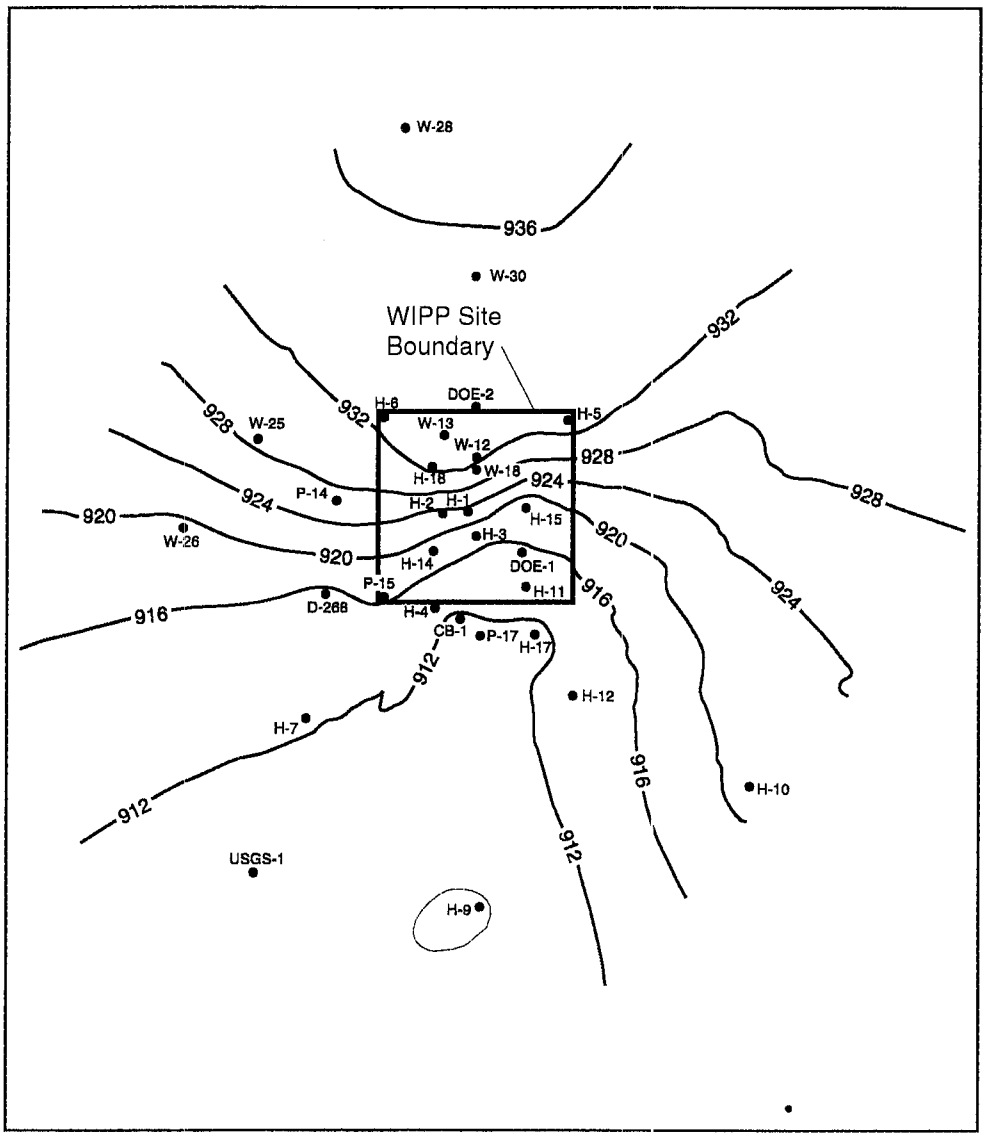

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Figure 2-31. Hydraulic Heads in the Culebra

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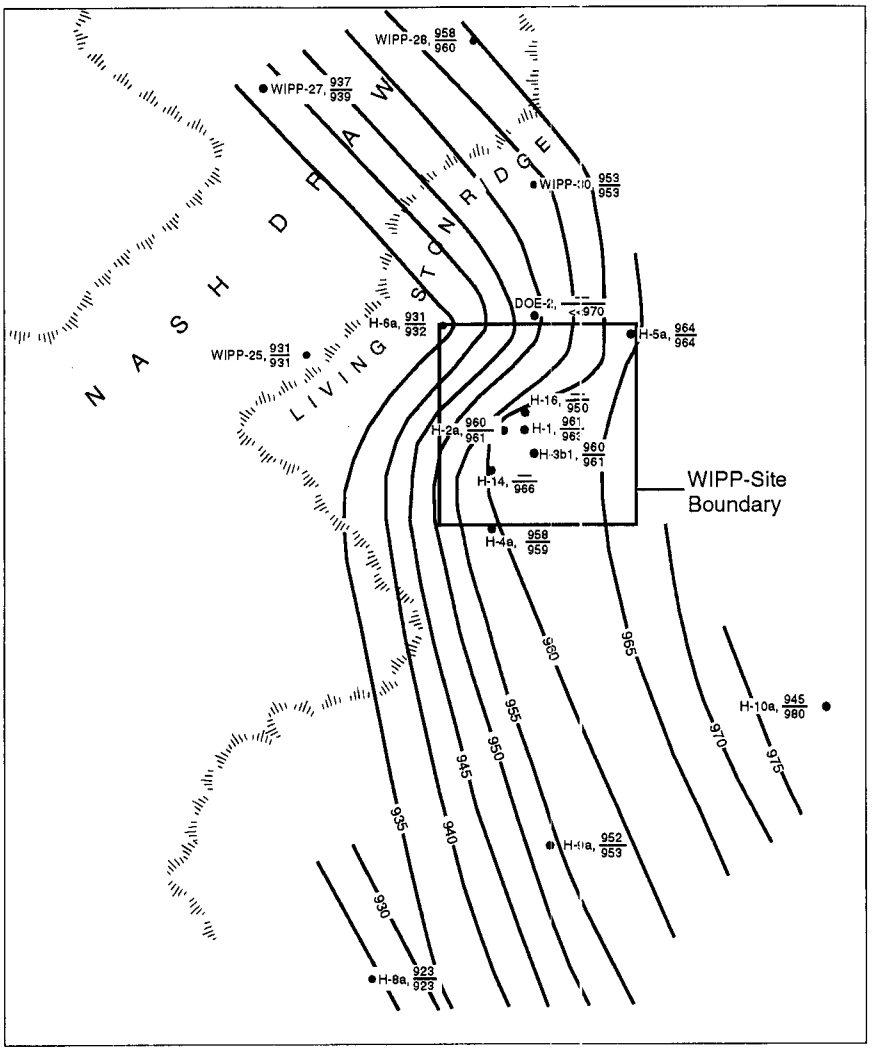

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Figure 2-32. Hydraulic Heads in the Magenta

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groundwater basin conceptual model, in that flow in shallower units is expected to be more sensitive to local topography.

Inferences about vertical flow directions in the Magenta have been made from well data collected by the DOE. Beauheim (1987a, 137) reported flow directions downwards out of the Magenta over the WIPP site, consistent with results of groundwater basin modeling. However, Beauheim concluded that flow directions between the Forty-niner and Magenta would be upward in the three boreholes from which reliable pressure data are available for the Forty-niner (H-3, H-14, and H-16), which is not consistent with the results of groundwater modeling. This inconsistency may be the result of local heterogeneity in rock properties that affect flow on a scale that cannot be duplicated in regional modeling.

As is the case for the Culebra, groundwater elevations in the Magenta have changed over the period of observation. The pattern of changes is similar to those observed for the Culebra, and is attributed to the same causes.

The Forty-niner

The Forty-niner is a confining hydrostratigraphic layer about 66 ft (20 m) thick throughout the WIPP area and consists of low-permeability anhydrite and siltstone. Tests by Beauheim (1987a, 119–123) in H-14 and H-16 yielded transmissivities of about 3×10^{-2} to 7×10^{-2} ft^2 per day (3×10^{-8} to 8×10^{-8} m^2 per second) and 5×10^{-3} to 6×10^{-3} ft^2 per day (5×10^{-9} to 6×10^{-9} m^2 per second), respectively. The porosity of the Forty-niner was measured as part of testing at the H-19 hydropad. Three claystone samples had effective porosities ranging from 9.1 to 24.0 percent. Four anhydrite samples had effective porosities ranging from 0.0 to 0.4 percent.

Hydrology of the Dewey Lake and the Santa Rosa

The Dewey Lake and the Santa Rosa, and surficial soils, overlie the Rustler and are the uppermost hydrostratigraphic units considered by the DOE. The Dewey Lake and overlying rocks are more permeable than the anhydrites at the top of the Rustler. Consequently, basin modeling indicates that most (probably more than 70 percent) of the water that recharges the groundwater basin (that is, percolates into the Dewey Lake from surface water) flows only in the rocks above the Rustler. As modeled, the rest leaks vertically through the upper anhydrites of the Rustler and into the Magenta or continues downwards to the Culebra. More flow occurs into the Rustler units at times of greater recharge. Even though it carries most of the recharge because of its low permeability in most areas, lateral flow in the Dewey Lake is slow.

The Dewey Lake

The Dewey Lake contains a productive zone of saturation, probably under water-table conditions, in the southwestern to south-central portion of the WIPP site and south of the site. Several wells operated by the J.C. Mills Ranch south of the WIPP site produce

sufficient quantities of water from the Dewey Lake to supply livestock. Short-term production rates of 25 to 30 gal per minute (5.7 to 6.8 m^3 per hour) were observed in boreholes P-9 (Jones 1978, Vol. 1., 167 and 168), WQSP-6, and WQSP-6a. The productive zone is typically found in the middle of the Dewey Lake, 180 to 265 ft (55 to 81 m) below ground surface and appears to derive much of its transmissivity from open fractures. Where present, the saturated zone may be perched or simply underlain by less transmissive rock. Fractures below the productive zone tend to be completely filled with gypsum. Open fractures and/or moist (but not fully saturated) conditions have been observed at similar depths north of the zone of saturation, at the H-1, H-2, and H-3 boreholes (Appendix HYDRO, 70). The Dewey Lake has not produced water within the WIPP shafts and or in boreholes in the immediate vicinity of the panels. For modeling purposes, the hydraulic conductivity of the Dewey Lake, assuming saturation, is estimated to be 3×10^{-3} ft per day (1×10^{-8} m per second), corresponding to the hydraulic conductivity of fine-grained sandstone and siltstone. The porosity of the Dewey Lake was measured as part of testing at the H-19 hydropad. Four samples taken above the gypsum-sealed region had measured effective porosities of 14.9 to 24.8 percent. Four samples taken from within the gypsum-sealed region had porosities from 3.5 to 11.6 percent.

The groundwater basin conceptual model relies on gradients established from the position of the water table for the driving force for flow. The DOE has estimated the position of the water table in the southern half of the WIPP site from an analysis of drillers' logs from three potash exploration boreholes and five hydraulic test holes. These logs record the elevation of the first moist cuttings recovered during drilling. Assuming that the first recovery of moist cuttings indicates a minimum elevation of the water table, an estimate of the water table elevation can be made, and the estimated water table surface can be contoured. This method indicates that the elevation of the water table over the WIPP waste panels may be about 980 m above sea level, as shown in Figure 2-33.

The Santa Rosa

The Santa Rosa ranges from 0 to about 300 ft (0 to 91 m) thick and is present over the eastern half of the WIPP site. It is absent over the western portion of the site. It crops out northeast of Nash Draw. The Santa Rosa near the WIPP site may have a saturated thickness of limited extent. It has a porosity of about 13 percent and a specific capacity of 0.14 to 0.20 gal per minute per ft (0.029 to 0.041 L per second per m) of drawdown, where it yields water in the WIPP region.

2.2.1.5 Hydrology of Other Groundwater Zones of Regional Importance

The groundwater regimes in the Capitan Limestone, which is generally regarded as the northern boundary of the Delaware Basin, and Nash Draw have been evaluated by the DOE as part of the WIPP project because of their importance in some processes, notably dissolution features, that the DOE has determined to be of low probability at the WIPP site.

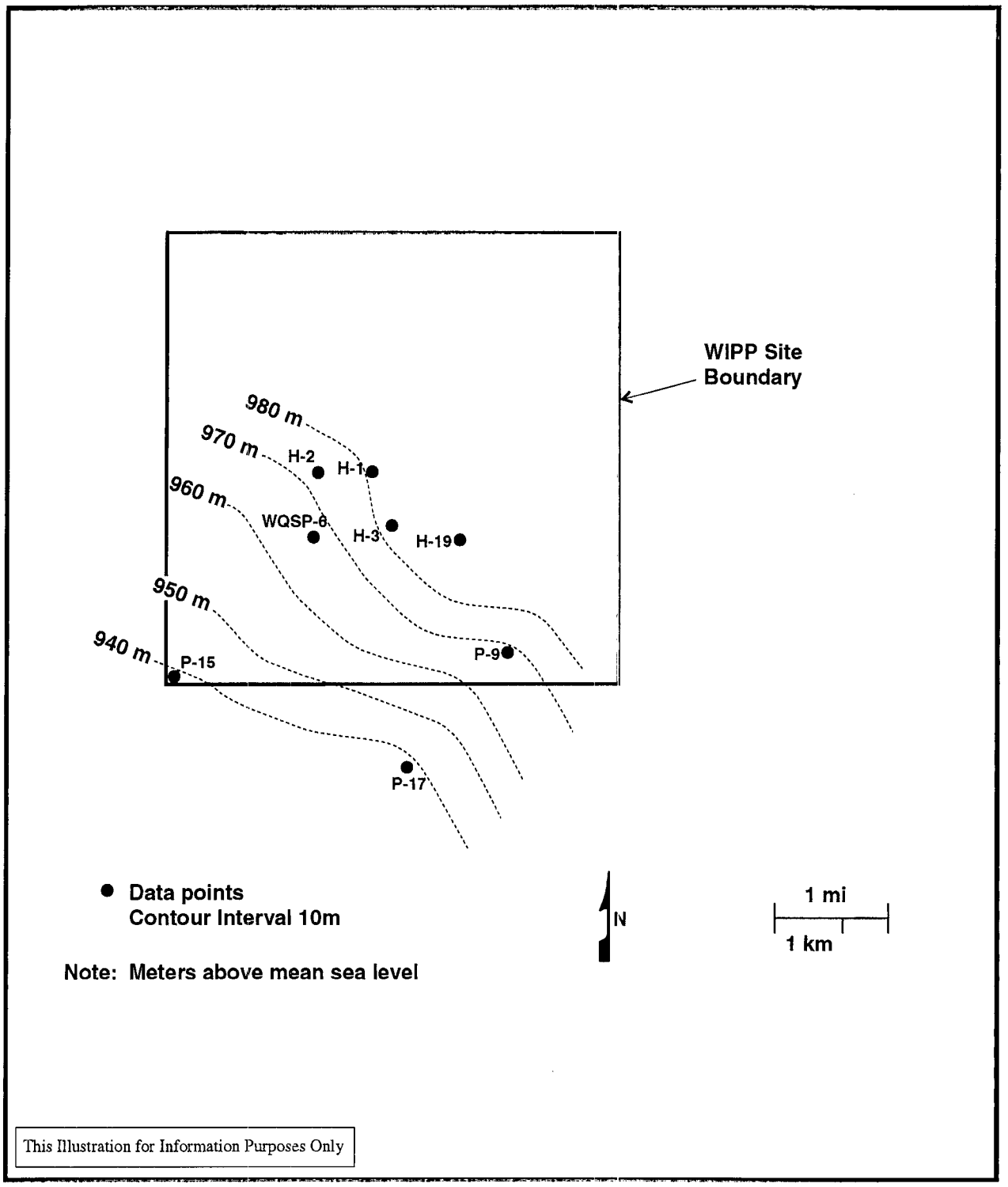

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Figure 2-33. Interpreted Water Table Surface

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The Capitan Limestone

The Capitan, which outcrops in the southern end of the Guadalupe Mountains, is a massive limestone unit that grades basinward into recemented, partly dolomitized reef breccia and shelfward into bedded carbonates and evaporites. A deeply incised submarine canyon near the Eddy-Lea county line has been identified. This canyon is filled with sediments of lower permeability than the Capitan and, according to Hiss (1976) restricts fluid flow. The hydraulic conductivity of the Capitan ranges from 1 to 25 ft per day (3.5×10^{-6} to 9×10^{-5} m per second) in southern Lea County and is 5 ft per day (1.7×10^{-5} m per second) east of the Pecos River at Carlsbad. Hiss reported in 1976 that average transmissivities around the northern and eastern margins of the Delaware Basin are 10,000 ft^2 per day (0.01 m^2 per second) in thick sections and 500 ft^2 per day (5.4×10^{-4} m^2 per second) in incised submarine canyons. Water table conditions are found in the Capitan aquifer southwest of the Pecos River at Carlsbad; however, artesian conditions exist to the north and east. The hydraulic gradient to the southeast of the submarine canyon near the Eddy-Lea county line has been affected by large oil field withdrawals. The Capitan limestone is recharged by percolation through the northern shelf aquifers, by flow from the south and west from underlying basin aquifers (see the Bell Canyon, Section 2.2.1.2), and by direct infiltration at its outcrop in the Guadalupe Mountains. The Capitan is important in the regional hydrology because breccia pipes in the Salado have formed over it, most likely in response to the effects of dissolution by groundwater flowing in the Castile along the base of the Salado (see Davies 1984).

Hydrology of the Rustler-Salado Contact Zone in Nash Draw

As discussed in Sections 2.1.3.4 and 2.1.6.2, in Nash Draw the contact between the Rustler and the Salado is an unstructured residuum of gypsum, clay, and sandstone created by the dissolution of halite and has been known as the brine aquifer, Rustler-Salado residuum, and residuum. The residuum is absent under the WIPP site. It is clear that dissolution in Nash Draw occurred after deposition of the Rustler. As described previously, the topographic low formed by Nash Draw is a groundwater divide in the groundwater basin conceptual model of the units above the Salado. The brine aquifer is shown in Figure 2-34.

Robinson and Lang described the brine aquifer (Section 2.1.3.4) in 1938 and suggested that the structural conditions that caused the development of Nash Draw might control the occurrence of the brine; thus, the brine aquifer boundary may coincide with the topographic surface expression of Nash Draw, as shown in Figure 2-29. Their studies show brine concentrated along a strip from 2 to 8 mi (3.2 to 13 km) wide and about 26 mi (42 km) long. Data from the test holes that Robinson and Lang drilled indicate that the residuum (containing the brine) ranges in thickness from 10 to 60 ft (3 to 18 m) and averages about 24 ft (7 m).

Hydraulic properties were determined by Hale et al. (1954) primarily for the area between Malaga Bend on the Pecos River and Laguna Grande de la Sal. They calculated a transmissivity value of 8,000 ft^2 per day (8.6×10^{-3} m^2 per second) and estimated the

potentiometric gradient to be 1.4 ft per mi (0.27 m per km). In this area, the Rustler-Salado residuum apparently is part of a continuous hydrologic system as evidenced by the coincident fluctuation of water levels in the test holes (as far away as Laguna Grande de la Sal) with pumping rates in irrigation wells along the Pecos River.

In the northern half of Nash Draw, the approximate outline of the brine aquifer as described by Robinson and Lang in 1938 has been supported by drilling associated with the WIPP hydrogeologic studies. These studies also indicate that the main differences in areal extent occur along the eastern side where the boundary is very irregular and, in places (test holes P-14 and H-07), extends farther east than previously indicated by Robinson and Lang (1938).

Other differences from the earlier studies include the variability in thickness of residuum present in test holes WIPP-25 through WIPP-29. These holes indicate thicknesses ranging from 11 ft (3.3 m) in WIPP-25 to 108 ft (33 m) in WIPP-29 in Nash Draw, compared to 8 ft (2.4 m) in test hole P-14, east of Nash Draw. The specific geohydrologic mechanism that has caused dissolution to be greater in one area than in another is not apparent, although a general increase in chloride concentration in water from the north to the south may indicate the effects of movement down the natural hydraulic gradient in Nash Draw.

The average hydraulic gradient within the residuum in Nash Draw is about 10 ft per mi (1.9 m per km); in contrast, the average gradient at the WIPP site is 39 ft per mi (7.4 m per km). This difference reflects the changes in transmissivity, which are as much as five orders of magnitude greater in Nash Draw. The transmissivity determined from aquifer tests in test holes completed in the Rustler-Salado contact residuum of Nash Draw ranges from 2×10^{-4} ft^2 per day (2.1×10^{-10} m^2 per second) at WIPP-27 to 8 ft^2 per day (8.6×10^{-6} m^2 per second) at WIPP-29. This is in contrast to the WIPP site proper, where transmissivities range from 3×10^{-5} ft^2 per day (3.2×10^{-11} m^2 per second) at test holes P-18 and H-5c to 5×10^{-2} ft^2 per day (5.4×10^{-8} m^2 per second) at test hole P-14. Locations and estimated hydraulic heads of these wells are illustrated in Figure 2-35.

Hale et al. (1954) believed the Rustler-Salado contact residuum discharges to the alluvium near Malaga Bend on the Pecos River. Because the confining beds in this area probably are fractured because of dissolution and collapse of the evaporites, the brine (under artesian head) moves up through these fractures into the overlying alluvium and then discharges into the Pecos River.

According to Mercer (1982), water in the Rustler-Salado contact residuum in Nash Draw contains the largest concentrations of dissolved solids in the WIPP area, ranging from 41,500 milligrams per liter in borehole H-1 to 412,000 milligrams per liter in borehole H-5c. These waters are classified as brines. The dissolved mineral constituents in the brine consist mostly of sulfates and chlorides of calcium, magnesium, sodium, and potassium; the major constituents are sodium and chloride. Concentrations of the other major ions vary according to the spatial location of the sample, are probably directly related to the interaction of the brine and the host rocks, and reflect residence time within

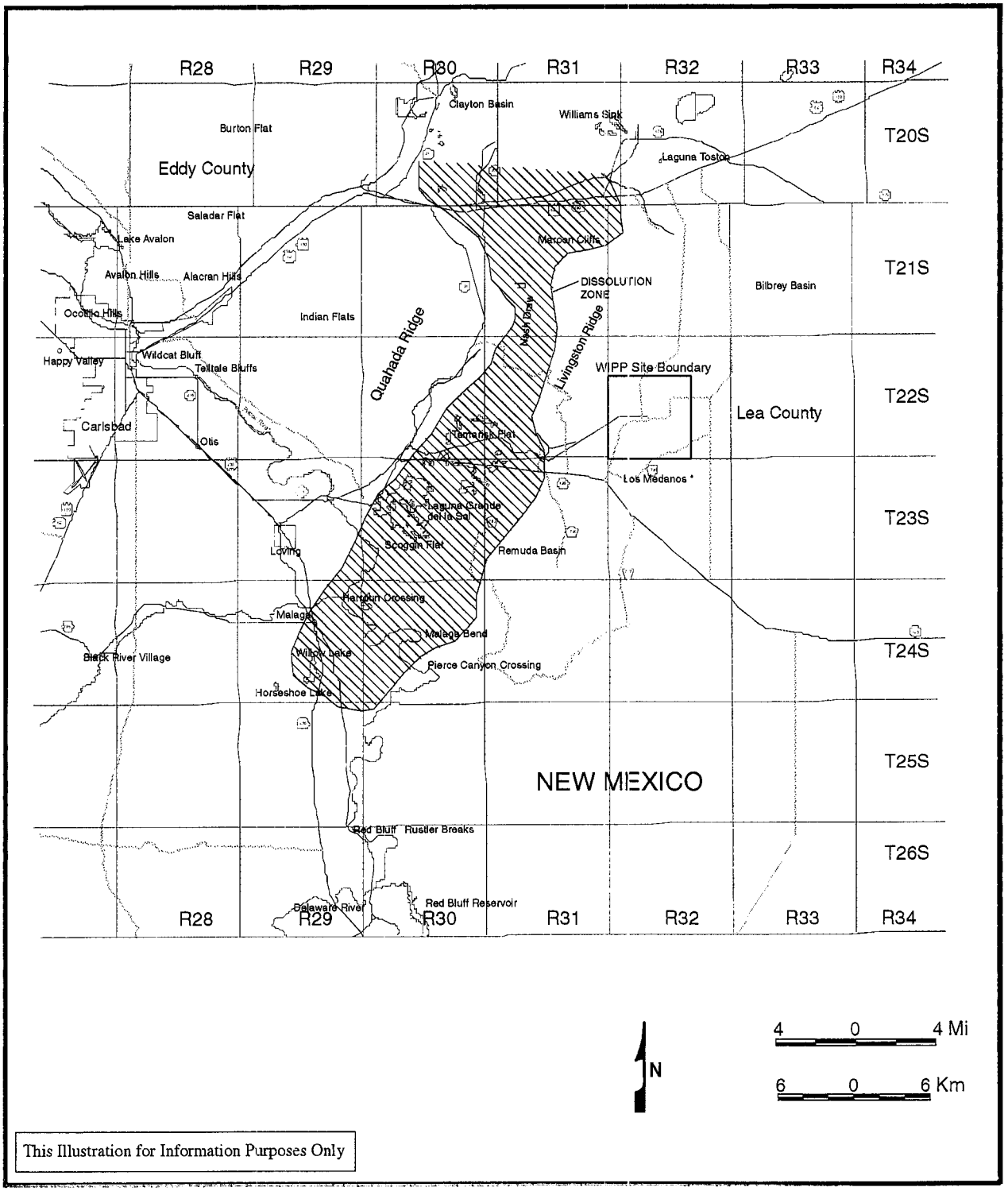

Figure 2-34. Brine Aquifer in the Nash Draw

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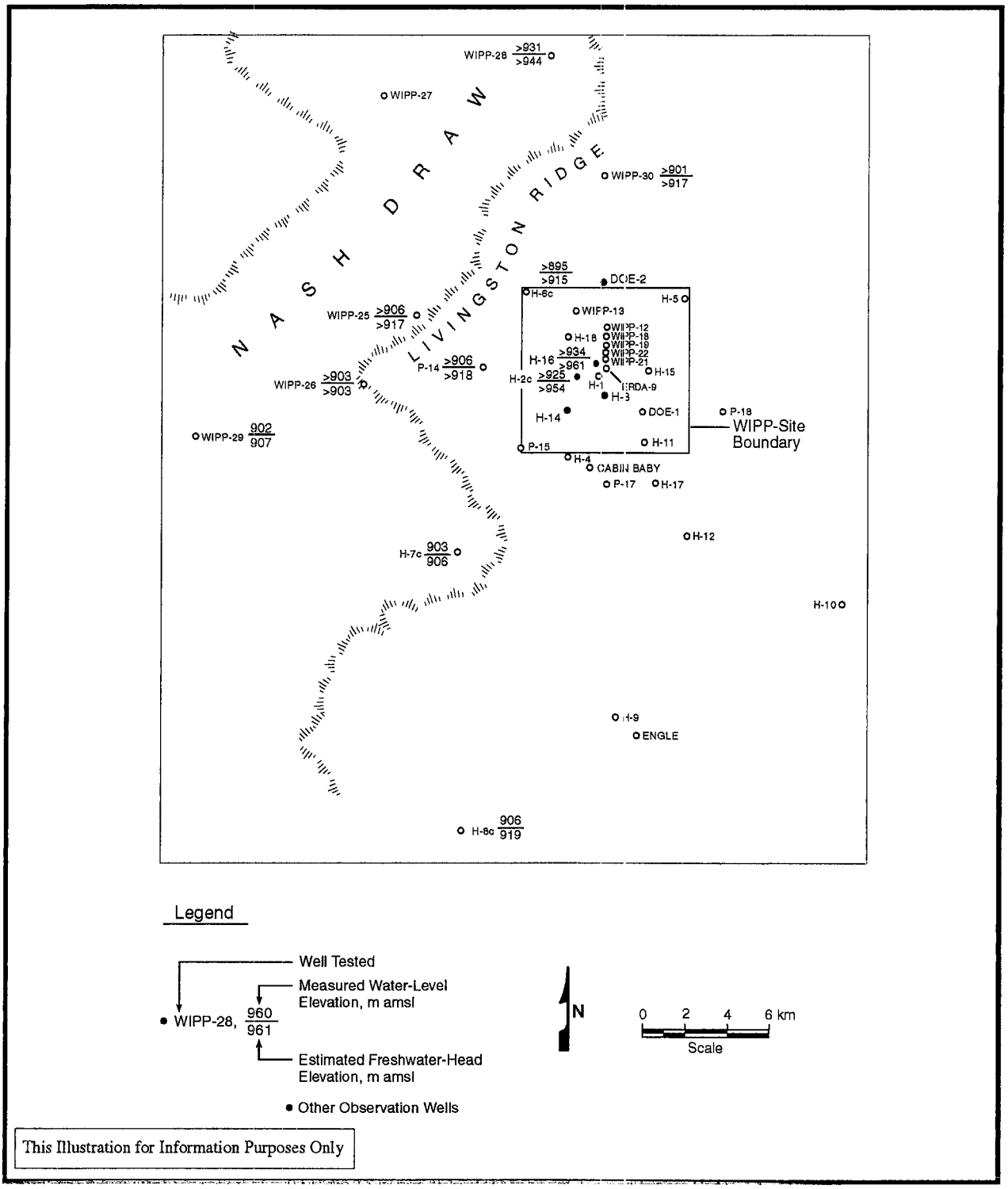

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Figure 2-35. Measured Water Levels of the Unnamed Lower Member and Rustler-Salado Contact Zone

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the rocks. Residence time of the brine depends upon the transmissivity of the rock. For example, the presence of large concentrations of potassium and magnesium in water is correlated with minimal permeability and a relatively undeveloped flow system.

2.2.1.6 Comparative Summary—Groundwater Hydrology

The DOE has collected a significant amount of data regarding the groundwater characteristics of the disposal system and the region surrounding it. At the time the EPA reviewed the WIPP program in 1989 and 1990, many of these data collection programs were either underway or were planned. All have been completed and have been incorporated into this application. The EPA's overall conclusion regarding the Salado in its 1990 document was that

> [a] significant number of studies have been conducted by the DOE on Salado Formation hydrology; these have provided a good basic understanding of the hydrologic conditions within the formation. Studies planned during the test phase will refine understanding of Salado formation hydrology relative to far-field permeabilities, brine inflow, and the role, nature, and extent of fracturing within marker beds. (EPA 1990a)

Similarly, the EPA acknowledged that the DOE was conducting additional programs regarding the hydrogeology of the Culebra. EPA did conclude, however, based on the data available that the variation in isotopic content and salinity within the Culebra is most likely because of the variation in transmissivity, although EPA expected the DOE to collect additional data.

The EPA examined data regarding the hydrology of the Castile and the possibility of the presence of a pressurized reservoir pocket. The EPA conclusion was that the only plausible mechanism for a brine pocket to affect the WIPP repository would be through human intrusion, which was beyond the EPA's study (EPA 1990b, 13079).

Finally, the EPA examined the record regarding the possibility of vertical flow between the various units in the WIPP disposal system. The EPA conclusion is similar to that reached by the DOE as the result of the more recent groundwater basin modeling. The EPA stated:

> Studies conducted to date provide a basic understanding of the potential vertical interactions that might occur between water-bearing intervals in the area of the WIPP. Data indicate that a natural interconnection between the Rustler and Bell Canyon formations and the Salado is unlikely, although vertical water movement between members of the Rustler may be occurring in localized areas. EPA believes that the potential for natural vertical hydrologic interaction to affect the repository is low. A number of hydrologic assessments which are to be conducted during the test phase, although not directly intended to address vertical fluid movement, will enhance the understanding of vertical fluid migration. (EPA 1990a)

2.2.2 *Surface-Water Hydrology*

The following information on surface-water hydrology has been extracted from DOE 1980 with appropriate updates. The WIPP site is in the Pecos River basin, which contains about 50 percent of the drainage area of the Rio Grande Water Resources Region. The Pecos River headwaters are northeast of Santa Fe, and the river flows to the south through eastern New Mexico and western Texas to the Rio Grande. The Pecos River has an overall length of about 500 mi (805 km), a maximum basin width of about 130 mi (209 km), and a drainage area of about 44,535 mi^2 (115,346 km^3). (About 20,500 mi^2 [53,095 km^2] contained within the basin have no external surface drainage and their surface waters do not contribute to Pecos River flows.) Figure 2-25 shows the Pecos River drainage area.

The Pecos River generally flows year-round, except in the reach below Anton Chico and between Fort Sumner and Roswell, where the low flows percolate into the stream bed. The main stem of the Pecos River and its major tributaries have low flows, and the streams are frequently dry. About 75 percent of the total annual precipitation and 60 percent of the annual flow result from intense local thunderstorms between April and September.

There are no perennial streams at the WIPP site. At its nearest point, the Pecos River is about 12 mi (19 km) southwest of the WIPP site boundary. A few small creeks and draws are the only westward flowing tributaries of the Pecos River within 20 mi (32 km) north or south of the site. Nash Draw, the largest surface drainage feature east of the Pecos River in the WIPP region, is a closed depression and does not provide surface flow into the Pecos. The Black River (drainage area: 400 mi^2 [1,036 km^2]) joins the Pecos from the west about 16 mi (26 km) southwest of the site. The Delaware River (drainage area: 700 mi^2 [1,813 km^2]) and a number of small creeks and draws also join the Pecos River along this reach. The flow in the Pecos River below Fort Sumner is regulated by storage in Sumner Lake, Brantley Reservoir, Lake Avalon, and by several other smaller irrigation dams.

Five major reservoirs are located on the Pecos River: Santa Rosa Lake, Sumner Lake, Brantley Reservoir, Lake Avalon, and the Red Bluff Reservoir, the last located just over the border in Texas (Figure 2-36). The storage capacities of these reservoirs and the Two Rivers Reservoir in the Pecos River Basin are shown in Table 2-4.

With regards to surface drainage onto and off of the WIPP site, there are no major natural lakes or ponds within 5 mi (8 km) of the site. Laguna Gatuña, Laguna Tonto, Laguna Plata, and Laguna Toston are playas more than 10 mi (16 km) north and are at elevations of 3,450 ft (1,050 m) or higher. Thus, surface runoff from the site (elevation 3,310 ft [1,010 m] above sea level) would not flow toward any of them. To the northwest, west and southwest, Red Lake, Lindsey Lake, and Laguna Grande de la Sal are more than 5 mi (8 km) from the site, at elevations of 3,000 to 3,300 ft (914 to 1,006 m). A low-flow investigation has been initiated by the USGS within the Hill Tank Draw drainage area, the most prominent drainage feature near the WIPP site. The drainage area is about 4 mi^2

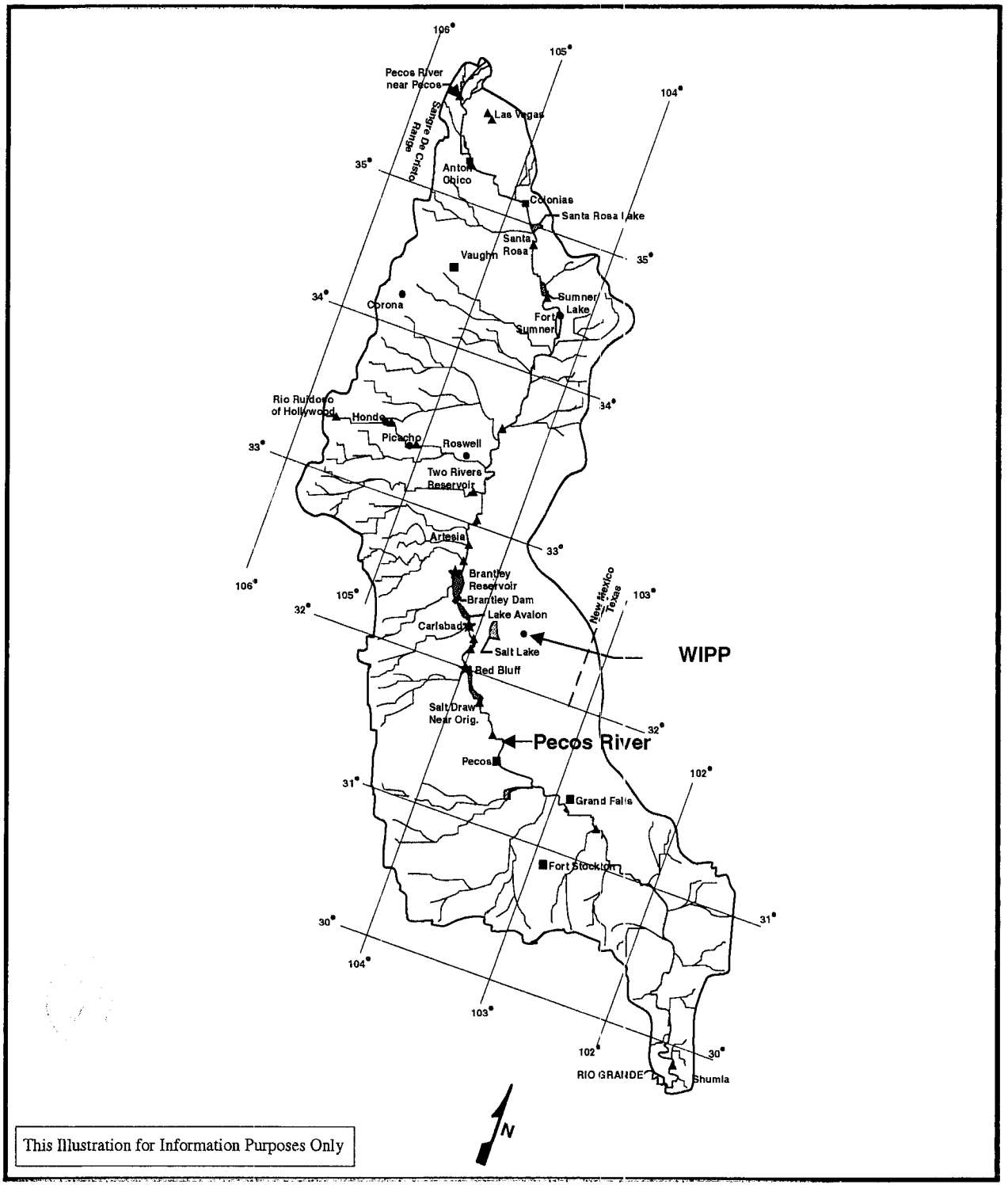

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Figure 2-36. Location of Reservoirs and Gauging Stations in the Pecos River Basin

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Table 2-4. Capacities of Reservoirs in the Pecos River Drainage

Reservoir	River	Total Storage Capacity[a] (acre-ft)	Use[b]
Santa Rosa	Pecos	282,000	FC
Sumner	Pecos	122,100	IR, R
Brantley	Pecos	42,000	IR, R, FC
Avalon	Pecos	5,000	IR
Red Bluff	Pecos	310,000	IR, P
Two Rivers	Rio Hondo	167,900	FC

[a] Capacity below the lowest uncontrolled outlet or spillway.
[b] Legend: FC = flood control
IR = irrigation
R = recreation
P = hydroelectric

(10.4 km^2), with an average channel slope of 1 to 100, and the drainage is westward into Nash Draw. Mercer (1982, 75) reports that during four years of observation only one flow occurred, and it was of such short duration it could not be measured.

As discussed in Section 2.5.2.3, the mean annual precipitation in the region is 13 in. (33 cm), and the mean annual runoff is 0.1 to 0.2 in. (0.25 to 0.5 cm). The maximum recorded 24-hour precipitation at Carlsbad was 5.12 in. (13.0 cm) in August 1916. The predicted maximum 6-hour, 100-year precipitation event for the site is 3.6 in. (9.1 cm) and is most likely to occur during the summer. The maximum recorded daily snowfall at Carlsbad was 10 in. (25.4 cm) in December 1923.

The maximum recorded flood on the Pecos River occurred near the town of Malaga, New Mexico, on August 23, 1966, with a discharge of 120,000 ft^3 (3,398 m^3) per second and a stage elevation of about 2,938 ft (895 m) above mean sea level. The surface elevation at the WIPP is over 500 ft (152 m) above the river bed and approximately 470 ft (143 m) above the elevation of this maximum historical flood elevation (DOE 1980, §7.4.1).

More than 90 percent of the mean annual precipitation at the site is lost by evapotranspiration. On a mean monthly basis, evapotranspiration at the site greatly exceeds the available rainfall; however, intense local thunderstorms may produce runoff and percolation.

Water quality in the Pecos River basin is affected by mineral pollution from natural sources and from irrigation return flows (Section 2.4.2.2 for surface-water quality). At Santa Rosa, New Mexico, the average suspended-sediment discharge of the river is about 1,650 tons per day (1,498 metric tons per day). Large amounts of chlorides from Salt Creek and Bitter Creek enter the river near Roswell. River inflow in the Hagerman area contributes increased amounts of calcium, magnesium, and sulfate; and waters entering

the river near Lake Arthur are high in chloride. Below Brantley Reservoir, springs flowing into the river are usually submerged and difficult to sample; springs that could be sampled had TDS concentrations of 3,350 to 4,000 milligrams per liter. Concentrated brine entering at Malaga Bend adds an estimated 70 tons/day (64 metric tons/day) of chloride to the Pecos River.

The EPA concluded in 1989 that there "are no surface water features near the WIPP that could potentially affect repository performance in such a way as to influence the no-migration demonstration" (EPA 1990a).

2.3 Resources

This section refers to resources that may exist at or beneath the WIPP site. The topic of resources is used to broadly define both economic (mineral and nonmineral) and cultural resources associated with the WIPP site. These resources are important because they (1) provide evidence of past uses of the area and (2) indicate potential future use of the area with the possibility that such use could lead to disruption of the closed repository.

Knowledge of the possible future uses for the area are important for properly designing institutional controls which reduce the likelihood that such future use will disrupt the repository. Because of the depth of the disposal horizon, it is believed that only the mineral resources are of significance in predicting the long-term performance of the disposal system. However, the nonmineral and cultural resources are presented for completeness because they are included in the FEP screening discussions in Chapter 8 and Appendix SCR. Information needed to make screening decisions includes natural resource distributions, including potable groundwaters, the distribution of drillholes, mines, excavations, and other man-made features that exploit these resources, the distribution of drillholes and excavation used for disposal or injection purposes, activities that significantly alter the land surface, agricultural activities that may affect the disposal system, archaeological resources requiring deep excavation to exploit, and technological changes that may alter local demographics. This information is presented here or is referenced.

With respect to minerals or hydrocarbons, reserves are the portion of resources that are economic at today's market prices and with existing technology. For hydrocarbons, proved (proven) reserves are an estimated quantity that engineering and geologic data analysis demonstrates, with reasonable certainty, is recoverable in the future from discovered oil and gas pools. Probable resources (extensions) consist of oil and gas in pools that have been discovered but not yet developed by drilling. Their presence and distribution can generally be surmised with a high degree of confidence. Probable reserves (new pools) consist of oil and gas surmised to exist in undiscovered pools within existing fields. (Definitions are from NMBMMR 1995, V-2 and V-3.)

Mineral resource discussions are focused principally on hydrocarbons and potassium salts, both of which have long histories of development in the region. Development of

either resource potentially could be disruptive to the disposal system. The information regarding the mineral resources concentrates on the following factors:

- Number, location, depth, and present state of development, including penetrations through the disposal horizon
- Type of resource
- Accessibility, quality, and demand
- Mineral ownership in the area

The discussion of cultural and economic resources is focused on describing past and present land uses unrelated to the development of minerals. The archaeological record supports the observation that changes in land use are principally associated with climate and the availability of forage for wild and domestic animals. In no case does it appear that past or present land use has had an impact on the subsurface beyond the development of shallow groundwater wells to water livestock.

2.3.1 Extractable Resources

The geologic studies of the WIPP site included the investigation of potential natural resources to evaluate the impact of denying access to these resources and other consequences of their occurrence. Studies were completed in support of the FEIS to ensure knowledge of natural resources, and the impacts of denying access were included in the decision-making process for WIPP. Of the natural resources expected to occur beneath the site, five are of practical concern: the two potassium salts sylvite and langbeinite, which occur in the MPZ; and the three hydrocarbons, crude oil, natural gas, and distillate liquids associated with natural gas, all three of which occur elsewhere in strata below the Castile. Other mineral resources beneath the site are caliche, salt, gypsum, and lithium; enormous deposits of these minerals near the site and elsewhere in the country are more than adequate (and more economically attractive) to meet future requirements for these materials. In 1995, the NMBMMR performed a reevaluation of the mineral resources at and within 1 mi (1.6 km) around the WIPP site. The following discussion is based in part on information from NMBMMR (1995).

2.3.1.1 Potash Resources at the WIPP Site

Throughout the Carlsbad Potash District, commercial quantities of potassium salts are restricted to the middle portion of the Salado, locally called the MPZ. A total of 11 zones (or distinct ore layers) have been recognized in the MPZ. Horizon Number 1 is at the base, and Number 11 is at the top. The 11th ore zone is not mined.

The USGS uses three standard grades—low, lease, and high—to quantify the potash resources at the site. The USGS assumes that the "lease" and "high" grades comprise reserves because some lease-grade ore is mined in the Carlsbad Potash District. Most of the potash that is mined, however, is better typified as high grade. Even the high-grade resources may not be reserves, however, if properties such as high clay content make

processing uneconomic. The analysis in the 1995 NMBMMR report distinguish between lease grade ore and economically mineable ore.

The NMBMMR 1995 study contains a comprehensive summary of all previous potash resource evaluations. Griswold (NMBMMR 1995, Chapter VII) used 40 existing boreholes drilled on and around the WIPP site to perform a reevaluation of potash resources. He selected holes that were drilled using brine so that the dissolution of potassium salts was inhibited. The conclusion reached by Griswold is that only the 4th and 10th ore zones contain economic potash reserves. The quantities are summarized in Table 2-5.

2.3.1.2 Hydrocarbon Resources at the WIPP Site

In 1974, the NMBMMR (Foster 1974) conducted a hydrocarbon resource study in southeastern New Mexico under contract to the Oak Ridge National Laboratory (ORNL). The study included an area of 1,512 mi^2 (3,916 km^2). At the time of that study, the proposed repository site was about 5 mi (8 km) northeast of the current site. The 1974 NMBMMR evaluation included a more detailed study of a four-township area centered on the old site; the present site is in the southwest quadrant of that area. The 1974 NMBMMR hydrocarbon resources study (Foster 1974) is presented in more detail in the FEIS (DOE 1980, §9.2.3.5). The reader is referred to the FEIS or the original study for additional information.

The resource evaluation was based both on the known reserves of crude oil and natural gas in the region and on the probability of discovering new reservoirs in areas where past unsuccessful drilling was either too widely spread or too shallow to have allowed discovery. Potentially productive zones were considered in the evaluation; therefore, the findings may be used for estimating the total hydrocarbon resources at the site. A fundamental assumption in the study was that the WIPP area has the same potential for containing hydrocarbons as the larger region studied for which exploration data are available. Whether such resources actually exist can be satisfactorily established only by drilling at spacings close enough to give a high probability of discovery.

The NMBMMR 1995 mineral resource reevaluation contains a comprehensive summary of all previous evaluations. Broadhead et al. (NMBMMR 1995, Chapter XI) provided a reassessment of hydrocarbon resources within the WIPP site boundary and within the first mile adjacent to the boundary. Calculations were made for resources that are extensions of known, currently productive oil and gas resources that are thought to extend beneath the study area with reasonable certainty (called probable resources in the report). Qualitative estimates are also made concerning the likelihood that oil and gas may be present in undiscovered pools and fields in the area (referred to as possible resources). Possible resources were not quantified in the study. The results of the study are shown in Tables 2-6 and 2-7.

Table 2-5. Current Estimates of Potash Resources at the WIPP Site

Mining Unit	Product	Recoverable Ore (10^6 tons) Within the WIPP site	Recoverable Ore (10^6 tons) One-Mi Strip Adjacent to the WIPP site
4th Ore Zone	Langbeinite	40.5 @ 6.99%*	126.0 @ 7.30%
10th Ore Zone	Sylvite	52.3 @ 13.99%	105.0 @ 14.96%

Source: NMBMMR 1995, Chapter VII.

Legend: T = tons

* Read as 4.05×10^6 tons of ore at 6.99 percent grade

2.3.1.3 Other Natural Resources

Other natural resources are known to occur within the Delaware Basin and are considered in the screening. For example, sulfur is produced in the vicinity of Orla, Texas; however, no sulfur resources have been identified in the vicinity of the WIPP; therefore, there are no projected impacts. Another resource that is extensively produced is groundwater.

Potable water occurs in numerous places within the Delaware Basin. Several communities rely solely on groundwater sources for drinking water. All such wells in the vicinity of the WIPP are shallow, generally no deeper than the Culebra. Sand, gravel, and caliche are produced in numerous areas within the Delaware Basin. In all cases, these are surface quarries that are generally shallow (tens of ft). No impact to the disposal system is expected from these activities.

2.3.2 Cultural and Economic Resources

The demographics, land use, and history and archaeology of the WIPP site and its environs are characterized in the sections that follow.

2.3.2.1 Demographics

The WIPP facility is located 26 mi (42 km) east of Carlsbad in Eddy County in southeastern New Mexico and includes an area of 10,240 acres (16 mi^2, or approximately 41 km^2). The facility is located in a sparsely populated area with fewer than 30 permanent residents living within a 10-mi (16-km) radius of the facility. The area surrounding the facility is used primarily for grazing, potash mining, and hydrocarbon production. No resource development that would affect WIPP facility operations or the long-term integrity of the facility is allowed within the 10,240 acres (41 km^2) that have been set aside for the WIPP project.

The permanent residence nearest to the WIPP site boundary is the J.C. Mills Ranch, which is 1.2 mi (2 km) to the south. The community nearest to the WIPP site is the town of Loving, New Mexico, 18 mi (29 km) west-southwest of the site center. The population

Table 2-6. In-Place Oil within Study Area

Formation	Within WIPP site (10^6 bbl[a])	One-mi strip adjacent to the WIPP site (10^6 bbl)	Total (10^6 bbl)
Delaware	10.33	20.8	31.13
Bone Spring	0.44	0.8	1.25
Strawn	0.4	0.4	0.8
Atoka	1.1	0.1	0.2
Total	**12.3**	**22.9**	**35.3**

Source: NMBMMR 1995, Chapter XI.
[a] bbl = barrel = 42 gallons

Table 2-7. In-Place Gas within Study Area

Formation	Gas Reserves (Mcf)[a]	
	Within WIPP Site	One-mi strip adjacent to the WIPP
Delaware	18,176	32,873
Bone Springs	956	1,749
Strawn	9,600	9,875
Atoka	123,336	94,410
Morrow	32,000	28,780

Source: NMBMMR 1995, Chapter XI.
[a] Mcf = thousand ft^3

of Loving decreased from 1,355 in 1980 to 1,243 in 1990. The nearest population center is the city of Carlsbad, New Mexico, 26 mi (42 km) west of the site.

The population of Carlsbad has decreased from 25,496 in 1980 to 24,896 in 1990. Hobbs, New Mexico, 36 mi (58 km) to the east of the site had a 1980 population of 29,153 and a 1990 population of 29,115. Eunice, New Mexico, 40 mi (64 km) east of the site, had a 1980 population of 2,970 and a 1990 population of 2,731. Jal, New Mexico, 45 mi (72 km) southeast of the site, had a population of 2,575 in 1980 and of 2,153 in 1990.

The WIPP site is located in Eddy County near the border to Lea County, New Mexico. The Eddy County population increased from 47,855 in 1980 to 48,605 in 1990. The Lea County population decreased from 55,993 in 1980 to 55,765 in 1990.

2.3.2.2 Land Use

At present, land within 10 mi (16 km) of the site is used for potash mining operations, active oil and gas wells and activities associated with hydrocarbon production, and grazing.

The WIPP Land Withdrawal Act (LWA) provides for the transfer of the WIPP site lands from the Department of the Interior (DOI) to the DOE and effectively withdraws the lands, subject to existing rights, from entry, sale, or disposition; appropriation under mining laws; and operation of the mineral and geothermal leasing laws. The LWA directed the Secretary of Energy to produce a management plan to provide for grazing, hunting and trapping, wildlife habitat, mining, and the disposal of salt tailings.

Between 1978 and 1988, the DOE acquired all active potash and hydrocarbon leases within the WIPP site boundary. These were acquired either through outright purchase or through condemnation. In one condemnation proceeding, the court awarded the DOE the surface and top 6,000 ft (1,800 m) of Section 31 and allowed the leaseholder to retain the subsurface below 6,000 ft (1,800 m). This was allowed because analysis showed that wells developed within this lease below the 6,000-ft (1,800-m) limit would be too far away from the waste panels to be of consequence to the WIPP. This is corroborated by current analyses. Consequently, as the result of the DOE's acquisition activities, there are no producing hydrocarbon wells within the volumetric boundary defined by the land withdrawal (T22S, R31E, S15-22, 27-34). One active well, referred to as James Ranch 13, was drilled in 1982 to tap gas resources beneath Section 31. This well was initiated in Section 6, outside the WIPP site boundary. The well enters Section 31 below a depth of 6,000 ft (1,800 m) beneath ground level.

Grazing leases have been issued for all land sections immediately surrounding the WIPP facility. Grazing within the WIPP site lands operates within the authorization of the Taylor Grazing Act of 1934, the Federal Land Policy and Management Act (FLPMA), the Public Rangelands Improvement Act of 1978, and the Bankhead-Jones Farm Tenant Act of 1973. The responsibilities of the DOE include supervision of ancillary activities associated with grazing (for example, wildlife access to livestock water development); tracking of water developments inside WIPP lands to ensure that they are configured according to the regulatory requirements; and ongoing coordination with respective allottees. Administration of grazing rights is in cooperation with the BLM according to the Memorandum of Understanding (MOU) and the coinciding Statement of Work through guidance established in the East Roswell Grazing Environmental Impact Statement. The WIPP site is composed of two grazing allotments administered by the BLM: the Livingston Ridge (No. 77027) and the Antelope Ridge (No. 77032).

2.3.2.3 History and Archaeology

From about 10,000 B.C. to the late 1800s, the WIPP site and surrounding region were inhabited by nomadic aboriginal hunters and gatherers who subsisted on various wild plants and animals. From about A.D. 600 onward, as trade networks were established with Puebloan peoples to the west, domesticated plant foods and materials were acquired in exchange for dried meat, hides, and other products from the Pecos Valley and Plains. In the late 1500s, the Spanish Conquistadors encountered Jumano and Apachean peoples in the region who practiced hunting and gathering and engaged in trade with Puebloans. After the Jumanos abandoned the southern Plains region, the Comanches became the major population of the area. Neighboring populations with whom the Comanches maintained relationships ranging from mutual trade to open warfare, included the Lipan, or Southern Plains Apache, several Puebloan Groups, Spaniards, and the Mescalero Apaches.

The best documented indigenous culture in the WIPP region is that of the Mescalero Apaches, who lived west of the Pecos. The lifestyle of the Mescalero Apaches represents a transition between the full sedentism of the Pueblos and the nomadic hunting and gathering of the Jumanos. In 1763, the San Saba expedition encountered and camped with a group of Mescaleros in Los Medaños. Expedition records indicate the presence of both Lipan and Mescalero Apaches in the region.

A peace accord reached between the Comanches and the Spaniards in 1786 resulted in two historically important economic developments: (1) organized buffalo hunting by Hispanic and Puebloan ciboleros and (2) renewal and expansion of the earlier extensive trade networks by Comancheros. These events placed eastern New Mexico in a position to receive a wide array of both physical and ideological input from the Plains culture area to the east and north and from Spanish-dominated regions to the west and south. Comanchero trade began to mesh with the Southwest American trade influence in the early nineteenth century. However, by the late 1860s the importance of Comanchero trade was cut short by Texan influence.

The first cattle trail in the area was established along the Pecos River in 1866 by Charles Goodnight and Oliver Loving. By 1868, Texan John Chisum dominated much of the area by controlling key springs along the river. Overgrazing, drought, and dropping beef prices led to the demise of open-range cattle ranching by the late 1880s.

Following the demise of open-range livestock production, ranching developed using fenced grazing areas and production of hay crops for winter use. Herd grazing patterns were influenced by the availability of water supplies as well as by the storage of summer grasses for winter feeding.

The town of Carlsbad was founded as Eddy in 1889 as a health spa. In addition to ranching, the twentieth century brought the development of the potash, oil, and gas industries that have increased the population eightfold in the last 50 years.

Although technological change has altered some of the aspects, ranching remains an important economic activity in the WIPP region. This relationship between people and the land is still an important issue in the area. Ranch-related sites dating to the 1940s and 1950s are common in parts of the WIPP area. These will be considered historical properties within the next several years, and thus will be treated as such under current law.

The Natural Historic Preservation Act (NHPA; 16 USC Part 470 et seq.) was enacted to protect the nation's cultural resources in conjunction with the states, local governments, Indian tribes, and private organizations and individuals. The policy of the federal government includes (1) providing leadership in preserving the prehistoric and historic resources of the nation; (2) administering federally owned, administered, or controlled prehistoric resources for the benefit of present and future generations; (3) contributing to the preservation of nonfederally owned prehistoric and historic resources; and (4) assisting state and local governments and the national trust for historic preservation in expanding and accelerating their historic preservation programs and activities. The act also established the National Register of Historic Places (National Register). At the state level, the State Historic Preservation Officer (SHPO) coordinates the state's participation in implementing the NHPA. The NHPA has been amended by two acts: the Archaeological and Historic Preservation Act (16 USC Part 469 et seq.) and the Archaeological Resource Protection Act (16 USC Part 470aa et seq.).

To protect and preserve cultural resources found within the WIPP site boundary, the WIPP submitted a mitigation plan to the New Mexico SHPO describing the steps to either avoid or excavate archaeological sites. A site was defined as a place used and occupied by prehistoric people. In May 1980, the SHPO made a determination of "no adverse effect from WIPP facility activities" on cultural resources. The National Advisory Council on Historic Preservation concurred that the WIPP Mitigation Plan is appropriate to protect cultural resources.

Known historical sites (more than 50 years old) in southeastern New Mexico consist primarily of early twentieth century homesteads that failed or isolated features from late nineteenth century and early twentieth century cattle or sheep ranching and military activities. To date, no Spanish or Mexican sites have been identified. Historic components are rare but are occasionally noted in the WIPP area. These include features and debris related to ranching.

Since 1976, cultural resource investigations have recorded 98 archaeological sites and numerous isolated artifacts within the 16-mi^2 (41-km^2) area enclosed by the WIPP site. In the central 4-mi^2 (10.4-km^2) area, 33 sites were determined to be eligible for inclusion on the National Register as an archaeological district. Investigations since 1980 have recorded an additional 14 individual sites outside the central 4-mi^2 (10.4-km^2) area that are considered eligible for inclusion on the National Register. The following major cultural resource investigations to date are broken out in the list that follows. Additional information can be found in the bibliography.

1977. The first survey of the area was conducted for SNL by Nielson of the Agency for Conservation Archaeology (ACA). This survey resulted in the location of 33 sites and 64 isolated artifacts.

1979. MacLennan and Schermer of ACA conducted another survey to determine access roads and a railroad right-of-way for Bechtel, Inc. The survey encountered two sites and 12 isolated artifacts.

1980. Schermer conducted another survey to relocate the sites originally recorded by Nielson. This survey redescribed 28 of the original 33 sites.

1981. Hicks directed the excavation of nine sites in the WIPP core area.

1982. Bradley (Lord and Reynolds 1985) recorded one site and four isolated artifacts in an archaeological survey for a proposed water pipeline.

1985. Lord and Reynolds examined three sites within the WIPP core area that consisted of two plant-collecting and processing sites and one base camp used between 1000 B.C. and A.D. 1400. The artifacts recovered from the excavations are in the Laboratory of Anthropology at the Museum of New Mexico in Santa Fe.

1987. Mariah Associates, Inc., identified 40 sites and 75 isolates in an inventory of 2,460 acres (10 km^2) in 15 quarter-section units surrounding the WIPP site. In this investigation, 19 of the sites were located within the WIPP site's boundary. Sites encountered in this investigation tended to lack evident or intact features. Of the 40 new sites defined, 14 were considered eligible for inclusion in the National Register, 24 were identified as having insufficient data to determine eligibility, and two were determined to be ineligible for inclusion. The eligible and potentially eligible sites have been mapped and are avoided by the DOE in its current activities at the WIPP site.

1988–1992. Several archaeological clearance reports have been prepared for seismic testing lines on public lands in Eddy County, New Mexico.

All archaeological sites are surface or near-surface sites, and no reasons exist (either geological or archeological) to suspect that deep drilling would uncover or investigate archaeological sites.

The Delaware Basin has been used in the past for an isolated nuclear test. This test, Project Gnome, took place in 1961 at a location approximately 8 mi (13 km) southwest of the WIPP. The primary objective of Project Gnome was to study the effects of an underground nuclear explosion in salt. The Gnome experiment involved the detonation of a 3.1-kiloton nuclear device at a depth of 1,200 ft (366 m) in the bedded salt of the Salado. The explosion created a cavity of approximately 1,000,000 ft^3 (28,000 m^3) and caused surface displacements over an area of about a 1,200-ft (366-m) radius. Fracturing and faulting caused measurable changes in rock permeability and porosity at distances up to approximately 330 ft (100 m) from the cavity. No earth tremors were reported at

distances over 25 mi (40 km) from the explosion. Project Gnome was decommissioned in 1979.

2.4 Background Environmental Conditions

Background environmental conditions are provided in this petition as part of the complete description of the WIPP and its vicinity. Background environmental conditions form the baseline for determining if releases to the environment have occurred during the operational period or during any post-operational monitoring period. Emphasis is placed on ecological conditions, water quality, and air quality and includes the following:

Ecological Conditions

- Vegetation
- Mammals
- Reptiles and amphibians
- Birds
- Arthropods
- Aquatic ecology
- Endangered species

Quality of Environmental Media

- Surface water
- Groundwater
- Air

2.4.1 Terrestrial and Aquatic Ecology

The vegetation, mammals, reptiles and amphibians, birds, arthropods, aquatic ecology, and endangered species of the WIPP site and its environs are characterized in the sections that follow.

2.4.1.1 Vegetation

The WIPP site is in an area characterized by stabilized sand dunes. The vegetation is dominated by shinnery oak, mesquite, sand sage, dune yucca, smallhead snakeweed, three-awn, and numerous species of forbs and perennial grasses. The dominant shrubs are deep-rooted species with extensive root systems. The shrubs not only stabilize the dune sand but serve as food, shelter, and nesting sites for many species of wildlife inhabiting the area.

The vegetation in the vicinity of the WIPP site is not a climax vegetation, at least in part because of past grazing management. The composition of the plant life at the site is heterogeneous because of variations in terrain and in the type and depth of soil. Shrubs are conspicuous members of all plant communities. The site lies within a region of

transition between the northern extension of the Chihuahuan Desert (desert grassland) and the southern Great Plains (short grass prairie); it shares the floral characteristics of both.

Grazing, primarily by domestic livestock, and fire control are largely responsible for the shrub-dominated seral communities of much of southeastern New Mexico. A gradual retrogression from the tall- and mid-grass-dominated vegetation of 100 years ago has occurred throughout the region. The cessation of grazing would presumably not alter the domination by shrubs, but it would result in an increase in grasses. Experimental exclosures have been established to study site-specific patterns of succession in the absence of grazing, but long-term results are not yet available.

The semiarid climate makes water a limiting factor in the entire region. The amount and timing of rainfall greatly influence plant productivity and, therefore, the food supply for wildlife and livestock. The seeds of desert plants are often opportunistic: they may lie dormant through long periods of drought to germinate in the occasional year of favorable rainfall. Significant fluctuations in the abundance and distribution of plants and wildlife are typical of this region. Several examples of such fluctuations have been documented in the area within 5 mi (8.3 km) of the center of the WIPP site, which has been intensively studied.

Two introduced species of significance in the region are the Russian thistle, or tumbleweed, a common invader in disturbed areas, and the salt cedar, which has proliferated along drainage ways.

Several distinct biological zones occur on or near the site: the mesa, the central dunes complex, the creosote-bush flats, the Livingston Ridge escarpment, and the Tobosa Flats in Nash Draw west of Livingston Ridge. A low, broad mesa named the Divide lies on the eastern edge of the study area and supports a typical desert-grassland vegetation. The dominant shrub and subshrub are mesquite and snakeweed, respectively. The most abundant grasses are black grama, bush muhly, ring muhly, and fluffgrass. Cacti, especially varieties of prickly pear, are present.

Where the ground slopes down from the Divide to the central dune plains, the soil becomes deep and sandy. Shrubs like shinnery oak, mesquite, sand sagebrush, snakeweed, and dune yucca are dominant. In some places, all of these species are present; in others, one or more are either missing or very low in density. These differences appear to be caused by localized variations in the type and depth of soil. Thus, a number of closely related but distinct plant associations form a patchwork complex, or mosaic, across the stabilized dunes in the central area. Hummocky, partially stabilized sand dunes occur, and large, active dunes are also present. The former consist of "islands" of vegetation, primarily mesquite, separated by expanses of bare sand. The mesquite-anchored soil is less susceptible to erosion, mainly by wind, than is the bare sand. The result is a series of valley-like depressions, or blowouts, between vegetated hummocks. Active dunes running east to west are found 10 mi (16 km) south and east of the site.

To the west and southwest, the soil changes again, becoming more dense and shallow (less than 10 in. [254 mm] to caliche) than in the dune area. The composition of the plant life is radically altered, and creosote bushes become dominant. Toward Livingston Ridge to the west and northwest, creosote bushes gradually give way to an acacia-dominated association at the top of the escarpment. The western face of the ridge drops sharply to a valley floor (flats) that is densely populated with tobosa grass, which is rare elsewhere in the study area.

2.4.1.2 Mammals

The most conspicuous wild mammals at the site are the black-tailed jack rabbit and the desert cottontail. Common small mammals found at the WIPP site include the Ord's kangaroo rat, the Plains pocket mouse, and the northern grasshopper mouse. Big-game species, such as the mule deer and the pronghorn antelope, and carnivores, such as the coyote, are present in small numbers.

2.4.1.3 Reptiles and Amphibians

Commonly observed reptiles in the study area are the side-blotched lizard, the western box turtle, the western whiptail lizard, and several species of snakes, including the bullsnake, the prairie rattlesnake, the western diamondback rattlesnake, the coachwhip, the western hognose, and the glossy snake. Of these, only the side-blotched lizard is found in all habitats. The others are mainly restricted to one or two associations within the central dunes area, although the western whiptail lizard and the western diamondback rattlesnake are found in areas dominated by creosote bush as well. The yellow mud turtle is found only in the limited number of aquatic habitats in the study area (that is, dirt stock ponds and metal stock tanks), but it is common in these locales.

Amphibians are similarly restricted by the availability of aquatic habitat. Stock-watering ponds and tanks may be frequented by tiger salamanders and occasional frogs and toads. Fish are sometimes stocked in the ponds and tanks.

2.4.1.4 Birds

Numerous birds inhabit the area either as transients or year-long residents. Loggerhead shrikes, pyrrhuloxias, and black-throated sparrows are examples of common residents. Migrating or breeding waterfowl species do not frequently occur in the area. Some raptors (for example, Harris hawks) are residents. The density of large avian predators' nests has been documented as among the highest recorded in the scientific literature.

2.4.1.5 Arthropods

About 1,000 species of insects have been collected in the study area. Of special interest are subterranean termites. Vast colonies of these organisms are located across the study area; they are detritivores and play an important part in the recycling of nutrients in the study area.

2.4.1.6 Aquatic Ecology

Aquatic habitats within a 5-mi (8-km) radius of the WIPP site are limited. Stock-watering ponds and tanks constitute the only permanent surface waters. Ephemeral surface-water puddles form after heavy thunderstorms. At greater distances, seasonally wet, shallow lakes (playas) and permanent salt lakes are found.

Laguna Grande de la Sal is a large, permanent salt lake at the south end of Nash Draw. Natural brine springs, effluent brine from nearby potash refineries, and surface and subsurface runoff discharge into the lake.

Several marine organisms are present in the Lower Pecos River and in the Red Bluff Reservoir. They include small, shelled protozoans (Foraminifera), a Gulf Coast shrimp, an estuarine oligochaete and a dragonfly, and several species of marine algae. These species have presumably been introduced. Salt-tolerant species of insects, oligochaetes, and nematodes and unusual algal assemblages characterize this stretch of the river. The combination of high salinity, elevated concentrations of heavy metals, and salt-tolerant and marine fauna makes the Lower Pecos River a unique system (DOE 1980, §7.1.2.).

2.4.1.7 Endangered Species

The DOE consulted with the U.S. Fish and Wildlife Service (FWS) in 1979 to determine the presence of threatened and endangered species at the WIPP site. At that time the FWS listed the Lee pincushion cactus, the black-footed ferret, the American peregrine falcon, the bald eagle, and the Pecos gambusia as threatened or endangered and as occurring or having the potential to occur on lands within or outlying the WIPP site. In 1989, the FWS advised the DOE that the list of species provided in 1979 is still valid, with the exception of the black-footed ferret. The DOE believes that its actions at the WIPP site will have no impact on any threatened or endangered species. In addition, there is no critical habitat for terrestrial species identified as endangered by either the FWS or the New Mexico Department of Game and Fish (NMDG&F) at the site area.

Also in 1989, the DOE consulted with the NMDG&F regarding the endangered species listed by the state in the vicinity of the WIPP site. The NMDG&F currently lists (based on NMDG&F Regulation 657, dated January 9, 1988) seven birds and one reptile that are in one of two endangerment categories and that occur or are likely to occur at the site. The NMDG&F agreed in 1989 that the proposed WIPP activities would probably not have appreciable impacts on endangered species listed by the state in the area. *A Handbook of Rare and Endemic Plants of New Mexico* published by the University of New Mexico (UNM 1984) lists the plants in New Mexico classified as threatened, endangered, or sensitive, and includes 20 species, representing 14 families, that are found in Eddy County and could occur at or near the WIPP site.

2.4.2 Water Quality

In this section, the DOE presents a discussion of the quality of groundwater and surface water in the WIPP area.

2.4.2.1 Groundwater Quality

Based on the major solute compositions described in Siegel et al. (1991), four hydrochemical facies are delineated for the Culebra as shown in Figure 2-37.

Zone A. A sodium chloride brine (approximately 3.0 molar) with a magnesium/calcium (Mg/Ca) mole ration between 1.2 and 2.0. This water is found in the eastern third of the WIPP site. The zone is roughly coincident with the region of low transmissivity described by LaVenue et al. in 1988. On the western side of the zone, halite in the Rustler has been found only in the unnamed lower member. In the eastern portion of the zone, halite has been observed throughout the Rustler.

Zone B. A dilute anhydrite-rich water (ionic strength < 0.1 molar) occurs in the southern part of the site. The Mg/Ca mole ratios are uniformly low (0.0–0.5). This zone is coincident with a high-transmissivity region, and halite is not found in the Rustler in this zone.

Zone C. Waters of variable composition with low to moderate ionic strength (0.3 to 1.6 molar) occur in the western part of the WIPP site and along the eastern side of Nash Draw. Mg/Ca mole ratios range from 0.5 to 1.2. This zone is coincident with a region of variable transmissivity. In the eastern part of this zone, halite is present in the lower member of the Rustler. Halite is not observed in the formation on the western side of the zone. The most halite-rich water is found in the eastern edge of the zone, close to core locations where halite is observed in the Tamarisk Member.

Zone D. A fourth zone can be defined based on inferred contamination related to potash refining operations in the area. Waters from these wells have anomalously high solute concentrations (3 to 6 molar) and potassium/sodium (K/Na) weight ratios (0.22) compared to waters from other zones (K/Na = 0.01 to 0.09). In the extreme southwestern part of this zone, the composition of the Culebra well water has changed over the course of a seven-year monitoring period. The Mg/Ca mole ratio at WIPP-29 is anomalously high, ranging from 10 to 30 during the monitoring period.

This zonation is consistent with that described by Ramey in 1985, who defined three zones. The fourth zone (D) was added by Siegel et al. in 1991 to account for the local potash contamination.

Together, the variations in solutes and the distribution of halite in the Rustler exhibit a mutual interdependence. Concentrations of solutes are lowest where Rustler halite is less abundant, consistent with the hypothesis that solutes in Rustler groundwaters are derived

locally by dissolution of minerals (for example, halite, gypsum, and dolomite) in adjacent strata.

The TDS in the Magenta groundwater ranges in concentration from 5,460 to 270,000 milligrams per liter. This water is considered saline to briny. The transmissivity in areas of Lower TDS concentrations is very low, thus greatly decreasing its usability, and the Magenta is not considered as a water supply. In general, the chemistry of Magenta water is variable. Groundwater types range from a predominantly sodium chloride type to a calcium-magnesium-sodium-sulfate type chemistry. The water chemistry may indicate a general overall increase in TDS concentrations to the south and southwest, away from the WIPP site, and a potential change to a predominantly sodium chloride water in that area.

In the WIPP area, the water quality of the Magenta is better than that of the Culebra. However, water from the Magenta is not used anywhere in the vicinity of the WIPP.

2.4.2.2 Surface-Water Quality

The Pecos River is the nearest permanent water source to the WIPP site. Natural brine springs, representing outfalls of the brine aquifer in the Rustler, feed the Pecos River at Malaga Bend, southwest of the site. This natural saline inflow adds approximately 70 tons of chloride per day to the Pecos River. Return flow from irrigated areas above Malaga Bend further contributes to the salinity. The concentrations of potassium, mercury, nickel, silver, selenium, zinc, lead, manganese, cadmium, and barium also show significant elevations at Malaga Bend but tend to decrease downstream. The metals presumably are rapidly adsorbed onto the river sediments. Natural levels of certain heavy metals in the Pecos River below Malaga Bend exceed the water quality standards of the World Health Organization, the EPA, and the State of New Mexico. For example, the maximum level for lead is 50 parts per billion, and levels of up to 400 parts per billion have been measured during WIPP-related studies.

As it flows into Texas south of Carlsbad, the Pecos River is a major source of dissolved salt in the west Texas portion of the Rio Grande Basin. Natural discharge of highly saline groundwater into the Pecos River in New Mexico keeps TDS levels in the water in and above the Red Bluff Reservoir very high. The TDS levels in this interval exceed 7,500 milligrams per liter 50 percent of the time and, during low flows, can exceed 15,000 milligrams per liter. Additional inflow from saline water-bearing aquifers below the Red Bluff Reservoir and irrigation return flows, and continues to degrade water quality between the reservoir and northern Pecos County in Texas. Annual discharge-weighted average TDS concentrations exceed 15,000 milligrams per liter. Water use is varied in the southwest Texas portion of the Pecos River drainage basin. For the most part, water use is restricted to irrigation, mineral production and refining, and livestock. In many instances, surface-water supplies are supplemented by groundwaters that are being depleted and are increasing in salinity.

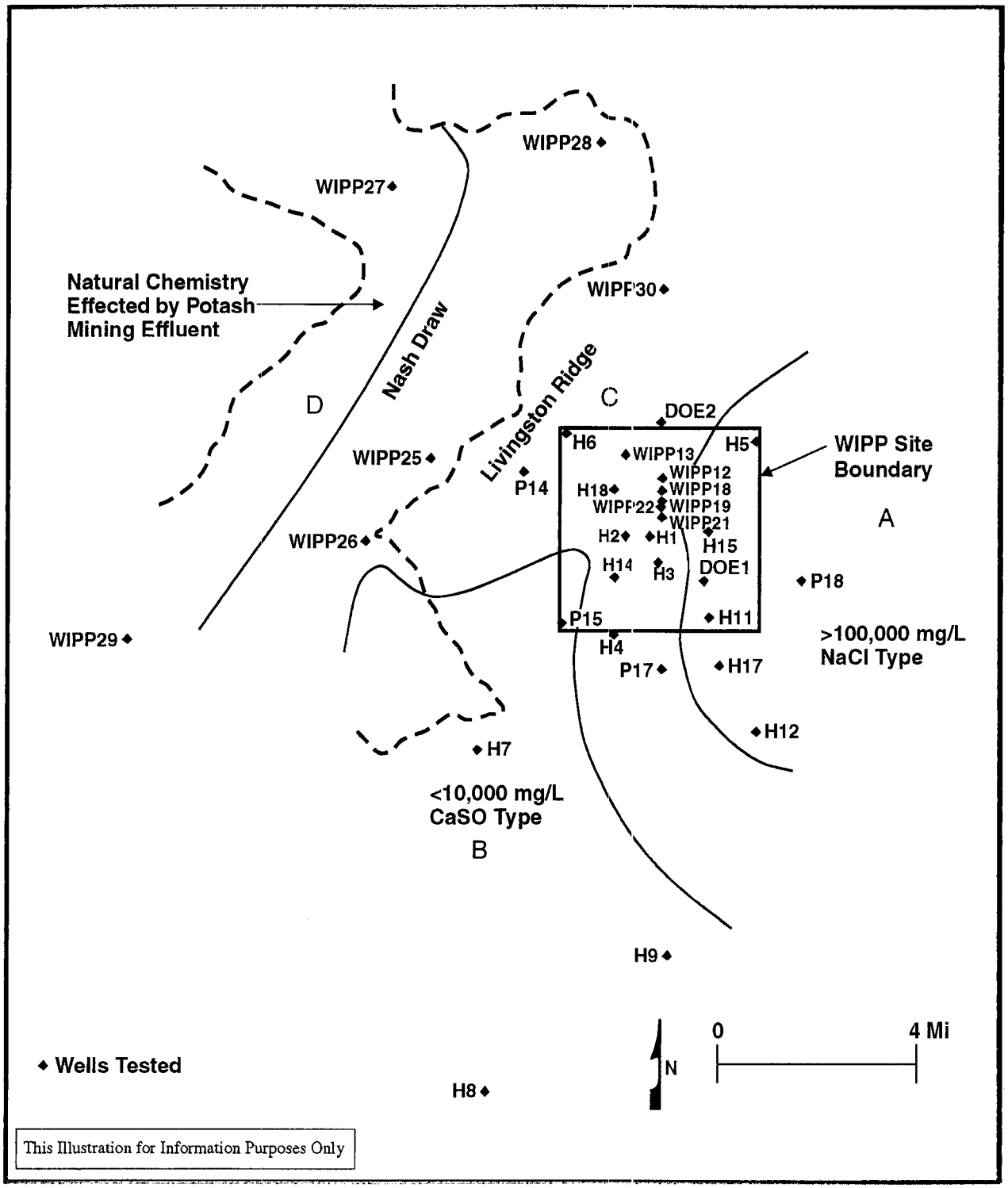

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Figure 2-37. Hydrochemical Zones of the Culebra

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2.4.3 Air Quality

Measurements of selected air pollutants at the WIPP site began in 1976 and were reported by DOE in the FEIS. Since the preparation of that document, a more extensive air quality monitoring program has been established. Seven classes of atmospheric gases regulated by the EPA have been monitored at the WIPP site between August 27, 1986, and October 30, 1994. These gases are carbon monoxide (CO), hydrogen sulfide (H_2S), ozone (O_3), nitrogen oxides (NO, NO_2, NO_x), and sulfur dioxide (SO_2). The total suspended particulates (TSPs) are monitored in conjunction with the air-monitoring programs of the WIPP. The results of the monitoring program are detailed in the annual reports for the WIPP Environmental Monitoring Program.

The volatile organic compound (VOC) monitoring program has focused on the air pathway since 1991. With more than four years of data, a credible basis for determining the range of the WIPP facility's background levels of five targeted VOCs has been established. VOC concentrations have been measured at the following locations:

- Near the top of the exhaust shaft (Station VOC-1)
- Near the air intake shaft (Station VOC-2)
- Ventilation air intake passageways to the waste-containing rooms (Station VOC-8)

These data are included in Appendix BAD and are summarized in Table 2-8.

2.5 Climate and Meteorological Conditions

The long time periods involved in the isolation of TRU-mixed waste are significant with respect to potential changes in climate. Climate changes are documented through studies of floral, faunal, and geological data and lead to fuller understanding of cyclic effects that may impact the long-term performance of the disposal system. This section explains the basis for the modeling of future climate change. Modeling assumptions are described in Chapter 8.

2.5.1 Historic Climatic Conditions

Data used to interpret paleoclimates in the American Southwest come from a variety of sources and indicate alternating arid and subarid to subhumid climates throughout the Pleistocene. The information in this section was taken from Swift 1992, included in this application as Appendix CLI.

Prior to 18,000 years ago, radiometric dates are relatively scarce, and the record is incomplete. From 18,000 years ago to the present, however, the climatic record is relatively well constrained by floral, faunal, and lacustrine data. These data span the transition from the last full-glacial maximum to the present interglacial period; given the global consistency of glacial fluctuations described below, they can be taken to be broadly representative of extremes for the entire Pleistocene.

Table 2-8. Background VOC Concentrations in the Ambient Air

Constituent	Station VOC-1 Average Concentration (ppbv)	Station VOC-2 Average Concentration (ppbv)	Station VOC-8 Average Concentration (ppbv)
Trichloro-trifluoroethane	0.63	0.18[a]	0.41
Methylene Chloride	0.32	0.20	0.31
Trichloroethane	17	1.0	66
Carbon Tetrachloride	0.12[a]	0.44	0.10
Trichloroethylene	0.14	0.13	0.11

a = average value is less than the detection limit of the method (estimated)
ppbv = parts per billion by volume

Early and Middle Pleistocene paleoclimatic data for the southwestern United States are incomplete and permit neither continuous reconstructions of paleoclimates nor direct correlations between climate and glaciation prior to the last glacial maximum, which occurred 22,000 to 18,000 years ago. Stratigraphic and soil data from several locations, however, indicate that cyclical alternation of wetter and drier climates in the Southwest had begun by the Early Pleistocene. Fluvial gravels in the Gatuña exposed in the Pecos River Valley of eastern New Mexico suggest wetter conditions 1.4 million years ago and again 600,000 years ago. The Mescalero caliche, exposed locally over much of southeastern New Mexico, suggests drier conditions 510,000 years ago, and loosely dated spring deposits in Nash Draw west of the WIPP imply wetter conditions occurring again later in the Pleistocene. The Blackwater Draw Formation of the southern High Plains of eastern New Mexico and western Texas, correlating in time to both the Gatuña and the Mescalero, contains alternating soil and eolian sand horizons that show at least six climatic cycles beginning more than 1.4 million years ago and continuing to the present.

Data used to construct the more detailed climatic record for the latest Pleistocene and Holocene come from six independent lines of evidence dated using carbon-14 techniques: plant communities preserved in packrat middens throughout the Southwest, including sites in Eddy and Otero counties, New Mexico; pollen assemblages from lacustrine deposits in western New Mexico and other locations in the Southwest; gastropod assemblages from western Texas; ostracod assemblages from western New Mexico; paleolake levels throughout the Southwest; and faunal remains from caves in southern New Mexico.

Prior to the last glacial maximum 22,000 to 18,000 years ago, evidence from faunal assemblages in caves in southern New Mexico, including the presence of species such as the desert tortoise that are now restricted to warmer climates, suggests hot summers and mild, dry winters. Lacustrine evidence confirms the interpretation of a relatively dry climate prior to and during the glacial advance. Permanent water did not appear in what

was later to become a major lake in the Estancia Valley in central New Mexico until some time before 24,000 years ago, and water depths in lakes at higher elevations in the San Agustin Plains in western New Mexico did not reach a maximum until sometime between 22,000 and 19,000 years ago. Ample floral and lacustrine evidence documents cooler, wetter conditions in the Southwest during the glacial peak. These changes were not caused by the immediate proximity of glacial ice. None of the Pleistocene continental glaciations advanced farther southwest than northeastern Kansas, and the most recent, late-Wisconsinan ice sheet reached its limit in South Dakota, approximately 750 mi (1,200 km) from WIPP. Discontinuous alpine glaciers formed at the highest elevations throughout the Rocky Mountains, but these isolated ice masses were symptoms, rather than causes, of cooler and wetter conditions and had little influence on regional climate at lower elevations. The closest such glacier to WIPP was on the northeast face of Sierra Blanca Peak in the Sacramento Mountains, approximately 135 mi (220 km) to the northwest.

Global climate models indicate that the dominant glacial effect in the Southwest was the disruption and southward displacement of the westerly jet stream by the physical mass of the ice sheet to the north. At the glacial peak, major Pacific storm systems followed the jet stream across New Mexico and the southern Rocky Mountains, and winters were wetter and longer than either at the present or during the previous interglacial period.

Gastropod assemblages at Lubbock Lake in western Texas suggest mean annual temperatures 41°F (5°C) below present values. Both floral and faunal evidence indicate that annual precipitation throughout the region was 1.6 to 2.0 times greater than today's values. Floral evidence also suggests that winters may have continued to be relatively mild, perhaps because the glacial mass blocked the southward movement of arctic air. Summers at the glacial maximum were cooler and drier than at present, without a strongly developed monsoon.

The jet stream shifted northward following the gradual retreat of the ice sheet after 18,000 years ago, and the climate responded accordingly. By approximately 11,000 years ago, conditions were significantly warmer and drier than previously, although still dominated by winter storms and still wetter than today. Major decreases in total precipitation and the shift toward the modern monsoonal climate did not occur until the ice sheet had retreated into northeastern Canada in the Early Holocene.

By Middle Holocene time, the climate was similar to that of the present, with hot, monsoon-dominated summers and cold, dry winters. The pattern has persisted to the present, but not without significant local variations. Soil studies show that the southern High Plains were drier from 6,500 to 4,500 years ago than before or since. Gastropod data from Lubbock Lake indicate the driest conditions from 7,000 to 5,000 years ago (precipitation, 0.89 times present values; mean annual temperature, 36°F (2.5°C) higher than present values), with a cooler and wetter period 1,000 years ago (precipitation, 1.45 times present values; mean annual temperature, 36°F (2.5°C) lower than present). Plant assemblages from southwestern Arizona suggest steadily decreasing precipitation from the Middle Holocene to the present, except for a brief wet period approximately 990 years

ago. Stratigraphic work at Lake Cochise (the present Willcox playa in southeast Arizona) shows two mid-Holocene lake stands, one near or before 5,400 years ago and one between or before 3,000 to 4,000 years ago; however, both were relatively short-lived, and neither reached the maximum depths of the Late Pleistocene high stand that existed before 14,000 years ago.

Inferred historical precipitation indicates that during the Holocene, wet periods were relatively drier and shorter in duration than those of the Late Pleistocene. Historical records over the last several hundred years indicate numerous lower intensity climatic fluctuations, some too short in duration to affect floral and faunal circulation. Sunspot cycles and the related change in the amount of energy emitted by the sun have been linked to historical climatic changes elsewhere in the world, but the validity of the correlation is uncertain. Correlations have also been proposed between volcanic activity and climatic change. In general, however, causes for past short-term changes are unknown.

The climatic record presented here should be interpreted with caution because its resolution and accuracy are limited by the nature of the data used to construct it. Floral and faunal assemblages change gradually and show only a limited response to climatic fluctuations that occur at frequencies that are higher than the typical life span of the organisms in question. For long-lived species such as trees, resolution may be limited to hundreds or even thousands of years. Sedimentation in lakes and playas has the potential to record higher frequency fluctuations, including single-storm events, but only under a limited range of circumstances. Once water levels reach a spill point, for example, lakes show only a limited response to further increases in precipitation.

With these observations in mind, three significant conclusions can be drawn from the climatic record of the American Southwest. First, maximum precipitation in the past coincided with the maximum advance of the North American ice sheet. Minimum precipitation occurred after the ice sheet had retreated to its present limits. Second, past maximum long-term average precipitation levels were roughly twice the present levels. Minimum levels may have been 90 percent of the present levels. Third, short-term fluctuations in precipitation have occurred during the present relatively dry, interglacial period, but they have not exceeded the upper limits of the glacial maximum.

Too little is known about the relatively short-term behavior of global circulation patterns to accurately predict precipitation levels over the next 10,000 years. The long-term stability of patterns of glaciation and deglaciation, however, do permit the conclusion that future climatic extremes are unlikely to exceed those of the Late Pleistocene. Furthermore, the periodicity of glacial events suggests that a return to full-glacial conditions is highly unlikely within the next 10,000 years.

2.5.2 Recent Climatic Conditions

Recent climatic conditions are provided to allow for the assessment of impacts of these factors on the disposal unit and the site.

2.5.2.1 General Climatic Conditions

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are mostly from the southeast and moderate. In late winter and spring, there are strong west winds and dust storms. During the winter, the weather is often dominated by a high-pressure system situated in the central portion of the western United States and a low-pressure system located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona.

2.5.2.2 Temperature Summary

Temperatures are moderate throughout the year, although seasonal changes are distinct. The mean annual temperature in southeastern New Mexico is 63°F (17°C). In the winter (December through February), nighttime lows average near 23°F (-9°C), and maxima average in the 50s (10° - 15°C). The lowest recorded temperature at the nearest Class-A weather station in Roswell was -29°F (-2°C) in February 1905. In the summer (June through August), the daytime temperature exceeds 90°F (32°C) approximately 75 percent of the time. The National Weather Service recently documented 122°F (50°C) at the WIPP site as the record high temperature for New Mexico. This temperature was recorded on June 27, 1994. Table 2-9 shows the annual average, maximum, and minimum temperatures from 1990 through 1994.

2.5.2.3 Precipitation Summary

Precipitation is light and unevenly distributed throughout the year, averaging 13 in. (33 cm) for the past five years. Winter is the season of least precipitation, averaging less than 0.6 in. (1.5 cm) of rainfall per month. Snow averages about 5 in. (13 cm) per year at the site and seldom remains on the ground for more than a day. Approximately half the annual precipitation comes from frequent thunderstorms in June through September. Rains are usually brief but occasionally intense when moisture from the Gulf of Mexico spreads over the region. Monthly average, maximum, and minimum precipitations recorded at the WIPP site from 1990 through 1994 are summarized in Figure 2-38.

2.5.2.4 Wind Speed and Wind Direction Summary

The frequencies of wind speeds and directions are depicted by windroses in Figures 2-39 through 2-42 for the WIPP site and Figure 2-43 for Carlsbad, New Mexico. In general, the predominant wind direction at the WIPP site is from the southeast, and the predominant wind directions in Carlsbad are from the south, southeast, and west.

2.6 Seismology

The purpose of the seismic studies is to build a basis from which to predict ground motions that the WIPP repository may be subjected to in the near and distant future. The concern about seismic effects in the near future, during the operational period, pertains

Table 2-9. Annual Average, Maximum, and Minimum Temperatures

Year	Annual Average Temperature (°C)	Annual Average Temperature (°F)	Maximum Temperature (°C)	Maximum Temperature (°F)	Minimum Temperature (°C)	Minimum Temperature (°F)
1990	17.8	64	46.1	115	-13.9	7
1991	17.2	63	42.8	109	-7.8	18
1992	17.2	63	42.8	109	-10	14
1993	17.8	64	42.8	109	-18.9	-2
1994	17.8	64	50	122	-14.4	6
Average	17.6	63.6	44.9	112.8	-13	8.6

Source: WIPP Annual Site Environmental Report for Calendar Years 1990 through 1994.

mainly to the design requirements for surface and underground structures for providing containment during seismic events. The concern about effects occurring over the long term, after the repository has been decommissioned and sealed, pertains more to relative motions (faulting) within the repository and possible effects of faulting on the integrity of the salt beds and/or shaft seals.

In this discussion, the magnitudes are reported in terms of the Richter scale, and all intensities are based on the modified Mercalli intensity scale. Most of the magnitudes were determined by the New Mexico Institute of Mining and Technology or are described in Appendix GCR.

2.6.1 Seismic History

Seismic data are presented in two time frames, before and after the time when seismographic data for the region became available. The earthquake record in southern New Mexico dates back only to 1923, and seismic instruments have been in place in the state since 1961. Various records have been examined to determine the seismic history of the area within 180 mi (290 km) of the site. With the exception of a weak shock in 1926 at Hope, New Mexico (approximately 40 mi [64 km] northwest of Carlsbad), and shocks in 1936 and 1949 felt at Carlsbad, all known shocks in the region before 1961 occurred to the west and southwest of the site more than 100 mi (160 km) away.

The strongest earthquake on record occurring within 180 mi (290 km) of the site was the Valentine, Texas, earthquake of August 16, 1931. It has been estimated to have been of magnitude 6.4 on the Richter scale (Modified Mercalli Intensity of VIII). The Valentine earthquake was 130 mi (209 km) south-southwest of the site. Its Modified Mercalli

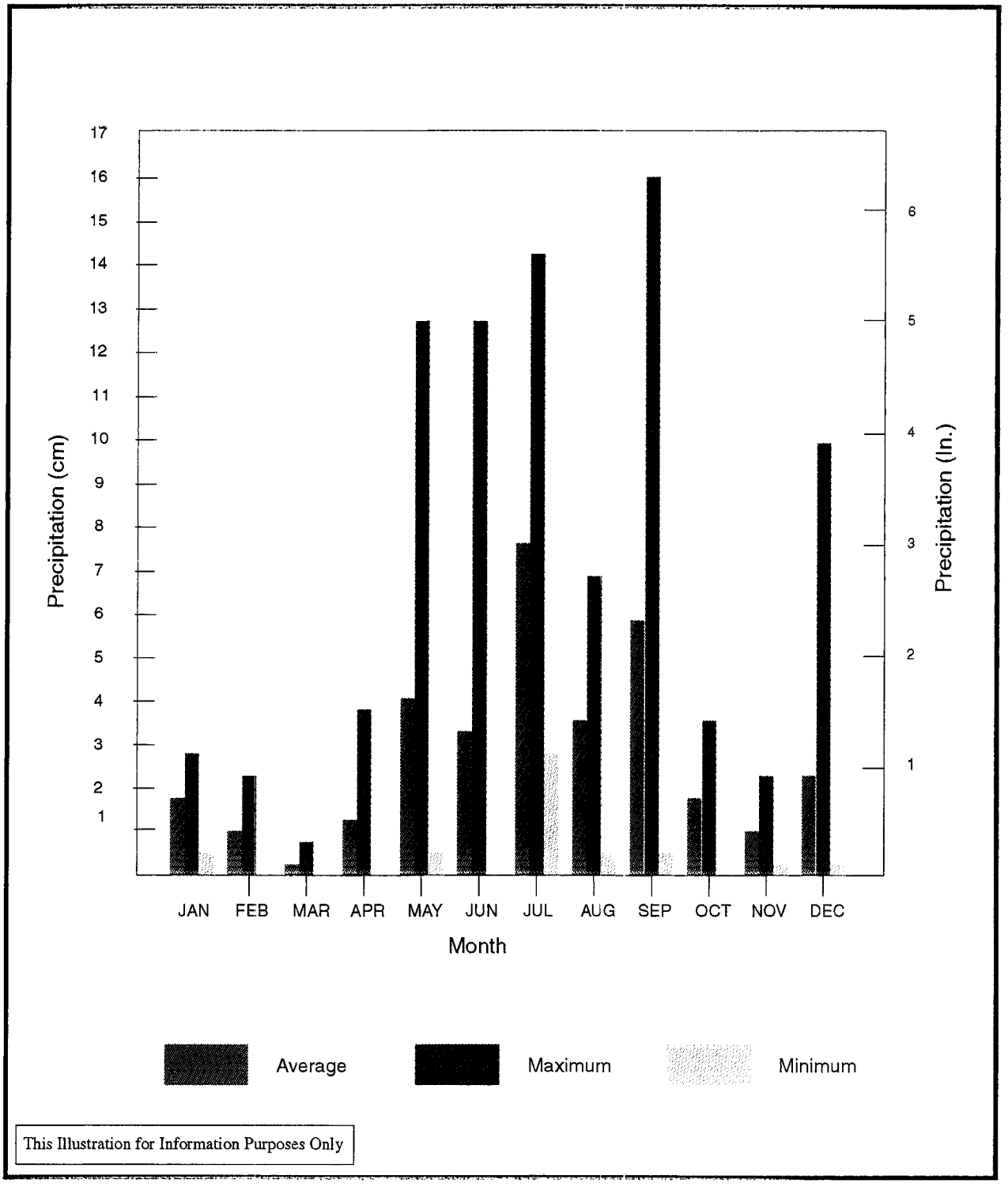

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Figure 2-38. Monthly Precipitation for the WIPP Site from 1990 through 1994

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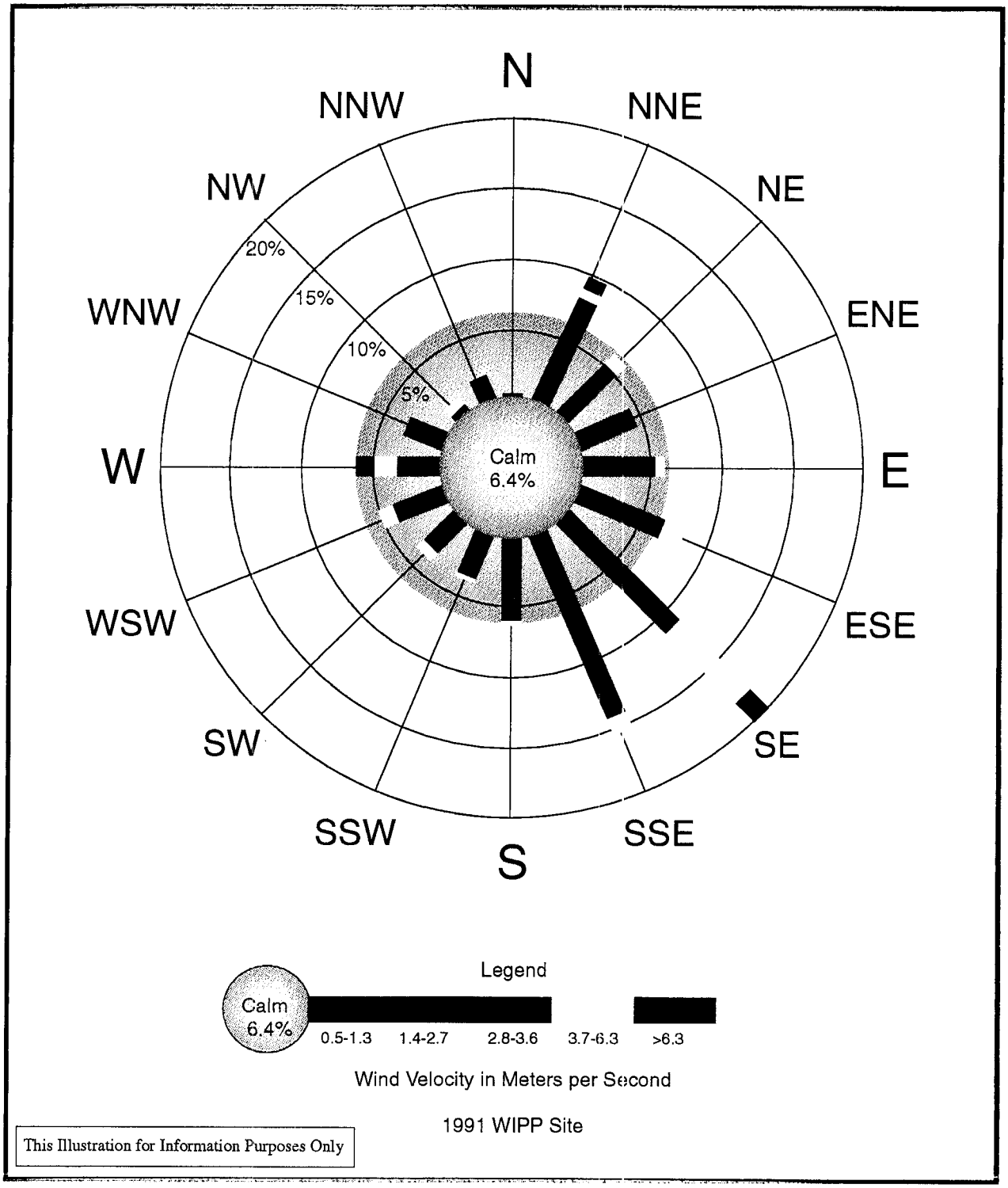

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Figure 2-39. 1991 Annual Windrose - WIPP Site

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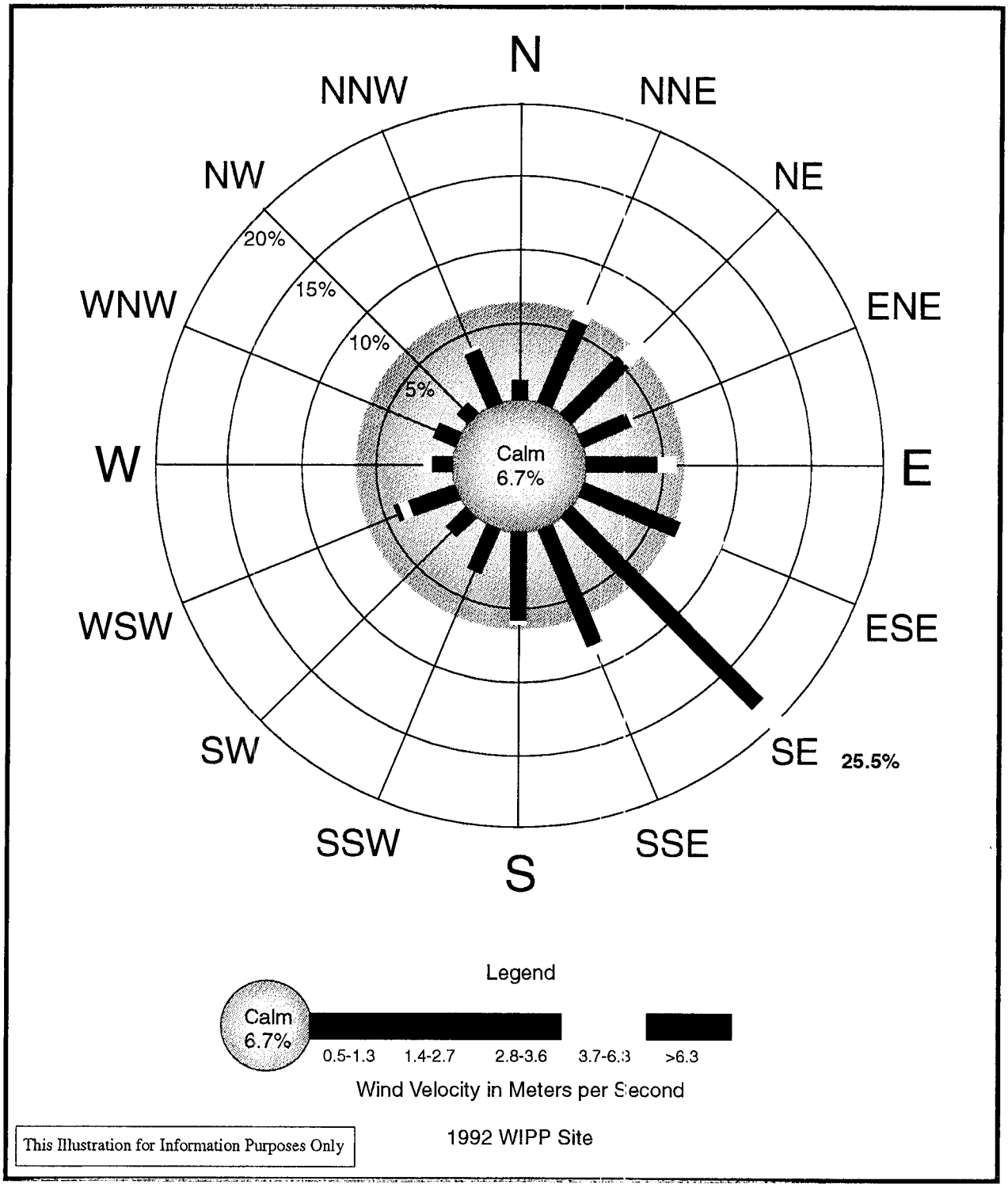

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Figure 2-40. 1992 Annual Windrose - WIPP Site

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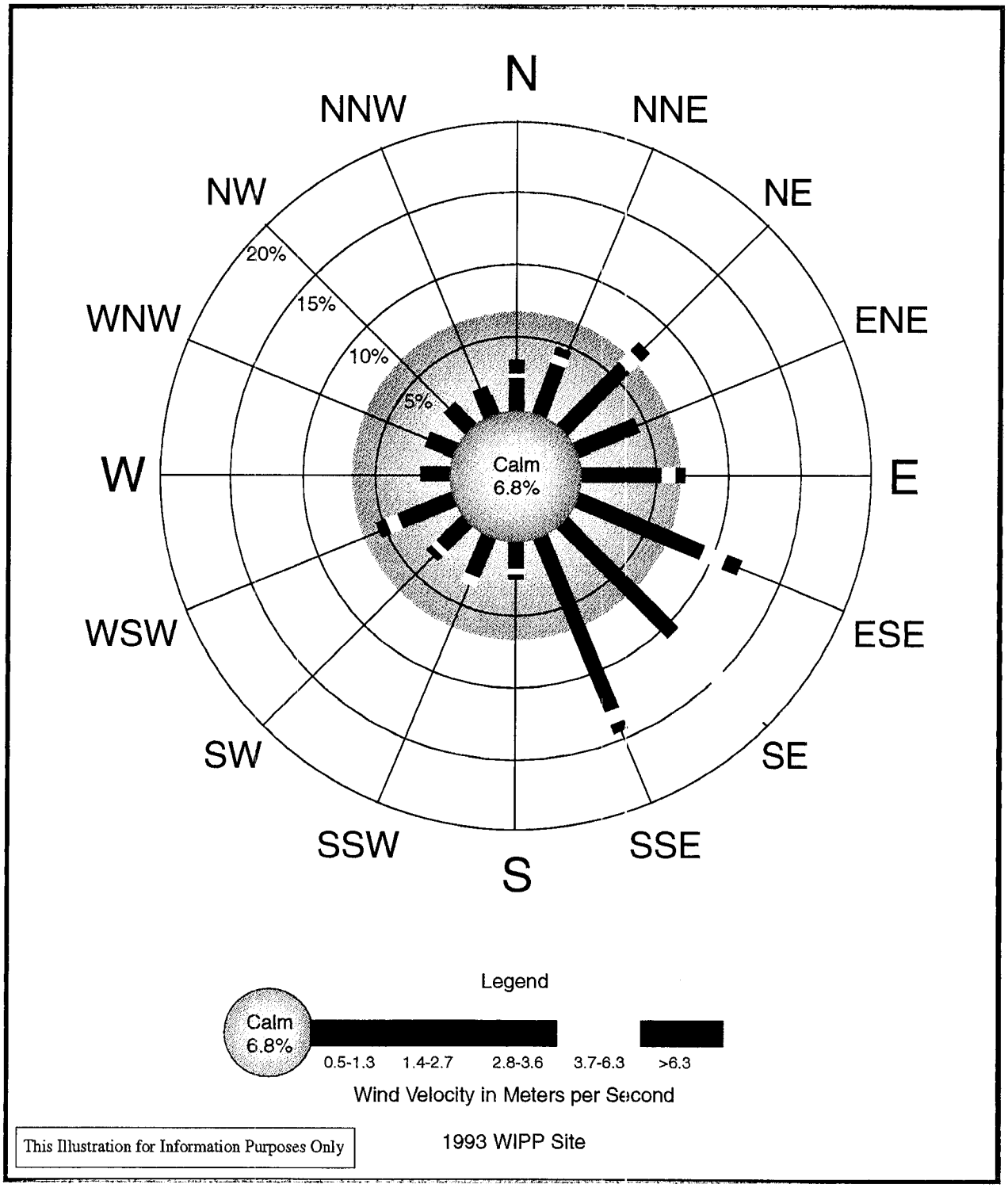

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Figure 2-41. 1993 Annual Windrose - WIPP Site

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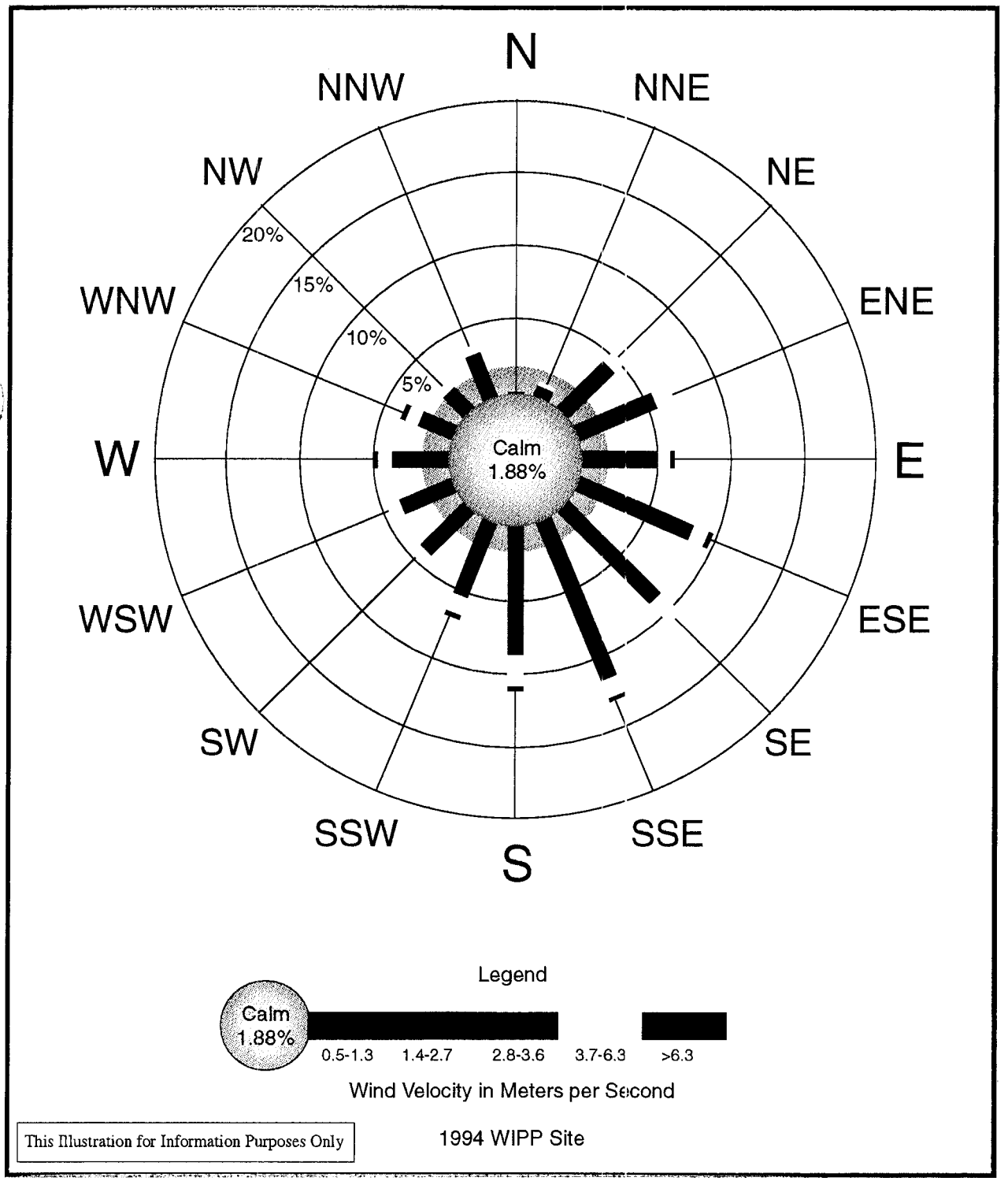

Figure 2-42. 1994 Annual Windrose - WIPP Site

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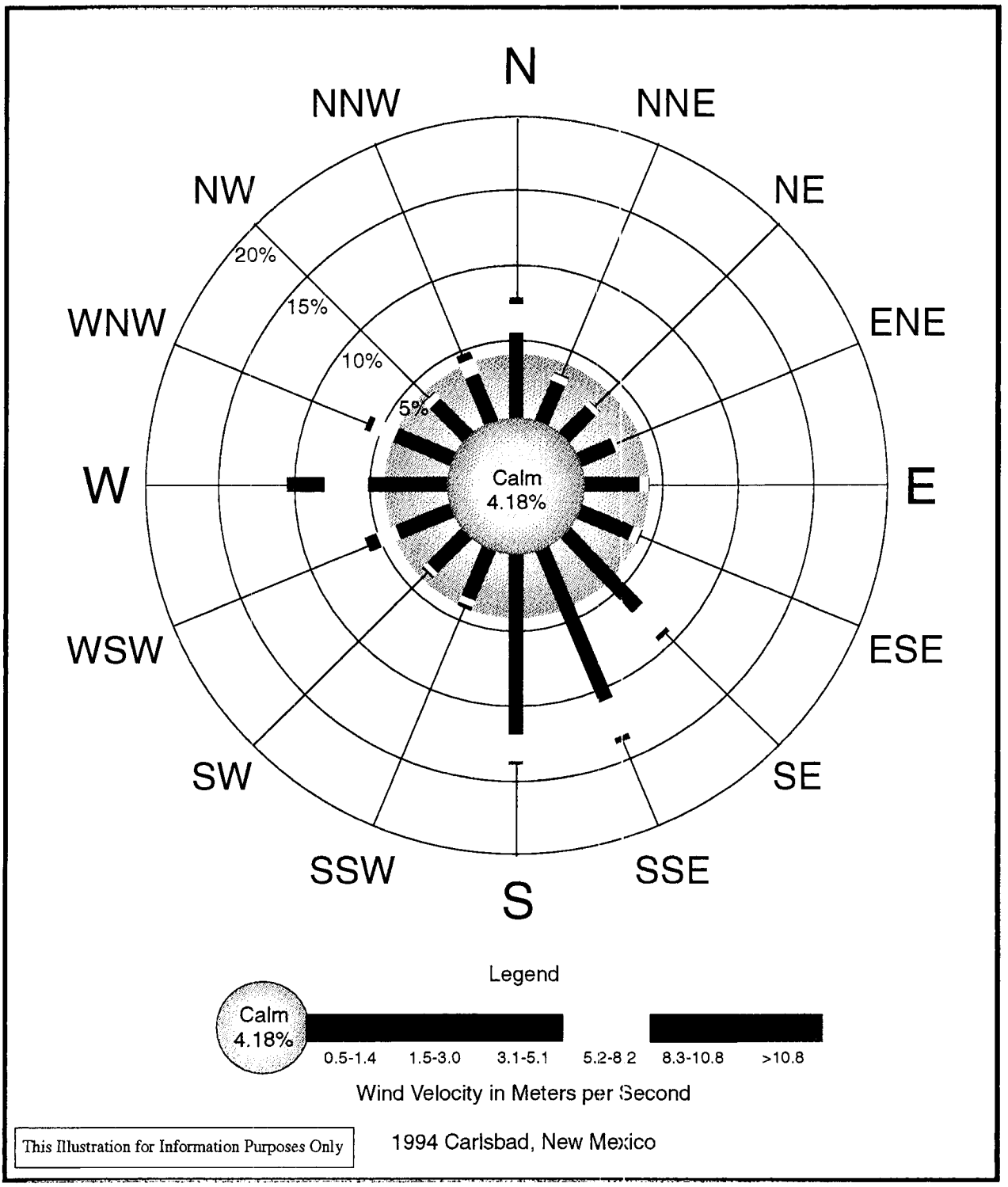

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Figure 2-43. 1994 Annual Windrose - Carlsbad, NM

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Intensity at the site is estimated to have been V; this is believed to be the highest intensity felt at the site in this century.

In 1887, a major earthquake occurred in northeast Sonora, Mexico. Although about 335 mi (539 km) west-southwest of the site, it is indicative of the size of earthquakes possible in the eastern portion of the Basin and Range Province, west of the province containing the site. Its magnitude was estimated to have been 7.8 (VIII to IX in Modified Mercalli Intensity). It was felt over an area of 0.5 million mi^2 (1.3 million km^2) (as far as Santa Fe to the north and Mexico City to the south); fault displacements near the epicenter were as large as 26 ft (8 m).

Since 1961, instrumental coverage has become comprehensive enough to locate most of the moderately strong earthquakes (local magnitude >3.5) in the region. Instrumentally determined shocks that occurred within 180 mi (290 km) of the site between 1961 and 1994 are shown in Figure 2-44. The distribution of these earthquakes may be biased by the fact that seismic stations were more numerous and were in operation for longer periods north and west of the site.

Except for the activity southeast of the site, the distribution of epicenters since 1961 differs little from that of shocks before that time. There are two clusters, one associated with the Rio Grande Rift on the Texas-Chihuahua border and another associated with the Central Basin Platform in Texas near the southeastern corner of New Mexico. The latter activity was not reported before 1964. It is not clear from the record whether earthquakes were occurring in the Central Basin Platform before 1964, although local historical societies and newspapers tend to confirm their absence before that time.

A station operating for 10 months at Fort Stockton, Texas, indicated many small shocks from the Central Basin Platform. Activity was observed at the time the station opened on June 21, 1964. This activity may be related to the underground injection of water for oil recovery. In the Ward–Estes North oilfield, operated by the Gulf Oil Corporation, the cumulative total of water injected up to 1970 was over 1 billion barrels. Accounting for 42 percent of the water injected in Ward and Winkler counties, Texas, the quantity is three times the total injected in all the oil fields of southeastern New Mexico during the same period. The nearest oil fields in the Delaware Basin, where secondary recovery might be attempted in the future, are adjacent to the WIPP site boundary in the Delaware Mountain Group.

The most recent earthquakes to be felt at the WIPP site occurred in January 1992 and April 1995 and are referred to as Rattlesnake Canyon and Marathon Texas Earthquakes, respectively. The Rattlesnake earthquake occurred 60 mi (100 km) east- southeast of the WIPP site. The earthquake was assigned a magnitude of 5.0. This event had no effect on any of the structures at the WIPP as documented by post-event inspections by the WIPP staff and the New Mexico Environment Department. This event was within the parameters used to develop the seismic risk assessment of the WIPP facility for the purpose of construction and operation. The Rattlesnake Canyon event likely was tectonic in origin based on the 12 ± 2-km depth.

The April 14, 1995 earthquake near Marathon, Texas, was located 150 mi (240 km) south of the WIPP site. The USGS estimated that moment magnitude for this event was 5.7. At a distance of 150 mi (240 km), an event of magnitude 5.7 would produce a maximum acceleration less than 0.01 g.

The Marathon earthquake should not be considered an unanticipated event. The shock occurred in the Basin and Range Province, a seismotectonic province with evidence for 24 Quarternary faults in West Texas and adjacent parts of Mexico. Two of these faults had recent surface-faulting events in the Holocene. Strong earthquakes have occurred within the West Texas part of the Basin and Range Province, most notably the M = 6.4 (Richter) Valentine, Texas, earthquake on August 15, 1931.

The WIPP site is located within the Great Plains seismotectonic province, a region which has no evidence of Quarternary faulting, even above major buried structures such as the Central Basin Platform. Because the Great Plains seismotectonic province is geologically distinct from the Basin and Range Province and lacks evidence for recent faulting, the maximum possible or credible earthquake for this region will be substantially smaller than similar earthquakes for the Basin and Range of West Texas.

2.6.2 Seismic Risk

Procedures exist that allow for formal determination of earthquake probabilistic design parameters. In typical seismic risk analyses of this kind, the region of study is divided into seismic source areas within which future events are considered equally likely to occur at any location. For each seismic source area, the rate of occurrence of events above a chosen threshold level is estimated using the observed frequency of historical events. The sizes of successive events in each source are assumed to be independent and exponentially distributed; the slope of the log number versus frequency relationship is estimated from the relative frequency of different sizes of events observed in the historical data. This slope, often termed the b value, is determined either for each seismic source individually or for all sources in the region jointly. Finally, the maximum possible size of events for each source is determined, using judgement and the historical record. Thus, all assumptions underlying a measure of earthquake risk derived from this type of analysis are explicit, and a wide range of assumptions may be employed in the analysis procedure.

In this section, the particular earthquake risk parameter calculated is peak acceleration expressed as a function of annual probability of being exceeded at the WIPP site. The particular analysis procedure applied to the calculation of this probabilistic peak acceleration is taken from a computer program written by McGuire in 1976. In that program, the seismic source zones are modeled geometrically as quadrilaterals of arbitrary shape. Contributions to site earthquake risk from individual source zones are integrated into the probability distribution of acceleration, and the average annual probability of accedence then follows directly.

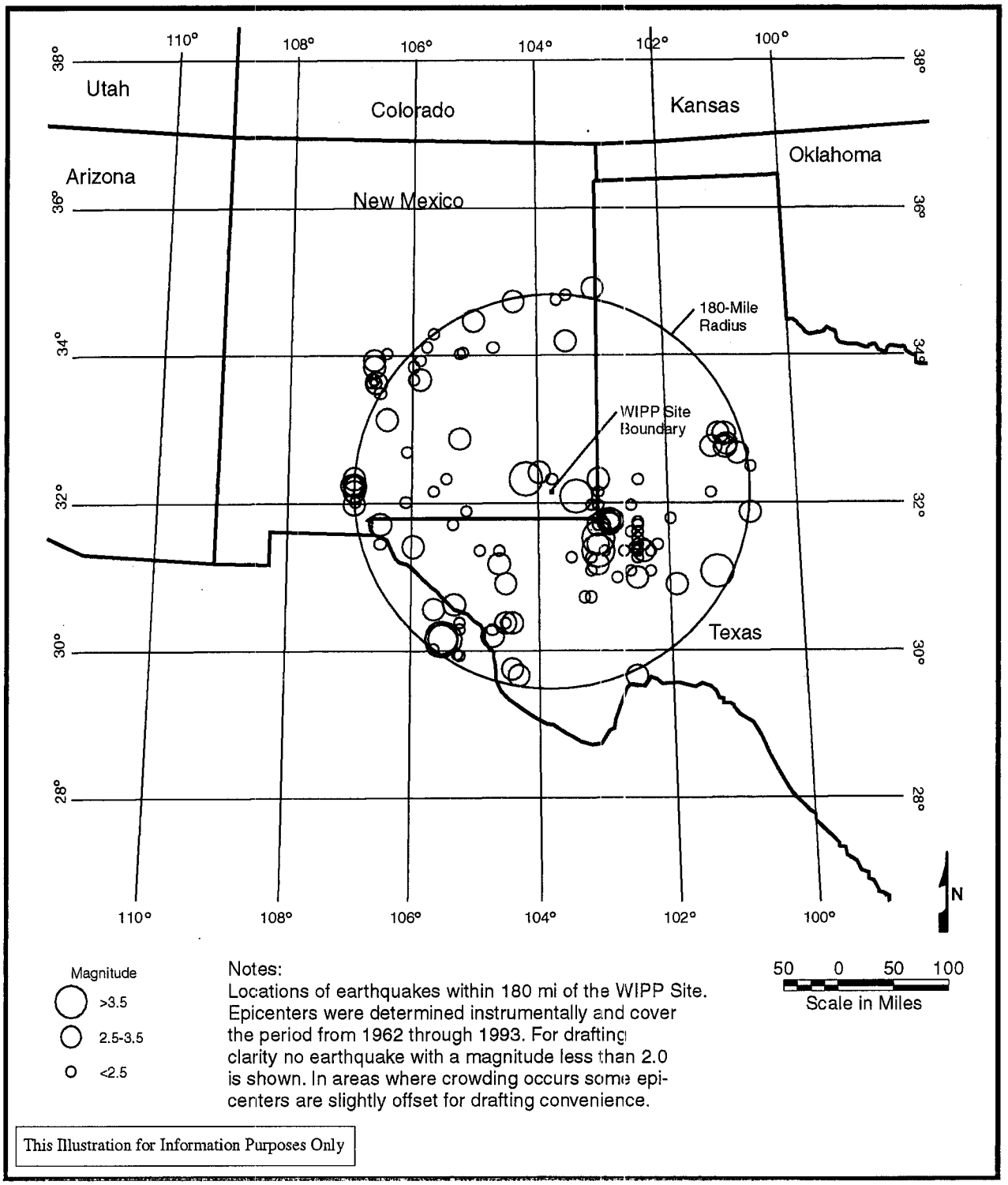

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Figure 2-44. Regional Earthquake Epicenters Occurring between 1962 and 1993

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In the analysis, the principal input parameters are as follows: site region acceleration attenuation, source zone geometry, recurrence statistics, and maximum magnitudes. Based on these parameters, several curves showing probabilistic peak acceleration are developed, and the conclusions that may be drawn from these curves are considered. The data treated in this way are used to arrive at a general statement of risk from vibratory ground motion at the site during its active phase of development and use.

Design Basis Earthquake

Details of the development of model inputs for seismic risk is provided in Appendix GCR.

The term Design Basis Earthquake (DBE) is used for the design of confinement structures and components at the WIPP facility. As used here, the DBE is equivalent to the design earthquake used in Regulatory Guide 3.24 (NRC 1974). That is, in view of the limited consequences of seismic events in excess of those used as the basis, the DBE is such that it produces ground motion at the WIPP facility with a recurrence interval of 1,000 years. In practice, the DBE is defined in terms of the 1,000-year acceleration and design response spectra.

The generation of curves expressing probability of occurrence or risk as a function of peak WIPP facility ground acceleration is discussed in detail in Appendix GCR for a number of possible characterizations of WIPP facility region source zones and source zone earthquake parameters.

The most conservative calculated estimate of the 1,000-year acceleration at the WIPP facility is approximately 0.075 g (g = 32 ft^2 per second [acceleration due to gravity]). The geologic and seismic assumptions leading to this 1,000-year peak acceleration include the consideration of a Richter magnitude 5.5 earthquake at the site, a 6.0 magnitude earthquake on the Central Basin Platform, and a 7.8 magnitude earthquake in the Basin and Range subregion. These values, especially the first two, are considered quite conservative, as are the other parameters used in the 0.075 g derivation are also very conservatively chosen. For additional conservatism, a peak design acceleration of 0.1 g is selected for the WIPP facility DBE. The design response spectra for vertical and horizontal motions are taken from Regulatory Guide 1.60 (NRC 1973) with the high frequency asymptote scaled to this 0.1 g peak acceleration value.

This DBE and the risk analysis that serves an important role in its definition are directly applicable to confinement structures and components at the WIPP facility. Underground structures and components are not subject to DBE. According to Pratt et al. (1979), mine experience and studies on earthquake damage to underground facilities show that tunnels, mines, wells, etc., are not damaged for sites having peak surface accelerations below 0.2 g.

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3.0 Facility Description

Abstract

This chapter provides technical information about the structures at the Waste Isolation Pilot Plant (WIPP) facility and the operations to be conducted at the facility. Descriptions of surface waste handling and support facilities, shafts and hoists, underground waste disposal and support facilities, emergency response, waste management support systems, and engineered barriers are also provided. This chapter provides information on the design objectives, design criteria, design performance projections, and design specifications for the disposal unit.

The WIPP facility consists of the 16-mi^2 (41.4-km^2) area placed under the jurisdiction of the DOE by the WIPP Land Withdrawal Act (LWA) (Public Law 102-579). The facility was divided into four functional areas: (1) the property protection area (formerly known as Zone I) is surrounded by a chain-link security fence that encloses 35 acres (0.14 km^2) and provides security and protection for all major surface structures; (2) the exclusive use area, an area of approximately 424 acres (1.70 km^2) surrounded by a barbed wire fence and posted no trespassing; (3) the off-limits area, which encompasses approximately 1,450 acres (5.9 km^2) and defines the area within which no prohibited articles (e.g., firearms) are allowed; and, (4) the WIPP land-withdrawal area, which is defined on the surface by a 16-section (41.4-km^2) federal land area under the jurisdiction of the DOE. The location of the WIPP land-withdrawal area was established for two reasons. First, for long-term performance, it assures that at least 1 mile of intact salt (i.e., no drilling or mining) exists between the waste disposal area and the accessible environment. Second, during operations, the area provides assurance that no permanent residences will be established close to the facility, thereby protecting the public from potential emissions.

The waste disposal area of the WIPP facility consists of eight panels, each of which contains seven rooms. At present, a 25-year operating time period is estimated to mine and fill all eight panels, the four access drifts, and the crosscuts in the WIPP repository. At the end of the 25-year period, up to 10 years will be required for decontamination, decommissioning, and closure activities.

General Facility Design

The WIPP facility is designed to accomplish three primary goals:

1. To receive, handle, and dispose of transuranic (TRU) waste and TRU-mixed waste (in this document, the term "TRU waste" is used to describe both TRU and TRU-mixed waste unless otherwise noted)
2. To protect the health and safety of workers, the public, and the environment
3. To comply with applicable radiation protection standards, environmental regulations, and requirements of federal, state, and local agencies

The surface facilities at the WIPP accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of TRU waste from the surface to the repository. The surface structures are located within a perimeter security fence. Access is controlled by security officers 24 hours a day. Four vertical shafts connect the surface facilities to the repository. The underground facilities include the waste disposal area, the shaft pillar area, and associated support facilities.

DOE Facility Acquisition Process. Federal facility acquisition policies were applied to the design and construction of the WIPP facility, in accordance with DOE Order 4700.1, *Project Management System*. In addition, WIPP structures were designed to meet DOE design and quality assurance (QA) requirements specified in DOE Order 6430.1, *General Design Criteria*. Each WIPP facility item was evaluated against the Design Classification System Criteria (see DOE 1990a, § 3.0, table 3.1.8). Application of these criteria identified no Design Class I items at the WIPP facility. The WIPP Waste Handling Building (WHB) was designed to meet the requirements applicable to Design Class II structures, systems, and components for nonreactor nuclear facilities. The underground area of the repository is classified as a Design Class IIIB nonreactor nuclear facility. The design class designations are defined for categorizing structures, systems, and components in accordance with the importance of their function relative to health and safety of the public and on-site personnel during plant operations.

Configuration Control. The configuration control of the WIPP facility is mandated by written procedures and policies as set forth in DOE Order 4700.1, *Project Management Program*. Any changes to the facility, and subsequently configuration documentation, must be reviewed and approved by cognizant personnel. These documented reviews are performed to determine if the change will affect the ability of the facility to comply with applicable environmental, safety, and health requirements.

As-Built Design

The WIPP facility's design meets the requirements of DOE Order 6430.1, *General Design Criteria*. Implementation of this DOE order results in the design and construction of facilities which assure safety during operations and protect human health and the environment during operations and after the decommissioning of the project. When facility operations cease, the areas in the repository that contain waste will be closed and the shafts will be sealed. The repository rooms are expected to close and consolidate into a mass comparable to intact salt, restoring the excavations to a condition approaching the undisturbed state.

Surface Structures. The WIPP surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground areas. The surface facilities are located in an area of approximately 35 acres (0.14 km^2) within the perimeter fence.

Waste Handling Building. The WHB and its associated systems provide a structure to unload waste containers from the incoming shipping containers and transfer the waste

containers to the underground disposal area via the Waste Shaft. The WHB is divided into four functional areas: the contact-handled transuranic (CH-TRU) waste handling area, the remote-handled transuranic (RH-TRU) waste handling area, the WHB support area, and the Waste Shaft.

In general, the WHB is constructed of steel beams with insulated steel siding. Certain portions of the building, such as the Hot Cell complex, are constructed of concrete for shielding and structural purposes. The floors in the waste handling areas are coated with an approved coating to minimize penetration of any radioactive contamination into the concrete or crevices, thereby making the decontamination process easier. The WHB is classified as Design Class II, since the building acts as a confinement barrier to control the potential release of radioactive material. As such, the WHB is designed for Design Class II loads including the design basis earthquake (DBE) and design basis tornado (DBT).

CH-TRU Waste Handling Operations. The CH-TRU waste area is a low bay area located in the west half of the WHB. It provides space and houses equipment for the unloading of TRUPACT-II shipping containers and the subsequent transfer of waste containers to the waste hoist for transfer underground. The CH-TRU waste handling area consists of approximately 50,000 ft^2 (4,648 m^2). The ventilation subsystem supporting the CH Bay area has an exhaust capability of approximately 18,450 ft^3 per minute (523 m^3 per minute).

During facility operations, the WIPP will receive and dispose up to 6.2 million ft^3 (175,600 m^3) of TRU waste. CH-TRU waste will be disposed at the WIPP facility in containers (55-gallon drums, standard waste boxes [SWBs], 85-gallon drums, or ten-drum overpacks) which are shown to meet U.S. Department of Transportation (DOT) Type A standards. TRU waste will arrive at the WIPP facility in sealed NRC-certified TRUPACT-II containers. Each NRC-certified TRUPACT-II typically carries two seven-packs (14 drums) of 55-gallon drums, or two SWBs.

TRUPACT-IIs arriving at the WIPP facility first enter the main gatehouse vehicle trap, where a visual inspection is performed to ensure that TRUPACT-IIs are not damaged and that the documentation that accompanies the shipment is complete. The Health Physics Technician performs a gamma and neutron radiation dose rate survey and compares the result to the DOT labels. The TRUPACT-II is directed to the TRUPACT-II receipt parking space outside of the WHB, where a radioactive contamination survey is performed. Any discrepancies are recorded and dispositioned prior to unloading. The TRUPACT-IIs are unloaded from their transportation trailers using a 13-ton forklift truck. They are then transported inside the WHB to the CH Bay through air locks.

The outdoor truck parking area and the CH Bay are being permitted as RCRA container storage areas.

RH-TRU Waste Handling Operations. The RH-TRU waste area is located in the east half of the WHB. The area includes structures and equipment for unloading RH-TRU waste shipping containers and transferring the waste in canisters from the shipping

containers to a shielded facility cask via the Hot Cell. The RH Bay area consists of approximately 30,000 ft^2 (2,789 m^2). The ventilation subsystem supporting the RH-TRU waste area has an exhaust capability of approximately 18,500 ft^3 per minute (524 m^3 per minute).

RH-TRU waste will arrive at the WIPP facility by truck or rail in a shielded, NRC-certified road cask. Inside the cask a single waste canister holds the equivalent of three 55-gallon drums of RH-TRU waste. Upon arrival, the shipment will be visually checked for damage, the documentation will be checked for completeness, and the road cask will be surveyed for radiation dose rates. The cask will then be positioned at the RH Bay and a contamination survey will be performed. If necessary, the cask will be decontaminated prior to unloading. The documentation will be verified for compliance and dispositioned prior to unloading. After it is determined that the waste shipment documentation is in order, the impact limiter collars are removed from the road cask. The cask is then upended and placed in a vertical position on the road cask transfer car with the RH Bay 140-ton overhead crane. The road cask outer lid is removed, and the cask is moved into the shielded cask unloading room, where the road cask inner lid is removed. The waste canister is removed from the road cask and processed through the Hot Cell complex. In the Hot Cell, the canister is inspected and a contamination survey is performed. The canister can be overpacked if necessary. The canister is then transferred into the canister shuttle car. The RH-TRU waste canister is then lifted into the shielded facility cask and the shielded gate doors are closed. The facility cask is rotated to a horizontal position and moved by the self-propelled facility cask transfer car to the waste shaft collar for lowering to the underground repository. The facility cask is then placed on the waste transfer machine assembly, which transfers the waste canister from the shielded cask into a horizontal storage borehole. After the waste canister is emplaced, the horizontal emplacement equipment inserts a shield plug into the borehole.

The RH Bay and Hot Cell Complex are being permitted as RCRA container storage units.

Waste Handling Building Support Areas. Support areas common to both the CH-TRU and RH-TRU waste areas of the WHB include the waste hoist support areas and the general HVAC required by the WHB. Air locks are located on both the CH-TRU and RH-TRU waste sides of the waste hoist. The air locks include the loading room on the CH-TRU waste sides of the waste hoist and the facility cask loading room on the RH-TRU waste side of the waste hoist. Access doors to the hoist are interlocked to ensure control of airflow. In general, airflows to the shaft from the CH-TRU waste loading room or from the RH-TRU waste facility cask loading room.

Waste Shaft and Hoist

The principal components of the shaft are the shaft collar, the shaft lining, and the shaft key, which terminates the lining in the salt formation. The waste hoist and Conveyance (located at the Waste Shaft) provides the primary method to transport radioactive waste canisters, underground mining and waste handling equipment, and materials between the

surface at the WHB and the underground horizon. The waste hoist subsystem is also used as a primary personnel evacuation system in an emergency.

The hoist has two sets of independent brakes, which are designed so that either brake set acting alone can stop and hold the fully loaded conveyance at any point in the shaft under emergency conditions. In the event of a power failure, the brakes are designed to set automatically. A control system detects malfunctions or abnormal operations of the hoist system, such as overtravel, overspeed, power loss, circuitry failure, or starts made from a wrong location. Upon detection, an alarm is triggered and the hoist automatically shuts down.

The waste hoist is a counter-balanced, multirope friction hoist that operates a single conveyance vertically in the Waste Shaft. The hoist is equipped with a conveyance, counterweight, tailropes, hoistropes, and guideropes.

Underground Facilities

The WIPP underground facilities are located at the repository horizon 2,150 ft (655 m) beneath the surface. These facilities include the waste disposal area, the mining area, an experimental area, the shaft pillar area, interconnecting drifts, and associated support facilities. The underground support facilities service and maintain all underground equipment for mining and disposal operations, monitor for radioactive contamination, and allow limited decontamination of personnel and equipment.

There will be eight waste panels, with each waste panel consisting of seven rooms. Rockbolts, or related types of ground support, are used as necessary. In the panels, this will typically consist of localized bolting on an as-needed basis. The storage rooms and panels will be excavated in stages coordinated with scheduled arrival of waste. Waste disposal is designed not only for the rooms but also for the panel entries and main entries in the waste disposal area.

CH-TRU and RH-TRU Waste Disposal Operations. At the repository horizon, the facility pallet carrying the containers of CH-TRU waste is removed from the hoist cage, placed on the underground transporter, and moved to the CH-TRU waste disposal room.

In the disposal room, the containers are removed from the pallet and placed in the waste stack. If the waste is packaged in drums, the drums are removed from the transporter by a forklift with a special front-end attachment and placed in their disposal location. If waste is packaged in the ten-drum overpack, the overpack is removed from the transporter by a method similar to the drums (seven-packs). If the waste is packaged in SWBs, a forklift with an SWB adaptor or slip sheets and a Brudi Attachment is used to transport the boxes to their disposal location. The empty pallet is reused after being surveyed for contamination and decontaminated, if necessary. After the eight panels are filled, waste will be emplaced in the four main entries. Waste will be placed in accessways to the storage panels in the same mode as in the storage rooms.

The facility cask loaded with the RH-TRU waste canister is driven from the waste hoist conveyance by the facility cask transfer car and transported by forklift to the disposal room. There, the facility cask is placed on the emplacement machine assembly. The emplacement machine assembly then inserts the canister into a predrilled horizontal hole bored into the room wall of the disposal area. A shielded plug is inserted in the hole to provide radiation shielding.

Experimental Area. The underground experimental area, located at the north end of the subsurface facilities, is separate from the other areas of the underground repository. This area provides space to perform tests and experiments and to study the behavior of the disposal system under monitored and controlled conditions. Part of this area will be deactivated during Fiscal Year 1996.

Mining Area. Entries, rooms, and panels will be mined as needed during the period of facility operations to maintain a reserve of disposal rooms. Separate ventilation systems for waste handling, mining and support operations are maintained.

Underground Fueling Station. The underground fuel dispensing room is located in an alcove in the mining area. This fuel dispensing room provides a location and pumping facilities for a portable fuel tank. Portable tank hoisting is done through the Waste Shaft or the Salt Handling Shaft (SHS), as required. A dry-chemical fire suppression system connected to a manually activated reserve supply is provided in the fueling area at all times. In the event of a fire, smoke and fumes will be routed directly to the common exhaust.

Emergency Response

The WIPP facility maintains personnel and equipment to respond to emergencies. Emergency operations, equipment, and personnel are discussed in the WIPP Contingency Plan.

Waste Management Support Systems

Subsystems will be employed at the WIPP facility to meet the WIPP objective of safe management of TRU waste as it is emplaced for permanent disposal in the underground repository.

Ventilation Systems. The ventilation systems for the WIPP facility are designed to confine releases of radioactive contamination within the plant, to provide the HVAC necessary for personnel comfort, and to assure satisfactory equipment operation. The total ventilation system for the WIPP facility consists of independent ventilation systems that supply the WHB, the Exhaust Filter Building, each surface support structure, and underground structures. The systems supplying the WHB and the underground structures are discussed in this chapter.

The ventilation systems serving potentially contaminated areas are once-through systems discharging to a monitored exhaust stack. The path of the ventilating air in the potentially contaminated areas runs from areas of low potential contamination toward areas of higher potential contamination.

Shafts. This system is comprised of four vertical shafts that extend from the surface to the underground storage horizon. The SHS and Waste Handling Shaft have permanently installed hoists capable of moving personnel, equipment, and materials between the surface and the repository.

Electrical System. The electrical system distributes and controls the electrical power required for the equipment and process loads (both on the surface and underground) that operate and monitor the various systems of the WIPP facility. The system interfaces with a public utility substation within the site, which provides the primary source of power. There are two other sources of power: a backup power system, which is supplied from two on-site diesel generators; and uninterruptible power supply systems, which supply transient-free, no-break power to selected operational loads and plant monitoring.

Fire Protection System. The fire protection program for the WIPP facility is designed to ensure personnel safety, mission continuity, and property conservation. The WIPP facility's fire protection systems cover the areas of the WHB, the support structures, and the underground vehicle fueling area. In addition, diesel-powered waste handling equipment have on-board fire suppression systems.

Roads. Access and on-site paved roads are designed to carry a load of an American Association of State Highway and Transportation Officials (AASHTO) Standard Truck #20-516 with the DOT limitations, not to exceed a total weight of 80,000 lb (36,320 kg). Facility roads include the north and south access roads, parking lots, and all roads and parking areas within the security fence.

Drainage. Rainwater runoff is diverted away from the surface facilities by a system of berms and ditches. The WIPP facility drainage system is designed so that storm runoff in the probable maximum precipitation event would not flood the WIPP facility.

Security. A gatehouse provides the means for the security force to control the authorized access of personnel and vehicles into the property protection area.

The property protection area is protected by a chain-link fence topped with strands of barbed wire. A vehicle trap at the gatehouse controls vehicle traffic in and out of the property protection area. The sliding gates of the vehicle trap restrict site access or egress while vehicle inspection is in process.

Pole-mounted high-intensity discharge lamps provide lighting along the property protection area perimeter fence. The lighting is powered from various power distribution centers and can be connected to the backup power supply system when utility power is not available.

Communications Systems. The intraplant communications system includes two-way communication by the public address system and its intercom phones and paging channels, an intraplant telephone system, mine phones, pagers and plectrons, portable two-way radios, and local and facility-wide alarm systems. The system is designed to provide immediate emergency instructions to facility personnel.

The external communication systems, designed to provide two-way communication with outside agencies or to summon emergency assistance from offsite, include the commercial telephone system and two-way radios. Direct dialing through any telephone located above or below ground allows contact with outside agencies. Failure of a single telephone station does not affect the balance of the telephone system.

Engineered Barriers

The design of the WIPP disposal system includes engineered barriers to significantly delay the migration of waste and waste constituents beyond the unit boundary. The repository will rely on seals in shafts to prevent migration from the excavated openings.

Disturbed Rock Zone. A key to understanding the discussions about both the WIPP facility operational and long-term sealing systems is a knowledge of the disturbed rock zone (DRZ) and its implications for the sealing of a drift or shaft. A DRZ exists around the mine openings where the Salado properties have been altered from the undisturbed values. This DRZ generally forms within the first few meters of the repository. Within the DRZ, intrinsic permeability and porosity are increased due to fracturing caused by the excavation of rock to form the repository.

Operational Period Panel Closure Systems. In regard to the WIPP, the DOE has defined panel closure as the closure of an underground hazardous waste management unit (HWMU) that will no longer receive waste for disposal. Panel closure is required during operations so the available air supply is adequate to service all active areas, to limit personnel exposure to the waste and the associated hazards, and to comply with the applicable parts of the RCRA. Monitoring of closed HWMUs, if necessary, will be defined in the facility operating permits.

Shaft Seal System. The shaft seal system performance plays an important role in meeting regulatory hazardous constituents release requirements. The shaft seal system is designed to limit the release of gas and brine (and, therefore, any other materials they might transport) from the underground repository. Although all engineering materials have uncertainties in properties, a combination of available, low-permeability materials provides an effective shaft seal system. Components in this design include long columns of clay, densely compacted salt, and a water stop of asphalt. To reduce system uncertainties and to provide additional assurance of compliance, additional components are added to this sealing system. Different materials perform identical functions within the design, thereby adding confidence in system performance. In choosing materials, emphasis is given to the permeability characteristics and mechanical properties of seal materials. In addition, the shaft seal system materials are also chemically and physically

compatible with the host rock formations, thus further enhancing confidence in long-term performance.

Post-Closure Plan Following Final Facility Closure. A number of regulations deal with the period of time that begins once the WIPP has undergone final facility closure and decommissioning. Under 40 CFR Part 191, the period consists of an active control period and a passive control period. Only 100 years of the active control period can be used in performance assessment. Under the no-migration standard in 40 CFR §268.6, the EPA is interested in the measures the DOE will take in terms of long-term passive institutional controls "...such as land withdrawal, records, and markers—to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits at the site may have terminated" (EPA 1990). The LWA of 1992 requires that the DOE prepare and submit a post-decommissioning land management plan. 20 NMAC 4.1, Subpart V, §264.117 requires post-closure care, including monitoring, security, and property use. Because of the numerous regulations, the DOE has prepared a single strategy for post-closure management of the WIPP. This strategy consists of three elements: (1) active controls, (2) monitoring, and (3) passive controls.

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3.0 FACILITY DESCRIPTION

This chapter provides technical information about the structures that comprise the Waste Isolation Pilot Plant (WIPP) facility and the operations to be conducted at the facility. Descriptions of surface waste handling and support facilities, shafts and hoists, underground waste disposal and support facilities, emergency response, waste management support systems, and engineered barriers are also provided. This chapter also provides information on the design objectives, design criteria, design performance projections, and design specifications for the disposal unit.

The WIPP facility is a transuranic (TRU) radioactive waste management facility owned and operated by the U.S. Department of Energy (DOE). The Westinghouse Electric Corporation Waste Isolation Division (WID) is the management and operating (M&O) contractor. The primary contact person is:

Mr. George Dials, Manager, Carlsbad Area Office
U.S. Department of Energy
P.O. Box 3090
Carlsbad, New Mexico 88221
(505) 234-7300

The WIPP facility consists of the 16-mi^2 (41.4 km^2) area placed under the jurisdiction of the DOE by the Waste Isolation Pilot Plant Land Withdrawal Act (LWA) (Public Law 102-579). The facility has been divided into four functional areas: (1) The property protection area (formerly known as Zone I) is surrounded by a chain-link security fence that encloses 35 acres (0.14 km^2), and provides security and protection for all major surface structures; (2) The exclusive use area, which is a 424-acre (1.70-km^2) area surrounded by a barbed wire fence that excludes the public; (3) The off-limits area, which encompasses approximately 1,450 acres (5.9 km^2) and defines the area within which no prohibited articles (e.g., firearms) are allowed; and, (4) the WIPP land-withdrawal area, which is defined on the surface by a 16-section measurement (41.4 km^2) federal land area under the jurisdiction of the DOE. The location of the WIPP land-withdrawal area was established for two reasons. First, for long-term performance, it assures that at least 1 mi (1.6 km) of intact salt (i.e., no drilling or mining other than those performed for the WIPP) exists between the waste disposal area and the accessible environment. Second, during operations, the area provides assurance that no permanent residences will be established in close proximity to the facility, and limits the types and duration of surface uses, thereby protecting the public from emissions.

The only radioactive wastes that may be emplaced in the WIPP are those that meet *both* the definition of TRU, as defined in DOE Order 5820.2A, *and* that can be certified to the project's waste acceptance criteria (WAC) (details are provided in Chapter 4). As defined in the DOE order, TRU waste is radioactive waste that, without regard to source or form, contains TRU radionuclides with half-lives greater than 20 years in concentrations greater than 100 nanocuries of alpha-emitting TRU isotopes per gram of waste. Generally, these wastes fall into two categories: contact-handled- (CH-) TRU waste, which has a surface dose rate of less than 200 millirem per hour, and remote-

handled- (RH-) TRU waste, which has a surface dose rate of 200 millirem per hour or greater. In accordance with the LWA, no RH-TRU waste with a surface dose rate in excess of 1,000 rem per hour will be shipped to WIPP. Furthermore, no more than 5 percent of the total volume of 250,000 ft^3 (7,080 m^3) of RH-TRU waste will exceed 100 rem per hour surface dose rate.

Due to the nature of the processes that produce the TRU wastes, many of the containers also contain wastes that are classified as hazardous wastes under the Resource Conservation and Recovery Act (RCRA). Generators of TRU waste must determine if their waste is regulated by RCRA as a hazardous waste. The determination is based on either representative samples, or knowledge of the waste, which indicates that it meets the definition of hazardous waste in Title 40 of the Code of Federal Regulations (CFR) Part 261. Each hazardous waste must be assigned one or more of the applicable U.S. Environmental Protection Agency (EPA) hazardous waste codes. Only those codes included in the WIPP RCRA Part A permit application can be managed at WIPP.

The waste disposal area of the WIPP facility consists of eight panels, each of which contains seven rooms (Figure 3-1), and the main entries. At present, a 25-year operating time period is estimated to mine and fill all eight panels and the four main entries in the WIPP repository. At the end of the 25-year period, it is currently estimated that up to 10 years will be required for decontamination and decommissioning and closure activities (see Appendix D&D).

The WIPP facility is designed to receive up to 6.2 million ft^3 (175,600 m^3) of CH-TRU waste and 250,000 ft^3 (7,080 m^3) of RH-TRU waste. However, the actual amount of waste to be received at the WIPP is governed by the LWA, which sets the total volume for TRU waste at a maximum of 6.2 million ft^3 (175,600 m^3). The LWA restricted RH-TRU waste to a maximum activity of 23 curies per liter and not to exceed a total of 5.1 million curies.

The WIPP facility was designed to process an average of 250,000 ft^3 (7,080 m^3) of CH-TRU waste and 7,500 ft^3 (210 m^3) of RH-TRU waste per year over a 25-year operating lifetime. The original full capacity design receipt rate for CH-TRU waste was 500,000 ft^3 (14,160 m^3) per year. A computer simulation study was conducted in 1994 to determine if the current CH-TRU Waste Handling System was adequate to accommodate the processing capacity originally provided in the facility's design. The study concluded that, with the existing equipment configuration, CH-TRU waste could be processed at an average rate of 14 Transuranic Package Transporters-IIs (TRUPACT-IIs) per day (300,000 ft^3 [8,500 m^3] per year), assuming two shifts per day operating four days per week.

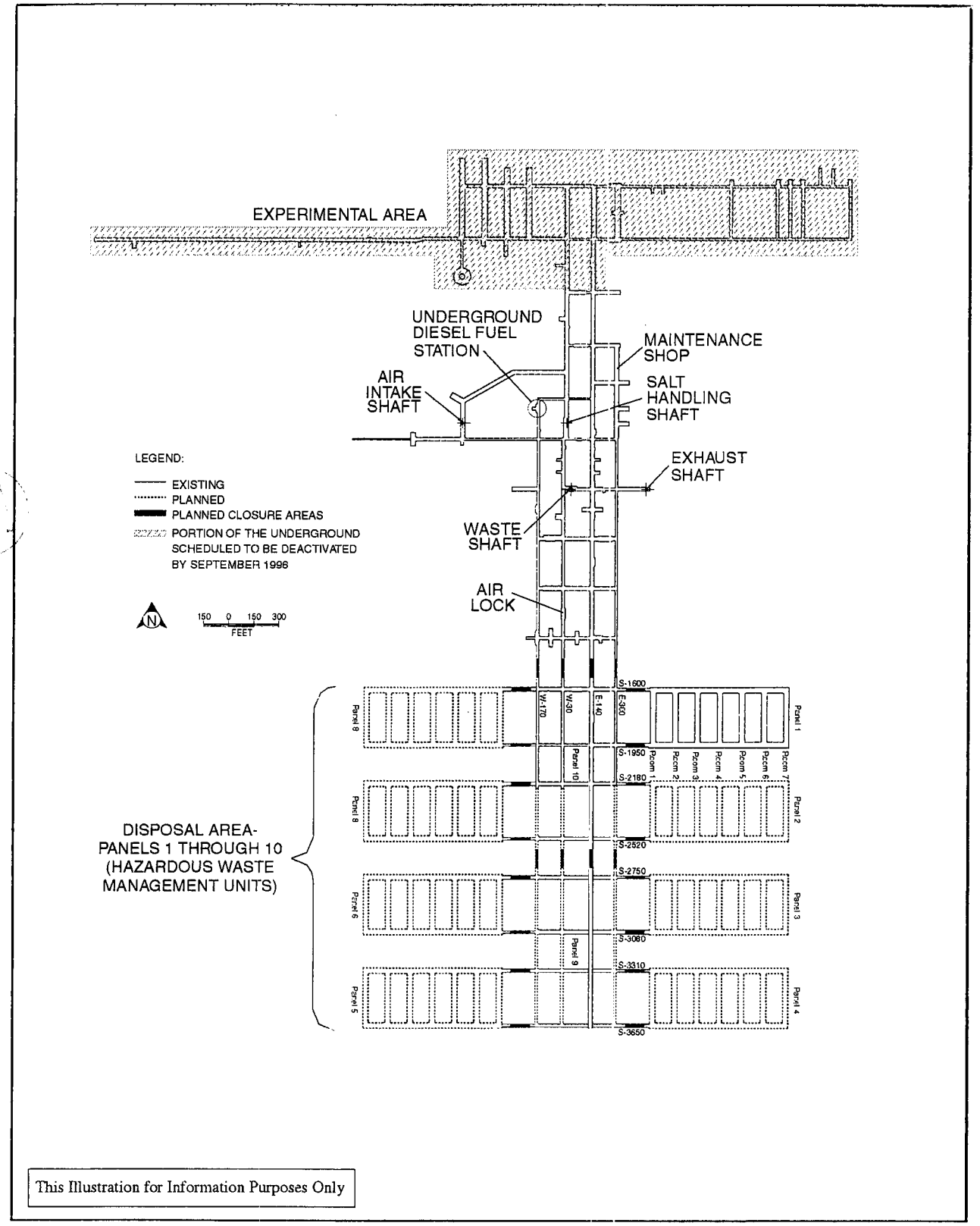

Figure 3-1. Plan View of WIPP Underground Facility and Panel Closure Systems NMVP-6342-047-0

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Table 3-1 delineates pertinent site features of the WIPP facility.

Table 3-1. WIPP Site Features

Facility name	Waste Isolation Pilot Plant
EPA ID No.	NM 4890139088
Location	26 miles east of Carlsbad, New Mexico Latitude: 32°22'11" N Longitude: 103°47'30" W
County	Eddy
Section	15-22 and 27-34
Township	22S
Range	31E
Site area	10,240 acres (41.4 km^2)
Facility area	35 acres (0.14 km^2)
Depth	2,150 ft (655 m)
Expected operational life of facility	25 years
Expected closure time (including decontamination and decommissioning)	10 years
Maximum amount of TRU waste allowed over life of facility[1]	6.2 million ft^3 (175,600 m^3)
Maximum amount of RH-TRU waste allowed over life of facility	250,000 ft^3 (7,080 m^3)

[1] The Land Withdrawal Act maximum is 6.2 million ft^3 (175,600 m^3) of TRU waste (CH and RH).

3.1 General Facility Design

The WIPP facility is designed to accomplish three primary goals:

1. To receive, handle, and dispose of TRU waste and TRU-mixed waste (in this document, the term "TRU waste" is used to describe both TRU and TRU-mixed waste unless otherwise noted)
2. To protect the health and safety of workers, the public, and the environment
3. To comply with applicable radiation protection standards, environmental regulations, and requirements of federal, state, and local agencies (as discussed in Appendix BECR)

The surface facilities at the WIPP accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of TRU waste from the surface to the underground. The surface structures are located within a perimeter security fence. Access is controlled by security officers 24 hours a day. Four vertical shafts connect the surface facilities to the underground. The underground facilities include the waste

disposal area, the shaft pillar area, and associated support facilities. Figure 3-2 provides a spatial view of the WIPP facility.

The WIPP facility will be operated as a clean facility, meaning that under normal operations, waste will be received, handled, and emplaced in closed containers. The WIPP project has implemented a variety of engineered and administrative controls to minimize and control contamination at the facility. These controls are discussed later in this chapter.

Sandia National Laboratories (SNL) was designated by the DOE's predecessor, the U.S. Energy Research and Development Administration (ERDA), to provide the conceptual design and cost estimate for the facility, the necessary supporting technical studies, the draft environmental impact statement, and the site selection. As the architect-engineer for the WIPP project, Bechtel National, Inc., was responsible for the development of the design of the facility. The U.S. Army Corps of Engineers managed the construction of the facility. As owner of the facility, the DOE developed design criteria and conducted independent review and verification of the adequacy of the design. This review was performed by Brookhaven National Laboratories, under contract to the DOE, as part of the facility safety analysis. Westinghouse Electric Corporation served as the Technical Support Contractor (1978–1985) and later as the M&O contractor (1985–present).

3.1.1 DOE Facility Acquisition Process

Federal facility acquisition policies were applied to the design and construction of the WIPP facility, in accordance with DOE Order 4700.1, *Project Management System*. In addition, WIPP structures were designed to meet DOE design and quality assurance (QA) requirements specified in DOE Order 6430.1, *General Design Criteria*. Each WIPP facility item was evaluated against the Design Classification System Criteria (see DOE 1995, § 3.1, Table 3.1-2). Application of these criteria identified no Design Class I items at the WIPP facility. The WIPP Waste Handling Building (WHB) was designed to meet the requirements applicable to Design Class II structures, systems, and components for nonreactor nuclear facilities. The underground area is classified as a Design Class IIIB nonreactor nuclear facility. The design class designations are defined for categorizing structures, systems, and components in accordance with the importance of their function relative to health and safety of the public and on-site personnel during plant operations.

3.1.2 Configuration Control

The configuration control of the WIPP facility is mandated by written procedures and policies as set forth in DOE Order 4700.1, *Project Management Program*. Any changes to the facility, and subsequently to configuration documentation, must be reviewed and approved by cognizant personnel. These documented reviews are performed to determine if the change will affect the ability of the facility to comply with applicable environmental, safety, and health requirements.

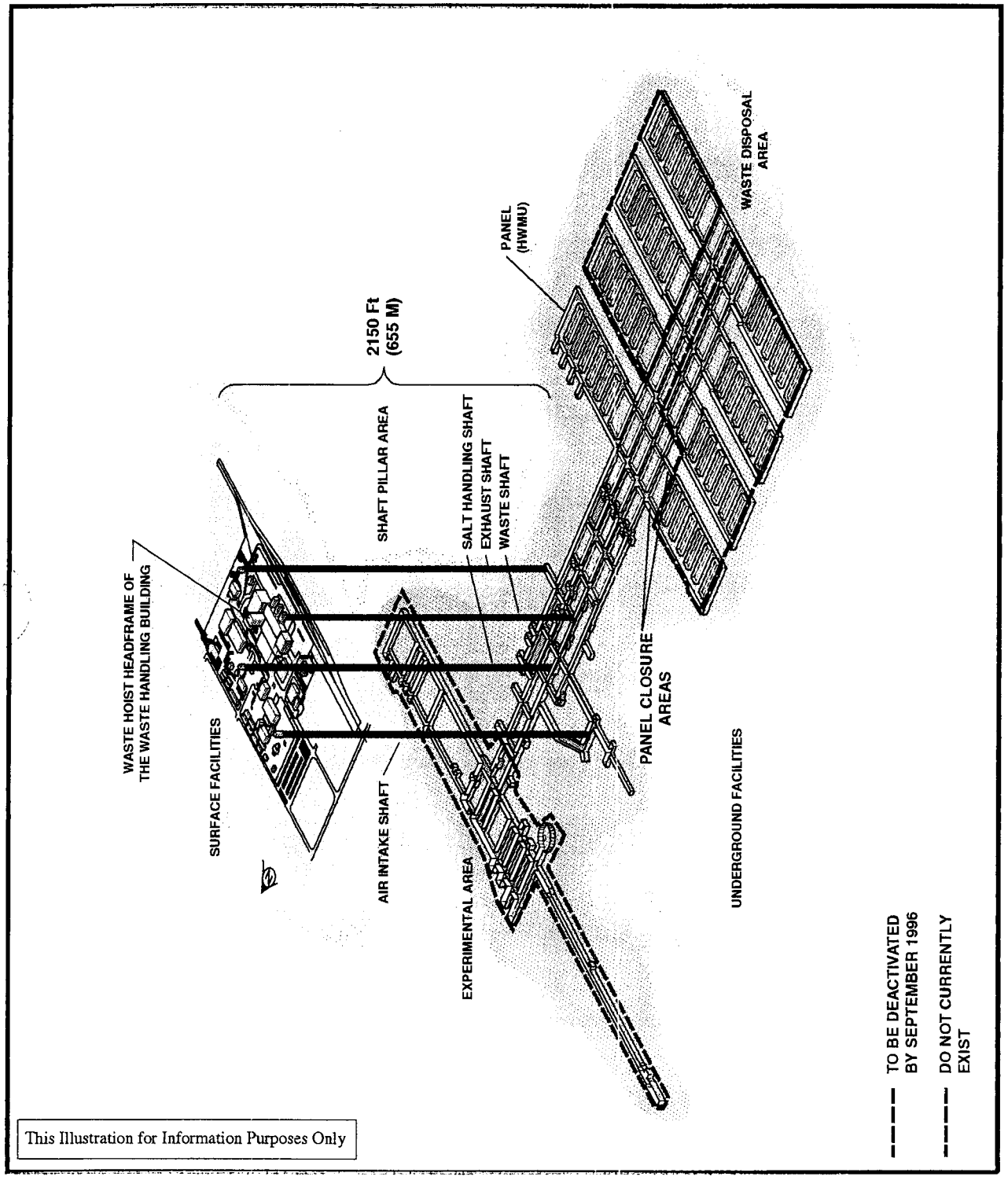

Figure 3-2. Spatial View of the WIPP Facility

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Proposed changes that could affect the Safety Analysis Report (SAR) must be approved by the DOE, who may elect to conduct an independent review of analyses supporting the change. Proposed changes that affect the portion of the facility covered by RCRA permitting requirements may also be subject to regulator approval and permit modification. Finally, any change that significantly alters the basis for a no-migration determination under this petition will also be subject to review and approval by the EPA.

QA requirements applicable to WIPP facility design and configuration control activities are founded on the basic and supplemental requirements of American Society of Mechanical Engineers' *Nuclear Quality Program Requirements for Nuclear Facilities* (ASME NQA-1). The requirements are implemented through the DOE Carlsbad Area Office's (CAO) *Quality Assurance Program Document*, which is provided in Appendix QAPD. Design QA elements include (1) documentation, review, and approval of design inputs; (2) control of design analyses, design verification, and design changes; and (3) institution of design interface controls and records management practices. Additional discussions of the QA requirements and programs are provided in Chapter 7.

3.2 As-Built Design

The WIPP facility was designed and constructed according to DOE Order 6430, General Design Criteria Manual for Department of Energy Facilities, draft, dated June 10, 1981, and codes and standards applicable at the time of construction. Facility modifications since that time have been designed according to the revision of DOE Order 6430 and codes and standards applicable at the time of modification.

3.2.1 Surface Structures

The WIPP surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground areas. The surface facilities are located in an area of approximately 35 acres (0.14 km^2) within the perimeter fence. The principal surface structure is the WHB; other surface structures include the following:

- Hoist Houses
- Support Building
- Guard and Security Building
- Water Pump House
- TRUPACT Maintenance Building
- Training Building
- Office Trailers
- Exhaust Filter Building
- Warehouse and Shops
- Engineering Building
- Core Storage Building
- Safety & Emergency Services Building
- Main Mine Fan and Exhaust Filter Building

3.2.2 Waste Handling Building

The primary function of the WHB and its associated systems is to provide a structure to unload waste containers from the incoming shipping containers, transfer the waste containers to the underground disposal area via the Waste Shaft, and store the waste containers as needed during the emplacement process. The WHB is divided into four functional areas, three of which are discussed in this section: the CH-TRU waste handling area, the RH-TRU waste handling area, and the WHB support area. The fourth area, the Waste Shaft, is discussed in Chapter 3.3. The general layout of the building is illustrated in Figures 3-3 and 3-4.

In general, the WHB is constructed of steel beams with insulated steel siding. Certain portions of the building, such as the Hot Cell complex, are constructed of concrete for shielding and structural purposes. The floors in the waste handling areas subject to potential contamination are coated with an approved coating to minimize penetration of any radioactive contamination into the concrete or crevices, thereby easing the decontamination process. The WHB is classified as Design Class II, because the building acts as a confinement barrier to control the potential release of radioactive material. As such, the WHB is designed for Design Class II loads including the design basis earthquake (DBE) and design basis tornado (DBT).

3.2.2.1 Design Basis Earthquake

Design Class II confinement structures and components are designed to withstand a DBE consistent with that suggested by the Nuclear Regulatory Commission's (NRC's) 1974 *Regulatory Guide 3.24* and as described in Section 2.6.2. The DBE based on the 1,000-year earthquake has been established through a seismic study of the WIPP facility region. The maximum ground acceleration for the DBE is 0.10 g (g = 32 ft per second squared [acceleration due to gravity]) in both horizontal and vertical directions. This value is used in analysis and design of appropriate surface facilities and equipment.

An updated assessment of the DBE was performed in 1990 by Bechtel as part of a comparison of facility design to DOE Order 6430.1A. Bechtel's assessment report showed the design classifications used in the original design for the WIPP either met or exceeded the newer standards for DBE for a nonreactor facility.

3.2.2.2 Design Basis Tornado

The DBT is the most severe tornado that could occur at the WIPP site, as suggested by Fujita in a 1978 study of the specific area. The DBT structures and components are designed to withstand the highest winds—183 mi (295 km) per hour—generated by this tornado. With regard to the DBT, the WIPP facility is designed on a single-failure basis, where it is considered that two or more failures will not occur simultaneously. Based on this design approach, it was not necessary to build structures at the WIPP facility to

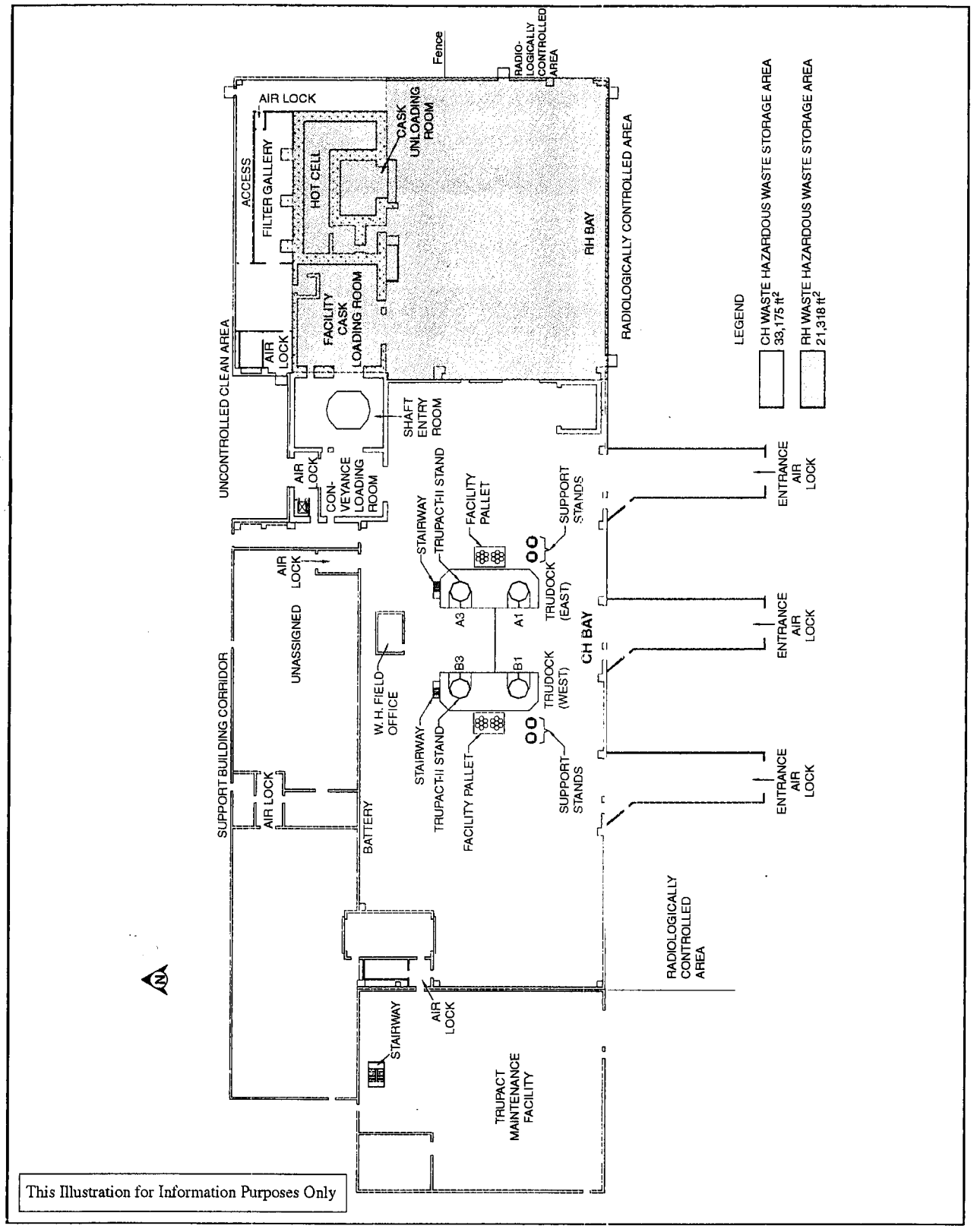

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Figure 3-3. Waste Handling Building Plan (ground floor)

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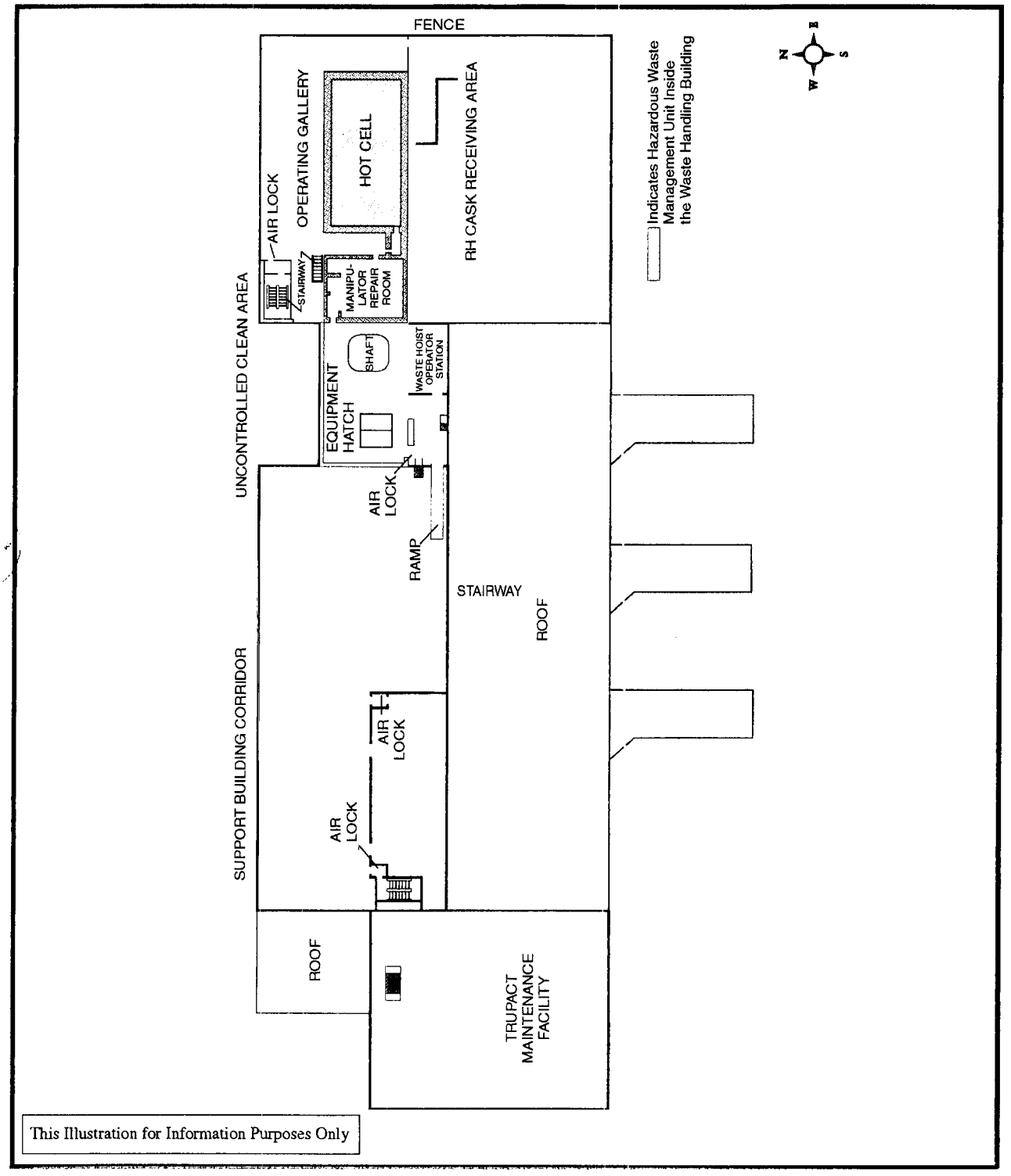

Figure 3-4. Waste Handling Building Plan (upper floor)

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withstand missiles generated by the DBT, because such missiles could not simultaneously penetrate the structures and the waste containers.

The tornado-resistant structures are designed for tornado loadings, which are calculated based on the tornado characteristics listed below. Fujita determined the parameters used for the DBT. They are the result of a site-specific wind and tornado study for the WIPP facility:

- Maximum wind speed — 183 mi per hour (294 km per hour) (including effects of suction vortices)
- Translational velocity — 41 mi per hour (66 km per hour)
- Tangential velocity — 124 mi per hour (200 km per hour)
- Radius of maximum wind — 325 ft (99 m)
- Pressure drop — 0.5 lb per in^2 (25.9 mm of mercury)
- Rate of pressure drop — 0.09 lb per in^2 per second (4.65 mm of mercury per second)

The above tornado parameters are based on a return period of 1,000,000 years. The maximum wind speed is the vector sum of all velocity components.

The DBT of 183 mi per hour (294 km per hour) with a return period of 10^6 years is used as the design basis for the Design Class II surface confinement and associated structures. The complete design loads criteria for Design Classes II, IIIA, and IIIB are delineated in Table 3-2.

3.2.3 CH-TRU Waste Handling Facilities

The CH-TRU waste area is a low bay area located on the first floor of the west half of the WHB. It provides space and houses equipment for the unloading of TRUPACT-II shipping containers and the subsequent transfer of waste containers to the waste hoist for transfer underground. This space in the WHB will be permitted as a container storage unit so that waste containers can be retained during pauses in the handling process. The CH-TRU waste handling area consists of approximately 50,000 ft^2 (4,645 m^2). The ventilation subsystem supporting the CH Bay area has an exhaust capability of approximately 18,450 ft^3 per minute (523 m^3 per minute).

During facility operations, the WIPP will receive and dispose up to 6.2 million ft^3 (175,600 m^3) of TRU waste. CH-TRU waste will be disposed of at the WIPP facility in containers (55-gallon drums, standard waste boxes [SWBs], 85-gallon drum overpacks, or ten-drum overpacks) that are shown to meet U.S. Department of Transportation (DOT) Type A standards. The waste handling operations process is illustrated in Figure 3-5 and the flow of CH-TRU waste to the repository is shown in Figure 3-6.

Table 3-2. Design Loads by Design Class for Surface Structures

DESIGN CLASS	STRUCTURE	SEISMIC	TORNADO	SNOW	WIND
II	Waste Handling Building	DBE	DBT	27 psf (132 kg/m^2)	183 mph (293 kph)
IIIA	Support Building	UBC[a]	No[a]	10 psf (49 kg/m^2)	99 mph (158 kph)
IIIA	Exhaust Shaft Filter Building	UBC	No	10 psf (49 kg/m^2)	99 mph (158 kph)
II	Station A	DBE	DBT	27 psf (132 kg/m^2)	183 mph (293 kph)
IIIA	Building 412	DBE	DBT	27 psf (132 kg/m^2)	183 mph (293 kph)
IIIB	Warehouse and Shops Building	UBC	No	10 psf (49 kg/m^2)	91 mph (146 kph)
IIIA	Water Pump House	UBC	No	10 psf (49 kg/m^2)	91 mph (146 kph)
IIIB	Salt Handling Shaft Hoist House and Electrical Room	UBC	No	10 psf (49 kg/m^2)	91 mph (146 kph)

[a]The main lateral-force-resisting structural members of the Support Building shall be designed for DBE and DBT to prevent the Support Building from collapsing on the adjacent WHB.

Key: psf = pounds per square foot; kg/m^2 = kilograms per square meter; mph = miles per hour; kph = kilometers per hour; UBC = uniform building code

TRUPACT-IIs arriving at the WIPP facility first enter the main gatehouse vehicle trap, where a visual inspection is performed to ensure that TRUPACT-IIs are not damaged and that the documentation that accompanies the shipment is complete. The TRUPACT-II is directed to the TRUPACT-II receipt parking space outside of the WHB, where a radioactive contamination survey is performed. Any discrepancies are recorded and dispositioned prior to unloading. The TRUPACT-IIs are unloaded from their transportation trailers using a 13-ton forklift truck. They are then transported inside the WHB to the CH Bay through air locks.

3.2.3.1 Entrance Air Locks

The TRUPACT-II shipping containers are unloaded from the transport trailers, cleaned, if appropriate, and transferred into the CH Bay of the WHB via one of the three entrance air locks (Figure 3-3). The air locks facilitate the ventilation system's control of static pressure and maintain the interior of the WHB at a subatmospheric pressure. The doors at each end of an air lock are interlocked to prevent both doors from being opened simultaneously. The air locks help to ensure that airflows into the WHB, thereby precluding the inadvertent release of contamination from the building.

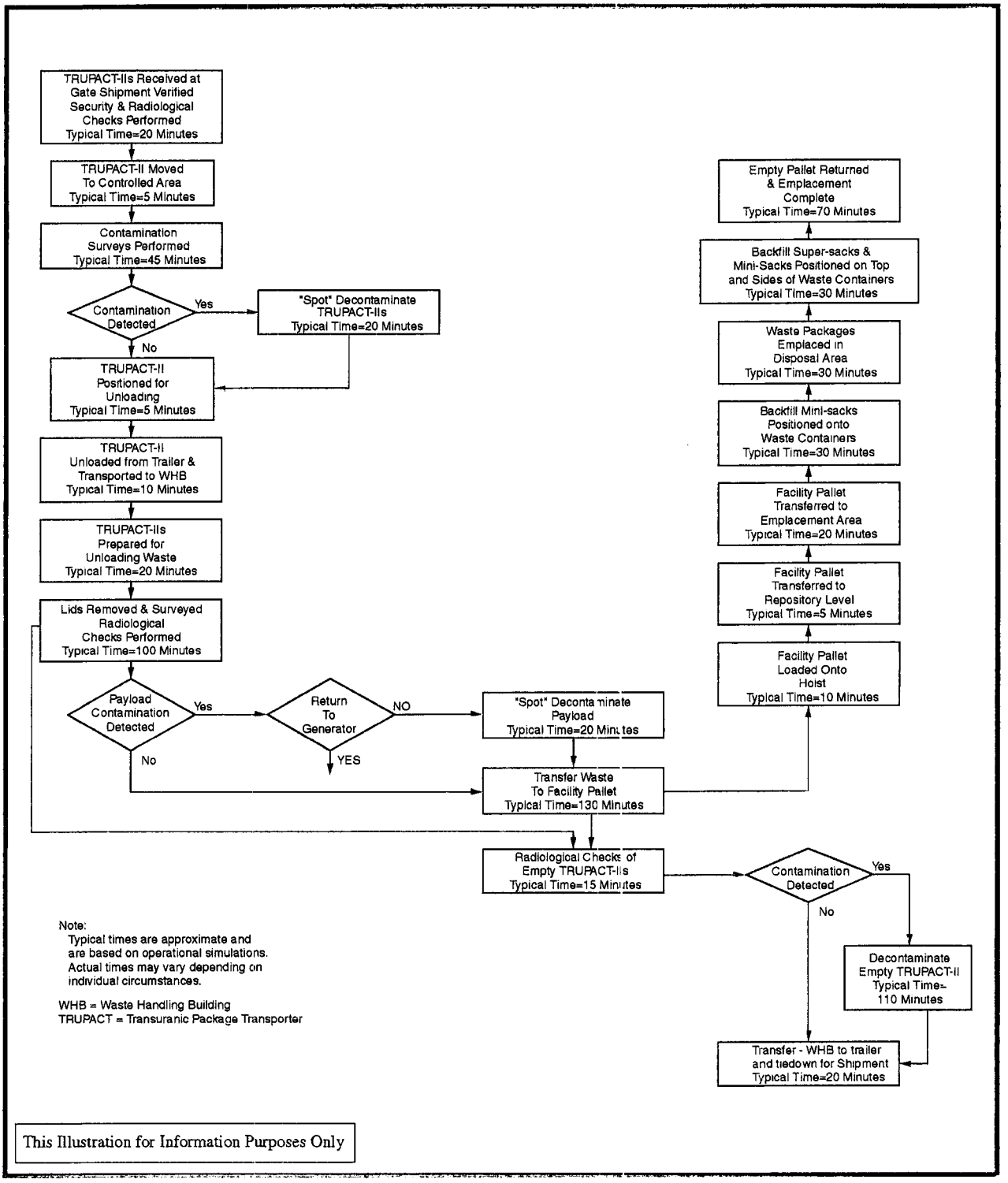

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Figure 3-5. WIPP Facility Surface and Underground CH-TRU Mixed Waste Process Flow Diagram

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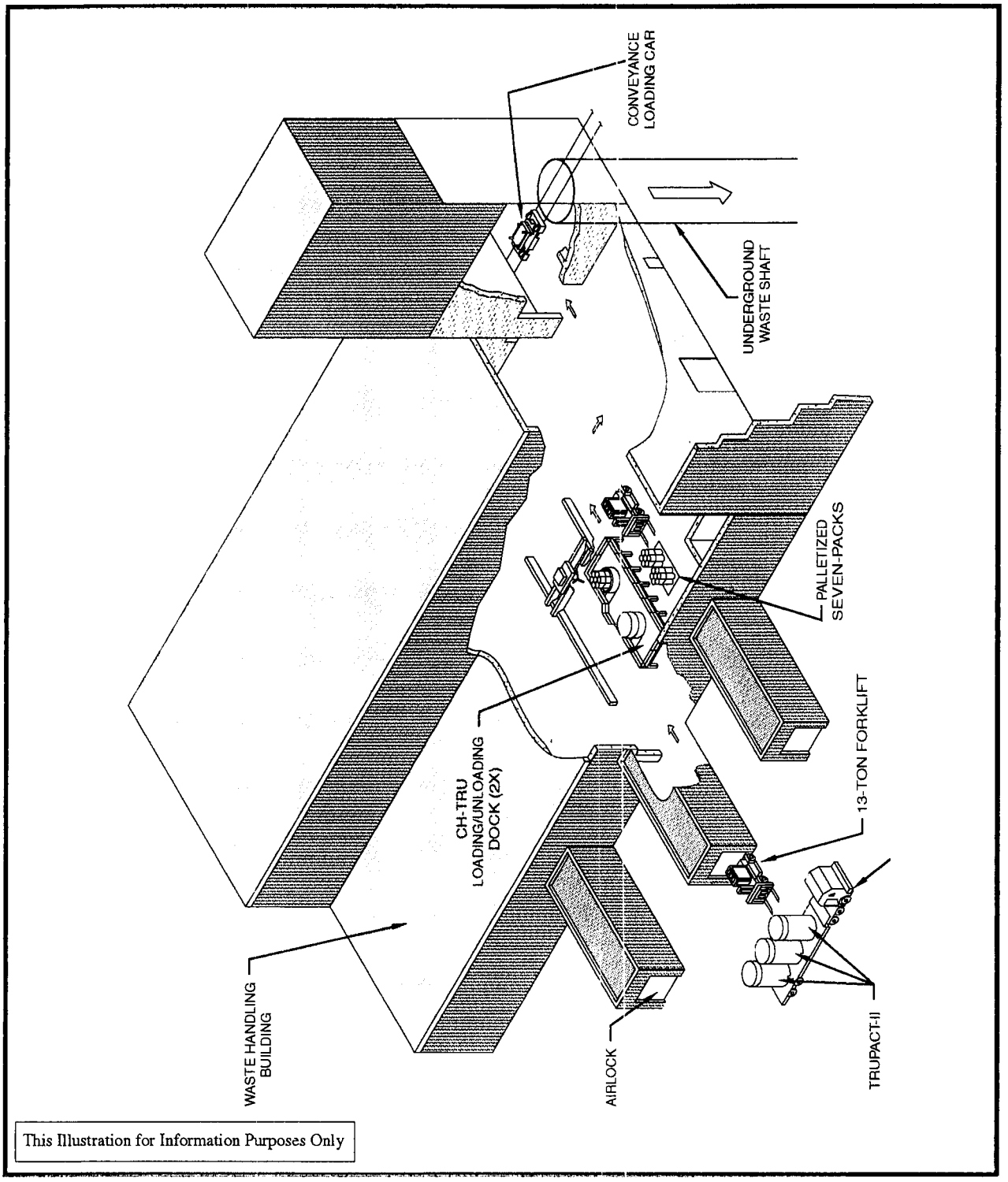

Figure 3-6. Flow of CH-TRU Waste to the Repository

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3.2.3.2 CH-TRU Waste Bay

The CH Bay on the CH-TRU waste side of the WHB is used for preparation, inspection, and inventory control of CH-TRU waste containers. The CH Bay is the primary area for surface CH-TRU waste handling operations (Figure 3-3). Inside the CH Bay, the TRUPACT-IIs are taken to one of two TRUPACT dock (TRUDOCK) staging stations where TRUPACT-IIs are opened, unloaded, and reassembled for shipment off-site. Each TRUDOCK has two TRUPACT-II support stands (workstation positions), each having the capability to handle and process one TRUPACT-II. The two TRUDOCKs—made of structural steel with aluminum work platforms—sit parallel to each other and are mirror images of each other with identical equipment. The perimeter columns of each TRUDOCK are anchored to the floor by bolts. Each TRUDOCK is equipped with an overhead crane for opening and unloading the TRUPACT-II shipping container. The dock structure provides convenient access to the shipping container for opening and unloading operations. The crane is designed to remain on its tracks and hold its load in the event of a DBE.

As the outer containment assembly lid is lifted using either an adjustable or non-adjustable center-of-gravity lift fixture, an external survey of the TRUPACT-II inner vessel will be performed to minimize the potential for spreading radioactive contamination should it be present. The inner vessel lid will be lifted under the vent hood, which is designed to ensure that any radioactive contamination is contained within the hood ventilation system and passed through a HEPA filter. If radiological contamination is detected, the inner vessel will be closed until a determination is made as to how to proceed. Depending on the amount and nature of the radioactivity and the area that is contaminated, the options include (1) decontaminate *in situ*; (2) decontaminate the containers; or (3) seal the TRUPACT-II and return it to the generator. If no internal contamination is detected at the TRUDOCK when the inner containment vessel lid is removed from the TRUPACT-II, then the payload is removed and placed on facility pallets. The empty TRUPACT-IIs are checked for contamination and decontaminated, if necessary; inspected and repaired, if necessary; and released for shipment.

The TRUPACT-II is moved into the WHB, opened and the waste containers are placed on facility pallets for movement underground. The loaded facility pallets are transferred to the conveyance loading car via forklift, loaded onto the hoist, and transferred to the underground disposal area (Chapters 3.3 and 3.4).

3.2.4 RH-TRU Waste Handling Facilities

The RH-TRU waste area is located in the east half of the WHB (Figure 3-7). The area includes structures and equipment for unloading RH-TRU waste shipping containers and transferring the waste in canisters from the shipping containers to a shielded facility cask via the Hot Cell. The RH Bay area consists of approximately 30,000 ft^2 (2,787 m^2). The RH-TRU waste handling process is illustrated in Figure 3-8. RH-TRU waste will arrive at the WIPP facility by truck or rail in a shielded, NRC-certified road cask. A

single waste canister, which holds the equivalent of three 55-gallon drums of RH-TRU waste. Upon arrival, the shipment will be visually checked for damage, the documentation will be checked for completeness, and the road cask will be surveyed for radiation dose rates. The cask will then be positioned at the RH Bay, and a contamination survey will be performed. The documentation will be verified for compliance and dispositioned prior to unloading. After it is determined that the waste shipment documentation is in order, the impact limiter collars are removed from the road cask. The cask is then upended and placed in a vertical position on the road cask transfer car with the RH Bay 140-ton overhead crane. The road cask outer lid is removed, and the cask is moved into the shielded cask unloading room, where the road cask inner lid is removed, and the waste canister is removed from the road cask and processed through the Hot Cell complex. In the Hot Cell, the canister is inspected and a contamination survey is performed. The canister can be overpacked if necessary. The canister is then transferred into the canister shuttle car. The RH-TRU waste canister is then lifted into the shielded facility cask, and the shielded gate doors are closed. The facility cask is rotated to a horizontal position and moved by the self-propelled facility cask transfer car to the Waste Shaft collar for lowering to the repository. The facility cask is then placed on the waste transfer machine assembly, which transfers the waste canister from the shielded cask into a horizontal storage borehole. After the waste canister is emplaced, the horizontal emplacement equipment inserts a shield plug into the borehole.

3.2.5 Waste Handling Building Support Areas

Support areas common to both the CH-TRU and RH-TRU waste areas of the WHB include the waste hoist support areas and the general heating, ventilation, and air conditioning (HVAC) areas required by the WHB. Air locks are located on both the CH-TRU and RH-TRU waste sides of the waste hoist (Figure 3-3). The air locks include the loading room on the CH-TRU waste side of the waste hoist and the facility cask loading room on the RH-TRU waste side of the waste hoist. Access doors to the hoist are interlocked to ensure control of airflow. In general, airflows to the shaft from the CH-TRU waste loading room or from the RH-TRU waste facility cask loading room.

The hoist control room provides space and equipment for the master control station (MCS) in the operation of the waste hoist. From the MCS, the conveyance hoist can be operated manually or automatically.

The HVAC equipment for the WHB is contained within the main mechanical equipment room, located on the upper level (Figure 3-4). This area houses the exhaust fans, HEPA filters (except for the Hot Cell HEPA filters, which are located adjacent to the Hot Cell), and associated equipment that controls ventilation flow within the WHB. In keeping with the design philosophy implemented at the WIPP facility, this system is designed to ensure that airflows from an area of low-potential contamination to one of higher-potential contamination.

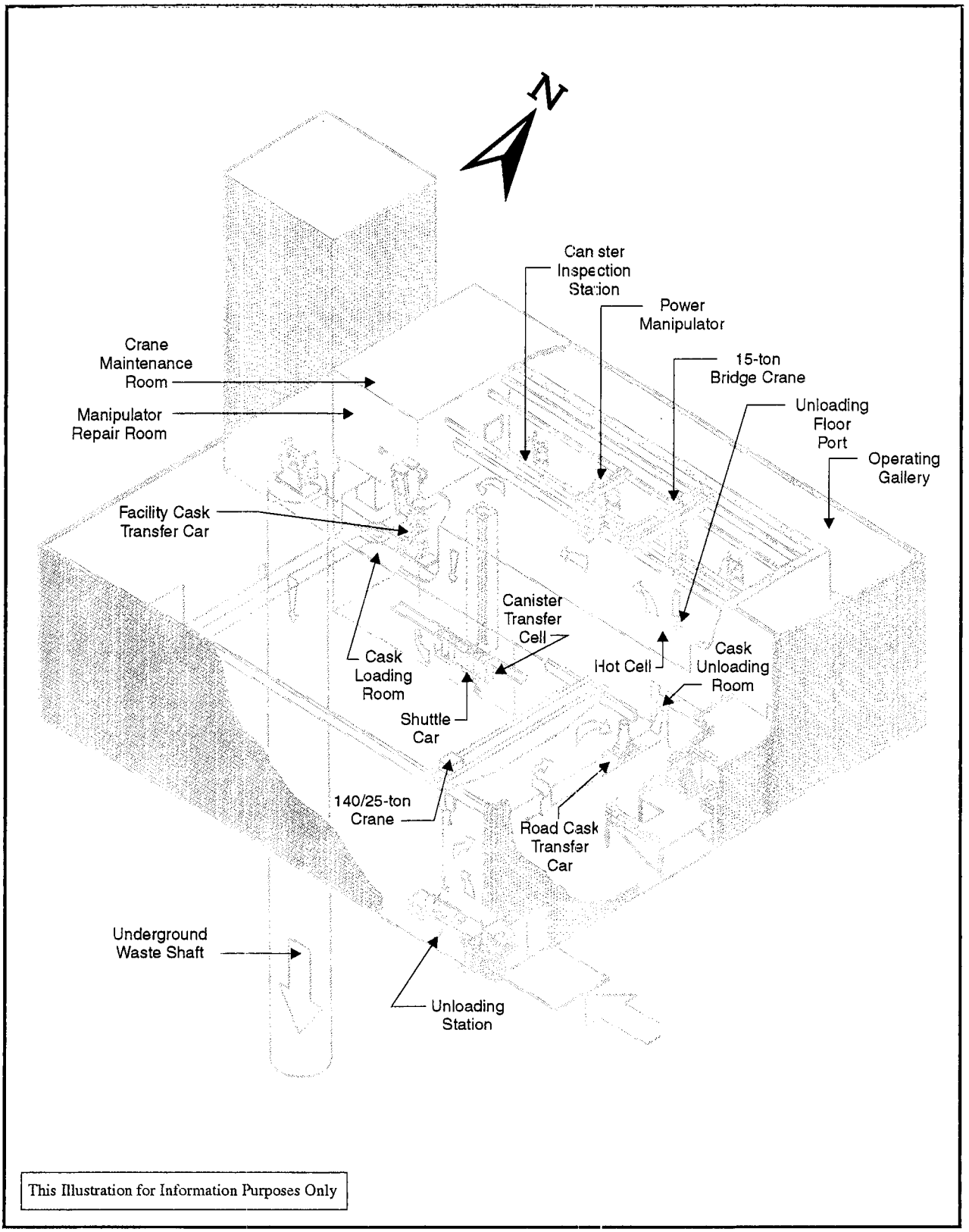

Figure 3-7. RH-TRU Waste Handling Surface Operation NMVP-6342-053-0

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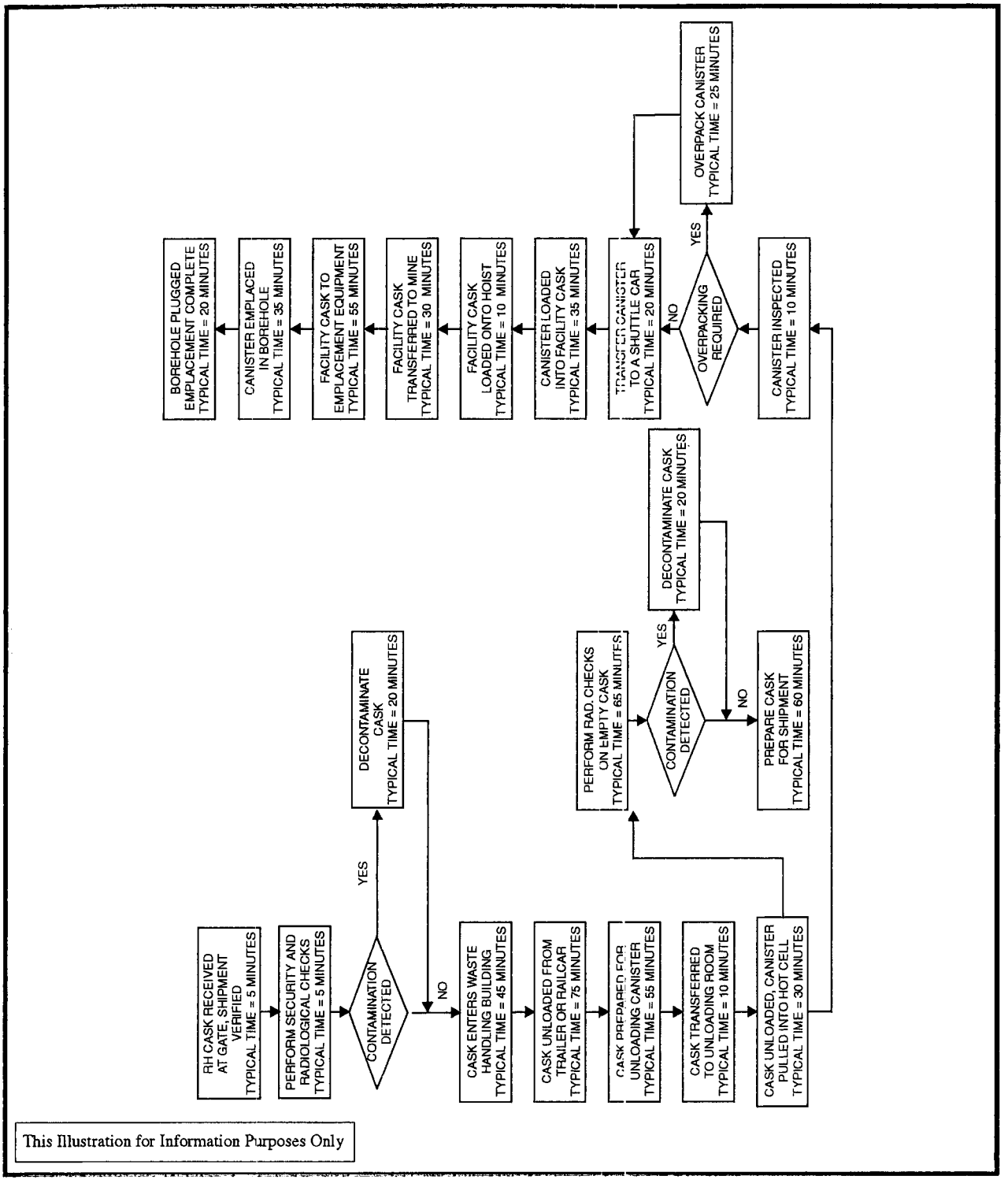

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Figure 3-8. WIPP Facility Surface and Underground RH-TRU Mixed Waste Process Flow Diagram

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3.3 Waste Shaft and Hoist

The principal components of the shaft are the shaft collar, the shaft lining, and the shaft key, which terminates the lining in the salt formation. The waste hoist and Conveyance (located at the Waste Shaft) provides the primary method to transport radioactive waste canisters, underground mining and waste handling equipment, and materials between the surface at the WHB and the underground horizon. The waste hoist subsystem is also used as a primary personnel evacuation system in an emergency. Figure 3-9 depicts the Waste Shaft and waste hoist arrangements.

The hoist has two sets of independent brakes, which are designed so that either brake set acting alone can stop and hold the fully loaded conveyance at any point in the shaft under emergency conditions. In the event of a power failure, the brakes are designed to set automatically. A control system detects malfunctions or abnormal operations of the hoist system, such as overtravel, overspeed, power loss, circuitry failure, or starts made from a wrong location. Upon detection, an alarm is triggered and the hoist automatically shuts down. The allowable stress for the steel members and connections is limited to 25 percent of the American Institute of Steel Construction (AISC) allowable stresses to allow for accelerations, decelerations, impact loading, and fatigue.

The waste hoist is a counterbalanced, multi-rope friction hoist that operates a single conveyance vertically in the Waste Shaft. The hoist is equipped with a conveyance, counterweight, headropes, tailropes, and guideropes. The waste hoist conveyance has an upper and lower deck. The lower deck, which is approximately 15 ft (4.6 m) below the upper deck, is used to transport waste containers, waste handling equipment, and materials to the repository. The upper deck may be used to carry personnel when the lower deck is empty. The waste hoist conveyance is capable of carrying a payload of 45 tons (41 metric tons). During loading and unloading operations, the conveyance is steadied by fixed guides. The hoist's maximum rope speed is 500 ft per minute (152 m per minute) with a counterweight of 51 tons (46 metric tons), which is used to balance the waste hoist conveyance.

The Waste Shaft provides for the movement of packaged radioactive waste, waste handling personnel, and equipment between the WHB and the underground waste handling station. The Waste Shaft also provides ventilation to the repository and helps maintain a negative pressure on the WHB to control any possible release of radioactivity. The shaft collar, situated about 400 ft (122 m) above the historic floodplain of the Pecos River, is supported by rock and is designed for all vertical and lateral loads. The collar slab surrounding the shaft is at a higher elevation than the surrounding ground. The concrete shaft collar, extending from the ground surface to the top of the rock, approximately 20 ft (6.1 m), forms the uppermost portion of the Waste Shaft and penetrates generally granular soils (Figure 3-9). It serves to retain adjacent soil and prevent surface runoff from entering the shaft. The collar is the foundation for the hoist tower, and the foundation slab and walls for the Hot Cell in the WHB.

The components of the shaft lining consist of the non-reinforced concrete shaft lining and the reinforced concrete shaft key. The concrete shaft lining, which extends from the bottom of the shaft collar to the top of the shaft key at the salt and rock interface approximately 850 ft (260 m) below the surface (Figure 3-9), controls water seepage into the Waste Shaft and retains loose rock. Water collection rings are installed in the concrete liner, one each beneath the Magenta and Culebra water-bearing zone and one at the base of the shaft key. The three collection rings are drained by a 2-in. (5.1-cm) diameter pipe that extends to the repository horizon.

The shaft key, a reinforced concrete ring, serves as the transitional element between the lined and unlined sections of the Waste Shaft. The key extends a minimum of approximately 56 ft (17.1 m) below the rock and salt interface into sound salt and is designed to resist the lateral pressure generated by salt creep and retain the rock formation. Chemical seal rings and water collection rings are provided with the shaft key to prevent water from flowing down the unlined shaft from the above lining.

3.4 Underground Facilities

The WIPP underground facilities are located on the repository horizon 2,150 ft (655 m) beneath the surface (Figure 3-1). These facilities include the waste disposal area, experimental area, mining area, shaft pillar area, interconnecting entries, and associated support facilities. The underground support facilities service and maintain all underground equipment for mining and disposal operations, monitor for radioactive contamination, and allow limited decontamination of personnel and equipment. Only the areas relevant to this petition are discussed further.

The disposal rooms and panel entries are designed to permit the permanent isolation of TRU waste. Validation of the disposal rooms' design was primarily based on data from four test rooms. The disposal rooms were analyzed by the WIPP architect and engineer with a finite element model using creep parameters from the test rooms. The results provided determinations of horizontal and vertical stresses, effective stresses, effective creep strains, principal stresses, room deformation and closure, and intersection closure. Nominal dimensions for the reference design are 13 ft (4 m) high × 33 ft (10 m) wide. This envelope accommodates the anticipated creep during the five years that a disposal room is expected to be open. Validation of the final design is in the WIPP Design Validation Final Report (Bechtel 1986).

During the disposal phase, the volume of TRU-mixed waste emplaced in the repository will not exceed 6.2 million ft^3 (175,600 m^3). Waste will be disposed of in the repository.

Main entries and crosscuts in the repository are constructed using either a continuous drum miner or roadheader. These areas provide access to the disposal area. The main entries link the shaft pillar/service area with the TRU-mixed waste management area and are separated by pillars. Normal entries are 13 ft (4.0 m) high and 14 ft (4.3 m) wide.

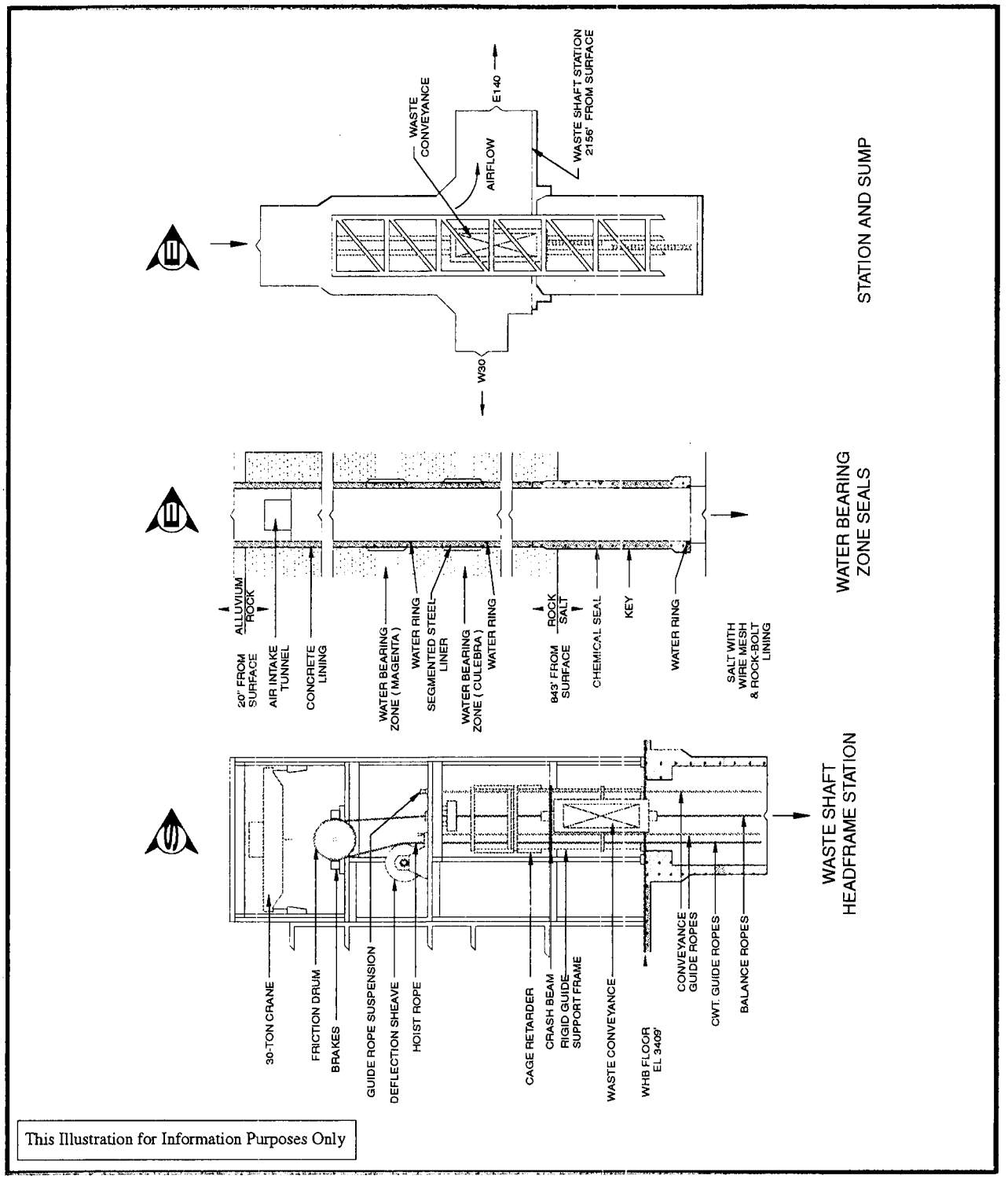

Figure 3-9. General Arrangement of the Waste Shaft

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Each of the underground disposal units labeled Panels 1 through 8 will have seven rooms. The location of these units is shown in Figure 3-1. The rooms will have nominal dimensions of 13 ft (4.0 m) high by 33 ft (10 m) wide by 300 ft (91 m) long and will be supported by 100-ft (31-m) wide pillars. If waste volumes disposed of in the eight panels fail to reach the stated design capacity, the DOE may choose to use the four main entries and crosscuts adjacent to the waste panels for disposal.

Panel 1 will be the first disposal unit to be used for waste disposal and was excavated from 1986 through 1988. Its rooms and panel entries have been rock-bolted to assure stability. Panel 1 rooms are typically pattern-bolted with 10-ft (3-m) mechanical bolts. In addition, Room 1 has been supplied with a supplementary roof-support system consisting of rock bolts, steel channel sets, and a wire-mesh and lacing system. The DOE intends to mine panels in the following order:

Panel 2 panel entries (up to S2520)
Panel 2
Panel 3 panel entries (up to S3080)
Panel 3
Panel 4 panel entries (up to S3650)
Panel 4
Panels 5, 6, 7, 8

It is anticipated that Panels 2 though 8 will only be open for around five years. This includes 30 months to mine and outfit the panel and 30 months to fill it with waste and close it. At normal waste throughput rates, rock bolting in Panels 2 through 8 may only be required locally (i.e., spot bolting).

Because the main entries must remain open and operational for a much longer period than any panel, they will require additional consideration from time to time. They are subject to regular and systematic inspection and evaluation, and appropriate ground-control measures will be implemented whenever necessary.

Table 3-3 lists types of equipment used in underground waste handling operations. The disposal rooms and panels will be excavated in stages coordinated with scheduled arrival of waste (i.e., completing excavation of the next panel will be scheduled to coincide with completing disposal operations in the previous one). Waste disposal is designed not only for the rooms but also for the panel entries and main entries in the waste disposal area.

Disposal areas containing TRU waste will have restricted access to limit exposure of individuals to radiation, radioactive materials, and hazardous constituent emissions. Normal access to and from these areas will be via the area control point. Personnel access for disposal operations will be conducted at a point upstream (ventilation) from TRU waste. Waste will be emplaced in such a way that personnel are working upstream of active waste emplacement operations in the ventilation airflow. This prevents

Table 3-3. Underground Waste Handling Equipment

Equipment	Function	Description
Horizontal Emplacement Equipment	Transfers RH-TRU waste canister from facility cask to horizontal borehole.	Waste transfer machine and borehole-related components.
Alignment Fixture	Provides reference plane for aligning waste transfer machine with respect to borehole.	Welded carbon-steel structure with base plate and vertical faceplate.
Shield Collar	Extends the shielding from facility cask to borehole.	A carbon-steel shield section used when emplacing a waste canister and shield plug into an unsleeved borehole.
41-Ton Forklift Truck	Transfers facility cask underground and places it on the emplacement machine.	Diesel-powered; has controls for lifting, tilting, fork positioning, and side-shift on both forks.
20-Ton Forklift Truck	Moves emplacement machine to borehole or storage location.	Same as 41-ton forklift truck except for capacity.
6-Ton Forklift Truck	General-purpose transfer.	Standard forklift with positioner attachments.
Underground Transporters	Moves the facility pallet to an underground storage room.	A diesel-powered tractor/trailer with an articulating frame steering system.
Brudi Attachments	Used with a 6-ton forklift truck with the forks removed to handle seven-drum packs and SWBs on a slip sheet.	Connects to the forklift truck front carriage.

exposing personnel to any airborne contamination from an accidental breach of waste containers. Work activities may occasionally require that personnel enter the downstream exhaust from an active room. In these instances, ALARA principles will be used to minimize potential exposures. Disposal areas will be continuously monitored for excessive radiation or radiological contamination when personnel are present.

3.4.1 Mining Area

Entries, rooms, and panels will be mined in a schedule that completes the next panel at the same projected time as disposal operations are to be completed in the previous panel while maintaining ventilation for waste handling and mining operations.

Mining is performed by two continuous mining machines. Prior to mining in new areas, probe holes are drilled to relieve any pressures that may be present. After mining, vertical pressure relief holes are drilled up at the main intersections of drifts and crosscuts. One of the mining machines is a roadheader with a milling head that rotates in line with the axis of the cutter boom, mining salt from the face. The mined salt is picked up from the floor by the loading apron. The other miner is a drum miner that rotates perpendicular to the axis of the cutter boom and cuts salt away from the working face. The mined salt is

pulled through the miner on a chain conveyor and then loaded in a haul vehicle that deposits it in the loading bin at the Salt Handling Shaft (SHS).

During and immediately after mining, a sounding survey of the roofs of drifts, using a scaling bar, identifies areas of drummy or slabby rock, which might present a subsequent safety hazard. Remedial work, including hand scaling of thin drummy areas, removal of larger drummy areas up to 18 in. (45.7 cm) thick with the continuous miners, or rock bolting, is accomplished immediately after soundings in any areas identified as potentially unstable. Additional scaling is performed, as required, using a mechanical scaler.

The main underground entries for the WIPP repository were designed based upon empirical data; site characterization data, including information from boreholes; surface geophysical measurements and laboratory tests; and mining and engineering standards universally applied to underground projects. The room-and-pillar design concept for the WIPP facility was based on general mining practice: such as potash mining in the Carlsbad vicinity and under similar lithologic conditions, although modifications in excavation dimensions and pillar widths were made to account for the differences in depth between potash mines and the WIPP facility repository horizon. Because the extraction ratio (the ratio of the area of salt removed by mining to the total area) at the WIPP facility is significantly lower than that used in potash mining, design parameters reflect this difference.

Design validation efforts for the WIPP facility began in 1981 with the Site and Preliminary Design Validation (SPDV) program, implemented to further characterize and validate the WIPP site geology and to provide preliminary validation of the underground excavation. The SPDV program involved excavating a test panel consisting of four full-sized SPDV test rooms, excavated 13 ft (4 m) high × 33 ft (10 m) wide × 300 ft (91 m) long, and separated by 100-ft (31-m)-wide pillars. Data obtained from geologic field activities and geomechanical instrumentation were analyzed to determine the suitability of the design criteria and design bases and to provide confirmation of the underground opening reference design.

Additional information was gathered, analyzed, and evaluated after completion of the SPDV program. A Final Design Validation Report was prepared giving the nominal dimensions for the disposal areas. As a part of the design validation process, geomechanical tests were conducted in SPDV test rooms. During the tests, salt creep rates were measured. Separation of bedding planes and fracturing were also observed. Consequently, a ground-control strategy was implemented. The ground-control program at the WIPP facility mitigates the potential for roof or rib falls and maintains normal excavation dimensions as long as access to the excavation is possible.

Data collected from geomechanical monitoring of the disposal units during the disposal phase will be evaluated periodically to help assess ground conditions. Any ground conditions exceeding established criteria will be evaluated for immediate and longer-term safety. Any operational activity in a room may be terminated depending on the results of

the evaluation, and if a roof fall is imminent, appropriate action will be taken to protect human health and the environment.

Geologic and geomechanical information are gathered from the WIPP facility underground on a regular basis, and the open disposal areas will be monitored. Geologic mapping, observational boreholes, and geomechanical instrumentation will be used to characterize the host rock, assess the effects of excavation, measure closure rates, and evaluate the behavior of the salt. This information will be used to further validate design criteria and monitor the stability of underground openings to ensure safety and operational reliability.

The data gathered from routine monitoring will be evaluated to provide early detection of conditions that could affect activities in the active disposal units during the disposal phase. If development of an unstable condition is confirmed, corrective action will be implemented. Although the monitoring system cannot predict the exact timing of any instability, it does provide early warning of deteriorating ground conditions. Over one year's warning was provided by geotechnical monitoring before each roof fall in SPDV Test Rooms 1 and 2.

Protection from radiological and chemical contaminants during the mining operations is provided by complete physical separation of the mining operations from the disposal operations. Separate ventilation supplies are provided, with pressure differentials maintained, to ensure that any ventilation leakage is from the mining areas to the disposal areas until they join for exhausting.

3.4.2 CH-TRU and RH-TRU Waste Disposal Operations

This section discusses CH- and RH-TRU waste disposal operations.

3.4.2.1 CH-TRU Waste Disposal

At the repository horizon, the facility pallet carrying the containers of CH-TRU waste is removed from the hoist cage, placed on the underground transporter, and moved to the CH-TRU waste disposal room. The disposal area provides space for 6.2 million ft^3 (175,600 m^3) of TRU waste containers. The shaft pillar area includes the four main entries and the crosscuts that provide access for these disposal rooms. The main entries link the shaft pillar and service area with the disposal area and are separated by pillars.

In the disposal room, the containers are removed from the pallet and placed in the waste stack. If the waste is packaged in drums, the drums are removed from the transporter by a forklift with a special front-end attachment and placed in their disposal location. If the waste is packaged in SWBs, a forklift with an SWB adaptor or slip sheets and a Brudi Attachment is used to transport the boxes to their disposal location. The empty pallet is reused after being surveyed for contamination and decontaminated, if necessary. After

the eight panels are filled, waste will be emplaced in the four main entries in the same mode as in the disposal rooms.

Magnesium oxide (MgO) will be used as a backfill in order to provide chemical control over the solubility of radionuclides. The MgO backfill will be purchased prepackaged in the proper containers for emplacement in the underground. Purchasing prepackaged backfill eliminates handling and placement problems associated with bulk materials, such as dust creation. In addition, prepackaged materials will be easier to emplace, thus reducing potential worker exposure to radiation. The MgO backfill will be purchased and received in two different containers: (1) a supersack holding 4,000 lbs (1,814 kg); and (2) a mini sack holding 25 lbs (11.3 kg). Quality assurance requirements, such as material quality and quantity, will be addressed by using current quality assurance procedures in the procurement process and receipt inspection. The filled containers will be shipped by road or rail and will be delivered underground using current shaft and material handling procedures and processes.

The mini sack will be 34 in. (86.4 cm) long, 6 in. (15 cm) in diameter and will be fabricated of a single layer of polyethylene or other suitable material. It will have an integral handle/hook attached into the sack closure. Six sacks will be manually placed in the external voids of each 7-pack unit just before the 7-pack is positioned on the waste stack. The mini sack will be lifted up behind the shrink wrap around the top of the 7-pack, slid into place, and held there by the four-in. hole in the lower slip sheet. Once the sacks are in place, the 7-pack will be positioned on the waste stack in the normal manner. No new equipment or training of operators is necessary. A similar process will be used for standard waste boxes (SWB), except that the sacks will be hung from the lift clips on these units.

Super sacks will be handled and placed using the slip sheet/BRUDI technique used for normal waste handling operations. Hence, no new equipment, procedures, or training are required. Once each row of waste units is in place, a layer of six super sacks will be placed on top of them. The super sack will be 5 ft (1.5 m) wide by 6 ft (1.8 m) deep by 1.5 ft (0.45 m) high and will be of multi-wall construction with a vapor/moisture barrier. The super sack will have an integral slip sheet or base attachment so that it can be handled and placed in a manner that is identical to how waste units are emplaced, using a BRUDI-like attachment on a lift truck.

Finally, mini sacks will be manually stacked on the floor in the space between the waste stack and ribside. These sacks can be placed horizontally or vertically as may be convenient and loading rates up to 100 lbs per linear ft (148.8 kg per linear m) can be achieved simply and quickly.

The DOE uses the WIPP WAC to assure that only waste compatible with the WIPP's operational and performance limitations is placed in the repository. These limitations, from the standpoint of hazardous waste constituents, are discussed in Chapter 4 and

Appendix WAP. If all waste falls within the envelope established by the WAC, no load management of waste will be necessary. That is to say, any WAC-compliant waste can be placed anywhere in the repository for disposal.

3.4.2.2 RH-TRU Waste Disposal

The facility cask loaded with the RH-TRU waste canister is driven from the waste hoist cage on the facility cask transfer car and transported by forklift to the disposal room. There, the facility cask is placed on the emplacement machine assembly. The emplacement machine assembly then inserts the canister into a predrilled horizontal hole bored into the wall of the disposal room. A shielded plug is inserted in the hole to provide radiation shielding.

The amount of RH-TRU waste disposal in each room is limited by thermal, structural, and physical considerations of equipment. Emplacement is administratively controlled not to exceed 10 kilowatts per acre. Based on the current equipment design, a spacing of approximately 8 ft (2.4 m) between centers for RH-TRU waste canisters has been specified.

3.4.3 Underground Fueling Station

The underground fuel dispensing room is located in an alcove in the mining area, as shown in Figure 3-1. This room provides a location and pumping facilities for a portable fuel tank. Portable tank hoisting is done through the Waste Shaft or the SHS, as required. A dry-chemical fire suppression system connected to a manually-activated reserve supply is provided in the fueling area at all times. In the event of a fire, smoke and fumes will be routed directly to the common exhaust.

3.5 Emergency Response

The WIPP facility maintains personnel and equipment to respond to emergencies. Emergency operations, equipment, and personnel are discussed in the WIPP Contingency Plan (see Appendix CONT).

3.6 Waste Management Support Systems

The following sections describe the subsystems that will be employed at the WIPP facility to meet the WIPP objective of safe management of TRU waste as it is emplaced for permanent disposal in the repository.

3.6.1 Ventilation Systems

The ventilation systems for the WIPP facility are designed to confine potential releases of radioactive contamination within the plant, provide the HVAC necessary for personnel comfort, and assure satisfactory equipment operation.

The total ventilation system for the WIPP facility consists of independent ventilation systems that supply the WHB, Exhaust Filter Building, each surface support structure, and underground structures. The systems supplying the WHB and the underground structures are discussed in this section. The ventilation systems serving potentially contaminated areas are once-through systems discharging to a monitored exhaust stack. The path of the ventilating air runs from areas of low-potential contamination toward areas of higher-potential contamination. The following subsections discuss the surface and underground ventilation systems in terms of their design basis, major components and operating characteristics, and safety considerations and controls.

Details of the surface ventilation system can be found in the WIPP SAR. The following discussion focuses on the underground ventilation system because of its importance to compliance calculations in Chapter 5.

The subsystems of the underground ventilation system provide a safe and suitable environment for personnel and underground operations during normal activities. The underground system is also designed to provide confinement and channeling of potential airborne radioactive material or fumes in the event of an accidental release or an underground fire.

The main underground ventilation system is divided into four separate flows (Figure 3-10), with the first flow serving the mining areas, a second serving the north areas, a third serving the disposal areas, and a fourth serving the Waste Shaft and station area. The four flows are recombined near the bottom of the Exhaust Shaft, which serves as a common exhaust route from the underground level to the surface.

The drifts and rooms within the repository have been mined running north to south or east to west. Locations in the underground area are identified with a coordinate system centered on the SHS. A drift running north-south and located 300 ft (91.4 m) east of the SHS is identified as E300, and a location in drift E300, located 90 ft (27.4 m) north of the SHS, is known as E300/N90 north. The Exhaust Shaft is located at S400/E475, and the Air Intake Shaft is located at N0/W625.

The Waste Shaft and station area receive an independent air supply. A relatively small quantity of air is drawn down the Waste Shaft to offset potential natural updraft convection currents and minimize the potential of any radioactive particles escaping up the shaft. This small quantity of air is immediately routed to the bottom of the Exhaust Shaft to avoid mixing potentially contaminated air with air being circulated throughout the repository.

The underground ventilation system is designed as an exhausting system in which the working environment is maintained below atmospheric pressure. The SHS and station, Air Intake Shaft (AIS) and station, panel mining area, and north area all have the capability for flow reversal. Flow reversal is not desired—and hence is not provided—for the waste disposal area, because control of potential contamination would become

impractical. Flow reversal may be necessary for abnormal conditions; for example, to control heat and smoke from a fire.

The underground ventilation system consists of centrifugal exhaust fans (located aboveground), two identical HEPA filter assemblies arranged in parallel, isolation dampers, a filter bypass arrangement, and associated ductwork. The fans—connected by the ductwork to the underground Exhaust Shaft so that they can independently draw air through the Exhaust Shaft—are divided into two groups. One group consists of main exhaust fans that provide an airflow of 425,000 standard ft^3 per minute (12,035 standard m^3 per minute) through the repository during normal operation. These fans are located near the Exhaust Shaft. The second group is comprised of the filtration fans, and each can provide 60,000 standard ft^3 per minute (1,700 standard m^3 per minute) airflow. These fans, located in the Exhaust Filter Building, are capable of being employed during the filtration mode, where exhaust is diverted through HEPA filters, or in the reduced or minimum ventilation mode of operation.

The underground mine ventilation is designed to supply sufficient quantities of air to all areas of the repository as required by 30 CFR 57, Subpart G and the New Mexico Safety Code for all mines. During normal operating mode (simultaneous mining and waste emplacement operations), approximately 140,000 actual ft^3 per minute (3,965 m^3 per minute) can be supplied to the panel area during the unfiltered "normal" mode of ventilation operation. This quantity was determined to be necessary based on projections of the level of work activity and the amount of diesel equipment expected to be in operation.

At any given time during waste emplacement activities, there may be a significant level of activity in three rooms. One room will be receiving CH-TRU waste containers, while the next room will be receiving RH-TRU waste. Drilling will be taking place in the third room for RH-TRU emplacement boreholes. The remaining rooms in a panel will either be completely filled with waste; be idle, awaiting waste handling operations; or being prepared for waste receipt. Approximately 35,000 ft^3 per minute (990 m^3 per minute) will be required in each of these active rooms during operations. This quantity of air is required to support the numbers and types of diesel equipment expected to be in operation in the area, support the personnel working underground, and exceed a minimum air velocity of 60 ft (18 m) per minute as specified in the WIPP Ventilation Plan. The remainder of the air is needed to account for air leakage through inactive rooms. Airflow quantities can be adjusted to assure compliance with applicable underground air quality requirements.

Air will be routed into a panel from the intake side. Air is routed through the individual rooms within a panel using underground bulkheads and air regulators. Bulkheads are constructed by erecting framing of rectangular steel tubing and screwing galvanized sheet metal to the framing. In order to accommodate creep, bulkhead members use telescoping extensions that are attached to the framing and can be adjusted periodically.

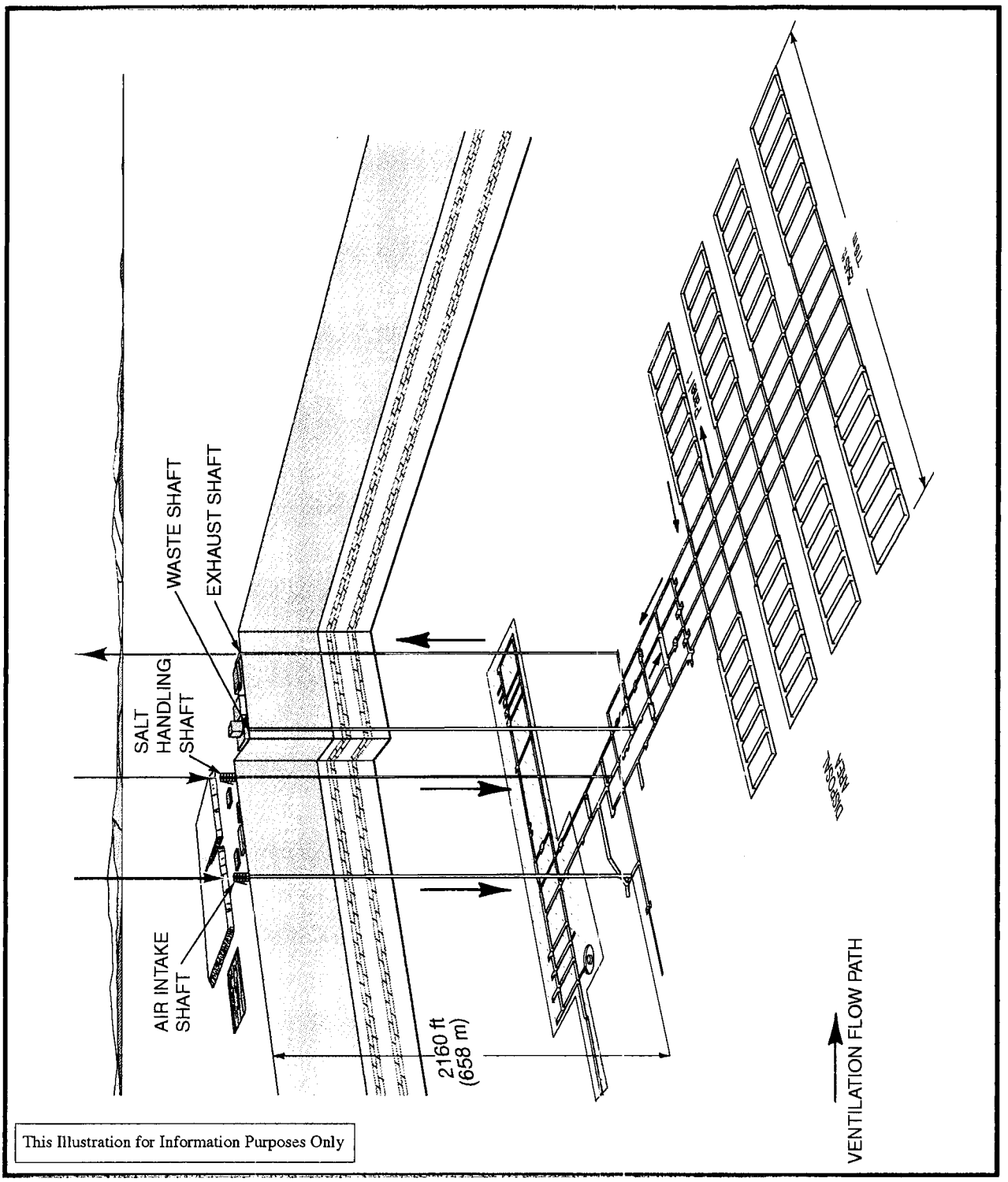

Figure 3-10. General Underground Panel 1 Ventilation System Airflow

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Because bulkheads are intended to seal the ventilation system, they use either a sheetmetal or rubber gasket that is attached to the bulkhead on one side and the salt on the other. Flow is also controlled using brattice cloth barricades. These barricades consist of chainlink fence that is bolted to the salt and covered with brattice cloth and are used in instances where the only flow control requirement is to block the air. Ventilation will be maintained only in all active rooms within a panel until waste emplacement activities are completed and the panel-closure system is installed. The air will be routed simultaneously through all the active rooms within the panel. The rooms that are filled with waste will be isolated from the ventilation system, while the rooms that are actively being filled will receive a greater volume of air to assure worker safety. After all rooms within a panel are filled, the panel will be closed using a closure system described in Appendix CLP.

Once a disposal room is filled and is no longer needed for emplacement activities, it will be barricaded against entry and isolated from the mine ventilation system by removing the air regulator and constructing chain link/brattice cloth barricades. There is no requirement for air for these rooms, because personnel and/or equipment will not be in these areas. For air dispersion modeling purposes, it is assumed that no air goes through each filled room.

The ventilation path for the waste disposal side is separated from the mining side by means of air locks, bulkheads, and salt pillars. A pressure differential is maintained between the mining side and the waste disposal side to ensure that any leakage is towards the disposal side. The pressure differential is produced by the surface fans in conjunction with the underground air regulators.

The system is designed to perform under three modes of operation: unfiltered mode (HEPA exhaust filtration system bypassed), filtered mode (exhaust filtered through HEPA filtration system if the concentrations of radioactive contaminants exceed preset limits), and air reversal mode. Continuous air monitors (CAMs) are installed to detect significant airborne radioactive contaminants in the waste disposal areas and in the discharge to the surface exhaust stack (Station A). The design airflow quantities are based upon federal and state mining laws and standard mining practices.

In the unfiltered "normal" mode, the two main surface exhaust fans, located near the Exhaust Shaft, continuously ventilate the underground areas during simultaneous mining and waste handling operation. All underground flows join at the bottom of the upcast Exhaust Shaft before upcasting to the surface for discharge to the atmosphere. In this mode, the filter assemblies are isolated and bypassed.

If both main exhaust fans are unavailable, they are isolated, and ventilation is supplied by operating one or two of the filtration exhaust fans. To accomplish this, the isolation dampers are opened, permitting air to flow from the main exhaust duct to the HEPA plenum. The isolation dampers of the filtration exhaust fan(s) to be employed are opened, and the selected fan(s) are switched on. In this mode, repository operations are extremely limited. Main exhaust fans and filtration exhaust fans cannot be operated simultaneously.

Outside air is supplied from the Air Intake Shaft and the SHS to the mining areas, waste disposal areas, and experimental complex via main entries. A relatively small quantity of outside airflows down the Waste Shaft to ventilate the Waste Shaft station. The ventilation system is designed to operate with the AIS as the primary source of fresh air. Under these circumstances, sufficient air is available to conduct all repository operations (waste handling, mining, experimentation, and support) simultaneously.

In the filtration mode, the exhaust air passes through two identical filter assemblies with one of the three Exhaust Filter Building associated fans operating (all other fans are stopped). This system provides a means for removing the airborne radioactive contaminants in the reduced exhaust flow before they are discharged through the exhaust stack to the atmosphere. The filtration mode can be activated either manually or automatically on detection of abnormally high concentrations of airborne radioactive particulates by the radiation monitoring system. One alarm from the Station A Effluent Sampling System, located at the top of the Exhaust Shaft on the surface, will automatically divert the exhaust air through the Exhaust Filter Building HEPA filter plenum. The reduced exhaust flow is diverted to the HEPA filters by isolation and diversion dampers on the exhaust fans and ductwork. Unfiltered exhaust flow with abnormally high concentrations of airborne radioactive particles is thereby prevented from escaping to the atmosphere.

Transfer of the exhaust system to the filtration mode can be accomplished automatically or manually by the Central Monitoring Room (CMR) operator. CAMs are located in the repository to monitor the airflow path for radiological contamination from the waste disposal area.

A set of booster fans permits selective reversal of airflow in the mining area, experimental area, AIS and station, and the SHS and station. In this mode, the airflow is reversed by opening and closing certain ventilation doors and air regulators and by operating the underground booster fans, which are located in drift W30. These fans are normally off and isolated with airflow bypassing the fans. The surface fans are stopped before attempting any air reversal scenarios. This mode of ventilation is only implemented manually under abnormal conditions, such as fire.

3.6.2 Shafts

This system is comprised of four vertical shafts that extend from the surface to the underground storage horizon. Three of the shafts—the SHS, the Exhaust Shaft, and the AIS—are described in the following sections. The SHS and has a permanently installed hoist capable of moving personnel, equipment, and materials between the surface and the repository. The Air Intake Shaft has a permanently installed hoist for emergency egress of personnel. The Waste Shaft is described in Section 3.3.

3.6.2.1 Salt Handling Shaft

The SHS is used to transport mined salt to the surface and to provide personnel and material transportation between the surface and the underground horizon. In addition, the shaft serves as a secondary source of downflow fresh air to the underground mining and disposal areas. It is also one route for the power, control, and communication cables.

The SHS is lined with fabricated steel that extends from the shaft collar to the top of the concrete keyway. A concrete shaft collar is located at the top of the shaft along with a salt surge pad and salt retaining wall to accommodate the removal of salt from the mine. The collar has a grated cover to allow airflow, but prevent large objects from falling into the shaft. The shaft extends past the underground horizon into the salt loading pocket and sump to accommodate the salt loading equipment and operations.

The salt handling hoist system has a salt hoisting capacity of approximately 90 tons per hour (82 metric tons per hour). It is a permanently installed double-drum hoist with a single skip/cage conveyance. The skip transfers excavated salt from the waste disposal level to a surface salt handling system located at the foot of the headframe. The maximum rope speed is 1,800 ft per minute (549 m per minute). A two-deck cage is located on top of the skip and is capable of transporting 18 people. The conveyance is equipped with safety dogs, which engage on the guide timbers and bring the skip to a stop anywhere in the shaft or headframe in the event of rope or attachment failure.

3.6.2.2 Exhaust Shaft

The Exhaust Shaft is the only upflow path to exhaust air from the underground disposal areas to the surface, and is not normally accessible to personnel. The shaft lining is concrete and extends above the ground level to form a collar that prevents surface water flow into the shaft in the event of surface flooding. The shaft collar is also designed to support the exhaust plenum elbow, which directs air to either the atmosphere or the Exhaust Filter Building. The shaft lining is comprised of nonreinforced concrete and a reinforced concrete shaft key. The shaft key extends approximately 56 ft (17.1 m) below the rock and salt interface. Three water collection rings are provided; one located below both water-bearing zones to collect shaft water seepage, and a third located at the bottom of the shaft key. Water is drained from these rings via a 2-in. (5.1-cm) pipe to the repository level. Chemical seal rings are installed behind the shaft key to prevent leakage from above into the salt level. The shaft is equipped with experimentation and data acquisition devices.

3.6.2.3 Air Intake Shaft

The AIS extends from the surface to the underground horizon and provides the primary path for fresh air to the underground areas. The AIS also serves as backup egress for personnel between the underground and the surface horizon in the event of an emergency, and provides a location to mount instrumentation for measuring hydrostatic pressures

behind the lining, salt pressure behind the shaft key, and radial convergence of the shaft. The AIS is lined with nonreinforced concrete from the top of the salt to the surface, and the liner is supported by a reinforced concrete key built into the wall of the shaft. The shaft collar extends approximately 1 ft (0.3 m) above the ground level to prevent surface water from flowing into the shaft. Air-operated doors are located on the shaft collar to allow the AIS conveyance to pass through. The collar has a grated cover that allows airflow, but prevents large objects from falling into the shaft. The AIS also has a subcollar that permits the placement of utility boxes during inclement weather. Water collection rings are installed in the shaft liner to collect shaft water seepage. The rings are drained via a 2-in. (5.1-cm) pipe to a tank at the shaft underground station. Chemical seal rings are located at the shaft key to prevent water migration past the key.

The AIS has a permanently installed headframe, five sheaves, and two shaft guides. The hoist system is a single-drum hoist, a hoist conveyance with a cage, and a galloway work platform. This platform provides personnel access for maintenance of the shaft. The maximum rope speed for the cage is 800 ft per minute (244 m per minute). Under normal operating conditions, the AIS hoist is not routinely used to move personnel to and from the underground horizon.

3.6.3 Electrical System

The electrical system distributes and controls the electrical power required for the equipment and process loads (both on the surface and underground) that operate and monitor the various systems of the WIPP facility. The system interfaces with a public utility substation on-site, which provides the primary source of power. There are two other sources of power: a backup power system, which is supplied from two on-site diesel generators; and uninterruptible power supply systems, which supply transient-free, no-break power to selected operational loads and plant monitoring.

3.6.3.1 Backup Power Source

In the event of loss of normal utility power, backup power will be supplied to critical loads by either of the two on-site diesel generators. The diesel generators are located in two separate skid-mounted enclosures adjacent to the Safety and Emergency Services Building. The backup generator subsystem consists of the generator units, controls, fuel tank, feeders, and switch gear, making power available to critical loads, such as safe evacuation of the repository and operation of monitoring and protective systems. Table 3-4 highlights manually switched backup loads and priority backup loads. The engines on the generator(s) are provided with a battery start system and have a separate closed-loop cooling system. The generators may be started or shut down either locally or remotely from the CMR.

Table 3-4. Diesel Generator Load

Manually Switched Backup Loads	Priority Backup Loads[a]
Uninterruptible Power System • Central Monitoring System • WHB-selected Continuous Air Monitors	x
Central Monitoring Room • HVAC System • Utilities	x
Fire Protection Systems • Waste Handling Building • Support Building	x
Fire Pump House	
Communications Systems	
Guard & Security Building	
Air Intake Shaft Hoist (if necessary for underground evacuation)	x
WHB lighting	
WHB cranes (the first five minutes only)	
WHB vacuum pumps	
Safety & Emergency Service Building	x

[a]Other loads are picked up depending on actual kilowatt loading or by load shedding.

3.6.3.2 Uninterruptible Power Supply Systems (Essential Loads)

The uninterruptible power supply (UPS) systems supply transient-free, reliable power. This ensures that the power to key systems (including the radiation detection system for airborne contamination, the Emergency Operations Center, and the CMR) is always available, even during the interval between the loss of off-site power and initiation of backup diesel generator power.

The UPS systems consist of a battery charger, battery, inverter, synchronizer, transfer switch, distribution panels, necessary-switch gear, and transformer. During loss of alternating current (AC) power input to the UPSs, the dedicated batteries could supply power to a fully loaded UPS for 30 minutes. It is expected that the AC power input to the UPS will be restored within 30 minutes via operator action (i.e., resumption of normal power source or initiation of diesel generators).

3.6.4 Fire Protection System

The fire protection program for the WIPP facility is designed to ensure personnel safety, mission continuity, and property conservation. The WIPP facility's fire protection systems cover the areas of the WHB, the support structures, and the underground vehicle fueling area.

3.6.4.1 Fire Water Supply and Distribution System

The fire water supply and distribution system receives its water supply from two independent, aboveground water storage tanks. The tanks are constructed with welded steel, each with a maximum capacity of 180,000 gal (681,300 l). At least half of each tank's capacity (90,000 gal [340,650 l]) must be reserved for fire fighting. The system is designed to provide 1,500 gal (5,700 l) per minute for two hours to the water distribution system supplying the fire hydrants and sprinkler systems. This flow rate is based on the calculated amount of water estimated for fire control.

Water is supplied to the WIPP facility structures by a compound loop distribution system serving the entire plant. Two centrifugal fire pumps—one electric-motor driven and one diesel-engine driven—are provided, each with the ability to deliver 100 percent of the design flow of 1,500 gal (5,700 l) per minute at a discharge pressure rate of 125 lb per in^2 (0.85 MPa). The fire water supply system pressure is maintained by a pressure maintenance jockey pump to avoid unnecessary fire pump starts.

The jockey pump is a centrifugal type with an approximate capacity of 10 gal (38 l) per minute.

3.6.4.2 Fire Detection and Suppression Systems

Fire protection systems are provided in the following areas:

Waste Handling Building

- Automatic Wet Pipe Sprinklers in all areas, except
  Hot Cell Complex (all elevations)
- Interior Fire Hose Connections in all areas, except
  Hot Cell Complex (all elevations)
- Fire Detection in the following areas:
  CH-TRU Waste Area
  RH-TRU Waste Area
  Hot Cell Complex (all elevations)
  Waste Hoist Tower (all elevations)
  Shielded Storage Room
- Manual Pull Stations
- Portable Fire Extinguishers

Support Building

- Automatic Wet Pipe Sprinklers (in all areas)
- Interior Fire Hose Connections
- Fire Detection in the following area:
  HVAC Fire Detection Instrumentation
- Manual Pull Stations
- Portable Fire Extinguishers

Water Pump House

- Automatic Wet Pipe Sprinklers
- Interior Fire Hose Connections
- Manual Pull Stations
- Portable Fire Extinguishers

Safety and Emergency Services Building

- Automatic Wet Pipe Sprinklers
- Manual Pull Stations
- Portable Fire Extinguishers

Underground Support Areas

- Automatic Dry Chemical Extinguishing System at the Fuel Station (actuated by thermal detectors)
- Manual Pull Stations
- Portable Fire Extinguishers
- Fire Truck

Salt Handling Hoist House and Headframe

- Automatic Wet Pipe Sprinklers
- Manual Pull Stations

Only fire extinguishing materials that are compatible with the materials involved in the fire will be used to extinguish fires. Only water and fire suppression foam will be used on fires involving TRU-mixed waste. Water and fire suppression foams are compatible with all components of the TRU-mixed waste. This is documented in the WIPP facility hazardous waste permit application (DOE 1996, App. C1).

3.6.4.3 Fire Alarm and Detection Systems

The fire alarm and detection system at the WIPP site is a signaling system comprised of a number of individual (local) alarm and detection systems that signal the CMR or, where deemed acceptable, provide only a local alarm.

Each local system is a stand-alone electrical circuit with fire detection instruments, manual actuators, and alarm devices. The electrical circuits are designed to initiate alarms, actuators, and remote signaling, as well as supervise its own system for

malfunctions. Besides the multicomponent local systems, a large number of stand-alone smoke detectors with integral audio alarms are employed throughout the site.

3.6.4.4 Evacuation Alarms

An emergency evacuation alarm system, which is installed throughout the plant, uses a distinct alarm. The evacuation alarm signals for the repository are automatically activated by the fire control system or by manual fire alarm boxes installed in all occupied areas. In areas where the noise level is high enough that an emergency message would be difficult to hear, such as areas of high traffic, or in remote areas where fans may be running, strobe lights will indicate an emergency situation.

In addition to the evacuation alarm system, the paging and general announcement system is used to inform and advise of normal and emergency conditions. The system may operate from either normal or UPS power, and thus can function in a normal power outage. Loss of a single speaker in a fire area does not result in a loss of communication, because there are many speakers installed throughout the area.

3.6.5 Roads

Access and on-site paved roads are designed to carry a load of an American Association of State Highway and Transportation Officials (AASHTO) Standard Truck #20-516 with the DOT limitations, not to exceed a total weight of 80,000 lb (36,320 kg). Facility roads include the north and south access roads, parking lots, and all roads and parking areas within the security fence.

Guard posts and railings are installed around parking areas and along roads inside the security fence to preclude any vehicles and personnel from entering or falling into any rainwater ditches.

3.6.6 Drainage

Rainwater runoff is diverted away from the surface facilities by a system of berms and ditches. The WIPP facility drainage system is designed so that storm runoff due to the probable maximum precipitation event would not flood the WIPP facility.

3.6.7 Security

3.6.7.1 Gatehouse, Fencing, and Gates

A gatehouse provides the means for the security force to control the authorized access of personnel and vehicles into the property protection area (formerly called Zone I). The gatehouse includes the following features:

- Areas for the screening of employees and visitors and inspection of hand-carried items
- Closed-circuit camera surveillance of on-site personnel approaching the gatehouse

The property protection area is protected by a chain-link fence topped with strands of barbed wire. At the gatehouse and guard and security building, the chain-link fence is replaced by the building walls. "No Trespassing" signs are posted on each gate and on the fence at regular intervals. In addition, warning signs are posted consistent with the requirements of 40 CFR § 264.14(c).

A vehicle trap at the gatehouse controls vehicle traffic in and out of the property protection area. The sliding gates of the vehicle trap restrict site access or egress while vehicle inspection is in process.

A manually-operated sliding vehicle gate in the north fence is provided for the salt haulage trucks. This gate also acts as an emergency exit for site personnel should the vehicle gate at the gatehouse not be usable for a site evacuation. The gate is locked when not in use. Gates are also located in the north fence at the northwest corner, in the south fence near the southeast corner, and in the east fence across from the gatehouse. These gates are also locked when not in use.

3.6.7.2 Lighting

Pole-mounted, high-intensity discharge lamps provide lighting along the property protection area perimeter fence. The lighting is powered from various power distribution centers and can be connected to the backup power supply system when utility power is not available.

3.6.8 Communications Systems

This section describes the internal and external communication systems used at the WIPP facility.

3.6.8.1 Internal Communications

The intraplant communications system includes: two-way communication by the public address system and its intercom phones and paging channels; an intraplant telephone system; mine phones; pagers and plectrons; portable two-way radios; and local and facility-wide alarm systems. The system is designed to provide immediate emergency instructions to facility personnel.

The public address and intercom system consists of handset stations and loudspeaker assemblies, each with multiple amplifiers. The system has multiple channels in the main buildings. The handsets are hand-held transmitter-receivers capable of transmitting to other independent handsets or to the public address loudspeakers. Communication

between parties within the plant can be established with the paging channel. Each designated location has a single set of speakers and a handset. Multiple sets are provided in large, open areas. To cover most areas in the plant, loudspeakers are properly oriented and volume levels are adjusted. If one station fails, the remaining stations are isolated from the out-of-service unit to prevent a failure in the remaining system.

The Dial Telephone system includes a Private Automatic Exchange (PAX) telephone network to provide two-way communication between any two telephones located above or below ground. This system provides direct dialing to outside telephones and direct dialing to WIPP facility telephones. Failure of a single telephone station does not affect the balance of the telephone system. If the telephone system should fail, the public address system and the portable two-way radios provide backup communications.

Plant radio stations in the Guard and Security Building, the Emergency Operations Center in the Safety and Emergency Services Building, and the CMR allow two-way radio communication with on-site personnel and with mobile and portable WIPP facility units operating on and off the WIPP site. Only the first two, however, are used in an emergency to contact off-site aid agencies.

Various alarm systems are used at the WIPP facility. The public address system has two alarm tones in use; a yelp and a gong. The signals are produced in the master public address console by a tone generator and are transmitted sitewide over the paging channel of the system, overriding its normal use. The signals are intermittent and of high intensity, lasting a minimum of three seconds. The evacuation tone is a yelp and is used for, and limited to, situations requiring immediate, rapid, and complete (or selective area) evacuation. The evacuation alarms are intermittent and of high intensity. The evacuation tone is initiated manually on the surface. In the repository, the evacuation tone may be initiated manually or automatically by underground fire detection and alarm systems. This tone is also a yelp, accompanied with strobe lights for high noise areas. These alarm signals take priority over other signals on the paging channel, but do not affect the intercom channels. Evacuation alarms using the public address system, local and plant-wide, can also be initiated manually from the CMR in the Support Building. The audible alarm signals are supplemented by warning lights in high ambient noise areas. These alarms are supplied with backup power if the off-site power supply fails. The PA system may also produce a gong tone followed by a message. Local fire alarms are bell tones. All persons who require unescorted access at the WIPP facility receive training, which includes recognition of and response to alarm signals.

3.6.8.2 External Communications

The external communication systems, designed to provide two-way communication with outside agencies or for summoning emergency assistance from off-site, include the commercial telephone system and two-way radios. Direct dialing from any telephone located above or below ground allows contact with outside agencies. Failure of a single telephone station does not affect the balance of the telephone system.

The WIPP telephone system is equipped with battery backup power. The system is also designed for generator backup power capability. The system contains a microwave radio that provides diversity from the land lines. These features result in minimum disruption of telephone service from loss of power or severed cables. In addition, the WIPP also has special telecommunications equipment independent of all other WIPP telephone systems. These include the satellite telephone, the Radio Frequency (RF) telephone link, and cellular service.

Plant radio stations in the Guard and Security Building and the Emergency Operations Center in the Safety and Emergency Services Building are used for two-way radio communication with the Eddy County and Lea County Sheriffs' departments, the Hobbs Fire Department, the New Mexico State Police, the Lea Regional Medical Center, the Guadalupe Medical Center, and the Otis Fire Response teams.

3.7 Engineered Systems

The design of the WIPP disposal system includes engineered systems to enhance performance. These include operational roof support systems that address short-term concerns and engineered barriers to significantly delay the migration of waste and waste constituents to the accessible environment.

3.7.1 Engineering Activities Underground

There are two major engineering activities that support the operation of the underground facility and assure that human health and the environment are not compromised by accidents involving roof falls. These are the ground-control program that addresses the stability of mined areas and the geomechanical-monitoring program that provides data for evaluating excavation stability.

3.7.1.1 Ground-Control Program

The ground-control program at the WIPP facility involves a very methodical approach to ensure that the repository is safe from any unplanned roof or rib falls. From the moment an excavation is mined, and throughout the life of the opening, care is taken to remove or restrain any loose, unsafe pieces of ground. Over time, areas of the roof, ribs, and floor may become unstable. To prevent this from occurring, a very comprehensive ground-control monitoring and support system has been implemented.

There are two major categories for the support systems: rock-bolt and supplementary. The rock-bolt systems are mechanically anchored bolts and a resin-anchored threaded bar. The supplementary systems include cable with mesh, truss, and the support system for Room 1, Panel 1.

The fundamentals on which the ground-control program at the WIPP facility are based are as follows:

- Ground stability is maintained as long as access is possible
- Ground-control maintenance efforts increase with the age of the openings
- Ground-control plans are specific, but flexible
- Regular ground-control maintenance is required

The approach the DOE has implemented in the ground-control program at the WIPP facility uses experience gained from observation and analysis of salt behavior underground. This experience allows various projections to be made regarding future ground-support requirements.

One of the key elements incorporated into this approach is that salt moves, or creeps. Because of its plastic nature, salt tends to flow into an excavated opening. Ground-support systems cannot resist salt creep, so in order to provide long-term support, the ground-control system must be able to accommodate the continuous creep of salt and restrain broken or fractured rock in the roof.

As more information becomes available regarding the long-term behavior of the WIPP underground excavations, the ground-control maintenance plan will be revised accordingly. The long-term plans are, therefore, flexible enough to accommodate changes. The ground-control plan is regularly reviewed and revised as iterative, periodic evaluations are performed.

3.7.1.2 Geomechanical Monitoring

The geomechanical monitoring program at the WIPP facility is an integral part of the ground-control program. HWMUs, drifts, and geomechanical test rooms will be monitored to provide confirmation of structural integrity. Geomechanical data on the performance of the repository shafts and excavated areas are collected as part of the geotechnical field-monitoring program. The results of the geotechnical investigations are reported annually. The report describes monitoring programs and geomechanical data collected during the previous year.

Description of the Geomechanical Monitoring System

The Geomechanical Monitoring System (GMS) provides *in situ* data to support the continuous assessment of the design for the WIPP repository facilities. Specifically, the GMS provides for:

- Early detection of conditions that could affect operational safety
- Evaluation of disposal room closure that ensures adequate access

- Guidance for design modifications and remedial actions
- Data for interpreting the behavior of underground openings, in comparison with established design criteria

The instrumentation in Table 3-5 is available for use in support of the geomechanical program.

The minimum instrumentation for panels 2 through 8 is one borehole extensometer installed in the roof at the center of each disposal room. The roof extensometers will monitor the dilation of the immediate salt roof beam and possible bed separations along clay seams. Additional instrumentation may be installed as conditions warrant.

Remote polling of the geomechanical instrumentation will be performed at least once every month. This frequency may be increased to accommodate any changes that may develop.

The results from the remotely read instrumentation will be evaluated after each scheduled polling. Documentation of the results will be provided annually in the Geotechnical Analysis Report.

Data from remotely read instrumentation are maintained as part of a geotechnical instrumentation system. The instrumentation system provides for data maintenance, retrieval, and presentation. The instrumentation system's cognizant engineer first retrieves the data from the instrumentation system and verifies their accuracy by assuring the measurements were taken in accordance with applicable instructions and that equipment calibration is known. Next, the cognizant engineer reviews the data after each polling to assess the performance of the instrument and of the excavation. Data which look anomalous are detected during this polling and are investigated to determine the cause (instrumentation problem, error in recording changing rock conditions). The data are then processed to calculate various parameters such as the change between successive readings and deformation rates. The results of this assessment are reported to the cognizant ground control engineer and operations personnel. Unexpected deformation rates are investigated by Geotechnical Engineering to determine if remediation is needed.

The stability of an open panel excavation is generally determined by the rock deformation rate. The excavation is considered unstable when there is a continuous increase in the deformation rate that cannot be controlled by the installed support system. The evaluation of the performance of the excavation is performed by Geotechnical Engineering. These evaluations will assess the effectiveness of the roof support system and estimate the stand-up time of the excavation. If the trend is toward adverse (unstable) conditions, then the results of these assessments are reported to the Operations Manager to determine if it is necessary to terminate waste disposal activities in the open panel.

Table 3-5. Instrumentation Used in Support of the Geomechanical Monitoring System

Instrument Type	Features	Parameter Measured	Range
Borehole Extensometer	The extensometer provides for monitoring the deformation parallel to the borehole axis. Units suitable for up to five measurements anchors in addition to the reference head. Maximum borehole depths shall be 50 ft.	Cumulative Deformation	0-2 in.
Borehole Television Camera	Closed circuit television may be used for monitoring areas otherwise inaccessible, such as boreholes or shafts.	Video Image	N/A
Convergence Points and Tape Extensometers	Mechanically anchored eyebolts to which a portable tape extensometer is attached.	Cumulative Deformation	2-50 ft
Convergence Meters	Includes wire and sonic meters. Mounted on rigid plates anchored to the rock surface.	Cumulative Deformation	2-50 ft
Inclinometers	Both vertical and horizontal inclinometers are used. Traversing type of system in which a probe is moved periodically through casing located in the borehole whose inclination is being measured.	Cumulative Deformation	0-30 degrees
Rock Bolt Load Cells	Spool type units suitable for use with rock bolts. Tensile stress is inferred from strain gauges mounted on the surface of the spool.	Load	0-300 kips
Earth Pressure Cells	Installed between concrete keys and rock. Preferred type is a hydraulic pressure plate connected to a vibrating wire transmitter.	Lithostatic Pressure	0-1000 psi
Piezometer Pressure Transducers	Located in shafts of robust design and construction. Periodic checks on operability required.	Fluid Pressure	0-500 psi
Strain Gauges	Installed within the concrete shaft key. Suitably sealed for the environment. Two types used—surface mounted and embedded.	Cumulative Deformation	0-3000 μin./in. (embedded) 0-2500 μin./in. (surface)

System Experience

Much experience in the use of geomechanical instrumentation was gained as the result of performance monitoring of panel 1, which began at the time of completion of the panel excavation in 1988. The monitoring system installed at that time involved simple measurements and observations (e.g., vertical and horizontal convergence rates, and visual inspections). Minimal maintenance of instrumentation is required, and the instrumentation is easily replaced if it malfunctions. Conditions throughout panel 1 are well known. The monitoring program continues to provide data to compare the performance of panel 1 with that established elsewhere in the repository. Panel 1 performance is characterized by the following:

- The development of bed separations and lateral shifts at the interfaces of the salt and the clays underlying the anhydrites a and b
- Room closures. A closure due only to the roof movement will be separated from the total closure
- The behavior of the pillars
- Fracture development in the roof and floor
- Distribution of load on the support system

Roof conditions are assessed from observation boreholes and extensometer measurements. Measurements of room closure, rock displacements, and observations of fracture development in the immediate roof beam are made and used to evaluate the performance of a panel. A description of the panel 1 monitoring program was presented to the members of the Geotechnical Experts Panel who concurred that it was adequate to determine deterioration within the rooms and that it could provide early warning of deteriorating conditions.

The assessment and evaluation of the condition of WIPP excavations is an interactive, continuous process using the data from the monitoring programs. Criteria for corrective action are continually reevaluated and reassessed based on total performance to date. Actions taken are based on these analyses and planned utilization of the excavation. Because WIPP excavations are in a natural geologic medium, there is inherent variability from point to point. The principle adopted is to anticipate potential ground control requirements and implement them in a timely manner, rather than to wait until a need arises.

3.7.2 Engineered Barriers

Engineered barriers can be divided into two categories; those that enhance operational performance, and those that enhance long-term performance. A key component to both

operational barriers and long-term barrier is the development and subsequent healing of a DRZ around excavations in salt.

3.7.2.1 Disturbed Rock Zone

A key to understanding the discussions about both the operational and long-term sealing systems is a knowledge of the DRZ and its implications for the sealing of a drift or shaft. A DRZ exists around the mine openings where the Salado properties have been altered from the undisturbed values. This DRZ generally forms within the first few meters of the excavation. Within the DRZ, intrinsic permeability and porosity are increased due to excavation-related stress redistribution. Within the DRZ, the dilation, drying, and dissolution of dissolved gas that occurs naturally in Salado brines cause varying degrees of brine flow. Increased permeability, decreased pore-fluid pressure, and partially saturated conditions within the DRZ all enhance potential gas flow pathways between the waste disposal rooms and brittle nearby interbed units, which may become locally fractured by being part of the DRZ and may, therefore, become locally more permeable than the surrounding salt. The DRZ is expected to undergo time-dependent changes in properties, with disturbed halite eventually healing to a final state equivalent to undisturbed halite.

The DRZ has been characterized by three approaches: visual observation, geophysical methods, and *in situ* hydrologic testing. Visual observations in boreholes and underground excavations indicate that fractures are common in the host rock surrounding the underground WIPP facility. Fracturing occurs at many scales. Geophysical studies have used seismic refraction, seismic tomography, surface wave analysis, electromagnetic methods, and direct current (DC) methods (Borns 1989). In conjunction with the *in situ* hydrologic tests, these studies define a DRZ extending to a depth of 3–16 ft (1–5 m) throughout the underground facility. The DC and electromagnetic methods indicate that fracture saturation and fracture density vary laterally along the excavations. These *in situ* studies also demonstrate that microfracturing and desaturation of the pore space have occurred within the DRZ. The dilation that results from the microfracturing in the DRZ is one component of the observed closure. The processes involved in the development of the DRZ are complex, although basically related to stress relief and rapid strain rates. The redistribution of stress around the excavation, along with the development of the DRZ, drives coupled processes, such as changes in permeability and porosity in response to fracture growth. In fact, input for a conceptual model of the repository zone requires the quantitative distributions for the porosity, permeability, and initial saturation of the DRZ. These parameters are discussed in Chapter 8.

In summary, the fundamental understanding of the creep process, along with a capable predictive technology, is well developed. This predictive technology is important, because continuum creep ultimately determines the time required for closure of the rooms and the eventual encapsulation of the waste, besides causing recompaction.

3.7.2.2 Operational Period Panel Closure Systems

Post-closure migration of hazardous waste or hazardous waste constituents to groundwater, surface waters, or the atmosphere, above levels that will harm human health or the environment, will not occur due to facility engineering and the geological isolation of the unit. The engineering aspects of closure are centered on the use of panel closures for each of the disposal panels in the repository and final facility seals placed in the shafts (see Section 3.7.2.3). The design of the panel closure system is based on the criteria that the closure system for closed panels will prevent migration of hazardous waste constituents in concentrations above health-based levels (HBLs) 5.0 ft (1.5 m) above the surface elevation during the 35-year operational and facility closure period and will withstand any flammable gas deflagration that may occur prior to final facility closure. The DOE developed a flexible design that allows components to be added or deleted to accommodate the conditions and waste characteristics encountered at the time of panel closure.

Following completion of waste emplacement in each underground Hazardous Waste Management Unit (HWMU) ventilation will be terminated in the full panel, and disposal-side ventilation will be established in the next panel to be used. The panel containing the waste will then be closed. A panel closure system will be emplaced in the panel access drifts, in accordance with the design in the WIPP facility Closure Plan in the RCRA Permit Application (see Appendix CLP). The panel closure system is designed to meet the following requirements established by the DOE for the design:

1. the panel closure system shall limit the migration of VOCs to the compliance point, so that compliance is achieved by at least one order of magnitude

2. the panel closure system shall consider potential flow of VOCs through the disturbed rock zone (DRZ) in addition to flow through closure components

3. the panel closure system shall perform its intended functions under loads generated by creep closure of the tunnels

4. the panel closure system shall perform its intended function under the conditions of a postulated methane explosion

5. the nominal operational life of the closure system is 35 years

6. the panel closure system for each individual panel shall not require routine maintenance during its operational life

7. the panel closure system shall address the most severe ground conditions expected in the waste disposal area

8. the design class of the panel closure system shall be IIIb (meaning that it will be built to generally accepted national design and construction standards)

9. the design and construction shall follow conventional mining practices

10. structural analysis shall use data acquired from the WIPP repository

11. materials shall be compatible with their emplacement environment and function

12. treatment of surfaces in the closure areas shall be considered in the design

13. thermal cracking of concrete shall be addressed

14. during construction, a quality assurance/quality control (QA/QC) program shall be established to verify material properties and construction practices

15. construction of the panel closure system shall consider shaft and underground access and services for materials handling

The performance standard for air emissions from the WIPP facility is established in Chapter 5. Releases must be below these limits for the facility to remain in compliance with no-migration standards. The following panel closure design has been shown, through analysis, to meet these standards, if emplaced in accordance with the specifications in Attachment I1 of Appendix CLP.

The panel closure system calls for a composite panel barrier system consisting of a rigid concrete plug with or without removal of the DRZ, and either an explosion-isolation wall or a construction-isolation wall. The design basis for this closure is such that the migration of hazardous waste constituents from closed panels during the operational and closure period would result in concentrations well below health-based standards. The design basis used as a source term the average concentrations of VOCs from CH-TRU waste containers as measured in headspace gases through January 1995. The VOCs are assumed to have been released by diffusion through the container vents and are assumed to be in equilibrium with the air in the panel. Emissions from the closed panel occur at a rate determined by gas generation within the waste and creep closure of the panel. The derivation of the emission rate is discussed in Chapter 5. Due to the relatively small amount of RH-TRU waste (approximately 5 percent of the total waste volume), VOC emissions from RH-TRU waste are not assumed to contribute significantly to total VOC emissions. Analysis in Chapter 5 shows that emissions meet the no-migration standard.

Figures 3-11 and 3-12 show a diagram of the panel closure design and installation envelopes. Attachment I1 of Appendix CLP provides the detailed design and the design analysis for the panel closure system. The panel closure design allows components to be

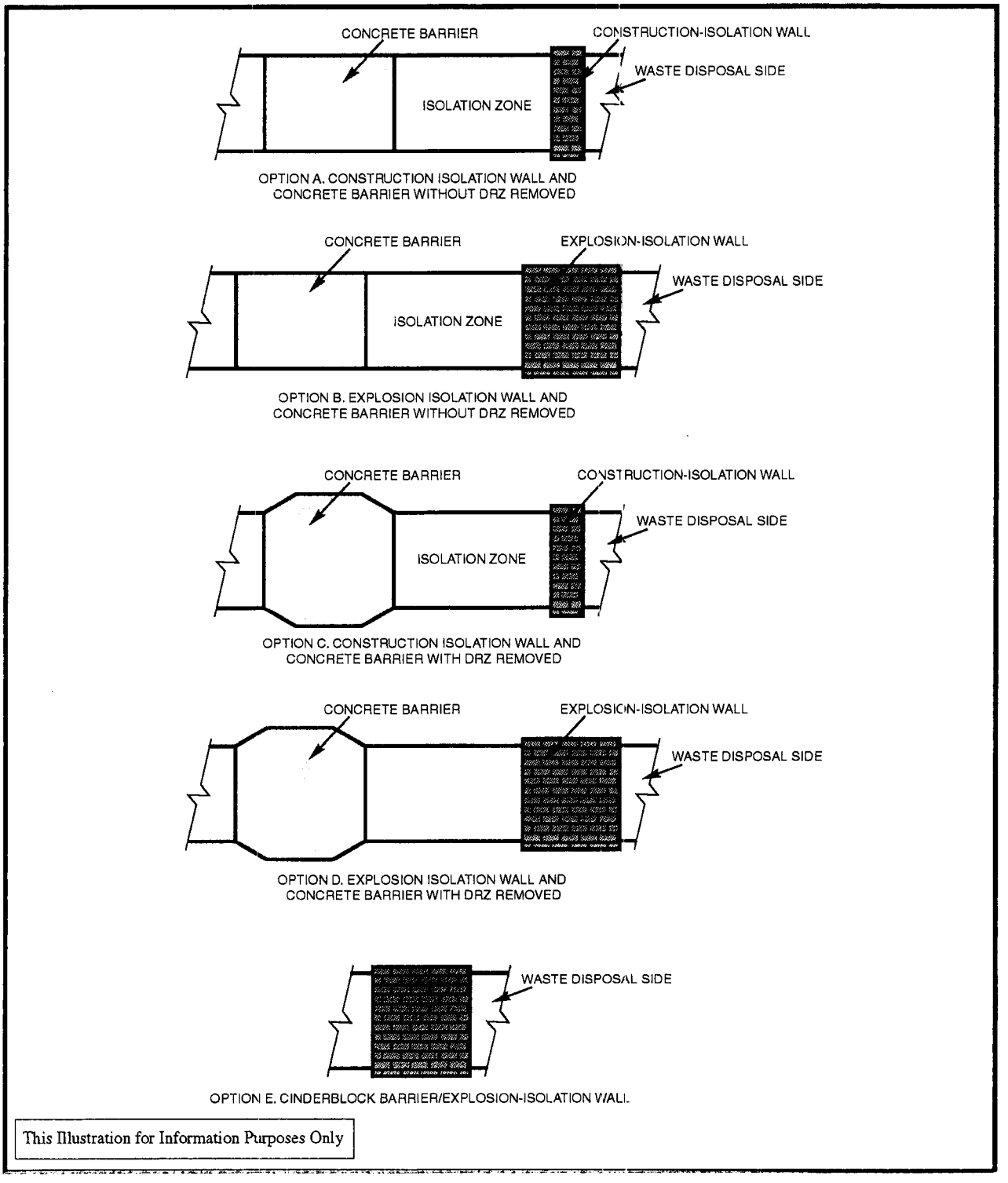

Figure 3-11. Design of a Panel Closure System

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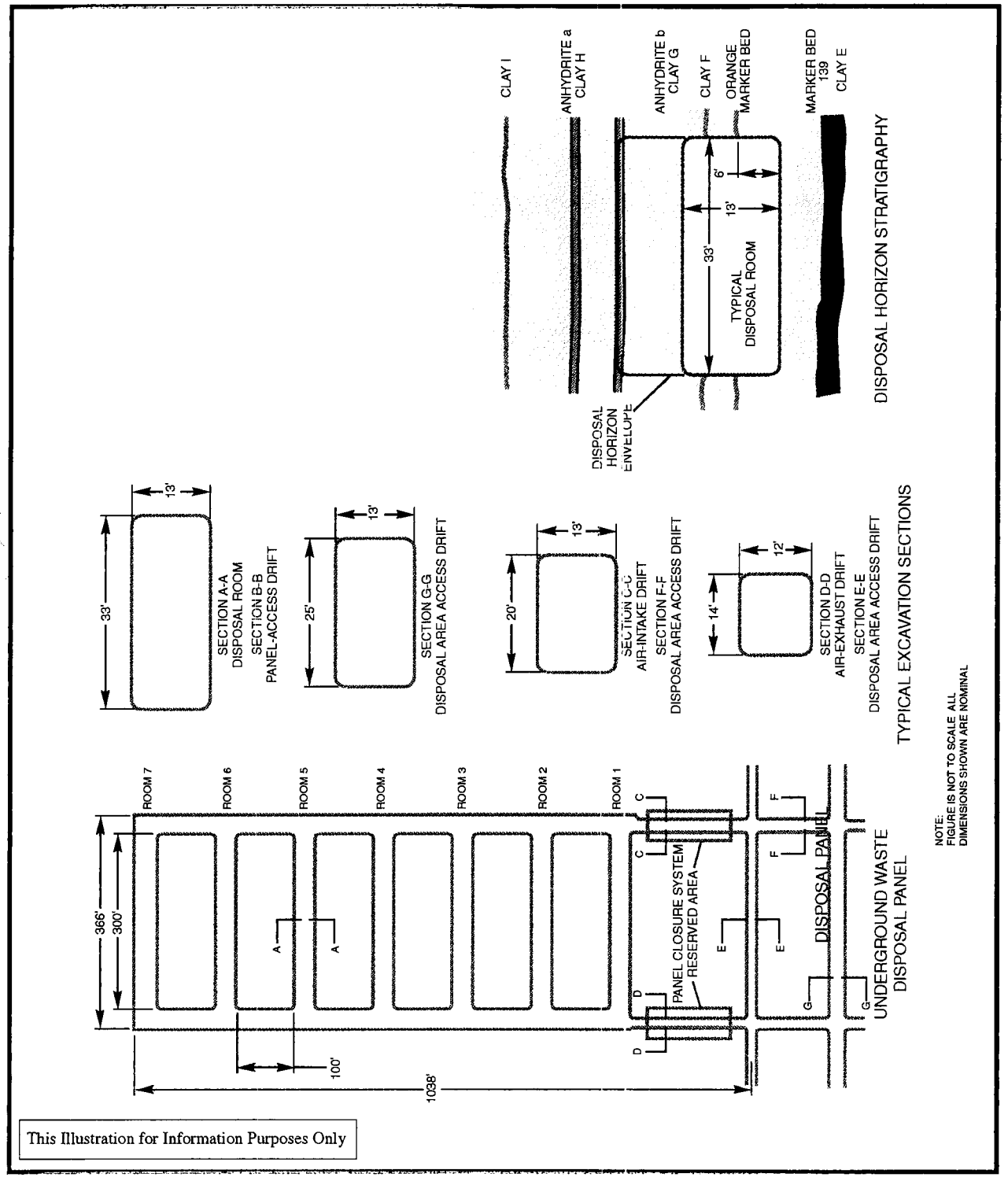

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Figure 3-12. Typical Disposal Room

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added or removed, or their shapes adjusted, depending on the particular ground conditions at the time of installation. For example, in Figure 3-11, Option A represents the likely closure of panels less than 20 years old at the time of final facility closure and whose entries are sufficiently intact that DRZ removal is not needed. Option B represents the preferred option for panels that will be closed for more than 20 years prior to final facility closure and whose entries are reasonably intact at time of closure. Option C may be desirable for panels whose entries require DRZ removal and whose closure precedes final facility closure by less than 20 years. Finally, Option D may be appropriate for panels whose entries require significant removal of the DRZ and whose closure will precede final facility closure by more than 20 years.

The 20-year limit in the design selection process is based on conservative analytical results that indicate methane, being generated by waste degradation at the rate of 0.1 mole per drum per year (see Attachment I1 of Appendix CLP), will not reach flammable concentrations for at least 20 years. As part of the decision making process on design selection, an investigation of the DRZ would precede the selection of the concrete component and the specification of the amount of excavation needed. These investigations could be done using geophysical methods (such as ground-penetrating radar) or drillholes. Drillholes can be investigated using video cameras or "scratchers."

Design Options A through D will function adequately as panel closures given the current state of knowledge about gas generation, the DRZ, the expected characteristics of the waste, and the inability of monitoring techniques to accurately detect extremely small concentrations of VOCs. However, if sufficient information is collected that allows the DOE to make less conservative assumptions regarding these items, Options A through D may provide significantly more protection than is actually needed. Consequently, the DOE has retained as a design concept Option E, which is simply the explosion wall portion of Options B and D. Option E represents a significantly simpler panel closure system that the DOE would use if:

- Work performed for the DOE indicates that gas generation rates under humid condititions may in some cases be close to zero (see Appendix PAR, PAR-58).

- Average headspace concentrations are less than the averages used in the calculations. As new wastes are generated, the use of organic solvents is expected to be drastically reduced. Some compounds, such as carbon tetrachloride, have already been banned from use at some generator sites

3.7.2.3 Shaft Seal System

The shaft seal system performance plays an important role in meeting regulatory hazardous constituents release requirements. The shaft seal system is designed to limit the release of gas and brine, and any other materials they might transport, from the repository. Although all engineering materials have uncertainties in properties, a combination of available, low-permeability materials provides an effective shaft seal

system. Components in this design include long columns of clay, densely compacted salt, and asphalt plus a salt-saturated concrete monolith, concrete plugs, and concrete-asphalt waterstops. Additional components were added to this shaft seal system to reduce system uncertainties and provide additional assurance of compliance. Different materials perform identical functions within the design, thereby adding confidence in system performance. In choosing materials, emphasis is given to the permeability characteristics and mechanical properties of shaft seal system materials. In addition, the system materials are also chemically and physically compatible with the host rock formations, thus further enhancing confidence in long-term performance.

Concrete, clay, and asphalt are common structural materials used extensively in hydrologic applications. Results from a series of multiyear, *in situ*, small-scale seal performance tests show that bentonite and concrete seals maintain very low permeabilities and show no evidence of deterioration in the WIPP environment. A large-scale field demonstration established that crushed salt can be successfully compacted. Laboratory tests show that compacted salt will consolidate through creep closure of the shaft from the initial compacted condition to a dense salt mass with nearly the same permeability as *in situ* salt.

The shaft seal system uses a variety of common materials that have very low permeability and demonstrated construction process technologies. For the long-term seal that resists both gas and brine flow, more than 500 ft (152 m) of compacted crushed salt is used in series with more than 400 ft (122 m) of clay barriers. The design retards gas flow in the short-term using a combination of a rigid concrete barrier, enhanced by concrete/asphalt waterstops, and a compacted clay barrier approximately 100 ft (31 m) high. Short-term brine flow down the shaft is limited by a clay barrier within the overlying formation and by a combination of more than 500 ft (152 m) of asphalt, clay, and concrete barriers within the Salado Formation. The complete system covers the entire length of the shaft with the upper 500 ft (160 m) consisting of compacted earthen fill. Dense, compacted seal components and rigid concrete components are particularly effective in rapidly enhancing healing of the DRZ in the Salado. See Appendix I2 in Appendix CLP for more information on shaft sealing systems.

Properly designed seals and plugs are used to limit migration of potentially contaminated liquid and gasses in the WIPP shafts and boreholes. Plugging an opening in the underground WIPP repository, whether a borehole or shaft, requires satisfactory mitigation of three potential leak paths:

- the opening itself
- the interface between the seal material and the host rock, and
- the disturbed rock zone (DRZ) surrounding the opening

Plugging and sealing activities use common engineering materials that possess low permeability, sound mechanical properties, and durability.

The shaft seal system limits transport of any fluid either up or down the shaft opening, the interface with the host rock, or the DRZ surrounding the opening. The entire shaft seal system is described in this section, including the configuration of materials, material specifications, construction methods, rock mechanics analyses, and fluid flow evaluations. Satisfactory shaft seal system performance is provided by the elements that comprise the complete seal design. These elements and the complete design package (hereafter referred to as the Final Design Report) will be provided to the EPA in October 1996.

The shaft seal system design package thoroughly explores function and performance of the WIPP shaft seal system and provides well documented assurance that such a shaft seal system could be constructed using available materials and methods. Sections of the Final Design Report provide hydrologic and structural calculations, material specifications and properties, construction methods, and engineering drawings. Documentation of material properties and their satisfactory application in the site-specific environment for periods in excess of regulatory requirements assure that the WIPP shaft seal system will meet performance expectations.

The purpose of the shaft seal system is to limit fluid flow within four existing shafts after the WIPP is decommissioned. Such a seal system would not be implemented for several decades, but to establish performance requirements now that can be achieved at that time, a shaft seal system possessing excellent durability, performance, and constructability, using existing technology, has been designed. The design approach specifies various common materials, which are configured in a manner that results in redundancy. It is recognized that the use of future developments may change the design described here, and that this design is not the only possible combination of materials and construction strategies that would adequately limit fluid flow within the shafts.

Site Setting

The geologic setting and groundwater hydrology in the proximity of the WIPP site are presented in Sections 2.1 and 2.2 of this petition, which are concerned with Site Characterization. Discussions in these sections establish low brine flow quantities and low hydrologic gradients, both very positive features with regard to sealing shafts or boreholes. Specific discussion of the relationship of the hydrologic setting and shaft seal elements is also provided in Appendix CLP. As noted in Section 2.2, one of DOE's site selection criteria is a favorable geologic setting which minimizes fluid flow as a transport mechanism. Although these positive hydrologic attributes are documented, the shaft seal design further mitigates potential fluid transport.

Rock mechanics aspects are important consideration in terms of system performance. Rock properties, in turn, affect hydrologic response of the shaft seal system. The

stratigraphic section contains lithologies which exhibit brittle and ductile behavior and the potential of the host rock to fracture, flow, and heal are consideredn in the seal system evaluation. Rock mechanics analyses address stability of seal components, influence of seal components on hydrological properties of surrounding rock, and construction. Analysis methods include finite element modeling and analytical techniques.

The hydrologic setting modeled in fluid flow analyses of the seal design is described in Chapter 2.0. For the purposes of the hydrologic sealing evaluation the lithologies have been divided into the Rustler (and overlying strata) and the Salado. The primary design concern is fluid transport phenomena of seal materials within Salado lithologies.

Design Guidance

Design guidance for the shaft seal system addresses the need for the WIPP to comply with system requirements and to follow accepted engineering practices using demonstrated technology. Shaft seal design guidance is summarized as follows:

- limit hazardous constituents reaching regulatory boundaries
- restrict groundwater flow through the sealing system
- use sound engineering materials possessing good long-term stability
- protect against structural failure of system components
- minimize subsidence and prevent accidental entry, and
- use available construction methods and materials

Details of the design respond to these qualitative design guidelines and present an implementation approach. The shaft seal system design was completed under a QA program that include review by independent, qualified experts. Reviewers examined the complete design, including conceptual, mathematical, and numerical models and computer codes. The design reduces uncertainty associated with any particular element by using multiple sealing system components and by components constructed from different materials.

Design Description

A brief description of the shaft seal system is given in this section. A much larger and detailed compilation of design drawings for each shaft seal system is provided in the Final Design Report. A schematic of the shaft seal system as configured for the AIS is shown in Figure 3-13. Slight differences in seal element geometry occur within the four shafts owing to different shaft diameters or slight stratigraphic variations.

The shaft sealing system comprises 13 elements that completely fill the shaft with engineered materials possessing high density and low permeability. Salado components

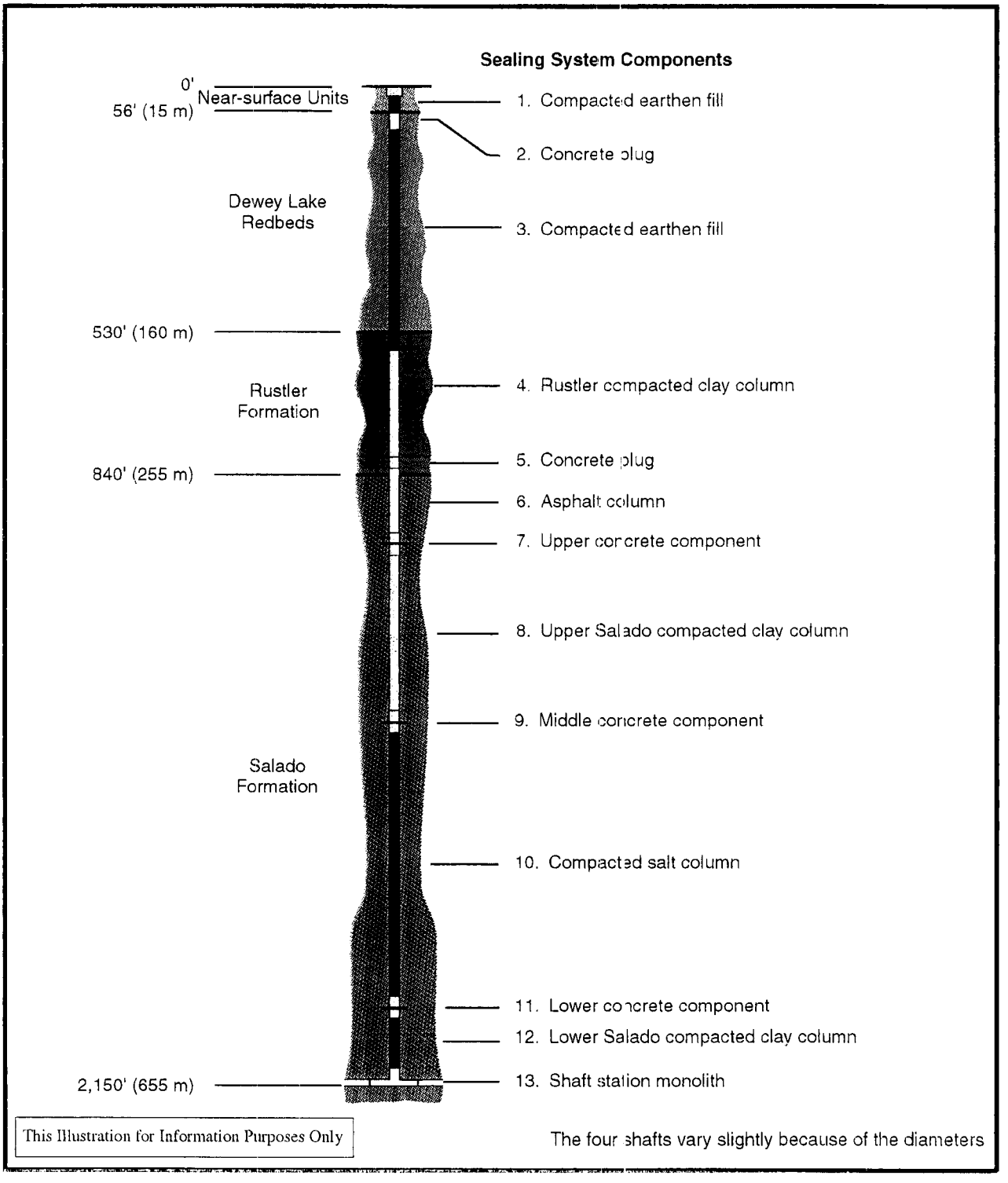

Figure 3-13. Schematic of the Air Intake Shaft Sealing System

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provide the primary regulatory barrier by limiting fluid transport along the shaft during the 10,000-year regulatory period. Components within the Rustler limit commingling between brine-bearing members, as required in state regulations. Components overlying the Rustler fill the shaft with common material of high density, consistent with good engineering practice. A brief description of the seal elements is given below. Requirements related to shaft preparation prior to emplacement of shaft seal system components will be detailed in the Final Design Report.

Shaft Station Monolith. At the bottom of each shaft, a salt-saturated concrete monolith is placed to fill the shaft station excavation. All concrete is placed using a slick line from the surface. The salt-saturated concrete is called Salado Mass Concrete (SMC) because it has been tailored to match site conditions. The SHS and the waste handling shaft have sumps which will also be filled with SMC as part of the monolith. Geometries of the monolith for the four shafts vary slightly because of the differing diameters and shaft station configurations.

Compacted Clay Columns. A commercial, well-sealing grade, sodium bentonite clay, is used for components 12 and 8 in the Salado and Component 4 in the Rustler. Construction specifications for these three components call for placement of compressed blocks to achieve design requirements. These compacted clay columns effectively limit brine movement from the time they are placed and provide an effective barrier to fluid migration throughout the 10,000-year regulatory period and thereafter. Lengths vary for each shaft based on individual shaft stratigraphy. The lower Salado compacted clay column ranges from 93 to 107 ft (28 to 33 m), the upper Salado compacted clay column ranges from 335 to 345 ft (102 to 105 m), and the Rustler compacted clay column ranges from 234 to 235 ft (71.3 to 71.6 m) in the four shafts. Locations of the Salado compacted clay columns were selected to limit brine and gas migration into the compacted salt column. The lower Salado compacted clay column stiffness is sufficient to promote early healing of fractures in the surrounding rock salt, thus removing the DRZ as a potential pathway for gases or brines.

The Rustler compacted clay column (Component #4) limits groundwater communication between the Magenta and Culebra. The Culebra accounts for most of the Rustler groundwater flow. Regionally, the Magenta has measurable flow, although it has no flow of significance in the vicinity of the WIPP site. Members above the Magenta (the Forty-niner), between the Magenta and Culebra (the Tamarisk), and below the Culebra (the unnamed lower member) are aquitards in the vicinity of the WIPP shafts. Existing shaft lining is removed from the water-bearing zones (Magenta and Culebra Members) for a distance of 10 ft (3 m) into each of the aquitards to allow the clay to contact the native rock and thus seal the shaft wall interface at these locations.

Concrete-Asphalt Waterstop Components. The upper (#7), middle (#9), and lower (#11) concrete components in the Salado are composed of three elements: an upper concrete plug, a central asphalt waterstop, and a lower concrete plug. These concrete components provide independent shaft cross section and DRZ seals that limit fluid

transport from above or below. Concrete fills irregularities in the shaft wall, while use of the SMC assures good bonding with salt. Salt creep against the rigid concrete components establishes a compressive stress state and promotes early healing of the DRZ surrounding the concrete plugs. The asphalt "waterstop" intersects the shaft cross section and the DRZ. Like the shaft station monolith, SMC is placed using a slick line while asphalt is placed using a heated slick line.

Concrete components 7, 9, and 11 have an overall design length of 50 ft (15 m). The concrete plugs on either side of the asphalt are identical. They fill the shaft cross section and have a design length of 23 ft (7 m). The plugs are keyed into the shaft wall. An asphalt waterstop is located between concrete plugs. In all cases, a kerf extending one shaft radius beyond the shaft wall is cut in the surrounding salt. The kerf is 1 ft (0.3 m) thick at its tip and 2 ft (0.6 m) thick at the shaft wall. The kerf, which cuts through the existing shaft DRZ, results in the formation of a "new" DRZ along its perimeter, but at these depths within the Salado, the "new" DRZ will heal shortly after construction, and thereafter the waterstop will provide a low permeability barrier to brine or gas migration.

Compacted Salt Column. Each shaft seal includes a length of compacted salt (Component #10) that varies from 559 to 563 ft (170 to 172 m) in the four shafts. Each compacted salt column is constructed of crushed Salado salt with about 1.5 wt percent water added during construction. Demonstrations have shown that WIPP salt can be dynamically compacted to a density equivalent to approximately 90 percent of the average density of intact Salado salt. The remaining void space is removed through consolidation caused by creep closure. The location of the compacted salt column near the bottom of the shaft assures the fastest achievable consolidation of the compacted salt column after repository closure. Salt creep increases rapidly with depth; therefore, at any given time, creep closure of the shaft is greatest at depth. The compacted salt column offers limited resistance to brine migration immediately after placement, but becomes less permeable as density increases. Analyses indicate that the salt column becomes an effective long-term barrier in less than 100 years.

Asphalt Column. An asphalt-aggregate mixture is specified for the asphalt column (Component #6), which bridges the Rustler/Salado contact. Length of the asphalt column ranges from 138 to 143 ft (42 m to 44 m) in the four shafts. The asphalt column is located above the upper concrete component (#7) and extends approximately 16 ft (5 m) above the Rustler/Salado interface. Existing shaft linings and keys are removed from 20 ft (6 m) above the top of the asphalt column to just below the lowest chemical seal ring. The asphalt column provides an essentially impermeable seal for the shaft cross section and along the shaft wall interface.

Concrete Plugs. A 20-ft (6-m) long concrete plug (Component #5) is located just above the asphalt column. The concrete plug, constructed of SMC, is placed directly on top of the asphalt column and keyed into the surrounding rock. The plug permits work to begin on the overlying clay column before the asphalt has completely cooled and allows the option of constructing the overlying clay column using dynamic compaction, although the

present design calls for construction using compressed clay blocks. Another concrete plug is (Component #2) located near the surface, extending 40 ft (12 m) downward from the top of the Dewey Lake. It is placed inside the existing shaft lining.

The shaft liner will be removed as necessary. In all lining removal areas, the shaft is grouted before removal of the shaft lining to assure structural stability of the shaft wall. The grout curtain begins 10 ft (3 m) above the lining removal areas and extends 10 ft (3 m) below the lining removal areas. Grouting is used to stabilize the shaft walls and thus provide safer working conditions; it is not considered a flow barrier within the sealing system.

Earthen Fill. Approximately 500 ft (160 m) of the upper shaft is filled with compacted earthen fill. These components (#3 and #1) use locally available fill. Component #3 is dynamically compacted (the same method used to construct the salt column) to a density at least equal to the surrounding materials. The length of this column varies from 447 to 486 ft (136 m to 148 m) in the four shafts. The uppermost earthen fill, Component #1, extends from the shaft collar through surface deposits downward to the top of the Dewey Lake Redbeds. Fill near the surface is compacted with a sheepsfoot roller or vibratory plate compactor. The length of this column varies from 40 to 92 ft (12 m to 28 m) in the four shafts.

Materials

The shafts will be entirely filled with dense materials possessing low permeability and/or other desirable attributes. Seal materials include concrete, clay, asphalt, and compacted salt. Other materials include cementitious grout and earthen fill. Concrete, clay, and asphalt are common construction materials, used extensively in hydrologic applications. Concrete is the most common structural material proposed for the WIPP shaft seal system, and its use and specification have a long history. Clay, used extensively in the seal system column, is often specified as a construction material and bentonitic clay is often specified as a low permeability liner for hazardous waste sites. Asphalt is a widely used paving and waterproofing material. It has been used as a seal filler between the concrete liner and the surrounding rock. Compaction and natural reconsolidation of crushed salt are uniquely applied as a seal material here. Cementitious grout and earthen fill complete the list of materials for which specifications are provided in the Final Design Report. Each material is described in the report in a format that includes:

- Functions
- Material characteristics
- Construction
- Performance requirements
- Verification methods
- References

Calculations are used, in part, to assess the ability of the seal system to limit migration of hazardous and radioactive waste constituents to the accessible environment. Both natural and engineered barriers combine to form the shaft seal system. The shaft seal system contains functional redundancy and uses different materials to reduce uncertainty in performance. All materials used in the shaft seal system are expected to maintain their engineering integrity for very long periods, although for design purposes, credit is taken for longevity only of those materials with strong scientific justification. Material specifications are used to develop input parameters for calculations. Input to calculations and treatment of shaft seal elements within the models are summarized in Chapter 8.0 of this petition.

Structural Analysis

The shaft seal system has been extensively evaluated with regard to structural issues. Mechanical, thermal, physical, and hydrological features of the system are included in a broad suite of structural calculations. Conventional structural mechanics applications would normally calculate the loads on system elements and compare the loads to failure criteria. Several such conventional calculations have been performed and show the seal elements to exist in a favorable, compressive stress state which is low in comparison to the strength of the seal materials. Thermal analyses have been performed to examine the effects of concrete heat of hydration and heat transfer for asphalt elements. Physical coupling between damaged rock (DRZ) and fluid flow and between the density and permeability of the consolidating salt column is evaluated within the scope of structural calculations. Creation of a fracture zone around the shaft, its increased transmissivity relative to unfractured rock, and its healing characteristics are analyzed. Similarly, time-dependent density and permeability are calculated for the reconsolidating salt column. The Final Design Report includes details of these structural analyses.

Structural calculations conducted as part of the design study generally address one or more of the following concerns: (1) stability of the component, (2) influences of the component on hydrological properties of the seal and surrounding rock, or (3) construction methods. Stability calculations address:

- Potential for thermal cracking of concrete seals
- Structural stability of seal components under loads resulting from creep of surrounding salt, other seal components through gravity or clay swelling, dynamic compaction, and potential repository-generated gas pressures
- Shaft-closure induced consolidation of compacted salt seals
- Impact of pore pressures on consolidation of compacted-salt seals

Structural calculations used to define input conditions to the hydrological calculations include:

- Spatial extent of the DRZ within the Salado surrounding the shafts as a function of depth, time, and seal material moduli
- Fracturing and DRZ development within Salado interbeds
- Compacted salt fractional density as a function of depth and time

Construction analyses examine:

- Emplacement and structural performance of asphalt waterstops
- Potential benefits of backfilling shaft stations

Finite-element modeling is the primary numerical modeling technique and the well documented finite-element computer programs, SPECTROM-32 and SPECTROM-41, are used in structural and thermal modeling, respectively. A commercial computer program, SALT_SUBSID, is used for subsidence modeling.

Structural calculations use models for all shaft features, including representation of the host rock and its damaged zone, as well as the seal materials themselves. Thermal and deformational properties of Salado salt represent argillaceous salt governed by the Multimechanism Deformation Coupled Fracture (MDCF) model. This model is an extension of the Munson-Dawson creep model, which is incorporated into the SPECTROM codes. Engineering properties of the seal materials are well understood. In general, these materials have outstanding performance in the favorable compressive stress state anticipated in the shafts. Therefore, discussion here emphasizes rock mechanics features of the seal system that pertain to the hydrologic performance, namely: treatment of the DRZ and the permeability/density relationship of the consolidating compacted salt column.

DRZ Behavior. The development and subsequent healing of a DRZ in the rock mass surrounding the WIPP shafts are significant concerns in the seal design. It is well known that an initial DRZ develops in the rock adjacent to the shaft immediately after excavation. Moreover, the DRZ within the Salado continues to develop because of salt creep. Within the formations above the Salado, the DRZ is assumed to be time-invariant, since the behavior of the rock masses encountered there is predominantly elastic. The temporal and spatial extent of the DRZ along the entire shaft length is addressed in the final seal system.

Laboratory and field measurements show that a DRZ has an enhanced permeability. The body of evidence strongly suggests that induced fracturing in salt is reversible and healed when the deviatoric stress states created by the opening are reduced. Rigid seal components (e.g., SMC) in the shaft provide a restraint to salt creep closure, thereby inducing healing stress states in the salt. Two different models are used to evaluate the development and extent of the salt DRZ. The first approach used ratios of time-dependent stress invariants to quantify the potential for damage or healing to occur. The second approach uses a damage stress criterion according to the MDCF model for WIPP salt.

Three analyses are performed to determine the behavior of the DRZ in the rock mass surrounding the shaft. The first analysis considers time-dependent DRZ development and subsequent healing in the Salado salt surrounding each of the four seal materials. All seal materials below a depth of about 984 ft (300 m) provide sufficient rigidity to heal the DRZ, a phenomenon that occurs quickly around rigid components near the shaft bottom. Asphalt does not create a stress state capable of healing the DRZ because it is located high in the Salado. The second analysis considers time-dependent development of the DRZ within anhydrite and polyhalite interbeds within the Salado. These results indicate that, with the exception of Marker Bed 117, no DRZ develops. For Marker Bed 117, the potential for fracturing is localized within 3.3 ft (1 m) of the shaft wall. The third analysis considers time-independent DRZ development within near-surface and Rustler, which include anhydrite, dolomite, and mudstone. Results indicate that no DRZ develops in anhydrite and dolomites for depths between 541 and 699 ft (165 and 213 m). For mudstone layers, the radial extent of the DRZ increases with depth, reaching a maximum of 2.6 shaft radii at a depth of 732 ft (223 m). These results are used as input conditions for the fluid-flow analyses.

Initially, the DRZ is a major flow path regardless of the material placed within the shaft. Therefore, to increase confidence in the overall shaft seal, low permeability layers (termed "waterstops") are included in the design to intersect the DRZ surrounding the shaft. These waterstops are placed to alter the flow direction either inward toward the shaft seal or outward toward intact salt. Structural calculations evaluate performance of the waterstops in terms of (1) intersecting the DRZ around the shaft, (2) inducing a new DRZ because of further excavation, and (3) promoting healing of the DRZ.

Calculational results indicate that the DRZ from the shaft can extend a radial distance as such as one shaft radius 9.8 ft (3.0 m). However, field measurements show that the enhanced permeability occurs in the first meter. Waterstop excavation extends the DRZ radially to about 1.4 shaft radii 14 ft (4.3 m). However, this extension is localized within the span of the concrete component and extends minimally past the waterstop tip. The DRZ extent reduces rapidly as the concrete and asphalt restrain creep of the surrounding salt. After 20 years, the spatial extent of the DRZ is localized near the asphalt/concrete interface, extending spatially into the salt a distance of less than 6.6 ft (2 m). Based on these results, construction of waterstops is possible without substantially increasing the DRZ. Furthermore, the waterstop extends well beyond the maximum extent of the DRZ surrounding the shaft and effectively (within two years of placement) intersects this flow path.

Compacted Salt Behavior. The deformational model for consolidating salt includes a nonlinear elastic component and a creep consolidation component. The nonlinear elastic modulus is density-dependent, based on laboratory test data performed on WIPP crushed salt. Creep consolidation behavior of crushed salt is based on three candidate models whose parameters are obtained from model fitting to hydrostatic and shear consolidation test data performed on WIPP crushed salt. Creep consolidation models include functional

dependencies on density, mean stress, stress difference, temperature, grain size, and moisture content.

A structural analysis and an analysis to determine effects of pore pressure on consolidation of compacted salt columns were used to evaluate the salt component of the shaft seal system. The structural calculation determines fractional density of the compacted salt column as a function of time and depth and uses the results to determine permeability. Results indicate that compacted salt column will increase from its initial fractional density of 90 percent to 96 percent within 40, 80, and 120 years after placement at the bottom, middle, and top of the compacted salt column, respectively. At a fractional density of 96 percent, the permeability of reconsolidating salt is of the order of 1×10^{-18} m^2. Based on these results, a desirable fractional density (hence, permeability) is achieved over a substantial length of the compacted salt column within 100 years of placement.

Fractional densities of the compacted salt column are calculated for arbitrary pore pressures of 0, 2, and 4 MPa. Results indicate that times required to consolidate the compacted salt column increase as the pore pressure increases, as expected. For example, for a pore pressure of 2 MPa, times required to achieve a fractional density of 96 percent are 92 years, 205 years, and 560 years at the bottom, middle, and top of the compacted salt column, respectively. A pore pressure of 4 MPa effectively prevents reconsolidation of the compacted salt column within 1,000 years. Fluid flow calculations show that only minimal transport of fluids to the compacted salt column will occur, so pore pressure equilibrium in the consolidating salt does not occur until desirable permeabilities are achieved.

Hydrologic Evaluations

The ability of the shaft seal system to satisfy design guidance is determined by the performance of the actual seal components within the physical setting in which they are constructed. The important elements of the physical setting are hydraulic gradients of the region, properties of the lithologic units surrounding a given seal component, and potential gas generation within the repository. Hydrologic evaluation focuses on processes that could result in fluid flow through the shaft seal system and the ability of the seal system to limit any such flow. If the carrier fluids are similarly limited, transport of radiological or hazardous constituents will be similarly limited.

The physical processes that could impact seal system performance are presented in detail in the Final Design Report. These process have been incorporated into four models, which are used to evaluate the design. Briefly, these models evaluate: (1) downward migration of groundwater from the Rustler; (2) gas migration and reconsolidation of the compacted salt column component; (3) upward migration of brines from the repository; and (4) flow between water-bearing zones in the Rustler. The first three are analyzed using numerical models of the AIS seal system and the finite-difference codes SWIFT II and TOUGH2. The fourth process is analyzed using an exact solution for fluid flow.

Results from the analyses are summarized in the following paragraphs and evaluated in terms of the design guidance.

Downward Migration of Rustler Groundwater. The shaft seal system is designed to limit groundwater flowing into and through the shaft sealing system. The principal source of groundwater to the seal system is the Culebra. The Magenta produces much less groundwater. No significant sources of brine or groundwater exist within the Salado; however, brine seepage has been noted at a number of the marker beds, and is included in the models. Downward migration of Rustler groundwater is limited to ensure liquid saturation of the compacted salt column does not impact the consolidation process and to limit quantities of brine reaching the repository horizon. Since it is clear that limitation of liquid flow into the salt column necessarily limits liquid flow to the repository, the volumetric flux of liquid into and through the salt column was selected as the design performance measure for this model.

Consolidation of the compacted salt column will be most rapid immediately following seal construction. Simulations are conducted for a 200-year period following closure to demonstrate that, during this initial period, downward migration of Rustler groundwater is insufficient to impact the consolidation process. Lateral migration of brine through the marker beds is quantified in the analysis and is not detrimental to consolidation of the salt column.

At steady-state, the flow rate is most dependent on the relative permeabilities of components of the shaft seal system. Potential flow paths within the seal system consist of the seal material, an interface with the host rock, and the host rock DRZ. Low permeability is specified for the engineered materials and construction methods ensure a tight interface; thus, the flow path most likely to impact performance is the DRZ. Rock mechanics calculations predict that the DRZ in the Salado will not be vertically continuous. Concrete and asphalt waterstops are included in the design as a means to mitigate DRZ impacts. Effects of marker beds and asphalt waterstops on limitation of downward migration are explicitly simulated through permeability variation of the layers of Salado DRZ. Initial, upper, and lateral boundary conditions of the hydrologic model are consistent with field measurements of the physical system. At the base of the shaft a constant, atmospheric pressure is assumed.

The initial available pore volumes in the filled repository and the AIS salt column are approximately 4.59×10^6 ft^3 (130,000 m^3) and 17,660 ft^3 (500 m^3), respectively. The hydrologic model predicts a maximum cumulative flow of less than 353 ft^3 (10 m^3) through the sealed shafts during the first 200 years following closure. If the marker beds have a disturbed zone immediately surrounding the shaft, the maximum flow is less than 706 ft^3 (20 m^3). Without the concrete and asphalt waterstops, volumetric flow increases but remains less than 1,800 ft^3 (50 m^3). Maximum fluid volume is less than 1/100 of 1 percent of the pore volume in the repository and less than 10 percent of the initial pore volume of the salt column.

Results of this model are considered conservative because fully saturated flow is assumed. Further conservatism is inherent in treatment of seal system components. The principal source of groundwater to the system originates in the Rustler. The upper Salado compacted clay component is located above the compacted salt column and will be placed at a liquid saturation state of approximately 80 percent. Bentonite clays exhibit strong hydrophilic characteristics, so that the small quantities of Rustler groundwater reaching the Upper Salado compacted clay column (Component #8) will be absorbed and retained by this seal component.

Gas/brine Migration. A multiphase flow model of the lower seal system evaluates the performance of components extending from the middle concrete component (Component #9, located at the top of the compacted salt column) to the repository horizon for 200 years following closure. During this time period, the principal fluid sources to the compacted salt column consist of gas generated by the waste and lateral brine migration within the Salado. The predicted downward migration of Rustler groundwater (discussed above) is included in this analysis. Performance measures for the model are the volume of gas that migrates through the shaft seal system components to the middle concrete component and the time-dependent permeability of the compacted salt column component. These performance measures address the need to limit fluid flow upward from the repository and to predict the performance of the compacted salt column.

Effects of gas generation are evaluated for three different repository repressurization scenarios, which simulate pressures as high as 14 MPa. Model results predict that high repository pressures do not produce appreciable differences in the volume of gas that migrates to the middle SMC component over the 200-year simulation period. A maximum of 21,200 ft^3 (600 standard m^3) of gas is dispersed throughout the shaft seal system reaching an elevation as high as the middle concrete component. Relatively low gas flow is due to the low permeability and rapid healing of the DRZ around the lower concrete components.

Rock mechanics calculations predict that the salt column will reconsolidate readily if pore fluids in the reconsolidating salt column do not reduce the effective stress. In the physical setting, pore fluids can create pore pressure and reduce the rate of reconsolidation. These effects have been implemented in the TOUGH2 model. Figure 3-14 plots effective permeability (an integrated value for the entire length of the compacted salt column) of the AIS salt column through 200 years after placement. The base case implements expected conditions of the lower seal system during the simulation period. Downward migration of Rustler groundwater has a small influence on compacted salt column permeability, as shown in Figure 3-14 for a continuous DRZ. Effects of higher repository gas pressure are negligible. These results show that the compacted salt column achieves effective permeabilities of less than 1×10^{-18} m^2 at 100 years following seal construction. For all simulations, salt reconsolidation slows as its density approaches that of the native salt formation. The permeability of the salt column after 50 to 75 years is sufficiently low to perform as an effective seal for the duration of the regulatory period.

Upward Migration of Brine. Upward migration of contaminated brines could occur through an inadequately sealed shaft if the fluid pressure in the Salado exceeds the measured heads in the Rustler. Results from modeling (discussed above) demonstrate that the compacted salt column will reconsolidate to a very low permeability within 100 years following repository closure. Structural results expounded upon in the Final Design Report show that the DRZ surrounding the lower Salado compacted clay column and the compacted salt column components will completely heal within the first several decades. As a result, upward migration to the Rustler/Salado contact through the sealed AIS is approximately 35 ft^3 (1 m^3) over the 10,000 year regulatory period.

Intra-Rustler Flow. Based on estimated undisturbed and measured disturbed head differences between the various members of the Rustler (see Table 3-1 of Appendix C of the Final Design Report), nonhydrostatic conditions exist within the Rustler. Therefore, the potential exists for vertical flow within water-bearing strata of the Rustler. The dolomitic members of the Rustler have the greatest potential to produce significant interflow within the Rustler in response to non-hydrostatic conditions. The relatively low undisturbed permeabilities of the mudstone and anhydrite units separating the Culebra and the Magenta naturally limit crossflow. However, the construction and subsequent closure of the shaft provide a potential vertical conduit connecting water-bearing units.

The primary motivation for limiting formation crossflow within the Rustler is to prevent mixing of formation waters within the Rustler, as required by State of New Mexico statute. Commonly, such an undertaking would limit migration of higher dissolved solids (high density) groundwater into lower dissolved solids groundwater. In the vicinity of the WIPP site, the Culebra has a higher density groundwater than the Magenta, approximately 64.94 lb/ft^3 (1,040 kg/m^3) versus 63.38 lb/ft^3 (1,015 kg/m^3), respectively. Heads estimated adjacent to the AIS at H-16 provide evidence for a vertical gradient downward from the Magenta to the Culebra. Therefore, in the vicinity of the shafts, the potential for fluid migration between the two most transmissive units is from the unit with the lower total dissolved solids to the unit with the higher dissolved solids. This calculation shows that potential flow rates between the Culebra and the Magenta is insignificant. Under expected conditions, intra-Rustler flow is expected to be of such a limited quantity that (1) it will not affect either the hydraulic or chemical regime within the Culebra or the Magenta and (2) it will not be detrimental to the seal system itself.

3.7.2.4 Post-Closure Plan Following Final Facility Closure

A number of regulations address the period of time that begins once the WIPP has undergone final facility closure and decommissioning. Under 40 CFR Part 191, the period consists of an active control period and a passive control period. Only 100 years of the active control period are used in performance assessment. Under the no-migration standard in 40 CFR §268.6, the EPA is interested in the measures the DOE will take in terms of long-term passive institutional controls ". . . such as land withdrawal, records, and markers—to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits at the site may have

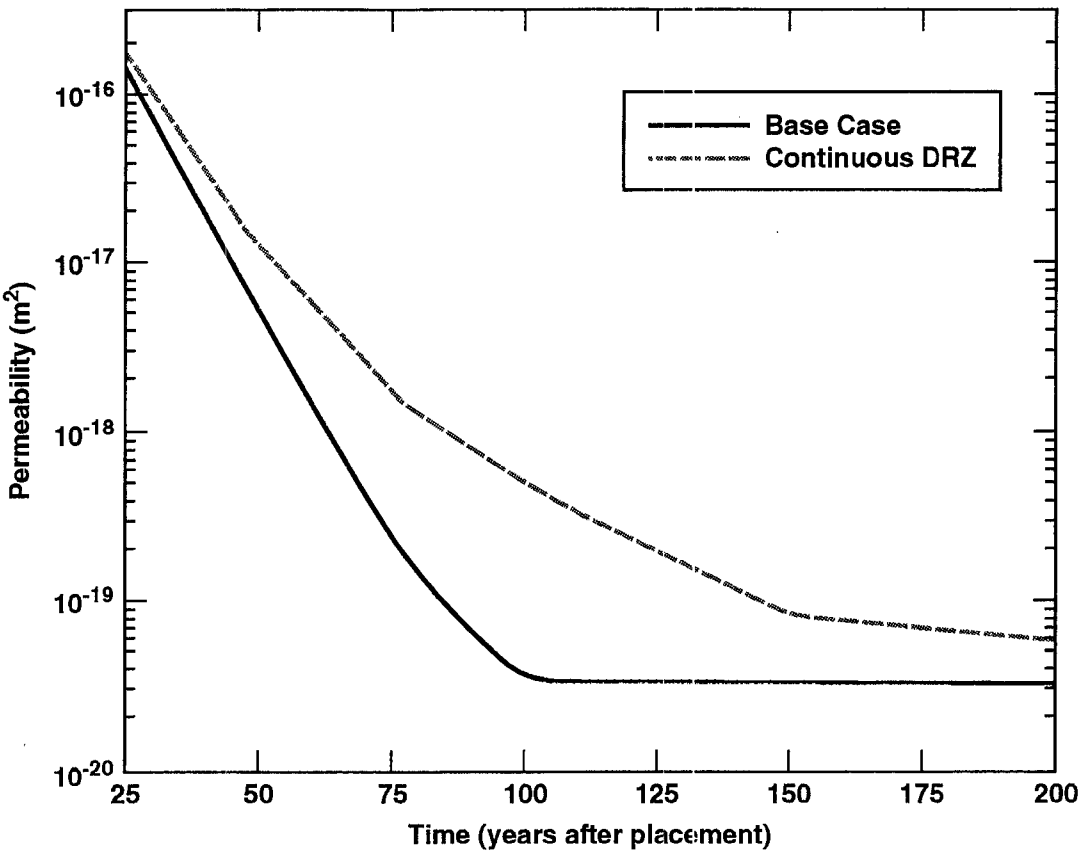

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Figure 3-14. Compacted Salt Column Permeability as a Function of Time

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terminated." (EPA 1990) The LWA of 1992 requires that the DOE prepare and submit a post-decommissioning land management plan. 20 NMAC 4.1, Subpart V, §264.117 requires post-closure care, including monitoring, security, and property use. Because of the numerous regulations, the DOE has prepared a single strategy for post-closure management of the WIPP. This strategy consists of three elements: 1) active controls, 2) monitoring, and 3) passive controls. These elements are discussed in detail in Appendices AAC, LTM, and PMR, respectively.

Active Controls

Once the facility is decommissioned, positive actions (referred to as "active institutional controls") will be taken to assure proper maintenance and monitoring. The DOE's active institutional control program has a primary objective of addressing all applicable requirements, including restoring the WIPP site as nearly as possible to its original condition, thereby equalizing any preference over other areas for development by humans in the future. Restoration of the WIPP site includes any necessary remedial actions or cleanup of releases resulting from decommissioning. In addition, the DOE will implement monitoring systems suitable for assessing disposal system performance if such monitoring is feasible. This long-term monitoring is presented in Section 6.3.

A detailed explanation of the active institutional controls selected by the DOE is provided in Appendix AAC. This is the DOE's reference design for active institutional controls. The reference design will be reviewed periodically and updated as appropriate during the WIPP disposal operations. The ongoing review and evaluation ensure that the active institutional controls implemented are appropriate for the conditions that may exist at that time. The DOE will review the reference design prior to implementation and all affected regulatory agencies will be consulted as part of this review.

As part of the active institutional controls program, the DOE has developed a set of design criteria upon which the reference design is based. These design criteria, listed below, describe how the active institutional controls will be implemented.

1. A fence line shall be established to control access to the repository's footprint area (the waste disposal area projected to the surface). A standard wire fence shall be erected along the perimeter of the repository surface footprint. The fence shall have gates placed approximately midway along each of the four sides

2. An unpaved roadway along the perimeter of the barbed wire fence shall be constructed to provide ready vehicle access to any point around the fenced perimeter, facilitate inspection and maintenance of the fence line, and permit visual observation of the repository footprint to the extent permitted by the lay of the land. This roadway shall connect to the paved south access road

3. To ensure visual notification, the fence line shall be posted with signs having, as a minimum, a legend reading "Danger—Unauthorized Personnel Keep Out" and a

warning against entering the area without specific permission of the DOE (or other local authority, such as the Eddy County Sheriff's Office)

4. Contractual arrangements shall be developed to ensure that periodic inspection and necessary corrective maintenance is conducted on the fence line, its associated warning signs, and the roadway. The DOE will maintain control over all contractual work and will maintain, in the operating record, the results of all inspections and maintenance activities

5. Through direct DOE staffing support and/or contractual arrangements, procedures shall be established to provide routine periodic patrols and surveillances of the protected area by personnel trained in security surveillance and investigation

6. Processes will be developed for monitoring and controlling the long-term testing requirements of the permanent marker system (PMS)

7. Processes will be developed to implement the periodic monitoring requirements of the disposal system's monitoring program. The procedures currently in place, such as the Environmental Monitoring Plan (DOE 1994), will initially be used

8. Recommendations will be developed for modifications to the active institutional controls appropriate for access control and surveillance upon installation of the PMS

9. Guidelines will be developed for recommending mitigating actions to be taken to address any abnormal conditions identified during periodic surveillance and inspections

10. Reports of activities associated with the post-disposal active access controls shall be prepared in accordance with regulatory requirements for submittal to the appropriate regulatory and legislative authority

Details on meeting these criteria are found in Appendix AAC.

Most of the active institutional control measures, such as long-term site monitoring and site remedial actions, will be implemented simultaneously with decommissioning. However, it may be possible to implement some measures earlier. For example, salt disposal may begin prior to final plant closure. Reclamation and restoration of unused disturbed surface areas has already begun. Guarding and maintenance activities, which are already in place, could evolve into an appropriate type of post-closure activity.

Passive Institutional Controls

Passive institutional controls include markers that warn of the presence of buried nuclear waste and identify: (1) the boundary of the disposal area footprint, (2) external records about the WIPP repository, and (3) continued federal ownership.

Passive institutional controls, as opposed to active institutional controls, are controls that, once established, can be expected to remain effective with minimal human surveillance and maintenance, or maintenance resulting from normal governmental activities. Passive controls may be instituted at the site, a remote location, or both.

With regards to passive controls, the DOE interprets the phrase "federal ownership and regulations regarding land or resource use" to mean that the DOE or some successor agency with nuclear waste management expertise will retain administrative control over the land. "Administrative control" means that the federal agency responsible for the land will institute regulations that impose appropriate restriction on land use and development. Regarding the WIPP facility, the DOE interprets the term "markers" to include any on-site structures engineered and constructed to preserve knowledge of the location of the wastes and convey associated hazards. The DOE interprets "records" to include any written information regarding the site and its contents, which are maintained to preserve knowledge of the site. The DOE intends to use passive institutional controls (ownership, markers, and records) throughout the entire controlled area.

In the proposed No-Migration Determination for the WIPP facility (EPA 1990), the EPA discussed the use of passive controls as part of an overall strategy to protect a land disposal facility and decrease the likelihood of human disruption. The EPA considers that, in the context of RCRA no-migration variance decisions, the question of human intrusion, either during operations or after closure, is best addressed by considering the likelihood of intrusion and imposing controls to make such intrusions unlikely. The EPA emphasizes that this approach to human intrusion is consistent with its general approach under RCRA, both in permitting and variances. Under RCRA, the EPA typically relies on both active and passive institutional controls imposed through general regulatory standards and site-specific conditions (e.g., RCRA permits) to ensure that access to a hazardous waste disposal site is appropriately restricted. The EPA considers that any permanent no-migration variance for the WIPP will have to impose long-term passive institutional controls, such as land withdrawal, records, and markers, to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits at the site may have terminated.

The DOE is committed to retaining control over the WIPP site for as long as possible. Accordingly, an extensive system of explanatory markers and records will be instituted to warn future generations about the location and dangers of these wastes. The DOE assumed that society in general will retain knowledge about these wastes and that future societies should be able to deter systematic or persistent exploitation of a disposal site.

The DOE's passive institutional control program for the WIPP will accomplish the following:

- Ensure a record of the disposal site and its contents are preserved
- Warn those who attempt to enter the disposal site vicinity of the hazards associated with activities that would disturb the subsurface

The DOE considers that passive institutional controls will render human intrusion sufficiently unlikely that the possibility need not be included in the long-term performance calculations.

A substantial amount of work has been completed in the area of passive institutional controls at the WIPP facility.

- *DOE Ownership.* The DOE has successfully gained control of the entire surface of the 16-section WIPP site and the entire subsurface, except for Section 31, where DOE control extends over the surface and the first 6,000 ft (1,829 m) of the subsurface, including the acquisition of oil, gas, and potash leases. The area now under the control of the DOE includes the following sections in Township 22 South, Range 31 East: 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, and 34
- *Land Use Controls.* Land use controls have been implemented addressing allowable uses of the withdrawal area

Beyond land ownership and implementation of use controls, the DOE has prepared a conceptual design for post-closure passive institutional controls, included in Appendix PMR. The design includes:

- Large surface monuments and earthen structures to mark the repository footprint
- One or more on-site buried rooms for the long-term storage of messages describing the nature of the repository
- Small subsurface markers
- Off-site archival storage of information pertaining to the WIPP, including its potential hazards

Shaft-Location Markers

The surface area over the waste disposal region will be identified by these passive institutional controls. Permanent surveyor markings engraved with the site elevation and coordinates will show the locations of shafts. The markers will be firmly anchored to the shaft plug and will also contain the site description, date of closure, land survey data, and

other information required by applicable regulations. A uniform system of coordinates will be adopted. The definitions of these coordinates will be included in the permanent records.

Permanent Marker System

A PMS designed to minimize the possibility of inadvertent human intrusion into the repository following the cessation of active controls will be implemented at the WIPP facility. The PMS will be comprised of messages, surface monument markers, small subsurface warning markers, on-site rooms for long-term storage of messages, archival storage of the WIPP information off-site, and large earthen structures marking the WIPP repository footprint on the surface. The PMS is still in the conceptual design process and will evolve prior to closure, based on activities to test marker effectiveness during disposal, decommissioning, and active access controls periods. Actual construction of the PMS will be completed 100 years following closure of the WIPP facility, in accordance with Appendix AAC.

The PMS will provide a durable record of the repository's existence, and its design will provide reasonable assurance that it will endure for at least 10,000 years. The system will be clearly visible from any portion of the repository's surface footprint. The current PMS design basis consists of a large earthen berm enclosing the perimeter of the repository's surface footprint. The design basis for the berm is a minimum width of 100 ft (30 m) and a height of 31 ft (10 m), with a 1.3 horizontal to 1.0 vertical slope. The berm would provide a dielectric or magnetic anomaly when compared to the local surface characteristics. Large monoliths will be arranged just inside the berm. The number of monoliths would be sufficient to allow future generations to reconstruct monolith orientation with several monoliths missing. An information center will be placed at the center of the monoliths, and two storage rooms would be buried about 20 ft (6 m) below the footprint. The PMS components will be designed and constructed to resist erosion and deposition. Construction materials will be selected for durability under the local climatic conditions and the predicted changes to those conditions in the long term.

Monuments will be engraved with the most critical warning information in a concise format, inscribed to a minimum depth of 0.5 in. (1.3 cm). More detailed information regarding the repository content, caution against intrusion, and the time of emplacement will be provided in protected vaults buried underground and in a surface information center. The information will be provided in multi-language translation and will include an assortment of symbols, pictographs, and diagrams to convey danger of intrusion. Universal symbols will enhance the likelihood of understanding by people of different backgrounds. To minimize the likelihood of future salvaging, the marking system will use materials with as little intrinsic value as is reasonable.

Subsurface markers would be less than 2 ft (0.6 m) in the longest dimension, made of inert material, and spaced so that they are likely to be discovered by drilling crews and professional archaeologists. The warning message would be engraved so that slight

erosion or fracture of the marker would not render it completely unintelligible. In addition, the markers would be buried at a greater depth than that used for plowing/tilling operations or amateur archaeological excavation, so that such activities would be unlikely to disturb them. Further details on the subsurface markers may be obtained from Appendix PMR.

Written Records

Written documentation of the WIPP will be placed in local, state, and federal agencies. Documentation will also be provided to international entities and commercial organizations that act as resource information centers for the petroleum and gas industries. Written records will use the most stable and durable media available at the time that the record deposits are made. These records will describe the location of the repository; the nature and hazard of the waste; the geologic, geochemical, and hydrologic data pertinent to waste containment; and environmental monitoring data from the preoperational baseline and summaries of data collected during Decontamination and Decommissioning (D&D) activities. Overall record selection for storage at the agencies selected will be in accordance with federal, state, and local regulations.

Specific documents which will be included in the archived information portfolio include:

1. Detailed maps describing the exact location of the repository
2. The SAR and the addenda which describes the disposal phase of the WIPP
3. The Final Environmental Impact Statement (FEIS) for the WIPP and the Supplement(s) to the Environmental Impact Statement
4. The NMVP and the No-Migration Determination for Disposal
5. The RCRA Permit
6. The Certification of Compliance with 40 CFR Part 191 and its associated application
7. Environmental and ecological background data collected during the preoperational phase of the WIPP and summaries of data collected during the disposal and decommissioning phases of the WIPP
8. Records of the waste containers' contents and disposal locations within the WIPP repository
9. Drawings defining the construction and configuration of the repository and shafts

10. Drawings, procedures, and the design report(s) describing how the waste was emplaced; how the repository was decommissioned, closed and sealed; and how the shafts were sealed

The National Archives will be the record holder responsible for the permanent storage of this information. In addition, other locations for this information will include publicly funded organizations which may expend the resources necessary to preserve the documents in well-controlled environments. However, the most likely strategy for long-term protection of the information is through widespread distribution. The information will be submitted to the following facilities and organizations for archiving:

1. Library of Congress
2. The state archives and libraries within the states of New Mexico and Texas
3. The city libraries of population centers in New Mexico and Texas exceeding 15,000 within 150 mi (240 km) of Carlsbad
4. The state libraries of the remaining 48 states
5. The local office of the Bureau of Land Management
6. The local office of the Bureau of Reclamation
7. The national library and national archives of all nations that possess nuclear weapons and/or operate nuclear power generating plants
8. The archive of the United Nations
9. The national archives and libraries of the signatory nations to the nuclear non-proliferation treaty
10. The U.S. Nuclear Regulatory Commission
11. The 53 federal regional depository libraries
12. The American Nuclear Society

This list of receiving organizations will be reviewed and expanded, as appropriate, as the time of transferring information approaches.

Location and hazards information will be submitted to various federal and state of New Mexico mapping agencies to ensure that the WIPP location and drilling or mining restrictions are identified on widely distributed maps used by almost all public and private organizations. These agencies include:

1. Bureau of Land Management
2. U.S. Geological Survey
3. Library of Congress
4. National Archives and Records Service
5. Defense Mapping Agency
6. International Boundary Commission
7. Federal Highway Administration, and the
8. New Mexico State Highway Department Planning and Research Division, Cartography Section

To ensure widespread location information of the WIPP site and the hazards associated with the emplaced waste, detailed maps and descriptions of the hazardous material will be sent to national and international professional societies of cartographers and geographers. Weitzberg (1982) suggests the following organizations and societies receive this location and hazards information:

1. The American Congress on Surveying and Mapping
2. The American Society of Cartographers
3. The Commission for the Geological Map of the World
4. The International Cartographic Association
5. The American Geographical Society
6. The Association of American Geographers
7. The International Geographical Union
8. The Society of Women Geographers
9. The American Geological Institute
10. The American Geophysical Union
11. The American Society of Professional Geographers

12. The National Geographic Society

13. The Federal Aviation Administration

Programs may be necessary to support implementation of passive institutional control activities with site-specific information.

Planned Evaluations. Upon closure of the WIPP, active controls will be implemented to control access to the site. In addition, monitoring systems will be managed to detect significant deviations in repository performance. With active control provided over the site, the schedule for constructing the PMS is a management option which could be extended for decades. Because the design of the PMS has a 10,000-year lifetime goal, it is prudent that the DOE conduct some testing of the construction materials planned for use as permanent marker material.

Berms. One aspect of the testing is the construction of a section of the berm. The overall size (height and width) of the test section of the berm will match the design of the permanent marker berm. However, the test berm length will be shorter than the full-sized berm. A section approximately 164 to 328 ft (50 to 100 m) long will be sufficient to test a number of different configurations. Included within the test section will be varying thicknesses of the salt core, the caliche layer, and the top layer of riprap and soil material. The DOE will construct a section of the berm to evaluate materials and construction techniques. Actual construction and testing will be initiated during the disposal phase to provide sufficient time for testing.

Monuments. Another aspect of passive institutional controls to be evaluated during testing is monuments. The major considerations that will be evaluated include the following:

1. Procuring, shipping, and erecting test monuments, and evaluating long-term environmental effects of wind, rain, and shifting sand on various types of dimensional stone

2. Evaluating the magnetic signature provided by sample permanent magnets buried within the berm to determine optimum locations and spacing

3. Evaluating the effects of various soils used as protective backfill for dimensional stone

4. Evaluating the effects of chemical interaction with the backfill material

5. Evaluating the environmental effects on the berm caused by wind, rain, and shifting sand

6. Evaluating the effects of plant root intrusion into the berm and potential for salt dissolution and berm slumping

7. Evaluating the effectiveness of sample radar reflectors buried within the berm at various distances

Messages. Messages will also be evaluated during the testing program. The primary aspects include the following:

- Evaluation of message text by presenting it to groups indigenous to the countries whose language is represented in the message

- Evaluation of message text by presenting it to linguists to assess the likelihood that the messages will continue to be understood through time

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4.0 Waste Description
Abstract

This chapter describes the physical and chemical characteristics of the transuranic-(TRU-) mixed waste destined for disposal at the Waste Isolation Pilot Plant (WIPP) facility. The volume of waste, types of waste, waste characterization techniques, and waste characterization program documentation are discussed. As a guide, the level of information presented in this chapter is commensurate with that necessary to maintain compliance with the standards in 40 CFR §268.6(a)(3).

TRU-mixed waste is defined as any TRU waste that also contains hazardous wastes regulated by the Resource Conservation and Recovery Act (RCRA) as defined in Title 40 of the Code of Federal Regulations (CFR) Part 261, Subparts C and D. TRU waste contaminated with hazardous constituents has physical and radiological characteristics similar to TRU waste that does not contain these constituents. TRU waste acceptable to the WIPP is divided into contact-handled (CH) and remote-handled (RH) based on the surface dose rate of the container. The waste forms described in this section represent all TRU waste to be sent to the WIPP facility, both TRU and TRU-mixed waste. All TRU wastes that will be certified for shipment are compatible and will be managed in the same way at the WIPP facility. The RCRA-regulated chemical component of TRU-mixed waste is not expected to have a significant effect on the long-term performance of the WIPP repository.

All waste characterization activities will be conducted at the Department of Energy (DOE) generator/storage sites, since the WIPP facility does not have the capability to visually inspect or sample and analyze the waste. The WIPP participates in the waste characterization by performing generator/storage site audits to verify that the waste characterization activities meet the applicable requirements established for waste intended for disposal at the WIPP facility. The 55-gallon drums, standard waste boxes (SWBs), ten-drum overpacks (TDOPs) and RH-TRU canisters will be examined at the generator site to verify that 1) the containers are structurally intact; 2) radioactive contamination is below acceptable limits; and 3) the accompanying documentation states that the waste meets the WIPP waste acceptance criteria and final permit requirements. Only when these items have been verified will the waste be transported underground for emplacement at the WIPP.

Waste Inventory

The major sources of TRU-mixed waste are plutonium reprocessing and fabrication and research and development activities. Since 1970, this waste has been segregated and placed in retrievable storage pending shipment to a permanent geologic repository. In the future, additional quantities of TRU-mixed waste will be generated from environmental restoration and decontaminating and decommissioning. The anticipated inventory of TRU waste consists of waste that is in retrievable storage and waste that will be generated in the future. This anticipated inventory is listed in the WIPP TRU Waste Baseline

Inventory Report (BIR) (DOE 1995d). The BIR was developed from information provided by the DOE generator/storage sites.

Waste Acceptance Criteria

Very specific acceptance criteria have been established for waste destined for the WIPP facility. The criteria govern the physical, radiological, and chemical composition of the waste and establish specifications for waste packaging. These criteria are based on Operational and Safety Requirements, Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC) regulations for transport of TRU waste, and RCRA waste analysis requirements. Waste acceptance criteria will be published by the DOE and implemented at the generator/storage sites prior to the shipment of waste to the WIPP facility.

Waste that does not meet the waste acceptance criteria may require treatment or processing. Any such treatment would be the responsibility of the site proposing to ship the waste to the WIPP facility.

Waste Characterization

TRU-mixed waste characterization, which involves the acquisition of chemical and physical data, is a primary component of compliance activities at the WIPP. Waste characterization activities include headspace gas sampling and analysis, solid sampling and analysis, nondestructive assay/nondestructive examination, and acceptable knowledge. Only that waste for which required waste characterization data are available will be accepted.

Plans and Program Summary. The waste characterization program is established in the WIPP Waste Analysis Plan and supported by the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP) (DOE 1995b). The QAPP governs the quality of data produced through the waste characterization program by establishing quality assurance (QA) objectives for analysis results (precision, accuracy, completeness, etc.) that must be met before the waste analysis data is used for waste acceptance. Also, analytical laboratories performing the waste analysis must participate in performance demonstration programs which ensure consistency in data quality among the generator sites.

Physical Waste Characteristics. TRU waste is packaged at the generator/storage sites in a primary confinement barrier (i.e., a DOE type 7A steel drum or SWB) to isolate the waste content from humans and the environment during transportation and handling. This packaging system may include rigid plastic inner liners, several layers of plastic bagging, and adsorbents in the void spaces.

Pursuant to the WIPP waste acceptance criteria, free liquids and pressurized containers are prohibited in the shipment of waste to the WIPP facility. Damp combustibles are neutralized (acids or alkalies), drained, or dried prior to packaging with adsorbents (e.g.,

vermiculite) to prevent the accumulation of condensate. Discarded equipment is disassembled to remove any liquids from fluid reservoirs or lines. Glass waste is dried or drained to remove free liquids. Sealed containers must be demonstrated to contain no pressure by puncturing or by other methods.

Chemical Waste Characteristics. The majority of TRU-mixed waste are reported to contain small quantities of spent halogenated solvents (Environmental Protection Agency [EPA] Hazardous Waste Codes F001–F005), which are used in plutonium fabrication operations for cleaning and degreasing of equipment, glassware, and components. Inorganic solidified waste may also contain trace quantities of listed solvents, primarily based on the RCRA "mixture" or "derived from" rules. Solidified organic waste, which represents less than 3 percent of the total TRU waste inventory, contains the greatest concentration of spent solvent used as degreasers and lathe coolants.

RCRA-regulated metals (EPA Hazardous Waste Codes D004–D011) also are present in some TRU-mixed waste. Metals are primarily associated with solid materials, such as lead shielding, stainless steel parts containing chromium, and iron-based metal equipment and tools. The concentration of metals in solidified inorganic waste depends on the amount and type of scrap materials incorporated during plutonium recovery operations. Typical scrap materials contain lead, chromium, and cadmium.

Analytical Methods. Characterization of TRU waste includes application of methods to generate the information necessary for each data user. These data are necessary to meet the particular objectives of each compliance program. This chapter defines the procedures used to characterize TRU waste at the generator/storage sites and the site-specific plans that identify and describe the administrative controls and procedures required to characterize, segregate and process, and package TRU waste in accordance with the waste acceptance criteria.

The DOE will use acceptable knowledge, as defined in EPA's *Waste Analysis at Facilities that Generate, Treat, Store, and Dispose of Hazardous Waste* (EPA 1994); nondestructive assay/nondestructive examination (NDA/NDE) techniques; and sampling and analysis methods to characterize TRU waste. The sampling and analysis methods used to characterize TRU waste are derived from SW-846, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (EPA 1992).

Provided in the QAPP are the quality assurance/quality control (QA/QC) requirements for ensuring that (1) all data are technically sound, statistically valid, and properly documented, and (2) all data meet the QA objectives. The QAPP addresses the QA/QC requirements specified in Chapter 1 of *SW-846*. Meeting the QA objectives outlined in the QAPP will provide the data necessary for WIPP facility compliance programs. If waste forms are not analyzed by these methods, alternative methods may be proposed, provided it can be demonstrated that data quality objectives of the QAPP are attained.

Supporting Documentation Requirements for Generators. Implementation of the TRU Waste Characterization Program at DOE sites requires that all waste

characterization activities be conducted in accordance with approved documentation that describes the management, operations, and QA for the program. These documents ensure conformance with all applicable regulatory, programmatic, and operational requirements. The sites may also need to develop other documents (e.g., TRU waste management plans, safety analysis reports, and operational safety requirements) that address site-specific programmatic and operational requirements.

Future Waste Characterization Activities. All waste will be certified according to the requirements specified in the final WIPP waste acceptance criteria and characterized in accordance with the WIPP Waste Analysis Plan and the QAPP prior to shipment to the WIPP facility. Generator/storage sites must identify and completely characterize individual waste streams.

Waste characterization facilities at DOE sites are being planned based on the quantities of TRU waste in immediately accessible storage (e.g., air-support buildings). Retrievably stored waste that is currently managed in earthen-covered storage will be characterized in accordance with schedules developed as part of retrieval operations, as well as the availability and sample throughput capacities of TRU waste characterization facilities.

4.0 WASTE DESCRIPTION

This chapter describes the physical and chemical characteristics of the transuranic (TRU) waste to be disposed of at the Waste Isolation Pilot Plant (WIPP) facility. A description of the types and an estimate of volumes of TRU waste to be emplaced in the WIPP facility is provided, including an estimate of the rate of waste emplacement. Selected waste analysis parameters, associated sampling and analytical techniques, and quality assurance (QA) programs are also summarized. Detailed information regarding TRU waste analysis requirements is provided in the Waste Analysis Plan (Appendix WAP).

TRU waste is defined by U.S. Department of Energy (DOE) Order 5820.2A as radioactive waste that has, without regard to source or form, been contaminated with alpha-emitting radionuclides having atomic numbers greater than 92, half-lives greater than 20 years, and concentrations greater than 100 nanocuries per gram at the time of assay. TRU waste is classified as contact-handled (CH) or remote-handled (RH), depending on the dose rate at the external surface of the container. CH-TRU waste is packaged TRU waste with an external surface dose rate of 200 millirem per hour or less, while RH-TRU waste has a radiation dose rate at the container surface that measures greater than 200 millirem per hour.

TRU-mixed waste is defined as any TRU waste that also contains hazardous wastes regulated by the Resource, Conservation, and Recovery Act (RCRA), as defined in Title 40 of the Code of Federal Regulations (CFR) Part 261, Subparts C and D. TRU waste contaminated with hazardous constituents has physical and radiological characteristics similar to TRU waste that does not contain these constituents. The waste forms described in this section represent all waste to be sent to the WIPP facility, both TRU and TRU-mixed. All TRU wastes that will be certified for shipment are compatible and will be managed the same way at the WIPP facility. The RCRA-regulated chemical component of TRU-mixed waste is not expected to have a significant effect on the long-term performance of the WIPP repository. Long-term repository behavior is likely to be affected by processes such as corrosion and microbial gas generation (Section 4.3.3.3), in which the RCRA-regulated constituents play virtually no part.

The WIPP facility will not have the capability to inspect TRU waste by either visual examination or sampling and analysis; therefore, all waste characterization and certification activities will be conducted at the DOE generator/storage sites sending waste to the WIPP facility. A detailed description of the waste screening and verification process for waste acceptance is provided in the Waste Analysis Plan (Appendix WAP). Procedures for the acceptance and emplacement of TRU waste at the WIPP facility involve receipt of CH-TRU waste in 55-gallon drums, standard waste boxes (SWBs), or ten-drum overpacks (TDOPs), and RH-TRU waste in RH canisters (Chapter 3). When visual inspection in the Waste Handling Building shows that (1) the waste containers are structurally intact, (2) radioactive contamination is below acceptable limits, and (3) the accompanying documentation states that they meet both the WIPP facility waste acceptance criteria (WAC) and the final permit requirements, the waste will be

transferred to the underground waste receiving station in a hoist cage and transported by forklift to a waste disposal area.

4.1 Waste Inventory

TRU waste management activities (generation, retrievable storage, etc.) are conducted at the following ten major DOE generator/storage sites:

1. Richland (Hanford) Site, Washington
2. Idaho National Engineering Laboratory (INEL), Idaho
3. Los Alamos National Laboratory (LANL), New Mexico
4. Oak Ridge National Laboratory (ORNL), Tennessee
5. Rocky Flats Environmental Technology Site (RFETS), Colorado
6. Savannah River Site (SRS), South Carolina
7. Argonne National Laboratory–East (ANL-E), Illinois
8. Lawrence Livermore National Laboratory (LLNL), California
9. Mound Laboratory (Mound), Ohio
10. Nevada Test Site (NTS), Nevada

Activities associated with the Federal Facilities Compliance Act (FFCA) have identified several additional sites that generate TRU waste in small quantities. The volume of waste from these minor sites comprise less than one percent of the total inventory. These sites are shown in Figure C-3 in Appendix WAP.

TRU waste has been generated from plutonium reprocessing, fabrication, and research and development activities. Since 1970, this waste has been placed in retrievable storage pending shipment to a permanent geologic repository. In the future, additional quantities of TRU waste will be generated from environmental restoration and decontamination and decommissioning activities; this waste is not expected to differ significantly from existing wastes. The anticipated inventory of TRU waste consists of the waste in retrievable storage and waste that will be generated in the future. The DOE anticipates that the generation of TRU waste to be disposed of at the WIPP facility will continue through the year 2020. This anticipated inventory is listed in the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (BIR) (DOE 1995c) published by the DOE in 1994 and revised in 1995. The BIR was developed from information provided by the DOE TRU waste generator/storage sites.

The waste inventory in the BIR is categorized as either retrievably stored or projected (i.e., to be generated in the future). The most recent estimates of mixed and unmixed CH- and RH-TRU waste to be sent to the WIPP facility are presented in Tables 4-1 and 4-2, respectively. Approximately 50 percent of TRU waste also contains hazardous wastes regulated under the RCRA.

Table 4-1. Total Estimated Quantity of CH-TRU Waste by Generator/Storage Site

Generator/Storage Site	Volume (m^3)[a] Retrievably Stored	Volume (m^3)[a] Future Generated
Mixed Waste		
Ames Laboratory	0.00E+00	1.00E-01
Argonne National Laboratory–East	6.21E+00	5.60E-01
Argonne National Laboratory–West	2.00E-02	2.48E+00
Energy Technology Engineering Center	2.10E-01	0.00E+00
Idaho National Engineering Laboratory	2.76E+04	1.00E+00
Lawrence Livermore National Laboratory	7.92E+00	4.47E+01
Los Alamos National Laboratory	7.66E+03	3.90E+03
Mound Laboratory	2.50E+00	0.00E+ 00
Nevada Test Site	6.20E+02	0.00E+00
Oak Ridge National Laboratory	7.83E+02	2.64E+02
Paducah Gaseous Diffusion Plant	3.45E+00	0.00E+00
Richland (Hanford) Site	1.36E+02	5.53E+03
Rocky Flats Plant	8.28E+02	5.38E+03
Sandia National Laboratories/New Mexico	1.04E+00	0.00E+00
Savannah River Site	1.01E+04	2.56E+03
University of Missouri	6.00E-02	1.60E+00
TOTAL	4.78E+04	1.77E+04
Non-Mixed Waste		
Argonne National Laboratory–East	2.29E+01	1.12E+00
Argonne National Laboratory–West	0.00E+00	3.36E+00
Bettis Atomic Power Laboratory	0.00E+00	1.24E+02
Energy Technology Engineering Center	1.66E+00	5.20E+00
Idaho National Engineering Laboratory	7.02E+03	0.00E+00
Knolls Atomic Power Laboratory	2.40E+00	0.00E+00
Lawrence Berkeley Laboratory	8.40E-01	4.42E+00
Lawrence Livermore National Laboratory	1.99E+02	6.44E+02
Los Alamos National Laboratory	3.20E+03	3.77E+03
Mound Laboratory	2.60E+02	0.00E+00
Pantex	6.24E-01	0.00E+00
Richland (Hanford) Site	9.18E+03	1.57E+04
Rocky Flats Plant	3.05E+02	5.17E+02
Sandia National Laboratories/New Mexico	7.00E+00	7.00E+00
Savannah River Site	4.47E+03	1.22E+04
TOTAL	2.47E+04	3.30E+04

[a]From the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE 1995c).

Table 4-2. Total Estimated Quantity of RH-TRU Waste by Generator/Storage Site

Generator/Storage Site	Volume (m^3)[a] Retrievably Stored	Volume (m^3)[a] Future Generated
Mixed Waste		
Argonne National Laboratory–West	8.65E+00	3.89E+00
Idaho National Engineering Laboratory	2.12E+01	1.68E+01
Knolls Atomic Power Laboratory	1.12E+01	2.52E+01
Los Alamos National Laboratory	1.50E+01	1.50E+01
Oak Ridge National Laboratory	9.94E+02	3.57E+02
Richland (Hanford) Site	0.00E+00	1.73E+03
TOTAL	1.05E+03	2.15E+03
Non-Mixed Waste		
Argonne National Laboratory–West	0.00E+00	2.37E+01
Batelle Columbus	0.00E+00	7.10E+01
Bettis Atomic Power Laboratory	0.00E+00	1.56E+00
Idaho National Engineering Laboratory	9.76E+00	0.00E+00
Los Alamos National Laboratory	7.63E+01	6.77E+01
Richland (Hanford) Site	3.32E+01	1.25E+03
Savannah River Site	0.00E+00	6.39E+01
TOTAL	1.19E+02	1.47E+03

[a]From the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE 1995c).

The DOE has categorized TRU waste by Waste Matrix Code Groups that reflect the physical form of the waste. Table 4-3 provides a summary of the estimated volumes of CH- and RH-TRU waste by Waste Matrix Code Groups. The wastes exist in a variety of forms, ranging from unprocessed laboratory trash (e.g., glassware, tools, and equipment) to solidified wastewater treatment sludges. The Waste Matrix Code Groups are described in Section 4.3.2. Table 4-4 provides the volumes of CH- and RH-TRU wastes within each Waste Matrix Code Group by DOE generator/storage site from the BIR.

Existing waste is currently maintained in retrievable storage, including aboveground and earthen-covered storage, at the DOE generator/storage sites. The majority of existing waste is in earthen-covered storage that is not readily accessible at present. The process for managing waste at the generator/storage sites and establishing schedules for the retrieval of this waste is regulated by the state environmental agencies.

A baseline schedule for the receipt of waste at the WIPP facility has been established. During the first few years of operation, receipt rates will increase gradually to allow waste handling operations to ramp-up to full capacity. It is also assumed that 60 percent of the waste received at the WIPP facility will arrive in drums and 40 percent will arrive in SWBs. The estimated receipt rates of CH- and RH-TRU wastes are provided in Tables 4-5 and 4-6, respectively. These schedules are based on the current design of the

Table 4-3. Estimated Transuranic Waste Disposal Inventory for the WIPP[a]

Waste Matrix Groups	Stored Volumes (m^3)	Projected Volumes (m^3)	Scaled Volumes (m^3)
CH-TRU Waste			
Combustible waste	7.10E+03	2.70E+04	6.20E+04
Filter waste	4.30E+02	1.10E+03	2.60E+03
Graphite waste	6.70E+02	4.30E+01	7.60E+02
Heterogeneous waste	3.00E+04	4.60E+03	3.90E+04
Inorganic nonmetal waste	1.20E+03	3.20E+02	1.80E+03
Lead/cadmium metal waste	5.60E+01	1.30E+02	3.10E+02
Salt waste	3.30E+01	6.00E+01	1.50E+02
Soils	3.70E+02	4.50E+02	1.30E+03
Solidified inorganic waste	1.70E+04	8.00E+03	3.40E+04
Solidified organic waste	1.50E+03	3.00E+ 02	2.10E+03
Unspecified metal waste	1.20E+04	8.60E+03	3.00E+04
Unknown	1.70E+03	0.00E+00	1.70E+03
TOTAL	7.21E+04	5.06E+04	1.76E+05
RH-TRU Waste			
Combustible waste	1.50E+01	3.20E+00	2.00E+01
Filter waste	8.90E-01	2.10E+00	4.30E+01
Heterogeneous waste	4.40E+02	3.30E+03	5.90E+03
Inorganic nonmetal waste			
Lead/cadmium metal waste	0.00E+00	6.00E+00	9.80E+00
Salt waste	0.00E+00	2.80E+00	4.60E+00
Solidified inorganic waste	6.10E+02	1.70E+02	9.00E+02
Unspecified metal waste	8.80E+01	8.60E+01	2.30E+02
Unknown	1.10E+01	2.40E+01	3.50E+01
TOTAL	1.16E+03	3.59E+03	7.14E+03

[a]From the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE 1995c).

facility and current waste emplacement assumptions (i.e., RH-TRU waste will be emplaced in the rooms prior to CH-TRU waste emplacement) and are subject to optimization as generator sites complete waste handling facilities and as future waste is generated. The totals can vary up to a maximum of 6.2 million ft^3 (175,600 m^3) of TRU waste, of which up to 250,000 ft^3 (7,080 m^3) can be RH-TRU waste.

4.1.1 CH-TRU Waste

Most TRU waste emits principally alpha radiation with very little beta and gamma radiation. Alpha particles are dangerous if inhaled or ingested, but do not represent an external radiation hazard. Beta emissions, like alpha, have limited penetration capabilities, and the waste container provides adequate personnel protection. CH-TRU waste is defined as TRU waste that contains predominantly alpha-emitting radioisotopes,

Table 4-4. WIPP Waste Profiles[a]

	Contact-Handled TRU (m^3)			Remote-Handled TRU (m^3)		
	Stored Volume	**Projected Volume**	**Total Volume**	**Stored Volume**	**Projected Volume**	**Total Volume**
Waste Matrix Code Group—Combustible Waste						
Idaho National Engineering Laboratory	6.71E+02	0.00E+00	6.71E+02	NA	NA	NA
Lawrence Livermore National Laboratory	4.89E+01	3.72E+02	4.21E+02	NA	NA	NA
Los Alamos National Laboratory	1.77E+03	2.46E+03	4.23E+03	1.48E+01	3.16E+00	1.80E+01
Mound Laboratory	5.61E+00	0.00E+00	5.61E+00	NA	NA	NA
Richland (Hanford) Site	5.26E+02	1.23E+04	1.28E+04	NA	NA	NA
Savannah River Site	4.07E+03	1.20E+04	1.60E+04	NA	NA	NA
Waste Matrix Code Group—Filter Waste						
Argonne National Laboratory–West	NA	NA	NA	8.90E-01	2.09E+00	2.98E+00
Idaho National Engineering Laboratory	3.24E+02	0.00E+00	3.24E+02	NA	NA	NA
Rocky Flats Plant	1.04E+02	1.09E+03	1.19E+03	NA	NA	NA
Waste Matrix Code Group—Graphite Waste						
Idaho National Engineering Laboratory	6.51E+02	0.00E+00	6.51E+02	NA	NA	NA
Rocky Flats Plant	1.81E+01	4.34E+01	6.15E+01	NA	NA	NA
Waste Matrix Code Group—Heterogeneous Waste						
Argonne National Laboratory–West	0.00E+00	3.36E+00	3.36E+00	5.90E-01	8.00E-02	6.70E-01
Batelle Columbus Laboratories	NA	NA	NA	0.00E+00	7.10E+01	7.10E+01
Bettis Atomic Power Laboratory	0.00E+00	1.24E+02	1.24E+02	0.00E+00	1.56E+00	1.56E+00
Energy Technology Engineering Center	1.66E+00	5.20E+00	6.86E+00	NA	NA	NA
Idaho National Engineering Laboratory	9.65E+03	1.00E+00	9.65E+03	1.36E+01	2.80E+00	1.64E+01
Knolls Atomic Power Laboratory	2.40E+00	0.00E+00	2.40E+00	1.12E+01	2.52E+01	3.65E+01
Lawrence Berkeley Laboratory	8.40E-01	4.42E+00	5.26E+00	NA	NA	NA
Mound Laboratory	4.20E-01	0.00E+00	4.20E-01	NA	NA	NA
Nevada Test Site	6.20E+02	0.00E+00	6.20E+02	NA	NA	NA
Oak Ridge National Laboratory	6.73E+02	2.64E+02	9.37E+02	3.83E+02	1.83E+02	5.66E+02
Pantex	6.20E-01	0.00E+00	6.20E-01	NA	NA	NA
Richland (Hanford) Site	8.57E+03	8.27E+02	9.40E-03	3.32E+01	2.97E+03	3.01E+03
Rocky Flats Plant	3.13E+02	8.05E+02	1.12E-03	NA	NA	NA

[a]From the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE 1995d).

NA = Waste Matrix Code Group not applicable to site CH-TRU or RH-TRU inventory.

Table 4-4. WIPP Waste Profiles[a] (continued)

	Contact-Handled TRU (m^3)			Remote-Handled TRU (m^3)		
	Stored Volume	Projected Volume	Total Volume	Stored Volume	Projected Volume	Total Volume
Savannah River Site	1.01E+04	2.56E+03	1.27E+04	0.00E+00	6.39E+01	6.39E+01
University of Missouri	6.00E-02	1.60E+00	1.66E+00	NA	NA	NA
Waste Matrix Code Group—Inorganic Non-Metal Waste						
Idaho National Engineering Laboratory	1.05E+03	0.00E+00	1.05E+03	NA	NA	NA
Rocky Flats Plant	1.11E+02	3.19E-02	4.29E+02	NA	NA	NA
Waste Matrix Code Group—Lead/Cadmium Metal Waste						
Argonne National Laboratory–East	1.10E+00	0.00E+00	1.10E+00	NA	NA	NA
Argonne National Laboratory–West	2.00E-02	2.48E-00	2.50E+00	0.00E+00	3.60E-01	3.60E-01
Energy Technology Engineering Center	2.10E-01	0.00E+00	2.10E-01	NA	NA	NA
Idaho National Engineering Laboratory	NA	NA	NA	0.00E+00	5.60E+00	5.60E+00
Richland (Hanford) Site	3.13E+00	2.90E-01	3.42E+00	NA	NA	NA
Rocky Flats Plant	5.19E+01	1.24E-02	1.76E+02	NA	NA	NA
Waste Matrix Code Group—Salt Waste						
Idaho National Engineering Laboratory	2.29E+01	0.00E+00	2.29E+01	0.00E+00	2.80E+00	2.80E+00
Lawrence Livermore National Laboratory	6.20E-01	2.91E-00	3.53E+00	NA	NA	NA
Rocky Flats Plant	9.45E+00	5.66E-01	6.61E+01	NA	NA	NA
Waste Matrix Code Group—Soil						
Idaho National Engineering Laboratory	3.80E+00	0.00E+00	3.80E+00	NA	NA	NA
Los Alamos National Laboratory	1.09E+02	1.45E+02	2.54E+02	NA	NA	NA
Mound Laboratory	1.47E+02	0.00E+00	1.47E+02	NA	NA	NA
Richland (Hanford) Site	1.12E+02	3.09E+02	4.21E+02	NA	NA	NA
Waste Matrix Code Group—Solidified Inorganic Waste						
Ames Laboratory	0.00E+00	1.00E-01	1.00E-01	NA	NA	NA
Argonne National Laboratory–East	2.31E+01	1.12E+00	2.42E+01	NA	NA	NA
Idaho National Engineering Laboratory	1.22E+04	0.00E+00	1.22E+04	2.10E+00	0.00E+00	2.10E+00
Lawrence Livermore National Laboratory	1.33E+01	6.62E+01	7.95E+01	NA	NA	NA
Los Alamos National Laboratory	4.85E+03	2.06E+03	6.91E+03	NA	NA	NA
Mound Laboratory	7.28E+00	0.00E+00	7.28E+00	NA	NA	NA

[a]From the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE 1995d).

NA = Waste Matrix Code Group not applicable to site CH-TRU or RH-TRU inventory.

Table 4-4. WIPP Waste Profiles[a] (continued)

	Contact-Handled TRU (m^3)			Remote-Handled TRU (m^3)		
	Stored Volume	**Projected Volume**	**Total Volume**	**Stored Volume**	**Projected Volume**	**Total Volume**
Oak Ridge National Laboratory	1.10E+02	0.00E+00	1.10E+02	6.11+02	1.74E+02	7.85E+02
Paducah Gaseous Diffusion Plant	3.45E+00	0.00E+00	3.45E+00	NA	NA	NA
Richland (Hanford) Site	1.46E+00	2.92E+03	2.93E+03	NA	NA	NA
Rocky Flats Plant	2.29E+02	2.99E+03	3.22E+03	NA	NA	NA
Savannah River Site	4.00E-02	0.00E+00	4.00E-02	NA	NA	NA
Waste Matrix Code Group—Solidified Organic Waste						
Argonne National Laboratory–East	3.00E-02	0.00E+00	3.00E-02	NA	NA	NA
Idaho National Engineering Laboratory	9.13E+02	0.00E+00	9.13E+02	NA	NA	NA
Richland (Hanford) Site	2.17E+00	1.53E+01	1.74E+01	NA	NA	NA
Rocky Flats Plant	1.33E+02	4.88E+01	1.82E+02	NA	NA	NA
Savannah River Site	4.05E+02	2.41E+02	6.46E+02	NA	NA	NA
Waste Matrix Code Group—Unspecified Metal Waste						
Argonne National Laboratory–East	4.96E+00	5.60E-01	5.52E+00	NA	NA	NA
Argonne National Laboratory–West	NA	NA	NA	7.17E+00	1.36E+00	8.53E+00
Idaho National Engineering Laboratory	7.56E+03	0.00E+00	7.56E+03	4.11E+00	5.60E+00	9.71E+00
Lawrence Livermore National Laboratory	1.44E+02	2.47E+02	3.91E+02	NA	NA	NA
Los Alamos National Laboratory	4.13E+03	3.01E+03	7.14E+03	7.65E+01	7.95E+01	1.56E+02
Mound Laboratory	1.02E+02	0.00E+00	1.02E+02	NA	NA	NA
Richland (Hanford) Site	1.03E+02	4.89E+03	4.99E+03	NA	NA	NA
Rocky Flats Plant	1.65E+02	4.30E+02	5.94E+02	NA	NA	NA
Waste Matrix Code Group—Unknown						
Argonne National Laboratory–West	NA	NA	NA	0.00E+00	2.37E+01	2.37E+01
Idaho National Engineering Laboratory	1.66E+03	0.00E+00	1.66E+03	1.11E+01	0.00E+00	1.11E+01

[a]From the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE 1995d).

NA = Waste Matrix Code Group not applicable to site CH-TRU or RH-TRU inventory.

Table 4-5. Estimated Annual Receipt Rates of CH-TRU Waste at the WIPP Facility

Operating Year	CH-TRU Waste (ft^3)	Drums/Year[a]	SWBs/Year[b]
1	14,000	1,050	100
2	57,000	4,200	400
3	80,000	5,460	520
4	140,000	10,500	1,000
5	245,300	18,060	1,720
6-22	285,000	21,000	2,000
23	245,000	18,060	1,720
24	200,000	14,700	1,400
25	140,000	10,500	1,000

[a]Drum volume = 7.35 ft^3 (0.208 m^3)
[b]SWB volume = 64.85 ft^3 (1.837 m^3)

Table 4-6. Estimated Annual Receipt Rates of RH-TRU Waste at the WIPP Facility[a]

Operating Year	RH-TRU Waste (ft^3)	Canisters/Year[a]
2	2,074	66
3	5,280	168
4	8,298	264
5–19 (15)	10,466	333

[a]Canister volume = 31.43 ft^3 (0.888 m^3)

can be managed in closed vented containers that provide protection from inhalation or ingestion, and emits less than 200 millirem per hour at the surface of the container.

The volume limit of TRU waste to be emplaced in the WIPP facility is 6.2 million ft^3 (175,600 m^3), as specified in the WIPP Land Withdrawal Act (LWA). The anticipated volume of the CH-TRU waste inventory is approximately 2.6 million ft^3 (73,300 m^3) of currently stored waste and 1.8 million ft^3 (54,300 m^3) of waste that the DOE will generate in the future. Estimates of the volume of waste yet to be generated are expected to change in the future as a result of environmental restoration and remediation activities.

4.1.2 RH-TRU Waste

A small percentage of TRU waste is designated as RH-TRU, because it contains radioactive isotopes that emit high gamma radiation and some neutron radiation, as well as alpha radiation, resulting in an external radiation dose greater than 200 millirem per

hour. Gamma radiation is more penetrating than alpha or beta radiation. It can pass through several inches of lead and must be heavily shielded for safe management and storage. The upper limit for RH-TRU waste that can be emplaced at the WIPP facility is a surface dose rate of 1,000 rem per hour, as specified in the LWA. In addition, any RH canister containing neutron radiation that exceeds 20 millirem per hour must be identified in the waste certification data package.

Section 7(a)(1)(B) of the LWA limits the RH-TRU waste volume so that no more than five percent of such waste may exhibit a dose rate in excess of 100 rem per hour. In addition, RH-TRU waste received at the WIPP facility must not exceed 23 curies per liter maximum activity level (averaged over the volume of the canister). Section 7(a)(2)(B) of the LWA limits the total curies of RH-TRU waste received at the WIPP facility to no more than 5,100,000 curies.

The total volume of RH-TRU waste that may be emplaced in the WIPP facility is limited by agreements with the State of New Mexico to 250,000 ft^3 (7,080 m^3). The RH-TRU waste inventory consists of 41,290 ft^3 (1,170 m^3) of currently stored waste and 127,750 ft^3 (3,620 m^3) of future generated waste.

4.2 Waste Acceptance Criteria

Very specific acceptance criteria have been established for waste destined for the WIPP facility. The criteria govern the physical, radiological, and chemical composition of the waste and establish specifications for waste packaging. These criteria are based on operational safety requirements, Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC) regulations for transport of TRU waste, and RCRA waste analysis requirements. WAC will be published by the DOE and implemented at the generator/storage sites prior to the shipment of waste to the WIPP facility.

Waste that does not meet the WAC may require treatment or processing. Any such treatment would be the responsibility of the site proposing to ship the waste to the WIPP facility. Waste that cannot be treated or processed to meet the WAC will not be disposed at the WIPP facility.

There are two levels of oversight applied to waste generator/storage sites to assure compliance with WAC and associated waste characterization requirements. One level involves review, approval, and audit of a site's waste certification program. The certification program must contain all the elements (technical and administrative) to determine if waste meets the WIPP WAC. This oversight is implemented by the National TRU Program (NTP), under the National TRU Waste Operations Office. The second level of oversight involves both the NTP and WIPP facility personnel and includes audits of waste characterization activities. These audits are performed to assure compliance with the WIPP Waste Analysis Plan (Appendix WAP) and associated QA requirements.

4.2.1 *Existing Waste Acceptance Criteria Based on Transportation and Operational Safety Requirements*

This section discusses the WAC associated with operational safety requirements relevant to compliance with the no-migration standards. The Waste Analysis Plan (Appendix WAP) includes a detailed description of TRU wastes that meet these criteria.

TRU waste managed at the WIPP facility will consist of solid and solidified inorganic and organic matrices. The WAC specifies that liquid waste is not acceptable at the WIPP. Every container holding waste with less than .53 gal (2 L) of liquid for a 55-gallon drum or 2.1 gal (8 L) in a SWB must contain as little residual liquid as is reasonably achievable, and all internal containers must contain less than one in. (2.5 cm) of liquid at the container bottom. In addition, RCRA-regulated ignitable (D001), corrosive (D002), and reactive (D003) wastes will not be accepted at the WIPP facility. TRU waste may not contain explosives, compressed gases, or nonradionuclide pyrophoric material. Radionuclide pyrophorics must be less than one percent by weight of the waste and be dispersed in the waste.

The hazardous wastes that will be accepted at the WIPP facility are described by EPA hazardous waste codes in Part A of the RCRA permit application (DOE 1995a, ch. A). Tables 4-7 and 4-8 list the EPA waste codes, the basis for hazardous waste classification, and the quantities of hazardous waste for each TRU-mixed waste stream. It should be reiterated here that many of the waste streams identify codes not listed in the RCRA Part A permit application, and that inclusion in the BIR does not make them acceptable to the WIPP for disposal. Each waste stream must be identified with the required documentation and waste characterization data, and presented to WIPP for approval. Only after a waste stream has been approved for disposal at WIPP and the generator site has been audited for compliance by the CAO/WID audit team can the waste be prepared for shipment to the WIPP. Tables 4-7 and 4-8 show waste stream information that is currently available to provide a view of the kinds of waste expected, but are neither exhaustive lists of waste that may eventually be accepted by the WIPP for disposal, nor lists implying any preapproval for acceptance.

4.2.2 *Bounding Criteria Based on Long-Term Disposal System Performance*

The DOE intends to comply with the EPA Land Disposal Restrictions, codified in 40 CFR Part 268, by demonstrating that hazardous constituents will not migrate beyond the unit boundary for 10,000 years after closure. If required, long-term performance-based criteria will be applied to the WIPP inventory based on disposal-system performance projections. Only the physical and chemical form of the waste and its potential interaction with the repository will be considered in the development of these criteria. Information used to formulate and identify these criteria may include waste characterization activities and modeling.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a]

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
AL-W005	Ames Laboratory	1000	Solidified inorganics	D004 D005 D006 D007 D008 D010 D011	Arsenic Barium Cadmium Chromium Lead Selenium Silver	0.0E+00	1.0E-01
AW-M001	Argonne–West	5400	Lead/cadmium metal waste	D006 D007 D008	Cadmium Chromium Lead	0.0E+00	1.9E+00
AW-M002	Argonne–West	5311	Lead/cadmium metal waste	D008	Lead	2.0E-02	5.8E-01
AW-T001[b]	Argonne–West		Heterogeneous	NA		0.0E+00	3.4E+00
BT-T002[b]	Bettis Atomic Power Laboratory		Heterogeneous	NA		0.0E+00	1.5E+01
BT-T003[b]	Bettis Atomic Power Laboratory		Heterogeneous	NA		0.0E+00	1.1E+02
BT-T004[b]	Bettis Atomic Power Laboratory		Heterogeneous	NA		0.0E+00	2.5E-04
BT-T005[b]	Bettis Atomic Power Laboratory		Heterogeneous	NA		0.0E+00	3.6E-06

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	ET-M001	Energy Technology Engineering Center		Lead/cadmium metal waste	D008	Lead	2.1E-01	0.0E+00
2	ET-T001[b]	Energy Technology Engineering Center		Heterogeneous	NA		1.7E+00	5.2E+00
3	IN-T001[b]	INEL		Solidified inorganics	NA		1.4E+04	0.0E+00
4	IN-W157	INEL	3150	Solidified inorganics	D006 D008 F001 F001 F001 F001 F002 F003 F003 F003	Cadmium Lead Trichloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride n-Butyl alcohol Methanol Xylenes	2.3E+02	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W161	INEL	5230	Inorganic nonmetal	F001 F001 F002	Trichloroethylene 1,1,1-Trichloroethane Methylene chloride	1.1E+02	0.0E+00
2	IN-W166	INEL	3150	Solidified inorganics	D008 F001 F001 F001 F002 F003 F003 F003	Lead 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Carbon tetrachloride Methylene chloride Xylenes n-Butyl alcohol Methanol	7.1E+01	0.0E+00
3	IN-W167	INEL	3150	Solidified organics	D022 F001 F001 F001 F003	Chloroform Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Xylenes	1.6E+02	0.0E+00
4	IN-W169	INEL	5440	Heterogeneous	D008 D022 D029 F001 F001	Lead Chloroform 1,1-Dichloroethylene Tetrachloroethylene Carbon tetrachloride	4.3E+03	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W169 (cont.)				F001 F001 F002 F003 F003 F005 F005	1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Ethyl benzene Xylenes Spent nonhalogenated solvents Benzene		
IN-W170	INEL	5440	Heterogeneous	D004 D006 D008 F003	Arsenic Cadmium Lead Acetone	4.4E-01	0.0E+00
IN-W171	INEL	5440	Heterogeneous	D004 D006 D008 F003	Arsenic Cadmium Lead Acetone	3.6E+00	0.0E+00
IN-W172	INEL	5440	Heterogeneous	F001 F002	1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride	1.7E+02	0.0E+00
IN-W174	INEL	3113	Solidified organics			1.5E+02	0.0E+00
IN-W177	INEL	3150	Solidified inorganics			1.8E+02	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)

[b]Unmixed waste stream (not classified as hazardous waste).

[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W179	INEL	3150	Solidified inorganics	D006 D007 D008 D009 D010 D011 F001 F001 F001 F003 F003 P015	Cadmium Chromium Lead Mercury Selenium Silver 1,1,1-Trichloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane Trichloroethylene Acetone Methanol Beryllium	5.5E+00	0.0E+00
IN-W181	INEL	3150	Solidified inorganics	D006 D007 D008 D009 F001 F001 F001 F001 F001 F002 F003	Cadmium Chromium Lead Mercury 1,1,2-Trichloro-1,2,2-trifluoroethane Carbon tetrachloride Trichloroethylene Tetrachloroethylene 1,1,1-Trichloroethane Methylene chloride Xylenes	9.5E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)

[b]Unmixed waste stream (not classified as hazardous waste).

[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W181 (cont.)				F003 F003 P015	n-Butyl alcohol Methanol Beryllium		
IN-W186	INEL	3150	Heterogeneous	D008 F001 F001 F001 F001 F002	Lead 1,1,2-Trichloro-1,2,2-trifluoroethane Trichloroethylene Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride	2.7E+03	0.0E+00
IN-W188	INEL	3150	Solidified inorganics	D006 D007 D008 D009 D022 D028 F001 F001 F001 F001 F001 F002 F003	Cadmium Chromium Lead Mercury Chloroform 1,2-Dichloroethane Trichloroethylene Tetrachloroethylene 1,1,2-Trichloro-1,2,2-trifluoroethane Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride Methanol	1.1E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W188 (cont.)				F003 F003 P015	n-Butyl alcohol Xylenes Beryllium		
IN-W189	INEL	5440	Heterogeneous	D008 F001	Lead 1,1,1-Trichloroethane	6.1E+00	0.0E+00
IN-W917	INEL	5440	Heterogeneous	D008 D022 F001 F001 F001 F001 F001 F002 F003 F003 F005	Lead Chloroform Trichloroethylene Tetrachloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Acetone Xylenes Toluene	5.8E+02	0.0E+00
IN-W198	INEL	5310	Combustible	D008 D022 D029 F001 F001	Lead Chloroform 1,1-Dichloroethylene Tetrachloroethylene 1,1,1-Trichloroethane		

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W198 (cont.)				F001 F001 F001 F002 F003 F003 F003 F003 F005 F005	Carbon tetrachloride Trichlorethylene 1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride Ethyl benzene Methanol Acetone Xylenes Toluene Benzene	1.3E+02	0.0E+00
IN-W202	INEL	5320	Combustible	D008 F001 F001 F001 F001 F002 F003	Lead Trichloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Xylenes	1.1E+02	0.0E+00
IN-W203	INEL	5440	Heterogeneous	D009	Mercury	7.2E+01	0.0E+00
IN-W204	INEL	5440	Heterogeneous	D008 D009	Lead Mercury	1.8E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W205	INEL	5300	Combustible	D008 F001 F001 F001 F001 F002 F003	Lead Trichloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Xylenes	8.3E-01	0.0E+00
2	IN-W214	INEL	5410	Filter	D009	Mercury	6.5E-01	0.0E+00
3	IN-W216	INEL	3150	Solidified inorganics	D005 D006 D007 D008 D009 D011 D022 D028 F001 F001 F001 F001 F001 F002	Barium Cadmium Chromium Lead Mercury Silver Chloroform 1,2-Dichloroethane Trichloroethylene Tetrachloroethylene 1,1,2-Trichloro-1,2,2-trifluoroethane Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride	1.9E+03	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W216 (cont.)				F003	Methanol		
				F003	n-Butyl alcohol		
				F003	Xylenes		
				P015	Beryllium		
IN-W220	INEL	3150	Solidified inorganics	D004	Arsenic	5.5E+02	0.0E+00
				D005	Barium		
				D006	Cadmium		
				D007	Chromium		
				D008	Lead		
				D009	Low mercury		
				F001	Carbon tetrachloride		
				F001	1,1,2-Trichloro-1,2,2-trifluoroethane		
				F001	Tetrachloroethylene		
				F001	Trichloroethylene		
				F001	1,1,1-Trichloroethane		
				F002	Methylene chloride		
				F003	n-Butyl alcohol		
				F003	Xylenes		
				F003	Methanol		
				F003	Ethyl benzene		
				F005	Toluene		
				P015	Beryllium		

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W221	INEL	3113	Solidified inorganics	F003 F003 F003	Xylenes n-Butyl alcohol Methanol	1.4E+01	0.0E+00
2	IN-W222	INEL	3150	Solidified inorganics	D006 D008 F001 F001 F001 F002 F003 F003 F003	Cadmium Lead Carbon tetrachloride 1,1,1-Trichloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride Methanol Xylenes n-Butyl alcohol	1.4E+01	0.0E+00
3	IN-W225	INEL	5440	Heterogeneous	D008 F001 F001 F001	Lead Trichloroethylene Carbon tetrachloride 1,1,1-Trichloroethane	3.2E+00	0.0E+00
4	IN-W228	INEL	3121	Solidified inorganics	D005 D006 D007 D008 D009	Barium Cadmium Chromium Lead Mercury	7.4E+02	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W228 (cont.)				D011	Silver		
				D022	Chloroform		
				D028	1,2-Dichloroethane		
				F001	Carbon tetrachloride		
				F001	Trichloroethylene		
				F001	1,1,2-Trichloro-1,2,2-trifluoroethane		
				F001	1,1,1-Trichloroethane		
				F001	Tetrachloroethylene		
				F002	Methylene chloride		
				F003	Xylenes		
				F003	Methanol		
				F003	n-Butyl alcohol		
				P015	Beryllium		
IN-W230	INEL	5200	Inorganic nonmetal	F001	1,1,2-Trichloro-1,2,2-trifluoroethane	1.8E+01	0.0E+00
				F001	Carbon tetrachloride		
				F001	1,1,1-Trichloroethane		
				F002	Methylene chloride		
IN-W240	INEL	5220	Inorganic nonmetal	D008	Lead	1.7E+02	0.0E+00
				D009	Mercury		
				F001	Carbon tetrachloride		
				F001	1,1,2-Trichloro-1,2,2-trifluoroethane		
				F001	1,1,1-Trichloroethane		

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W243	INEL	5220	Inorganic nonmetal	D008 D029 F001 F001 F001 F002 F003 F005	Lead 1,1-Dichloroethylene Trichloroethylene Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride Xylenes Toluene	1.9E+02	0.0E+00
2	IN-W245	INEL	8900	Inorganic nonmetal	D008 F001 F001 F001	Lead Trichloroethylene Carbon tetrachloride 1,1,1-Trichloroethane	1.7E+02	0.0E+00
3	IN-W247	INEL	8900	Inorganic nonmetal	D008 D028 D029 F001 F001 F001 F001 F002 F003 F003	Lead 1,2-Dichloroethane 1,1-Dichloroethylene Trichloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Methanol Acetone	2.0E+02	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W247 (cont.)				F005 F005	Toluene Benzene		
IN-W249	INEL	8900	Inorganic nonmetal	D009	Mercury	2.8E+00	0.0E+00
IN-W250	INEL	5311	Combustible	D008	Lead	5.0E+01	0.0E+00
IN-W252	INEL	5311	Combustible	D008 D022 D028 D029 F001 F001 F001 F001 F002 F003 F003 F003 F005 F005	Lead Chloroform 1,2-Dichloroethane 1,1-Dichloroethylene Trichloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Acetone Ethyl benzene Xylenes Toluene Benzene	1.6E+02	0.0E+00
IN-W254	INEL	5311	Combustible	D008 F001	Lead Trichloroethylene	1.0E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W254 (cont.)				F001 F001 F002	Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride		
IN-W256	INEL	5311	Combustible	D008	Lead	2.6E+01	0.0E+00
IN-W259	INEL	5400	Heterogeneous	D008	Lead	5.9E+01	0.0E+00
IN-W260A	INEL	3100	Uncategorized metal	D008	Lead	8.8E+00	0.0E+00
IN-W263	INEL	4200	Soils	D006 D007 D008 D009 D010 D011	Cadmium Chromium Lead Mercury Selenium Silver	3.8E+00	0.0E+00
IN-W265	INEL	5430	Heterogeneous	F001 F001 F001 F001 F001 F002 F003 F003	Carbon tetrachloride 1,1,1-Trichloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane Trichloroethylene Tetrachloroethylene Methylene chloride Xylenes n-Butyl alcohol	4.8E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W265 (cont.)				F003 F004	Methanol Nitrobenzene		
IN-W269A	INEL	5000	Heterogeneous	D008	Lead	2.6E+01	0.0E+00
IN-W271	INEL	3190	Heterogeneous	D009	Mercury	4.2E-01	0.0E+00
IN-W272	INEL	5000	Graphite	F001 F002	1,1,1-Trichloroethane Methylene chloride	1.9E+00	0.0E+00
IN-W275	INEL	5000	Graphite	F001	1,1,1-Trichloroethane	6.4E+00	0.0E+00
IN-W276	INEL	5000	Graphite	D022 D028 F001 F001 F001 F001 F002 F003 F005 F005	Chloroform 1,2-Dichloroethane 1,1,1-Trichloroethane Tetrachloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride Methanol Toluene Benzene	3.9E+02	0.0E+00
IN-W280	INEL	5100	Uncategorized metal	D009	Mercury	3.6E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W281	INEL	5400	Heterogeneous	D005 D006 D007 D008 D009 D010 D011	Barium Cadmium Chromium Lead Mercury Selenium Silver	3.5E+02	0.0E+00
2	IN-W283	INEL	5400	Heterogeneous	D008 F002 F003	Lead Methylene chloride Xylenes	1.0E+00	0.0E+00
3	IN-W285	INEL	5400	Heterogeneous	D008	Lead	6.5E+01	0.0E+00
4	IN-W287	INEL	5100	Uncategorized metal	D008	Lead	2.1E+02	0.0E+00
5	IN-W289	INEL	8200	Heterogeneous	D004 D005 D006 D007 D008 D009 F001	Arsenic Barium Cadmium Chromium Lead Mercury 1,1,1-Trichloroethane	2.5E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W289 (cont.)				F002 P015	Methylene chloride Beryllium		
IN-W291	INEL	5000	Heterogeneous	F003	Ethyl ether	6.4E+02	0.0E+00
IN-W294	INEL	5100	Uncategorized metal	D008 D022 F001 F001 F001 F001 F002 F005	Lead Chloroform Trichloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Toluene	4.4E+02	0.0E+00
IN-W296	INEL	5100	Uncategorized metal	D008 D028 D029 F001 F001 F001 F001 F002 F003 F003	Lead 1,2-Dichloroethane 1,1-Dichloroethylene 1,1,1-Trichloroethane Carbon tetrachloride Trichloroethylene 1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride Acetone Ethyl benzene	4.7E+03	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
IN-W296 (cont.)				F003 F003 F005 F005	Methanol Xylenes Toluene Benzene		
IN-W298	INEL	5100	Uncategorized metal	D008 F001 F001 F001 F002	Lead Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride	7.5E+01	0.0E+00
IN-W300	INEL	5100	Uncategorized metal	D008 F001 F001 F001 F002 P015	Lead Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Beryllium	1.5E+03	0.0E+00
IN-W302	INEL	8200	Heterogeneous	F001 F002	1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride	1.1E+02	0.0E+00
IN-W304[b]	INEL	5190	Uncategorized metal	NA		6.7E+01	0.0E+00
IN-W305[b]	INEL	5300	Combustible	NA		4.7E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)

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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W306.1	INEL	8200	Solidified inorganics			3.1E+02	0.0E+00
2	IN-W306.2	INEL	8200	Uncategorized metal			3.1E+02	0.0E+00
3	IN-W306.3	INEL	8200	Heterogeneous			3.1E+02	0.0E+00
4	IN-W306.4	INEL	8200	Filter			3.1E+02	0.0E+00
5	IN-W308	INEL	8200	Unknown			1.2E+03	0.0E+00
6	IN-W309	INEL	3114	Solidified organics	D005 D011 F001 F001 F001 F001 F001 F002 F004 P015	Barium Silver Trichloroethylene Tetrachloroethylene Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,1-Trichloroethane Methylene chloride Nitrobenzene Beryllium	3.6E+02	0.0E+00
7	IN-W311	INEL	3140	Salt waste	D028 F001	1,2-Dichloroethane 1,1,1-Trichloroethane	6.6E+00	0.0E+00
8	IN-W312	INEL	3140	Salt waste			3.2E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W314	INEL	3140	Salt waste	F001	1,1,1-Trichloroethane	1.1E+00	0.0E+00
2	IN-W325	INEL	5300	Combustible			4.2E-01	0.0E+00
3	IN-W327	INEL	5300	Combustible			4.3E+00	0.0E+00
4	IN-W329	INEL	5400	Heterogeneous			1.1E+00	0.0E+00
5	IN-W330	INEL	5310	Combustible			7.4E+00	0.0E+00
6	IN-W332	INEL	3150	Solidified inorganics			8.3E-01	0.0E+00
7	IN-W334	INEL	5000	Heterogeneous			5.5E+00	0.0E+00
8	IN-W336	INEL	5300	Combustible			4.1E+00	0.0E+00
9	IN-W338	INEL	8200	Unknown			1.3E+00	0.0E+00
10	IN-W339	INEL	8200	Unknown			8.7E+00	0.0E+00
11	IN-W342	INEL	8200	Unknown			4.3E-01	0.0E+00
12	IN-W345	INEL	5000	Heterogeneous			1.5E+01	0.0E+00
13	IN-W347	INEL	3113	Solidified inorganics			5.4E+01	0.0E+00
14	IN-W350	INEL	8200	Unknown			2.1E-01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W351	INEL	5000	Heterogeneous			1.5E+00	0.0E+00
2	IN-W353[b]	INEL		Solidified inorganics	NA		2.1E-01	0.0E+00
3	IN-W354[b]	INEL	3140	Salt waste	NA		2.1E-01	0.0E+00
4	IN-W355[b]	INEL	3140	Salt waste	NA		1.3E+00	0.0E+00
5	IN-W356[b]	INEL	3140	Salt waste	NA		4.7E+00	0.0E+00
6	IN-W366[b]	INEL	3000	Inorganic nonmetal	NA		2.5E+00	0.0E+00
7	IN-W369[b]	INEL	5340	Graphite	NA		1.2E+01	0.0E+00
8	IN-W370[b]	INEL	5340	Graphite	NA		6.7E+01	0.0E+00
9	IN-W371[b]	INEL	5100	Uncategorized metal	NA		2.1E-01	0.0E+00
10	IN-W374[b]	INEL	5210	Inorganic nonmetal	NA		9.7E+00	0.0E+00
11	KA-T001[b]	Knolls Atomic Power Laboratory		Heterogeneous	NA		2.4E+00	0.0E+00
12	LA-T001[b]	LANL		Uncategorized metal	NA		7.5E+01	5.8E+02
13	LA-T004[b]	LANL		Combustible	NA		1.5E+03	1.7E+03

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	LA-T005[b]	LANL		Uncategorized metal	NA		1.4E+03	1.2E+03
2	LA-T006[b]	LANL		Solidified inorganics	NA		4.5E+00	3.0E+01
3	LA-T007[b]	LANL		Uncategorized metal	NA		6.9E+00	5.8E+01
4	LA-T008[b]	LANL		Soils	NA		1.1E+02	1.4E+02
5	LA-T009[b]	LANL		Uncategorized metal	NA		4.2E+01	5.8E+01
6	LA-W001	LANL		Uncategorized metal			2.2E+03	1.4E+02
7	LA-W002	LANL		Solidified inorganics			3.1E+03	5.8E+02
8	LA-W003	LANL		Solidified inorganics	D004	Arsenic	1.3E+03	5.8E+02
9	LA-W004	LANL		Combustible	D005	Barium	2.5E+02	7.2E+02
10	LA-W005	LANL		Uncategorized metal	D006	Cadmium	2.1E+02	7.3E+02
11	LA-W006	LANL		Solidified inorganics	D007	Chromium	5.1E+02	8.7E+02
12	LA-W009	LANL		Uncategorized metal	F001 F002 F005	Spent halogenated solvents Spent halogenated solvents Spent nonhalogenated solvents	1.4E+02	2.8E+02

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	LB-T001[b]	Lawrence Berkeley Laboratory		Heterogeneous	NA		8.4E-01	4.4E+00
2	LL-M001	LLNL		Combustible	D006 D008 D040	Cadmium Lead Trichloroethylene	5.2E+00	1.2E+01
3	LL-T001[b]	LLNL		Solidified inorganics	NA		1.2E+01	6.0E+01
4	LL-T002[b]	LLNL		Combustible	NA		4.4E+01	3.6E+02
5	LL-T003[b]	LLNL		Uncategorized metal	NA		1.4E+02	2.2E+02
6	LL-T004[b]	LLNL		Salt waste	NA		6.2E-01	2.9E+00
7	LL-T005[b]	LLNL		Filter	NA		1.7E+01	3.3E+01
8	LL-W018	LLNL		Uncategorized metal	D008	Lead	1.9E+00	2.7E+01
9	LL-W019	LLNL		Solidified inorganics	D040 F002	Trichloroethylene Spent halogenated solvents	8.2E-01	6.4E+00
10	MD-M001	Mound Plant	5250	Inorganic nonmetal			2.1E-01	0.0E+00
11	MD-T001[b]	Mound Plant	3121	Solidified inorganics	NA		4.8E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)

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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	MD-T002[b]	Mound Plant	5310	Combustible	NA		3.5E+00	0.0E+00
2	MD-T003[b]	Mound Plant	4100	Soils	NA		1.2E+02	0.0E+00
3	MD-T004[b]	Mound Plant	8900	Uncategorized metal	NA		2.1E+01	0.0E+00
4	MD-T005[b]	Mound Plant	4200	Soils	NA		3.0E+01	0.0E+00
5	MD-T006[b]	Mound Plant	5110	Uncategorized metal	NA		6.0E+01	0.0E+00
6	MD-T007[b]	Mound Plant	5190	Uncategorized metal	NA		5.0E+00	0.0E+00
7	MD-T008[b]	Mound Plant	5319	Combustible	NA		1.5E+00	0.0E+00
8	MD-T009[b]	Mound Plant	5390	Combustible	NA		2.1E-01	0.0E+00
9	MD-T010[b]	Mound Plant	5410	Heterogeneous	NA		4.2E-01	0.0E+00
10	MD-T011[b]	Mound Plant	5420	Uncategorized metal	NA		1.6E+01	0.0E+00
11	MD-T012[b]	Mound Plant	5490	Heterogeneous	NA		6.2E-01	0.0E+00
12	MD-T013[b]	Mound Plant	5311	Combustible	NA		4.2E-01	0.0E+00
13	MD-W002	Mound Plant	3150	Solidified inorganics			2.5E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	NT-W001	Nevada Test Site	5490	Heterogeneous	D006 D007 D008 D011 F001 F001 F001 F002 F003 P015	Cadmium Chromium Lead Silver Trichloroethylene 1,1,2-Trichloro-1,2,2-trichloroethane Carbon tetrachloride Spent halogenated solvents Methanol Beryllium	6.1E+02	0.0E+00
2	OR-W042	ORNL	3120	Solidified inorganics	D006 D007 D008 D009	Cadmium Chromium Lead Mercury	1.1E+02	0.0E+00
3	OR-W044	ORNL	5400	Heterogeneous	D006 D008 D009 D011	Cadmium Lead Mercury Silver	5.2E+02	2.6E+02
4	OR-W045	ORNL	8000	Heterogeneous	D006 D008	Cadmium Lead	3.6E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
OR-W045 (cont.)				D009 D011	Mercury Silver		
OR-W047	ORNL	5400	Heterogeneous	D006 D008 D009 D011	Cadmium Lead Mercury Silver	1.5E+02	0.0E+00
PA-W014	Paducah Gaseous Diffusion Plant	1220	Solidified inorganics			3.0E-01	0.0E+00
PA-W015	Paducah Gaseous Diffusion Plant	3129	Solidified inorganics	D007	Chromium	1.2E+00	0.0E+00
PA-W015A	Paducah Gaseous Diffusion Plant	1190	Solidified inorganics			6.0E-01	0.0E+00
PX-T001[b]	Pantex Plant	5330	Heterogeneous	NA		6.2E-01	0.0E+00
RF-M001	RFETS	3150	Solidified inorganics	D004 D005 D006 D007 D008 D009	Arsenic Barium Cadmium Chromium Lead Mercury	0.0E+00	9.5E+02

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-M001				D010	Selenium		
2	(cont.)				D011	Silver		
					D018	Benzene		
					D019	Carbon tetrachloride		
					D035	Methyl ethyl ketone		
					D040	Trichloroethylene		
					F001	Spent halogenated solvents		
					F002	Spent halogenated solvents		
					F003	Spent nonhalogenated solvents		
					F005	Spent nonhalogenated solvents		
3	RF-M002	RFETS	5330	Heterogeneous	F001	Spent halogenated solvents	1.9E+00	0.0E+00
					F002	Spent halogenated solvents		
					F003	Spent nonhalogenated solvents		
4	RF-T001[b]	RFETS	3129	Solidified inorganics	NA		7.4E+00	6.1E+00
5	RF-T002[b]	RFETS	5330	Heterogeneous	NA		3.9E+01	1.8E+02
6	RF-T003[b]	RFETS	3119	Inorganic nonmetal	NA		3.2E+00	-3.2E+00[c]
7	RF-T004[b]	RFETS	3141	Salt waste	NA		0.0E+00	8.6E+00
8	RF-T005[b]	RFETS	3129	Solidified inorganics	NA		4.2E-01	1.6E+01

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-T006[b]	RFETS		Solidified inorganics	NA		0.0E+00	0.0E+00
2	RF-T007[b]	RFETS	5330	Heterogeneous	NA		2.1E-01	0.0E+00
3	RF-T010[b]	RFETS	3150	Solidified inorganics	NA		6.3E-01	2.5E+01
4	RF-T011[b]	RFETS	5112	Uncategorized metal	NA		8.2E+01	8.3E+01
5	RF-T036[b]	RFETS	3119	Heterogeneous	NA		1.3E+00	2.0E+00
6	RF-T037[b]	RFETS	5190	Uncategorized metal	NA		1.3E+00	3.6E+00
7	RF-T038[b]	RFETS	3121	Solidified inorganics	NA		2.1E+00	2.8E+01
8	RF-T052[b]	RFETS	5122	Inorganic nonmetal	NA		7.8E+01	7.1E+00
9	RF-T056[b]	RFETS	5123	Inorganic nonmetal	NA		1.3E+00	6.0E-01
10	RF-T057[b]	RFETS	5129	Inorganic nonmetal	NA		6.7E+00	3.7E+00
11	RF-T059[b]	RFETS	3119	Solidified inorganics	NA		0.0E+00	0.0E+00
12	RF-T060[b]	RFETS	3119	Graphite	NA		1.8E+01	6.6E+00
13	RF-T063[b]	RFETS	1190	Solidified inorganics	NA		2.5E-01	0.0E+00
14	RF-T066[b]	RFETS	5410	Filter	NA		3.7E+01	1.3E+02

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-T067[b]	RFETS	5410	Filter	NA		6.3E-01	0.0E+00
2	RF-T069[b]	RFETS	3212	Solidified organics	NA		1.2E+01	0.0E+00
3	RF-T076[b]	RFETS	3119	Solidified inorganics	NA		0.0E+00	0.0E+00
4	RF-W008	RFETS	5900	Heterogeneous	D006 D007 D008 F001 F002 F005	Cadmium Chromium Lead Spent halogenated solvents Spent halogenated solvents Spent nonhalogenated solvents	1.9E+00	0.0E+00
5	RF-W010	RFETS	3150	Solidified inorganics	F002 D006 D008 F001 F001 F002 F005 F005	Methylene chloride Cadmium Lead Carbon tetrachloride 1,1,1-Trichloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane Methyl ethyl ketone Toluene	1.4E+02	8.3E+01

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-W011	RFETS	5112	Uncategorized metal	D008 F001 F001 F002 F002	Lead Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride 1,1,2-Trichloro-1,2,2-trifluoroethane	6.6E+01	3.3E+02
2	RF-W012	RFETS	5330	Heterogeneous	F001 F001 F002 F002 F005 F005	Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride 1,1,2-Trichloro-1,2,2-trifluoroethane Methyl ethyl ketone Toluene	2.6E+02	6.1E+02
3	RF-W013	RFETS	3222	Solidified organics	F001 F001 F002 F002	1,1,1-Trichloroethane Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluorethane Methylene chloride	1.1E+02	0.0E+00
4	RF-W026	RFETS	3114	Inorganic nonmetal	F001 F001	Carbon tetrachloride 1,1,1-Trichloroethane	2.1E-01	0.0E+00
5	RF-W028	RFETS	7211	Lead/cadmium metal waste	D008	Lead	3.8E+00	8.0E+00
6	RF-W029	RFETS	5311	Lead/cadmium metal waste	D008	Lead	2.2E+01	1.0E+02

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-W032	RFETS	3119	Inorganic nonmetal	D008	Lead	2.7E+00	1.1E+01
2	RF-W036	RFETS	3119	Heterogeneous	D004 D006 D007 D008 F001 F001 F002 F002 F005	Arsenic Cadmium Chromium Lead 1,1,1-Trichloroethane Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluorethane Methylene chloride Methyl ethyl ketone	2.9E+00	1.1E+01
3	RF-W037	RFETS	5190	Uncategorized metal	D008	Lead	4.6E+00	2.0E+01
4	RF-W038	RFETS	3121	Solidified inorganics	D007	Chromium	1.5E+00	2.1E+01
5	RF-W040	RFETS	3111	Solidified inorganics	D004 D005 D006 D007 D008 D009 D010 D011	Arsenic Barium Cadmium Chromium Lead Mercury Selenium Silver	1.7E+00	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
RF-W040 (cont.)				F001 F001 F002 F002 F005	1,1,1-Trichloroethane Carbon tetrachloride Methylene chloride 1,1,2-Trichloro-1,2,2-trifluorethane Methyl ethyl ketone		
RF-W041	RFETS	5311	Lead/cadmium metal waste	D008	Lead	2.6E+01	1.1E+01
RF-W052	RFETS	5122	Inorganic nonmetal	D005 D008 F001 F001 F002 F002	Barium Lead Carbon tetrachloride 1,1,1-Trichloroethane Methylene chloride 1,1,2-Trichloro-1,2,2-trifluorethane	1.4E+01	2.8E+02
RF-W056	RFETS	5123	Inorganic nonmetal	D006	Cadmium	1.3E+00	3.0E+00
RF-W057	RFETS	5129	Inorganic nonmetal	F001 F001 F002 F002	Carbon Tetrachloride 1,1,1-Trichloroethane Methylene chloride 1,1,2-Trichloro-1,2,2-trifluorethane	6.3E-01	1.6E+01
RF-W058	RFETS	3141	Salt waste	D007	Chromium	9.4E+00	4.8E+01
RF-W059	RFETS	3119	Solidified inorganics	D007	Chromium	1.2E+01	1.5E+02

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-W060	RFETS	3119	Graphite	D006	Cadmium	4.2E-01	3.7E+01
2	RF-W063	RFETS	1190	Solidified inorganics	D007	Chromium	1.75E+01	0.0E+00
3	RF-W065	RFETS	6290	Solidified inorganics			2.12E-01	0.0E+00
4	RF-W066	RFETS	5410	Filter	D004 D006 D007 D008 D009 D010 D011 F001 F002 F005	Arsenic Cadmium Chromium Lead Mercury Selenium Silver Spent halogenated solvents Spent halogenated solvents Spent nonhalogenated solvents	5.0E+01	7.2E+02
5	RF-W067	RFETS	5410	Filter	D005 D006 D007 D008 D009 F001	Barium Cadmium Chromium Lead Mercury Spent halogenated solvents	9.0E+00	0.0E+00

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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
RF-W067 (cont.)				F002 F003	Spent halogenated solvents Spent nonhalogenated solvents		
RF-W068	RFETS	3129	Solidified inorganics	D006 D007 D008 F001 F001 F002 F002 F005 F005	Cadmium Chromium Lead 1,1,1-Trichloroethane Carbon tetrachloride 1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride Methyl ethyl ketone Toluene	1.8E+01	6.3E+01
RF-W069	RFETS	3212	Solidified organics	D006 D007 D008 F001 F001 F002 F002 F005 F005	Cadmium Chromium Lead Carbon tetrachloride 1,1,1-Trichloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane Methylene chloride Toluene Methyl ethyl ketone	4.4E+00	2.3E+01

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RF-W076	RFETS	3119	Solidified inorganics	D006 D007 D008 F001 F001 F002 F002 F005 F005	Cadmium Chromium Lead 1,1,1-Trichloroethane Carbon tetrachloride Methylene chloride 1,1,2-Trichloro-1,2,2-trifluoroethane Methyl ethyl ketone Toluene	3.33E+01	0.0E+00
2	RL-M001	Hanford		Uncategorized metal	D006 D009	Cadmium Mercury	7.1E+00	9.6E+02
3	RL-M002	Hanford		Uncategorized metal	D008	Lead	1.1E+01	1.5E+03
4	RL-M003	Hanford		Uncategorized metal			3.2E+00	4.2E+02
5	RL-M004	Hanford		Heterogeneous			4.2E+00	5.7E+02
6	RL-M005	Hanford		Solidified inorganics	D009	Mercury	1.5E+00	2.3E+02
7	RL-M006	Hanford		Heterogeneous	D019 F003	Carbon tetrachloride Spent nonhalogenated solvents	1.6E+00	2.5E+02

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	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-M007	Hanford		Soils	D007 D010	Chromium Selenium	1.2E+01	3.7E+01
2	RL-M008	Hanford		Uncategorized metal	D006 D007 D008	Cadmium Chromium Lead	4.8E+01	1.2E+03
3	RL-M009	Hanford		Combustible			1.9E+01	2.4E+02
4	RL-M010	Hanford		Combustible	D006 D009	Cadmium Mercury	4.2E-01	5.5E+00
5	RL-M011	Hanford		Combustible	D007 D008	Chromium Lead	8.4E-01	1.0E+01
6	RL-M012	Hanford		Combustible	D019	Carbon tetrachloride	2.1E-01	2.7E+00
7	RL-M013	Hanford		Combustible	D019 F001 F002 F003 F004 F005	Carbon tetrachloride Spent halogenated solvents Spent halogenated solvents Spent nonhalogenated solvents Spent nonhalogenated solvents Spent nonhalogenated solvents	6.2E-01	7.7E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-M014	Hanford		Combustible	D005 D006 D007 D008 D009	Barium Cadmium Chromium Lead Mercury	4.6E+00	5.8E+01
2	RL-M015	Hanford		Combustible	D005 D006 D007 D008	Barium Cadmium Chromium Lead	1.5E+01	1.9E+02
3	RL-M016	Hanford		Combustible	D007 D008 D019	Chromium Lead Carbon tetrachloride	1.7E+00	2.1E+01
4	RL-M017	Hanford		Solidified organics	F003	Spent nonhalogenated solvents	2.8E-01	2.0E+00
5	RL-M018	Hanford		Solidified organics			1.9E+00	1.3E+01
6	RL-M019	Hanford		Lead/cadmium metal waste	D005 D006 D007 D008 D009	Barium Cadmium Chromium Lead Mercury	1.3E+00	1.2E-01

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-M020	Hanford		Lead/cadmium metal waste	D007 D008	Chromium Lead	1.9E+00	1.7E-01
2	RL-M021	Hanford		Uncategorized metal	D006 D008 D009	Cadmium Lead Mercury	6.7E+01	8.9E+03
3	RL-M022	Hanford		Combustible	D006 D008 D009	Cadmium Lead Mercury	3.2E+00	4.2E+02
4	RL-M023	Hanford		Combustible			4.2E-01	5.5E+00
5	RL-M024	Hanford		Solidified organics			2.3E+00	1.6E+01
6	RL-M031	Hanford		Heterogeneous			6.3E-01	7.7E+00
7	RL-M032	Hanford		Solidified inorganics	D007 F003	Chromium Spent nonhalogenated solvents	2.1E-01	3.2E+01
8	RL-T025[b]	Hanford		Uncategorized metal	NA		3.4E+01	8.1E+02
9	RL-T026[b]	Hanford		Combustible	NA		1.2E+02	2.8E+03
10	RL-T027[b]	Hanford		Solidified inorganics	NA		1.3E+00	2.9E+03

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-T028[b]	Hanford		Soils	NA		6.3E-01	2.7E+02
2	RL-T029[b]	Hanford		Combustible	NA		3.7E+02	8.9E+03
3	RL-T030[b]	Hanford		Uncategorized metal	NA		2.1E-01	2.7E+00
4	RL-T101[b]	Hanford	5400	Heterogeneous	NA		3.7E+02	0.0E+00
5	RL-T102[b]	Hanford	5400	Heterogeneous	NA		1.6E+02	0.0E+00
6	RL-T103[b]	Hanford	4200	Soils	NA		7.4E+01	0.0E+00
7	RL-T104[b]	Hanford	5400	Heterogeneous	NA		3.7E+00	0.0E+00
8	RL-T105[b]	Hanford	5400	Heterogeneous	NA		5.3E+01	0.0E+00
9	RL-T106[b]	Hanford	5400	Heterogeneous	NA		6.0E+00	0.0E+00
10	RL-T107[b]	Hanford	5400	Heterogeneous	NA		3.6E+03	0.0E+00
11	RL-T108[b]	Hanford	5400	Heterogeneous	NA		2.1E+01	0.0E+00
12	RL-T109[b]	Hanford	5400	Heterogeneous	NA		1.3E+01	0.0E+00
13	RL-T110[b]	Hanford	5400	Heterogeneous	NA		3.2E+02	0.0E+00
14	RL-T111A[b]	Hanford	5400	Heterogeneous	NA		1.1E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-T112[b]	Hanford	5400	Heterogeneous	NA		8.9E+01	0.0E+00
2	RL-T113[b]	Hanford	5400	Heterogeneous	NA		2.6E+01	0.0E+00
3	RL-T114[b]	Hanford	5400	Heterogeneous	NA		1.5E+01	0.0E+00
4	RL-T115[b]	Hanford	5400	Heterogeneous	NA		6.5E+02	0.0E+00
5	RL-T116[b]	Hanford	5400	Heterogeneous	NA		8.3E+00	0.0E+00
6	RL-T117[b]	Hanford	5400	Heterogeneous	NA		1.1E-01	0.0E+00
7	RL-T118[b]	Hanford	5400	Heterogeneous	NA		2.5E+02	0.0E+00
8	RL-T119[b]	Hanford	5400	Heterogeneous	NA		7.7E-01	0.0E+00
9	RL-T120[b]	Hanford	5400	Heterogeneous	NA		7.2E+01	0.0E+00
10	RL-T122[b]	Hanford	5400	Heterogeneous	NA		1.3E+01	0.0E+00
11	RL-T123[b]	Hanford	5400	Heterogeneous	NA		1.2E-01	0.0E+00
12	RL-T124[b]	Hanford	5400	Heterogeneous	NA		4.2E-01	0.0E+00
13	RL-T125[b]	Hanford	5400	Heterogeneous	NA		1.1E+01	0.0E+00
14	RL-T127[b]	Hanford	5400	Heterogeneous	NA		1.9E+02	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
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Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-T128[b]	Hanford	5400	Heterogeneous	NA		3.2E-01	0.0E+00
2	RL-T129[b]	Hanford	5400	Heterogeneous	NA		8.7E+00	0.0E+00
3	RL-T130[b]	Hanford	5400	Heterogeneous	NA		1.0E+01	0.0E+00
4	RL-T131[b]	Hanford	5400	Heterogeneous	NA		2.6E+01	0.0E+00
5	RL-T132[b]	Hanford	5400	Heterogeneous	NA		6.3E-01	0.0E+00
6	RL-T133[b]	Hanford	5400	Heterogeneous	NA		2.1E+01	0.0E+00
7	RL-T134[b]	Hanford	5400	Heterogeneous	NA		1.1E-01	0.0E+00
8	RL-T135[b]	Hanford	5400	Heterogeneous	NA		2.1E-01	0.0E+00
9	RL-T136[b]	Hanford	5400	Heterogeneous	NA		1.1E-01	0.0E+00
10	RL-T137[b]	Hanford	5400	Heterogeneous	NA		1.0E+02	0.0E+00
11	RL-T138[b]	Hanford	5400	Heterogeneous	NA		4.1E+01	0.0E+00
12	RL-T139[b]	Hanford	5400	Heterogeneous	NA		1.5E+02	0.0E+00
13	RL-T140[b]	Hanford	5400	Heterogeneous	NA		6.9E+00	0.0E+00
14	RL-T141[b]	Hanford	5400	Heterogeneous	NA		7.4E+01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	RL-T142[b]	Hanford	5400	Heterogeneous	NA		8.5E-01	0.0E+00
2	RL-T143[b]	Hanford	5400	Heterogeneous	NA		5.3E+01	0.0E+00
3	RL-T144[b]	Hanford	5400	Heterogeneous	NA		3.9E+02	0.0E+00
4	RL-T145[b]	Hanford	5400	Heterogeneous	NA		1.0E+02	0.0E+00
5	RL-T146[b]	Hanford	5400	Heterogeneous	NA		1.6E+02	0.0E+00
6	RL-T148[b]	Hanford	5400	Heterogeneous	NA		8.5E-01	0.0E+00
7	RL-T150[b]	Hanford	5400	Heterogeneous	NA		2.5E+02	0.0E+00
8	SA-T001[b]	Sandia National Laboratories	8900	Heterogeneous	NA		7.0E+00	7.0E+00
9	SA-W134	Sandia National Laboratories	8900	Heterogeneous			1.0E+00	0.0E+00
10	SR-T001[b]	Savannah River Site		Solidified organics	NA		2.0E+02	1.2E+02
11	SR-T002[b]	Savannah River Site		Combustible	NA		4.1E+03	1.2E+04

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	SR-W006	Savannah River Site	2000	Solidified organics			2.5E-02	0.0E+00
2	SR-W026	Savannah River Site	5400	Heterogeneous	D004 D006 D007 D008 D009 D011 D018 D019 D022 D026 P015	Arsenic Cadmium Chromium Lead Mercury Silver Benzene Carbon tetrachloride Chloroform Cresol Beryllium	1.1E+02	1.3E+03
3	SR-W027	Savannah River Site	5400	Heterogeneous	D004 D006 D007 D008 D009 D011 D018 D019 D022	Arsenic Cadmium Chromium Lead Mercury Silver Benzene Carbon tetrachloride Chloroform	5.0E+03	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report.* (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-7. Identification/Classification of CH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator/ Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Hazardous Waste Determination	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
SR-W027 (cont.)				D026	Cresol		
				F001	Spent halogenated solvents		
				F002	Spent halogenated solvents		
				F003	Spent nonhalogenated solvents		
				F005	Spent nonhalogenated solvents		
				P015	Beryllium		
SR-W053	Savannah River Site	3111	Solidified inorganics	D004	Arsenic	2.0E-02	0.0E+00
				D005	Barium		
				D006	Cadmium		
				D007	Chromium		
				D008	Lead		
				D009	Mercury		
				D010	Selenium		
				D011	Silver		
				F001	Spent halogenated solvents		
				F002	Spent halogenated solvents		
				F005	Spent nonhalogenated solvents		

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. (Note: In the BIR, some of the waste streams carry EPA hazardous waste codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
[c]Negative value indicates this stream has been reclassified.

Table 4-8. Identification/Classification of RH-TRU Waste Streams to be Disposed of at the WIPP Facility[a]

Waste Stream ID	Generator and Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Classification	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
AW-M003	Argonne–West	5410	Filter			8.9E-01	2.1E+00
AW-T002[b]	Argonne–West		Unknown	NA		0.0E+00	2.4E+01
AW-W016	Argonne–West	3190	Lead/cadmium metal waste	D006	Cadmium	0.0E+00	2.6E-01
AW-W018	Argonne–West	6200	Uncategorized metal			7.1E+00	8.8E-01
AW-W019	Argonne–West	6200	Uncategorized metal			1.1E-01	0.0E+00
AW-W020	Argonne–West	5400	Heterogeneous	D006	Cadmium	5.9E-01	8.0E-02
AW-W021	Argonne–West	5100	Uncategorized metal	D005 D006	Barium Cadmium	0.0E+00	4.8E-01
AW-W022	Argonne–West	3150	Lead/cadmium metal waste	D006	Cadmium	0.0E+00	1.0E-01
BC-T001[b]	Batelle Columbus Laboratories	5400	Heterogeneous	NA		0.0E+00	7.1E+01
BT-T001[b]	Bettis Atomic Power Laboratory		Heterogeneous	NA		0.0E+00	1.6E+00
IN-M001	INEL		Salt waste			0.0E+00	0.0E+00
IN-M002	INEL		Heterogeneous			6.2E-01	2.8E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE, 1995c). (Note: In the BIR, some of the waste streams carry EPA Hazardous Waste Codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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NA - not applicable

Table 4-8. Identification/Classification of RH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator and Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Classification	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-M003	INEL		Uncategorized metal			0.0E+00	0.0E+00
2	IN-M004	INEL		Lead/cadmium metal waste			0.0E+00	2.8E+00
3	IN-M005	INEL		Lead/cadmium metal waste			0.0E+00	2.8E+00
4	IN-W139	INEL		Heterogeneous	D008	Lead	5.4E+00	0.0E+00
5	IN-W146	INEL	3129	Solidified inorganics	D006 D007 D008 D009 D011	Cadmium Chromium Lead Mercury Silver	2.1E+00	0.0E+00
6	IN-W260B	INEL	3100	Uncategorized metal	D008	Lead	2.2E+00	0.0E+00
7	IN-W269B	INEL		Heterogeneous	D008	Lead	2.6E-01	0.0E+00
8	IN-W322	INEL	5190	Uncategorized metal			1.9E+00	0.0E+00
9	IN-W323	INEL	5440	Heterogeneous	D008	Lead	1.9E+00	0.0E+00
10	IN-W337	INEL	8200	Unknown			2.1E-01	0.0E+00

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE, 1995c). (Note: In the BIR, some of the waste streams carry EPA Hazardous Waste Codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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NA - not applicable

Table 4-8. Identification/Classification of RH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

	Waste Stream ID	Generator and Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Classification	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
1	IN-W341	INEL	8200	Unknown			2.1E-01	0.0E+00
2	IN-W349	INEL	8200	Unknown			6.4E+00	0.0E+00
3	IN-W358[b]	INEL	5000	Heterogeneous	NA		5.4E+00	0.0E+00
4	IN-W359[b]	INEL	8200	Unknown	NA		6.4E-01	0.0E+00
5	IN-W360[b]	INEL	8200	Unknown	NA		2.1E-01	0.0E+00
6	IN-W372[b]	INEL	8200	Unknown	NA		3.5E+00	0.0E+00
7	KA-W016	Knolls Atomic Power Laboratory	5000	Heterogeneous	D004 D005 D006 D007 D008 D009 D010 D011 D018 D035	Arsenic Barium Cadmium Chromium Lead Mercury Selenium Silver Benzene Methyl ethyl ketone	1.1E+01	2.5E+01

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE, 1995c). (Note: In the BIR, some of the waste streams carry EPA Hazardous Waste Codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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NA - not applicable

Table 4-8. Identification/Classification of RH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator and Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Classification	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
KA-W016 (cont.)	Knolls Atomic Power Laboratory	5000	Heterogeneous	D039 D040 F001 F002 F003 F005	Tetrachloroethylene Trichloroethylene Spent halogenated solvents Spent halogenated solvents Spent nonhalogenated solvents Spent nonhalogenated solvents		
LA-T010[b]	LANL		Combustible	NA		1.5E+01	3.3E+00
LA-T011[b]	LANL		Uncategorized metal	NA		5.1E+01	6.0E+01
LA-T012[b]	LANL		Uncategorized metal	NA		1.1E+01	4.5E+00
LA-WR01	LANL		Uncategorized metal			2.1E+00	0.0E+00
LA-WR05	LANL		Uncategorized metal			1.3E+01	1.5E+01
OR-W040	ORNL	5400	Heterogeneous	D006 D008 D009 D011	Cadmium Lead Mercury Silver	3.8E+02	1.8E+02

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE, 1995c). (Note: In the BIR, some of the waste streams carry EPA Hazardous Waste Codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
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NA - not applicable

Table 4-8. Identification/Classification of RH-TRU Waste Streams to be Disposed of at the WIPP Facility[a] (continued)

Waste Stream ID	Generator and Storage Site	Waste Matrix Code	Waste Matrix Code Group	EPA Hazardous Waste Code(s)	Basis for Classification	Retrievably Stored Waste (m^3)	Future Generated Waste (m^3)
OR-W046	ORNL	3000	Solidified inorganics	D006 D007 D008 D009	Cadmium Chromium Lead Mercury	6.1E+02	1.7E+02
RL-M201	Hanford	5400	Heterogeneous			0.0E+00	1.7E+03
RL-T111B[b]	Hanford	5400	Heterogeneous	NA		1.7E-01	0.0E+00
RL-T121[b]	Hanford	5400	Heterogeneous	NA		2.5E+01	0.0E+00
RL-T126[b]	Hanford	5400	Heterogeneous	NA		4.2E+00	0.0E+00
RL-T147[b]	Hanford	5400	Heterogeneous	NA		1.7E+00	0.0E+00
RL-T149[b]	Hanford	5400	Heterogeneous	NA		6.9E-01	0.0E+00
RL-T202[b]	Hanford	5400	Heterogeneous	NA		0.0E+00	1.2E+03
SR-T003[b]	SRS	5400	Heterogeneous	NA		0.0E+00	3.2E+01

[a]From *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (DOE, 1995c). (Note: In the BIR, some of the waste streams carry EPA Hazardous Waste Codes that are not included in the RCRA Part A Permit Application. The characteristic wastes will have to be treated and/or repackaged prior to shipment to the WIPP facility. Listed wastes with Hazardous Waste Codes not included in the RCRA Part A Permit Application will not be shipped to the WIPP unless a permit modification is obtained. The volumes for these streams are included in the table to provide realistic volume estimates.)
[b]Unmixed waste stream (not classified as hazardous waste).
NA - not applicable

4.3 Waste Characterization

Waste characterization refers to the testing, sampling and analysis, and nondestructive assay/nondestructive examination (NDA/NDE) of the waste. The examination and evaluation of waste generation documentation and associated records are also important parts of waste characterization. The DOE has established a TRU Waste Characterization Program to identify waste characterization data needs and facilitate the development and implementation of waste characterization programs at the DOE generator/storage facilities.

4.3.1 Plans and Program Summary

A TRU Waste Management Plan was developed by the DOE to establish planning strategies to support the WIPP Disposal Decision Plan. It provides an overview of the TRU Waste Characterization Program, including a waste characterization document hierarchy, a summary of waste characterization requirements, and guidance regarding the implementation of waste characterization programs at the DOE generator/storage sites.

The TRU Waste Characterization Program requirements are complemented by a *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP) (DOE 1995b), portions of which are included in the Waste Analysis Plan (Appendix WAP). Each generator/storage site planning to send its waste to the WIPP facility must develop a site-specific quality assurance project plan (QAPjPs) and a WAC certification plan to address applicable TRU waste characterization requirements. Additional discussions of the QA requirements and programs are provided in Chapter 7.

4.3.1.1 Waste Characterization Program

The QAPP addresses the quality assurance/quality control (QA/QC) requirements associated with RCRA General Waste Analysis requirements (40 CFR § 264.13) and No-Migration Variance Petition waste characterization requirements of the RCRA Land Disposal Restrictions (40 CFR § 268.6). Each generator/storage site is required to prepare a QAPjP that addresses applicable requirements specified in DOE Order 5700.6C and the QAPP. The QAPjPs are reviewed and approved by the DOE Carlsbad Area Office (DOE/CAO) prior to the implementation of the site-specific TRU waste characterization programs.

The DOE/CAO NTP developed the BIR, which includes waste information that will be used to assess compliance with the long-term performance requirements specified under 40 CFR § 268.6. The BIR was developed based primarily on process knowledge information. As waste characterization data are obtained through the implementation of the site-specific TRU waste characterization programs, the information provided in the BIR will be reviewed and updated as appropriate.

4.3.1.2 Waste Certification Program

TRU waste intended for emplacement at the WIPP facility must meet the WIPP WAC (Section 4.2). The DOE requires that each TRU waste generator/storage site develop and implement a program that establishes procedures for waste certification and the associated QA. Site-specific plans (Section 4.3.5) identify and describe the administrative controls and procedures required to identify TRU waste, segregate and process waste forms, and package waste in accordance with the WIPP WAC.

QA programs for certifying that the wastes meet the specified criteria must be developed by each TRU waste generator/storage site (Section 4.3.5). The QA programs are reviewed and approved by the CAO. Waste certification programs are audited periodically (at least annually) by the CAO to ensure compliance with the WIPP WAC.

4.3.2 Physical Waste Characteristics

TRU waste is packaged at the generator/storage sites in a primary confinement barrier (e.g., a DOT Specification 7A type container or SWB) to isolate the waste from humans and the environment during transportation and handling. This packaging system may include rigid plastic inner liners, several layers of plastic bagging, and adsorbents in the void spaces.

Pursuant to the WIPP WAC, free liquids and pressurized containers are prohibited in shipment of waste to the WIPP facility. Damp combustibles are neutralized, drained, or dried prior to packaging with adsorbents (e.g., vermiculite) to prevent the accumulation of condensate. Discarded equipment is disassembled to remove any liquids from fluid reservoirs or lines. Glass waste is dried or drained to remove all free liquids. Pressurized containers must be punctured to demonstrate that they are no longer pressurized.

The TRU waste inventory is classified according to 11 WIPP Waste Matrix Code Groups (The unknown category given in Table 4-3 will be reclassified into one of the 11 when charactrization is complete or they will not be accepted at the WIPP). All TRU waste to be sent to the WIPP facility are represented by a WIPP Waste Matrix Code Group, the highest tier of information describing acceptable waste forms. Tables 4-3 and 4-4 summarize the total volumes of CH- and RH-TRU waste by Waste Matrix Code Group. Many of the waste matrix groupings reflect the definition of "debris" as provided in 40 CFR § 268.2(g):

> *Debris* means solid material exceeding a 2.3-in. (60-mm) particle size that is intended for disposal and that is: a manufactured object; or plant or animal matter; or natural geologic material. However, the following materials are not debris: Any material for which a specific treatment standard is provided in Subpart D, Part 268, namely lead acid batteries, cadmium batteries, and radioactive lead solids; Process residuals such as smelter slag and residues from the treatment of waste, wastewater, sludges, or air emission residues; and Intact containers of hazardous waste that are not ruptured and that retain at least 75% of their original volume. A mixture of debris that has not been treated to the standards provided by § 268.45 and other

> material is subject to regulation as debris if the mixture is comprised primarily of debris, by volume, based on visual inspection.

"Hazardous debris" is defined according to 40 CFR § 268.2(h) as follows:

> *Hazardous debris* means debris that contains a hazardous waste listed in Subpart D of part 261 of this chapter, or that exhibits a characteristic of hazardous waste identified in Subpart C of part 261 of this chapter.

The Waste Matrix Code Groups have been summarized in the BIR by the following acceptable WIPP Waste Profiles:

- *Combustible waste* includes debris that is approximately 95 percent by volume, or more, combustible materials. Examples of combustible debris are materials constructed of plastic, rubber, wood, paper, and cloth

- *Filter waste* includes debris that is approximately 50 percent by volume, or more, High Efficiency Particulate Air (HEPA) filters or other filters constructed of more than one material type (e.g., metal, inorganic nonmetal, and combustibles)

- *Graphite waste* includes debris that is approximately 95 percent by volume, or more, graphite-based solid materials. Examples of graphite debris may include crucibles, graphite components, and pure graphite

- *Heterogeneous waste* includes waste that is at least 50 percent by volume debris materials that do not meet the criteria for assignment to other categories. An example is waste that is a mixture of metal and combustible debris, neither of which comprises 95 percent of the waste by volume

- *Inorganic nonmetal waste* includes waste that is approximately 95 percent by volume, or more, inorganic nonmetal debris. Examples of wastes in this category include glass and ceramics

- *Lead/cadmium metal waste* includes debris that is approximately 95 percent by volume, or more, metal that contains bulk lead or cadmium (separable or bonded) as part of the matrix. Examples of waste in this category include glovebox parts with lead clad in stainless steel or cadmium sheets

- *Uncategorized metal waste* includes debris that is approximately 95 percent by volume, or more, metal but either lacks sufficient characterization information to enable more definitive assignment into one of the other metal categories, or contains both lead and cadmium (separable or bonded) as part of the bulk matrix

- *Salt waste* includes waste that is at least 50 percent by volume salts, including interstitial liquids, if present. An example of waste in this category includes stable pyrochemical salts

- *Soil* includes waste that is greater than approximately 95 percent by volume soil, including sand, silt, and rock/gravel, with rock/gravel volumes totaling less than 50 percent of the matrix

- *Solidified inorganic waste* includes waste that is at least 50 percent by volume inorganic process residues. Examples of solidified inorganic wastes are solidified sludges and particulates

- *Solidified organic waste* includes waste that is at least 50 percent by volume organic process residues. These are defined as process residues with a base structure that is primarily organic. The matrix may contain some inorganic solids content such that up to approximately 20 percent by weight of the waste would remain as residue (i.e., ash/solids) following incineration. Examples of solidified organic wastes are organic resins, organic sludges, and solidified organic liquids

The Waste Analysis Plan (Appendix WAP) includes a detailed description of acceptable waste forms and the processes generating each waste stream by Waste Matrix Code Group.

4.3.3 Chemical Waste Characteristics

The reported EPA Hazardous Waste Codes associated with TRU-mixed waste are provided in Tables 4-7 and 4-8. The majority of TRU-mixed waste contains small quantities of spent halogenated solvents (EPA Hazardous Waste Codes F001–F005), that are used in plutonium fabrication operations for cleaning and degreasing of equipment, glassware, and components. Inorganic solidified waste may also contain trace quantities of listed solvents, primarily based on the RCRA "mixture" or "derived from" rules. Solidified organic waste, which represents less than three percent of the total TRU waste inventory, contains the greatest concentration of spent solvent used as degreasers and lathe coolants.

RCRA-regulated metals (EPA Hazardous Waste Codes D004–D011) are also present in some TRU-mixed waste. Metals are primarily associated with solid materials, such as lead shielding, stainless steel parts containing chromium, and iron-based metal equipment and tools. The concentration of metals in solidified inorganic waste depends on the amount and type of scrap materials incorporated during plutonium recovery operations. Typical scrap materials contain lead, chromium, and cadmium.

This section describes the chemical characteristics of the waste important to the assessment of compliance with 40 CFR § 268.6 during disposal operations and closure of the repository.

4.3.3.1 Toxicity

The toxicity of a chemical is its ability to cause damage to the human body when ingested, inhaled, or absorbed by the skin. Chemical toxicity is classified by two toxicity groups: carcinogens and noncarcinogens.

Carcinogenicity is the ability of a substance to cause the development of cancerous growths in living tissue. The EPA uses a weight-of-evidence system for the carcinogenic classification of RCRA-regulated constituents (EPA 1989, 7-11):

- Class A carcinogens are those constituents for which there is sufficient evidence for human carcinogenicity
- Class B1 and B2 constituents are probable human carcinogens, with evidence from animal studies and limited or no data in humans
- Class C constituents are possible human carcinogens, with limited evidence from animal studies
- Class D constituents cannot be classified as to human carcinogenicity
- Class E constituents are noncarcinogens

TRU-mixed waste contains hazardous constituents that belong to one or more of these categories of carcinogens, including halogenated and some nonhalogenated organic constituents and metals. Carbon tetrachloride, a Class B2 carcinogen, is one of the most prevalent organic constituents in TRU-mixed waste, and lead is the predominant toxic metal present in the waste.

4.3.3.2 Chemical Compatibility

TRU waste to be disposed of at the WIPP facility is limited in form to dewatered, solid, or solidified material. Corrosives, explosives, and nonradioactive pyrophorics are prohibited in TRU waste. These restrictions ensure that the waste is in a nonreactive form for safe shipping, handling, and disposal. All wastes to be emplaced in the WIPP facility are compatible with the packaging materials, each other, and the salt repository.

The chemical components of the waste were assessed in detail to determine chemical compatibility within and between the different waste forms from the generator/storage sites (DOE 1995a, app. D-13). The analysis of chemical compatibility was based on *A Method for Determining the Compatibility of Hazardous Wastes* (see EPA [1980] in the bibliography). Any new chemical components identified in the waste will not be accepted at the WIPP until they have been screened for chemical compatibility.

4.3.3.3 Waste Transformation Mechanisms

Waste transformation processes, such as corrosion, radiolysis, and biodegradation, will play a significant role in defining the immediate environment of the waste over the long term. The nonradionuclide components of the waste can be altered to varying degrees by these processes, resulting in the production of decomposition products.

This section describes various waste transformation mechanisms that are expected to occur prior to closure of the repository. Gas generation processes are highly dependent on the availability of brine in the repository. Inundated conditions are not expected during the 35-year operational/closure time frame; therefore, in determining the "best estimates" for gas generation, a humid environment is assumed.

Anoxic Corrosion

Two types of corrosion can occur in the WIPP repository environment: oxic and anoxic. Oxic corrosion occurs in the presence of oxygen and is represented by the following equation:

$$xFe + \tfrac{1}{2}yO_2 \rightarrow Fe_xO_y \qquad (4.1)$$

where Fe_xO_y is a form of iron oxide (Fe_2O_3 or Fe_3O_4). This reaction will preferentially occur as long as oxygen is present in the repository atmosphere. After a panel of waste has been closed and the above reaction has consumed the available free oxygen, anoxic corrosion can then occur if moisture is present. A simplified anoxic corrosion reaction is represented by:

$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2. \qquad (4.2)$$

Other possible anoxic corrosion reactions involve the production of iron hydroxide, $Fe(OH)_2$, or iron oxy-hydroxide, FeO•OH. The exact reaction(s) that will occur are currently uncertain, but all anoxic corrosion reactions produce hydrogen gas and consume water in the process. Anoxic corrosion reactions cannot occur in the absence of moisture.

Brush (1991) proposed a range of hydrogen generation rates in a humid environment of 0 to 1 moles per drum per year. It was assumed that a humid environment would be maintained by a pool of free brine on the floor of a room. The rate-limiting step is the vapor-phase transport of molecules from the pool to the metal surfaces suspended above the pool. No such pool of brine is expected to be present in a panel during the operational/closure period of the WIPP facility. Observations of brine occurrences show that limited amounts of brine do appear on freshly excavated faces of the repository, but these weeps and encrustations cease to form after a few years.

It is, therefore, highly unlikely that significant amounts of hydrogen will be generated during the operational/closure period because of the lack of a credible source of moisture required to drive this gas generation process. Gas generation rates are discussed in Appendix GAS. For hydrogen generation from anoxic corrosion under humid conditions, Appendix GAS discusses the basis for a "best estimate" of 0 moles per drum per year.

Radiolysis

Radiolysis involves high-energy particles or radiation (e.g., alpha, beta, and gamma rays) reacting with constituents of TRU waste to produce a variety of products. The high-energy particles transmit their energy by colliding with matter they encounter, thus generating excited electrons, ions, and free radicals. Inherent in this energy transfer process is the fact that the range of influence of alpha and beta particles is very small. In addition, depending on the configuration and location of the nuclide, a portion of the energy from radiation could be lost through dissipation without radically affecting the surroundings.

Radiolysis refers to the dissociation of chemical bonds by alpha particles emitted during the radioactive decay of the actinide elements in TRU waste. Radiolysis of hydrogenous materials (e.g., plastics, cellulosics, water) in the waste will result in the generation of hydrogen and other gases. Radiolysis of water and brine in WIPP facility disposal rooms will produce H_2 and O_2 and consume H_2O, but will not significantly affect the overall gas or H_2O contents of the repository (Appendix GAS).

Biodegradation

Microbial decomposition of nonradioactive components of TRU waste will change the waste over time. Unless drums are breached or the repository is resaturated with brine, non-halophilic bacteria will dominate, while halophilic or halotolerant bacteria will prevail when the waste contacts the salt environment. The repository may contain viable populations of microbes (indigenous or introduced). Both aerobic and anaerobic degradation may occur in isolated areas of the waste. Aerobic activity will be restricted to areas of active oxygen generation by radiolysis. Over the long term, the continual presence of high levels of sulfate, which is contained in the salt, will favor anaerobic activity by the sulfate reducers. Microbes in the WIPP facility may cause some biodegradation of waste containers and waste matrices, altering the chemistry of the repository.

Microbial activity in the WIPP facility disposal rooms may produce CO_2, N_2, NH_3, H_2S, H_2, and CH_4 and consume O_2 gases. The best estimate of the quantity of gas generated by microbial activity under humid conditions has been determined to be 0.1 moles per drum per year (Appendix GAS). Microbial consumption of substrates, such as cellulosics and, perhaps, plastic and rubber materials, may produce significant quantities of gas, but it is unknown whether water will be produced or consumed. The microbial survival rate is

also unknown, because it is influenced by the concentration of nutrients and humid or inundated conditions.

Volatilization

Volatilization is the change of state from liquid to vapor. The volatilization of organic solvents present in some TRU waste is a function of their vapor pressures and the physical form of the waste. Volatile organic compounds (VOCs) are present in the headspace of the waste containers due to their volatilization potential; Appendix WAP summarizes the headspace gas data collected to date. Solidified waste forms reduce the rate of volatilization of organics that may be present.

The waste packaging will also affect the amounts of VOCs released. The waste is packaged in multiple layers of plastic bags and placed in containers that are vented with carbon composite filters. Although the vents will prevent any explosive mixtures of gases (i.e., hydrogen and methane) from forming in the drums, the rate of diffusion through the inner bags and the carbon composite filter limits the degree of volatilization of VOCs.

4.3.4 Analytical Methods

Characterizing TRU waste includes applying methods to generate the information necessary for each data user. These data are necessary to meet the particular objectives of each compliance program. This section defines the procedures used to characterize TRU waste at the generator/storage sites and the site-specific plans that identify and describe the administrative controls and procedures required to characterize, segregate and process, and package TRU waste in accordance with the WAC.

The DOE will use acceptable knowledge, as defined in EPA's *Waste Analysis at Facilities that Generate, Treat, Store, and Dispose of Hazardous Waste* (EPA 1994); NDA/NDE techniques; and sampling and analysis methods to characterize TRU waste. The sampling and analysis methods used to characterize TRU waste are derived from *SW-846,* "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," (EPA 1992a) and are summarized in Appendix WAP.

Provided in the QAPP are the QA/QC requirements for ensuring that (1) all data are technically sound, statistically valid, and properly documented, and (2) all data meet the QA objectives. The QAPP addresses the QA/QC requirements specified in Chapter 1 of *SW-846.* The methods outlined in the QAPP will provide the data necessary for WIPP facility compliance programs. Alternative methods may be proposed, provided they can demonstrate that data quality objectives of the QAPP are attained.

4.3.4.1 Headspace Sampling and Analysis

Headspace sampling and analysis refers to determining the composition and concentrations of flammable gases (hydrogen and methane) and halogenated and nonhalogenated VOCs in the air located in the void volumes (or headspace) of waste containers. The specific requirements for sampling and quantifying gases and VOCs are described in the QAPP.

4.3.4.2 Homogeneous Solids and Soils/Gravel Sampling and Analysis

Solidified waste forms include several waste matrices, such as inorganic wastewater treatment sludges, organic sludges, solidified liquids, inorganic process solids or soil, resins, and pyrochemical salts. Solid waste sampling and analysis are used to determine if a waste is toxic under 40 CFR Part 261 Subpart C and to quantify the concentrations of hazardous constituents (40 CFR Part 261, app. VIII) in solid waste. The specific QA/QC requirements and QA objectives for each method specified in the Waste Analysis Plan are provided in the QAPP.

4.3.4.3 Radiographic Examination

Radiographic examination is a nondestructive, nonintrusive technique that qualitatively evaluates the contents of a waste container. This technique includes the use of X-rays and a video system to inspect the contents of a waste container and allows the operator to view events in progress. Radiographic examination is used to examine and verify the physical form of the waste, identify individual waste objects/parts, and verify the absence of certain prohibited items. The data quality objectives and QA/QC requirements for radiography are specified in the QAPP.

4.3.4.4 Visual Examination

Visual examination consists of sorting and examining the contents of the containers to remove prohibited items before packaging and to characterize materials that may affect the performance assessment. For example, visual examination is used to verify waste material parameters, such as metal and cellulose.

The DOE will use visual characterization for all waste generation process lines and repackaging programs. The QAPP addresses the use of visual examination to verify radiography data. All waste containers are characterized by radiography, but waste containers are statistically selected for visual examination. Data obtained from visual examination are also used to determine the percentage of waste containers incorrectly certified according to WIPP WAC.

4.3.4.5 Acceptable Knowledge

Acceptable knowledge is used in conjunction with other waste characterization techniques to delineate waste streams, identify listed wastes from nonspecific and specific sources in accordance with 40 CFR §261.31, and determine the toxicity characteristics associated with TRU debris wastes. Acceptable knowledge is a key component in properly determining hazardous waste under RCRA. The physical form and the associated increased health and safety risks associated with obtaining a representative sample of TRU debris wastes clearly justify the use of acceptable knowledge to make hazardous waste determinations.

The proper assignment of listed Hazardous Waste Codes relies on knowledge of the materials and processes that generated the waste and not on the concentration of constituents. Nuclear weapons production resulted in a variety of wastes contaminated with spent solvents used for cleaning and degreasing (i.e., hazardous waste codes F001-F005). Acceptable knowledge documentation must be used to identify these TRU wastes.

To ensure consistency in the use and interpretation of acceptable knowledge information, sites must compile the minimum required information in an auditable record. Sites must develop and implement written procedures that describe the compilation, use, and confirmation of acceptable knowledge. In addition, sites must demonstrate, by complying with written procedures, that discrepancies in information will be documented and that hazardous waste codes will be conservatively applied.

The DOE/CAO will audit DOE sites to initially grant TRU waste certification authority to each site. The DOE/CAO will conduct audits at least annually thereafter to verify compliance with approved plans and procedures. Sites will implement corrective action plans that address all audit findings. Waste stream characterization and certification authority will be revoked if noncompliance with the WAP and QAPP are identified by the DOE/CAO at a site.

The DOE will review waste stream profile forms and associated data packages to ensure that radiography and headspace gas data confirm acceptable knowledge and that the correct hazardous waste codes have been assigned to each waste stream. If complete and adequate information is not provided by the generator regarding the hazardous waste determinations, then the waste will not be authorized for shipment to and disposal at the WIPP facility. Acceptable knowledge is further addressed in Appendix WAP.

4.3.5 Supporting Documentation Requirements for Generators

Implementation of the TRU Waste Characterization Program at DOE sites requires that all waste characterization activities be conducted in accordance with approved documentation that describes the management, operations, and QA for the program. These documents ensure conformance with all applicable regulatory, programmatic, and operational requirements. The sites may also need to develop other documents (e.g.,

TRU waste management plans, safety analysis reports, and operational safety requirements) that address site-specific programmatic and operational requirements. The documentation requirements critical to the implementation of the TRU Waste Characterization Program at each site are discussed below.

All generator/storage sites will ensure that implementation of their site-specific waste characterization program meets the QA requirements of DOE Order 5700.6C. The QAPP describes the specific data quality objectives for the TRU Waste Characterization Program and incorporates the applicable elements of other governing documents, including *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations* (EPA 1992b). The QAPP and the associated document *Transuranic Waste Characterization Sampling and Analysis Methods Manual* (DOE 1996) currently establish analytical methods for meeting regulatory requirements. Additional discussion on QA is presented in Chapter 7 of this petition. The process used for the development and approval of site-specific QAPjPs is included as an attachment to the WIPP Waste Analysis Plan (Appendix WAP).

4.3.5.1 Site Certification Plans

The generator/storage sites must prepare plans that specify how the requirements of the WAC will be met. These plans must include the administrative, procedural, and process controls used to determine waste acceptability. Additional detail on the certification process is provided in the Waste Analysis Plan (Appendix WAP).

4.3.5.2 Quality Assurance Project Plans

Prior to initiating waste characterization activities, the sites must prepare site-specific QAPjPs. These site-specific documents, developed in accordance with the applicable requirements in DOE Order 5700.6C and the QAPP, define quality management and program elements that provide for planning, implementation, and assessment of the TRU Waste Characterization Program and data collection activities. Preparation, review, and approval of QAPjPs are discussed in the Waste Analysis Plan (Appendix WAP).

4.3.5.3 Standard Operating Procedures

The QAPP requires that each DOE generator/storage site develop, implement, and control written standard operating procedures (SOPs) that provide detailed descriptions of routine, standardized, or critical waste characterization activities. The SOPs serve as the basis for quality assessments of waste characterization activities, because they provide detailed descriptions of required activities.

4.3.5.4 Performance Demonstration Program

All facilities characterizing TRU waste for disposal at the WIPP facility must successfully participate in the applicable portions of the Performance Demonstration Program (PDP)

for the TRU Waste Characterization Program. The PDP assists in determining a facility's ability to meet the QA objectives identified in the QAPP.

The PDP includes the analyses in the TRU Waste Characterization Program that can be realistically tested for applicable performance parameters. Facility performance will be demonstrated by the successful analysis of blind-audit samples. Blind-audit samples (hereafter referred to as PDP samples) will be used as an independent means to assess facility performance regarding compliance with the QAPP QA objectives. Acceptable performance will be demonstrated by all participating facilities prior to the initial analysis of TRU waste samples, as well as on a continuing basis.

The PDP samples must be analyzed using the same methods the facility anticipates using for the analysis of TRU waste samples. These methods will be developed and approved within the specifications of the QAPP. Additional guidance is provided in the *Transuranic Waste Characterization Sampling and Analysis Methods Manual* (DOE 1996).

4.3.6 Waste Characterization Information Summary

To date, TRU waste has been characterized using NDA/NDE and headspace gas sampling and analysis. Results of headspace gas analyses are provided in Appendix WAP.

Analytical data on the concentrations of 29 VOCs in the headspace gases have been collected from approximately 900 drums from the INEL and the RFETS. Weighted average headspace concentrations have been calculated (Appendix WAP) and are summarized in Table 4-9. The data represent all Waste Matrix Code Groups except soil and unknown waste forms, which represent less than two percent of the inventory. The most prevalent VOCs observed in the headspace gases are methylene chloride, carbon tetrachloride, and 1,1,1-trichloroethane. These VOCs have been observed in average concentrations that range between 100 parts per million by volume (ppmv) and 1,000 ppmv after being weighted to reflect estimated proportions of Waste Matrix Code Groups within the DOE complex.

4.3.7 Future Waste Characterization Activities

All waste will be certified according to the requirements specified in the final WIPP WAC and characterized in accordance with the WIPP Waste Analysis Plan (Appendix WAP) and the QAPP prior to shipment to the WIPP facility. Generator/storage sites must identify and completely characterize individual waste streams. The BIR will be updated periodically to reflect the most current waste stream information.

Waste characterization facilities are being planned based on the quantities of TRU waste in immediately accessible storage (e.g., air-support buildings). Retrievably stored waste that is currently managed in earthen-covered storage will be characterized in accordance

Table 4-9. Weighted Average Concentrations of Headspace Gases[1]

Constituent	Weighted Average (parts per million by volume)
1,1,1-Trichloroethane	3.17E+02
1,1,2,2-Tetrachloroethane	9.35E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	3.30E+01
1,1-Dichloroethane	1.02E+01
1,1-Dichoroethylene	1.15E+01
1,2,4-Trimethylbenzene	1.22E+01
1,2-Dichloroethane	9.07E+00
1,3,5-Trimethylbenzene	8.62E+00
Butanol	7.81E+01
Methyl ethyl ketone	6.37E+01
Methyl isobutyl ketone	7.90E+01
Acetone	7.98E+01
Benzene	9.25E+00
Bromoform	9.38E+00
Carbon tetrachloride	3.76E+02
Chlorobenzene	1.25E+01
Chloroform	2.53E+01
(cis)-1,2-Dichloroethylene	8.97E+00
Cyclohexane	2.75E+01
Ethyl benzene	1.16E+01
Ethyl ether	1.33E+01
Hydrogen (% vol.)	1.2E-01
Methane	6.00E-03
Methanol	2.13E+02
Methylene chloride	3.68E+02
o-Xylene	1.60E+01
p/m-Xylene	1.93E+01
Tetrachloroethylene	9.40E+00
Toluene	1.94E+01
Trichloroethylene	2.51E+01

[1]From Appendix WAP, Attachment C2

with schedules developed as part of retrieval operations, as well as the availability and sample throughput capacities of TRU waste characterization facilities.

Newly-generated waste is defined as waste generated after the development and implementation of a QA program that meets the requirements specified in the QAPP. Newly-generated waste may be characterized prior to packaging (e.g., visual examination of debris waste during packaging or sampling of sludges prior to solidification).

A large percentage of waste will be generated as part of decontamination, decommissioning, and environmental restoration. Final waste forms generated by these activities will be characterized in accordance with the QAPP and will meet the WIPP WAC. Waste characterization will be incorporated into plans and schedules for these activities.

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5.0 Environmental Impact Analysis

Abstract

This chapter examines the potential environmental and human health impacts associated with the waste emplacement activities at the Waste Isolation Pilot Plant (WIPP) throughout its projected 25 years of operation, as well as potential impacts during the ten-year closure period. Under Title 40 of the Code of Federal Regulations (CFR) § 268.6, the Environmental Protection Agency (EPA) requires that anyone seeking an exemption from the prohibition against land disposal of hazardous waste submit a petition to the Administrator demonstrating, to a reasonable degree of certainty, that hazardous constituents will not migrate from the disposal unit for as long as the waste remains hazardous. The EPA has interpreted "no migration" to mean that hazardous constituents shall not exceed those associated with agency-approved human health-based levels (HBLs) beyond the boundary of the disposal unit. Prior to final closure of the WIPP facility, the potential for migration of hazardous constituents exists from the volatilization of organic compounds through the air. The anticipated maximum ground-level concentrations (5.0 ft [1.5 m] above the ground surface) of hazardous constituents are quantified, taken as the point of compliance, and compared to the HBLs.

Basis for No-Migration Demonstration

The information presented in this chapter includes the migration pathway during disposal operations, the screening process used to determine indicator constituents, and the methodologies used to determine HBLs and concentration estimates for comparison to HBLs. The DOE has specified a point 5.0 ft (1.5 m) above the ground immediately adjacent to the underground ventilation exhaust duct as the no-migration boundary for emissions during operations and closure. This point has been selected since it is the nearest point to the emission source where a hypothetical individual could be exposed to hazardous constituents from disposed waste.

Migration Pathway. The media available for hazardous-constituent transport at the WIPP facility include air, ground and surface waters, and soil. All transuranic (TRU) wastes are kept in containers during receipt, handling, and emplacement operations. By the nature of the WIPP facility and its operations, there are no credible mechanisms for direct release of hazardous constituents into water or soil. The WIPP Safety Analysis Report identifies the air pathway as the only possible migration pathway during disposal operations. Accordingly, for the assessment of releases occurring during these operations, the migration of hazardous constituents from the WIPP repository is evaluated only for the air pathway.

All waste containers destined for shipment to the WIPP facility will be vented with a particulate filter to prevent buildup of flammable or explosive gases as a result of radiolysis and eliminate any pressurization caused by changes in temperature and elevation. During the WIPP operational period, volatile organic compounds (VOCs) in the vapor state may be released into the air due to diffusion across these filters; therefore, the migration of VOCs via the air pathway must be quantified. Metals in the waste exist

in predominantly monolithic forms, such as tools, equipment, and lead shielding. The filters are designed to prevent the release of particulates, including metal particulates, to the environment during waste handling and disposal operations.

Contaminant Screening and Concentrations. To reduce the number of VOCs carried through the analyses, the VOCs were screened using the concentration-toxicity screening technique. The VOCs in this reduced set are referred to as "indicator" VOCs. The indicator VOCs represent approximately 99 percent of the risk due to migration in air.

The weighted average of measured headspace-gas concentrations obtained from sampling and analysis of wastes at Idaho National Engineering Laboratory (INEL) and Rocky Flats Environmental Technology Site (RFETS) were used to screen the initial list of VOCs for the no-migration demonstration. When a VOC was not detected, a value of one-half the sample quantitation limit was used as the headspace concentration of that VOC. These concentrations are conservatively assumed to remain constant throughout the 35-year operational/closure time frame.

Methodology for Determining Health-Based Levels. The methodology for calculating HBLs is described in the proposed ruling on Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities. In this proposed 40 CFR 264 Subpart S, the action levels, or HBLs, are calculated given the exposure assumptions for the media of interest and the toxic or carcinogenic effects for each hazardous constituent. The proposed Subpart S recommends that a continuous lifetime exposure duration of 70 years be assumed; however, because the operational/closure phase of the facility is 35 years, a 35-year exposure duration is used to determine HBLs for this assessment. The assumed risk levels for carcinogens are 10^{-6} for Class A or B carcinogens and 10^{-5} for Class C carcinogens; these levels may be interpreted as the occurrence of one excess cancer case in populations of 1,000,000 and 100,000 persons, respectively. In determining HBLs for noncarcinogens, the chemical-specific reference concentrations are used, which estimate the daily exposure an individual can experience without appreciable risk of adverse effects during a lifetime. Because the guidelines refer to excess health risks, the calculated HBLs will be applied only to migration of hazardous constituents from the disposed waste.

No-Migration Demonstration

In order to demonstrate no migration during disposal operations and closure of the facility, the concentration of each indicator VOC in air at the point of maximum predicted ground-level concentration is calculated. Air dispersion modeling was required for estimating the maximum ground-level concentrations. The EPA recommends that no-migration variance petitioners use the Industrial Source Complex (ISC) model to assess the dispersion of hazardous constituents in the air pathway.

The results of the air dispersion modeling provide maximum annual average concentrations for the area within the WIPP site boundary that are used to calculate air dispersion factors (ADFs). The maximum ground-level (5.0 ft [1.5 m] above ground)

concentration predicted by the model occurred approximately 130 ft (40 m) from the exhaust shaft and results in an ADF of 12.3×10^{-3}. The ADF is used in the no-migration calculations to estimate the maximum ground-level concentration for each indicator VOC from calculated exhaust shaft concentrations.

The no-migration demonstration for the air pathway is based on the average concentration of hazardous constituents during of the filling of the last panel equivalent, that is, during the last panel cycle. The average includes potential releases from nine closed panel equivalents, since this will be the state of the repository when it is approaching full capacity and releases are maximized. In addition, ventilation barriers will be installed on individual rooms within a panel as they are filled with waste containers. Therefore, the average used in the demonstration takes into account the presence of ventilation barriers on six of the seven rooms within a panel; the seventh room is assumed to not yet have a ventilation barrier installed.

The panel closure system design includes the use of low-permeability materials that restrict the diffusion of VOCs from the closed panel; therefore, gas pressurization is assumed to be the only process that would cause VOCs to migrate beyond a closed panel.

The maximum ground-level concentrations of indicator VOCs are one-third to five orders of magnitude below the HBLs. The no-migration demonstration used the following conservative assumptions in determining compliance point concentrations:

1. All drums (for the purposes of this assessment, all calculations were performed on a per drum basis, rather than using drum equivalents or a mixture of drums and standard waste boxes (SWBs)) are fitted with the model NFT-013 carbon composite filter

2. The effective gas generation rate is constant in closed panels and unventilated rooms

3. The actual source of VOCs will exist throughout the operational/closure phase and will maintain the average concentrations in drum and panel headspaces (i.e., no depletion of the source over time)

4. VOC concentrations in the closed panel atmosphere are instantaneously equivalent to the average drum headspace concentrations

5. There is no decrease in closure system permeability due to creep closure over time

6. Enough moisture will exist to create humid environmental conditions for gas generation

7. The last panel cycle is considered representative of the entire 35-year operational/closure time period

8. There will be 81,000 drums disposed of in each panel

Other assumptions that may contribute to the overall uncertainty of the estimates are as follows:

- The mine ventilation flow rate will remain constant throughout the operational/closure phase
- Weighted average drum headspace concentrations of VOCs represent all waste to be disposed of at the WIPP

The EPA HBLs are developed for environmental receptors, based on what the EPA has established as acceptable risk. Additional conservatism exists in the use of these HBLs for a point of compliance within the WIPP property protection area. This is because any chronic exposure within this area will be to workers, as opposed to the public. Since workers include only healthy adults, the risks can be higher as evidenced by the generally higher exposure limits established by the Occupational Health and Safety Administration (OSHA).

The no-migration calculation results show that operations at the WIPP facility both during and after waste emplacement and facility closure are not expected to result in the migration from the facility of hazardous constituents in concentrations above the HBLs.

Prediction and Assessment of Infrequent Events

This chapter identifies and examines infrequent events that could potentially result in the movement of hazardous constituents beyond the point of compliance. The events considered are natural, waste- and facility-induced, and human-induced and are beyond the realm of what can be reasonably expected to occur during routine disposal operations and closure of the facility.

An assessment of the natural events that have the potential to impact the WIPP facility and a qualitative evaluation of the likelihood of these events are presented. The discussion addresses natural events in the following categories: climatic fluctuations, near-surface events, and tectonic events.

Waste- and facility-induced events include the thermal and chemical effects of the waste, the mechanical effects of the facility, the modification of the hydrologic regime by the presence of the facility, and fires occurring in the waste. The facility design takes these effects into account.

Certain human-induced events could conceivably impact the integrity of the WIPP repository. These events include design and operational flaws, human intrusion, induced groundwater perturbations, and induced biosphere alterations.

5.0 ENVIRONMENTAL IMPACT ANALYSES

This chapter examines the potential environmental and human health impacts associated with the waste emplacement activities at the Waste Isolation Pilot Plant (WIPP) throughout its projected 25 years of operation, as well as potential impacts during the ten-year closure period. Under Title 40 of the Code of Federal Regulations (CFR) § 268.6, the U.S. Environmental Protection Agency (EPA) requires that anyone seeking an exemption from the prohibition against land disposal of a hazardous waste submit a petition to the Administrator demonstrating, to a reasonable degree of certainty, that hazardous constituents will not migrate from the disposal unit for as long as the wastes remain hazardous. The EPA has interpreted "no migration" to mean that hazardous constituents shall not exceed agency-approved human health-based levels (HBLs) beyond the boundary of the disposal unit (EPA 1992, 1). Prior to final closure of the WIPP facility, the potential for migration of hazardous constituents exists from the volatilization of organic compounds from waste containers through the air. The annual average concentrations of hazardous constituents are quantified and compared to the HBLs. Chapter 8 examines the potential environmental and human health impacts after closure.

5.1 Basis for No-Migration Demonstration

The information presented below includes the migration pathway during disposal operations, the screening process used to determine indicator constituents, and the methodologies used to determine HBLs and concentration estimates for comparison to HBLs. The DOE has specified a point 5.0 ft (1.5 m) above the ground immediately adjacent to the underground ventilation exhaust duct as the no-migration boundary for emissions during operations and closure. This point has been selected since it is the nearest point to the emission source where a hypothetical individual could be exposed to hazardous constituents from disposed waste.

5.1.1 Migration Pathway

The media available for hazardous-constituent transport at the WIPP facility include air, ground and surface waters, and soil. All transuranic (TRU) wastes are kept in containers during receipt, handling, and emplacement operations. By the nature of the WIPP facility and its operations, there are no credible mechanisms for direct release of hazardous constituents into water or soil. The WIPP Safety Analysis Report (DOE 1995, 7-35) identifies the air pathway as the only possible migration pathway during disposal operations. The EPA has concluded in the Conditional No-Migration determination for the test phase of the WIPP facility that the only possible migration pathway during the test phase is through the exhaust shaft (55 FR 47708) and that releases through brine, salt, or other geological media are implausible (55 FR 47703). Characteristics of the facility during operations are expected to the same as those for the test phase. Accordingly, for the assessment of releases occurring during these operations, the migration of hazardous constituents from the WIPP repository is evaluated only for the air pathway. Post-closure migration is examined in Chapter 8.

All waste containers destined for shipment to the WIPP facility will be vented with a particulate filter to prevent the buildup of flammable or explosive gases as a result of radiolysis and eliminate any pressurization caused by changes in temperature and elevation. During the WIPP operational period, volatile organic compounds (VOCs) in the vapor state may be released into the air due to diffusion across these filters; therefore, the migration of VOCs via the air pathway must be quantified. Metals in the waste exist in predominantly monolithic forms such as tools, equipment, and lead shielding. The filters are designed to prevent the release of particulates, including metal particulates, to the environment during waste handling and disposal operations.

5.1.2 Contaminant Screening

To limit the number of VOCs carried through the analyses, the VOCs were screened using the concentration-toxicity screening technique (EPA 1989, 5-23). The VOCs in this reduced set are referred to as "indicator" VOCs. These indicator VOCs represent approximately 99 percent of the risk due to air emissions. This screening methodology is described in detail in Appendix VOC.

The initial VOCs reported by DOE generator/storage sites and subject to the screening methodology were selected based on the following criteria:

- the VOC is a listed solvent in 40 CFR Part 261, Subpart D, or
- the VOC is a toxicity characteristic organic in 40 CFR Part 261, Subpart C, or
- the VOC is a hazardous constituent listed in 40 CFR Part 261, Appendix VIII

The weighted averages of measured headspace-gas concentrations (Section 5.2.1) obtained from the sampling and analysis of wastes from the Idaho National Engineering Laboratory (INEL) and the Rocky Flats Environmental Technology Site (RFETS) were used to screen the initial list of VOCs. When a VOC was not detected, a value of one-half the sample quantitation limit was used as the headspace concentration of that VOC. These concentrations are conservatively assumed to remain constant throughout the 35-year WIPP facility operational/closure time frame.

The VOCs selected for inclusion in the assessments contained in this chapter are listed in Table 5-1. The selected VOCs are referred to as indicator VOCs.

5.1.3 Methodology for Determining Health-Based Levels

The methodology for calculating HBLs is described in the proposed ruling on Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (55 *Federal Register* (FR) 30797). In this proposed 40 CFR 264 Subpart S, the action

Table 5-1. VOCs Selected for Inclusion in the Analyses

Constituent Type	Constituent
Carcinogens	Carbon tetrachloride
	Chloroform
	1,1-Dichloroethylene
	1,2-Dichloroethane
	Methylene chloride
	1,1,2,2-Tetrachloroethane
	1,1,1-Trichloroethane
Noncarcinogens	Chlorobenzene
	Toluene

levels, or HBLs, are calculated given the exposure assumptions for the media of interest and the toxic or carcinogenic effects for each hazardous constituent. The proposed Subpart S recommends that a continuous lifetime exposure duration of 70 years be assumed; however, because the operational/closure phase of the facility is 35 years, a 35-year exposure is assumed in determining HBLs for this assessment. The assumed risk levels for carcinogens are 10^{-6} for Class A or B carcinogens and 10^{-5} for Class C carcinogens; these levels may be interpreted as the occurrence of one excess cancer case in population of 1,000,000 and 100,000 persons, respectively. In determining HBLs for noncarcinogens, the chemical-specific reference concentrations are used, which estimate the daily exposure an individual can experience without appreciable risk of adverse effects during a lifetime. Because the guidelines refer to excess health risks, the calculated HBLs are applied only to potential migration of hazardous constituents from the disposed waste.

The methodology for determining HBLs is derived from the EPA's *Risk Assessment Guidance for Superfund* (EPA 1989). Although the EPA provides alternate "standard default exposure factors," exposure assumptions outlined in the proposed Subpart S are used for this no-migration demonstration, where applicable.

To calculate the HBLs in air for carcinogens with an absorption factor conservatively assumed to be equal to 1, the following equation is used:

$$HBL = \frac{TRL \times AT}{EF \times ED \times URF} \qquad (5\text{-}1)$$

where

HBL = HBL for carcinogen, $\mu g/m^3$
TRL = target risk level (TRL), 10^{-5} (Class C) or 10^{-6} (Class A and B)
AT = averaging time, 25,550 days for carcinogens (70 years × 365 days/year)
EF = exposure frequency, 365 days/year
ED = exposure duration, 35 years
URF = unit risk factor (URF) for carcinogen, $(\mu g/m^3)^{-1}$

Equation 5-1 was derived from equations in EPA (1989), and this derivation is shown below.

EPA (1989, 6-44) provides the calculation of residential exposure from inhalation of airborne (vapor phase) chemicals as:

$$INTAKE\ (mg/kg - day) = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad (5\text{-}2)$$

where

CA = contaminant concentration, $\mu g/m^3$
IR = inhalation rate, assuming exposure time (ET) of 24 hours/day, 20 m^3/day
BW = body weight, 70 kg

EPA (1989, 8-6) also describes chronic intake as:

$$INTAKE = \frac{RISK}{SF} \qquad (5\text{-}3)$$

where

SF = cancer slope factor (CSF), $(mg/kg\text{-}day)^{-1}$

To express the carcinogenic effect in terms of unit risk factor, as provided in EPA (1989, 7-13), the following equation is used:

$$URF = \frac{SF \times IR}{BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad (5\text{-}4)$$

Solving for slope factor in equation (5-4):

$$SF = \frac{URF \times BW}{IR} \times \left(\frac{1 \times 10^3\ \mu g}{mg} \right) \qquad (5\text{-}5)$$

Combining equation (5-3) and (5-5):

$$INTAKE = \frac{RISK \times IR}{URF \times BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \quad (5\text{-}6)$$

Setting equations (5-2) and (5-6) equal to each other:

$$\frac{RISK \times IR}{URF \times BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \quad (5\text{-}7)$$

and solving for CA,

$$CA = \frac{RISK \times AT}{EF \times ED \times URF} \quad (5\text{-}8)$$

where

CA = HBL, $\mu g/m^3$
RISK = TRL, unitless

For carbon tetrachloride (CCl_4), a class B2 carcinogen, the HBL is calculated as follows:

$$HBL_{CCL_4} = \frac{(10^{-6}) \times (25{,}550\ days)}{(365\ days/year) \times (35\ years) \times (1.5 \times 10^{-5}\ (\mu g/m^3)^{-1})} = 0.133\ \mu g/m^3$$

For noncarcinogens, the HBLs in air are calculated as follows:

$$HBL = \frac{THQ \times RfC \times AT \times (10^3\ \mu g/mg)}{EF \times ED} \quad (5\text{-}9)$$

where

HBL = HBL for noncarcinogen, $\mu g/m^3$
THQ = target hazard quotient (THQ), assumed to be 1
RfC = reference concentration for the noncarcinogen, mg/m^3
AT = averaging time, 12,775 days for noncarcinogens (ED × 365 days/year)
EF = exposure frequency, 365 days/year
ED = exposure duration, 35 years.

Equation (5-9) was derived from equations in EPA (1989), and is shown below. EPA (1989, 8-11) provides the calculation for intake as:

$$INTAKE = HQ \times RfD \tag{5-10}$$

where

HQ = hazard quotient, unitless
RfD = reference dose, mg/kg-day

EPA (1989, 8-5) provides the calculation for the reference dose as:

$$RfD = \frac{RfC \times IR}{BW} \tag{5-11}$$

where

RfC = reference concentration, $\mu g/m^3$

Combining equations (5-10) and (5-11):

$$INTAKE = \frac{HQ \times RfC \times IR}{BW} \tag{5-12}$$

Setting equations (5-2) and (5-12) equal to each other:

$$\frac{HQ \times RfC \times IR}{BW} = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3 \ \mu g} \right)$$

and solving for CA:

$$CA = \frac{HQ \times RfC \times AT}{EF \times ED} \times \left(\frac{1 \times 10^3 \ \mu g}{mg} \right) \tag{5-13}$$

where

CA = HBL, $\mu g/m^3$
HQ = THQ, unitless

An example calculation of equation (5-9) is the HBL for toluene as follows:

$$HBL_{Toluene} = \frac{(1) \times (4.00 \times 10^{-1}\ mg/m^3) \times (12{,}775\ days) \times (10^3\ \mu g/mg)}{(365\ days/year) \times (35\ years)} = 400\ \mu g/m^3$$

The toxicity measures (i.e., URFs and reference concentrations [RfCs]) used in the calculations are presented in Table 5-2. The main source of these data was the *Integrated Risk Information System* (IRIS) (EPA 1994a); the data in the IRIS system are updated monthly and are reviewed and approved by the EPA. For several VOCs, however, toxicity data were not available, either because the data were under review by EPA, or because an assessment of the compound's toxicity has not yet been conducted. A subsequent search of the *Health Effects Assessment Summary Tables* (HEAST) (EPA 1994b) was performed to determine the toxicity characteristics for those VOCs without data in the IRIS. The data obtained from the HEAST tables have not been updated since 1994. Therefore, when information in HEAST conflicted with the IRIS regarding the classification of a chemical as a carcinogen or noncarcinogen, the information and classification in the IRIS were used.

In calculating the HBLs for both carcinogens and noncarcinogens, an exposure duration of 35 years was assumed. For noncarcinogens, the averaging time is equivalent to the exposure duration; therefore, this assumption has no effect on the calculated value of the HBL. This assumption is reasonable, because waste emplacement is expected to last 25 years, and a ten-year closure period follows. The calculated HBL for each indicator VOC in air is listed in Table 5-3.

The post-closure of the facility follows the closure period and is the time period during which no-migration must be demonstrated for 10,000 years. The post-closure period is considered equivalent to placement of waste in a land-treatment unit; at this point, the facility will be configured to perform as designed. The 70-year exposure period will be assumed for the long-term HBLs for any media of concern. These HBLs are presented in Chapter 8 and calculated in Appendix LTHBL.

5.2 No-Migration Demonstration

5.2.1 Headspace Concentrations of VOCs

Analytical data on the concentrations of 31 VOCs in drum headspaces have been collected from approximately 930 drums at the INEL and the RFETS. These data and the methodology for calculating weighted average headspace concentrations are described in Appendix WAP, Appendix C2. The most prevalent volatile organic hazardous constituents observed in the headspace gases are carbon tetrachloride, methylene chloride, and 1,1,1-trichloroethane, which are included in this analysis. Table 5-4 lists the weighted average headspace concentrations, *HS*, for the indicator VOCs.

Table 5-2. Toxicity Data for Indicator VOCs

Constituent	Chemical Class	URF ($\mu g/m^3)^{-1}$	RfC (mg/m^3)
Carbon tetrachloride	B2	1.50E-5[b]	ND
Chlorobenzene	D	ND	2.00E-02[a]
Chloroform	B2	2.30E-05[b]	ND
1,1-Dichloroethylene	C	5.00E-05[b]	ND
1,2-Dichloroethane	B2	2.60E-05[b]	ND
Methylene chloride	B2	4.70E-07[b]	ND
1,1,2,2-Tetrachloroethane	C	5.80E-05[c]	ND
Toluene	D	ND	4.00E-01[b]
1,1,1-Trichloroethane	C	1.60E-06[c]	ND

[a]Data from EPA (1994b)
[b]Data from EPA (1994a)
[c]Data from Superfund Technical Support Center

Key: ND = No data; B2 = Class B2 carcinogen; $\mu g/m^3$ = micrograms per cubic meter; C = Class C carcinogen; D = Noncarcinogen; mg/m^3 = milligrams per cubic meter

Table 5-3. Calculated HBLs for Indicator VOCs

Constituent	HBL ($\mu g/m^3$)
Carbon tetrachloride	1.33E-01
Chlorobenzene	2.00E+01
Chloroform	8.70E-02
1,1-Dichloroethylene	4.00E-01
1,2-Dichloroethane	7.70E-02
Methylene chloride	4.26E+00
1,1,2,2-Tetrachloroethane	3.45E-01
Toluene	4.00E+02
1,1,1-Trichloroethane	1.25E+01

Table 5-4. Weighted Average Concentrations of Headspace Gases

Constituent	*HS* Weighted Average Concentration (ppmv)
Carbon Tetrachloride	375.5
Chlorobenzene	12.5
Chloroform	25.3
1,1-Dichloroethylene	11.5
1,2-Dichloroethane	9.1
Methylene Chloride	368.5
1,1,2,2-Tetrachloroethane	9.4
Toluene	19.4
1,1,1-Trichloroethane	317.1

ppmv = parts per million by volume

5.2.2 VOC Releases From Open Panels

VOCs will be released from the open panel when the VOCs diffuse through the carbon composite filters installed on each container (one per drum and two per standard waste box [SWB]). While a panel is being filled with waste containers, and up to the time the panel closure system installation is complete, this diffusion process is assumed to occur continuously. Normal mine ventilation procedures will direct fresh air through the open panel until the panel closure system (Appendix CLP) is installed or until a ventilation barrier is installed for a filled room within the open panel. The ventilation air will maintain a constant concentration gradient across the filters, allowing the diffusion of VOCs through the filters into the air stream.

The VOC diffusion characteristics across the filters are based on the measured hydrogen (H_2) diffusion characteristic and the calculated ratio of VOC-to-H_2 diffusivity in air. This method was taken from a diffusion study conducted at the INEL, which reviewed the methods and results of past investigators in defining transport characteristics across filters and compared new results from transport experiments with those from an estimation method. The study is described in Appendix DIF. The study demonstrated that the calculated values compared favorably with the measured data. The estimated diffusion rates for the VOCs analyzed are within an order of magnitude of the measured values.

The information in the study indicates that at least two types of filters, models NFT-013 and NFT-020, are being used to prevent the buildup of hydrogen gas in waste containers intended for disposal at WIPP. To be conservative, this assessment assumes that all drums (for the purposes of this assessment, all calculations were performed on a per drum basis, rather than using drum equivalents or a mixture of drums and SWBs) are fitted with model NFT-013 filters, which provide the highest diffusion rate.

Diffusion characteristics were calculated using the equations below. For filter-specific diffusion characteristics, the ratio of VOC-to-H_2 diffusivities in air are calculated as follows:

$$\frac{D_{VOC\ -\ air}}{D_{H_2\ -\ air}} = \left(\frac{P_{c,VOC}}{P_{c,H_2}}\right)^{1/3} \times \left(\frac{T_{c,VOC}}{T_{c,H_2}}\right)^{-1/2} \times \left[\frac{\left(\frac{1}{MW_{air}} + \frac{1}{MW_{VOC}}\right)}{\left(\frac{1}{MW_{air}} + \frac{1}{MW_{H_2}}\right)}\right]^{1/2} \qquad (5\text{-}14)$$

where

$D_{VOC\text{-}air}$ = diffusivity of the VOC in air, mole/s/mole fraction/drum
$D_{H2\text{-}air}$ = diffusivity of hydrogen in air, mole/s/mole fraction/drum
$P_{c,\,VOC}$ = critical pressure of the VOC, atm
$P_{c,H2}$ = critical pressure of hydrogen, 12.8 atm
$T_{c,VOC}$ = critical temperature of the VOC, K
$T_{c,H2}$ = critical temperature of hydrogen, 33.2K
MW_{VOC} = molecular weight of the VOC, g/mole
MW_{H2} = molecular weight of hydrogen, 2.016 g/mole
MW_{air} = molecular weight of air, 28.946 g/mole

The filter-specific VOC diffusion characteristics from the ratio of VOC-to-H_2 diffusivities in air are calculated using the following equation:

$$D_{VOC} = \left(\frac{D_{VOC\ -\ air}}{D_{H_2\text{-}\ air}}\right) \times D_{H_2} \qquad (5\text{-}15)$$

where

D_{VOC} = the VOC diffusion characteristic through a model NFT-013 carbon composite filter, mole/s/mole fraction/drum
D_{H2} = the diffusion characteristic for hydrogen through a model NFT-013 carbon composite filter, 1.17E-5 mole/s/mole fraction/drum

Calculated VOC diffusion rates and VOC-specific inputs for the calculations are given in Table 5-5.

The average drum emission rate (the term "average" is used for the drum emission rate because weighted average drum headspace concentrations are used in the computations) for each VOC is calculated from the diffusion rate as shown below and summarized in Table 5-6.

$$ADE = D_{VOC} \times MF_{VOC} \times 31{,}536{,}000\ s/year \qquad (5\text{-}16)$$

Table 5-5. VOC Diffusion Rates

Constituent	*Pc* Critical Pressure (atm)	*Tc* Critical Temperature (K)	*MW* Molecular Weight (g/mole)	*Dvoc* Diffusivity (mole/s/mole fraction/ drum)
Carbon Tetrachloride	45.0	556.4	153.84	1.21E-06
Chlorobenzene	44.6	632.4	112.56	1.16E-06
Chloroform	54.0	536.4	119.39	1.34E-06
1,1-Dichloroethylene	51.3	495	96.95	1.40E-06
1,2-Dichloroethane	53	561.6	98.97	1.32E-06
Methylene Chloride	60.0	510.0	84.94	1.47E-06
1,1,2,2-Tetrachloroethane	57.6	644.5	167.86	1.21E-06
Toluene	40.6	591.7	92.13	1.19E-06
1,1,1-Trichloroethane	42.4	545.0	133.42	1.21E-06

Table 5-6. VOC Emissions for a Full Open Panel

Constituent	Mole Fraction (MF) (mole/mole)	AORE (mole/room/ year)	ACRE (mole/room/ year)	AOPE (mole/panel/ year)
Carbon Tetrachloride	3.76E-04	1.66E+02	2.17E+00	1.79E+02
Chlorobenzene	1.25E-05	5.29E+00	7.23E-02	5.73E+00
Chloroform	2.53E-05	1.24E+01	1.46E-01	1.33E+01
1,1-Dichloroethylene	1.15E-05	5.88E+00	6.65E-02	6.27E+00
1,2-Dichloroethane	9.10E-06	4.38E+00	5.26E-02	4.70E+00
Methylene chloride	3.69E-04	1.98E+02	2.13E+00	2.10E+02
1,1,2,2-Tetrachloroethane	9.40E-06	4.15E+00	5.44E-02	4.48E+00
Toluene	1.94E-05	8.42E+00	1.12E-01	9.10E+00
1,1,1-Trichloroethane	3.17E-04	1.40E+02	1.83E+00	1.51E+02

where

ADE = average drum VOC emission rate, mole/drum/year

MF_{VOC} = mole fraction of the VOC, mole/mole

The mole fraction of each VOC is calculated from its weighted average headspace concentration by:

$$MF_{VOC} = (HS_{VOC}) \times (10^{-6}\ mole\ fraction/ppmv) \qquad (5\text{-}17)$$

where

HS_{VOC} = weighted average headspace concentration for VOC, ppmv.

The mole fraction of carbon tetrachloride is calculated using equation (5-17), as follows:

$$MF_{CCl_4} = (375.5\ ppmv) \times (10^{-6}\ mole\ fraction/ppmv)$$

$$MF_{CCl_4} = 3.76 \times 10^{-4}\ mole/mole$$

For carbon tetrachloride, the average drum emission rate is calculated as follows:

$$ADE_{CCl_4} = 1.21 \times 10^{-6}\ mole/s/mole\ fraction/drum \times 3.76 \times 10^{-4}\ mole/mole$$

$$\times\ 31{,}536{,}000\ s/year = 1.43 \times 10^{-2}\ mole/drum/year$$

During the placement of waste at WIPP, closure systems will be used to isolate wastes in a full panel and to remove these filled panels from ventilation. Similarly, as individual rooms are filled, ventilation barriers will be used to eliminate ventilation through the filled rooms and to isolate these rooms. Consequently, the average open panel emission rate (AOPE) (the term "average" is used for the open panel emission rate because weighted average drum headspace concentrations are used in the computations) is dependent on the number of full rooms that have ventilation barriers and the number of drums in rooms without ventilation barriers.

The average open room emission rate (AORE) (the term "average" is used for the open room emission rate because weighted average drum headspace concentrations are used in the computations) is dependent on the number of drums that have been emplaced in the room and the diffusion of VOCs across the drum vent filters. Assuming a continuous fresh air flow across the filters, VOCs will diffuse from the drums at a rate that is

dependent on the concentration gradient across the filters and the diffusion properties of the VOCs, as described in Appendix DIF. The AORE is calculated using the equation

$$AORE_{VOC} = ADE_{VOC} \times nD \qquad (5\text{-}18)$$

where

$AORE_{VOC}$ = average open room VOC emission rate, mole/room/year
ADE_{VOC} = average drum VOC emission rate, mole/drum/year
D = number of drums in the room, drum/room.

As described previously, VOCs will diffuse from the drums at a rate dependent on the concentration gradient across these filters. After a room is filled and the ventilation barrier is installed, fresh air will no longer flow across the waste drums, and VOC concentrations in the dead air space above the filter will begin to build up and approach the concentrations in the drum headspace. Therefore, the concentration of VOCs that would be present in the panel atmosphere would be equivalent to the weighted average drum headspace concentration. For the no-migration demonstration, it is conservatively assumed that the average drum headspace concentrations serve as a constant source of VOCs.

The ventilation barrier consists of low-permeability materials that restrict ventilation flow through a room. Thus, migration of VOCs past the barriers is assumed to only occur by displacement from room volume reduction due to creep closure and by continued gas generation from the waste. Appendix GAS includes information on gas generation by WIPP waste. Of the three gas-generating mechanisms described in Appendix GAS (radiolysis, microbial degradation, and corrosion), microbial degradation is assumed to contribute the most to the generation rate during the operational and closure period of 35 years. The best estimate for gas generation from microbial degradation under humid conditions is 0.1 moles of gas per drum per year (see Appendix GAS), and the analysis conservatively assumes that a humid condition will exist.

The average creep closure rate, as discussed in Appendix I1 of Appendix CLP, will result in a reduction of the room void volume of 4,096 ft^3 (116 m^3) per year for each room. Converting this volumetric reduction rate to a molar (gas) displacement rate, using the Ideal Gas Law:

$$GDR = \frac{116\ m^3}{room/year} \times \frac{P}{RT} \qquad (5\text{-}19)$$

where

GDR = gas displacement rate due to salt creep (creep closure), mole/drum/year
P = pressure, atm
R = Ideal Gas Constant, 0.082 L • atm/mole • K
T = temperature, K

Since one full room contains 11,571 drums of waste, this rate expressed on a drum basis is:

$$GDR = \frac{116\ m^3}{room/year} \times \frac{1\ atm}{\left(\frac{0.082\ L \cdot atm}{mole \cdot K}\right) \times (298K)} \times \left(\frac{1 \times 10^3\ L}{m^3}\right) \times (room/11{,}571 drum)$$

An effective gas generation rate (gas generation rate plus gas displacement rate) can be calculated as follows:

$$GR = GGR + GDR \qquad (5\text{-}20)$$

$$GDR = (4.74 \times 10^3\ mole/room/year) \times (room/11{,}571 drums)$$

$$GDR = 0.4\ mole/drum/year$$

where

GR = effective gas generation rate, mole/drum/year
GGR = gas generation rate due to microbial degradation in a humid environment, 0.1 mole/drum/year
GDR = gas displacement rate due to salt creep (creep closure), 0.4 mole/drum/year

$$GR = (0.1\ mole/drum/year) + (0.4\ mole/drum/year)$$

$$GR = 0.5\ mole/drum/year$$

Using this effective gas generation rate for a room of 11,571 drums that has the ventilation barrier in place, the average closed room emission rate (ACRE) (the term "average" is used for the yearly closed room emission rate because weighted average drum headspace concentrations are used in the computations) for each VOC is calculated as:

$$ACRE_{VOC} = (GR) \times (11{,}571\ drum/room) \times MF_{VOC} \quad (5\text{-}21)$$

where

$ACRE_{VOC}$ = average closed room VOC emission rate, mole/room/year
GR = effective gas generation rate, mole/drum/year
MF_{VOC} = VOC mole fraction, mole/mole

The AOPE for each VOC is based on the number of full rooms, the number of drums in the open room, and the emission rates from each type of room. AOPE is calculated as:

$$AOPE_{VOC} = (R_o \times AORE_{VOC}) + (R_c \times ACRE_{VOC}) \quad (5\text{-}22)$$

where

$AOPE_{VOC}$ = average open panel VOC emission rate, mole/panel/year
$AORE_{VOC}$ = average open room VOC emission rate, mole/room/year
$ACRE_{VOC}$ = average closed room VOC emission rate, mole/room/year
R_o = number of open rooms in the open panel, 1 room/panel
R_c = number of closed rooms in the open panel, room/panel

A sample calculation for the AOPE for carbon tetrachloride with 5,786 drums in the open room and three rooms with ventilation barriers is as follows:

$$AORE_{CCl_4} = 1.43 \times 10^{-2}\ mole/drum/year \times 5{,}786\ drum/room$$

$$AORE_{CCl_4} = 8.27 \times 10^{1}\ mole/room//year$$

$$ACRE_{CCl_4} = 0.5\ mole/year/drum \times 11{,}571\ drum/room \times 3.76 \times 10^{-4}\ mole/mole$$

$$ACRE_{CCl_4} = 2.18\ moles/room/year$$

$$AOPE_{CCl_4} = (1\ room/panel \times 8.27 \times 10^{1}\ mole/room/year) + (3\ room/panel \times 2.18\ mole/room/year)$$

The highest AOPE would occur just prior to closure of the filled panel. At this time, six of the seven rooms within the panel would have ventilation barriers in place, and the remaining room would contain 11,571 drums, but would not have a ventilation barrier installed. The AORE, ACRE, and AOPE for this full, but unclosed, panel are presented in Table 5-6.

5.2.3 VOC Releases From Closed Panels

As described in Section 5.2.2, VOCs will diffuse from the drums at a rate dependent on

$$AOPE_{CCl_4} = 8.9287 \times 10^{1}\ moles/panel/year$$

the concentration gradient across these filters (Appendix DIF). As the concentration gradient decreases, the diffusion rate of each VOC decreases. After a panel is closed, fresh air will no longer flow across the waste drums, and VOC concentrations in the air space above the filter will begin to build up and approach the concentrations in the drum headspace. Therefore, the concentration of VOCs that would be present in the panel atmosphere would be equivalent to the weighted average drum headspace concentration. For the no-migration demonstration, it is conservatively assumed that the weighted average drum headspace concentrations serve as a constant source of VOCs.

Because the design of the panel closure systems will allow some pressurization, gas pressurization is assumed to be the only process that would cause VOCs to migrate beyond a closed panel. The panel closure systems will be designed to withstand some pressure buildup; however, for this demonstration, the leakage rate from the panel closure system is conservatively assumed to be equivalent to the effective gas generation rate.

From equation (5-20), the effective gas generation rate is

$$GR = 0.5\ mole/drum/year$$

For a closed panel of 81,000 drums, the average closed panel emission rate (ACPE) (the term "average" is used for the yearly closed panel emission rate because weighted average headspace concentrations are used in the computations) for each VOC is calculated as:

$$ACPE = (GR) \times (81{,}000\ drums/panel) \times MF_{VOC} \qquad (5\text{-}23)$$

Indicator VOC-specific ACPEs are provided in Table 5-7.

Table 5-7. VOC Emissions from Full Closed Panels

Constituent	ACPE (mole/panel/year)
Carbon Tetrachloride	1.52E+01
Chlorobenzene	5.06E-01
Chloroform	1.02E+00
1,1-Dichloroethylene	4.66E-01
1,2-Dichloroethane	3.69E-01
Methylene chloride	1.49E+01
1,1,2,2-Tetrachloroethane	3.81E-01
Toluene	7.86E-01
1,1,1-Trichloroethane	1.28E+01

5.2.4 Mine Ventilation

The underground ventilation system directs fresh air through rooms without ventilation barriers within open panels of waste and past the closed panels of waste, and exhausts the air into the atmosphere near the southeast corner of the facility property protection area via the exhaust shaft. Gases released from the panels of waste will mix with the ventilation air and be released into the atmosphere. At the surface of the facility, the mine ventilation air is released to the atmosphere at a rate of 425,000 standard ft^3 (12,000 m^3) per minute.

5.2.5 Air Dispersion Modeling

Air Dispersion Modeling (ADM) was performed using the Long-Term Version of the Industrial Source Complex (ISCLT3) model (EPA 1995). The results were used to calculate annual average concentrations within the WIPP site boundary. The maximum concentration was estimated to occur 131 ft (40 m) north of the exhaust fans that release the ventilation air into the atmosphere. For details on the input parameters required for using the ISCLT3 model, see Appendix ADM. The specific output list files for the model run may also be found in Appendix ADM. The concentrations were modeled in accordance with EPA (1992). The air dispersion factor (ADF) used for determining VOC concentrations and subsequent comparison to HBLs is 12.3×10^{-3}. Figure 5-1 shows ADFs for the WIPP site based on coarse grid model runs, and Figure 5-2 shows ADFs in the property protection area based on fine grid runs.

5.2.6 Estimation of the Maximum Concentration of Hazardous Constituents

The no-migration demonstration for the air pathway is based on the average concentration of hazardous constituents over the filling of the last panel equivalent, that is, during the last panel cycle. This average includes nine closed panel equivalents, the state of the repository when it is approaching full capacity and releases are maximized. Actual potential public and worker risks based on these emissions are given in Appendix RA.

To calculate the concentration of a VOC at the exhaust shaft resulting from the emission from one open panel, the following calculation is performed:

$$SXPE_{VOC} = \frac{AOPE_{VOC} \times MW \times 10^6\ \mu g/g \times P_o}{V \times (525{,}600\ \text{min/}year) \times (0.0283\ m^3/ft^3)} \qquad (5\text{-}24)$$

where

$SXPE_{VOC}$ = VOC concentration at the exhaust shaft for emission from a single open panel, $\mu g/m^3$

$AOPE_{VOC}$ = average VOC emission rate for a single open panel, mole/panel/year

MW = molecular weight of the VOC, g/mole

V = mine ventilation rate, 425,000 standard ft^3/minute (12,000 standard m^3/minute)

P_o = number of open panel equivalents, one panel

To continue with the previous example for the carbon tetrachloride emission concentration at the exhaust shaft for a single open panel with 5,786 drums in one open room and three rooms with ventilation barriers, each with 11,571 drums, contributing to emissions is calculated as follows:

$$SXPE_{CCl_4,40{,}499\,drums} = \frac{(8.9287\times10^1\ mole/panel/year)\times(153.84\,g/mole)\times(10^6\mu g/g)\times 1\,panel}{(425{,}000\,standard\,ft^3/\text{min})\times(525{,}600\,\text{min/}year)\times(0.0283\,m^3/ft^3)}$$

$$SXPE_{CCl_4,\ 40{,}499\,drums} = 2.17\ \mu g/m^3$$

The emission concentration from one closed panel is calculated as:

$$SCPE_{VOC} = \frac{ACPE_{VOC} \times MW \times 10^6\ \mu g/g \times P_c}{V \times (525{,}600\ \text{min/}year) \times (0.0283\ m^3/ft^3)} \qquad (5\text{-}25)$$

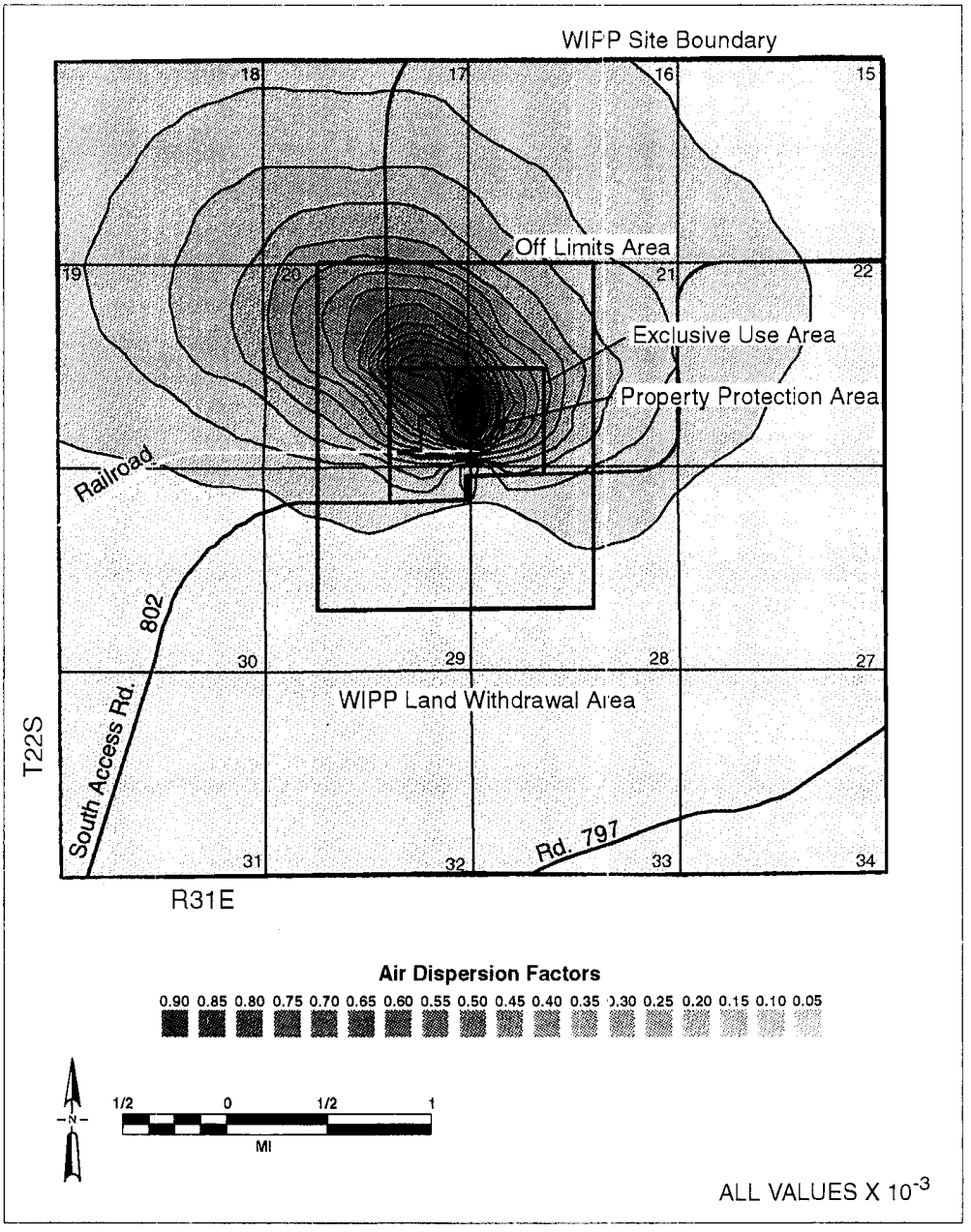

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Figure 5-1. Air Dispersion Factors for the WIPP Site

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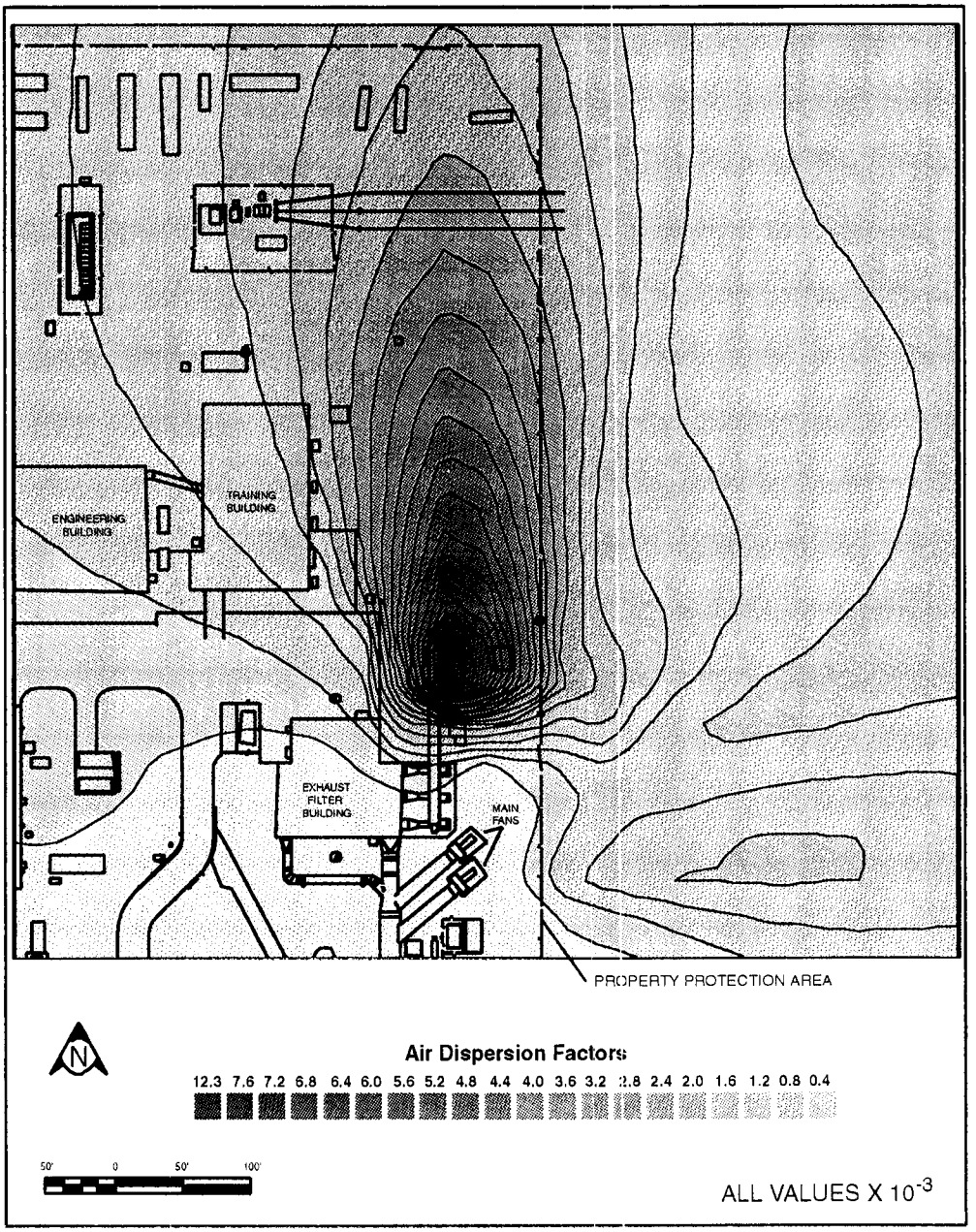

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Figure 5-2. Air Dispersion Factors Inside the Property Protection Area

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where

$SCPE_{VOC}$ = VOC emission concentration at the exhaust shaft for a single closed panel, µg/m^3

$ACPE_{VOC}$ = average VOC emission rate for a single closed panel, mole/panel/year

MW = molecular weight of the VOC, g/mole

V = mine ventilation rate, 425,000 standard ft^3/minute (12,000 standard m^3/minute)

P_c = number of closed panel equivalents, one panel

The carbon tetrachloride emission concentration at the exhaust shaft for a single closed panel is calculated as follows:

$$SCPE_{VOC} = 3.7 \times 10^{-1}\ \mu g/m^3/panel$$

$$SCPE_{CCl_4} = \frac{(1.52\times10^1\ mole/panel/year)\times(153.84\ g/mole)\times(10^6\ \mu g/g)\times 1\ panel}{(425{,}000\ standard\ ft^3/\text{min})\times(525{,}600\ \text{min}/year)\times(0.0283\ m^3/ft^3)}$$

To determine the hazardous constituent emissions from the repository when it is filled to its capacity, the following calculation is performed for each month of the last panel cycle (two and one-half years) and results are averaged:

$$EC_{VOC} = (P_o \times SXPE) + (P_c \times SCPE) \qquad (5\text{-}26)$$

where

EC_{VOC} = exhaust shaft concentration of a VOC for emissions from one open panel equivalent and nine closed panel equivalents, µg/m^3

$SXPE_{VOC}$ = VOC concentration at the exhaust shaft for emissions from a single open panel, µg/m^3

$SCPE_{VOC}$ = VOC concentration at the exhaust shaft for emissions from a single closed panel, µg/m^3

P_o = number of open panel equivalents, one panel

P_c = number of closed panel equivalents, nine panels

For the calculations, the number of drums begins with zero in the open panel equivalent and increases by 2,700 per month for a total of 81,000. The calculations used for averaging carbon tetrachloride concentrations are given in Table 5-8. The calculations show periodic fluctuations in open panel emission concentrations that result from filling and closure of rooms within the panel.

Table 5-8. Exhaust Shaft Concentrations for Carbon Tetrachloride in Last Panel Cycle

Time Period for Filling the Last Panel Equivalent (month)	Exhaust Shaft Emission Concentration for Single Open Panel Equivalent (SXPE) ($\mu g/m^3$)	Exhaust Shaft Emission Concentration for Single Closed Panel Equivalent (SCPE) ($\mu g/m^3$)	EC_{VOC} Exhaust Shaft Concentration for 9 Closed and One Open Panel Equivalents ($\mu g/m^3$)
1.1	1.01E+00	3.70E-01	4.34E+00
2.1	2.02E+00	3.70E-01	5.35E+00
3.2	3.03E+00	3.70E-01	6.36E+00
4.3	4.04E+00	3.70E-01	7.37E+00
5.4	1.06E+00	3.70E-01	4.39E+00
6.4	2.07E+00	3.70E-01	5.40E+00
7.5	3.08E+00	3.70E-01	6.41E+00
8.6	4.09E+00	3.70E-01	7.42E+00
9.6	1.11E+00	3.70E-01	4.45E+00
10.7	2.12E+00	3.70E-01	5.45E+00
11.8	3.13E+00	3.70E-01	6.46E+00
12.8	4.14E+00	3.70E-01	7.47E+00
13.9	1.17E+00	3.70E-01	4.50E+00
15.0	2.18E+00	3.70E-01	5.51E+00
16.0	3.18E+00	3.70E-01	6.52E+00
17.1	4.19E+00	3.70E-01	7.52E+00
18.1	1.22E+00	3.70E-01	4.55E+00
19.3	2.23E+00	3.70E-01	5.56E+00
20.3	3.24E+00	3.70E-01	6.57E+00
21.4	4.25E+00	3.70E-01	7.58E+00
22.5	1.27E+00	3.70E-01	4.60E+00
23.5	2.28E+00	3.70E-01	5.61E+00
24.6	3.29E+00	3.70E-01	6.62E+00
25.7	4.30E+00	3.70E-01	7.63E+00
26.8	1.33E+00	3.70E-01	4.66E+00
27.8	2.33E+00	3.70E-01	5.67E+00
28.9	3.34E+00	3.70E-01	6.67E+00
30.0	4.35E+00	3.70E-01	7.68E+00
		Average:	6.01E+00

The averages over the last panel cycle are taken as the exhaust shaft concentrations, $EC_{VOC,\,AVE}$. The exhaust shaft concentrations for each indicator VOC are given in Table 5-9.

Table 5-9. Maximum Concentrations of Indicator VOCs

Constituent	$EC_{VOC, AVE}$ Exhaust Shaft Concentration ($\mu g/m^3$)	$EC_{VOC, AVE} \times$ ADF Annual Average Concentration, ($\mu g/m^3$)	HBLs ($\mu g/m^3$)
Carbon Tetrachloride	6.01E+00	7.39E-02	1.33E-01
Chlorobenzene	1.44E-01	1.77E-03	2.00E+01
Chloroform	3.28E-01	4.04E-03	8.70E-02
1,1-Dichloroethylene	1.24E-02	1.53E-04	4.00E-01
1,2-Dichloroethane	9.73E-02	1.20E-03	7.70E-02
Methylene chloride	3.55E+00	4.37E-02	4.26E+00
1,1,2,2-Tetrachloroethane	1.64E-01	2.02E-03	3.45E-01
Toluene	1.85E-01	2.28E-03	4.00E+02
1,1,1-Trichloroethane	4.40E+00	5.41E-02	1.25E+01

To determine the annual average concentration of each constituent, $EC_{VOC, AVE}$ is multiplied by the ADF as shown in the example below for carbon tetrachloride:

$$(6.01\ \mu g/m^3) \times (12.3 \times 10^{-3}) = 7.39 \times 10^{-2}\ \mu g/m^3$$

The annual average concentration for each indicator VOC at the maximum exposure point is compared to the respective HBL in Table 5-9.

Annual average concentrations range from 1.8 to 175,000 times below HBLs, demonstrating there will be no migration of hazardous constituents above HBLs via the air pathway.

5.2.7 Summary

As shown in Table 5-9, the predicted annual average concentrations of VOCs are 1.8 to 175,000 times below the HBLs. The no-migration demonstration used the following conservative assumptions in determining compliance point concentrations:

1. All drums are fitted with the model NFT-013 carbon composite filter
2. The effective gas generation rate is constant in closed panels and closed rooms

3. The actual source of VOCs will exist throughout the operational/closure phase and will maintain the average concentrations in drum and panel headspaces (i.e., no depletion of the source over time)
4. VOC concentrations in the closed panel atmosphere are instantaneously equivalent to the drum weighted average headspace concentrations
5. There is no decrease in closure system permeability due to creep closure over time
6. Enough moisture will exist to create humid environmental conditions for gas generation
7. The last panel cycle is considered representative of the entire 35-year operational/closure time period
8. There will be 81,000 drums disposed of in each panel
9. Weighted average drum headspace concentrations of VOCs, which are based on INEL and RFETs headspace gas sampling, are considered bounding for the DOE complex as a whole (see discussion in Section 9.5).

Another assumption that may contribute to the overall uncertainty of the estimates is that the mine ventilation flow rate will remain constant throughout the operational/closure phase.

The EPA HBLs are developed for environmental receptors, based on what the EPA has established as acceptable risk. Additional conservatism exists in the use of these HBLs for a point of compliance within the WIPP property protection area. This is because any chronic exposure within this area will be to workers, as opposed to the public. Since workers include only healthy adults, the risks can be higher as evidenced by the generally higher exposure limits established by OSHA.

The no-migration calculation results show that operations at the WIPP facility both during and after waste emplacement and facility closure are not expected to result in the migration of hazardous constituents in concentrations above the HBLs.

5.3 Prediction and Assessment of Infrequent Events

This section identifies and examines infrequent events that could potentially result in the movement of hazardous constituents beyond the point of compliance. The events considered are natural, waste- and facility-induced, and human-induced and are not expected to impact the repository during routine disposal operations and closure. Infrequent events related to long-term performance are examined in Chapter 8 and Appendix SCR.

5.3.1 Natural Events

An assessment of the natural events that have the potential to impact the WIPP facility and a qualitative evaluation of the likelihood of these events are presented in the following sections. The discussion addresses natural events in the following categories: climatic fluctuations, near-surface events, and tectonic events.

5.3.1.1 Climatic Fluctuations

The present regional climate, as described in Section 2.5.2, is semiarid with generally warm temperatures. Due to the long-term nature of climatic fluctuations, no significant fluctuations are expected to occur during the 35-year operational/closure time frame.

5.3.1.2 Near-Surface Events

Natural near-surface processes (i.e., flooding, tornadoes, range fires, meteorite impacts, erosion, dissolution, and sedimentation) are not expected to pose adverse impacts to the repository.

Flooding. Severe flooding could theoretically impact the surface portion of the facility and, if the shafts were open, possibly the underground portion of the repository. However, there is no potential for flooding at the WIPP facility. The WIPP site, located 12 mi (19 km) from the Pecos River, is 500 ft (150 m) above the river in elevation and more than 400 ft (120 m) above the floodplain. Estimates of maximum probable flood on the Pecos River result in an increase in water level of approximately 80 ft (24 m) (Appendix GCR, Section 6.2). Protection from flooding caused by intense local precipitation is provided by a system of peripheral interceptor diversions. Additionally, grade elevations of roads, tracks, and surface facilities are designed so that stormwater will drain offsite under the most severe conditions. Shaft collars prevent water from entering the shaft. Therefore, flooding of the WIPP site during the 35-year operational/closure time frame is regarded as an improbable event. Flood protection structures are listed in the WIPP Resource Conservation and Recovery Act (RCRA) Part B Permit Application (DOE 1996) as protective structures that are subject to routine inspection.

Tornadoes. Tornadoes have the potential to affect the surface structures of the WIPP facility. However, the structural portions of the underground repository will not be affected by storms or other atmospheric phenomena. Therefore, tornado-induced impacts will not result in a release of waste constituents from the disposal unit.

Tornadoes in New Mexico have occurred, on average, at the rate of about nine per year on six tornado days from 1953 to 1976. The greatest number of tornadoes in one year was 18 (in 1972) and the least was zero (in 1953). The average tornado density in New Mexico is 0.7 per 1,000 mi^2 (2,600 km^2) (DOE 1995, 2-51).

The surface structures of the WIPP facility are designed to withstand the Design Basis Tornado (DBT) (discussed in Section 3.2.2.2) with a return period of 1,000,000 years. Therefore, no tornado-induced impacts are anticipated during the 35-year operational/closure period.

Range Fires. The WIPP site is characterized by an arid climate and desert vegetation. Potential range fires at the site are not expected to impact the containment ability of the repository.

During disposal operations, range fires would not be expected to cause extensive damage to the surface structures, because of the buffer afforded by clearing vegetation from the property protection area and the fire protection systems employed at the site.

The Final Environmental Impact Statement (FEIS) (DOE 1980, 9-111) analyzed the effects of a range fire near the site, assuming that such a fire could release radionuclides that may have accumulated in the surrounding vegetation during routine operations. This analysis concluded that the maximum individual radiation doses as a result of a range fire would be small fractions of the doses delivered by natural background radiation. While this study did not address other hazardous constituents that may accumulate in vegetation, it can be assumed that exposure to other substances would also be very small, because their concentrations in the waste are small.

Meteorite Impact. Meteorite impact is a phenomenon of sufficient improbability that it will not significantly contribute to risk. In 1980, Burkholder concluded that meteorite impact is one of the scenarios that is unimportant to the performance of nuclear waste isolation systems. Neither the FEIS nor the SAR considered a meteorite impact scenario a credible event.

Erosion. As discussed in Section 2.1.6, the site has been geomorphically stable since the mid-Pleistocene. No extreme rates of erosion that could impact the repository are occurring at the WIPP site.

The WIPP site is on the western flank of a low drainage divide that separates Nash Draw and San Simon Swale. Erosional processes are operating very slowly at the site. The effect of erosion on the site during the operational/closure period is expected to be negligible.

Dissolution. Section 2.1.4, 2.1.6, and Appendix DEF indicate that much of the land surface surrounding the WIPP facility exhibits a karst topography, characteristically pitted by numerous depressions. Most of the karst features are present north and west of the facility and appear to be absent in the immediate vicinity of the facility. These depressions are most likely the result of dissolution of the evaporites in the Rustler and upper Salado formations during wetter climates. No impact from dissolution is expected during the 35-year operational/closure time frame.

Sedimentation. Sedimentation would be of concern to a facility at or near the surface over long (geologic) time periods. Sedimentation has not been a significant geomorphic process at the WIPP site since at least the mid-Pleistocene.

No significant sedimentation is presently occurring. This condition is expected to prevail throughout the operational/closure period. No impacts from sedimentation are anticipated during this time frame.

5.3.1.3 Tectonic Phenomena

Any natural tectonic processes that have been active in the past are generally considered to indicate future events. In the region in which the WIPP facility is located, these processes are: seismic activity, faulting and folding, and igneous activity. These processes are not expected to impact repository integrity.

Seismic Activity. As described in Section 2.6, seismic activity in the region has been historically low. A Design Basis Earthquake (DBE) has been established based on an estimate of the 1,000-year recurrence interval peak acceleration of 0.1 of gravity (Section 3.2.2.1).

Faulting and Folding. Faulting and folding, if present, have the potential to disrupt the integrity of a repository. These processes have affected the region surrounding the WIPP site, but have not been identified at the site. This is expected to be true throughout the 35-year operational/closure time frame; therefore, no impacts are expected from these processes.

Igneous Activity. Igneous activity at or near a repository could potentially impact repository performance. No igneous processes are active at or near the WIPP site. Igneous processes are not expected to occur at the site during the operational/closure period.

5.3.2 Waste- and Facility-Induced Events

Waste- and facility-induced events include the thermal and chemical effects of the waste, the mechanical effects of the facility, the modification of the hydrologic regime by the presence of the facility, and fires occurring in the waste. The facility design takes into account these effects, as described in the following sections.

5.3.2.1 Thermal Effects

Thermal analyses show that more than 150 kilowatts of heat-generating waste can be emplaced in an acre of storage facility without unacceptable impacts on the salt beds or the surrounding environment. As a conservative design basis for the WIPP facility, a limit of 10 kilowatts per acre has been chosen.

Contact-handled (CH) TRU waste in general has very low heat generation rates and will not approach the 10 kilowatt-per-acre limit. Remote-handled (RH) TRU waste could generate up to 300 watts per canister without exceeding the thermal limit for the WIPP facility, because 50 percent of all canisters projected for shipment to the WIPP facility will have less than one watt each. Thermal effects are not expected at the WIPP facility due to either the waste or the facility.

5.3.2.2 Chemical Effects

The WIPP Waste Acceptance Criteria (WAC) (discussed in Section 4.2) ensure the safe handling and emplacement of the waste at the WIPP facility. Chemical properties of the waste are discussed in Section 4.3.3, and chemical compatibility is addressed in Section 4.3.3.2.

As described in Section 4.3.3.3, gas generation will occur to some extent prior to closure of the facility. These gases will be the by-products of microbial degradation of the waste forms; anoxic corrosion and radiolysis are not expected to generate gas in significant quantities during the operational/closure period. The best-estimate rate of microbial degradation is 0.1 moles per drum per year (Appendix GAS), which will not result in significant pressure buildup behind the panel closure systems (see Appendix CLP). Other effects, such as the potential for methane explosion, are addressed in the design of the operational panel closure system and details are found in Appendix CLP. In summary, chemical effects are either addressed through design or not expected to adversely impact the facility during this time frame.

5.3.2.3 Mechanical Effects

The repository level at the WIPP facility is 2,150 ft (655 m) below the surface. At that depth, the rock is expected to return to lithostatic pressure around the waste within approximately 100 years after final closure of the facility. There has been some subsidence of the ground surface above potash mines in the area; however, due to the size of the land-withdrawal area and the controls placed on mining, no subsidence is expected to occur above the WIPP underground facilities during the 35-year operational/closure period.

5.3.2.4 Modification of the Hydrologic Regime

The only water-bearing zones in the region that could be affected by the WIPP facility are the Culebra and Magenta members in the Rustler Formation, more than 1,000 ft (305 m) above the waste region. The only facility-related effects to the hydrologic regime are those that have already been felt due to the mining of the four shafts to the waste disposal level and the pumping in several boreholes around the site for hydrologic characterization. These effects are not expected to impact disposal operations and facility closure. It is anticipated that these effects will disappear as the hydrologic regime re-equilibrates itself.

5.3.2.5 Waste Fire

There is little likelihood of fires in the waste during the operational period. The WAC limits quantities of pyrophorics (which are permissible only if they are radionuclides) to one percent by weight, and they must be generally dispersed in the waste. The WIPP SAR states that, based on a thorough review of waste handling operations and past

experience at other facilities, spontaneous combustion within a drum of waste is considered a limiting, not credible, event.

Experimental evidence supports the conclusion that there is minimal risk of sustained combustion of packaged TRU-mixed waste due to spontaneous internal combustion. The fire hazard to the WIPP facility is primarily limited to exposure of waste packages to external fires. Operational techniques and administrative controls enhance fire safety in waste emplacement areas and, in conjunction with appropriate fire detection and suppression methods (see Section 3.6.4), essentially eliminate the waste related fire hazards.

5.3.3 Human-Induced Events

Certain human-induced events could conceivably impact the integrity of the WIPP repository. These events include design and operational flaws, human intrusion, induced groundwater perturbations, and induced biosphere alterations. The following sections describe the safeguards that have been developed to minimize the potential for human-induced events to affect repository performance.

5.3.3.1 Improper Design and Operation

All portions of the WIPP facility design, construction, and operation have been and will continue to be carried out under a strict quality assurance (QA) program (Chapter 7). The WIPP QA program meets the federally mandated requirements of a nuclear facility QA program. The enforcement of the QA program and other management controls will significantly reduce the risk of facility design or operation impacting the integrity of the repository.

5.3.3.2 Human Intrusion

The DOE will rely on institutional controls, both active and passive, imposed through general regulatory standards and site-specific conditions to ensure that access to the WIPP site is appropriately restricted. Prior to closure of the WIPP facility, access to the repository will be strictly controlled. After closure, the DOE will impose long-term passive institutional controls, such as land withdrawal, records, and markers, to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits at the site may have terminated.

The DOE has taken a number of steps to reduce the likelihood of human intrusion after closure of the facility. The federal government controls the entire surface and subsurface estate at the WIPP site, with the exception of a small portion of the subsurface estate (Section 3.1) that is currently leased below 6,000 ft (1,830 m) for oil and gas production. Upon final closure of the WIPP site, the DOE will notify all state and county planning, deed and record offices, oil and gas commissions, and other agencies to prevent access by unknowing parties. The DOE also plans to place permanent warning markers at the site. Recordkeeping and marker systems will be implemented with a "defense in depth"

approach, whereby the durability of marker system components and messages, the ability to interpret the messages, and the accessibility of the records are ensured. The DOE believes that, cumulatively, these types of measures will be effective in reducing the likelihood of human intrusion into the repository so that it will not be a credible scenario for either the operational/closure or the post-closure periods. See Appendices LTM and PMR for additional information.

5.3.3.3 Perturbation of the Groundwater System

The groundwater system is presently perturbed due to the excavation already in place within the repository. As closure of the repository advances, the groundwater system will resume the pre-excavation characteristics. No adverse impacts are expected to occur as a result of changes in the groundwater system.

5.3.3.4 Biosphere Alterations

Upon final closure, the WIPP facility will be completely sealed from the biosphere. No alterations in the biosphere are expected to occur from the WIPP facility.

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6.0 Monitoring

Abstract

Monitoring programs have been implemented to establish background environmental conditions at the Waste Isolation Pilot Plant (WIPP) site and surrounding area. The Radiological Baseline Program and the Ecological Monitoring Program have quantified environmental parameters of interest to the facility. These two programs, originating in 1985, have established the baseline of parameters against which future operational sampling programs will be evaluated. The majority of the data was accumulated between 1985 and 1991. Other environmental monitoring includes meteorological, air quality, water quality, wildlife population, and surface feature monitoring.

Confirmatory VOC monitoring (see Appendix CMP) will be conducted during initial stages of the disposal phase to determine whether or not health-based levels (HBLs) are exceeded. Regular sampling in the underground repository during filling and closure of panel 1 will be performed and analyses assessed quarterly. Monitoring activities to support long-term performance of the repository will be focused on data collection for hydrological, geological, geochemical, and structural performance aspects. The data will be used to determine whether or not there are deviations from expected long-term performance.

In the development of the WIPP project monitoring programs, potential pathways for release of radiological and nonradiological contaminants to the environment were evaluated. The *Waste Isolation Pilot Plant Safety Analysis Report* identifies the atmospheric pathway as the only credible pathway for the release of radiological and hazardous organic contaminants that might result in a potential dose to the public (DOE 1995).

Environmental Monitoring

The operational environmental monitoring activities are described in the *WIPP Environmental Monitoring Plan* (EMP) (DOE 1994). The EMP describes the monitoring of a comprehensive set of parameters to detect potential environmental impact. The ecological portions of the program focus on the immediate area surrounding the facility, whereas radiological surveillance generally covers a broader geographic area, including nearby ranches, villages, and cities. This environmental monitoring will continue throughout the project's disposal phase and closure of the facility. Any impacts will be determined by a quantitative analysis comparing operational monitoring results against the established baselines.

Meteorological Monitoring. The primary function of the meteorological monitoring is to provide data to aid in modeling atmospheric conditions for the radiological environmental surveillance. Data are obtained from a meteorological station located just beyond the northeast corner of the property protection area. The station measures wind speed, wind direction, barometric pressure, differential temperatures between 10 and 33 ft

(3 and 10 m) and 3 and 131 ft (1 and 40 m), dew point, and precipitation. These parameters are continuously measured and the data collected on the Central Monitoring System (CMS).

In addition to the meteorological monitoring station, the WIPP facility maintains a supplemental meteorological station that records temperature and barometric pressure at 5.0 ft (1.5 m), with wind speed and wind direction measured at 33 ft (10 m).

Air Quality Monitoring. Pollutant gas measurements were discontinued in 1994. Data generated by the analyzers showed these gases (sulfur dioxide, carbon monoxide, ozone, hydrogen sulfide, and oxides of nitrogen) to be at the lower limits of detection. Total suspended particulates (in micrograms per m^3) continue to be measured weekly by the low-volume continuous air samplers at off-site locations.

Water Quality Sampling. Water quality sampling is conducted in conjunction with the hydrologic radioactivity sampling as part of the Water Quality Sampling Program (WQSP). In accordance with the WQSP, groundwater samples are collected from wells drilled and completed specifically for the WIPP studies. Since the program's start in January 1985, the groundwater quality data have been used to characterize the WIPP water quality.

Wildlife Population Monitoring. The population density of raptors, breeding birds, and small nocturnal mammals is measured annually to assess the effects of WIPP activities on wildlife populations. Two permanent study plots adjacent to the WIPP facility are used; one for mammals and one for birds. The data from the study plots are compared to two control plots to assess the effects of WIPP activities on wildlife populations.

Aerial Monitoring. Aerial photographs of the WIPP are taken and used to document surface disturbance, development, and reclamation activities at the WIPP and surrounding lands. This photography allows documentation of changes in the WIPP vicinity. Any unusual changes noted are evaluated, and the cause and the potential role of WIPP activities in affecting these changes is determined.

Volatile Organic Compound Monitoring

The volatile organic compound (VOC) monitoring program has focused on the air pathway since 1991. The airborne emission of VOCs is the only credible pathway for release from the WIPP during disposal operations, and this pathway will be eliminated upon final closure. With more than four years of data having been collected, a credible basis for determining the WIPP facility's background levels of the targeted VOCs has been established.

The background VOC monitoring plan conducted for the WIPP to date is described in detail in the *VOC Monitoring Plan* (WEC 1994b). The program was designed to demonstrate that the concentrations of hazardous constituents which would have been emitted during the test phase would not have exceeded levels established by the

Environmental Protection Agency (EPA) beyond the unit boundary. The program consisted of monitoring the air exhausted from the mine's ventilation shaft for VOCs that might have been released from the test wastes. To differentiate between ambient or background VOCs from aboveground and underground sources and VOCs released from transuranic- (TRU-) mixed wastes, VOC concentrations have been measured at the following locations:

- Near the top of the Exhaust Shaft (Station VOC-1)
- Near the air intake shaft (Station VOC-2)
- Ventilation air intake passageways to the waste-containing rooms (Station VOC-8)

Sampling was designed to follow a regular schedule, with the samples analyzed for five target VOCs. The samples were then analyzed for other organics present in sufficient quantities to be detected. The five target compounds were carbon tetrachloride, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, and 1,1,2-trichloro-1,2,2-trifluoroethane. These compounds were selected due to their prevalence in TRU-mixed wastes and their inclusion in the conditinal no-migration determination.

The concentrations of VOCs at the point of compliance during disposal operations and facility closure have been estimated to be one-third to five orders of magnitude below HBLs. Since these calculations were based on conservative assumptions, and since the DOE has collected more than four years of data to support the validity of background levels of VOCs in air, the Department of Energy (DOE0 will implement confirmatory VOC monitoring activities into the disposal phase.

The DOE has prepared a VOC monitoring plan that describes the aspects of a VOC monitoring strategy. The plan has been prepared so that the DOE can show that the assumptions and predictions used to demonstrate compliance to the environmental performance standards are valid. Validity is shown when observed emissions are equal to or less than those predicted. The VOC Confirmatory Monitoring Plan (CMP) is provided in Appendix CMP. The CMP includes monitoring design, sampling and analysis procedures, and quality assurance objectives. This plan is submitted in compliance with 20 NMAC 4.1, Subpart V, §264.602, §268.6, and §270.23(a)(2).

In this petition, the DOE demonstrates the theoretical compliance with the environmental performance standards of 20 NMAC 4.1, Subpart V, §264.601(c), and §268.6. This CMP describes a sampling and analysis program to confirm the theoretical calculations. The monitoring program is capable of quantifying VOC concentrations in the ambient mine air at the WIPP. The CMP addresses the following information requirements:

- Rationale for the design of the monitoring program, based on possible pathways, operations, engineered and natural barriers, and monitoring locations optimized for detection

- Descriptions of the specific elements of the monitoring program including the type of monitoring, the location of stations, the frequency of sampling, the target analytes, the

schedule for implementation, the equipment used, the sampling and analytical techniques, and the data recording and reporting procedures

The design of the CMP used the results of background VOC monitoring activities at the WIPP. These data are presented in Appendix BAD. These data represent the anticipated background levels of VOCs during operations at the WIPP.

The DOE's intent is to collect air samples upstream and downstream of Panel 1 beginning just prior to waste emplacement and proceeding until at least six months following completion of panel closure. The DOE will continue monitoring until the criterion for terminating monitoring are met. These criterion are established in Appendix CMP for each target analyte.

The current VOC monitoring program uses EPA Compendium Method TO-14 (EPA 1988). The DOE has had success with TO-14 at the WIPP if care is taken in placing samplers to avoid high dust and if stringent cleaning requirements are imposed for the clean canisters. This is necessary because of the extremely low concentrations that are being monitored. The DOE is evaluating the use of the Fourier Transform Infra-Red (FTIR) technique for monitoring VOCs at WIPP. This method is being used successfully at other locations and has recently been approved by the EPA for measuring the concentration of VOCs in the headspace gases of drums of TRU waste. If FTIR becomes viable, the monitoring plan will be revised and the revisions will be submitted to the New Mexico Environment Department (NMED) for approval prior to implementation.

The CMP will be run under a Quality Assurance Plan that conforms to the document entitled "EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations" (EPA 1994). Quality Assurance criteria for the target analytes are given in Appendix CMP along with a discussion of other aspects of the Quality Assurance Program including sample handling, calibration, analytical procedures, data reduction, validation and reporting, performance and system audits, preventive maintenance, and corrective actions.

Long-Term Monitoring

Because the WIPP is a mined geological repository designed to permanently isolate contaminants, no post-closure monitoring for the detection of releases is proposed because the migration of contaminants is unlikely even for thousands of years. However, regulations that apply to the analysis of system performance require an evaluation of techniques that would address other aspects of the disposal system performance over a relatively short time period. These methods evaluate whether performance deviates significantly from what is expected. The DOE interprets this standard as a requirement that a monitoring program be used with regard to addressing uncertainties associated with long-term performance predictions, and that the time period over which diagnostic data can be collected be realistic in terms of exercising active institutional controls over the site. This monitoring will be performed with a variety of techniques designed to detect detrimental deviations without jeopardizing waste isolation. With this objective in mind,

selection and specification of monitoring activities addressed the four areas of performance: hydrological, geological, geochemical, and structural. Based on the disposal system monitoring requirements and following an evaluation of current geophysical and experimental technologies, a disposal system monitoring system has been conceived composed of a subsidence network, a monitoring program, and a baseline database.

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6.0 MONITORING

Monitoring programs have been undertaken to establish background environmental conditions at the Waste Isolation Pilot Plant (WIPP) site and surrounding area. The Radiological Baseline Program and the Ecological Monitoring Program have quantified environmental parameters of interest to the facility. These two programs, originating in 1985, have established the baseline of parameters against which future operational sampling programs will be evaluated. The majority of the data was accumulated between 1985 and 1991. The final baseline reports were published as appendices in the *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1991* (Westinghouse 1992). Other environmental monitoring includes meteorological, air quality, water quality, wildlife population, and surface feature monitoring.

Confirmatory VOC monitoring (see Appendix CMP) will be conducted during initial stages of the disposal phase to determine whether or not health-based levels (HBLs) are exceeded. Regular sampling in the underground repository during filling and closure of panel 1 will be performed and analyses assessed quarterly. Monitoring activities to support long-term performance of the repository will be focused on data collection for hydrological, geological, geochemical, and structural performance aspects. The data will be used to determine whether or not there are deviations from expected long-term performance.

In the development of the WIPP project monitoring programs, potential pathways for release of radiological and nonradiological contaminants to the environment were evaluated. The *Waste Isolation Pilot Plant Safety Analysis Report* identifies the atmospheric pathway as the only credible pathway for the release of radiological and hazardous organic contaminants that might result in a potential dose to the public (DOE 1995).

6.1 Environmental Monitoring

The operational environmental monitoring activities are described in the *WIPP Environmental Monitoring Plan* (EMP) (DOE 1994). The EMP describes the monitoring of a comprehensive set of parameters to detect potential environmental impact. The ecological portions of the program focus on the immediate area surrounding WIPP, whereas radiological surveillance generally covers a broader geographic area, including nearby ranches, villages, and cities. This environmental monitoring will continue throughout the project's disposal phase and closure of the facility. Any impacts will be determined by a quantitative analysis comparing operational monitoring results against the established baselines.

The Nonradiological Environmental Surveillance (NES) programs were preceded by the WIPP biology programs (1975–1982), which combined scientific and technical expertise from six universities to develop an extensive baseline of information describing the major components of the Los Medaños ecosystem prior to the initiation of WIPP construction activities. The principal functions of the NES are as follows:

- To detect and quantify the impacts of construction and operational activities at the WIPP on the surrounding ecosystem
- To continue developing of the ecological database for the Los Medaños area initiated by the WIPP biology program
- To investigate unusual or unexpected elements in the ecological databases
- To provide environmental data that are important to the mission of the WIPP project, but which have not or will not be acquired by other programs

The ecological monitoring includes five specific programs: (1) meteorological monitoring, (2) air quality monitoring, (3) water quality monitoring, (4) wildlife population monitoring, and (5) surface disturbance monitoring through the analysis of aerial photographs.

In addition to the ecological monitoring programs, the WIPP program also conducts salt-impact studies, which consist of soil chemistry and analysis for chlorides, sodium, calcium, magnesium, potassium, and pH. These studies will determine the impacts on the surrounding environment from the excavation and storage of salt resulting from the mining of the repository.

The results of the ecological monitoring and the salt studies are published in the Annual Site Environmental Report (ASER), the most recent of which is provided as Appendix SER. The statistical baseline for all of the areas was compiled and published in the *Statistical Summary of the Radiological Baseline Program for the Waste Isolation Pilot Plant* (DOE 1992).

6.1.1 Meteorological Monitoring

The meteorological monitoring provides data to aid in modeling atmospheric conditions for the radiological environmental surveillance. Data are obtained from a meteorological station located just beyond the northeast corner of the property protection area. The station measures wind speed, wind direction, barometric pressure, differential temperatures between 10 and 33 ft (3 and 10 m) and 10 and 131 ft (3 and 40 m), dew point, and precipitation. These parameters are continuously measured and the data stored as real-time data in the Central Monitoring Room (CMR).

In addition to the meteorological monitoring station, the WIPP facility maintains a supplemental meteorological station that records temperature and barometric pressure at 5.0 ft (1.5 m), with wind speed and wind direction measured at 33 ft (10 m).

6.1.2 Air Quality Monitoring

Pollutant gas measurements were discontinued in 1994. Data generated by the analyzers showed these gases (sulfur dioxide, carbon monoxide, ozone, hydrogen sulfide, and oxides of nitrogen) to be at the lower limits of detection. Total suspended particulates (in

micrograms per cubic meter) continue to be measured weekly by the low-volume continuous air samplers at off-site locations.

6.1.3 Water Quality Monitoring

The water quality monitoring program is conducted in conjunction with the hydrologic radioactivity monitoring as part of the *Water Quality Sampling Program* (WQSP) (Westinghouse 1991). In accordance with the WQSP, groundwater samples are collected from wells drilled and completed specifically for the WIPP studies. Since the program's start in January 1985, the groundwater quality data have been used to establish the WIPP water quality background characterization (see Appendix BWQ).

These water quality data are used in the predictive models supporting the WIPP PA. The WQSP supports this effort by providing water chemistry data for use in predictive modeling of the potential solubility and transport of radionuclides and chemical components along potential flow pathways. As a part of the environmental monitoring program, the WQSP provided water quality data on key environmental parameters for groundwater near the WIPP. Samples were routinely analyzed for general chemical parameters (including metals) and EPA-listed hazardous organic substances. The data collected by this program are compiled and presented in the ASER.

6.1.4 Wildlife Population Monitoring

The population density of raptors, breeding birds, and small nocturnal mammals is measured annually to assess the effects of WIPP activities on wildlife populations. Two permanent study plots adjacent to the WIPP facility are used; one for mammals and one for birds. The data from the study plots are compared to two control plots to assess the effects of WIPP activities on wildlife populations.

Although not compiled as a baseline, the wildlife monitoring data are presented annually in the ASER. Each year they are compared to data of previous years and fluctuations in densities are evaluated against a number of parameters.

6.1.5 Aerial Monitoring

Aerial photographs of the WIPP are taken and used to document surface disturbance, development, and reclamation activities at the WIPP and surrounding lands. This photography allows documentation of changes in the WIPP vicinity. Any unusual changes are evaluated, and the cause and the potential role of WIPP activities in affecting these changes is determined (Appendix SURV contains the most recent aerial photographs).

6.2 Volatile Organic Compound Monitoring

VOC monitoring has been performed at the WIPP facility to establish background VOC levels at the site. This monitoring is described in Section 6.2.1. During initial stages of the disposal phase, confirmatory VOC monitoring will be performed in the repository. This monitoring is described in Section 6.2.2.

6.2.1 Background Volatile Organic Compound Monitoring

The VOC monitoring program has focused on the air pathway since 1991. The airborne emission of VOCs is the only credible pathway for release from the WIPP during disposal operations, and this pathway will be eliminated upon final closure. With more than four years of data collected, a credible basis for determining the WIPP facility's background levels of the targeted VOCs has been established. These data are included in Appendix BAD.

The VOC monitoring plan conducted for the WIPP to date is described in detail in the *VOC Monitoring Plan* (Westinghouse, 1994a). The program demonstrates that the concentrations of hazardous constituents which would have been emitted during the test phase would not have exceeded levels established by the EPA beyond the unit boundary. The program monitored the air exhausted from the mine's ventilation shaft for VOCs that might have been released from the test wastes. To differentiate between ambient or background VOCs from aboveground and underground sources and VOCs released from transuranic- (TRU-) mixed wastes, VOC concentrations have been measured at the following locations:

- Near the top of the Exhaust Shaft (Station VOC-1)
- Near the air intake shaft (Station VOC-2)
- Ventilation air intake passageways to the waste-containing rooms (Station VOC-8)

Sampling followed a regular schedule with the samples analyzed for the quantities of five target VOCs. The samples were then analyzed for other organics present in sufficient quantities to be detected. The five target compounds were: carbon tetrachloride, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, and 1,1,2-trichloro-1,2,2-trifluoroethane. These compounds were selected due to their prevalence in TRU-mixed wastes and their inclusion in the conditional no-migration determination. The *VOC Monitoring Quality Assurance Project Plan* (QAPjP) identifies the following data quality objectives as applicable to the VOC monitoring program (Westinghouse 1994b):

- Method detection limit of 0.5 parts per billion or one-fifth of any HBL for a targeted constituent, whichever is greater
- Precision (i.e., relative percent difference between field duplicate samples) of ±15 percent
- Accuracy of ±10 percent

- Data completeness of 90 percent, as adjusted statistically to account for the results of data validation audits

The EPA Compendium Method TO-14, which specifies passivated stainless steel canisters for sample collection, was used as guidance to meet these objectives. The analytical methods consisted of cryogenic trapping and gas chromatography/mass spectrometry. Results of the VOC monitoring program have been provided annually to the EPA. Quality assurance/quality control (QA/QC) activities conducted in accordance with the VOC Monitoring QAPjP included duplicate sampling, spiked samples, and annual audits of the laboratory conducting the analyses.

6.2.2 Confirmatory Volatile Organic Compound Monitoring

The concentrations of VOCs at the point of compliance during disposal operations and facility closure have been estimated to be one-third to five orders of magnitude below HBLs (Chapter 5). Since these calculations were based on conservative assumptions, and since the DOE has collected more than four years of data to support the validity of background levels of VOCs in air, the Department of Energy (DOE) will implement confirmatory VOC monitoring activities into the disposal phase.

The DOE has prepared a VOC monitoring plan that describes the aspects of a VOC monitoring strategy. The plan has been prepared so that the DOE can show that the assumptions and predictions used to demonstrate compliance to the environmental performance standards are valid. Validity is shown when observed emissions are equal to or less than those predicted. The VOC Confirmatory Monitoring Plan (CMP) is provided in Appendix CMP. The CMP includes monitoring design, sampling and analysis procedures, and quality assurance objectives. This plan is submitted in compliance with 20 NMAC 4.1, Subpart V, §264.602, §268.6, and §270.23(a)(2).

In this petition, the DOE demonstrates the theoretical compliance with the environmental performance standards of 20 NMAC 4.1, Subpart V, §264.601(c), and §268.6. This CMP describes a sampling and analysis program to confirm the theoretical calculations. The monitoring program is capable of quantifying VOC concentrations in the ambient mine air at the WIPP. The CMP addresses the following information requirements:

- Rationale for the design of the monitoring program, based on possible pathways, operations, engineered and natural barriers, and monitoring locations optimized for detection

- Descriptions of the specific elements of the monitoring program including the type of monitoring, the location of stations, the frequency of sampling, the target analytes, the schedule for implementation, the equipment used, the sampling and analytical techniques, and the data recording and reporting procedures

The design of the CMP used the results of background VOC monitoring activities at the WIPP. These data are presented in Appendix BAD. These data represent the anticipated background levels of VOCs during operations at the WIPP.

The DOE's intent is to collect air samples upstream and down stream of Panel 1 beginning just prior to waste emplacement and proceeding until at least six months following completion of panel closure. The DOE will continue monitoring until the criterion for terminating monitoring are met. These criterion are established in Appendix CMP fore each target analyte.

The current VOC monitoring program uses EPA Compendium Method TO-14 (EPA 1988). The DOE has had success with TO-14 at the WIPP if care is taken in placing samplers to avoid high dust and if stringent cleaning requirements are imposed for the clean canisters. This is necessary because of the extremely low concentrations that are being monitored. The DOE is evaluating the use of the Fourier Transform Infra-Red (FTIR) technique for monitoring VOCs at WIPP. This method is being used successfully at other locations and has recently been approved by the EPA for measuring the concentration of VOCs in the headspace gases of drums of TRU waste. If FTIR becomes viable, the monitoring plan will be revised ans the revisions will be submitted to the NMED for approval prior to implementation.

The CMP will be run under a Quality Assurance Plan that conforms to the document entitled "EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations", (EPA 1994). Quality Assurance criteria for the target analytes are given in Appendix CMP along with a discussion of other aspects of the Quality Assurance Program including sample handling, calibration, analytical procedures, data reduction, validation and reporting, performance and system audits, preventive maintenance, and corrective actions.

6.3 Long-Term Monitoring

Because the WIPP is a mined geological repository designed to permanently isolate contaminants, no post-closure monitoring for the detection of releases is proposed, since the migration of contaminants is unlikely even for thousands of years. This is substantiated by the analysis of system performance described in Chapter 8. However, regulations that apply to the WIPP long-term performance require evaluating techniques that would address other aspects of the disposal system performance over a relatively short time period. These methods evaluate whether performance deviates significantly from what is expected.

Requirements for monitoring a disposal system are included in long-term performance standards to the extent that such monitoring can detect any detrimental and significant deviation from expected performance. The DOE interprets this standard as a requirement that a monitoring program be used to address uncertainties associated with the long-term performance predictions, and that the time period over which diagnostic data can be

collected be realistic in terms of exercising active institutional control over the site. Monitoring activities at the WIPP facility would most likely include the measurement of subsidence, among other things. In addition, groundwater sampling in the Rustler would continue.

Monitoring a mined geologic disposal system is intended to address "significant concerns" associated with the performance of the isolation system. The EPA points out that monitoring approaches to address "significant concerns" should be limited to those that could provide meaningful data in a relatively short time. Furthermore, the DOE monitoring system must not jeopardize the integrity of the disposal system.

As a result of the specific requirements contained in long-term performance standards, the post-closure monitoring program at the WIPP facility shall have the objective of detecting substantial and detrimental deviation from the expected performance of the disposal system. This monitoring will be performed with a variety of techniques designed to detect detrimental deviations without jeopardizing waste isolation. With this objective in mind, selection and specification of monitoring activities for the long-term monitoring (LTM) program addressed the four following areas of performance:

- *Hydrological*—possibilities for hydrological monitoring include, but are not limited to, a long-term assessment of the assumptions made regarding the movement of fluids through the Rustler

- *Geological*—geological performance can be assessed by monitoring subsidence at the surface

- *Geochemical*—geochemical performance may be assessed to substantiate assumptions regarding waste characteristics, brine characteristics, and waste-rock interactions

- *Structural*—structural performance would be assessed by evaluating man-made features such as shaft seals, plugs, and human intrusion barriers

Based on the assumption that migration of contaminants from a geologic repository is unlikely for at least thousands of years, the disposal system monitoring requirements (i.e., identification and quantification of detrimental deviations from anticipated repository performance and maintenance of disposal system integrity), and following an evaluation of current geophysical and experimental technologies, a long-term disposal system monitoring program has been conceived. Details of this monitoring program evaluation and development are presented in Appendix LTM. Elements of the LTM program are: a subsidence network, an environmental monitoring program, and a baseline database.

6.3.1 Subsidence Network

Several subsidence studies have been completed to evaluate the potential for, and predict the magnitude of, subsidence due to the development of the repository. These calculations account for a range of waste volumes, waste densities, and backfill types. Subsidence was also calculated for conditions where no backfill would be used. The Backfill Engineering Analysis Report (BEAR) (Westinghouse 1994) contains the most detailed data and calculations on subsidence. Contour maps, included in Appendix ADM, detail subsidence predictions using influence function and National Coal Board (NCB) methods with and without backfill. The maximum subsidence was also calculated using the mass conservation method. A Subsidence Data Study (SDS) performed specifically for the final facility configuration will predict subsidence related to repository performance and investigate factors that influence subsidence. The study will predict subsidence with respect to time for the repository and define the bounding limits that may indicate poor repository performance.

An SDS will define the most favorable positions for any additional benchmarks and oversee their placement in the network. In order to monitor subsidence, a network of benchmarks must be placed over the area of interest. Benchmarks have been installed over and around the general vicinity of the WIPP. These benchmarks are adequate for initial data gathering. However, the current network is too coarse to provide sufficient data points to accurately define subsidence over the repository for the long term. Contour plots of expected subsidence in the BEAR (Westinghouse 1994) show that the maximum subsidence can occur in a circular area with a radius as small as 1,000 ft (305 m); most of the current benchmarks are 1,000 ft (305 m) apart. Powers (1993) has recommended placing a network over the repository footprint that would extend 2,000 ft (610 m) past the 16-section (41.4-km^2) site boundary. This would encompass the entire predicted subsidence area for angles of draw up to 45 degrees. Additional benchmarks shall be placed to increase the density over the repository. These new benchmarks will be installed after completion of the SDS. The SDS will evaluate and determine the quantity and placement of the benchmarks to best determine subsidence.

After establishing the supplemental benchmark locations, the benchmarks that meet the National Geodetic Survey Class I, first-order standards will be installed and surveyed. All placement and survey data will be documented in the baseline database. Provisions will be made to maintain and replace benchmarks when required and to coordinate benchmark placement with the passive markers design.

6.3.2 Monitoring Program

The Long-Term Monitoring Program (LTMP) consists of monitoring the subsidence network and, for a limited period, the environment and groundwater. Subsidence monitoring is accomplished with a Class I Leveling Survey. The surveys will be performed every 10 years during the operational phase and thereafter in accordance with the Disposal System Monitoring Program schedule. The leveling surveys will be

performed as described in a QA/QC procedure to ensure the data are documented and validated. The data will be included in the baseline database.

Implementation of the operational environmental monitoring is contained in the WIPP EMP (DOE 1994). The EMP, which transitioned from the preoperational programs, includes monitoring a comprehensive set of parameters to detect any potential environmental impact. The ecological portions of the program focus on the immediate area surrounding the facility, whereas radiological surveillance covers a broader geographic area, including nearby ranches, villages, and cities. This environmental monitoring will continue throughout the project's disposal and closure phases. Any impacts will be determined by a quantitative analysis comparing operational monitoring results against previously collected data. Data from ongoing environmental monitoring are published annually.

6.3.3 Baseline Database

Establishment of environmental monitoring baselines for both radiological and nonradiological parameters was completed by compilation and publication of baseline reports. These programs have transitioned into the disposal phase; pertinent data collection will continue through the life of the project. The database will be updated regularly with data collected during the environmental monitoring program.

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7.0 Quality Assurance
Abstract

The Department of Energy (DOE) quality assurance (QA) policy is to establish, maintain, and implement an effective QA program that complies with applicable requirements of DOE Orders and Environmental Protection Agency (EPA) regulations. It is the DOE's goal to fulfill its mission while ensuring that not only are risks and environmental impacts identified and minimized, but also that safety, reliability, and performance are maximized.

WIPP QA programs define the management systems to be employed to meet the requirements prescribed by the Carlsbad Area Office's (CAO's) Quality Assurance Program Document (QAPD). Specifying requirements and associated guidance for QA programs ensures that all participants develop and implement effective management systems to ensure that items, processes, and services meet or exceed applicable CAO QA requirements.

Effective implementation of the CAO QA program depends on the efforts of all levels of the CAO organization. The CAO organization is structured so that the individual performing the work is responsible for achieving and maintaining quality; line management is responsible for verifying the quality; and independent assessors are responsible for assessing the quality of the work. The CAO Manager has overall responsibility for the development and implementation of the CAO QA program. Under his or her direction the CAO QA Manager is responsible for defining, integrating, and ensuring effective implementation of the CAO QAPD.

The QA program for the Waste Isolation Pilot Plant (WIPP) facility may be broken into various parts. Work is performed in accordance with established, approved, and documented technical standards and administrative controls. Items and processes are designed using sound engineering and scientific principles and appropriate standards. Controls are established to ensure that procured items and services meet applicable technical and QA requirements and that they perform as specified. Inspection and testing of specified items and processes are conducted using established criteria. The *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP) establishes a single program applying to all DOE transuranic (TRU) waste generator sites that anticipate shipping radioactive and mixed wastes to the WIPP. The WIPP monitoring program includes radiological and nonradiological monitoring and is carried out in accordance with the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T. The long-term demonstration activities are conducted under the Sandia National Laboratories (SNL) CAO-approved Quality Assurance Program Description.

Oversight authority for QA programs rests with the DOE. Also, each project participant is responsible for conducting management and independent assessments and identifying

and tracking areas for improvement. These assessments are conducted to measure program compliance and effectiveness of management and processes and to promote improvement.

7.0 QUALITY ASSURANCE

7.1 Purpose

The U.S. Department of Energy (DOE) quality assurance (QA) policy is to establish, maintain, and implement an effective QA program that complies with the applicable requirements of DOE Orders and the U.S. Environmental Protection Agency (EPA) regulations. It is the DOE's goal to fulfill its mission while ensuring that risks and environmental impacts are identified and minimized, and that safety, reliability, and performance are maximized.

WIPP QA programs define the management systems to be employed for meeting the requirements prescribed by the Carlsbad Area Office's (CAO's) Quality Assurance Program Document (QAPD), which is included in this document as Appendix QAPD. Specifying requirements and associated guidance for QA programs ensures that all participants develop and implement effective management systems to ensure that items, processes, and services meet or exceed applicable CAO QA requirements.

7.2 Quality Assurance Program Management

Effective implementation of the CAO QA program depends on the efforts of all levels of the CAO organization (including the CAO Manager, senior management, line management, and the personnel performing work). In the CAO organization, the individual performing the work is responsible for achieving and maintaining quality; line management is responsible for verifying the quality; and independent assessors are responsible for assessing the quality of the work. The CAO Manager has overall responsibility for developing and implementing the CAO QA program. Under his or her direction, the CAO QA Manager is responsible for defining, integrating, and ensuring effective implementation of the CAO QAPD.

7.2.1 Organization

The CAO and WIPP Project organizational structures, primary interfaces, functional responsibilities, and levels of authority for activities affecting quality are described and documented in the CAO QAPD. The hierarchy of QA program requirements and the organizational interfaces between the major project participants are illustrated in Figure 7-1. Major responsibilities of project participants are as follows:

- The CAO is the controlling organization for Waste Isolation Pilot Plant (WIPP) QA program development, implementation, and assessment

- The CAO reviews and approves the QA program documents of the Scientific Advisor (Sandia National Laboratories [SNL]), the Management and Operating (M&O) contractor (Westinghouse Waste Isolation Division [WID]), and the transuranic (TRU) waste generator sites

- The WID is responsible for establishing and implementing a QA program for WIPP site operation and maintenance, for monitoring the site environment, and for receipt of waste

- SNL is responsible for establishing and implementing a QA program for activities involved in the development, confirmation, and verification of models used to simulate long-term repository performance. SNL also conducts research, experiments, and tests to collect the data needed for input to the models

- TRU waste generator sites are responsible for establishing and implementing a QA program for TRU and TRU-mixed waste characterization and for implementation of the waste certification programs

7.2.2 Quality Assurance Program Requirements

QA program requirement sources include several federal requirements (10 CFR Part 71, 10 CFR Part 830, 40 CFR Part 194, 40 CFR Part 261, 40 CFR Part 264, and 40 CFR § 268.6), DOE Orders (primarily DOE 5700.6C), and consensus standards (American Society of Mechanical Engineers [ASME] Quality Assurance Requirements for Nuclear Facilities [ASME NQA-1], NQA-2a Part 2.7, and NQA-3, excluding Sections 2.1 (b) and (c) and 17.1). The CAO QAPD (see Appendix QAPD) reflects the WIPP QA requirements, lists sources of program requirements and guidance, and describes the organizational interfaces and responsibilities. The CAO QAPD is a program-wide document that establishes the required QA program controls applicable to all CAO participants.

Participant QA program descriptions include discussions of how the QA requirements will be satisfied, taking into consideration the probability and consequences of risk associated with the work. These discussions include the rationale and methodology used for the compliance determination, as well as discussions addressing applicability of the requirements to the work being performed.

The rigor of QA controls is commensurate with, but not limited to, the following criteria:

1. Function or end-use of the item
2. Importance and end-use of the data generated
3. Probability of failure
4. Complexity or uniqueness of design, fabrication, or implementation
5. Reproducibility of the result
6. History of the item or service quality
7. Necessity for special controls or processes
8. Ability to demonstrate functional compliance

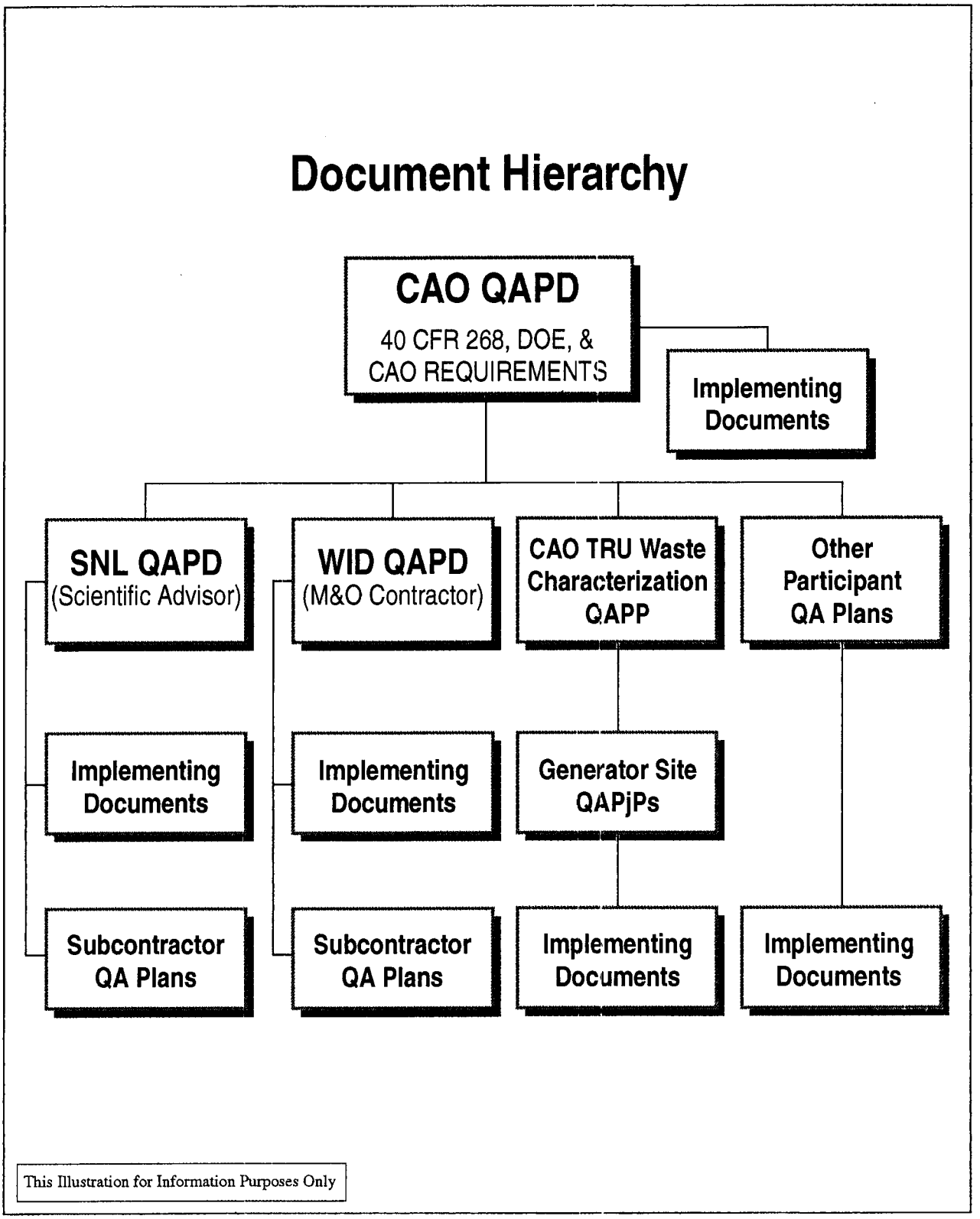

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Figure 7-1. Hierarchy of DOE QA Programs

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7.2.3 Qualification and Training Requirements

Personnel performing work are qualified and capable of performing their assigned tasks. In addition, personnel responsible for performing inspections, tests, and independent assessments must meet specific training and qualification requirements. Project participants have established formal methods for the evaluation, selection, indoctrination, training, and qualification of personnel performing work that comply with the requirements of the CAO QAPD.

7.2.4 Quality Improvement, Nonconformances, and Corrective Action

A culture which promotes continuous improvement is fundamental and integral to the WIPP mission; therefore, each organization's management seeks continuous improvement in the performance and efficiency of work processes and activities.

All personnel are responsible for identifying conditions adverse to quality. A condition adverse to quality is defined as one that, if not corrected, could have an adverse effect on compliance with the applicable requirements. The condition adverse to quality must be evaluated, the corrective action defined and taken, and the completion and effectiveness of the corrective action verified. Corrective actions must address the extent of the problem and the actions taken to resolve the problem. Significant deficiencies also require a determination of root cause and action to preclude reoccurrence. All actions must have scheduled completion dates.

Management at all levels strives to foster a "no-fault" attitude to encourage personnel to identify nonconforming items, activities, and processes and encourages personnel to suggest improvements. The nonconformance control process is documented in applicable QA plans or implementing procedures. Nonconformances are documented, evaluated, and dispositioned, and corrective actions taken, as appropriate.

7.2.5 Documents and Records

Documents and records provide evidence of the quality of the work and that the QA program was followed in the performance of the work. Documents and records generated under the CAO QA program are specified, prepared, reviewed, approved, controlled, maintained, revised, and disposed of in accordance with the CAO QAPD (see Appendix QAPD). The CAO QAPD provides a single reference for all project participants in meeting QA records management requirements. The records management system is documented in appropriate QA plans and implementing procedures.

Documents affecting quality that specify requirements, prescribe processes, or establish designs important to compliance, such as instructions, procedures, drawings, test plans, and management plans, are controlled to assure that correct documents are employed. Controlled documents are reviewed by competent personnel using specified criteria for adequacy, correctness, and completeness prior to approval and issuance. Review comments are resolved. Review comment documentation is maintained by the

originating organization. Responsibilities for document preparation are specified, and the documents are controlled during the preparation, review, approval, issuance, use, and revision processes.

7.3 Quality Assurance Program Implementation

7.3.1 Work Processes

Work is performed in accordance with established, approved, and documented technical standards and administrative controls. Work is planned, authorized, and accomplished under controlled conditions using approved instructions, procedures, drawings, or other appropriate means. Implementing procedures are developed, reviewed, and approved by technically competent personnel and contain information, including the following elements, appropriate for the work being performed:

- Prerequisites, limits, precautions, process parameters, and conditions necessary to accomplish of the process, including calibration requirements

- Special qualifications and training requirements

- Acceptance criteria, including applicable codes and standards

Personnel performing work are responsible for complying with appropriate instructions, which include or reference procedure, personnel, and equipment qualification requirements. Items are identified and controlled to ensure their proper use. Items are maintained to prevent their damage, loss, or deterioration. Equipment used for process monitoring or data collection is calibrated and maintained. Handling, storage, cleaning, shipping, and other means of preserving, transporting, and packaging items is conducted in accordance with established work and inspection procedures, shipping instructions, or other specified documents.

7.3.2 Design

Items and processes are designed using sound engineering and scientific principles and appropriate standards. Design work, including changes, incorporates appropriate requirements, such as general design criteria and design bases. Design interfaces are identified and controlled. The adequacy of design products are verified by individuals or groups independent from those who performed the work. Verification is completed prior to approval and implementation of the design.

7.3.2.1 Design of Data Quality Objectives

For future work, particularly waste characterization activities, environmental monitoring, monitoring of the disposal system performance, sampling and analysis activities, and field measurements of geological factors, groundwater, meteorologic, and topographic activities, the concept of designing data quality objectives for environmental data will

apply. Project goals will be documented, decisions and inputs identified, the study bounded, and a decision rule developed. Limits on decision errors will determine the degree of confidence necessary for the data to be considered valid.

For past work, where data have already been collected, the end-use of the data determines the amount of uncertainty permissible. Existing data undergo a formal qualification process before being used in compliance submittals. Refer to Section 7.6.1 for further discussion on the qualification of existing data.

7.3.3 Procurement Control

The requirements of the CAO QAPD are passed down from the CAO to its contractors. In addition, each CAO contractor is required to pass down the appropriate CAO QAPD requirements to its subcontractors. Controls are established to ensure that procured items and services, including laboratory services, meet applicable technical and QA requirements and that they perform as specified. Prospective suppliers are evaluated and selected on the basis of documented criteria. Procurement controls ensure that approved suppliers continue to provide acceptable items and services. Audits and surveillances are performed on quality-affecting vendors and subcontractors to verify that the requirements are met.

7.3.4 Inspection and Test Control

Inspections determine acceptance or rejection. Tests determine the capability of an item to meet specified requirements by subjecting the item to a set of operating conditions. Essential parts of work planning processes include identifying the following:

1. Items and processes to be inspected or tested
2. Any equipment to be used in performing the inspection or test, including the equipment identification number, calibration due date, and the type, range, accuracy, and tolerance of the equipment
3. Parameters or characteristics to be evaluated
4. Procedures, techniques, and related requirements documents used to control and perform the inspection or test
5. Appropriate prerequisites and provisions for assuring that all requirements and objectives have been met
6. Acceptance criteria
7. Hold points
8. Organizations responsible for performing the tests and inspections

Inspection and testing of specified items and processes are conducted using established acceptance and performance criteria. The acceptance of items and processes shall be made by and documented by qualified and authorized personnel.

Equipment used for inspections and tests is calibrated and maintained. The control system for monitoring, testing, and using data collection equipment prevents the use of

suspect and out-of-tolerance equipment in activities that could affect quality. If such equipment is inadvertently used, the control system provides for segregation and evaluation of the items checked and the data obtained using the out-of-tolerance or defective equipment.

7.3.5 Waste Characterization Program

QA requirements and program guidance for waste characterization is contained in the *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP) (DOE 1996). The QAPP establishes a single program applying to all DOE TRU waste generator sites that anticipate shipping radioactive and mixed wastes to the WIPP. The comprehensive scope of the Waste Characterization QAPP, encompassing all generator sites, is necessary for achieving a level of consistency in TRU and TRU-mixed waste certification. The Waste Characterization QAPP addresses QA requirements from the following sources:

- 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials*
- 40 CFR Part 268, *Land Disposal Restrictions*
- 40 CFR Part 264, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*
- 40 CFR Part 191, *Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes*

The original scope of the Waste Characterization QAPP was developed for the WIPP test phase (the test phase was canceled October 21, 1993, prior to implementation). The document was updated to be consistent with the preoperational work scope. The Waste Characterization QAPP uses established quality objectives for determining whether or not waste destined for the WIPP meets acceptance criteria.

Flow-down of applicable QA requirements from the Waste Characterization QAPP to each generator site is accomplished through the development of site-specific QA project plans. The QA project plans for each TRU waste generator site identify QA and QC provisions in response to the requirements of the QAPP, establish organizational roles and responsibilities, describe the waste certification process, and reference approved procedures to be used.

In addition to nondestructive test methods and waste sampling and analysis, TRU and TRU-mixed waste characterization uses acceptable knowledge. QA controls for acceptable knowledge include design documentation (e.g., drawings, specifications), construction and acceptance test records, operating reports, and process stream analyses.

7.3.6 WIPP Site Monitoring Programs

The environmental monitoring program at WIPP was initially established to acquire preoperational baseline environmental data in accordance with DOE Orders. The current

program includes radiological and nonradiological monitoring carried out in accordance with the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T (DOE 1991a). The guide is based on implementation of DOE Order 5400.1, *General Environmental Protection Program* and DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*

The radiological portion of the site environmental monitoring program includes liquid and airborne effluents, ambient airborne particulates, biotic samples, soils and sediments, surface and drinking water, and groundwater. Nonradiological monitoring includes local meteorology, ambient volatile organic compounds (VOCs), airborne gases, ecological plots, aerial photography, and salt-impact studies.

QA requirements for WIPP environmental data operations are specified in the WID Quality Assurance Program Description (Westinghouse 1996, attachment II, 2). Specified tolerances for data uncertainty, in terms of data accuracy, precision, and completeness, are contained in project-specific plans for air, groundwater, stormwater, VOC, and site effluent monitoring. A series of approved procedures, instructions, and drawings are used to implement the technical and QA requirements. Data are assessed routinely and reported in the annual site environmental report. QA plans and procedures have also been issued for hazardous materials management and Resource Conservation and Recovery Act (RCRA) compliance.

7.4 Quality Assurance Program Assessment

Oversight authority for QA programs rests with the CAO. Each project participant is responsible for conducting assessments and identifying and tracking areas for improvement. Assessments are conducted to measure program compliance, effectiveness of management and processes, and promote improvement. The accepted mechanisms for these assessments are management assessment and independent assessment.

Managers at all levels periodically assess the performance of their organization. The purpose for management assessment is to determine the effectiveness of QA program provisions that enable the organization to meet customer requirements and expectations.

Several levels of independent assessments occur within the QA program:

- CAO performs independent assessment of major project participant processes and products

- All program participants internally assess their programs using personnel independent of the work

- Subcontractors undergo source inspections, surveys, and audits performed by other project participants

7.5 Sample Control

Samples are controlled and identified in a manner consistent with their intended use, such as is specified in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846) (EPA 1986). Sample control procedures define responsibilities, such as interfaces between organizations for documenting and tracking sample possession from sample collection and identification through handling, preservation, shipment, transfer, analysis, storage, and final disposition. Nonconforming samples will be documented, evaluated, identified, and segregated in accordance with QAPD requirements

7.6 Control of Scientific Investigations

All technical investigations and data collection activities performed in support of WIPP are defined, controlled, verified, and documented. Process variables affecting scientific investigations are measured and controlled, as described in Section 7.3.4. Scientific investigations are performed and documented in accordance with test plans, procedures, and scientific notebooks. Planning for scientific investigations assures that the appropriate information is collected and that outside factors are eliminated or their effects minimized. Planning also determines the criteria used for subsequent evaluation of collected data and is coordinated with other organizations that provide input or use the results.

Data generated through scientific investigations are reviewed and validated prior to reporting the results. Data are recorded, identified, and traceable to the scientific investigation from which they were generated. Data collection and analysis are critically reviewed and questions resolved before the results are used or reported. Uncertainty limits are assigned to the data prior to their use.

7.6.1 Qualification of Existing Data

It is necessary to qualify existing data (used in performance assessment computer codes and models) with indeterminate quality where there is limited evidence that the data were collected under the formal control of an adequate QA program. An adequate QA program is one that meets the requirements of NQA-1, NQA-2a part 2.7, and NQA-3 (excluding Sections 2 (b) and (c) and 17.1), and transmits all the applicable QA requirements to each process, organization, or activity involved in the work being done, in a manner that provides traceability, replication, and accountability. Data that were not collected in accordance with the requirements of the CAO QAPD (see Appendix QAPD) shall be qualified for their intended use. The procedure developed for data qualification considers both QA programmatic and technical criteria.

The process for qualifying existing data to be used in no-migration modeling has been established by the CAO. The process is based on the Nuclear Regulatory Commission's (NRC's) guidance documents, NUREGs 1298 (NRC 1988a).

The process for qualifying existing data includes three major steps. The data qualification process begins with identifying the data packages that support the performance assessment calculations. An independent review team then evaluates the QA requirements and technical status of the data package. If the QA requirements applicable to the data package are determined to be acceptable, the data are considered qualified. If the QA requirements are determined to be unacceptable, alternative methods for qualifying the data are selected as follows:

- using corroborating data, (inferences drawn to corroborate the existing data shall have relationships that are clearly identified and justified)
- performing and documenting confirmatory testing
- performing and documenting peer review in accordance with QAPD requirements

Data that cannot be qualified are abandoned.

7.6.2 Background - Evolving Quality Assurance Program Requirements

The current DOE CAO QAPD (see Appendix QAPD) blends QA requirements and guidance from multiple sources. However, the DOE WIPP Project work has been performed under formal QA programs since 1977 and throughout several project phases.

1977–1980 *Site and Characterization Phase*. The earliest WIPP QA programs were based on the nuclear power plant QA requirements of the NRC's Title 10 CFR Part 50, Appendix B and ANSI/ASME N45.2 (the precursor to NQA-1). The ASME NQA-1 standards were issued in 1979 and began to be incorporated into the preferred QA standard.

1980–1983 *Site and Preliminary Design Validation Phase*. NQA-1 requirements, as suggested by the DOE Order 5700.6A, were the basis for WIPP QA programs.

1983–1989 *Construction Phase*. NQA-1 continued to be recognized through DOE Orders as the preferred standard for QA through DOE 5700.6B.

1989–1993 *Test Phase*[1]. The WIPP QA programs began to incorporate program elements from DOE Order 5700.6C while retaining the requirements of NQA-1.

1994–present *Preoperational Phase*. For environmental data quality, the current requirements are taken from DOE Order 5700.6C and selected EPA guidance documents. The process for qualifying existing data utilizes

[1]Tests were canceled October 21, 1993, prior to implementation.

guidance from NUREGs 1297 and 1298. Title 10 CFR § 830.120 QA requirements apply to DOE nuclear facility contractors, including WIPP and the TRU waste generator sites. NQA-1, NQA-2a Part 2.7, and NQA-3 (excluding Sections 2 (b) and (c) and 17.1). QA requirements are also incorporated into the WIPP QA program.

7.7 Long-Term Compliance Quality Assurance

Pursuant to 40 CFR 268.6 (b)(4), activities performed by SNL were conducted under a CAO-approved Quality Assurance Program Description. This document defines management, performance, assessment, sample control, scientific investigation, software QA requirements, training, and records management. The SNL WIPP QAPD is supported by 40 QA procedures (QAPs).

The No-Migration Variance Petition (NMVP) Analysis was conducted under a plan developed and approved under SNL WIPP QAP 9-1, *Quality Assurance Requirements for Conducting Analyses*. This plan documents the analysis approach and defines additional SNL WIPP QAPs that specify the applicable QA requirements:

QAP 6-3 *Conducting and Documenting Reviews of Documents*
QAP 9-2 *Quality Assurance Requirements for the Selection and Documentation of Parameter Values used in WIPP Performance Assessment*
QAP 9-5 *Conducting and Documenting Routine Calculations*
QAP 17-1 *WIPP Quality Assurance Records Source Requirements*
QAP 19-1 *WIPP Computer Software Quality Assurance Requirements*

The overall SNL QA program was determined to be adequate and effectively implemented as of August 1995. The full SNL QA program is being audited by the CAO. The data evaluated by the CAO during these audits of SNL include work performed since August 1995. This date also coincides with the issue date of the latest SNL procedures. Surveillances performed since August 1995 supplement and support the findings of the CAO QA program audits of SNL.

Data quality is applicable to data used in the development of parameters identified in Appendix PAR. Site-specific experimental data that were used directly in the calculation of performance were collected under an approved QA plan (e.g., the Quality Assurance Program Description) or were qualified as described in Section 7.6.1.

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8.0 Long-Term Compliance Analysis
Abstract

For the long-term performance portion of the Waste Isolation Pilot Plant (WIPP) No-Migration Variance Petition (NMVP), and consistent with Title 40 of the Code of Federal Regulations (CFR) §268.6, modeling techniques and bounding calculations are used to demonstrate that there will be "no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous." As part of the demonstration, brine and gas migration from the repository is simulated for a period of 10,000 years. The Department of Energy (DOE) also uses bounding calculations to compare maximum possible concentrations of gas-phase hazardous constituents at the disposal unit boundary to Environmental Protection Agency- (EPA) approved health-based levels (HBLs).

Long-term performance calculations in this petition are deterministic and based on the median or mode of parameter distributions or other constant values specified in the simulation database. The DOE has implemented assumptions and selected input parameter values in source term calculations and the simulation model, that, cumulatively, tend to overestimate, rather than underestimate, the potential for hazardous constituent migration. As a consequence of this approach, the results of calculations for the time period early into the long-term demonstration significantly overestimate gas generation and pressurization of the repository (see Appendix OUTPUT p. OUTPUT-iii). Simulated consequences for about the first 50-100 years after closure are unrealistically conservative and should be interpreted only within the context of the long-term demonstration.

Conceptual Model

The WIPP disposal unit is specified as the Salado Formation contained within the subsurface projection of the land-withdrawal area. Modeling and bounding calculations consider two potential hazardous constituent migration pathways to the disposal unit boundaries. One potential pathway is outward from the waste-disposal panels through anhydrite interbeds to the lateral disposal unit boundary. At its closest point, the lateral unit boundary is located approximately 7,874 ft (2,400 m) south of the southern edge of the waste-disposal panels. The other potential pathway is upward through facility shafts that connect the repository to the upper disposal unit boundary (i.e., top of the Salado). The upper disposal unit boundary is located approximately 1,305 ft (398 m) above the waste-disposal panels.

The conceptual model includes creep closure of the waste-disposal panels, a process that will consolidate waste in the disposal areas. The altered stress field created by the excavation will also result in a system of fractures surrounding the excavation and the shaft, referred to as a disturbed rock zone (DRZ). The conceptual model considers brine inflow to the waste-disposal panels in response to pressure gradients created by the excavation. Opposing brine inflow is the fluid pressure increase expected in the repository resulting from creep closure and waste-generated gas. The conceptual model

includes two-phase flow from the repository and dilation or fracturing of interbeds; the latter is a process capable of increasing the mass transport of hazardous constituents.

The reference design of the repository is a ten-panel waste disposal region. Cylindrical seals in the four shafts will consist of salt columns interleaved with concrete plugs, clay, and other engineered materials. The conceptual model includes the possibility for fluid to flow through or around the shaft seals and panel closures.

Computer Simulation

The primary software code used in the simulation is BRAGFLO (BRine And Gas FLOw). BRAGFLO calculates the overall movement of gas and brine in the disposal unit. BRAGFLO also contains the submodels for estimating gas generation in the repository, disposal room closure and consolidation, and interbed fracturing. Changes in void volume of the waste resulting from creep closure are coupled to BRAGFLO through SANTOS, a code that provides a "porosity surface" used as a reference to track changes in room volume.

Bounding Calculations

For long-term bounding calculations, the weighted average concentration for each volatile organic compound (VOC) is used as the source term concentration when waste characterization data are available. Weighted headspace concentrations are corrected for void volume conditions expected in the repository. When no waste characterization data are available, saturated vapor concentrations are used to represent source term concentrations for VOCs. Because waste characterization data are not available for semi-volatile compounds (SVOCs), saturated vapor concentrations are also assumed for this class of organic constituents. Soil-based concentrations are calculated assuming gas-available porosity within shaft seals and within anhydrite markers beds at the subsurface disposal unit boundaries; the calculated concentrations are then compared to soil-based HBLs.

According to the conceptual model, organic constituents partition into the liquid phase from the gas phase as estimated by Henry's Law. By this approach, concentrations in the brine phase will always be less than concentrations in the gas phase. Consequently, liquid-phase compliance is achieved as a result of demonstrating no migration for gas-phase organic constituents.

Long-Term Model Demonstration of No-Migration

The simulation results presented in this demonstration are based on a conservative assumption of high gas-generation rates. Gas generation is purposely modeled to increase the potential for migration of brine and gas away from the repository and into the anhydrite interbeds and sealed shaft. The modeling approach implemented is conservative based on the assumption that the entire inventory of ferrous metals, cellulosics, plastics, and rubbers in the waste is available to generate gas. No credit is

taken for the 50 percent probability that biodegradation may not occur, a modeling assumption that would result in lower gas generation rates (Wang and Brush 1996a, 1).

BRAGFLO brine- and gas-flow simulations show zero gas saturations at all disposal unit boundaries, with exception of the shaft. Nonzero initial gas saturations within the shaft components make interpretation of cumulative gas flow in the shaft ambiguous. The DOE demonstrates that gas-phase organic constituent concentrations at the shaft unit boundary will be orders of magnitude below HBLs using bounding soil-based concentrations. Based on the predicted brine saturation of the waste-disposal panels, the BRAGFLO simulation demonstrates that contaminated brine is physically incapable of leaving the waste area. Consequently, the DOE demonstrates that there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous.

Long-Term Demonstration Appendices

The following appendices are referred to in Chapter 8:

Appendix LTHBL. Appendix LTHBL documents derivation of health-based soil levels referenced in the long-term no-migration demonstration.

Appendix SCR. Consistent with guidance contained in EPA (1992), Appendix SCR assesses uncertainty with respect to a comprehensive inventory of potential natural events, waste/facility-induced events, and human-induced events. The analysis also provides the framework for the overall conceptual model underlying the long-term simulation.

Appendix PAR. This appendix documents the basis for selecting input parameter values used in the long-term simulation. Parameter sheets are provided for selected input parameters (i.e., those listed in parameter tables of Chapter 8). The full parameter database used in the NMVP simulation is attached.

Appendix MASS. The NMVP Appendix MASS is used to document fundamental modeling assumptions underlying the long-term no-migration BRAGFLO simulation. Assumptions are also discussed in Chapter 8 (Section 8.2, Section 8.3, and Table 8-14), Appendix SCR, Appendix PAR, and Appendix BRAGFLO.

Appendix OUTPUT. This appendix includes the BRAGFLO output data files used to plot graphic results in Chapter 8. Chapter 8 figures are reproduced in Appendix OUTPUT.

Appendix BRAGFLO. The theory and implementation of the BRAGFLO code are provided in this appendix. The appendix is a component of the BRAGFLO *User's Manual* developed for Sandia National Laboratories' WIPP Quality Assurance Program Description (QAPD).

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8.0 LONG-TERM COMPLIANCE ANALYSIS

This chapter evaluates the long-term compliance of the Waste Isolation Pilot Plant (WIPP) underground disposal unit with requirements codified in Title 40 of the Code of Federal Regulations (CFR) § 268.6. The Department of Energy (DOE) uses modeling techniques and bounding calculations to show "to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous" (40 CFR 268.6). This requirement is interpreted as follows:

- "Hazardous constituents" are those listed in Appendix VIII of 40 CFR § 261

- "No migration" means that predicted hazardous-constituent concentrations do not exceed Environmental Protection Agency (EPA)-approved human health-based levels (HBLs) defined for soil media at the disposal unit boundary, or bounding analyses show that such conditions will not occur

- "For as long as the wastes remain hazardous" refers to a 10,000-year demonstration period

To demonstrate compliance with 40 CFR § 268.6 over the long term (i.e., after closure of the repository), the potential for migration of hazardous constituents in the brine and/or the gas phase beyond the boundary of the disposal unit has been evaluated. Aspects of the analysis addressed within this chapter include:

- Description of the compliance methodology, including the overall modeling strategy, and other fundamental features of the analyses

- Definition of the conceptual model, model geometry, and numerical codes that implement the conceptual models, including parameters used to model brine and gas flow and hazardous-constituent migration

- Definition of the hazardous-constituent source term, including the conceptual and mathematical basis and applicable parameters used in the analysis

- Explanation of the results of the modeling and bounding analyses and consideration of uncertainty and parameter sensitivity

8.1 Compliance Methodology

A two-phase flow model is used in this No-Migration Variance Petition (NMVP) to simulate the migration of brine and gas from the waste-disposal region. Assuming that liquid-phase and gas-phase hazardous constituents are contained in these respective phases, the DOE presents the outcome of this computer simulation to demonstrate no migration. To demonstrate no migration for gas-phase hazardous constituents, the DOE

also uses bounding calculations to compare predicted concentrations of gas-phase hazardous constituents at the disposal unit boundary to EPA-approved HBLs.

Long-term performance calculations in this petition are deterministic and based on the median or mode of parameter distributions or other constant-value parameters specified in the simulation database. The DOE has implemented assumptions and selected input parameter values in source term calculations and the simulation model, that, cumulatively, tend to overestimate, rather than underestimate, the potential for hazardous-constituent migration. Additional features of the compliance analysis method are described in this section, including the list of hazardous constituents analyzed for the long-term demonstration, derivation of HBLs for these constituents, and the definition of the disposal unit and potential migration pathways.

8.1.1 Hazardous Constituents and Health-Based Levels

Organic and metal hazardous constituents considered for modeling in this demonstration are consistent with the RCRA Part B Permit Application for the WIPP site (DOE 1995) and Appendix VIII hazardous constituents of 40 CFR 261. Table 8-1 lists these 20 volatile organic compounds (VOCs), ten semi-volatile organic compounds (SVOCs), and 14 metal hazardous constituents. HBLs for each compound are also listed in Table 8-1.

HBLs are media-specific levels of exposure the EPA considers adequately protective of human health. Derived from experimental data and/or assigned by EPA working groups, HBLs are a measure of potential human carcinogenicity or systemic toxicity resulting from exposure to hazardous constituents. The information used to develop the HBLs in Table 8-1 is largely based on a database of health effects for organic and metal constituents maintained by the EPA; the September (1995) version of the Integrated Risk Information System (IRIS) (EPA 1995). Appendix LTHBL contains a summary of cancer slope factors (CSFs) and reference doses (RfDs) used in this analysis and describes the EPA method used to calculate the HBLs. Exceptions to the method are also identified for a subset of constituents, including the HBL for lead, which was assigned by the EPA, and the HBLs for three organic constituents temporarily withdrawn by the EPA for risk assessment review or other reasons (tetrachloroethylene, 1,1,1-trichloroethane, and trichloroethylene).

HBLs are calculated according to the EPA method outlined in Appendix E to proposed 40 CFR § 264 Subpart S (55 FR 30870). For carcinogenic chemicals in this analysis, HBLs are derived from CSFs assuming a 70-kg adult ingests contaminated soil at a rate of 0.1 g/day over a period of 70 years. For systemic toxicants, HBLs are developed from RfDs assuming that a 16-kg child (age one to six years) ingests 0.2 g of contaminated soil per day over a five-year period. Ideally, health-based compliance is demonstrated by comparing allowable HBL concentrations to predicted concentrations of hazardous constituents along potential exposure pathways at a disposal unit boundary. The DOE conservatively applies oral exposure HBLs along pathways intersecting the WIPP subsurface unit boundary at depths ranging from 820 to 2,132 ft (250 to 650 m) below the surface.

Table 8-1. Hazardous Constituents and Health-Based Levels

Constituents	Health-Based Soil Level (mg/kg)	Synonyms
Volatile Organic Compounds		
Benzene	24.1	
Bromoform	88.6	Tribromomethane
Carbon disulfide	8,000	Carbon bisulfide
Carbon tetrachloride	5.4	
Chlorobenzene	1,600	
Chloroform	114.8	
1,2-Dichloroethane	7.7	Ethylene dichloride
cis 1, 2-Dichloroethylene (ene)	ND	(Z)-1,2-Dichloroethylene
1,1-Dichloroethylene (ene)	11.7	Vinylidene chloride
Isobutanol	24,000	Isobutyl alcohol
Methyl ethyl ketone	48,000	2-Butanone
Methylene chloride	93.3	Dichloromethane
1,1,2,2-Tetrachloroethane	35.0	
Tetrachloroethylene (ene)	13.7	Perchloroethylene
Toluene	16,000	Benzene, methyl
1, 1, 1-Trichloroethane	7,200	Methyl chloroform
1, 1, 2-Trichloroethane	122.8	
Trichloroethylene (ene)	63.6	TCE
Trichlorofluoromethane	24,000	Freon-11
Vinyl chloride	ND	Chloroethylene (ene)
Semi-Volatile Organic Compounds		
Cresols (o,m,p)	4,000	Cresylic acid, Methyl phenol
ortho-Dichlorobenzene	7,200	1,2-Dichlorobenzene
1,4-Dichlorobenzene	ND	p-Dichlorobenzene
2,4-Dinitrotoluene	1.0	
2,4-Dinitrophenol	160	
Hexachlorobenzene	0.4	Perchlorobenzene
Hexachloroethane	80	
Nitrobenzene	40	
Pentachlorophenol	5.8	Chlorophene
Pyridine	80	Azabenzene, Azine
Metals		
Antimony	32	
Arsenic	4.7	
Barium	5,600	
Beryllium	1.6	
Cadmium	40	
Chromium	400	
Lead	400	
Mercury	ND	
Nickel	1600	
Selenium	400	
Silver	400	
Thallium	6.4	

ND - No health-based data available

8.1.2 Disposal Unit and Migration Pathways

Consistent with the definition in EPA's conditional no-migration determination for the WIPP facility, the long-term disposal unit is specified as the Salado Formation bounded by the 16-mi^2 (41.4-km^2) land-withdrawal area. Specifically, "any movement of constituents above "hazardous" levels into overlying or underlying formations, or beyond

the lateral boundaries of the land-withdrawal area would constitute migration" (55 FR 47704).

Modeling and bounding calculations conducted for this demonstration consider two potential migration pathways. One potential pathway is outward from the waste-disposal panels to the lateral unit boundary through anhydrite interbeds. The other potential pathway is upward through facility shafts that connect the repository to the upper disposal unit boundary (i.e., top of the Salado). Although specific migration paths are calculated during the modeling simulation, the following are features of these two general pathways:

- **Lateral Boundary -** At its closest point, the lateral boundary is located approximately 7,874 ft (2,400 m) south of the southern edge of the waste-disposal panels. Migration from the waste-disposal panels to the subsurface unit boundary could potentially occur through anhydrite interbeds (Figure 8-1). Migration is possible if the pressure increase from gas generation processes in the repository is sufficient to overcome the pressure at the subsurface unit boundary. Migration may be enhanced if the pressure increase is sufficient to initiate fracturing of anhydrite interbeds. Because Marker Bed (MB) 139 is located below the waste disposal horizon, this unit is expected to be the primary pathway for liquid-phase constituents. MB 138 and anhydrites a and b are located stratigraphically above the panels and are expected to be the principal pathway for migration of gas-phase constituents (Figure 8-1).

- **Shaft Boundary** - The upper boundary of the disposal unit is located approximately 1,305 ft (397.7 m) above the waste-disposal panels. Vertical migration of liquid-phase or gas-phase hazardous constituents up the shafts is possible if the pressure gradient between the waste-disposal panels and overlying strata causes upward flow. Lateral migration to the base of the shafts from the waste-disposal panels may occur through access drifts (and overlying and underlying disturbed rock zones (DRZs)) or through anhydrite interbeds (Figure 8-1).

8.1.3 Disposal System Conceptual Model

To define the conceptual model, the disposal system is interpreted differently than the 40 CFR § 268.6 disposal unit. The disposal system is defined as the combination of engineered and natural barriers that isolate waste within the disposal unit, or the more general features, events, and processes (FEPs) that are capable of affecting isolation of the waste and require consideration in the simulation. The Salado Formation forms the natural barrier to hazardous-constituent migration from the repository. Seal closures in shafts and boreholes form the engineered barrier system.

The conceptual model(s) of the disposal system provide(s) the framework for organizing and linking FEPs that can be simulated with quantitative models. Consistent with EPA guidance (EPA 1992, 34-35), the overall conceptual model for this demonstration is based on an uncertainty analysis of natural events, waste and facility-induced events, and

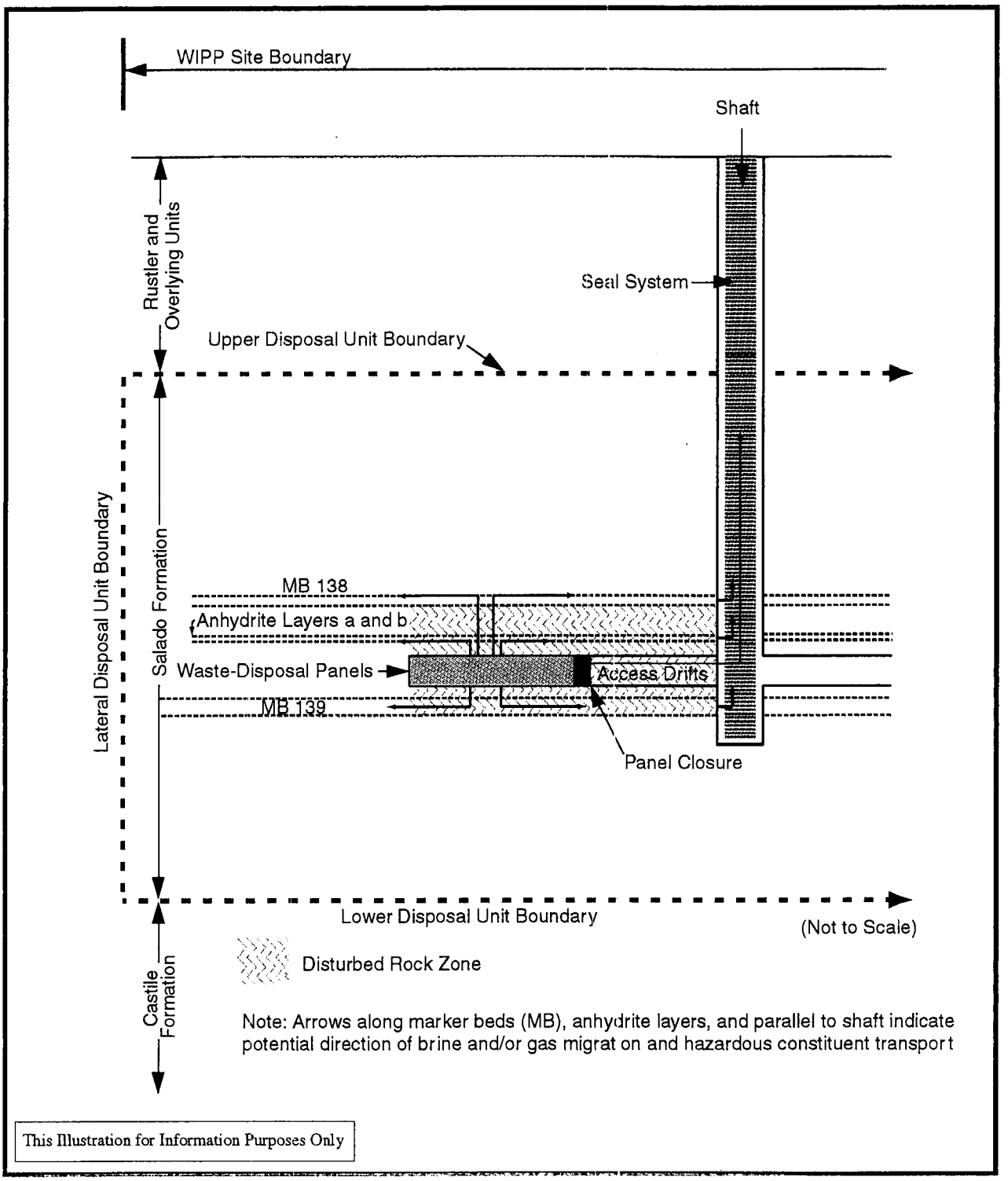

Figure 8-1. Disposal Unit and Migration Pathways - 40 CFR 268.6.

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human-induced events, including long-term disposal system features and processes. Uncertainty analysis topics and modeling issues are evaluated in detail in Appendix SCR and Appendix MASS. The following overview of the conceptual model covers some principal aspects of the disposal system considered in the brine- and gas-migration simulation.

1. **Salt creep.** Salt creep occurs naturally in Salado halite in response to deviatoric stress created by the excavation. Creep closure of the waste-disposal panels will eventually consolidate waste in the disposal areas until loading in the surrounding rock is uniform. The altered stress field created by the excavation will also result in a system of fractures surrounding the excavation, referred to as the DRZ. The DRZ is characterized by different mechanical and hydrological properties relative to intact rock beyond the DRZ. A DRZ is also assumed to develop within the Salado around shafts connecting the repository to the surface

2. **Two-phase flow—brine and gas.** Brine flow to the waste-disposal panels in response to pressure gradients created by the excavation is considered in the conceptual model. This process determines gas-generation rates and repository pressure and is important in assessing the mobility of hazardous constituents. Brine flow into the repository may decrease as repository pressure increases, and brine and gas may flow away from the repository if two key conditions are met: (1) fluid pressure in the repository exceeds fluid pressures in surrounding regions of the disposal system and (2) phase saturation conditions of brine or gas in the repository and surrounding regions of the disposal system are conducive to flow

3. **Gas-generation processes.** The conceptual model includes gas-generation processes that may result from a variety of post-closure chemical reactions, primarily those occurring between brine, metals, microbes, cellulose and similar materials (cellulosics), plastics, and rubber materials. The dominant gas-generation processes are anoxic corrosion of ferrous metals in the waste, which produces H_2, and microbial degradation of cellulosics, plastics, and rubbers in the waste, which produce CO_2 and CH_4, as well as minor amounts of N_2 and H_2S. In general, as gas pressure rises due to creep closure and gas generation, it may retard consolidation of the waste region; as gas pressure approaches lithostatic, fracturing of anhydrites beyond the DRZ may result

4. **Release mechanisms**. Conceptually, as rooms and access drifts creep closed, waste containers will be crushed and brine and waste-generated gas may fill some of the void volume in the waste disposal region. Based on prior evaluations, the DOE believes chemical conditions in the post-closure environment will rapidly become anoxic and chemically reducing. For liquid-phase hazardous constituents to be generated, sufficient brine inflow must occur to dissolve solid-phase waste constituents or serve as a media for partitioning of vapor-phase organics into the brine. Furthermore, repository conditions such as pressure, temperature, and chemical conditions (e.g., pH and Eh) must be suitable to dissolve and mobilize existing metallic hazardous constituents. Conservatively, by assuming that brine and gas are

contaminated, the conceptual model assumes instantaneous release and mobility of hazardous constituents in the gas and liquid phases

5. **Dilation/fracturing of the anhydrite interbeds**. Mass transport of hazardous constituents contained in the brine and gas phase may occur in unfractured anhydrite interbeds. However, their relatively low permeability is expected to restrict and slow migration rates. Dilation or fracturing of interbeds is capable of increasing the mass transport of hazardous constituents. Potential transport processes along this flow path include advection, diffusion, dispersion, retardation, and sieving

6. **Repository features**. The conceptual model considers a 10-panel waste-disposal area: panels 1 through 8 consist of seven disposal rooms each, while panels 9 and 10 represent the central access drifts and cross-cuts (See Figure 3-1, Chapter 3). As discussed in 8.2.3, these waste-disposal areas are distinguished for the long-term simulation as an isolated "waste panel," containing one tenth of the total disposal volume, and the "rest of repository," which includes the remaining nine tenths of the disposal volume. Panel closures in drifts accessing the waste-disposal panels are considered in the conceptual model, as are excavated drifts accessing the shafts (operations region) and the excavated experimental area north of the shafts (experimental region)

7. **Shaft Seals**. The conceptual model includes the effect of shaft seals, engineered components that are designed to restrict movement of fluids into or away from the repository. Cylindrical seals will consist of salt columns interleaved with concrete plugs, clay, and other engineered materials

8.2 Repository and Transport Models

This section discusses the repository and transport modeling system that is the basis for the brine- and gas-flow simulation. Following a brief overview of the computer codes and model geometry used to simulate brine and gas flow, the discussion focuses on major components of the conceptual model: (1) the repository (creep closure, repository fluid flow, gas generation), (2) the shaft and shaft seals, (3) the Salado Formation (impure halite, anhydrite interbeds, DRZ), and (4) geologic units above the Salado, because of their influence on fluid flow through the shafts. For each model component, this section discusses how the conceptual model is implemented and lists selected parameter values used in the analysis. Terms requiring definition for this discussion include:

- Mathematical model - describes how the conceptual model will be incorporated into the simulation, representing processes such as fluid flow, mechanical deformation, etc.

- Numerical model - provides an approximation to the solutions of mathematical models

- Computational model - implements numerical models and defines parameter values

- Model parameters - used as input to mathematical, numerical, or computational models. Model parameters are derived from a number of sources, including experimental data (See Appendix PAR, p. PAR-7)

8.2.1 Simulation Codes

Figure 8-2 illustrates the relationship between the two simulation codes used in this demonstration and the processes or particular components of the system modeled by each code. BRAGFLO (BRine And Gas FLOw) calculates the overall movement of gas and brine in the disposal unit and surrounding formations. BRAGFLO also contains the submodels for estimating gas generation in the repository, disposal room closure and consolidation, and interbed fracturing. Changes in permeability and gas storage volume of the waste resulting from creep closure are coupled to BRAGFLO through SANTOS, a code that provides a "porosity surface" used as a reference to track changes in room volume. SANTOS results are included in BRAGFLO through a series of look-up tables that provide data describing dynamic changes in porosity as a function of time and pressure.

An explanation of how the scientific codes referred to above are implemented in the no-migration simulation is provided in this section. Detailed and technical description of the BRAGFLO code can be found in Appendix BRAGFLO. The individual parameter sheets in Appendix PAR include discussions of the basis and justification for selecting the fixed-value code input parameters presented in this section.

8.2.2 Model Geometry

Models for the repository, the shaft and shaft seal, the Salado Formation, and hydrostratigraphic units above the Salado are linked by a common model geometry implemented through the BRAGFLO computer code. BRAGFLO uses a two-dimensional repository geometry to represent the three-dimensional geometry of the disposal system. Processes that affect the repository and surrounding strata, including two-phase fluid flow, gas generation, and changes in repository volume due to salt creep are simulated using a geometry that can be discussed within the context of the vertical north-south cross section through the disposal system illustrated in Figure 8-3. Material regions are denoted by different colors, and the square grid blocks discretized in the model (see Appendix BRAGFLO for details of the finite-difference method) are shown without regard to scale. Each grid block is associated with material and fluid properties representing an important feature of the disposal system, including hydrostratigraphic units overlying the Salado Formation. Overlying units are important because of their influence on undisturbed flow through the shaft system.

While effective in showing the relationship among material regions in the model and how connections are made within the finite-difference scheme, the equidimensional grid system illustrated in Figure 8-3 greatly distorts the volumetric relationship between grid blocks. To interpret the vertical distortion, note that the Δy on the vertical axis in Figure 8-3 represents the actual thickness of the grid blocks. While the grid system measures

roughly 2,950 ft (900 m) in vertical thickness, the relatively thin waste panel area appears disproportionately thick. To recognize the horizontal distortion, note that the modeling system extends approximately 29 mi (47 km) from north to south.

The top-down (plan) view of the model shown in Figure 8-4 illustrates the dimension of the grid system in the direction orthogonal (out-of-plane) to Figure 8-3. This view shows the discretization adopted to simulate radially convergent or divergent flow. Effects of flow in the third (out-of-plane) dimension are approximated with a two-dimensional element configuration that simulates radially convergent or divergent flow centered on the repository. Colors in Figure 8-4 are consistent with colors for material regions in Figures 8-3 at the repository depth (node rows 8, 9, and 10). In this text, width corresponds to the x (lateral) dimension of nodes, thickness refers to the y (vertical) dimension, and depth refers to the z (out-of-plane) dimension. The effects of the grid assumptions on fluid flow processes in the Salado are discussed in Section 8.2.5 and in Appendix MASS (Section MASS.1.1).

BRAGFLO subdivides hydrostratigraphic units at elevations near the repository horizon based on the observed differences in permeability between anhydrite-rich interbeds and halite-rich intervals. The DOE approximates the variable southerly dip in the Salado by incorporating a 1-degree dip to the south in the BRAGFLO computational mesh. This dip is not indicated in Figure 8-3.

8.2.3 The Repository

The repository is represented by regions 23-27 in Figure 8-3. Region (23) is an isolated waste-disposal panel, conceptually corresponding to either panel 4 or 5 at the southern edge of the repository. The rest of the repository (24) includes panels and access drifts comprising the remaining nine-tenths of the waste disposal region volume. The two regions are discriminated primarily for the purpose of analyzing disturbed performance of the repository, an event screened from the conceptual model in Appendix SCR (Section SCR.3.1.1). Referring to Figure 8-3, the remaining regions in the repository are panel closures (25), the operations region (26), and the experimental region at the north end of the repository (27). The four shafts connecting the repository to the surface are represented in the simulation with a single shaft, represented by regions 3-11. The lower shaft region (11) intersects the repository between the operations region and the experimental region.

For each region of the repository depicted in the BRAGFLO model, the model geometry preserves the true excavated volume. Lateral dimensions have been defined to preserve volume and retain important cross-sectional areas and distances between defined regions. Conservatively, simplifications in the model tend to overestimate the potential for brine contact with waste, which is a critical factor in determining the quantity of brine that could potentially contain hazardous constituents. Simplifications include (1) removing all pillars from panels, resulting in homogeneous waste regions through which fluid can flow directly and (2) eliminating pillars and panel closures in the rest of the repository

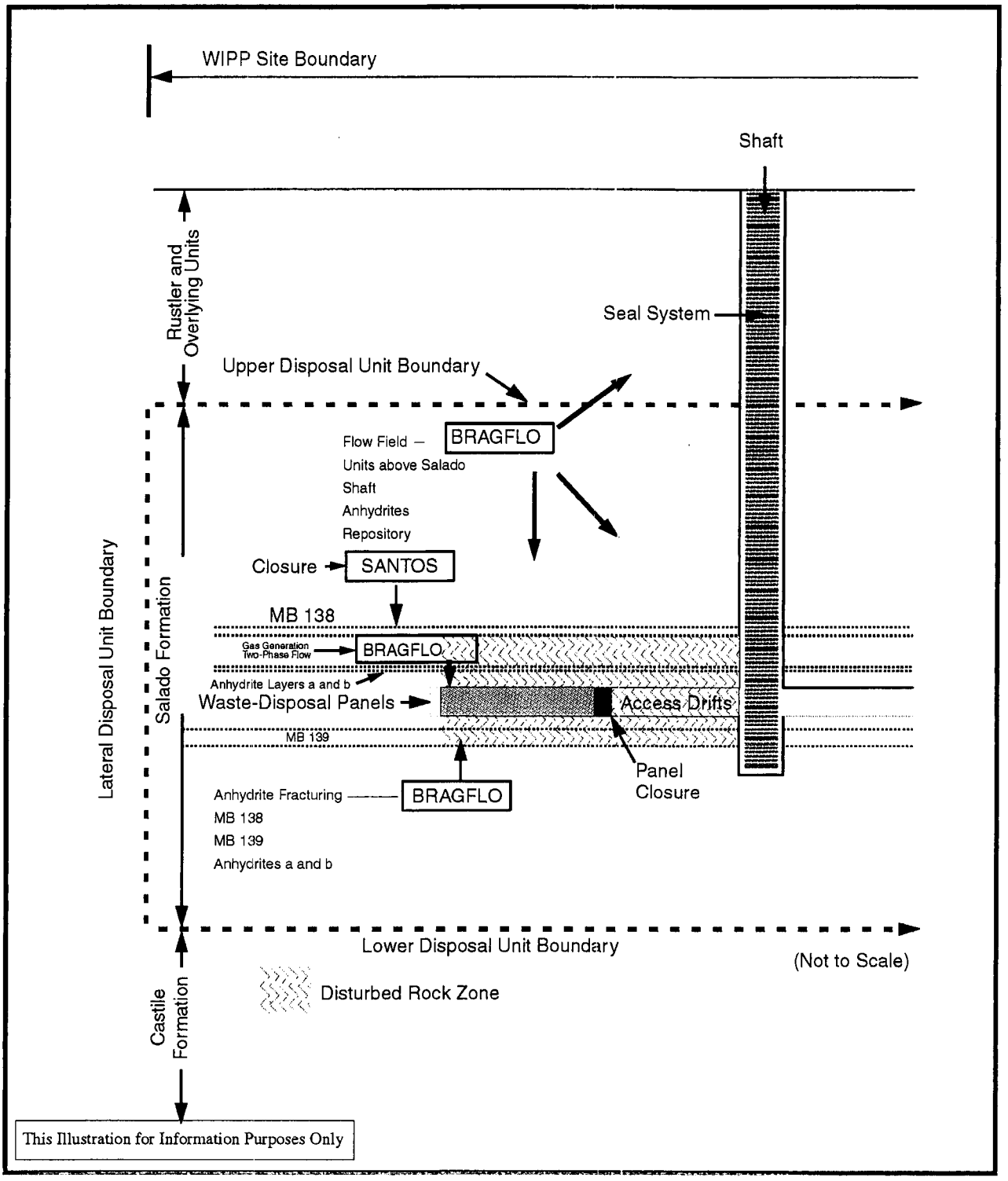

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Figure 8-2. Schematic Side View of the Disposal System Illustrating the Principal Simulation Codes Used in the No-Migration Demonstration.

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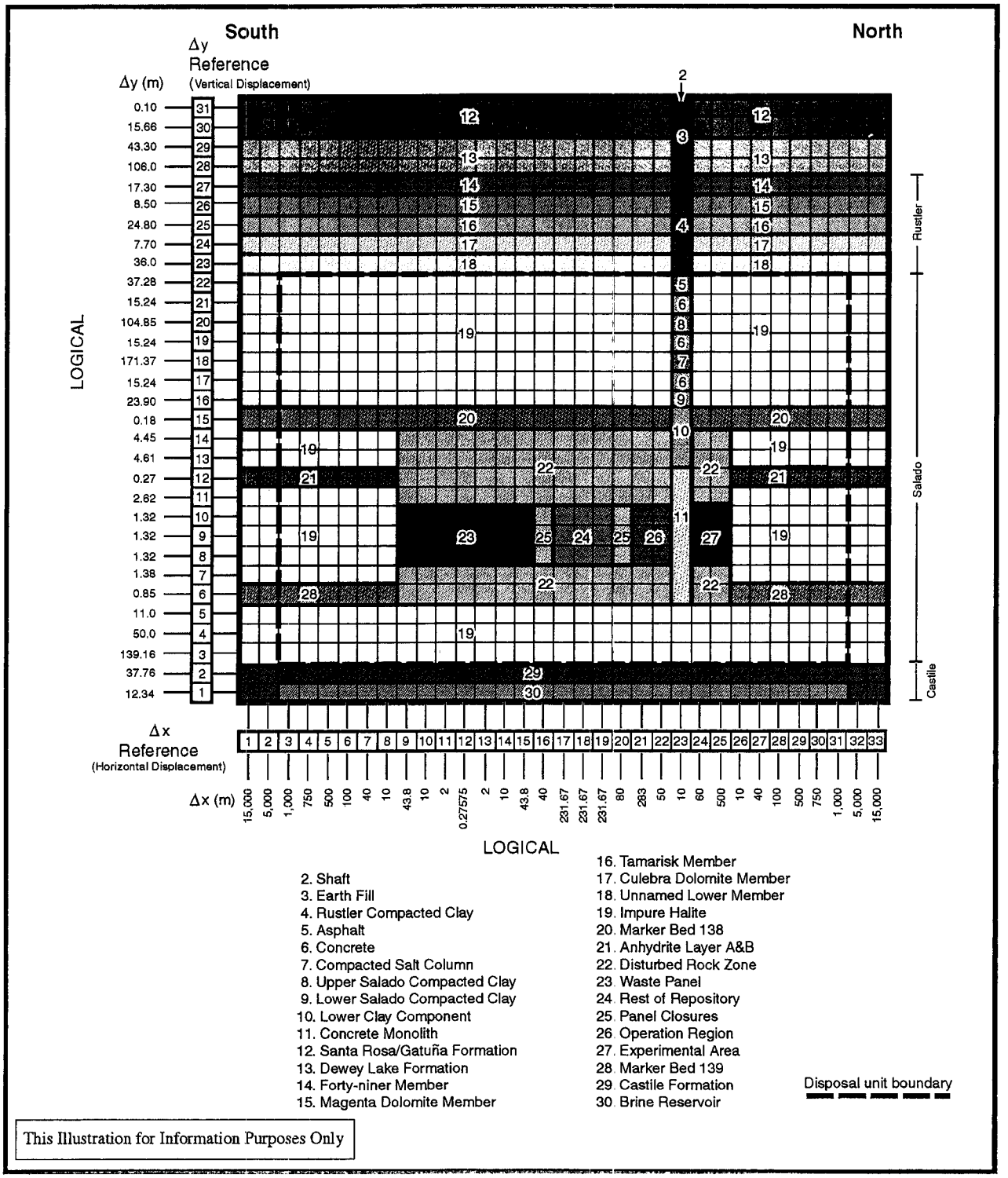

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Figure 8-3. A Side View of the BRAGFLO Elements and the Material Regions Used for No-Migration Simulation

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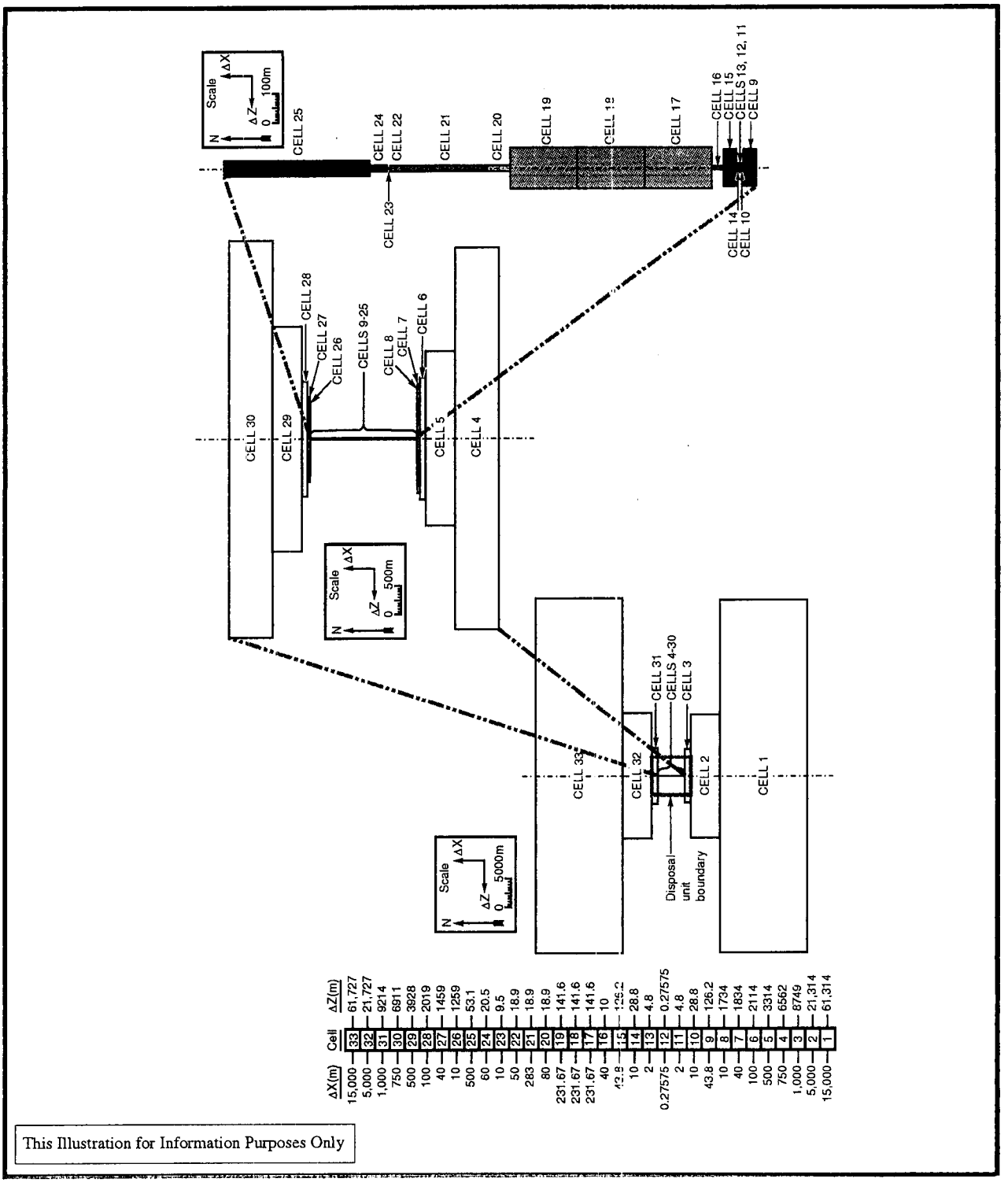

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Figure 8-4. A Top-down View of the Element Columns in BRAGFLO for the No-Migration Simulation

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(24), resulting in a very large region of homogeneous waste with assigned transmissive properties. Three submodels have been defined within the repository and are described in this section: Creep Closure (8.2.3.1), Repository Fluid Flow (8.2.3.2), and Gas Generation (8.2.3.3).

8.2.3.1 Creep Closure

Inward salt creep of rock and the repository response is generally referred to as creep closure. The amount of waste consolidation resulting from creep closure, and the time it takes to consolidate the waste, are governed by properties of the waste (waste strength), properties of the surrounding rock, the dimensions and location of the room, and the quantities and pressure of fluids present in the room. Creep closure of waste disposal areas will cause their volume to decrease as the Salado deforms to consolidate and encapsulate the waste, changing waste porosity and permeability. Waste strength and fluid pressure may act to resist creep closure.

Fluids that could affect closure are brine that may enter the repository from the Salado, air present in the repository when it is sealed, and gas produced by waste degradation. Closure and consolidation slowed by fluid pressure in the repository can be quantified according to the principle of effective stress:

$$\sigma_T = \sigma_e + p \qquad (1)$$

where σ_T is the stress caused by the weight of the overlying rock and brine (an essentially constant value), p is the pressure of the repository pore fluid, and σ_e is the stress applied to the waste skeleton or matrix. In this formulation, the waste is considered a skeleton structure immersed in pore fluids. As the pore pressure increases, an increasing amount of overburden stress is supported by pore fluid pressure, and less overburden stress is supported by the strength of the waste matrix. If gas and brine quantities in the repository stabilize, creep closure will act to establish a constant pressure and pore volume.

Two major material-response models are required for closure analyses. The first describes how the halite in the formation surrounding the waste deforms (creeps) as a function of time and stress. The second model describes the state of consolidation of the waste as a function of applied stress.

Halite deformation is predicted using a multimechanism-deformation (M-D) steady-state creep model with workhardening/recovery transient response. At the WIPP, potential creep mechanisms are governed by the temperature and shear stress at a given location at any given time. Although WIPP conditions are expected to be isothermal at the ambient natural underground temperature, all of the mechanisms can be active at the same time because of the large range of stress states that occur around underground rooms and shafts. The focus of the mechanistic part of the model is definition of steady-state creep strain, with transient creep strain described through a multiplier on the steady-state rate, thus accommodating both transient changes in stress loading and unloading. More information is presented in Munson et al. (1995, 10).

The volumetric plasticity model is the mathematical model for room closure and waste consolidation. The experimental data used in this model are summarized and interpreted in Butcher et al. (1991, 65-76) and Luker et al. (1991, 693-702). The volumetric plasticity model and M-D model are numerically implemented in the SANTOS computer code to calculate the closure of disposal rooms for the no-migration simulation.

As a boundary condition, SANTOS requires estimates of the fluid pressure and, hence, the quantity of gas present in a disposal room. These estimates are obtained using the average-stoichiometry model of gas generation (Section 8.2.3.3) with different rates of gas generation that reflect different assumptions about the quantity of brine that might be available in a waste disposal room. The different rates of gas generation used in SANTOS bound the possible conditions for gas content in the repository. With the volumetric plasticity model and the fluid pressure boundary condition, SANTOS calculates the pore volume of the disposal room through time.

In this no-migration simulation, the time-dependent effects on volume of creep closure calculated by SANTOS are linked to the fluid flow code BRAGFLO via a porosity surface (a look-up table), which relates porosity or void volume to (a) time after sealing, and (b) gas pressure. At the beginning of a time step, BRAGFLO evaluates the pressure of a cell in the waste disposal region. The code then consults the porosity surface to find the void volume of the cell appropriate for a given time and pressure. The void volume in the cell is iteratively adjusted during a time step solution for consistency with gas generation, fluid movement, and repository pressure. Additional details about the porosity surface method are included in Section 1.11 of Appendix BRAGFLO. The porosity surface method of incorporating the dynamic effect of creep closure in the simulation has been determined to be a reasonable representation of repository behavior observed in more complex models (Freeze et al. 1995, 4-2).

The operations area and experimental area (regions 26 and 27 in Figure 8-3) are modeled as unfilled after closure. In contrast to regions containing waste, these regions are expected to close in less than 200 years and do not require a porosity surface.

8.2.3.2 Repository Fluid Flow

Fluid flow modeling within the repository is concerned with two aspects of system performance: (a) fluid flow and fluid distribution in the waste, which is important for assessing gas generation rates, repository pressure, and hazardous-constituent mobility; and (b) the migration of gas and brine to and from the Salado and shafts. The permeability of waste at a given time can influence repository system performance by affecting the rate of flow of gas or brine through the waste. Tests reported by Luker et al. (1991, 693-702) on simulated waste compacted under a lithostatic load have shown material permeabilities ranging from about 10^{-12} to 10^{-16} m^2. For the NMVP simulation, the waste disposal region is assigned a constant permeability of 1.70×10^{-13} m^2. The waste disposal region is assigned an initial porosity of 84.8 percent. This porosity value is

adjusted during the simulation based on the porosity surface calculated by SANTOS to account for pressure-dependent consolidation of the waste by creep closure.

The operational region in Figure 8-3 refers to the region between the panel closures and the base of the shaft. The operational and experimental regions are assigned a constant permeability of 10^{-11} m^2 and a constant porosity of 0.18. These parameter values are intended to represent closed excavations containing no waste. The panel closure system is assigned a 10^{-15} m^2 permeability, which is equal to the permeability of the DRZ. The permeability value is constant, and is consistent with a concrete permeability specified in a time-dependent permeability range used to characterize concrete materials in the shaft (e.g., 10^{-19} $m^2 < k < 10^{-14}$ m^2).

Parameters used in the disposal room and repository flow model are shown in Table 8-2. Material properties in the waste are assumed to be homogeneous and are distributed in the BRAGFLO model in cells with volumes much larger than an individual waste container. The effects of wicking (the retention of brine in a capillary fringe), which may occur on scales smaller than the cell volumes in BRAGFLO, are included in the simulation of gas generation, as discussed in Section 8.2.3.3.

Fluid flow in the repository, shafts, and surrounding rock must be estimated using principles of multiphase flow, a result of expecting both brine and gas in the repository. Two-phase immiscible flow is analyzed in this simulation by two-phase Darcy equations incorporating capillary pressure and relative permeability. To implement these equations, BRAGFLO requires specification of two-phase characteristic curves for capillary pressure and relative permeability as a function of saturation. Experimental results (Christian-Frear 1995, 3-18) support the second modified Brooks-Corey capillary pressure model, as well as a model proposed by van-Genuchten-Parker. Both of these models are described in Section 1.9 of Appendix BRAGFLO. Since the available evidence supports use of either model, the DOE selected the second modified Brooks-Corey capillary pressure and relative permeability curves for use in this demonstration. Details about multiphase flow equations and parameters are included in Appendix BRAGFLO (Sections 1.8 and 1.9) and Appendix PAR.

8.2.3.3 Gas Generation

Gas generation affects repository pressure, which is, in turn, an important parameter in other processes modeled in the repository, such as creep closure, interbed fracture, and two-phase flow. As discussed in Appendix BRAGFLO (Section 1.13) and Wang and Brush (1996a, 1-17), this simulation uses the average-stoichiometry model to estimate the potential for gas generation in the waste disposal region. Parameter values for the average-stoichiometry gas-generation model are summarized in Table 8-3 and detailed in Appendix PAR (pp. PAR-53–PAR-82).

Gas-generation processes considered in the simulation include anoxic corrosion and microbial degradation. Radiolysis is not included in the model on the basis of laboratory

Table 8-2. Repository[a] and Panel Closures Parameter Values

Parameter (units)	Value Used in Calculation[b]
Permeability, k (m^2) - Waste and Repository Regions	1.70×10^{-13}
Permeability, k (m^2) - Operations and Experimental Regions	10^{-11}
Permeability (m^2) - Panel Closures	10^{-15}
Effective Porosity (%) - Waste and Repository Regions	84.8
Effective Porosity (%) - Operations and Experimental Regions	18.0
Effective Porosity (%) - Panel Closures	7.5
Threshold Pressure, P_t (Pa) - Repository[c]	0
Threshold Pressure, P_t (Pa) - Panel Closures	8.67×10^4
Residual Brine Saturation[d], S_{br} (unitless) - Repository	0.276
Residual Brine Saturation[d], S_{br} (unitless) - Operational and Experimental Regions	0
Residual Brine Saturation[d], S_{br} (unitless) - Panel Closures	0.20
Residual Gas Saturation[d], S_{gr} (unitless) - Repository	0.075
Residual Gas Saturation[d], S_{gr} (unitless) - Operational and Experimental Regions	0
Residual Gas Saturation[d], S_{gr} (unitless) - Panel Closures	0.20
Pore Distribution Parameter[d], λ (unitless) - Repository	2.89
Pore Distribution Parameter[d], λ (unitless) - Operational and Experimental Regions	0.7
Pore Distribution Parameter[d], λ (unitless) - Panel Closures	0.94
Maximum Capillary Pressure[d] (Pa) - Repository and Panel Closures	10^8
Rock Compressibility (1/Pa) - Repository	0
Pore Compressibility (1/Pa) - Panel Closures	2.64×10^{-9}

[a] Unless specifically listed, "Repository" refers to operations, experimental, and waste regions.
[b] Median values are based on parameter distributions identified in Appendix PAR (pp. PAR-11–PAR-52).
[c] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability (see Appendix PAR, PAR-25–PAR-32).
[d] Two-phase flow: Brooks-Corey model is used (see Appendix PAR,PAR-51–PAR-52).

experiments and model calculations that demonstrate the process to be an insignificant gas-generation mechanism compared to corrosion and biodegradation (Wang and Brush 1996a, 1-17). For the purpose of calculating repository pressure and fluid flow, the properties of the generated gas are assumed to be those of H_2.

Table 8-3. Average-Stoichiometry Gas-Generation Model Parameter Values

Parameter (units)	Values Used in Calculation[a]
Inundated Corrosion Rate for Steel without CO_2 Present (m/s)	7.94×10^{-15}
Humid Corrosion Rate for Steel	0
Anoxic Corrosion Stoichiometric Factor X (unitless)	1.0
Microbial Degradation Rate of Cellulosics Under Humid Conditions (mol/kg * s)	6.34×10^{-10}
Microbial Degradation Rate of Cellulosics under Brine-Inundated Conditions (mol/kg * s)	4.92×10^{-9}
Factor β for Microbial Reaction Rates (unitless)	0.5
Average Density of Cellulosics in CH Waste (kg/m^3)	54.0
Average Density of Cellulosics in RH Waste (kg/m^3)	17.0
Average Density of Iron-Based Materials in CH Waste (kg/m^3)	170.0
Average Density of Iron-Based Materials in RH Waste (kg/m^3)	100.0
Average Density of Plastics in CH Waste (kg/m^3)	34.0
Average Density of Plastics in RH Waste (kg/m^3)	15.0
Average Density of Rubber in CH Waste (kg/m^3)	10.0
Average Density of Rubber in RH Waste (kg/m^3)	3.3
Bulk Density of Iron Containers, CH Waste (kg/m^3)	139.0
Bulk Density of Iron Containers, RH Waste (kg/m^3)	2.59×10^3
Bulk Density of Plastic Liners, CH Waste (kg/m^3)	26.0
Bulk Density of Plastic Liners, RH Waste (kg/m^3)	3.1
Total Volume of RH Waste (m^3)	7.08×10^3
Total Volume of CH Waste (m^3)	1.69×10^5
Wicking Saturation (unitless)	0.5

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR (pp. PAR-53–PAR-82).

Specific to this simulation, anoxic corrosion of ferrous metals and microbial degradation of cellulosics, plastics, and rubbers is assumed to occur and generate gas at rates limited only by the availability of brine and solid reactant in a computational cell. Assuming that all cellulosics, plastics, and rubbers are available to degrade and participate in the gas-generation process is conservative. Biodegradation is considered to have a 50 percent chance of occurring, primarily due to uncertainties in the long-term survival of microbes (Wang and Brush 1996a, 1).

Anoxic corrosion is represented by a 'generic' equation given in Section 1.13 of Appendix BRAGFLO and Wang and Brush (1996a, 4-8) and Wang and Brush (1996b, 1). This equation accounts for the stoichiometry of H_2 generation represented by two possible anoxic steel corrosion reactions.

$$Fe + 2H_2O \rightarrow H_2 + Fe(OH)_2 \quad (2)$$

$$3Fe + 4H_2O \rightarrow 4H_2 + Fe_3O_4 \quad (3)$$

In the BRAGFLO simulation, the steel content of the repository is depleted over time separately in each cell in the computational grid (i.e., a cell-by-cell basis). Because the total quantity of aluminum and aluminum alloys is a small fraction of the quantity of iron-based metals, corrosion of aluminum is omitted for simplicity.

In the gas generation model, the effective corrosion reaction rate in a grid block is, in part, determined by two factors: the fraction of the steel in contact with brine (inundated rate) and the fraction of steel in contact with gas (humid rate). Conceptually, the two factors represent pore volume in a cell saturated with brine (S_w) and gas (S_g), where $S_w + S_g = 1$. Because gas generation from anoxic corrosion has been observed to be negligible under humid conditions (see Appendix PAR, PAR-56), the humid reaction rate is assigned a value of zero in the simulation. Consequently, gas production from anoxic corrosion is driven solely by the inundated rate, which varies linearly between brine saturation values $0 < S_w < 1$. Corrosion can continue in cells, depending on parameter values, until either all steel in a cell is consumed or brine saturation in a cell equals zero. In the simulation, brine is consumed as gas generation proceeds in each computational cell.

Effects of wicking (the retention of brine in a capillary fringe) on the corrosion gas-generation rate are incorporated in the analysis through the use of a wicking parameter. Including wicking is conservative: estimated rates of gas generation are higher for waste that is in direct contact with brine as explained in Appendix PAR (p. PAR-80). The DOE assumes no passivation of steel by CO_2 and H_2S released from biodegradation reactions, a process capable of preventing anoxic corrosion. Laboratory results suggest that CO_2 and H_2S production rates are relatively slow, and a proposed MgO chemical backfill will likely inhibit accumulation of CO_2 in the repository (Wang and Brush 1996a, 1-17; Wang and Brush 1996b, 1). Parameters in the corrosion equation are assigned fixed values, as summarized in Table 8-3.

Similar to modeling anoxic corrosion, microbial degradation is represented by a 'generic' equation, and the inventory of cellulosics, plastic, and rubber materials is also depleted on a cell-by-cell basis. Biodegradable materials are depleted at a rate dependent on the amount of brine present in a computational cell, consistent with the method used to determine the effective corrosion reaction rate. For this simulation, it is assumed that the microbial degradation process neither produces nor consumes water. Depending on parameter values, gas generation by microbial degradation can continue in a cell until all

biodegradable materials are consumed. Parameters used to model microbial degradation are summarized in Table 8-3.

8.2.4 Shafts and Shaft Seals

The four shafts connecting the repository to the surface are represented in this simulation with a single shaft, shown as regions 3 through 11 on Figure 8-3. This single shaft has a cross section and volume equal to the total cross section and volume of the four actual shafts it represents and is separated from the waste disposal region in the model by the true north-south distance from the waste to the nearest shaft (the Waste Shaft). Upon closure of the repository, the shafts will be sealed, as described in Section 3.3.2.

Seal component materials and properties used in the simulation are given in Table 8-4. From top to bottom (Figure 8-3), the seal system is represented in the simulation by the following materials:

1. an earthen fill region above the Rustler Formation (region 3)
2. a clay region in the Rustler Formation (region 4, designated Rustler Compacted Clay in Table 8-4)
3. an asphalt region at the top of the Salado (region 5)
4. three concrete sections (upper, middle, lower) within the Salado (region 6)
5. a thick section of compacted crushed salt within the Salado (region 7)
6. an upper compacted clay region within the Salado (region 8, designated Upper Salado Compacted Clay in Table 8-4)
7. a lower compacted clay region within the Salado (region 9, designated Lower Salado Compacted Clay in Table 8-4)
8. a basal clay component below MB 138 (region 10, designated Bottom Clay in Table 8-4)
9. a lower concrete section at the repository horizon (region 11, shaft station concrete monolith)

Conceptually, the simulation considers the maturation of the DRZ surrounding the shaft with respect to variation in the rate of DRZ healing with depth, time, and the type of adjacent seal material. For example, the DRZ in the halite adjacent to concrete members is assumed to heal very rapidly because of the rigidity of the concrete and the high lithostatic stress. Against less rigid seal components and at higher elevations in the shaft, the DRZ is assumed to heal more slowly. Depending on shaft material properties and depth of emplacement, the simulation also considers potential time-dependent consolidation of the shaft materials.

Table 8-4. Shaft Materials Parameter Values

Parameter (units)	Value Used in Calculation[a]
All Shaft Materials	
Residual Brine Saturation, S_{br} (unitless)[b]	0.2
Residual Gas Saturation, S_{gr} (unitless)[b]	0.2
Pore Distribution, λ (unitless)[b]	0.94
Maximum Capillary Pressure (Pa)[b]	10^8
Clay Shaft Materials	
Permeability (m^2) - Rustler Compacted Clay (T = 0 - 10,000 yrs.)	5.00×10^{-19}
Permeability (m^2) - Upper Salado Compacted Clay (T = 0 - 10 yrs.)	7.65×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T = 10 - 25 yrs.)	5.02×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T = 25 - 50 yrs.)	3.02×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T = 50 - 100 yrs.)	1.16×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T > 100 yrs.)	5.00×10^{-17}
Permeability (m^2) - Lower Salado Compacted Clay (T = 0 - 10 yrs.)	9.32×10^{-17}
Permeability (m^2) - Lower Salado Compacted Clay (T = 10 - 25 yrs.)	1.74×10^{-17}
Permeability (m^2) - Lower Salado Compacted Clay (T = 25 - 50 yrs.)	7.07×10^{-19}
Permeability (m^2) - Lower Salado Compacted Clay (T > 50 yrs.)	5.00×10^{-19}
Permeability (m^2) - Bottom Clay (T = 0 - 10,000 yrs.)	5.00×10^{-19}
Thickness (m) - Rustler Compacted Clay	94.3
Thickness (m) - Upper Salado Compacted Clay	104.85
Thickness (m) - Lower Salado Compacted Clay	23.9
Thickness (m) - Bottom Clay	9.24
Effective Porosity (%) - Rustler Compacted Clay	24.0
Effective Porosity (%) - Upper and Lower Salado Compacted Clays and Bottom Clay	24.0
Threshold Pressure P_t (Pa) - All Clays[c]	2.0×10^5 to 1.20×10^6
Pore-Volume Compressibility (1/Pa) - Rustler Compacted Clay	1.96×10^{-9}
Pore-Volume Compressibility (1/Pa) - Upper Salado Compacted Clay	1.81×10^{-9}
Pore-Volume Compressibility (1/Pa) - Lower Salado Compacted Clay and Bottom Clay	1.59×10^{-9}
Salt Shaft Material	
Permeability (m^2) - Salt (T = 0 - 10 yrs.)	1.74×10^{-15}
Permeability (m^2) - Salt (T = 10 - 25 yrs.)	1.66×10^{-15}
Permeability (m^2) - Salt (T = 25 - 50 yrs.)	1.65×10^{-15}
Permeability (m^2) - Salt (T = 50 - 100 yrs.)	6.83×10^{-18}
Permeability (m^2) - Salt (T = 100 - 200 yrs.)	5.27×10^{-20}
Permeability (m^2) - Salt (T > 200 yrs.)	5.35×10^{-21}
Thickness (m) - Salt	171.37

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR (pp. PAR-83–PAR-156).

[b] Two-phase flow: Brooks-Corey model is used in this simulation (see Appendix PAR, PAR-51).

[c] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.

Table 8-4. Shaft Materials Parameter Values (continued)

Parameter (units)	Value Used in Calculation[a]
Effective Porosity (%) - Salt	5.00
Threshold Pressure P_t (Pa) - Salt (T = 0 - 10 yrs.)[c]	7.16×10^4
Threshold Pressure P_t (Pa) - Salt (T = 10 - 25 yrs.)[c]	7.28×10^4
Threshold Pressure P_t (Pa) - Salt (T = 25 - 50 yrs.)[c]	7.29×10^4
Threshold Pressure P_t (Pa) - Salt (T = 50 - 100 yrs.)[c]	4.87×10^5
Threshold Pressure P_t (Pa) - Salt (T = 100 - 200 yrs.)[c]	2.62×10^6
Threshold Pressure P_t (Pa) - Salt (T > 200 yrs.)[c]	5.78×10^6
Pore-Volume Compressibility (1/Pa) - Salt	1.60×10^{-9}
Concrete Shaft Materials	
Permeability (m^2) - Concrete (T = 0 - 400 yrs.)	1.78×10^{-19}
Permeability (m^2) - Concrete (T > 400 yrs.) and Concrete Monolith (T = 0 - 10,000 yrs.)	10^{-14}
Thickness (m) - Concrete	45.72
Thickness (m) - Concrete Monolith	9.08
Effective Porosity (%)	5.00
Threshold Pressure P_t (Pa) - Concrete (T = 0 - 400 yrs.)[c]	1.72×10^6
Threshold Pressure P_t (Pa) - Concrete (T > 400 yrs.)[c] and Concrete Monolith (T = 0 - 10,000 yrs.)[c]	3.91×10^4
Pore-Volume Compressibility (1/Pa) - Concrete and Concrete Monolith	2.64×10^{-9}
Asphalt Shaft Material	
Permeability (m^2) - (T = 0 - 10,000 yrs.)	6.76×10^{-17}
Thickness (m)	37.28
Effective Porosity (%)	1.00
Threshold Pressure P_t (Pa)[c]	0.00
Pore-Volume Compressibility (1/Pa)	2.97×10^{-8}
Earthen Fill Material Above Rustler	
Permeability (m^2) (T = 0 - 10,000 yrs.)	10^{-14}
Thickness (m)	165.06
Effective Porosity (%)	32.0
Threshold Pressure P_t (Pa)[c]	3.91×10^4
Maximum Capillary Pressure (Pa)	10^8
Pore-Volume Compressibility (1/Pa)	3.1×10^{-8}

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR (pp. PAR-83–PAR-156).

[b] Two-phase flow: Brooks-Corey model is used in this simulation (see Appendix PAR, PAR-51).

[c] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.

To reflect shaft material consolidation and DRZ maturation, effective permeabilities of selected shaft regions are adjusted with time in the BRAGFLO simulation in a stepwise fashion (Table 8-4). Enhanced flow expected through the surrounding DRZ before healing occurs is modeled by increasing the permeability of the adjacent shaft component. In some cases, this adjustment counteracts the expected decrease in permeability resulting from consolidation. The increase in permeability noted for concrete from 1.78×10^{-19} to 10^{-14} m^2 is conservative: the permeability of concrete within the Salado Formation is not expected to degrade to the permeability of silty sand, and, in fact, physical and hydraulic properties of concrete seals are expected to remain stable over the long term. Note that Appendix PAR (p. PAR-83) lists only the initial permeability for asphalt, salt, and clay shaft materials within the Salado and not the effective permeabilities calculated for BRAGFLO for each time step presented in Table 8-4.

8.2.5 The Salado Formation

Fluid flow in the Salado under natural conditions is minimal or nonexistent (see Section 2.2). Excavation of the repository alters natural pressure gradients in the Salado, creating the potential for fluid flow. Fluid flow, gas generation, and volume changes due to creep closure may cause changes in pressure gradients through time. Salt creep, as well as possible fracturing due to high repository pressure, alters the permeability and other flow properties of the rock near the repository. Depending on the pressure gradient and creep altered material properties, gas and brine flow may be enhanced in affected portions of the Salado relative to fluid flow under natural conditions.

For this demonstration, the DOE conceptualizes the Salado as a porous medium composed of several rock types arranged in layers, through which fluid flow occurs according to Darcy's Law (Appendix BRAGFLO, 1-9). Two rock types, impure halite and anhydrite, are used to represent the intact Salado. The simulation assumes spatially constant properties for Salado rock types based on observations of compositional and structural regularity in layers exposed by the repository. The inference is that there is little variation in large-scale averages of rock or flow properties across the disposal system. Near the repository, the DRZ has increased permeability compared to intact rock and offers little resistance to flow between anhydrite interbeds and the repository.

Except for anhydrite interbeds, model parameters are also spatially invariant within each material region. At relatively low repository pressures, porosities of all Salado materials vary slightly; however, for interbeds, the model implemented to simulate the effects of interbed fracturing causes large increases in both porosity and permeability above a designated fracture initiation pressure. Details of the fracture approximation model are provided in Section 8.2.5.2, and assumptions about Salado flow in general are presented in Appendix MASS (Sections MASS.1.1, MASS.1.2, and MASS.1.3). Specific information about the major rock types used in the model is presented in following sections.

8.2.5.1 Impure Halite

For the NMVP simulation, rock and hydraulic properties of impure halite are assigned in BRAGFLO to areas of the Salado represented by intact, pure halite, argillaceous halite, and polyhalite, including minor anhydrite and clay interbeds. A comparison between the simplified stratigraphy used in this simulation model and a model with a more detailed stratigraphy in the vicinity of the repository is identified by reference in Appendix MASS (Section MASS.1.6). The model comparison identified in Appendix MASS supports the stratigraphic representation used for this simulation.

Table 8-5 shows various parameter values used in modeling the impure halite. Supported by four hydraulic tests in the underground repository believed to represent far-field conditions and stratigraphic variation in the Salado, the median value for permeability calculated for this region is 3.16×10^{-23} m^2. Additional information on parameter values is contained in Appendix PAR (pp. PAR-157—PAR-182), including the distinction between rock compressibility and pore compressibility in the simulation.

Gas may not be able to flow through or into intact, halite-rich strata of the Salado under realistic conditions for the repository. As halite is modeled as 100 percent brine-saturated, the capillary resistance of the rock must be overcome to displace brine from pores and drive gas into the rock. This describes the concept of threshold pressure. An

Table 8-5. Salado Formation Halite Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	3.16×10^{-23}
Effective Porosity (%)	1.0
Threshold Pressure, P_t (Pa)[b]	3.41×10^{7}
Residual Brine Saturation, S_{br} (unitless)[c]	0.3
Residual Gas Saturation, S_{gr} (unitless)[c]	0.2
Pore Distribution, λ (unitless)[c]	0.7
Maximum Capillary Pressure (Pa)	10^{8}
Rock Compressibility[d] (1/Pa)	9.75×10^{-11}
Initial Pressure (Pa)	12.5×10^{6}

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR (pp. PAR-157–PAR-182).
[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$ where PCT_A and PCT_EXP are constants and k is the permeability.
[c] Two-phase flow: Brooks-Corey model used in this simulation (see Appendix PAR, PAR-51).
[d] Pore compressibility = Rock compressibility/effective porosity.

empirical relationship between threshold pressure and permeability in non-WIPP rocks (Davies 1991, 17–19) suggests that threshold pressure will be sufficiently high that gas will not be able to flow into the halite-rich strata of the Salado under any conditions foreseeable for the WIPP (See Appendix MASS, Section MASS.1.7). Values used by the DOE for impure halite threshold pressure are set to prevent the flow of gas into this material. This is a conservative assumption, because gas flow into impure or pure halite would decrease the pressure in the repository and the driving force available for flow elsewhere.

8.2.5.2 Salado Interbeds

Three distinct anhydrite interbeds are modeled in this BRAGFLO simulation representing MB 138 (region 20), anhydrite layers a and b (region 21), and MB 139 (region 28). The three interbeds are assigned the same parameter values, and the parameters are initially spatially constant. Porosity and permeability can vary spatially during a simulation depending on interbed fracturing. The interbeds in the model differ only in stratigraphic location and thickness and are included because they exist in the disturbed region around the repository where fluid is expected to be able to flow with relative ease compared to the surrounding formation. MB 139 and anhydrite layers a and b are present within the DRZ that forms around excavations; MB 138 may be above the DRZ, but is below the long-term seal components that will be constructed in the shafts. MB 138 is included because of uncertainty in the long-term isolation of MB 138 from the repository.

In BRAGFLO, brine flows between the Salado and the repository in response to fluid potential gradients that may form over time. Due to the low permeability of the impure halite and relatively small surface area involved, direct brine flow between the impure halite and the repository is limited. The interbeds included in the BRAGFLO model of the Salado (regions 20, 21, and 28), however, can serve as conduits for brine flow between the impure halite and the repository. Conceptually, brine flows laterally along higher-permeability interbeds towards or away from the repository and vertically between the interbeds and the lower-permeability halite. Because the interbeds have a very large contact area with adjacent halite-rich rock, even very small flux from the halite into the interbeds (for brine inflow) or to the halite from the interbeds (for brine outflow) can accumulate into a significant quantity of brine. In this manner, halite serves as a source or sink for brine in the repository. It is expected that, due to density differences between gas and brine and their resulting stratification within the repository, brine outflow will occur in MB 139, and gas outflow will occur in anhydrite layers a and b or MB 138. However, the model does not preclude other flow patterns. Parameters associated with the interbeds are shown in Table 8-6.

Interbeds contain natural fractures that may be partially healed. If high pressure develops in an interbed, its preexisting fractures may dilate, or new fractures may form, altering its porosity and permeability. Pressure-dependent changes in permeability are supported by experiments conducted in the underground repository and in the laboratory. Accordingly, the DOE has implemented in BRAGFLO a porous-media model of interbed dilation and fracturing that causes the porosity and permeability of a computational cell in an interbed

Table 8-6. Salado Formation Anhydrite Layers a and b and Marker Beds 138 and 139 Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	1.29×10^{-19}
Effective Porosity (%)	1.1
Threshold Pressure, P_t (Pa)[b]	9.74×10^5
Residual Brine Saturation, S_{br} (unitless)[c]	0.084
Residual Gas Saturation, S_{gr} (unitless)[c]	0.077
Pore Distribution, λ (unitless)[c]	0.644
Maximum Capillary Pressure (Pa)	10^8
Rock Compressibility[d] (1/Pa)	8.26×10^{-11}

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR (pp. PAR-183–PAR-204).
[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.
[c] Two-phase flow: Brooks-Corey model used for all simulation (see Appendix PAR, PAR-51).
[d] Pore compressibility = Rock compressibility/effective porosity.

to increase as its pore pressure rises above a designated value (Appendix PAR, PAR-205–PAR-212). The threshold pressure of dilated or fractured interbeds is expected to decrease with increasing fracture aperture. Thus, fluid is expected to be able to flow outward readily if adequate pressure is available to initiate and sustain dilation of the interbeds.

There is a trade-off between the effects of permeability and porosity enhancements. Dilation or fracturing of interbeds is expected to increase the transmissivity of interbed intervals. Increased porosity will increase storage, which will retard outward flow.

The model used to implement the effects of interbed dilation is explained in detail in Appendix BRAGFLO (Section 1.10). In summary, it assigns a fracture initiation pressure above which local fracturing takes place, and changes in permeability and porosity occur above this pressure. Below this fracture initiation pressure, an interbed has constant permeability and compressibility. For the small, constant value of compressibility used initially, changes in porosity with pressure are extremely small. Above the fracture initiation pressure, the local compressibility of the interbed is assumed to increase linearly with pressure. This greatly increases the rate at which porosity increases with increasing pore pressure. Additionally, permeability increases by a power function of the ratio of altered porosity to initial porosity. This formulation results in large increases in permeability for modest increases in porosity. For numerical reasons (i.e., to prevent unbounded changes in parameter values), a pressure is specified above which porosity and permeability change no further. The maximum porosity is the sum of the incremental

porosity in Table 8-7 and the effective porosity listed in Table 8-6. Incremental porosities are 3.9 percent for MB139 and MB138, and 23.9 percent for anhydrite layers a and b.

In situ and laboratory evidence, summarized in Appendix PAR (pp. PAR-192–PAR-195), suggests that if the threshold pressure of interbeds is low enough, waste-generated gas may be able to move through intact interbeds at pressures expected within the disposal system. The threshold pressure used in this simulation (9.74×10^5 Pa) for intact interbeds is sufficiently low to allow gas migration.

Table 8-7 lists parameters used in the model of interbed dilation and fracture. Additional information about interbed parameters is included in Appendix PAR (pp. PAR-205–PAR-212).

8.2.5.3 Disturbed Rock Zone

As discussed in Chapter 3, in the DRZ near the repository, permeability and porosity are expected to generally increase. The increases in permeability and porosity in interbeds are not expected to be completely reversible with creep closure of the disposal rooms, and healing of the halite may not completely eliminate pathways between the interbeds and the disposal region. The increase in DRZ permeability increases the ability of fluid to flow from interbeds to the waste disposal region. The increase in DRZ porosity provides a volume in which some fluid could be retained so that it does not contact waste. DRZ pore volume can also slow hazardous-constituent migration.

This simulation conservatively approximates the effects of the DRZ with respect to brine flow to the repository. The permeability of the region around the repository is increased relative to intact Salado rock for the duration of the simulation and the threshold pressure is set to zero. Acting to prevent fluid retention in the DRZ, DRZ porosity is purposely assigned a value similar to that of intact Salado materials. The DRZ extends above and below the repository from the base of MB 138 to MB 139. Defining the DRZ in this

Table 8-7. Salado Formation Anhydrite Layers a and b and Marker Beds 138 and 139 Fracture Parameter Values

Parameter (units)	Value Used in Calculation[a]
Fracture Initiation Pressure at MB139, base of shaft (Pa)	12.7×10^6
Increment to give Full Fracture Porosity (%), MB139 and MB138	3.9
Increment to give Full Fracture Porosity (%), anhydrite layers a and b	23.9
Maximum Permeability (m^2)	10^{-9}
Increment above Fracture Initiation Pressure to Obtain Max. Fracture Pressure (Pa)	3.8×10^6

[a] All above values are constant.

manner creates a permanent high-permeability region that does not significantly impede flow between the repository and interbeds. Table 8-8 shows parameter values used in the representation of the DRZ.

8.2.6 Units Above Salado Formation

Geologic formations above the Salado include, in ascending order, the following: (1) the Rustler, consisting of an unnamed lower member, and the Culebra, Tamarisk, Magenta and Forty-Niner members; (2) the Dewey Lake; (3) the Santa Rosa; and (4) the Gatuña. Geologic units above the Salado influence the direction and magnitude of fluid flow through the shafts by contributing to the pressure gradient between the waste-disposal panels and the rest of the disposal system.

BRAGFLO considers the Culebra and Magenta members of the Rustler Formation, and Supra-Rustler units (the Dewey Lake, Santa Rosa, and Gatuña Formations). The other three Rustler members are modeled as effectively impermeable. These units are represented in the BRAGFLO element mesh (Figure 8-3) by regions 14, 16, and 18. For modeling purposes, Gatuña and Santa Rosa Formation model parameters are combined and reported in the Santa Rosa Formation parameter table. BRAGFLO discretizes and calculates flow in these units to establish the pressure gradient in the disposal system. Parameter values for relevant non-Salado units are summarized in Tables 8-9, 8-10, 8-11, and 8-12, and described in more detail in Appendix PAR (pp. PAR-229–PAR-295).

Table 8-8. Disturbed Rock Zone Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	10^{-15}
Effective Porosity (%)	1.29
Threshold Pressure, P_t (Pa)[b]	0
Residual Brine Saturation, S_{br} (unitless)[c]	0
Residual Gas Saturation, S_{gr} (unitless)[c]	0
Pore Distribution, λ (unitless)[c]	0.7
Maximum Capillary Pressure (Pa)	10^8
Rock Compressibility (1/Pa)[d]	7.41×10^{-10}

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR (pp. PAR-213–PAR-228).

[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.

[c] Two-phase flow: Brooks-Corey model used in this simulation (see Appendix PAR, PAR-51).

[d] Pore compressibility = Rock compressibility/effective porosity.

Table 8-9. Culebra Member of the Rustler Formation Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	2.10×10^{-14}
Effective Porosity (%)	15.1
Threshold Pressure, P_t (Pa)[b]	1.50×10^4
Residual Brine Saturation, S_{br} (unitless)[c]	0.084
Residual Gas Saturation, S_{gr} (unitless)[c]	0.077
Pore Distribution, λ (unitless)[c]	0.644
Maximum Capillary Pressure (Pa)	10^8
Rock Compressibility (1/Pa)	10^{-10}
Thickness (m)	7.7
Initial Pressure (Pa)[d]	8.22×10^5

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR.
[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{(PCT\_EXP)}$, where PCT_A and PCT_EXP are constants and k is the permeability.
[c] Two-phase flow: Brooks-Corey model used in simulation (see Appendix PAR, PAR-51).
[d] Pore compressibility = Rock compressibility/effective porosity

Table 8-10. Magenta Member of the Rustler Formation Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	6.3×10^{-16}
Effective Porosity (%)	13.8
Threshold Pressure, P_t (Pa)[b]	5.1×10^4
Residual Brine Saturation, S_{br} (unitless)[c]	0.084
Residual Gas Saturation, S_{gr} (unitless)[c]	0.077
Pore Distribution, λ (unitless)[c]	0.644
Maximum Capillary Pressure (Pa)	10^8
Rock Compressibility (1/Pa)[d]	2.64×10^{-10}
Thickness (m)	8.5
Initial Pressure (Pa)	9.17×10^5

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR.
[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.
[c] Two-phase flow: Brooks-Corey model used in this simulation (see Appendix PAR, PAR-51).
[d] Pore compressibility = Rock compressibility/effective porosity

Table 8-11. Dewey Lake Formation Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	5.0×10^{-17}
Effective Porosity (%)	14.3
Threshold Pressure, P_t (Pa)[b]	1.22×10^5
Residual Brine Saturation, S_{br} (unitless)[c]	0.084
Residual Gas Saturation, S_{gr} (unitless)[c]	0.077
Pore Distribution, λ (unitless)[c]	0.644
Maximum Capillary Pressure (Pa)	10^8
Rock Compressibility (1/Pa)[d]	10^{-8}
Thickness (m)	149.3
Initial Pressure	hydrostatic, water table at 980 m, 43.3 m below top of formation
Initial Pressure (atm) 8.4% Residual Liquid Saturation, Above Water Table	1

a Median values were used based on the data and parameter distributions contained in Appendix PAR.
b Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.
c Two-phase flow: Brooks-Corey model used in this simulation (see Appendix PAR, PAR-51).
d Pore compressibility = Rock compressibility/effective porosity

8.2.7 Hazardous-Constituent Migration

BRAGFLO simulations do not directly differentiate between cumulative brine flow and migration of brine potentially containing hazardous constituents. Brine flow modeled by BRAGFLO may include brine originally contained in the Salado. To address this modeling issue, the DOE assumes that brine containing hazardous constituents must originate within the waste disposal region. Depending on the BRAGFLO results, this assumption presents two compliance alternatives: 1) model the transport of brine from the waste region into the Salado or shaft system using a constituent transport code or 2) show that brine is immobile in the waste region. The mobility of brine in the waste region is determined by two-phase flow processes explicitly incorporated into the BRAGFLO code.

8.2.8 Boundary and Initial Conditions for Repository and Transport Modeling

The start of the long-term simulation occurs when the shaft seals are emplaced and the waste is isolated. Initial pressure and liquid saturation conditions are defined for each computational grid block. Assuming hydrostatic equilibrium, initial pressures in the Salado (interbeds, DRZ, etc.), as well as shaft components within the Salado, are

Table 8-12. Santa Rosa Formation Parameter Values

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	10^{-10}
Effective Porosity (%)	17.5
Threshold Pressure, P_t (Pa)[b]	0
Residual Brine Saturation, S_{br} (unitless)[c]	0.084
Residual Gas Saturation, S_{gr} (unitless)[c]	0.077
Pore Distribution, λ (unitless)[c]	0.644
Maximum Capillary Pressure (Pa)	10^8
Rock Compressibility (1/Pa)[d]	10^{-8}
Thickness (m)	15.76
Initial Pressure (atm) 8.36% Residual Liquid Saturation	1

[a] Median values were used based on the data and parameter distributions contained in Appendix PAR.
[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$, where PCT_A and PCT_EXP are constants and k is the permeability.
[c] Two-phase flow: Brooks-Corey model used in simulation (see Appendix PAR, PAR-51).
[d] Pore compressibility = Rock compressibility/effective porosity

calculated based on the elevation difference and change in hydraulic head relative to an initial pressure specified at the repository horizon. The initial pressure is specified as 12.5 MPa at a point in the Salado halite (Appendix PAR, PAR-180). With exception of the Culebra and Magenta members, initial pressures in non-Salado units are calculated based on a hydrostatic pressure gradient established by a water table elevation of 3,215 ft (980 m) above mean seal level. For ground surface grid blocks and regions above the water table, initial pressures are specified as atmospheric (0.101 MPa)

8.2.8.1 Salado Rock Types and DRZ Initial Conditions

Initial conditions for the BRAGFLO model specify no gradient for flow in the Salado. Porosity in Salado lithologic units is initially 100 percent liquid-saturated.

To set the near-repository, partially-drained DRZ initial condition for the long-term simulation, a five-year simulation is executed prior to the long-term modeling. This simulation is configured to allow partial desaturation of the DRZ, consistent with removal of brine through the ventilation system during disposal operations. DRZ permeability is set at 10^{-17} m^2 for the time period -5 to 0 yrs. Permeability in the DRZ is assigned a constant value of 10^{-15} m^2 for the 10,000-year simulation; porosity is assumed to be as low as intact Salado to reduce storage volume.

8.2.8.2 Waste/Disposal Region Initial Conditions

The simulation assumes that individual waste panels remain open for five years, allowing for waste emplacement. Consequently, an initial period of five years is used to account for depressurization around the excavated regions; this corresponds to an assigned time period of -5 to 0 years. Pressure for the five years before time zero in the excavated region is maintained at atmospheric. Waste materials are emplaced at time zero years (t = 0). At time zero, the waste is placed at a liquid saturation of 0.015 and a pressure of one atmosphere. The remaining excavations outside the waste disposal area are assigned a gas saturation of 100 percent and an initial pressure of one atmosphere. Corrosion and/or biodegradation reactions that produce gas are modeled to begin at t = 0 years. The concentrations of ferrous metals and biodegradables in the waste regions are assigned initial parameter values of 10.2 lb/ft^3 and 4.07 lb/ft^3 (163 and 65.2 kg/m^3), respectively.

8.2.8.3 Units Above the Salado

For the time period -5 to 0 years, all regions above the Salado are treated as impermeable to prevent water from draining into the shaft. Conceptually, this corresponds to the existence of effective liners in the shafts during disposal operations.

No-flow boundary conditions are assigned along all of the exterior boundaries of the computational mesh except at the far field boundaries of the Culebra and Magenta members and the top of the grid (i.e., the ground surface). The boundaries of the Culebra and Magenta members are maintained at initial pressures of 0.822 MPa and 0.917 MPa, respectively. Pressure in the saturated zone below the water table in the Dewey Lake Formation is maintained with respect to the water table elevation 194 ft (59 m) below the ground surface. Unsaturated regions above the water table are maintained at one atmosphere (0.101 MPa) and held constant at a liquid saturation equal to the residual saturation (8.4 percent).

8.2.8.4 Shaft Initial Conditions

Initial conditions in the shaft are defined beginning with their emplacement at t = 0 years. Initial pressures in the earthen fill and Rustler Compacted Clay shaft regions are held constant at the initial pressure of one atmosphere (0.101 MPa). Pressures in the asphalt, concrete, compacted salt and clay regions below the non-Salado units are calculated assuming a hydrostatic pressure gradient relative to the 12.5 MPa far-field pressure assigned to the Salado halite at the repository horizon. Initial liquid saturations of shaft materials are earthen fill 0.20, concrete 1.0, all clays 0.79, salt 0.32, and asphalt 0.0 percent.

8.3 Hazardous-Constituent Source Term and Mobility

The source term can be thought of as the quantity of hazardous constituents available for transport. Actual quantities available for transport are controlled by both the waste form and by constituent mobility or immobility in the post-closure environment. Mobility is,

in turn, controlled by long-term physical and chemical processes (e.g., availability of transport media and release mechanisms). Given these constraints, this no-migration demonstration defines the organic hazardous-constituent source term for the gas phase in terms of concentration. This section presents the organic gas-phase source term conceptual model, including underlying assumptions, equations, and parameter values used to calculate the source term. The DOE presents several implicit assumptions related to demonstrating no-migration for liquid-phase hazardous constituents, but believes that explicitly defining a source term for liquid-phase hazardous constituents is inappropriate, given the available information.

8.3.1 Source-Term Conceptual Model

Transuranic waste is packaged at the generator sites in a primary-confinement barrier (i.e., metal drum or container). The packaging may include several internal barriers: layers of plastic; plastic, metal, and glass containers; and adsorbents in the void spaces. VOCs and SVOCs are present within solidified liquids and sludges and in trace quantities sorbed onto cellulosics and other solid waste materials. A VOC gas/vapor phase occurs within drum headspaces, voids within the drum, and within inner layers of confinement. Hazardous-constituent metals will also exist in the solid phase. The primary hazardous metal constituent in the waste is lead in leaded rubber gloves and shielding. Other regulated metals may occur in trace concentrations in soil, debris, sludges, solidified liquids, and as metals used in tools, equipment, and machinery. The WIPP Waste Acceptance Criteria (WAC) and other DOE efforts are designed to preclude the presence of free liquids; therefore, a significant initial liquid phase is not a feature of the conceptual model. Conceptually, the hazardous-constituent, liquid-phase results from brine inflow and waste dissolution in the closed repository.

As presented in the uncertainty analyses in Appendix SCR, the DOE considered the potential effects of a number of possible chemical and thermal processes in the disposal room environment. Some of these processes serve to immobilize hazardous constituents, while others serve to enhance mobility. When information is limited, conservative assumptions are made to overestimate the source term or hazardous-constituent mobility.

A number of assumptions are presented in this section to summarize the source-term conceptual model. Assumptions related to using bounding calculations as a measure of gas-phase compliance, and to aid conceptualization of liquid-phase hazardous constituents, include:

1. Hazardous constituents are immediately mobile in the gas and liquid phase at repository closure (conservative assumption: the pressure, temperature, and chemical conditions, e.g., pH and Eh, may not be suitable to completely dissolve and mobilize regulated metals, and time-dependent mechanisms would decrease the initial source-term concentrations for organic and metal constituents)

2. Hazardous constituents exist in the gas and brine phase in the waste-disposal panels at constant concentration over time (conservative assumption: assumes an infinite

source and complete persistence; some metals and organics will migrate from the source-term region and organics will likely degrade)

3. Migration of hazardous constituents from the repository does not decrease the initial source-term concentration (conservative assumption of an infinite source term: in reality, some hazardous constituents will migrate away from the waste-disposal panels and the source term should decrease with time)

4. Initial VOC concentrations in the gas phase are calculated from average concentrations from headspace measurements weighted by the waste inventory (reasonable assumption: see Chapter 4)

5. Initial headspace-derived VOC concentrations in the gas phase are applied to the initial waste disposal region volume to derive an initial mass of VOCs. This mass is distributed over the final waste disposal region void volume calculated at the end of the 10,000-year BRAGFLO simulation (conservative assumption: constant source term gas-phase densities are based on the void volume of the final consolidation state. This overestimates the VOC source term over the entire modeling period)

6. Transformations and biodegradation of organic constituents are not modeled, because of uncertainty in comparing terrestrial and site/condition specific degradation rates (conservative assumption: organic source term will likely be depleted by the same processes assumed to occur for microbial gas generation; despite uncertainty, typical organic half-lives range from 10s to 1,000s of days, orders of magnitude less than the 10,000-year compliance period—see Table SCR-3 in Appendix SCR)

7. An ambient temperature of about 300 K (27°C) in the repository precludes thermal desorption of organics sorbed to waste forms. Heat generation mechanisms from radioactive decay and other processes are inconsequential (reasonable assumption: see Section SCR.2.2.5)

8. Post-closure release mechanisms capable of elevating VOC concentrations in the repository above headspace concentrations are inconsequential (reasonable assumption: see Section SCR.2.2.5)

9. VOCs for which headspace data are not available are assumed to be present in sufficient quantities to saturate and maintain saturation of the gas phase (conservative assumption: available headspace data suggest that typical VOC concentrations are up to two orders of magnitude below saturation levels)

10. For the gas-phase hazardous-constituent source term, partitioning between the liquid and gas phases is not explicitly included in the analyses (conservative assumption: assumption maximizes hazardous-constituent concentrations for the gas-phase source term - see Section SCR.2.4.1.1)

11. SVOCs are assumed to be present in the brine in sufficient quantities to saturate and maintain saturation of the gas phase (conservative assumption: in reality, neither the brine nor the gas will be saturated with SVOCs)

12. Colloids and organic complexing agents capable of enhancing or inhibiting hazardous-constituent mobility and transport for metals are not modeled (conservative assumption: bounding approach makes mobility enhancement irrelevant and ignoring retardation mechanisms is conservative)

8.3.2 Gas-Phase Source Term

A gas-phase source term is necessary for VOC and SVOC hazardous constituents. As presented in Chapter 4, the weighted average concentration for each VOC is used as the source-term concentration when waste headspace data are available. For the long-term demonstration, weighted headspace concentrations are increased to reflect final void volume conditions expected in the repository resulting from creep closure.

When no waste headspace data are available, saturated vapor concentrations are used to bound source-term concentrations for VOCs. Because headspace data are not available for SVOCs, saturated vapor concentrations are also assumed for SVOCs. The methods used to establish these source terms are described in this section. Cis 1,2-dichloroethylene and vinyl chloride are not considered in this analysis. No health-based soil levels are defined in the IRIS-2 database or the 40 CFR 264 Subpart S proposed rule and the DOE believes the use of saturated vapor concentrations for other organic constituents adequately bound comparisons to HBLs.

8.3.2.1 Container Headspace-Derived Concentrations

Correcting container headspace concentrations for use in the long-term demonstration involves calculating the effect of void volume conditions in the repository on VOC concentrations in the gas phase. Porosity changes in the waste are expected as waste containers are compacted as a result of creep closure of the repository. This process will control the pore volume available for gas storage and will influence gas-phase concentrations. Initial and final porosities of the waste-disposal panels are calculated by BRAGFLO based on time histories of porosity as a function of time and pressure conditions in the repository. As discussed in Section 8.2.3.1, the SANTOS computer code provides the pressure, time, and porosity history. Initially, the waste disposal excavations are assumed to be gas-saturated (0.985) at atmospheric pressure (0.101 MPa) with an initial porosity of 84.8 percent.

Conceptually, as the repository closes, VOC gas-phase density will increase and waste pore volume will decrease. Simultaneously, molar concentrations of VOCs (expressed as ppmv) will decrease as waste-generated gas dilutes the system. To account for the increase in gas-phase density, initial masses of gas-phase organic compounds are derived from initial VOC gas-phase densities (mass/volume) and initial repository volume

conditions. This initial mass is distributed over the final system pore volume to derive the final gas-phase source-term concentration, which is then held constant.

Mathematically, the process of deriving a mass parameter by applying the concentration (ρ_d) to the initial waste disposal region volume is as follows:

$$\rho_d = \rho_i \quad (4)$$

$$m_i = \rho_i \times V_i \quad (5)$$

where

ρ_d = organic gas-phase concentration (mass/volume) prior to closure
ρ_i = organic gas-phase concentration (mass/volume) derived from headspace measurements
m_i = mass of organic VOC in gas phase prior to closure
V_i = initial waste disposal region volume

Assuming that mass (m_i) in the waste region remains constant throughout the compliance time frame, this mass is distributed over the final repository gas-available volume (V_f) to derive the final organic gas-phase concentration (ρ_f):

$$\rho_f = m_i/V_f \quad (6)$$

This approach is conservative based on several rationales, including:

- No credit is taken for expected dilution of organic gas-phase concentrations by waste-generated gas. Molar concentrations (expressed as ppmv) of organic gas-phase constituents will decrease as the proportion of moles of hydrogen, methane, and other gases increase as a result of gas generation processes.

- The source-term concentration held constant for the 10,000-year compliance period is calculated from the final system pore volume.

Headspace measurements shown in the last column in Table 8-13 have been weighted to derive average VOC concentrations representing all waste groups, and converted to units of g/m^3. In Section 8.4, weighted average concentrations (ρ_i) are subsequently corrected for gas-available void volume conditions in the repository (ρ_d).

8.3.2.2 Saturated Vapor Concentrations

Table 8-13 lists saturated vapor concentrations for VOCs and SVOCs for which there are no data or that have not been detected during waste characterization. For VOCs, Table 8-13 shows this to be conservative: measured VOC headspace concentrations to date are at least two orders of magnitude lower than saturated vapor concentrations. Assuming a

saturated ideal gas mixture at 300 k, the partial pressure of each constituent in the gas phase is the constituent vapor pressure at 300 k. The equation used to derive the saturated vapor concentration (ρ_i) for these organic hazardous constituents is given by:

$$\rho_i = P_i M_i / RT \quad (7)$$

where

$$P_i = P_v$$

ρ_i	=	saturated-vapor concentration of hazardous constituent (i) in the gas phase (mass/volume)
P_i	=	the partial pressure of hazardous constituent (i) in the gas phase (Pa)
M_i	=	molecular weight of hazardous constituent (i) (g/mol)
R	=	universal gas constant (Nt-m/gmole/K)
T	=	absolute temperature of the gas phase in volume V (300 K)
P_v	=	vapor pressure of hazardous constituent (i) at the gas mixture temperature

8.3.3 Liquid-Phase Source Term

Brine inflow is the only significant source of liquid solvent available for dissolution of gas-phase organic hazardous constituents into a liquid phase (see Section MASS.1.5 and Section SCR.2.2.2). Because the weight of gas that dissolves in a given quantity of liquid can be estimated using Henry's Law, it follows that resulting concentrations in the liquid will always be less than that of the gas phase. By correlation, if compliance can be demonstrated for the organic hazardous constituents in the gas phase, compliance for hazardous constituents in the liquid phase is also demonstrated. The migration of liquid-phase organic hazardous constituents is also bounded by the modeling approach selected for hazardous-constituent metals in the liquid phase discussed in the following paragraph.

Solubilities of metallic constituents in WIPP brine can be estimated by a number of established speciation/solubility codes, such as EQ3/6, PHRQPITZ, and FMT. However, all require thermodynamic data, and thermodynamic data and information on solid phase equilibrium chemistry for RCRA-regulated metals are, in general, not available for high ionic strength brines. Use of Pitzer equations to estimate the solubilities of RCRA-regulated metals is also not recommended for the high ionic strength brines, unless verified experimentally. Given these constraints, and the possibility that the BRAGFLO simulation could indicate brine migration from the waste region, the DOE has reserved a bounding approach designed to track the transport of a surrogate tracer using a constituent transport code. To demonstrate relative concentration at the unit boundary, the tracer element would be assumed to have an infinite inventory and a solubility of 1 kg/m^3, with no credit for decay, sorption, or diffusion during transport.

Table 8-13. Gas-Phase Source-Term Parameters

Constituents	Weighted Average Concentration of Headspace Gases (ppmv)	Molecular Weight (g/mol)	Vapor Pressure at 27° C[a] (Pa)	Saturated Vapor Concentration (g/m^3)	ρ_d Weighted Average Concentration (g/m^3)
Benzene	9.25	78.11	1.39E+04	4.35E+02	2.95E-02
Bromoform	9.38	252.8	8.96E+02[b]	9.08E+01	9.70E-02
Carbon disulfide	ND	76.14	5.19E+04	1.58E+03	1.58E+03[f]
Carbon tetrachloride	375.5	153.8	1.66E+04	1.02E+03	2.36E+00
Chlorobenzene	12.52	112.6	1.80E+03	8.12E+01	5.76E-02
Chloroform	25.33	119.4	2.86E+04	1.37E+03	1.24E-01
1,2-Dichloroethane	9.07	98.96	1.17E+04	4.64E+02	3.67E-02
cis 1, 2-Dichloroethylene	8.97	96.95	2.94E+04	1.14E+03	3.56E-02 - NA
1,1-Dichloroethylene	11.46	96.95	8.00E-04[c]	3.11E+03	4.54E-02
Isobutanol	ND	74.12	1.86E+03	5.53E+01	5.53E+01[f]
Methyl ethyl ketone	63.66	72.1	1.33E+04	3.84E+02	1.88E-01
Methylene chloride	368.5	84.94	6.20E+04	2.11E+03	1.28E+00
1,1,2,2-Tetrachloroethane	9.35	167.9	8.08E+02	5.44E+01	6.42E-02
Tetrachloroethylene	9.40	165.9	2.70E+03	1.80E+02	6.38E-02
Toluene	19.4	92.13	4.19E+03	1.55E+02	7.31E-02
1, 1, 1-Trichloroethane	317.1	133.4	1.80E+04	9.62E+02	1.73E+00
1, 1, 2-Trichloroethane	ND	133.4	3.31E-03	1.77E+02	1.77E+02[f]
Trichloroethylene	25.10	131.4	1.01E-04	5.32E+02	1.35E-01
Trichlorofluoromethane	ND	137.4	1.10E-05	6.01E+03	6.01E+03[f]
Vinyl chloride	ND	62.5	4.12E-05	1.03E+04	1.03E+04[f] - NA
Cresols (o,m,p)	ND	108	4.83E+01	2.09E+00	2.09E+00[f]
ortho-Dichlorobenzene	ND	146.9	2.71E+02	1.60E+01	1.60E+01[f]
1,4-Dichlorobenzene	ND	146.9	2.72E+02	1.60E+01	1.60E+01[f] - NA
2,4-Dinitrotoluene	ND	182	6.80E-01[c]	4.96E-02	4.96E-02[f]
2,4-Dinitrophenol	ND	184.1	5.52E-03[d]	4.07E-04	4.07E-04[f]
Hexachlorobenzene	ND	284.78	3.03E-01[e]	3.46E-02	3.46E-02[f]
Hexachloroethane	ND	236.7	1.01E+02[b]	9.58E+00	9.58E+00[f]
Nitrobenzene	ND	123	4.08E+01	2.01E+00	2.01E+00[f]
Pentachlorophenol	ND	266.34	1.27E-01[d]	1.36E-02	1.36E-02[f]
Pyridine	ND	79	3.08E+03	9.75E+01	9.75E+01[f]

[a] Values calculated from equations and coefficients in Reid et al. (1987), unless otherwise indicated.
[b] Values interpolated using Clausius-Clapeyron equation and values tabulated in Perry et al. (1984).
[c] Values are from EPA (1986).
[d] Value is at 25° C tabulated in Stephenson and Malanowski (1987).
[e] Value is at 25° C tabulated in Bidleman (1984).
[f] Saturated Vapor Concentration.

ND - No headspace data available; saturated vapor concentrations are used for source term.
NA - Not applicable; constituents are screened from the analysis because health data are not published.

8.4 Long-Term Model Demonstration of No Migration

This section presents the results of simulation modeling and bounding calculations supporting the NMVP for the WIPP disposal unit. The DOE reports the behavior of the repository predicted by BRAGFLO, including average pressure build-up, cumulative gas generation, and brine saturation. Effects on the Salado Formation and shaft regions in response to repository behavior are also described. For liquid-phase migration, the DOE reports the mobility of brine in the repository and the potential for brine containing hazardous constituents to migrate from the waste region. For gas-phase migration, the DOE demonstrates through bounding calculations that concentrations of gas-phase organic constituents will not exceed HBLs at any unit boundary regardless of the conclusions drawn from two-phase flow modeling.

To the extent appropriate to the adopted methodology, this section addresses modeling considerations outlined in the EPA guidance manual *No-Migration Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners* (EPA 1992). These considerations are outlined below:

- **Justification of Assumptions and Model Input Parameters**. Justification for the overall conceptual model is addressed in Appendix SCR and Appendix MASS. Justification for assignments of specific parameter values is contained in Appendix PAR. Input data are based on waste-specific and site-specific experimental programs, or are assigned reasonable or reasonably conservative values. Where appropriate, parameter values and modeling assumptions are implemented to either represent the actual physical system or to bias the modeling and calculations toward overestimating the potential for migration. Table 8-14 summarizes selected modeling assumptions relevant to undisturbed brine and gas migration. The degree of conservatism or realism believed associated with these assumptions is identified, including reasonable assertions based on expected conditions or reasonable simplifications used to facilitate modeling.

- **Model Confirmation and Calibration.** Direct comparison or calibration of predicted brine and gas migration to actual field measurements is not practical for several reasons, including the extremely low permeabilities of the Salado Formation and the duration of the modeling simulation.

- **Uncertainty and Sensitivity Analyses.** Stochastic and conceptual model uncertainty is assessed in Appendix SCR and summarized in Section 8.4.3 to identify events or processes capable of contributing significant uncertainty to the demonstration. Parameter sensitivity is considered in Section 8.4.4.

8.4.1 Brine and Gas Migration

Sensitivity analyses in previous brine- and gas-flow simulations have shown the significant effect that gas-generation rates have on brine and gas flow (WIPP PA 1992, 6-2). In general, previous simulations indicated that if gas generation is relatively low,

Table 8-14. Summary of Primary Model Configuration Assumptions[a]

GENERAL ASSUMPTIONS

- Brine- and gas-flow fields are based on a single 2D geometry with radially symmetric flow divergent from and convergent to the repository. **(reasonable)**
- Deterministic (median value) selection of material properties. **(reasonably conservative)**
- Two-phase flow (brine and gas) obeys Darcy's Law for compressible fluids in all media. Phases are pure components; Brooks-Corey two-phase characteristic equations are used to describe two-phase flow. **(reasonably conservative)**
- Prior to excavation, Salado is in hydrostatic equilibrium, i.e., no gradients exist in the Salado. After excavation, brine flow is induced by repository effects. **(realistic)**
- Gas has the composition and physical properties of hydrogen. **(reasonable)**
- All liquid possesses properties of Salado brine. **(reasonable)**
- Gas does not dissolve in brine. **(reasonable)**
- Initial conditions - Waste panels remain open for five year waste emplacement period. **(reasonable)**
- For purposes of numerical modeling, the model domain extends 22.4 km from the repository and extends upward from the base of the Salado to the surface. Below the Culebra boundary, no-flow boundary conditions are assigned to the boundary of the model domain. Constant pressure and saturation conditions are applied at the model domain boundary of the Culebra and overlying units and along the surface. **(reasonable)**
- Pressure is specified in hydrostratigraphic units overlying the Salado. **(realistic)**
- Klinkenburg effect is included. **(realistic)**
- At pressures near lithostatic or in excess of lithostatic, brittle layers in the surrounding formation will fracture; pressure conditions exceeding lithostatic conditions are not stable. **(reasonable)**
- Grid dimensions associated with all regions (e.g., shaft, waste disposal panels, etc.) are preserved and do not change with time. **(reasonable)**

ANHYDRITE AND HALITE ASSUMPTIONS

- Simplified stratigraphy with two lithologic types: anhydrite and impure halite. **(reasonable)**
- Anhydrite interbeds: MB 138, combined anhydrite layers a and b, and MB 139 only. **(reasonable)**
- Post-closure brine inflow from clay consolidation is negligible. **(reasonable)**
- Pressure-dependent fracturing occurs at near-lithostatic pressure; modeled with pressure dependent permeability and porosity. **(reasonable simplification)**
- One degree uniform dip to south within the Salado. **(realistic)**
- Gas does not penetrate impure halite due to high threshold pressure (P_t). **(conservative)**
- Initial (pre-excavation) impure halite and anhydrite porosity specified; varies with pressure because of compressibility. **(realistic)**
- Permeabilities, porosities, and Salado brine saturation are adjusted in the excavation at time $t_0 = 0$ for the 10,000-year simulation (e.g., at repository closure). Initial Salado brine saturation specified as fully saturated. **(realistic)**
- Impure halite permeability specified constant in time. **(reasonable)**
- Intact anhydrite permeability initially spatially constant. **(reasonable)**

DISTURBED ROCK ZONE

- Permeability specified and constant during operational phase; for initial model conditions operational DRZ becomes partially desaturated and depressurized. **(reasonable)**
- At $t_0 = 0$, DRZ is assigned time-invariant, high permeability (DRZ does not heal). **(conservative)**
- Threshold capillary pressure is zero. **(conservative)**
- At $t_0 = 0$, porosity specified as impure halite. **(conservative)**
- Initial conditions - Brine saturation specified as fully saturated; variation calculated during operational phase as brine flows in and drains out. **(reasonable)**
- Initial pressure in hydrostatic equilibrium with rest of Salado. **(realistic)**

[a]Fundamental assumptions underlying the brine- and gas-flow simulation are explained in detail in Appendix MASS.

Table 8-14. Summary of Primary Model Configuration Assumptions (continued)

WASTE/DISPOSAL REGION ASSUMPTIONS

- All pillars removed from panels resulting in homogeneous waste region. (**conservative**)
- Pore space is fully connected in all regions. (**reasonable**)
- Waste and panel closures are emplaced simultaneously: at $t_0 = 0$, waste region is assigned a constant high permeability. Panel closures are assumed ineffective in long-term sealing. (**conservative**)
- Porosity and pore volume of waste region vary with creep closure, which is a function of time dependent gas generation, fluid movement and repository pressure. (**reasonable**)
- Wicking of brine occurs through capillary forces and results in increased contact of brine and waste. (**conservative**)
- Pressure at $t_0 = 0$ is atmospheric; brine content in the repository at end of operational period is discarded to reflect removal during ventilation. The moisture content of representative emplaced waste is used to specify the initial brine saturation of the waste region. (**reasonable**)
- Threshold capillary pressure is zero. (**reasonable**)
- Effects of backfill on chemical conditions, fluid flow, and consolidation in the waste region are not considered. (**conservative**)

GAS GENERATION

- Two gas-generation processes are assumed to occur simultaneously: anoxic corrosion and microbial degradation of all cellulosics, plastics and rubbers. (**conservative**)
- In the average-stoichiometry model, rates of gas generation by corrosion and microbial generation change depending on brine saturation of waste region. (**reasonable**)
- Brine is consumed by corrosion but is neither consumed nor produced during microbial degradation. (**reasonable**)
- If brine saturation equals zero in a cell, gas generated by anoxic corrosion and microbial degradation ceases. (**reasonable**)
- If brine is present, gas continues to be generated on a cell-by-cell basis until all reactant inventories are depleted. (**reasonable**)

SHAFT SEAL DESIGN

- Highly-compacted crushed salt barrier and clay barriers provide long-term seal. (**realistic**)
- Short-term seals (concrete and asphalt) limit short-term brine inflow and retard short-term gas migration. (**realistic**)
- Porosity of shaft seals and intervening shaft regions is constant at consolidated levels. (**reasonable**)
- Effective permeability of shaft regions varies with time in a step-wise fashion to reflect consolidation. (**reasonable**)
- Time-varying DRZ properties are included in the effective permeability of the adjacent shaft components. (**reasonable**)
- Permeability of concrete shaft seal components degrades to that equivalent of silty-sand. (**conservative**)

HAZARDOUS-CONSTITUENT MIGRATION

- Gas-phase organic compounds mix with waste-generated gas and are transported simultaneously as a single gas having the physical properties of hydrogen gas. (**reasonably conservative**)
- Gas and brine are immiscible. (**reasonable**)
- The mobility of hazardous-constituent metals dissolved in brine and organic constituents partitioned into the brine phase is a bounding compliance measure. (**reasonable**)
- Transport of a surrogate metal tracer assuming only advective and dispersive processes is a bounding compliance measure. No credit would be taken for retardation through sorption to fixed substrates within the repository or along migration pathways. (**conservative**: mobilized metals will likely be absorbed to waste forms, clays and anhydrites, or engineered components of the disposal system (e.g., clay in shaft seals))

[a]Fundamental assumptions underlying the brine- and gas-flow simulation are explained in detail in Appendix MASS.

the pressure in the repository tends to rise slowly as brine from the far field flows into the repository and equilibrates with the far field. Under this condition, the direction of flow has tended to be inward toward the repository, making the repository behave as a brine sink. Conversely, if closure proceeds quickly and gas is generated sufficiently for pressure within the repository to build quickly to near-lithostatic levels, fluids can, depending on residual saturation, migrate slowly away from the repository and into the anhydrite interbeds and sealed shaft.

The simulation results presented in this section are based on a conservative assumption of conditions that enhance high gas-generation rates. Gas generation is purposely modeled to enhance the potential for migration of brine and gas away from the repository and into the anhydrite interbeds and sealed shaft. As discussed in Section 8.2.3.3, the modeling approach implemented is conservative based on the assumption that the entire inventory of ferrous metals, cellulosics, plastics, and rubbers in the waste is available to generate gas. No credit is taken for the 50 percent probability that biodegradation may not occur and that gas-generation rates could, therefore, be lower.

8.4.1.1 Repository Behavior

As expected, the BRAGFLO simulation indicates that average pressure in the waste disposal region increases with time (Figure 8-5). The pressure increase is primarily attributed to gas being generated more quickly than pressure can be relieved by fluids flowing out of the anhydrite layers or up the sealed shaft. Smaller contributions to the pressure build-up occur through reduction of void volume by creep closure. For the high gas-generation conditions assumed, pressure rises rapidly from atmospheric pressure to 12 MPa over the first 500 years after closure. After the first 400 to 500 years, repository pressure rises gradually to a peak value of 14.13 MPa at 6,200 to 6,400 years followed by a steady decrease to 14.11 MPa at 10,000 years. The total amount of gas generated by biodegradation and by anoxic corrosion during 10,000 years (according to the BRAGFLO simulation) is shown in Figure 8-6. Approximately 650×10^6 moles of gas are generated during the first 400 to 500 years. Gas generation then slows, and the total quantity at 10,000 years is 716×10^6 moles. At reference conditions of 30°C (86°F) and 0.101 MPa, this amount of gas would occupy a volume of 100×10^9 m^3.

The BRAGFLO simulation shows cumulative brine flow into the repository from the DRZ and the far field (Figure 8-7). At the same time, the pore volume (void space) present in the repository is reduced by creep closure, as shown in Figure 8-8. Eighty-nine percent of the brine inflow occurs during the first 50 years, 198,400 ft^3 (5,620 m^3) of brine, and the remaining 24,400 ft^3(690 m^3) of brine enters the repository during the last 9,950 years of the 10,000-year simulation. Total pore volume in the repository decreases from 13×10^6 to 5.86×10^6 ft^3 (370×10^3 to 166×10^3 m^3) during the first 50 years. The closure rate subsequently slows, and the minimum pore volume 3.1×10^6 ft^3 (88×10^3 m^3) is achieved after 1,060 years. The pore volume then increases slightly to a final value of 3.2×10^6 ft^3 (91×10^3 m^3) during the remaining 8,940 years. The increase is due to the pressure exerted by the gas in the repository.

The average brine saturation in the waste during 10,000 years is depicted in Figure 8-9. The initial increase in brine saturation during the first 50 years is due to brine inflow, rapid creep closure, and a sharp reduction in pore volume in the waste. Once the repository ceases to close, brine consumption due to corrosion causes brine saturation to decrease. Figure 8-9 shows this transition as a sharp increase in average brine saturation to just above five percent (at 50 years), followed by a steady decrease to 0.0002 percent at 500 years. The brine saturation then continues to decrease gradually for the rest of the 10,000-year period.

The BRAGFLO simulation indicates that consumption of ferrous metals by corrosion slows markedly and essentially ceases after the first 500 years (Figure 8-10). Figure 8-11 shows similar behavior involving consumption of the inventory of biodegradable materials (consumption progresses rapidly during the first 350 years and halts for the next 650 years). Biodegradation then resumes at a slower rate and ceases after 6,400 years. The continued presence of unreacted solid waste (i.e., ferrous metals, cellulosics, plastics, and rubber) indicates that the corrosion and biodegradation processes cease. As discussed in Section 8.2.3.3, brine must be present for biodegradation and corrosion to take place. The brine originally present in the waste, together with the brine flowing into the repository, are consumed during the first 400 to 500 years by the ongoing corrosion. Both processes are then limited by the lack of brine and proceed at much lower rates. As noted earlier, the reduction in brine inflow (and resulting brine availability) is a direct consequence of several factors, including the pressure increase and repository closure.

8.4.1.2 Brine-Migration Model Predictions

The BRAGFLO simulation indicates that no brine leaves the waste disposal region during the 10,000-year period. This conclusion results from a comparison of calculated brine saturation in the waste region with the estimated residual brine saturation (S_{br}) of the waste (see Appendix PAR, PAR-37). As described in Appendix PAR, S_{br} is the brine saturation required to permeate the waste matrix sufficiently to create an incipient network of interconnected pores. For brine saturations below S_{br}, the brine phase relative permeability, according to two-phase flow theory, is zero; hence, brine would be immobile. For brine saturations above S_{br}, brine phase relative permeability slowly increases from a value of zero at the S_{br}, to a value of one for fully brine-saturated conditions (see Appendix BRAGFLO, Section 1.9).

This demonstration takes advantage of literature-based data of residual liquid saturations measured for unconsolidated materials. These materials include soils and sands of various size gradations, as well as artificial materials, including uniformly-sized glass beads and simulated fragmented mixtures. As analogs for residual brine saturation in the waste region, unconsolidated materials are appropriate; the waste region is initially unconsolidated and consolidated materials generally exhibit higher values of residual liquid saturation. Appendix PAR discusses residual brine saturations assigned to various components of the disposal system.

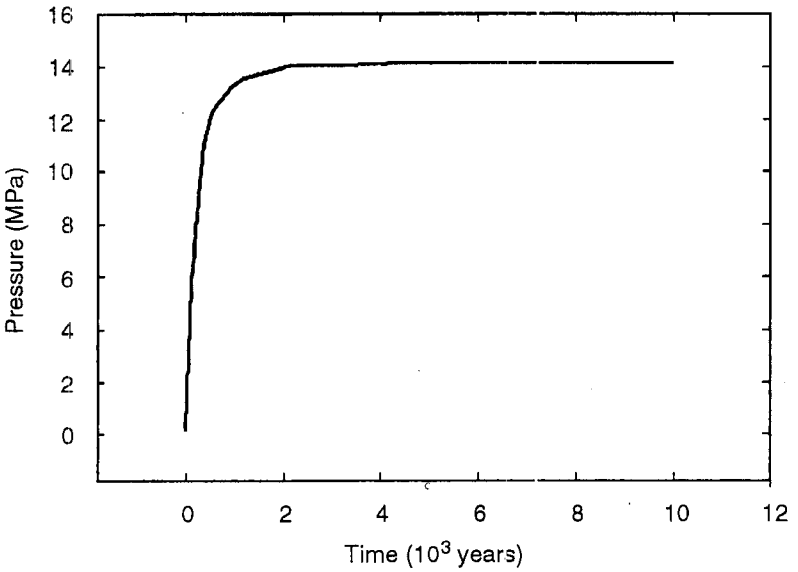

Figure 8-5. Average Pressure in the Repository

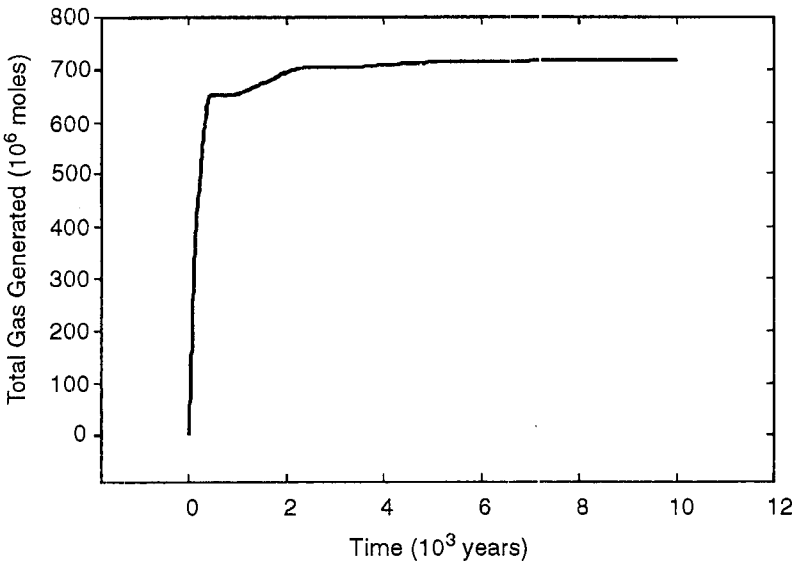

Figure 8-6. Cumulative Amount of Gas Generated by Corrosion and Biodegradation

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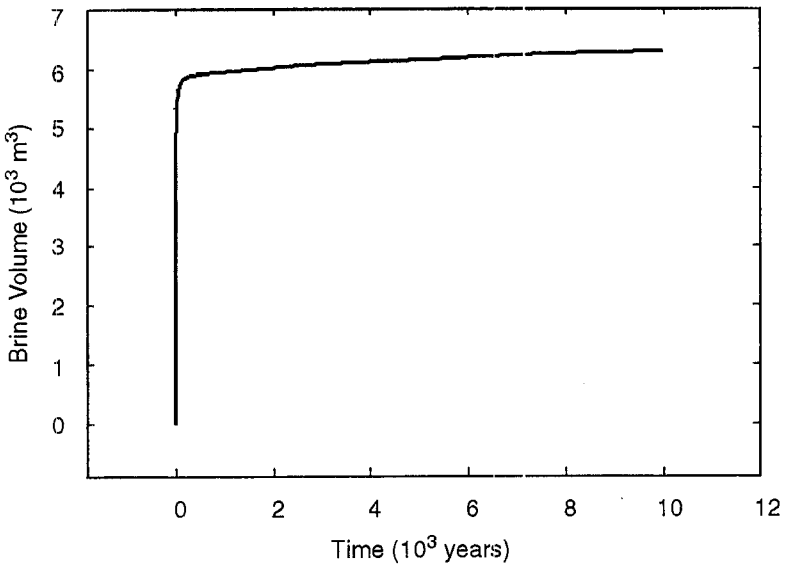

Figure 8-7. Cumulative Brine Flow into the Repository

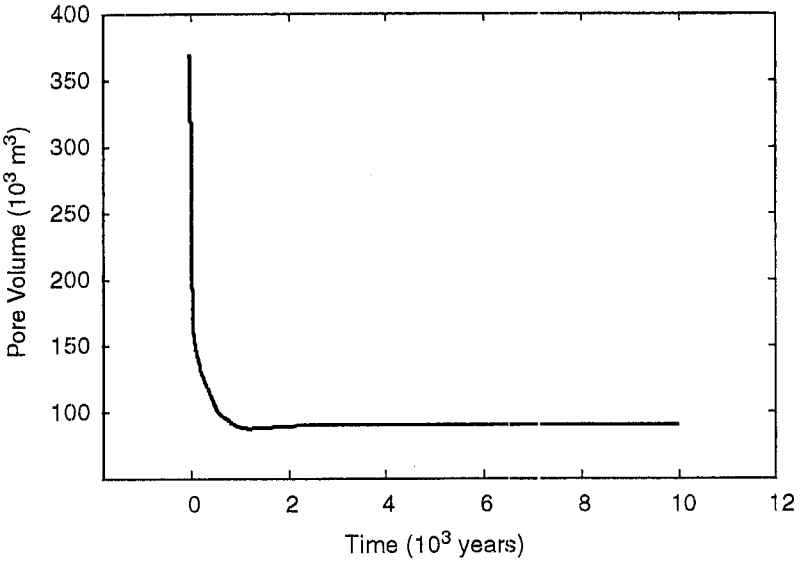

Figure 8-8. Total Pore Volume in the Repository

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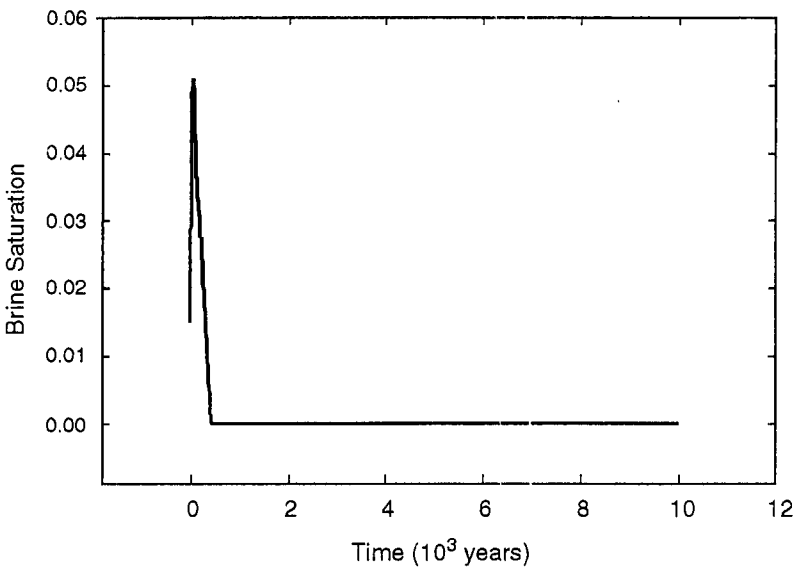

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Figure 8-9. Average Brine Saturation in the Repository

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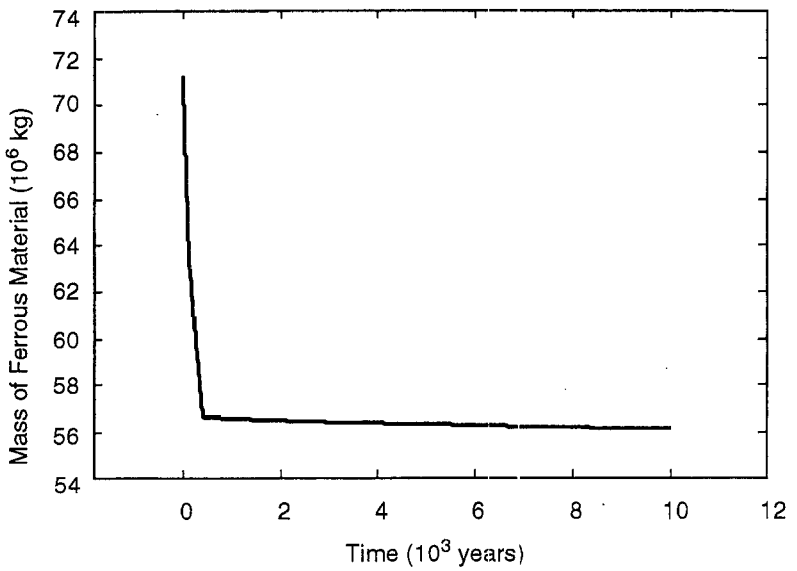

Figure 8-10. Mass of Ferrous Metal Remaining in the Repository

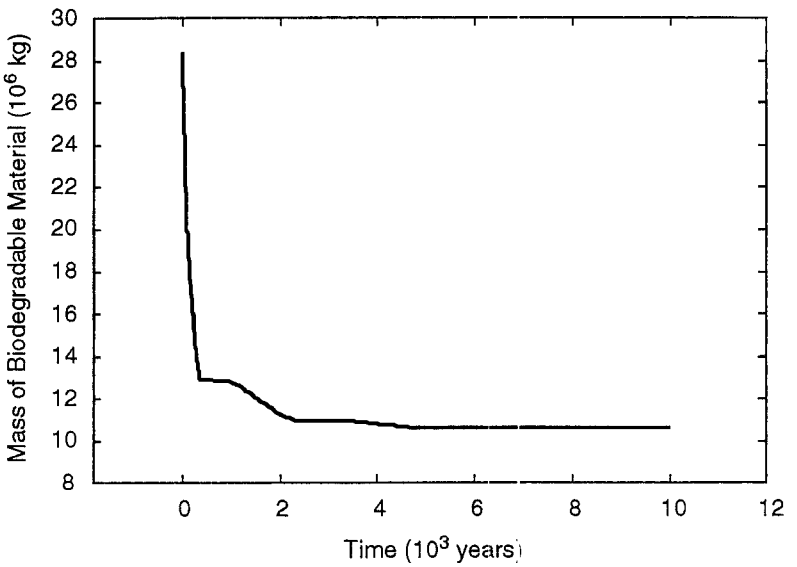

Figure 8-11. Mass of Biodegradable Material Remaining in the Repository

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Figure 8-12 reproduces the plot of the modeled residual brine saturation in the waste disposal region. The constant residual brine saturation of 27.6 percent used in BRAGFLO and a bounding literature-based S_{br} value are also plotted on Figure 8-12. As indicated in Section 8.4.1.1, the waste region undergoes an early peak in brine saturation before decreasing for the duration of the simulation. The peak brine saturation (5.1 percent) is well below the expected residual brine saturation, and is below the bounding S_{br} (7.8 percent). The bounding S_{br} value represents initiation of continuous liquid flow through a glass bead mixture tested by Brooks and Corey (1964), a value that is believed to conservatively underestimate the amount of brine necessary to allow continuous flow through the waste.

The BRAGFLO simulation predicts outward movement of brine only from the DRZ surrounding the repository. This brine has not been in contact with the waste and does not contain hazardous constituents. The majority of brine that enters the marker beds 46,860 ft^3 (1,327 m^3) does so at the southern and northern interfaces between the DRZ and MB 139; MB 139 experiences a small increase in permeability due to fracturing, somewhat enhancing brine flow in that unit.

The cumulative brine flow into MB 139 toward the south is 29,600 ft^3 (838 m^3), as shown in Figure 8-13. An additional 17,100 ft^3 (485 m^3) of brine flows into MB 139 toward the north, as shown in Figure 8-14. Cumulative flows of brine into the other anhydrite interbeds (MB 138 and anhydrite layers a and b) are less than 141 ft^3 (4 m^3). There is essentially no flow of brine up the shaft at the MB 138/halite interface (4.19×10^{-11} m^3).

8.4.1.3 Gas-Migration Model Predictions

As a consequence of low permeability and high threshold pressure, halite behaves as an essentially impermeable barrier to gas flow in the BRAGFLO simulation. Figure 8-15 shows gas saturation calculated at 10,000 years within the halite immediately above MB 138. The zero gas saturation indicates no migration of the gas into or through the halite, and that the halite remains fully brine-saturated at all times. Gas saturation across the repository shaft at the MB 138 horizon is not depicted in Figure 8-15.

The BRAGFLO gas migration results indicate that gas pressure in the repository is not sufficient to produce extensive gas migration in anhydrite units. However, the build up in gas pressure is sufficient to drive gas into the DRZ and result in a small amount of pressure-dependent fracturing in anhydrite layers a and b. The BRAGFLO simulation indicates that gas migrates from the repository through the DRZ into anhydrite layers a and b (in both directions). The simulation also shows gas migrating into MB 138 and along dip to the south of the repository. Gas does not migrate into MB 138 toward the north or into MB 139 in either direction. Gas migration in both directions in anhydrite layers a and b is likely a result of a small increase in permeability in these units due to fracturing. The fracture initiation pressure is not reached in MB 138. Gravitational separation of the two immiscible fluids results in gas preferentially migrating upward, and not downward into MB 139.

The extent of migration is represented in Figures 8-16 through 8-18 as maximum gas saturations reached during the 10,000-year simulation. Figures 8-15 and 8-16 show gas in anhydrite layers a and b (to the south and north of the repository, respectively). Figure 8-18 shows gas migration into MB 138 toward the south. Given that the zero origin represents the edge of the waste panels in each of these figures, the illustrations demonstrate that gas does not migrate to the lateral boundaries of the disposal unit. Based on gas saturation, the BRAGFLO simulation predicts gas to migrate relatively short distances from the repository. The greatest migration distance, 2,050 ft (625 m), occurs in the combined anhydrite layers a and b layer in the northerly direction (Figure 8-17).

Complicating interpretation of gas flow in the shaft are local capillary pressure gradients created between various shaft seal components, and an assumption of an initial mobile gas in the pore space of shaft material regions. The nonzero initial gas saturation precludes meaningful interpretation of cumulative gas flow in the shaft. Qualitatively, any gas leaving the waste-disposal panels must mix with a large volume of preexisting gas in the pore space of shaft components. This suggests the gas mixture at the shaft unit boundary may be dominated by a large component of gas unrelated to the waste-disposal panels. For this demonstration, however, the DOE relies on the bounding analyses described in Section 8.4.2.1 to establish the no-migration of gas-phase organic hazardous constituents.

8.4.2 Comparison to Health-Based Levels

The BRAGFLO simulation shows that no gas flows past the lateral unit boundaries. Because BRAGFLO results cannot be interpreteted definitively regarding gas flow in the shaft, bounding calculations are used in this section to demonstrate that gas-phase organic hazardous-constituent soil concentrations will not exceed HBLs for soil at the unit boundary in the shaft. This section also applies bounding calculations at the lateral unit boundary.

The BRAGFLO simulation indicates no brine leaving the waste disposal region. Consequently, a hazardous constituent transport code is not required to simulate the transport of the surrogate tracer from the waste disposal region, nor is a comparative evaluation of liquid-phase hazardous-constituent concentrations to HBLs.

8.4.2.1 Gas-Phase Bounding Calculations

This section compares bounding soil concentrations for gas-phase VOC and SVOC hazardous constituents with allowable soil concentrations derived from EPA-approved HBLs. Soil-based concentrations are calculated assuming gas-available porosity within the asphalt shaft seal and within the applicable anhydrite units at the subsurface disposal

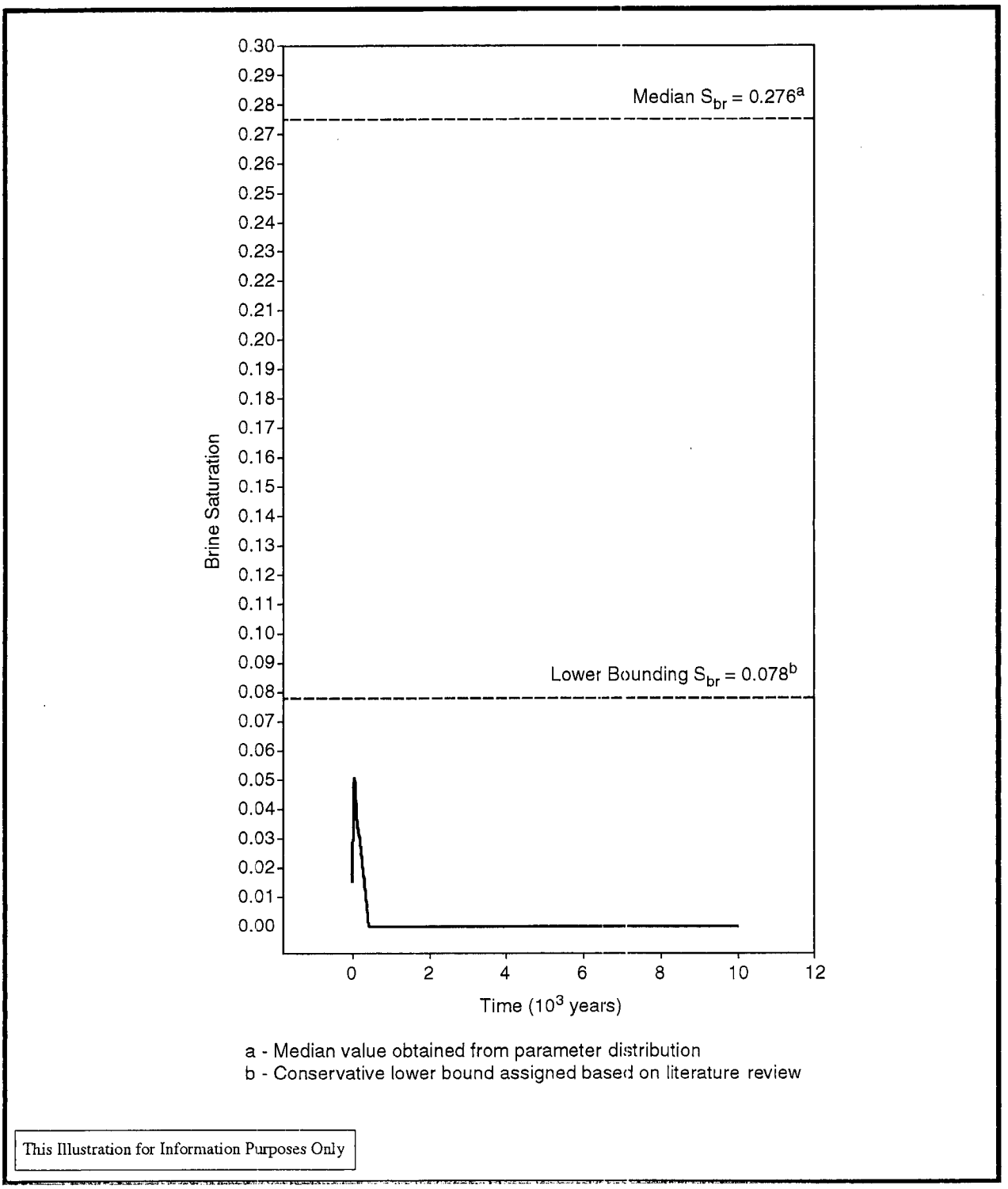

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Figure 8-12. Comparison of Repository Brine Saturation with Estimated Residual Brine Saturation (S_{br}) of the Waste Region

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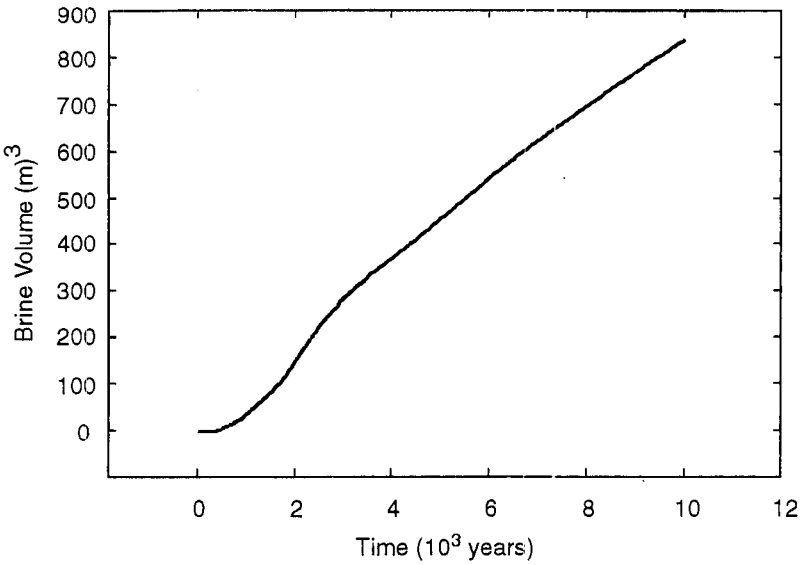

Figure 8-13. Cumulative Brine Flow into Marker Bed 139 at Southern Edge of Repository

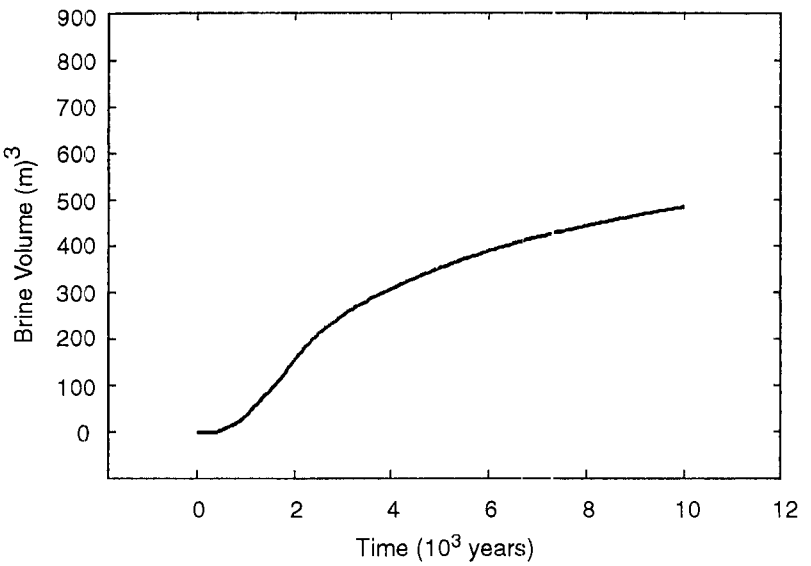

Figure 8-14. Cumulative Brine Flow into Marker Bed 139 at Northern Edge of Repository

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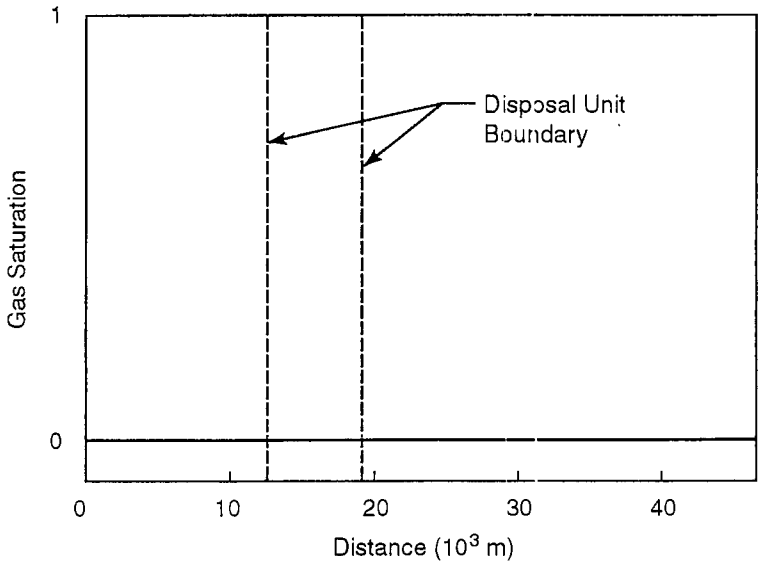

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Figure 8-15. Gas Saturation at 10,000 Years in Halite Layer Immediately Above Marker Bed 138 Across the Model Domain.

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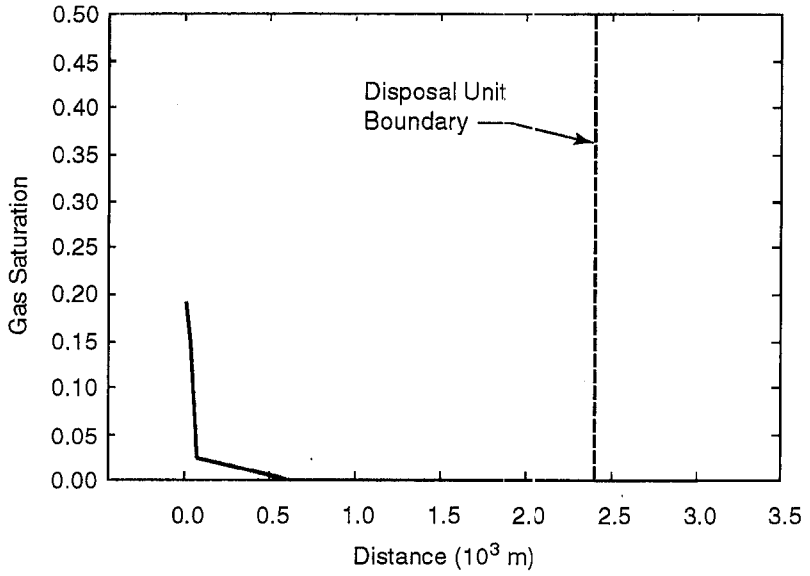

Figure 8-16. Maximum Gas Saturation in Anhydrite Layers a and b South of the Repository

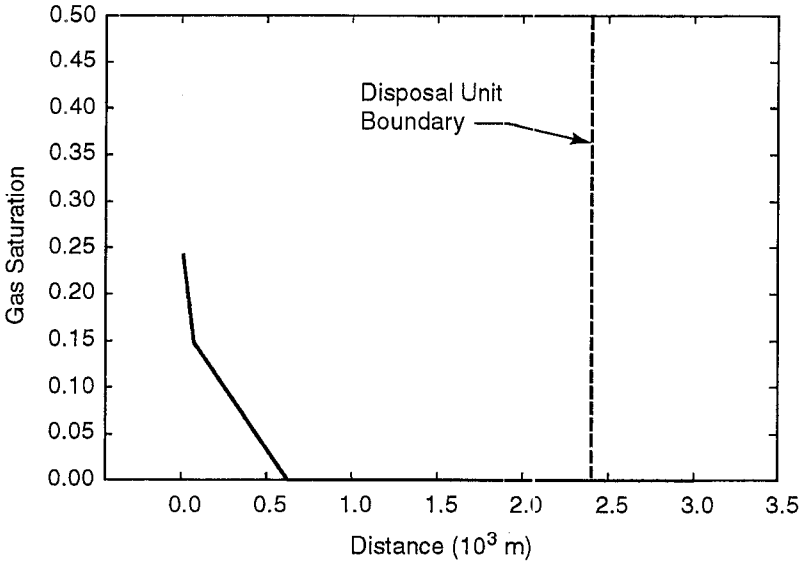

Figure 8-17. Maximum Gas Saturation in Anhydrite Layers a and b North of the Repository

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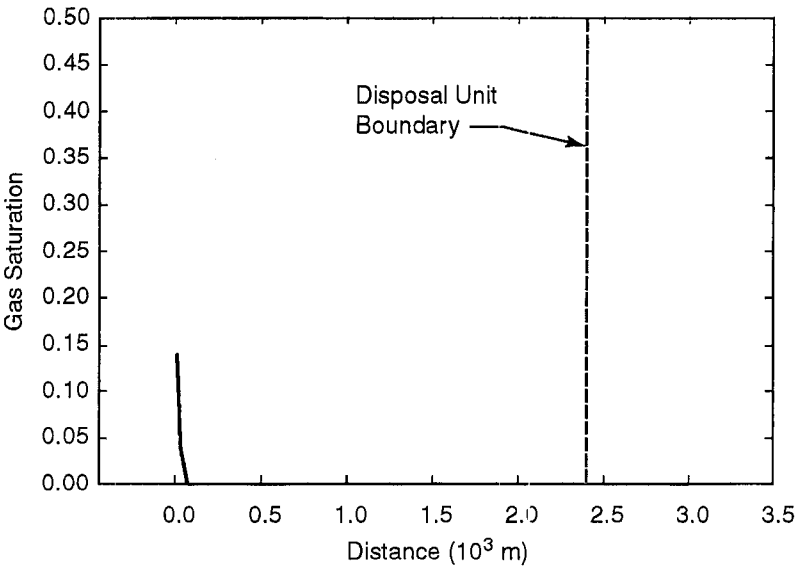

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Figure 8-18. Maximum Gas Saturation in Marker Bed 138 South of the Repository

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unit boundaries. The general equation used to derive soil-based concentrations for organic hazardous constituents in the gas phase is given by:

$$C^i_{sb} = M_i/M = 1000\rho_i\phi\, s_g V/\rho_{sd} V = 1000\rho_i\phi\, s_g/\rho_{sd} \quad (8)$$

where

$$\rho_{sd} = [\rho_{gr}(1-\phi) + \rho_b(1-s_g)\phi + \rho_m\phi\, s_g] \quad (9)$$

$$s_g = 1 - s_b, \text{ and} \quad (10)$$

C^i_{sb}	=	soil-based concentration of hazardous constituent i in volume V (mg/kg)
M_i	=	mass of hazardous constituent i contained in the gas phase in volume V (mg)
M	=	combined mass of solid, brine, and gas phases in volume V (kg)
ρ_i	=	concentration of constituent i or mass of hazardous constituent i per volume of the gas phase in volume V (g/m^3)
ϕ	=	porosity of solid (unitless)
s_g	=	saturation of the gas phase (unitless)
s_b	=	brine saturation (unitless)
V	=	combined volume of solid, brine, and gas phases (m^3)*
ρ_{sd}	=	combined mass of solid, brine and gas phases in volume V (kg/m^3)
ρ_{gr}	=	grain density of the solid in volume V (kg/m^3)
ρ_b	=	brine density (kg/m^3)
ρ_m	=	density of the gas phase (kg/m^3) - $\rho_m\phi\, s_g = 0$**

*note that the volume parameter cancels out, making thickness of the pathway inconsequential
**density of the gas mixture is assumed to be negligible in comparison to the anhydrite and brine density

From equation (8) through (10), soil-based concentrations of hazardous constituents increase with porosity, gas saturation and partial pressure of the hazardous constituents in the gas phase. Partial pressures are assumed to be bounded by concentrations in the waste region. Values for parameters needed to calculate upper bounds for soil-based concentrations are presented in Table 8-15.

Headspace-Derived Source Term. As discussed in Section 8.3.3, drum headspace measurements are available to bound soil concentrations for 20 gas phase VOCs. The source-term conceptual model assumes equilibration of VOC headspace measurements in the waste region and subsequent compression to the bounding concentrations by creep closure. Weighted average concentrations for these constituents are expressed in g/m^3 in Table 8-13, Section 8.3. The bounding concentrations maintained for the 10,000-year modeling period are calculated as follows:

Table 8-15. Parameter Values Used in Deriving Bounding Soil-Based Concentrations of Organic Gas-Phase Hazardous Constituents

Parameter	Value Used	Units
Universal Gas Constant	8.32	(Nt-m/gmole/K)
Repository Temperature	300K	-
Excavated Volume	4.36E+05	(m^3)
Initial Repository Porosity	0.848	-
Initial Gas Saturation in Repository	0.985	-
Initial Gas Volume	3.64E+05	(m^3)
Final repository porosity	0.209	-
Final repository gas saturation	1.0	-
Final gas volume in repository	9.11E+04	(m^3)
Grain density - Anhydrite	2.75E+03	(kg/m^3)
Porosity - Anhydrite	0.011	-
Grain density - Seal	2.02E+03	(kg/m^3)
Porosity - Seal	0.01	(kg/m^3)
Gas saturation- anhydrite	1.0	(kg/m^3)
Gas saturation - upper shaft seal	1.0	-
Brine density	1.23E +03	(kg/m^3)

$$\rho_i^i = \rho_{hs}^i V_r^0 / V_r^f$$

$$V_r^0 = S_r^{g0} \phi_r^0 V_e,$$

$$V_r^f = S_r^{gf} \phi_r^f V_e,$$

where

ρ_{hs}^i = concentration of VOC i in drum headspace (g/m^3)

V_r^0 = volume of gas in waste region at t = 0 when the repository is decommissioned (m^3)

V_r^f = volume of gas in waste region at t = 10,000 years (m^3)

V_e = excavated volume in the waste region at t = 10,000 years (m^3)

S_r^{g0} = gas saturation in the repository at t = 0 when the repository is decommissioned (unitless)

ϕ_r^0 = porosity of the waste region at t = 0 when the repository is decommissioned (unitless)

S_r^{gf} = gas saturation in the repository at t = 10,000 years (unitless), and

ϕ_r^f = porosity of the waste region at t = 10,000 years (unitless)

Saturated-Vapor-Pressure-Derived Source Term. For the four VOCs and 10 SVOCs with no headspace data, saturated vapor pressures are used to calculate bounding soil-based concentrations. Section 8.3.2.2 provides the equation used to derive saturated vapor concentrations, expressed in g/m^3.

Bounding Demonstration. Table 8-16 directly compares derived soil-based concentrations (mg/kg) with HBL soil concentrations (mg/kg). Results are presented using parameters for anhydrites and asphalt shaft seal materials, including a bounding assumption in both materials of no brine saturation: this assumption results in maximum gas saturation of anhydrite and shaft seal material pore space (e.g., 100 percent gas saturation), and maximizes the calculated quantity of hazardous constituents at the boundary.

By correcting source-term concentrations for gas-available porosities at the unit boundary, the methodologies described above assume no credit for any processes capable of diluting or attenuating concentrations along the migration pathway. Representing the highest gas phase soil-based concentration possible along potential migration pathways, compliance is demonstrated by showing these concentrations to be at least two orders of magnitude smaller than the corresponding hazardous-constituent HBL. This comparison demonstrates that gas phase hazardous-constituent concentrations will never exceed HBLs established by the EPA.

8.4.3 Prediction of Infrequent Events - Uncertainty Analyses

The conceptual basis for this simulation contains the aspects (i.e., FEPs) of the demonstration that the DOE believes contribute significantly to uncertainty (268.6 (b)(5)). A conceptual screening process presented in Appendix SCR is used to minimize or account for the effects of stochastic and conceptual model uncertainty. Consistent with draft guidance contained in EPA (1992, 38-39), Appendix SCR identifies and assesses a comprehensive inventory of potential natural events, waste/facility-induced events, and human-induced events. Where appropriate, Appendix SCR presents quantitative and qualtitative assessments of chemical, thermal, and mechanical processes listed in EPA's (1992) no-migration guidance document, as well as for applicable FEPs considered in the overall WIPP program. A summary of the FEPs considered in the no-migration demonstration is provided in Tables 8-17, 8-18, and 8-19.

The following screening classification is applied in Appendix SCR and Tables 8-17, 8-18, and 8-19 to systematically account for stochastic and conceptual model uncertainty:

- FEPs are considered in the no-migration demonstration

- FEPs are insignificant to the results of the demonstration and are screened on the basis of consequence (labeled SO-C) - FEPs having an adverse impact on waste isolation are assessed accordingly

Table 8-16. Bounding Comparison to Health-Based Soil Levels for Volatile and Semi-Volatile Organic Compounds

Constituents	Saturated Vapor Concentration (g/m^3)	ρ_{hs}^{i} Weighted Average Headspace Concentration (g/m^3)	Source-Term Concentration (g/m^3)	Bounding Anhydrite Soil Concentration for Constituent i (mg/kg)	Bounding Shaft Soil Concentration for Constituent i (mg/kg)	Health-Based Soil Level for Constituents i (mg/kg)
Benzene	4.35E+02	2.95E-02	2.03E-01	5.71E-04	7.05E-04	24.1
Bromoform	9.08E+01	9.70E-02	6.66E-01	1.88E-03	2.32E-03	88.6
Carbon disulfide	1.58E+03	ND	1.58E+03	6.41E+00	7.91E+00	8,000
Carbon tetrachloride	1.02E+03	2.36E+00	1.62E+01	4.57E-02	5.64E-02	5.4
Chlorobenzene	8.12E+01	5.76E-02	3.96E-01	1.11E-03	1.38E-03	1,600
Chloroform	1.37E+03	1.24E-01	8.50E-01	2.40E-03	2.96E-03	114.8
1,2-Dichloroethane	4.64E+02	3.67E-02	2.52E-01	7.10E-04	8.77E-04	7.7
cis 1,2-Dichloroethylene	1.14E+03	3.56E-02	1.70E-01	6.88E-04	8.50E-04	NA
1,1-Dichloroethylene	3.11E+03	4.54E-02	3.12E-01	8.79E-04	1.09E-03	11.7
Isobutanol	5.53E+01	ND	5.53E+01	2.23E-01	2.76E-01	24,000
Methyl ethyl ketone	3.84E+02	1.88E-01	1.29E+00	3.64E-03	4.49E-03	48,000
Methylene chloride	2.11E+03	1.28E+00	8.80E+00	2.48E-02	3.06E-02	93.3
1,1,2,2-Tetrachloroethane	5.44E+01	6.42E-02	4.41E-01	1.24E-03	1.53E-03	35.0
Tetrachloroethylene	1.80E+02	6.38E-02	4.38E-01	1.23E-03	1.53E-03	13.7
Toluene	1.55E+02	7.31E-02	5.02E-01	1.41E-03	1.75E-03	16,000
1,1,1-Trichloroethane	9.62E+02	1.73E+00	1.19E+01	3.35E-02	4.14E-02	7,200
1,1,2-Trichloroethane	1.77E+02	ND	1.77E+01	7.16E-01	8.84E-01	122.8
Trichloroethylene	5.32E+02	1.35E-01	9.27E-01	2.61E-03	3.23E-03	63.6
Trichlorofluoromethane	6.01E+03	ND	6.01E+03	2.45E+01	3.03E+01	24,000
Vinyl chloride	1.03E+04	ND	1.63E+04	4.17E+01	5.16E+01	NA
Cresols (o,m,p)	2.09E+00	ND	2.09E+00	8.46E-03	1.04E-02	4,000
ortho-Dichlorobenzene	1.60E+01	ND	1.60E+01	6.45E-02	7.97E-02	7,200
1,4-Dichlorobenzene	1.60E+01	ND	1.60E+01	6.48E-02	8.00E-02	NA
2,4-Dinitrotoluene	4.96E-02	ND	4.96E-02	2.01E-04	2.48E-04	1.0
2,4-Dinitrophenol	4.07E-04	ND	4.07E-04	1.65E-06	2.03E-06	160
Hexachlorobenzene	3.46E-02	ND	3.46E-02	1.40E-04	1.73E-04	0.4
Hexachloroethane	9.58E+00	ND	9.58E+00	3.88E-02	4.79E-02	80
Nitrobenzene	2.01E+00	ND	2.01E+00	8.13E-03	1.00E-02	40
Pentachlorophenol	1.36E-02	ND	1.36E-02	5.48E-05	6.77E-05	5.8
Pyridine	9.75E+01	ND	9.75E+01	3.94E-06	4.87E-01	80

NA - Not applicable, no health-based data available or published.
ND - No headspace data

Table 8-17. Natural FEPs and Their Screening Classifications

FEPs		Screening Classification	Comments	Reference Appendix SCR Section
GEOLOGICAL				1.1
Stratigraphy				1.1.1
	Stratigraphy	NMD		
Tectonics				1.1.2
	Changes in regional stress	SO-C		
	Regional tectonics	SO-C		
	Regional uplift and subsidence	SO-C		
Structural effects				1.1.3
Deformation				1.1.3.1
	Salt deformation	NMD near repository.	SO-P elsewhere	
	Diapirism	SO-P		
Fracture development				1.1.3.2
	Formation of fractures	NMD near repository.	SO-P elsewhere	
	Changes in fracture properties	NMD near repository.	SO-C elsewhere	
Fault movement				1.1.3.3
	Formation of new faults	SO-P		
	Movement along faults	SO-P		
Seismic activity				1.1.3.4
	Earthquakes	NMD	DRZ assumptions	
	Ground shaking	NMD	DRZ assumptions	
Crustal processes				1.1.4
Igneous activity				1.1.4.1
	Volcanic activity	SO-P		
	Magmatic activity	SO-C		
Metamorphism				1.1.4.2
	Metamorphism	SO-P		
Geochemical effects				1.1..5
Dissolution				1.1.5.1
	Shallow dissolution	SO-C		
	Lateral dissolution	SO-C		
	Deep dissolution	SO-P		
	Solution chimneys	SO-P		
	Breccia pipes	SO-P		
	Collapse breccias	SO-P		
Mineralization				1.1.5.2
	Fracture infilling	SO-C		
	Hydrothermal alteration	SO-P		
SUBSURFACE HYDROLOGICAL				1.2
Groundwater flow characteristics				1.2.1
	Saturated groundwater flow	SO-C		
	Unsaturated groundwater flow	SO-C		
	Groundwater flow: fractures	SO-C		
	Effects of preferential pathways	SO-C		
Changes in groundwater flow				1.2.2
	Thermal effects on groundwater flow	SO-C		
	Saline groundwater intrusion	SO-P		
	Fresh groundwater intrusion	SO-C		
	Density effects on groundwater flow	SO-C		
	Hydrological response to earthquakes	SO-C		

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table 8-17. Natural FEPs and their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
SUBSURFACE GEOCHEMICAL			1.3
Groundwater geochemistry			1.3.1
Groundwater geochemistry	NMD		
Changes in groundwater chemistry			1.3.2
Saline groundwater intrusion	SO-C		
Fresh groundwater intrusion	SO-C		
Changes in groundwater Eh	SO-C		
Changes in groundwater pH	SO-C		
Effects of dissolution on groundwater chemistry	SO-C		
GEOMORPHOLOGICAL			1.4
Physiography			1.4.1
Physiography	NMD		
Meteorite impact			1.4.2
Meteorite impact	SO-P		
Denudation			1.4.3
Weathering			1.4.3.1
Mechanical weathering	SO-C		
Chemical weathering	SO-C		
Erosion			1.4.3.2
Aeolian erosion	SO-C		
Fluvial erosion	SO-C		
Mass wasting	SO-C		
Sedimentation			1.4.3.3
Aeolian deposition	SO-C		
Fluvial deposition	SO-C		
Lacustrine deposition	SO-C		
Mass wasting	SO-C		
Soil development			1.4.4
Soil development	SO-C		
SURFACE HYDROLOGICAL			1.5
Fluvial			1.5.1
Surface flow characteristics: stream/river flow	SO-C		
Lacustrine			1.5.2
Surface water bodies	SO-C		
Infiltration / recharge / discharge			1.5.3
Groundwater discharge	SO-C		
Groundwater recharge	SO-C		
Infiltration	SO-C		
Changes in surface hydrology			1.5.4
Changes in groundwater recharge / discharge	SO-C		
Lake formation / infilling	SO-C		
River flooding	SO-C		
CLIMATIC			1.6
Climate			1.6.1
Precipitation	SO-C		
Temperature	SO-C		
Wind	SO-C		
Climate change			1.6.2
Meteorological			1.6.2.1
Climate change	NMD		
Drought	SO-C		

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table 8-17. Natural FEPs and their Screening Classifications (continued)

FEPs		Screening Classification	Comments	Reference Appendix SCR Section
Glaciation				1.6.2.2
	Glaciation	SO-P		
	Permafrost	SO-P		
MARINE				1.7
Seas				1.7.1
	Coastal waters	SO-C		
	Ocean waters	SO-C		
	Estuaries	SO-C		
Marine sedimentology				1.7.2
	Coastal erosion	SO-C		
	Marine sediment transport and deposition	SO-C		
Sea level change				1.7.3
	Sea level change	SO-C		
ECOLOGICAL				1.8
Flora & fauna				1.8.1
	Plants	SO-C		
	Animals	SO-C		
	Microbes	SO-C		
Changes in flora & fauna				1.8.2
	Natural ecological development	SO-C		

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

- FEPs are not likely to affect the results of demonstration and is screened on the basis of low probability of occurrence (labeled SO-P) - FEPs having a reasonable likelihood of occurring during the isolation period are assessed accordingly

Appendix SCR also demonstrates conservatism. Conservatism includes identifying and taking no credit for selected FEPs that might result in "beneficial" consequence to the demonstration. For example, considering FEPs, such as organic degradation, sorption kinetics, and colloid agglomeration, would result in reducing the amount of hazardous constituents calculated to reach the disposal unit.

Uncertainty can also be related to uncertainty involving imprecisely known variables, i.e., the variability or uncertainty in the population from which a statistical measure is derived. Model input values selected on the basis of statistical parameter distributions incorporate this range of uncertainty. To account for parameter and conceptual model uncertainty, the DOE has implemented a number of reasonably conservative assumptions and modeling approaches that, cumulatively, tend to overestimate the potential for brine and gas flow.

Table 8-18. Waste-Induced or Repository-Induced FEPs and Their Screening Classification

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
MECHANICAL EFFECTS			2.1
Subsystem Characteristics			2.1.1
Geological characteristics	NMD		2.1.1.1
Repository characteristics	NMD		2.1.1.2
Waste and container characteristics	NMD		2.1.1.3
Backfill characteristics	SO-C		2.1.1.4
Seal characteristics	NMD		2.1.1.5
Post-closure monitoring	SO-C		2.1.1.6
Gas Generation			2.1.2
Microbial Gas Generation			2.1.2.1
Microbial degradation of organic material	NMD		
Effects of temperature on microbial degradation	NMD		
Effects of pressure on microbial degradation	SO-C		
Effects of radiation on microbial degradation	SO-C		
Effects of biofilms on microbial degradation	NMD		
Corrosion			2.1.2.2
Gases from metal corrosion	NMD		
Effects of galvanic coupling on gas generation rates	SO-P		
Chemical effects from corrosion on gas generation rates	NMD		
Radiolytic Gas Generation			2.1.2.3
Radiolysis of brine	SO-C		
Radiolysis of cellulosics	SO-C		
Helium production	SO-C		
Radioactive gas production	SO-C		
Rock Mechanics			2.1.3
Excavation-induced fracturing			2.1.3.1
Formation of disturbed rock zone	NMD		
Excavation-induced local changes in stress	NMD		
Salt Creep			2.1.3.2
Salt creep	NMD		
Changes in stress field due to salt creep	NMD		
Roof Falls			2.1.3.3
Roof falls	NMD		
Mechanical Effects of Gas Generation			2.1.3.4
Mechanical effects of gas generation	NMD		
Effects of Explosions			2.1.3.5
Gas effects: explosions	NMD		
Explosions due to nuclear criticality	SO-P		
Mechanical Effects of Materials			2.1.3.6
Consolidation of waste	NMD		
Backfill	SO-C		
Movement of canisters	SO-C		
Mechanical failure of canisters	NMD		
Consolidation of seals (salt)	NMD		
Mechanical failure of seals (salt)	SO-P		

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table 8-18. Waste-Induced or Facility-Induced FEPs and Their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
Mechanical failure of seals (concrete)	SO-P		
Mechanical failure of seals (clay)	SO-P		
Investigation borehole seal failure	SO-C		
Subsidence			2.1.3.7
Subsidence	SO-C		
Large-scale fracturing	SO-P		
Fluid Dynamics			2.1.4
Repository-induced flow			2.1.4.1
Brine inflow	NMD		
Capillary rise			2.1.4.2
Wicking	NMD		
Effects of Gas Generation			2.1.4.3
Brine flow due to gas production	NMD		
Backfill-Hydraulic Effects	SO-C	Beneficial	2.1.4.4
CHEMICAL AND BIOCHEMICAL EFFECTS			2.2
Repository			2.2.1
Metal corrosion	SO-C		2.2.1.1
Microbial processes	SO-C		2.2.1.2
Radiolysis	SO-C		2.2.1.3
Dissolution reactions	SO-C		2.2.1.4
Dissolution reaction kinetics	SO-C	Beneficial	2.2.1.4
Decomposition of cementitious sludges	SO-C	Beneficial	2.2.1.5
Chemical effects of backfill	SO-C	Beneficial	2.2.1.6
Leachate			2.2.2
Initial liquid content	NMD		
Brine inflow	NMD		
Leachate Formation	NMD		
Waste/Waste Container Persistence			2.2.3
Waste persistence	NMD		
Container persistence	SO-C	Beneficial	
Oxidation/Reduction Potential			2.2.4
Organics			2.2.4.1
Degradation of organics	SO-C	Beneficial	
Metals			2.2.4.2
Metal speciation	SO-C		
Redox kinetics	SO-C		
Localized reducing zones	SO-C		
Redox fronts	SO-P		
Adsorptivity			2.2.5
Organics			2.2.5.1
Post-closure VOC release mechanisms and increased volatilization potential	SO-C		
Metals			2.2.5.2
Sorption	SO-C	Beneficial	
Sorption kinetics	SO-C		
Changes in sorptive surfaces	SO-C		

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table 8-18. Waste-Induced or Facility-Induced FEPs and Their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
Hydrolysis			2.2.6
Organics			2.2.6.1
Organic hydrolytic degradation	SO-C	Beneficial	
Organic half-lives	SO-C	Beneficial	
Metals			2.2.6.2
Metal hydrolysis reactions	SO-C		
Reaction kinetics	SO-C		
Hazardous-Constituent Degradation			2.2.7
Organics			2.2.7.1
Aerobic degradation	SO-C	Beneficial	
Anaerobic degradation	SO-C	Beneficial	
Hydrolysis/substitution	SO-C	Beneficial	
Degradation of organic products	SO-C		
Metals			2.2.7.2
Metals	SO-P		
THERMAL EFFECTS			2.3
Heat Generation			2.3.1
Radioactive decay	SO-C		2.3.1.1
Nuclear criticality	SO-P		2.3.1.2
Exothermic reactions	SO-C		2.3.1.3
Thermo-Mechanical Effects			2.3.2
Thermally-induced stress and fracturing	SO-C		
Thermal-Fluid Dynamic Effects			2.3.3
Convection	SO-C		
Thermo-Chemical Effects			2.3.4
Chemical changes (brine chemistry)	SO-C		
WASTE MOBILITY AND TRANSPORT			2.4
Liquid Phase Source Term			2.4.1
Organics			2.4.1.1
Solubility of hazardous VOC/SVOCs	SO-C	Beneficial	
Non-aqueous phase liquids	SO-P		
Metals			2.4.1.2
Hazardous metal solubility	SO-C		
Reaction kinetics	SO-C	Beneficial	
Organic complexation	SO-C		
Colloid complexation	SO-C		
Gas Phase Source Term			
Organics			
VOC/SVOC volatilization	NMD		2.4.2
Inner-layer correction factors	SO-C		2.4.2
Retardation of Hazardous Constituents			2.4.3
Organics			2.4.3.1
Retardation of VOC/SVOC	SO-C	Beneficial	
Metals			2.4.3.2
Sorption processes	SO-C	Beneficial	
Sorption kinetics	SO-C		
Precipitation	SO-C	Beneficial	

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table 8-18. Waste-Induced or Facility-Induced FEPs and Their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
Transport Modes			2.4.4
Solute Transport			2.4.4.1
Transport of dissolved, aqueous metals	NMD		
Colloid Transport			2.4.4.2
Colloid transport	SO-C		
Colloid filtration	SO-C	Beneficial	
Colloid agglomeration and stability	SO-C	Beneficial	
Colloid sorption	SO-C	Beneficial	
Particulate Transport			2.4.4.3
Particle suspensions	SO-C		
Rinse	SO-C		
Microbial Transport			2.4.4.4
Microbial transport of hazardous metals	SO-C		
Retardation of microbes carrying metals	SO-C	Beneficial	
Gas Transport			2.4.4.5
Transport of hazardous organic gases	NMD		
Transport Mechanisms			2.4.5
Advection			2.4.5.1
Advection	NMD		
Unsaturated flow	NMD		
Diffusion			2.4.5.2
Diffusion of hazardous constituents	SO-C		
Matrix diffusion	SO-C	Beneficial	
Thermo-Chemical Transport Phenomena			2.4.5.3
Soret effect	SO-C		
Electrochemical Transport Phenomena			
Electrochemical effects	SO-C		2.4.5.4
Galvanic coupling	SO-P		
Electrophoresis	SO-P		
Physicochemical Transport Phenomena			2.4.5.5
Dilution	NMD		
Alpha recoil	SO-C		
Enhanced diffusion due to chemical gradients	SO-C		
Formation of colloids due to chemical gradients	SO-C		
Mixing of waters of different salinities	SO-C		
Osmosis	SO-C	Beneficial	

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table 8-19. Human-Initiated Events and Processes and Their Screening Classifications

FEPs	Screening Classification			Reference Appendix SCR Section
	Recent & Ongoing	Future Outside	Future Inside	
DRILLING				3.1
Drilling intrusion				3.1.1
Oil & gas exploration	SO-C	SO-C	SO-P	
Potash exploration	SO-C	SO-C	SO-P	
Water resources exploration	SO-C	SO-C	SO-P	
Oil & gas exploitation	SO-C	SO-C	SO-P	
Groundwater exploitation	SO-C	SO-C	SO-P	
Enhanced oil & gas recovery	SO-C	SO-C	SO-P	
Oil & gas storage	SO-C	SO-C	SO-P	
Fluid disposal	SO-C	SO-C	SO-P	
Archeology	NA	SO-P	SO-P	
Geothermal	NA	SO-P	SO-P	
Other resources	NA	SO-P	SO-P	
Deliberate intrusion	NA	NA	SO-P	
Drilling-induced flow				3.1.2
Drilling fluid loss (e.g. thief zones)	SO-C	SO-C	SO-P	
Blowouts	SO-C	SO-C	SO-P	
Fluid extraction				3.1.3
Oil & gas extraction	SO-C	SO-C	SO-P	
Water extraction	SO-C	SO-C	SO-P	
Fluid injection				3.1.4
Enhanced oil and gas production	SO-C	SO-C	SO-P	
Hydraulic fracturing	SO-C	SO-C	SO-P	
Waterflooding	SO-C	SO-C	SO-P	
Liquid waste disposal	SO-C	SO-C	SO-P	
Hydrocarbon storage	SO-C	SO-C	SO-P	
Borehole-induced solution and subsidence				3.1.5
Borehole-induced solution and subsidence	SO-C	SO-C	SO-P	
EXCAVATION ACTIVITIES				3.2
Mining				3.2.1
Potash mining	SO-C	SO-C	SO-P	
Excavation-related flow				3.2.2
Hydrological effects of potash mining	SO-C	SO-C	SO-P	
Geochemical effects of excavations				
Solution mining	SO-C	SO-C	SO-P	
Improper Design and Operation	SO-P	SO-P	SO-P	3.3
Biosphere Alterations	SO-C	SO-C	SO-C	3.4

SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability
NA Not applicable.

8.4.4 Sensitivity Analyses

The EPA (1992) draft NMVP guidance document suggests that the petitioner should provide an assessment of the influence of changes in the magnitude of model parameters in order to demonstrate that the simulation shows the greatest sensitivity to the most influential processes (US EPA 1992, 32). Monte Carlo uncertainty analyses, in which multiple simulations are performed using different sampled values for important parameters, have been performed using preliminary versions of the modeling system used in the NMVP (WIPP Performance Assessment Department 1992, 6-1 through 6-12; WIPP Performance Assessment Department 1993, 7-1 through 7-3; Helton et al. 1993, 5-1). Results of these preliminary analyses provide qualitative insights about the potential effect that varying model parameters used in this demonstration might have on gas and brine migration.

In general, quantitative comparison between the current BRAGFLO simulation and preliminary modeling activities is inappropriate, primarily due to differences in model configuration and assumptions. Qualitatively, sensitivity analyses and experience using the BRAGFLO code have led to identifying a subset of BRAGFLO parameters that are considered most influential to model results. Table 8-20 lists selected parameters and discusses their relative importance with respect to gas and brine migration. These parameters fall into three groups: those for which uncertainty has the potential to result in substantial changes in gas or brine migration; those for which uncertainty may result in minor changes in gas or brine migration; and those for which uncertainty has little or no effect on gas or brine migration. The order of parameters within each group is alphabetical, and does not indicate a relative ranking. Parameters in the first group are primarily related to the total amount of gas generated, which is, in turn, sensitive to the amount of brine available for corrosion and microbial activity. Parameters in the second group are primarily related to rates of gas generation or to material properties of the repository and surrounding rock. Parameters in the third group include those for which reasonable uncertainty would not result in changes in gas and brine migration.

Given the determination that no migration is demonstrated using bounding comparisons to HBL soil concentrations for the organic gas phase hazardous constituents, rather than gas migration distance, and also given the determination that no brine will leave the waste region, uncertainty in these parameters does not have the potential to affect migration of hazardous constituents from the disposal unit. Model sensitivity to these parameters is discussed to demonstrate, as suggested in the EPA guidance, that the modeling system shows appropriate sensitivity to influential processes.

Table 8-20. Qualitative Discussion of Model Sensitivity to Selected Parameters

Parameter	Discussion
	Parameters for which Uncertainty May Affect Gas and Brine Migration
Gas Generation: PROB_DEG	**Probability that microbial degradation reactions will occur and will generate gas.** For this analysis, this parameter was set at the value which resulted in the maximum potential for microbial gas generation. Other values for this parameter would have resulted in less gas generation and could affect gas and brine migration.
Gas Generation: SAT_WICK	**Brine saturation in the waste region adjusted for capillary-rise into waste material.** Capillary rise in the waste was not incorporated into previous simulations. Increasing the parameter value would tend to increase gas generation.
Halite: PRMX_LOG	**Intrinsic permeability of impure Salado halite.** Gas and brine migration are believed to be sensitive to this parameter, as noted in previous BRAGFLO simulations. Halite permeability affects the amount of brine that may enter the repository and be available for gas generation.
Marker Bed: PRMX_LOG	**Intrinsic permeability of anhydrite MB 139.** Gas and brine migration are believed to be sensitive to this parameter, as noted in previous BRAGFLO simulations. Marker bed permeability affects the amount of brine that may enter the repository and be available for gas generation. Marker bed permeability may also affect the extent to which gas and brine migrate away from the repository.
	Parameters for which Uncertainty May Have a Small Effect on Gas and Brine Migration
Gas Generation: CORRMCO2	**Inundated corrosion rate for steel without CO_2 present.** Gas and brine migration are believed to be moderately sensitive to this parameter, as noted in previous BRAGFLO simulations.
Gas Generation: GRATMICI	**Brine-inundated microbial degradation rate.** Gas and brine migration are believed to be moderately sensitive to this parameter, as noted in previous BRAGFLO simulations.
Gas Generation: GRATMICH	**Humid microbial degradation rate.** Gas and brine migration are believed to be moderately sensitive to this parameter, as noted in previous BRAGFLO simulations.
Gas Generation: FBETA	**Reaction between microbial gas product with steel and steel corrosion product (coefficient Factor β).** Coefficient Factor β represents a process not incorporated into previous simulations. Increasing this factor would increase the gas generation rate, but the total amount of gas generated is believed to be relatively insensitive to this parameter.
Halite: POROSITY	**Effective porosity of impure Salado halite.** Gas and brine migration may be moderately sensitive to variation in this parameter because of its influence on the porosity of the DRZ, which affects the volume available for storage of gas near the repository.
Marker Bed: RELP_MOD	**Choice of relative permeability model for two-phase flow in MB 139.** The Brooks-Corey relative permeability model was used for this analysis for all material regions. Previous analyses have suggested that gas migration in MB 139 may be moderately sensitive to the use of the Brooks-Corey model, rather than the Van Genuchten/Parker model. Brine migration is expected to be insensitive to this choice.

Table 8-20. Qualitative Discussion of Model Sensitivity to Selected Parameters (continued)

Parameter	Discussion
Parameters for which Uncertainty Is Expected to Have Little or No Effect on Gas and Brine Migration	
Halite: COMP_RCK-	**Rock compressibility of impure Salado halite.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Halite: PRESSURE	**Far field pore pressure in the Salado Formation.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Marker Bed: COMP_RCK	**Rock compressibility of anhydrite MB 139.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Marker Bed: PORE_DIS	**Pore size distribution of anhydrite MB 139.** Gas and brine migration are expected to be insensitive to variation in this parameter
Marker Bed: SAT_RBRN	**Residual brine saturation of anhydrite MB 139.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Marker Bed: SAT_RGAS	**Residual gas saturation of anhydrite MB 139.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Shaft Asphalt: PRMX_LOG	**Intrinsic permeability of asphalt plug at the Rustler/Salado Formation interface (0-10,000 years).** Given the high level of confidence in the long-term performance of the asphalt component of the shaft seal system, gas and brine migration is not expected to be sensitive to variation in this parameter. As is true for the properties of all major components in the shaft seal systems, fluid migration could be strongly affected if different materials with different properties were used.
Shaft Clay: PRMX_LOG	**Initial intrinsic permeability of clay materials in the shaft placed in the lower Salado Formation (corrected for DRZ effect in time steps).** Given the high level of confidence in the long-term performance of the clay component of the shaft seal system, gas and brine migration is not expected to be sensitive to variation in this parameter. As is true for the properties of all major components in the shaft seal systems, fluid migration could be strongly affected if different materials with different properties were used.
Shaft Concrete: PRMX_LOG	**Intrinsic permeability of concrete shaft materials (i.e., upper, middle, and lower plugs) within the Salado Formation (0-400 years).** Given the high level of confidence in the early-time performance of the concrete component of the shaft seal system, gas and brine migration is not expected to be sensitive to variation in this parameter. As is true for the properties of all major components in the shaft seal systems, fluid migration could be strongly affected if different materials with different properties were used.
Shaft DRZ: PRMX_LOG	**Factor used to capture the effect of the DRZ on fluid flow around the shaft, by increasing the intrinsic permeability of the relevant shaft material.** The equation that incorporates the shaft DRZ parameter is described in shaft material parameter sheets for salt, asphalt, and clay. The DRZ shaft parameter is not used for concrete or earth shaft materials, where a DRZ is not expected to form. This parameter was not used in previous simulations, and gas and brine migration are expected to be insensitive to variation in it.

Table 8-20. Qualitative Discussion of Model Sensitivity to Selected Parameters (continued)

Parameter	Discussion
Shaft Salt: PRMX_LOG	**Intrinsic permeability of compacted crushed salt within the Salado Formation.** Given the high level of confidence in the long-term performance of the salt component of the shaft seal system, gas and brine migration is not expected to be sensitive to variation in this parameter. As is true for the properties of all major components in the shaft seal systems, fluid migration could be strongly affected if different materials with different properties were used.
Shaft Salt: PORE_DIS	**Pore size distribution of compacted crushed salt.** Given the high level of confidence in the long-term performance of the salt component of the shaft seal system, gas and brine migration are not expected to be sensitive to variation in this parameter. As is true for the properties of all major components in the shaft seal systems, fluid migration could be strongly affected if different materials with different properties were used.
Shaft Salt: SAT_RBRN	**Residual brine saturation of compacted crushed salt.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Shaft Salt: SAT_RGAS	**Residual gas saturation of compacted crushed salt.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Waste Panels: SAT_RGAS -	**Residual gas saturation of model regions containing waste.** Gas and brine migration are expected to be insensitive to variation in this parameter.
Waste Panels: SAT_RBRN -	**Residual brine saturation of model regions containing waste.** Increasing SAT_RBRN would tend to inhibit brine flow through waste-containing regions. Conversely, decreasing SAT_RBRN would tend to facilitate brine flow at low brine saturations. As discussed in Section 8.4.1.2, SAT_RBRN would have to be decreased to 5.1 percent for brine to become mobile, which is much less than the 27.6 percent median value used in the demonstration. Gas and brine migration are expected to be insensitive to variation in this parameter.

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9.0 Regulatory Compliance Assessment
Abstract

This chapter demonstrates compliance, based on the information and results presented in the preceding chapters, with the no-migration standards of Title 40 of the Code of Federal Regulations (CFR) § 268.6 during disposal operations and closure of the facility.

Containment of Releases

During waste emplacement operations at the Waste Isolation Pilot Plant (WIPP) facility, containment of volatile organic compounds (VOCs) will be required. Containers of transuranic (TRU) waste must be vented through carbon composite filters to preclude the buildup of hydrogen as the result of radiolysis and other processes known to occur in drums of radioactive waste; these filters will also prevent the release of metals in particulate form. This venting allows passive diffusion of VOCs from the containers during waste emplacement.

The no-migration demonstration assumes a maximum of 10 panel-equivalents during the operational/closure time period (eight panels and all associated access drifts). Based on this scenario, concentrations of VOCs resulting from releases past nine closed and one full open panel equivalents have been calculated to be between one-third and five orders of magnitude below the health-based levels (HBLs) at the point of compliance, thereby meeting the containment requirements of 40 CFR § 268.6 for operations at the WIPP facility.

The long-term calculations, presented in Chapter 8, demonstrate that the containment requirements will also be met for the post-closure period. BRAGFLO brine and gas flow simulations show zero gas saturations at all subsurface disposal unit boundaries, with exception of the shaft. As a bounding compliance demonstration, the DOE demonstrates that gas-phase organic constituent concentrations at the shaft unit boundary will be orders of magnitude below HBLs using bounding soil-based concentrations. Based on the predicted brine saturation of the waste-disposal panels, the BRAGFLO simulation demonstrates that contaminated brine is physically incapable of leaving the waste area. Consequently, the DOE demonstrates that there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous.

Human Intrusion

The Resource Conservation and Recovery Act (RCRA) requires that institutional controls be used to ensure that access to hazardous waste disposal sites is appropriately restricted. The Department of Energy (DOE) has taken a number of steps to reduce the likelihood of human intrusion after closure of the facility. Upon closure of the facility, the DOE will notify local agencies to prevent access to the land, and permanent warning markers will be placed (as required by 40 CFR 191 standards). Cumulatively, these types of measures

will be effective in reducing the likelihood of human intrusion into the repository, and, therefore, satisfy this aspect of the RCRA regulations.

Monitoring Requirements

Operational Monitoring. The monitoring requirements of 40 CFR § 268.6(a) include a plan which "detects migration at the earliest practicable time." Migration from panels will result in VOC concentrations which are one-third to five orders of magnitude below the HBLs; the conservative assumptions made in the migration calculations provide a significant margin of safety. Because of this, and because the DOE has collected more than four years of data on background levels of VOCs in air at the site, the DOE will implement confirmatory VOC monitoring activities into the disposal phase.

Long-Term Monitoring. Similar to the assurance requirements under 40 CFR § 191.14, RCRA long-term monitoring will consist of methods and techniques designed to focus on indicators of effective long-term performance of the repository. This approach provides an alternative to intrusive methods of monitoring for potential contaminant migration, which may jeopardize the integrity of the disposal unit.

Infrequent Events and Processes

Under 40 CFR § 268.6, an analysis must be performed to identify and quantify any aspects of a no-migration demonstration that contribute significantly to uncertainty. It must include "an evaluation of the consequences of predictable future events, including, but not limited to, earthquakes, floods, severe storm events, droughts, or other natural phenomena." These infrequent events are not expected to occur within the 35-year operational/closure time frame.

Waste Acceptance/Waste Compliance

The DOE is currently implementing waste characterization programs at each of the 10 major generator/storage sites in accordance with the *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP). Each generator/storage site will develop a Quality Assurance Project Plan (QAPjP) to address all TRU waste characterization requirements. The DOE has established acceptance criteria for waste to be disposed of at the WIPP facility. These criteria address operational safety requirements, Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC) regulations for TRU waste transportation, and RCRA waste analysis requirements. Waste acceptance criteria certification programs are overseen by the National Transuranic Programs Office to ensure that TRU waste received at the WIPP facility meet these criteria.

A performance-based waste envelope will be identified through performance assessment modeling and other analyses to predict waste parameters that may adversely affect the ability of the WIPP to isolate waste. Once identified, bounding characteristics relative to the types and forms of waste to be disposed will be developed.

Program/Facility Modifications Designed to Enhance Repository Performance

In order to demonstrate compliance with 40 CFR § 268.6, performance will be assessed. Portions of the engineered waste management system, portions of the naturally occurring repository, and/or the TRU waste to be disposed of in the facility may be modified as required to ensure compliance. Factors that will be considered include effectiveness of the modification with regard to longevity, degree, and confidence. Other factors include availability of proposed technology, operational constraints at DOE generator/storage sites, regulatory constraints, and cost.

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9.0 REGULATORY COMPLIANCE ASSESSMENT

The objective of this chapter is to demonstrate compliance, based on the information and results presented in the preceding chapters, with the no-migration standards of Title 40 of the Code of Federal Regulations (CFR) § 268.6 during disposal operations, closure of the facility, and post-closure.

9.1 Containment of Releases

As specified in 40 CFR § 268.6(a), the U.S. Department of Energy (DOE) must demonstrate that hazardous constituents will not migrate beyond the unit boundary as long as the wastes remain hazardous. "No migration" is interpreted as no movement beyond the unit boundary in concentrations exceeding health-based levels (HBLs) established by the U.S. Environmental Protection Agency (EPA) (EPA 1992, 1). For the post-closure period the unit boundary used to demonstrate compliance for the Waste Isolation Pilot Plant (WIPP) facility is defined as the portion of the Salado Formation bounded laterally by the land-withdrawal area. For the disposal and closure period, the location of the maximum concentration 5.0 ft (1.5 m) above the surface of the facility is used as the point of compliance. Modeling techniques and bounding calculations are used to demonstrate no migration, based on concentrations and toxicities of hazardous constituents in the waste and predicted physical and chemical conditions of the disposal system and surrounding area.

9.1.1 Operational Containment

During waste emplacement operations at the WIPP facility, containment of volatile organic compounds (VOCs) will be required. Containers of transuranic (TRU) waste must be vented through carbon composite filters to preclude the buildup of hydrogen as the result of radiolysis and other processes known to occur in drums of radioactive waste. This venting allows passive diffusion of VOCs from the containers during waste emplacement. The no-migration demonstration in Chapter 5 is based on average headspace gas data, an estimated effective gas generation rate, the mine ventilation rate, and an air dispersion factor predicted through modeling.

The operational no-migration demonstration assumes a maximum of 10 panel-equivalents during the operational/closure time period (eight panels and all associated access drifts). A panel-equivalent is defined as a hazardous waste management unit containing 81,000 drums of waste. Of the ten panel equivalents, nine are assumed to be closed and one is assumed to be open with filling and closure of rooms containing 11,571 drums within the panel to occur over a 2.5-year period. Based on this scenario, concentrations of VOCs resulting from releases past panels have been calculated to be between one-third and five orders of magnitude below the health-based levels (HBLs) at the point of compliance, thereby meeting the containment requirements of 40 CFR § 268.6 for operations at the WIPP facility.

9.1.2 Long-Term Containment

In order to assess post-closure repository performance, the long-term behavior of the waste in the repository and the effectiveness of the waste management system in isolating the waste is considered. For the purposes of a long-term no-migration demonstration, the undisturbed performance of the repository is the primary focus. The unit boundary for the long-term demonstration is the Salado Formation bounded by the land-withdrawal area.

The long-term calculations, presented in Chapter 8, demonstrate that the containment requirements will also be met for the post-closure period. BRAGFLO brine and gas flow simulations show zero gas saturations at all subsurface disposal unit boundaries, with exception of the shaft. As a bounding compliance demonstration, the DOE demonstrates that gas-phase organic constituent concentrations at the shaft unit boundary will be orders of magnitude below HBLs using bounding soil-based concentrations. Based on the predicted brine saturation of the waste-disposal panels, the BRAGFLO simulation demonstrates that contaminated brine is physically incapable of leaving the waste area. Consequently, the DOE demonstrates that there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous.

9.2 Human Intrusion

In its conditional No-Migration Determination (NMD) for the WIPP test phase, the EPA stated that although the variance for the WIPP is based on a finding of no migration during the test phase, it focused on the undisturbed performance of the repository. The EPA stated its belief that, in the context of Resource Conservation and Recovery Act (RCRA) no-migration variance decisions, the question of human intrusion is best addressed by considering the likelihood of intrusion and the imposition of controls to make such intrusions unlikely events. This topic was addressed by the EPA in the proposed NMD for the WIPP facility.

The EPA emphasized that this approach to human intrusion is consistent with its general approach under the RCRA, both in permitting and variances. Under the RCRA, the EPA typically relies on institutional controls, both active and passive, imposed through general regulatory standards and site-specific conditions to ensure that access to a hazardous waste disposal site is appropriately restricted. The EPA stated that any WIPP no-migration variance in the disposal phase will have to impose long-term passive institutional controls (such as land withdrawal, records, and markers) to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits for the facility may have terminated.

The DOE has taken a number of steps to reduce the likelihood of human intrusion after closure of the facility. The federal government owns the entire surface and subsurface estate at the WIPP site, with the exception of a portion of the subsurface estate that is currently leased below 6,000 ft (1,829 m) for oil and gas production. Upon final closure of the WIPP facility, the DOE will notify all state and county planning offices, deed and

record offices, oil and gas commissions, and other agencies to prevent access by unknowing parties. The DOE will also place permanent warning markers at the site, as required by 40 CFR Part 191. Record-keeping and marker systems will be implemented with a "defense in depth" approach, ensuring the durability of marker system components and messages, the ability to interpret the messages, and the accessibility of the records.

The DOE has prepared a post-closure management strategy that consists of active and passive institutional controls, as described in Chapter 3 and detailed in Appendices AAC and PMR. Cumulatively, these controls will effectively reduce the likelihood of human intrusion into the repository and will, therefore, satisfy this aspect of the RCRA regulations.

9.3 Monitoring Requirements

The WIPP facility has established operational monitoring programs as discussed in Chapter 6. The monitoring programs at the WIPP facility are operated under approved Quality Assurance Project Plans (QAPjPs) to ensure that all data are collected in accordance with established Data Quality Objectives (DQOs). Monitoring systems have been installed, sampling programs have been implemented in and around the WIPP facility, and background data have been collected.

9.3.1 Operational Monitoring

The air pathway is the only credible release pathway during disposal operations, and this pathway will be eliminated upon final closure of the WIPP facility. A VOC monitoring program was established in 1991 to obtain background air data in preparation for the test phase. Background air data are included in Appendix BAD and have been provided annually to the EPA.

The monitoring requirements of 40 CFR § 268.6(a) include a plan which "detects migration at the earliest practicable time." Migration from panels will result in VOC concentrations at the point of compliance which are one-third to five orders of magnitude below the HBLs; therefore, the conservative assumptions made in the migration calculations provide a significant margin of safety. Because of this, and because the DOE has collected more than four years of data on background levels of VOCs in air at the site, the DOE will implement confirmatory VOC monitoring activities into the disposal phase.

9.3.2 Long-Term Monitoring

Similar to the assurance requirements under 40 CFR § 191.14, RCRA long-term monitoring will consist of methods and techniques to focus on indicators of effective long-term performance of the repository. This approach provides an alternative to intrusive methods of monitoring for potential contaminant migration, which may jeopardize the integrity of the disposal unit. Long-term monitoring (LTM) is described in Chapter 6, and Appendix LTM.

9.4 Infrequent Events and Processes

Under 40 CFR § 268.6, an analysis must be performed to identify and quantify any aspects of a no-migration demonstration that contribute significantly to uncertainty. It must include "an evaluation of the consequences of predictable future events, including, but not limited to, earthquakes, floods, severe storm events, droughts, or other natural phenomena." These infrequent events, discussed in Section 5.3, are not expected to impact the repository within the 35-year operational/closure time frame.

The site selection process for the WIPP facility involved review of extensive geologic information for the WIPP site, consideration of the relative remoteness of the site, and consideration of the limited quantities of groundwater in the area (Section 1.2). Near-surface processes and events, including flooding, tornados, range fires, meteorite impact, erosion, dissolution, and sedimentation, are discussed in Chapter 8. Appendix SCR provides screening arguments for eliminating natural events and processes that are not included in the performance simulations.

9.5 Waste Acceptance/Waste Compliance

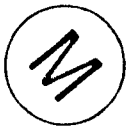
The DOE is currently planning to implement waste characterization programs at each of the ten major generator/storage sites in accordance with the *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP). Each generator/storage site will develop a QAPjP to address all TRU waste characterization requirements.

Waste characterization activities are currently ongoing at two generator/storage facilities: the Idaho National Engineering Laboratory (INEL) and the Rocky Flats Environmental Technology Site (RFETS). Headspace sampling and analyses have been conducted for approximately 900 drums of waste at the INEL and RFETS; the majority of the waste sampled at the INEL was generated at the RFETS. The no-migration demonstrations documented in Chapter 5 and Chapter 8 are based on these data.

Although waste characterization data from other generator/storage sites are not currently available, the data presented in Appendix WAP are considered bounding for headspace gas concentrations used in no-migration calculations. Much of the machining process for weapons manufacturing took place at the RFETS. Because VOCs were used in cleaning machine parts during the manufacturing process, it is likely that waste from the RFETS will contain higher concentrations of VOCs than the other DOE facilities in the weapons complex. In addition, the waste at the INEL and RFETS represent the largest portions of the existing TRU-mixed waste inventory.

As described in Section 4.2, the DOE has established acceptance criteria for waste to be disposed of at the WIPP facility. These criteria address operational safety requirements, Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC) regulations for TRU waste transportation, and RCRA waste analysis requirements. The final criteria will include criteria from the performance assessment models as well as

possible conditions that may be imposed by the EPA as part of a no-migration variance. The application of these criteria to the TRU and TRU-mixed waste inventory defines the inventory acceptable for disposal at the WIPP. Waste acceptance criteria (WAC) certification programs are overseen by the Office of National TRU Programs to ensure that TRU waste received at the WIPP facility meet these criteria.



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10.0 CERTIFICATION

The U. S. Department of Energy (DOE), through its Carlsbad Area Office, has signed as "owner and operator," and Westinghouse Electric Corporation, acting through its Waste Isolation Division (WID), has signed this No-Migration Variance Petition (NMVP) for the facility as "co-operator."

The DOE has determined that dual signatures best reflect the actual apportionment of Resource Conservation and Recovery Act (RCRA) responsibilities as follows:

- The DOE's RCRA responsibilities are for policy, programmatic directives, funding and scheduling decisions, Waste Isolation Pilot Plant (WIPP) requirements of DOE generator sites, auditing, and oversight of all other parties engaged in work at the WIPP, as well as general oversight.

- The WID's RCRA responsibilities are for certain day-to-day operations (in accordance with general directions given by the DOE and in the Management and Operating Contract as part of its general oversight responsibility), including, but not limited to, the following: certain waste handling, monitoring, record keeping, certain data collection, reporting, technical advice, and contingency planning.

In accordance with the requirements of Title 40 of the Code of Federal Regulations § 268.6(g), the following statement is made regarding the submittal of this NMVP to the Environmental Protection Agency (EPA):

> I certify under penalty of law that I have personally examined and am familiar with the information submitted in this petition and all attached documents, and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

Owner and Operator Signature: *Originals signed by George Dials
Title: Manager, Carlsbad Area Office
for: U.S. Department of Energy
Date: **

Co-Operator Signature: *Originals signed by Joe Epstein
Title: General Manager
for: Westinghouse Electric Corporation
Date: **

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GLOSSARY OF TERMS

40 CFR PART 261. *Identification and Listing of Hazardous Waste*. This part identifies those solid wastes which are subject to regulation as hazardous wastes under Parts 262–265, 268, 270, 271, and 124 of Title 40 of the Code of Federal Regulations.

40 CFR PART 264. *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*. This subpart establishes minimum national standards which define the acceptable management of hazardous waste.

40 CFR PART 264. Subpart G. This subpart of 40 CFR Part 264 defines closure and post-closure requirements pertaining to hazardous waste management units.

40 CFR PART 264. Subpart X. This subpart specifies requirements that apply to owners and operators of facilities that treat, store, or dispose of hazardous waste in miscellaneous hazardous waste management units.

40 CFR PART 268. This regulation restricts the land disposal of hazardous waste and specifies treatment standards and/or treatment technologies that must be met or applied before hazardous wastes may be land disposed. Section 268.6 provides for petitioning to allow land disposal of untreated hazardous waste if it can be demonstrated to a reasonable degree of certainty that there will be no migration of hazardous constituents from the disposal unit for as long as the waste remains hazardous.

40 CFR PART 270. This regulation establishes provisions for the Hazardous Waste Permitting Program under Subtitle C of RCRA. This regulation and the associated State of New Mexico regulation require the permitting of the WIPP as a hazardous waste management unit.

ACCEPTABLE KNOWLEDGE. The detailed knowledge of the processes and materials that generated the wastes in the DOE system.

ACTINIDE. An element in the actinide series beginning with element 89 and continuing through element 103. All the transuranic nuclides considered in this document are actinides.

ACTIVE INSTITUTIONAL CONTROL. (1) Controlling access to a disposal site by any means other than passive institutional controls, (2) performing maintenance operations or remedial actions at a site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance (40 CFR § 191.12).

ACTIVITY. A measure of the rate at which a material emits nuclear radiation, usually given in terms of the number of nuclear disintegrations occurring in a given length of time. The unit of activity used in this document is the curie (Ci).

ADSORPTION. (1) Bonding, frequently ionic, of a substance to soil or some other medium. A substance is said to be adsorbed if the concentration in the boundary region of a soil particle is greater than in the interior of the continuous phase. (2) Adherence of gas molecules, or of ions or molecules in solution, to the surface of solids with which they are in contact.

AIR DISPERSION FACTOR. The ratio of the average concentration of a hazardous constituent released into the atmosphere to its maximum concentration at or beyond the unit boundary.

AIR LOCK. An intermediate chamber between zones of different static pressure.

ALARA. As Low As Reasonably Achievable; radiation protection program for minimizing personnel exposures.

ALPHA PARTICLE. A positively charged particle emitted in the radioactive decay of certain nuclides. Made up of two protons and two neutrons bound together, it is identical to the nucleus of a helium atom. It is the least penetrating of the three common types of radiation—alpha, beta, and gamma radiation.

ANHYDRITE. A mineral consisting of anhydrous calcium sulfate ($CaSO_4$). It is gypsum without water and is denser, harder, and less soluble.

ANOXIC CORROSION. Corrosion of metals in the absence of oxygen by anaerobic bacteria.

ANTHROPOGENIC. A phenomenon resulting from actions or processes originated by human society.

ANTICLINE. A fold of rocks whose core contains the stratigraphically older rocks; it is normally convex upward.

AQUIFER. An underground geological formation or part of a formation that is capable of yielding a significant amount of water to a well or spring (40 CFR § 191.12).

ARENACEOUS. Of the texture or character of sand.

ARGILLACEOUS ROCKS. Rocks containing appreciable amounts of clay, especially shale.

ARTESIAN. Refers to water confined underground under pressure so that it will rise in a well. Sometimes the word is used to mean that the water flows out at the surface, but that, strictly speaking, is "flowing artesian."

BACKFILL. Material placed around the waste containers, partially filling the open space in the disposal room.

BARRIER. "[A]ny material or structure that prevents or substantially delays movement of water and/or radionuclides toward the accessible environment. For example, a barrier may be a geologic structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around waste, provided that the material or structure substantially delays movement of water or radionuclides" (40 CFR § 191.12). Barriers also prevent or delay the movement of hazardous constituents.

BASELINE INVENTORY REPORT. Baseline waste inventory report for all transuranic wastes in the DOE complex.

BELL CANYON FORMATION. A sequence of rock strata that form the uppermost formation of the Delaware Mountain Group (Early Permian). It is immediately below the Castile Formation at about 4,000 ft (1,219 m) below the surface at the WIPP site contains oil at some locations.

BENTONITE. A commercial term applied to expansive clay materials containing montmorillonite (smectite) as the essential mineral.

BETA PARTICLE. A negatively charged particle emitted in the radioactive decay of certain nuclides; a free electron.

BIODEGRADATION. The process of consumption by microbial substances—usually organic materials such as cellulosics.

BIOLOGICAL HALF-LIFE. The time required for an organism to eliminate half the amount of a radionuclide ingested or inhaled.

BRAGFLO. A computer code used to simulate gas and brine flow, incorporating the effects of disposal room consolidation and closure, gas generation, and interbed fracturing.

BRINE. Saline water containing calcium (Ca), sodium (Na), potassium (K), chlorides (Cl), and minor amounts of other elements.

CALCITE. Calcium carbonate ($CaCO_3$).

CALIBRATE. To vary parameters of an applied computational model within a reasonable range until differences between observed data and computed values are minimized.

CALICHE. A limy material commonly found in layers on or within the surface of stony soils of arid or semiarid regions. It occurs in the form of gravels, sands, silts, and clays cemented together by calcium carbonate (lime) or as crusts at the surface of the soil.

CAMBRIAN. The first and oldest period of the Paleozoic Era.

CANISTER. As used in this document, a container, usually cylindrical, for remotely handled TRU waste. The waste will remain in this canister during and after burial. A canister affords physical containment but not shielding; shielding is provided during shipment by a cask.

CAPITAN REEF. A buried fossil limestone reef of Permian age that rings the Delaware Basin except in the south.

CARBONATES. A compound containing the radical CO_3^-, for example, a calcium and magnesium mineral such as $CaMg(CO_3)_2$, dolomite.

CARCINOGENICITY. The ability of a substance to cause the development of cancerous growths in living tissue. Such substances are usually grouped in two classifications: (1) those that are known to induce cancer in man or animals either by operational exposure in industry or by ingestion in feedstuffs and (2) those that have been found to cause cancer in animals under experimental conditions.

CARLSBAD POTASH DISTRICT. The area east of Carlsbad and north and west of the Los Medaños site formally designated by the U.S. Geological Survey as having potentially economic grades of potash mineralization.

CASK. A massive shipping container providing shielding for highly radioactive materials and holding one or more canisters.

CASTILE FORMATION. A formation of evaporite rocks (mainly anhydrite with a few halite interbeds) of Permian age that immediately underlies the Salado Formation in which the WIPP disposal level is excavated. May contain brine pockets.

CENTRAL BASIN PLATFORM. The geological region covering an area of several hundreds of square miles separating the Delaware and Midland basins.

CENTRAL MONITORING ROOM (CMR). A room at the WIPP facility equipped to monitor alarm functions and provide reliable communications.

CENTRAL MONITORING SYSTEM (CMS). A computer system that monitors the WIPP facility instrumentation; operated from the Central Monitoring Room.

CHELATION. The process by which a central metal ion such as Cu^{2+} is attached to two or more nonmetal atoms in the same molecule, called ligands, where heterocyclic rings are formed between the cation and the anions.

COMPLIANCE EVALUATION. The assessment of compliance of a mined geologic waste repository. Title 40 CFR § 268.6 requires such evaluations be made to demonstrate to a reasonable degree of certainty (40 CFR § 268.6) that the performance standards will be met.

COMPUTATIONAL MODEL. The computational model is the implementation of the mathematical model. The implementation may be through analytical or numerical means. Often the analytical solution is numerically evaluated (e.g., numerical integration or evaluation of complex functions); hence, both solution techniques are typically coded on the computer. Consequently, the computational model is often called a computer model.

COMPUTER MODEL. A computer code to implement a corresponding mathematical model either by evaluating an analytical solution or by using a numerical technique.

CONCEPTUAL MODEL. A set of assumptions, usually qualitative, used to describe and represent a system for some analytical purpose. For a physical system, these assumptions address the system's geometry and dimensionality, initial and boundary conditions, time dependence, material properties, internal processes, and any other characteristics relevant to its behavior. The assumptions should be consistent with one another and with the known properties of the system within the context of its intended analytical purpose.

CONFIRMATION. For the purposes of this document, a term used to indicate support or establishment of certainty and/or validity of models used in reference to specific performance issues of the repository over any specific time frame of interest. In general, laboratory and field experiments at the Waste Isolation Pilot Plant and elsewhere are conducted to provide data in support of models (e.g., gas generation). Confirmation is used in a mechanistic sense and is not intended to have specific legal implications (*see* VALIDATION).

CONSERVATIVE. As a term used with predictions or estimates, "conservative" means one in which the uncertain inputs are used in a way that overestimates an adverse impact.

CONSULTATION AND COOPERATION AGREEMENT. An agreement that affirms the intent of the Secretary of Energy to consult and cooperate with the State of New Mexico with respect to State public health and safety concerns. The term "Agreement" means the July 1, 1981, Agreement for Consultation and Cooperation, as amended by the November 30, 1984, "First Modification," the August 4, 1987, "Second Modification," and the March 22, 1988, modification to the Working Agreement.

CONTACT-HANDLED WASTE. Transuranic waste that has a measured radiation dose rate at the container surface of 200 millirem per hour or less and can be safely handled without special equipment when placed in containers.

CORROSIVITY. The tendency of a metal to deteriorate by chemical attack.

CREEP. A very slow, usually continuous, time-dependent movement of soil or rock; refers to the geologic phenomenon experienced as the gradual flow of salt under compressive loading.

CREEP CLOSURE. Closure of underground openings, especially openings in salt, by plastic flow of the surrounding rock under lithostatic pressure.

CULEBRA DOLOMITE. The lower of two layers of dolomite within the Rustler Formation that are locally water bearing.

CULTURAL RESOURCE SITES. Human-associated ruins of archaeologic significance.

DECOMMISSIONING. Actions taken upon abandonment of the repository to reduce potential environmental, health, and safety impacts, including repository sealing as well as activities to stabilize, reduce, or remove radioactive materials or demolish surface structures.

DECOMMISSIONING PHASE. The term "decommissioning phase" means the period of time beginning with the end of the disposal phase and ending when all shafts at the Waste Isolation Pilot Plant repository have been backfilled and sealed.

DELAWARE BASIN. An area in southeastern New Mexico and adjacent parts of Texas where a sea deposited large thicknesses of evaporites some 250 million years ago. It is partially surrounded by the Capitan Reef.

DELAWARE MOUNTAIN GROUP. A set of three formations that underlie the Castile Formation at the Los Medaños site. The uppermost of these is the Bell Canyon Formation.

DESATURATE. To remove liquid from a material to reduce the degree of saturation. If all the liquid is removed from pores and cracks, the material is said to be completely dried.

DESIGN BASIS EARTHQUAKE (DBE). An earthquake that is the most severe design basis accident of this type and that produces the vibratory ground motion for which safety class items are designed to remain functional.

DESIGN BASIS TORNADO (DBT). A tornado that is the most severe design basis accident of that type applicable to the area under consideration.

DEVONIAN WOODFORD SHALE. This is a Devonian-age geological marker about 15,600 ft (4,755 m) deep that separates the Silurian Period from the Mississippian Period.

DEWEY LAKE (REDBEDS). Geologic formation overlying the Rustler Formation.

DIFFUSION, MOLECULAR. Movement of a contaminant due to the cumulative effect of the random motions of molecules.

DISCHARGE POINT (OR AREA). In groundwater hydraulics, the point (or area) where water comes out of an aquifer onto the surface.

DISPOSAL. See Land Disposal.

DISPOSAL FACILITY. A facility or part of a facility into which hazardous waste is intentionally placed and in which hazardous waste will remain after closure.

DISPOSAL PHASE. The term "disposal phase" means the period of time during which transuranic waste is disposed of at the Waste Isolation Pilot Plant, beginning with the initial emplacement of transuranic waste underground for disposal and ending when the last container of transuranic waste is emplaced underground for disposal.

DISPOSAL ROOM. An excavated cavity in the Waste Isolation Pilot Plant underground in which transuranic waste will be emplaced during disposal operations.

DISPOSAL SYSTEM. For purposes of defining the NMVP conceptual model, the disposal system is defined as the combination of engineered and natural barriers and other assurances that isolate waste after disposal, or the more general features, events, and processes that are capable of affecting performance of the disposal unit.

DISPOSAL UNIT (LONG-TERM SIMULATION). For purposes of the long-term simulation, the disposal unit is bounded by the upper and lower formational contacts of Salado Formation contained within the 16-mi^2 (41-km^2) land-withdrawal area. Specifically, "any movement of constituents above hazardous levels into overlying or underlying formations, or beyond the lateral boundaries of the land-withdrawal area would constitute migration" (55 FR 47704).

DISSOLUTION. The process whereby a space or cavity in or between rocks is formed by the solution of part of the rock material.

DISTURBED ROCK ZONE. That portion of the geologic barrier of which the physical and/or chemical properties may have changed significantly as a result of underground construction activities.

DOLOMITE. A sedimentary rock consisting mostly of the mineral dolomite: $CaMg(CO_3)_2$. It is commonly found with limestone.

DOME (BRECCIA PIPE). A type of hill found near the Los Medaños site; under at least a few of these hills lies a roughly cylindrical volume of breccia pipes (rock reconstituted of coarse rock fragments).

DRIFT. A horizontal passageway in a mine.

EFFLUENT. Wastewater or airborne emissions discharged into the environment.

EMPLACEMENT. At the Waste Isolation Pilot Plant, the placing of radioactive wastes in the repository.

ENGINEERED ALTERNATIVES. Potential modifications to the design or operation of the WIPP or to waste forms that, if adopted, will provide increased assurance that the WIPP will perform in compliance with environmental protection and safety requirements.

ENGINEERED BARRIERS. Backfill, seals, and any other man-made barrier components of the disposal system.

EVAPORITE. A sedimentary rock composed primarily of minerals produced by precipitation from a solution that has become concentrated by the evaporation of a solvent, especially salts deposited from a restricted or enclosed body of seawater or from the water of a salt lake. In addition to halite (NaCl) these salts include potassium, calcium, and magnesium chlorides and sulfates.

EVENT. A phenomenon that occurs instantaneously or within a short time interval relative to the time frame of interest.

FAULT. A surface or zone of rock fracture along which there has been displacement.

FAULT TREE. A tree-like cause-and-effect diagram of hypothetical events. Analysis of fault trees is used to investigate failures in a system or concept.

FILTER BANK. An arrangement of air filters in series and/or parallel.

FLOWPATH. The path traveled by a "zero-charged," "floating" particle released into a groundwater flow field.

FLUVIAL. Pertaining to streams.

FORMATION (GEOLOGIC). The basic rock-stratigraphic unit in the local classification of rocks. It consists of a body of rock (usually sedimentary) generally characterized by some degree of internal lithologic homogeneity or distinctive features.

FORTY-NINER MEMBER. Upper anhydrite and mud stone layer of Rustler Formation.

GAS GENERATION MODEL. A computational model that can simulate and/or predict the rate and quantity of gases generated by waste transformation processes in a disposal room of the decommissioned repository.

GAS GENERATION RATE. The combined gas production rate from all species of gases produced as a result of transuranic waste transformations such as corrosion, microbial degradation, and/or radiolysis at any given time. The rate of gas production throughout the history of the repository is expected to vary depending on repository conditions with respect to humidity, total or partial brine inundation, competitive reactions that absorb specific gases, and the ability of the repository to retain the gases generated. The term is also applied to individual gases.

GATUÑA. A geologic formation covering the Dewey Lake Formation in a wide ranging area. It is basically Pleistocene in age and of medium to coarse brown soil.

GENERATOR AND/OR STORAGE SITES. Refers to the Department of Energy sites nationwide where transuranic wastes are generated and/or stored as a result of activities associated with nuclear weapons production.

GEOMORPHOLOGY. The study of landscape development.

GROUNDWATER. Water below the land surface in a zone of saturation.

GROUT. A mortar or cement slurry (of high water content) used to plug potential fluid-flow paths in geologic or engineered structures.

GUADALUPIAN. Geological group of rocks below the Castile about 4,100 ft (1,250 m) to about 8,000 ft (2,438 m) below the surface. Contains the Bell Canyon, Brushy Canyon, and Cherry Canyon formations.

GYPSUM. A mineral consisting of hydrous calcium sulfate: $CaSO_4 \cdot 2H_2O$. It is soft and, when pure, white.

HALITE. The mineral rock salt: NaCl.

HALO-TOLERANT BACTERIA. Refers to bacteria that can survive and reproduce in highly saline environments.

HAZARDOUS CONSTITUENT. Those chemicals identified in Appendix VIII of 40 CFR Part 261.

HAZARDOUS MATERIAL. Any material that has been determined to be capable of posing a risk to health, safety, or property.

HAZARDOUS WASTE. A hazardous waste as defined in 40 CFR § 261.3.

HEAD, HYDRAULIC. *See* HYDRAULIC POTENTIAL.

HEADSPACE GASES. The free gas volume at the top of a closed container (between the container lid and the waste inside the container) or containment, such as a drum or bin, containing TRU-mixed or simulated waste. The gas may be generated from biological, chemical, or radiolytic processes; this would include contributions from volatile organic compounds (VOCs) present in the waste.

HEPA FILTER. A high-efficiency particulate air filter usually capable of 99.7 percent efficiency as measured by a standard photometric test using 0.3-micron droplets (aerodynamic equivalent diameter) of dioctylphthalate (DOP).

HORIZON. In geology, an interface indicative of a particular position in a stratigraphic sequence. For instance, the waste-emplacement horizon in the Salado Formation at the Waste Isolation Pilot Plant is the level about 650 meters (2,150 feet) deep where openings are mined for waste disposal.

HOST ROCK. The rock unit, in this case the Salado Formation, in which the radioactive waste is to be emplaced.

HUNDRED-YEAR STORM. A storm that, on a statistical basis, is expected to recur only once every hundred years.

HYDRAULIC CONDUCTIVITY. A quantity defined in the study of groundwater hydraulics that describes the ability of rock to transmit groundwater. It is measured in feet per day or equivalent units. It is equal to the hydraulic transmissivity divided by the thickness of the aquifer.

HYDRAULIC GRADIENT. A quantity defined in the study of groundwater hydraulics that describes the rate of change of head with distance.

HYDRAULIC POTENTIAL (OR HYDRAULIC HEAD). Hydraulic pressure corrected for the potential energy of elevation. In an aquifer it is equivalent to the highest level of a column of water that the pressure in the aquifer will support. It is measured relative to a specified level, which in this document is sea level.

HYDRAULIC TRANSMISSIVITY. A measure of the ability of rock to transmit groundwater. It is measured in square feet per day or equivalent units.

HYDRAULICS, HYDROLOGY. These two terms tend to be used interchangeably, but technically they are not the same. Hydraulics is an engineering discipline; hydrology is the related science. Hydraulics deals with the flow of water. Hydrology deals with water: its properties, circulation, and distribution, from the time it falls as rainwater until it is returned to the atmosphere through evapotranspiration or flows into the ocean.

HYDROLOGIC MODELING. The process of using a mathematical representation of a hydrologic system (as embodied in a computer code) to predict the flow of groundwater and the movement of dissolved substances.

IN SITU. In the natural or original position. The phrase is used in this document to distinguish in-place experiments, rock properties, and so on, from those measured in the laboratory.

INJECTION WELL. A well into which fluids are injected.

INSTITUTIONAL CONTROLS. Human actions to control a waste management facility such as the WIPP. Institutional controls are described as "active" and "passive." Active institutional controls are defined in 40 CFR § 191.12 as: (1) controlling access to a disposal site by any means other than passive institutional controls, (2) performing maintenance operations or remedial actions at a site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance. Passive institutional controls are defined in 40 CFR §191.12 as: (1) permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system.

INTENSITY, EARTHQUAKE. A measure of the effects of an earthquake on humans and structures at a particular place. Not to be confused with magnitude.

INTERNATIONAL SYSTEM OF UNITS. The version of the metric system which has been established by the International Bureau of Weights and Measures and is administered in the United States by the National Institute of Standards and Technology. The abbreviation for this system is "SI" (40 CFR § 191.12).

INTERSTITIAL BRINE. Brine distributed in the pore space (voids) of a rock mass.

ION EXCHANGE. A phenomenon in which chemical species in one phase or material exchange with similar species in another phase.

LAMPROPHYRIC DIKE. A tabular igneous intrusion with a texture characterized by phenocrysts of biotite, hornblende and pyroxene, and other mafic mineral embedded in a fine-grained crystalline groundmass.

LAND DISPOSAL. Emplacement in or on the land, except in a corrective action management unit, and includes, but is not limited to, placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, underground mine or cave, or placement in a concrete vault, or bunker intended for disposal purposes.

LAND WITHDRAWAL ACT. Public Law 102-579, which withdraws the land at the Waste Isolation Pilot Plant site from "entry, appropriation, and disposal"; transfers jurisdiction of the land from the Secretary of the Interior to the Secretary of Energy; reserves the land for activities associated with the development and operation of the Waste Isolation Pilot Plant; and includes many other requirements and provisions pertaining to the protection of public health and the environment.

LANGBEINITE. A mineral, $K_2Mg_2(SO_4)_3$, used in the fertilizer industry as a source of potassium sulfate.

LEACHATE. Means any liquid, including any suspended components in the liquid, that has percolated through or drained from hazardous waste.

LEACHING. The process of extracting a soluble component from a solid by the percolation of a solvent (in this report, water) through the solid.

LEONARDIAN. The geologic formation from 8,000 ft (2,438 m) to 11,400 ft (3,475 m) below the surface. Middle of the Permian zone.

LEVEL-LINE SURVEY. A cross-country survey in which changes in elevation with respect to sea level are very carefully measured.

LITHOLOGY. The study and examination of rocks.

LITHOSTATIC PRESSURE. Subsurface pressure due to the weight of overlying rock or soil.

LONG TERM. Refers to the 10,000 years after shaft sealing for which performance assessment calculations and models assess the behavior of the repository with respect to compliance with 40 CFR Part 191 and 40 CFR § 268.6.

LOS MEDAÑOS. In this report, the area in southeastern New Mexico surrounding the site proposed for the WIPP repository. In Spanish it means "dune country."

LOWER EXPLOSIVE LIMIT. The minimum concentration of gas or vapor in air below which a substance does not burn when exposed to an ignition source.

MAGENTA DOLOMITE. The upper of two layers of dolomite within the Rustler Formation that are locally water-bearing.

MAGNITUDE, EARTHQUAKE. A measure of the total energy released by an earthquake. Not to be confused with intensity.

MALAGA BEND. A sharp bend in the Pecos River 20 mi (32.2 km) southeast of Carlsbad, New Mexico, and directly east of the town of Malaga.

MARKER BEDS (MB). MBs are well-defined layers of rock that mark distinct divisions in major geological strata or geological time frames.

MATHEMATICAL MODEL. The mathematical representation of a conceptual model (i.e., the algebraic, differential or integral equations) that predict quantities of interest of a system and any constitutive equations of the physical material that appropriately approximate system phenomena in a specified domain of the conceptual model.

MEAN. The average value. For a given set of n values, the mean is the sum of their values divided by n.

MEDIAN. The median of a set of data is the value such that half of the observations are less than that value and half are greater than that value.

MERCALLI INTENSITY. A scale of measurement of earthquake intensity.

MESCALERO CALICHE. An informal name for the layer of white calcium carbonate containing rock and soil of varying thickness found overlaying the Rustler in the WIPP area.

METHANOGENESIS. The generation of methane through the decomposition of organic matter in wastes.

MIGRATION. In the context of 40 CFR § 268.6, "migration" means the movement of hazardous constituents beyond the boundary of a hazardous waste management unit in concentrations exceeding applicable regulatory levels.

MISCELLANEOUS HAZARDOUS WASTE MANAGEMENT UNIT. A waste management unit where hazardous waste is treated, stored, or disposed of, and that is not a container, tank, surface impoundment, pile, land treatment unit, landfill, incinerator, boiler, industrial furnace, underground injection well, or unit eligible for a research, development, and demonstration permit (40 CFR § 260.10).

MISSISSIPPIAN. Geologic formation from 15,000 to 15,600 ft (4,572 to 4,755 m) below the surface at the WIPP site.

MIXED WASTE. Mixed waste contains both radioactive and hazardous components, as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively.

NASH DRAW. A shallow valley, approximately 5 mi (8.1 km) wide, open to the southwest located to the west of the WIPP site.

NATURAL BARRIERS. The repository host rock and surrounding geologic structures and formations. The natural barriers extend from the engineered barrier to the compliance boundary.

NEW MEXICO HAZARDOUS WASTE ACT. The New Mexico legislation which establishes the state hazardous waste management program. The state law is no less stringent than the federal law, and is consistent with the federal RCRA regulations, 40 CFR Parts 260 through 270.

NO-MIGRATION. Adequate isolation of RCRA-regulated constituents such that "no-migration" of hazardous-waste constituents beyond the unit boundary occurs for as long as the wastes remain hazardous.

NO-MIGRATION DETERMINATION. In the context of the Test Phase, the term "no-migration determination" means the Final Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant published by the Environmental Protection Agency on November 14, 1990 (55 FR 47700), and any amendments thereto, pursuant to the Solid Waste Disposal Act (42 United States Code 6901 et seq.). The Department of Energy has decided not to pursue the testing activities in the WIPP underground for which the conditional No-Migration Determination was made.

ORDOVICIAN. Rock zone between 16,900 ft and 18,200 ft (5,151 m and 5,547 m) below the surface at the WIPP site and also denotes geologic time 438–505 million years ago.

OVERPACK. A container put around another container. In the WIPP, overpacks would be used on damaged or otherwise contaminated drums, boxes, and canisters that it would not be practical to decontaminate.

OXIC CORROSION. Oxidation of metals by molecular oxygen (O_2).

PACKAGING. The assembly of components necessary to ensure compliance with packaging requirements. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle, tie-down system, and auxiliary equipment may be designated as part of the packaging.

PALEOZOIC. Major geological age from 245 million years to 570 million years. Denotes a wide range of geological strata from different subgeological periods, i.e., Permian, Pennsylvanian, Mississippian, etc.

PANEL. A group of several underground rooms connected by drifts. Within the Waste Isolation Pilot Plant, a panel consists of seven rooms connected by drifts at each end.

PASCAL (PA). A unit of pressure obtained by dividing force (in Newtons) by area (in meters squared).

PASSIVE INSTITUTIONAL CONTROLS. "(1) [P]ermanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system" (40 CFR § 191.12).

PENNSYLVANIAN. This is a geologic period of approximately 286 to 320 million years ago. Pennsylvanian rocks are found about 12,800 to 15,000 ft (3,901 to 4,572 m) below the Los Medaños surface. Contains oil and natural gas.

PERFORMANCE ASSESSMENT. A term used to denote quantitative activities carried out to evaluate the long-term ability of the Waste Isolation Pilot Plant to effectively isolate the waste, to ensure long-term health and safety of the public by complying with 40 CFR § 268.6, and to supply data/information to the compliance analysis for demonstrating regulatory compliance. The final analysis of compliance will consist of a qualitative assessment of the quantitative results of the performance assessment.

PERMEABILITY. In hydrology, the capacity of a rock sediment or soil to transmit fluids under specified conditions.

PERMIAN BASIN. A region in the Central United States where, during the Permian Period (245 to 286 million years ago), there were many shallow seas that laid down vast beds of evaporites. The Delaware basin is a part of the Permian basin.

pH. A term used to describe the hydrogen-ion activity or concentration of a solution.

PHYSIOGRAPHY. A description of the natural features of the surface of the earth.

PLUTONIUM. A metallic, radioactive element, symbol Pu, atomic number 94, in the actinide series of elements; used as a nuclear fuel, to produce radioactive nuclides for research, and as the fissile agent in nuclear weapons.

POINT SOURCE. A source of effluents that is small enough in dimensions that it can be treated as if it were a point. The converse (not used in this document) is a diffuse source. A point source can be either a continuous source or a source that emits effluents only in puffs or for a short time.

POLYHALITE. An evaporite mineral: $K_2MgCa_2(SO_4)_4 \cdot 2H_2O$. It is a hard, nearly insoluble mineral with no economic value.

POROSITY. The percentage of porous rock that consists of open space.

POST-CLOSURE PERIOD. A designated period of time beginning with the end of the Decommissioning Phase and extending through the end of the regulatory time frame of 10,000 years.

POTASH. A potassium compound, especially as used in agriculture or industry.

POTENTIOMETRIC SURFACE. A subsurface map of the hydraulic potentials of an aquifer. It is usually represented in figures as a contour map, each point estimating how high the water would rise in a well tapping that aquifer at that point.

PRECAMBRIAN ROCKS. The deepest rock zone under WIPP (18,000 ft [5,486 m]) and the oldest at +600 million years.

PUBLIC LAW 96-164. The U.S. Department of Energy National Security and Military Applications of Nuclear Energy Act of 1980. Public Law 96-164 directed the Department of Energy to proceed with the design and development of the Waste Isolation Pilot Plant.

PUBLIC LAW 102-579. *See* LAND WITHDRAWAL ACT.

QUALITY ASSURANCE. The planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service.

QUALITY ASSURANCE PROGRAM PLANS (QAPP). Documents that describe the overall program plans and activities to meet the project's quality assurance goals.

QUALITY ASSURANCE PROJECT PLANS (QAPJP). Documents that ensure site-specific waste characterization activities meet the data quality objectives.

QUALITY CONTROL. Those quality assurance activities that provide a means to control and measure the characteristics of a structure, system, or component to established requirements.

RADIOLYSIS. Chemical decomposition by the action of radiation.

REAL-TIME RADIOGRAPHY. A nondestructive, nonintrusive examination technique that enables a qualitative (and in some cases semiquantitative) evaluation of the contents of a waste container. Real-Time Radiography utilizes x-rays to inspect the contents of the waste container and allows the operator to view events in progress (real time). Real-Time Radiography is used to examine and verify the physical form of the waste for certain waste forms, identify individual waste components, and verify the absence of certain noncompliant items, as applicable.

REASONABLE. (1) Not conflicting with reason, (2) not extreme or excessive, (3) having the faculty of reason, or (4) possessing sound judgment.

RECHARGE POINT (OR AREA). In groundwater hydraulics, the point (or area) where surface water enters an aquifer.

RELATIVE PERMEABILITY. In an immiscible two-phase fluid flow system containing gas and water, each phase will exhibit a relative permeability determined by the relative fraction of pore space occupied by that phase (i.e., phase saturation). As defined in Appendix BRAGFLO, the relative permeability of one phase increases with increasing saturation, whereby increasing saturation in that phase acts to displace the other and reduce the relative permeability of that phase (see also Appendix PAR, residual gas and brine saturation).

REMOTE-HANDLED WASTE. Transuranic wastes that have a measured radiation dose rate at the container surface greater than 200 millirem per hour. RH-TRU waste received at the WIPP may not exceed 1,000 rem per hour (Public Law 102-579, Section 7(a)(1)(A)). RH-TRU waste received at the WIPP may not exceed requiring shielding for safe handling.

REPOSITORY. The portion of the Waste Isolation Pilot Plant underground system within the Salado Formation, including the access drifts, waste panels, and experimental areas, but excluding the shafts.

REPOSITORY/SHAFT SYSTEM. The Waste Isolation Pilot Plant underground workings, including the shafts, all engineered and natural barriers, and the altered zones within the Salado Formation and overlying units resulting from construction of the underground workings.

RESERVES. Mineral resources that can be extracted profitably by existing techniques and under present economic conditions.

RESISTIVITY. Measure of electrical resistance in a fluid such as brine.

RESOURCE CONSERVATION AND RECOVERY ACT PERMIT APPLICATION. An application, which is submitted by the owner/operator of a hazardous waste management unit to the state (if authorized by the Environmental Protection Agency) or to the Environmental Protection Agency, for a Resource Conservation and Recovery Act permit to operate the unit.

RESOURCES. Mineralization that is concentrated enough, in large enough quantity, and in physical and chemical forms such that extraction is currently or potentially feasible and profitable.

RETRIEVABLE. Describes storage of radioactive waste in a manner designed for recovery without loss of control or release of radioactivity.

RHEOLOGIC RESPONSE. Strain or deformation of a rock material resulting from the material being subjected to an external stress.

ROOM. An excavated cavity within a panel in the underground. Within the Waste Isolation Pilot Plant, a room is about 33 ft (10 m) wide, 13 ft (4 m) high, and 299 ft (91 m) long.

RUSTLER FORMATION. The evaporite beds, including mudstones, of Permian age that immediately overlie the Salado Formation.

SAFETY ANALYSIS REPORT (SAR). A safety document providing a concise but complete description and safety evaluation of the site, the design, normal and emergency operations, potential accidents, and predicted consequences of such accidents, and the means proposed to prevent such accidents or to mitigate the consequences of such accidents. An SAR documents the adequacy of safety analysis for a nuclear facility to ensure that the facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations.

SALADO FORMATION. A geologic formation of Late Permian age in southeastern New Mexico. At the Waste Isolation Pilot Plant site, it is composed of salt beds with minor amounts of anhydrite (45 numbered anhydrite marker beds: Marker Bed 101 through Marker Bed 145) and clay. It is the host unit for the Waste Isolation Pilot Plant repository.

SAN SIMON SINK. The central, most depressed area of San Simon Swale.

SAN SIMON SWALE. A broad depression about 15 mi (24 km) east of the WIPP site, open to the southeast.

SATURATED. In considerations of multiphase flow, a condition in which all connected pores in a given volume of material contain the same fluid. A material may be saturated by gas or liquid.

SCENARIO. A combination of naturally occurring or human-induced events and processes that represent realistic future changes to the repository, geologic, and geohydrologic systems that could cause or promote the escape of radionuclides and/or hazardous constituents from the repository.

SEAL. An engineered barrier designed to isolate the waste and to impede fluid flow in the shafts.

SEDIMENTARY. Rocks formed by the accumulation of sediments.

SEISMIC RISK ZONE. A designation of a geographic region expressing the maximum intensity of earthquakes that could be expected there.

SHAFT. A man-made hole, either vertical or steeply inclined, that connects the surface with the underground workings of a mine.

SHAFT PILLAR. The cylindrical volume of rock around a shaft from which major underground openings are excluded in order that they not weaken the shaft.

SHALLOW-DISSOLUTION ZONE. A zone of residual material at the interface of the Rustler and Salado Formations in Nash Draw west of the WIPP site left after dissolution of the salt. It is highly permeable and often contains brine.

SITE CHARACTERIZATION. The process of making geologic and environmental studies to identify potential sites for mined geologic repositories. Detailed site characterization goes further: all additional data are collected that would be necessary if a license application were to be submitted.

SLUDGE. Refers to de-watered contact-handled transuranic wastes containing both organic and inorganic constituents that must meet the Waste Acceptance Criteria for shipment and disposal at the Waste Isolation Pilot Plant repository. High sludges are contact-handled transuranic waste where the sludge component constitutes 50 percent or more of the waste volume; low sludges are the same type of waste containing less than 50 percent by volume of sludge.

SOLUBILITY. The ability or tendency of one substance to blend uniformly with another (e.g., solid in liquids, liquid in liquid, gas in liquid, and gas in gas). Solids vary from 0 to 100 percent in their degree of solubility in liquids depending on the chemical nature of the substance(s); to the extent that they are soluble, they lose their crystalline form and become molecularly or ionically dispersed in the solvent

to form a true solution. Liquids and gases are often said to be miscible in other liquids and gases rather than soluble.

SOLUTE. A substance which is dissolved in another substance called the solvent. The solute is uniformly dispersed in the solvent either molecularly or ionically.

SOLVENT. A substance capable of dissolving another substance (solute) to form a uniform dispersed mixture (solution) at the molecular or ionic level. Solvents are, accordingly, characterized as either polar or non-polar. Water is strongly polar; hydrocarbon solvents are non-polar.

SORPTION. The binding on a microscopic scale of one substance to another, such as by adsorption or ion exchange. In this document, the word is especially used in the sorption of solutes onto aquifer solids.

SOURCE TERM. Source term is the quantity of hazardous constituents available for transport or the maximum concentration of hazardous constituents in a particular phase, depending on the type of information available.

SPALLINGS. During drilling, material surrounding the eroded borehole that is transported by gas escaping to the lower pressure borehole.

STANDARD WASTE BOX (SWB). A waste container measuring approximately 6 by 4.5 by 3 ft (1.8 by 1.4 by 0.9 m) high, with rounded ends.

STRATA. Geologic term for layers of the earth's crust.

STRATIGRAPHIC. Involves the science and study of the origin, composition, and proper sequence in which various rock strata were layered during various geological ages. Used in this text to describe geological layered formations above and below the WIPP repository and their physical characteristics.

STUDY AREA. The region about the Los Medaños site studied in the evaluation of that site.

SYLVITE. A mineral, KCl, used in the manufacture of fertilizer.

TAMARISK MEMBER. Middle anhydrite layer of Rustler Formation.

TECTONIC ACTIVITY. Movement of the earth's crust such as uplift and subsidence and the associated folding, faulting, and seismicity.

THERMAL FIELD. The field or set of temperatures throughout a volume. Use of the term usually connotes temperatures that differ from point to point.

THERMAL GRADIENT. The rate of change of temperature per unit length.

TOXICITY. The ability of a substance to cause damage to living tissue, impairment of the central nervous system, severe illness or, in extreme cases, death when ingested, inhaled, or absorbed by the skin.

TRANSMISSIVITY. For a confined aquifer, the product of hydraulic conductivity and aquifer thickness.

TRANSURANIC NUCLIDE. A nuclide with an atomic number greater than that of uranium (92). All transuranic nuclides are produced artificially and are radioactive.

TRANSURANIC PACKAGE TRANSPORTER (TRUPACT)-II. Package designed to transport contact-handled TRU-mixed waste to the WIPP site. It is a cylinder with a flat bottom and a domed top that is transported in the upright position.

TRANSURANIC WASTE. The term "transuranic waste" means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste, (2) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations, or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61.

TREATMENT. Means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or as to render such waste non-hazardous, or less hazardous; safe to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

TYPE A PACKAGING. Means a packaging designed to retain the integrity of containment and shielding required by this part under normal conditions of transport as demonstrated by the tests set forth in 49 CFR § 173.465 or 173.466, as appropriate.

UNINTERRUPTIBLE POWER SUPPLY (UPS). A power supply that provides automatic, instantaneous power, without delay or transients, on failure of normal power. It can consist of batteries or full-time operating generators. It can be designated as standby or emergency power depending on the application. Emergency installations must meet the requirements specified for emergency.

UNIT BOUNDARY. In the context of 40 CFR § 268.6, the unit boundary is that the point at which "migration" occurs if hazardous constituents pass that point in concentrations exceeding health-based levels.

VOLATILE ORGANIC COMPOUNDS (VOCs). RCRA-regulated organic compounds which readily pass into the vapor state and are present in contact-handled transuranic mixed waste.

VUGS. Small cavities in a rock.

WASTE ACCEPTANCE CRITERIA. A set of conditions established for permitting transuranic wastes to be packaged, shipped, managed, and disposed of at the Waste Isolation Pilot Plant.

WASTE CHARACTERIZATION. Sampling, monitoring, and analysis activities to determine the nature of the waste.

WASTE CHARACTERIZATION PROGRAM. The processes of transuranic waste analysis to support the No-Migration Determination, Part B of the Resource Conservation and Recovery Act permit application, other permits, transportation requirements, and other program requirements. These analyses include documentation of waste generation processes, visual examination of waste components, radiography analysis, and waste assay for radionuclide content. Waste matrix and headspace gas chemical analyses are also part of the characterization program.

WASTE FORM. A term used to emphasize the physical and chemical properties of the waste.

WASTE MATRIX. The material that surrounds and contains the hazardous constituents and to some extent protects them from being released into the surrounding rock and groundwater. Only material within the canister (or drum or box) that contains the waste is considered part of the waste matrix.

WOLFCAMPIAN. Lower member of Permian age in Southeastern New Mexico.

WORKING AGREEMENT. Appendix B of the Agreement of Consultation and Cooperation, which sets forth the working details of that Agreement.

ACRONYMS

AAC	Active Access Control
AASHTO	American Association of State Highway and Transportation Officials
AC	Alternating Current
ACA	Agency for Conservation Archaeology
acfm	Actual Cubic Feet per Minute
ACGIH	American Conference of Governmental Industrial Hygienists
ACGLF	Adjustable Center-of-Gravity Lift Fixture
ACPE	Average Closed Panel Emission Rate
ACRE	Average Closed Room Emission Rate
ADF	Air Dispersion Factor
ADM	Air Dispersion Modeling
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AFFF	Aqueous Film Forming Foam
AIM	Agricultural and Industrial Minerals, Inc.
AISC	American Institute of Steel Construction
ALARA	As Low As Reasonably Achievable
AMS	Atmospheric Monitoring Station
ANL-E	Argonne National Laboratory–East
ANL-W	Argonne National Laboratory–West
ANSI	American National Standards Institute
AOPE	Average Open Panel Emission Rate
AORE	Average Open Room Emission Rate
AQCR	Air Quality Control Regulations
ARM	Area Radiation Monitoring
ASER	Annual Site Environmental Report
ASME	American Society of Mechanical Engineers
ASME NQA-1	American Society of Mechanical Engineers' *Nuclear Quality Program*
AT	Averaging Time
atm	Atmospheres
BAD	Background Air Data
BEAR	Backfill Engineering Analysis Report
BECR	Biennial Environmental Compliance Report
BFB	Bromofluorobenzene
BH	Borehole Data
BIR	Baseline Inventory Report
BLM	U.S. Bureau of Land Management
BRAGFLO	Brine and Gas Flow
BS	Blank Spike
BSD	Blank Spike Duplicates
BSEP	Brine Sampling and Evaluation Program
BWQ	Background Water Quality
C&C	Consultation and Cooperation
C&SH	Construction and Salt Handling Shaft

CAA	Clean Air Act
CAAA	Clean Air Act Amendment
CAM	Continuous Air Monitor
CAMCON	Compliance Assessment Methodology Controller
CAO	Carlsbad Area Office
CB	Cabin Baby
CBP	Central Basin Platform
CCA	Compliance Certification Application
CCDF	Complementary Cumulative Distribution Function
CDF	Cumulative Distribution Function
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CH	Contact-Handled
CLP	Closure Plans
CMP	Confirmatory Monitoring Plan
CMR	Central Monitoring Room
CO	Carbon Monoxide
COE	U.S. Army Corps of Engineers
CONT	Contingency Plan
CRQL	Contract Required Quantitation Limits
CRS	Closure Review Study
CSF	Cancer Slope Factor
CWA	Clean Water Act
D&D	Decontamination and Decommissioning
DBE	Design Basis Earthquake
DBT	Design Basis Tornado
DC	Direct Current
DCCA	Draft Compliance Certification Application for 40 CFR 191
DEF	Deformation
DIF	Diffusion
DMG	Delaware Mountain Group
DNAG	*The Decade of North American Geology* by A.R. Palmer
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DOL	U.S. Department of Labor
DOP	Dioctylphthalate
DOT	U.S. Department of Transportation
DQO	Data Quality Objective
DRZ	Disturbed Rock Zone
DZ	Disturbed Zone
EATF	Engineered Alternatives Task Force
EC	Exhaust Shaft Concentration
ED	Exposure Duration
EEG	Environmental Evaluation Group

EF	Exposure Frequency
EFB	Exhaust Filter Building
EM	Emergency Management
EMP	Environmental Monitoring Plan
EMR	Environmental Monitoring Report
EOC	Emergency Operations Center
EP	Event and Process
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ET	exposure time
ERDA	U.S. Energy Research and Development Administration
ETEC	Energy Technology Engineering Center
FC	Flood Control
FEIS	Final Environmental Impact Statement
FEP	Feature, Event, and Process
FFCA	Federal Facilities Compliance Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FLPMA	Federal Land Policy and Management Act
FP	Future Panel
FR	Federal Register
FSAR	Final Safety Analysis Report
ft^3	Cubic Foot
FTIR	Fourier transform infrared spectroscopy
FWS	Fish and Wildlife Service
g	Gram
GAS	Gas-Generation
GC	gas chromatography
GCR	Geological Characterization Report
GEP	Good Engineering Practice
GMS	Geomechanical Monitoring System
GSB	Guard and Security Building
HAP	Hazardous Air Pollutant
HBL	Health-Based Level
HEAST	Health Effects Assessment Summary Tables
HEPA	High Efficiency Particulate Air
HERE	Horizontal Emplacement and Retrieval Equipment
HLW	High-Level Waste
HMTA	Hazardous Materials Transportation Act
HPIC	High Pressure Ionization Chamber
HQ	Headquarters
HSWA	Hazardous and Solid Waste Amendments
HTMR	High Temperature Metals Recovery
HVAC	Heating, Ventilation, and Air Conditioning
HWMR	Hazardous Waste Management Regulations
HWMU	Hazardous Waste Management Units

IAEA	International Atomic Energy Act
ICV	Inner Containment Vessel
IDB	Integrated Database
INEL	Idaho National Engineering Laboratory
IR	Irrigation
IRIS	Integrated Risk Information System
ISC	Industrial Source Complex
ISCLT3	Industrial Source Complex Long-Term, Version 3
K	Degrees Kelvin
KAPL	Knolls Atomic Power Laboratory
L	Liters
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LCS	Laboratory Control Samples
LDR	Land Disposal Restrictions
LLNL	Lawrence Livermore National Laboratory
LLW	Low-Level Waste
LTM	Long-Term Monitoring
LTMP	Long-Term Monitoring Program
LWA	Land Withdrawal Act
m	Meter
m^3	Cubic Meter
M&O	Management and Operations
MASS	Modeling Assumptions
MB	Marker Bed
MCS	Master Control Station
M-D	Multimechanism-Deformation
MDCF	Multimechanism Deformation Coupled Fracture
MDL	Minimum Detection Level
MF	Mole Fraction
mg	Milligram
min	Minute
mm	Millimeter
MOC	Managing and Operating Contractor
mol	Mole
MOU	Memorandum of Understanding
MOUND	Mound Laboratory
MP	Markers Panel
MRL	Method Reporting Limit
MS	Mass Spectrometry
MSDS	Material Safety Data Sheet
MSHA	Mine Safety and Health Act
µg	Microgram
MWIR	Mixed Waste Inventory Report
NAAQS	National Ambient Air Quality Standards

1	NACEPT	National Advisory Council on Environmental Policy and Technology
2	NAS-NRC	National Academy of Sciences-National Research Council
3	NCB	National Coal Board
4	NDA/NDE	Non-Destructive Assay/Non-Destructive Examination
5	NEPA	National Environmental Policy Act
6	NES	Nonradiological Environmental Surveillance
7	NESHAP	National Emission Standards for Hazardous Air Pollutant
8	NGS	National Geodetic Survey
9	NHPA	National Historic Preservation Act
10	NID	Nonradionuclide Inventory Database
11	NIOSH	National Institute of Occupational Safety and Health
12	NLS	Nonlinear Equations
13	NMAC	New Mexico Administrative Code
14	NMAQCB	New Mexico Air Quality Control Bureau
15	NMBMMR	New Mexico Bureau of Mines and Mineral Resources
16	NMD	No-Migration Determination
17	NMDG&F	New Mexico Department of Game and Fish
18	NMED	New Mexico Environment Department
19	NMHWA	New Mexico Hazardous Waste Act
20	NMV	No-Migration Variance
21	NMVP	No-Migration Variance Petition
22	No_x	Nitrous Oxide
23	NPDES	National Pollutant Discharge Elimination System
24	NRC	U.S. Nuclear Regulatory Commission
25	NRHP	National Register of Historic Places
26	NTPO	National TRU Program Office
27	NTS	Nevada Test Site
28	NTWO	Office of National TRU Waste Operations
29	NUTS	Nuclide Transport System
30	NWPA	Nuclear Waste Policy Act
31	NWS	National Weather Service
32	OCA	Outer Containment Assembly
33	OD	Outer Diameter
34	OEDC	Organization for Economic Cooperation and Development
35	OP&R	Overpack and Repair
36	OPRR	Overpack and Repair Room
37	ORNL	Oak Ridge National Laboratory
38	OSHA	Occupational Safety and Health Administration
39	P&P	Planning and Permitting
40	PA	Performance Assessment
41	PAD	Paducah Gaseous Diffusion Plant
42	PAR	Parameter Sheets
43	PAX	Private Automatic Exchange
44	PBWAC	Performance-Based Waste Acceptance Criteria
45	PCB	Polychlorinated Biphenyl

PDP	Performance Demonstration Program
PDPP	Performance Demonstration Program Plan
PM	Permanent Marker
PMR	Post-Closure Monitoring Report
PMS	Permanent Marker System
PPE	Personal Protective Equipment
ppmv	Parts per Million by Volume
PRP	Parameter Records Package
PTB	Project Technical Baseline
Q	Air Flow Rate
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAPD	Quality Assurance Program Document
QAPjP	Quality Assurance Project Plan
QAPP	Quality Assurance Program Plan
QARD	QA Requirements Document
R	Recreation
RBP	Radiological Baseline Program
RCRA	Resource Conservation and Recovery Act
RCS	Radar Cross-Section
RCSMP	Regulatory Compliance Strategy and Management Plan Requirements for Nuclear Facilities
REG	Regularoty Interpretations
RF	Radio Frequency
RfC	Reference Concentration
RfD	Reference Dose
RFETS	Rocky Flats Environmental Technology Site
RFP	Rocky Flats Plant
RH	Remote-Handled
RM	Rock Mechanics
ROD	Record of Decision
RPD	Relative Percent Difference
RTR	Real-Time Radiography
SAR	Safety Analysis Report
SARA	Superfund Amendments and Reauthorization Act
SARP	Safety Analysis Report for the TRUPACT-II Shipping Package
SB	Support Building
scfm	Standard Cubic Feet Per Minute
SCPE	Single Closed Panel Emission
SCR	Screening
SDD	System Design Description
SDS	Subsidence Data Study
SDWA	Safe Drinking Water Act
SEIS	Supplement Environmental Impact Statement
SEPM	Society of Economic Paleontologists and Mineralogists

SER	Annual Site Environmental Report for Calendar year 1993
SF	Slope Factor
SHPO	State Historic Preservation Officer
SHS	Salt Handling Shaft
SLO	State Land Office
SMC	Salado Mass Concrete
SNL	Sandia National Laboratories
SO_2	Sulphur Dioxide
SOP	Standard Operating Procedure
SPDV	Site Preliminary Design Validation
SPIV	Site and Preliminary Design Validation
SPM	Systems Prioritization Methodology
SPM-1	Systems Prioritization Method-1
SQL	Sample Quantitation Limit
SRS	Savannah River Site
SSBI	Small-Scale Brine Inflow
SSZ	Site Source Zone
STAR	Stability Array
STP	Standard Temperature and Pressure
SUM	Summary of Site-Characterization Studies
SURV	Aerial Surveys
SVOC	Semi-Volatile Organic Compound
SWB	Standard Waste Box
SXPE	Single Open Panel Equivalent
TCI	Tentatively Identified Compounds
TD	Total Depth
TDOP	Ten-Drum Overpack
TDS	Total Dissolved Solids
THQ	Target Hazard Quotient
TLD	Thermoluminescent Dosimetry
TOC	Total Organic Carbon
TRAMPAC	TRUPACT-II Authorized Methods for Payload Control
TRL	Target Risk Level
TRU	Transuranic
TRUCON	TRUPACT-II Content
TRUDOCK	TRUPACT Dock
TRUPACT	Transuranic Package Transporter
TSCA	Toxic Substances Control Act
TSP	Total Suspended Particulates
TV	Television
TWA	Time-Weighted Averages
U/G	Underground
UBC	Uniform Building Code
UCRL	University of California Research Laboratories
UHP	Ultra High Purity

UIC	Underground Injection Control
ULF	Ultra-Low Frequency
UNAMAP	Users Network for Applied Modeling of Air Pollution
UNM	University of New Mexico
UPS	Uninterruptible Power Supply
URF	Unit Risk Factor
USBM	U.S. Bureau of Mines
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	Underground Storage Tank
USTR	Underground Storage Tank Regulations
UTM	Universal Transverse Mercator
VLF	Very-Low Frequency
VOC	Volatile Organic Compound
VOC	VOC Screening Methodology
WAC	Waste Acceptance Criteria
WACCC	Waste Acceptance Criteria Certification Committee
WAP	Waste Analysis Plan
WHB	Waste Handling Building
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WMC	Waste Matrix Code
WMCG	Waste Matrix Code Group
WPO	Work Project Order
WQSP	Water Quality Sampling Program
WTWBIR	WIPP Transuranic Waste Baseline Inventory Report
WVDP	West Valley Demonstration Project
yr	Year

DOE/CAO-96-2160

Final
No-Migration
Variance Petition

M

June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume II of VIII

Appendices AAC, ADM, APS, BAD, BECR

APPENDIX AAC

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APPENDIX AAC

AAC.1.0 INTRODUCTION

AAC.1.1 Purpose

This report was developed to describe the conceptual design of a system the Department of Energy (DOE) may implement for compliance with the requirement to control access to the disposal site. In addition, this report addresses the scheduling process for control of inspection, maintenance, and periodic reporting related to Long Term Monitoring (LTM) of disposal system performance, environmental monitoring in accordance with the Consultation and Cooperation (C & C) Agreement between the DOE and the state of New Mexico, and evaluation of testing activities related to the Permanent Marker System (PMS) design.

In addition to access control, the control or cleanup of releases from the site is addressed in the Conceptual Decontamination and Decommissiong Plan. The monitoring of parameters related to disposal system performance is addressed in the Long Term Monitoring Design Concept Description (March 1995, Draft). Together, these three documents cover the full range of active institutional controls planned after disposal of the transuranic (TRU) waste in the Waste Isolation Pilot Plant (WIPP) repository.

Title 40 CFR §191.12 defines "Active Institutional Control" as:

- Controlling access to a disposal site by any means other than passive institutional controls
- Performing maintenance operations or remedial actions at a site
- Controlling or cleaning up releases from a site
- Monitoring parameters related to disposal system performance

Title 40 CFR §191.14(a) states;

> Active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal.

Title 40 CFR §264.117(a)(1) states;

> Post-closure care for each hazardous waste management unit subject to the requirements of §§ 264.117 through 264.120 must begin after completion of closure of the unit and continue for 30 years after that date.

Title 40 CFR §264.601 states;

> A miscellaneous unit must be...maintained and closed in a manner that will ensure protection of human health and the environment.

Title 40 CFR §264.603 states;

> A miscellaneous unit that is a disposal unit must be maintained in a manner that complies with § 264.601 during the post-closure care period.

AAC.1.2 Scope

The design description addresses a means of controlling access to the repository's surface footprint (the repository area projected to the surface). It is anticipated that active control of access to the site will be exercised by the DOE or other federal government entity for as long as practicable and at least 100 years after disposal. Access control will preclude the inadvertent intrusion into the disposed waste by deep drilling or mining of natural resources. The report also describes a process for scheduling activities related to testing elements of the PMS and the activities required to meet the needs of the LTM of the repository performance. Many of these activities will be initiated during the disposal phase to establish databases and are planned to continue beyond the time after removal of the site structures and return of the land disturbed by the WIPP activitives to a stable ecological state. Permanent marker testing and LTM requirements will have some impact on returning the land to a stable ecological state.

AAC.1.3 Background

The WIPP was authorized by Public Law 96-164, December 1979, *Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980*, as a research and development facility to demonstrate the safe disposal of radioactive wastes. The wastes are derived from DOE defense-related activities. Specifically, the mission of the WIPP project is to conduct research, demonstration, and siting studies relevant to the permanent disposal of TRU wastes. Some of these wastes will be mixed wastes (co-contaminated with hazardous constituents).

The Land Withdrawal Act (LWA), signed into law in October 1992, addresses the disposal phase of the WIPP project, the period following closure of the site, and removal of the surface facilities.

The LWA set aside 10,240 acre (4,144 hectare) acres in Eddy County, 26 mi (16 km) east of Carlsbad, NM as the WIPP site. A 277-acre (112-hectares) portion within the site is bounded by a barbed wire fence and contains the surface facilities and mined salt. Figure AAC-1 is a cutaway illustrating the geometrical relationship of the surface facilities and the underground repository.

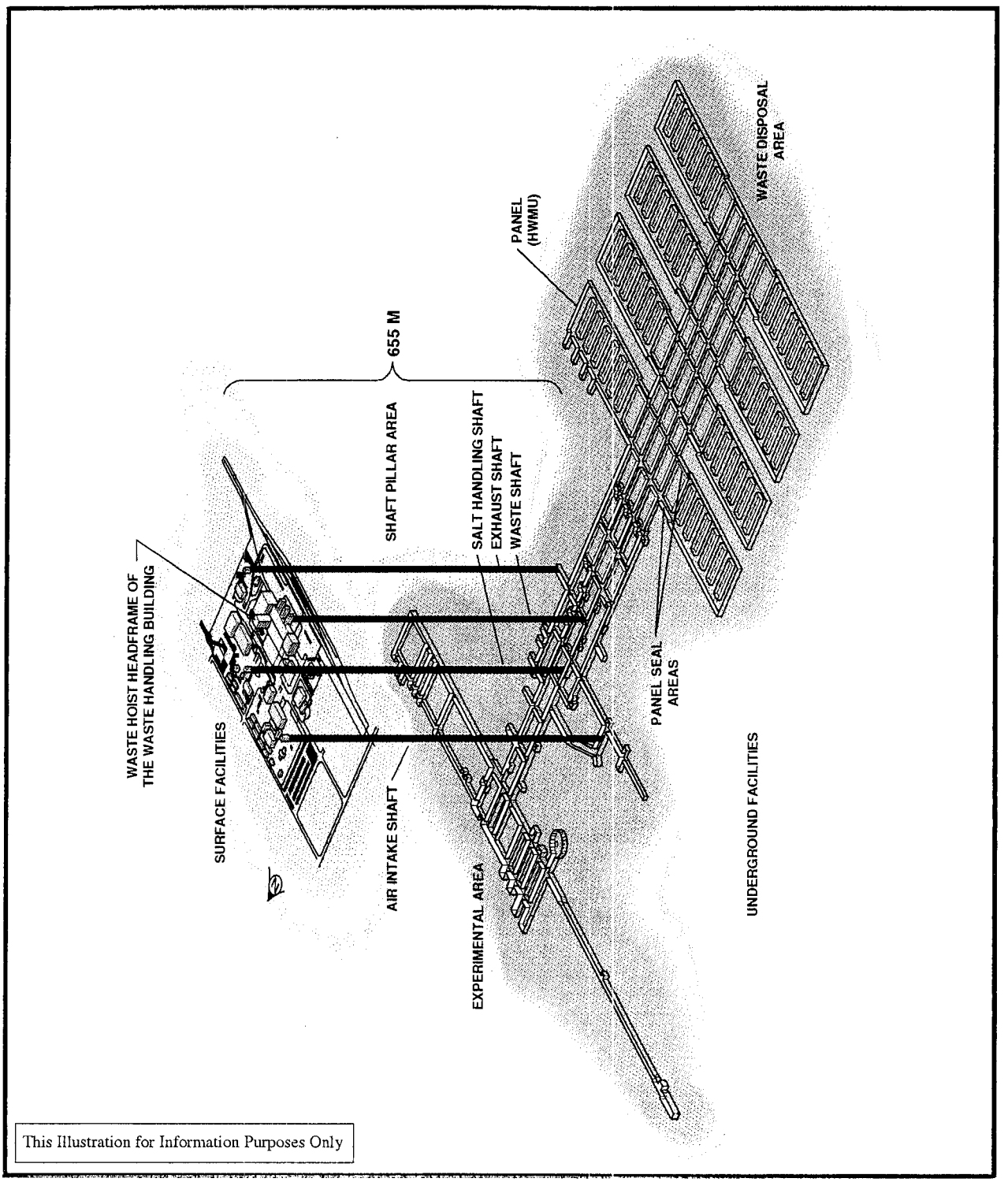

Figure AAC-1. Spatial View of WIPP Surface & Underground Facilities

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Upon receipt of the necessary certifications and permits from the Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED), the DOE will begin emplacing for disposal contact-handled- (CH-) TRU waste in the repository. This activity is scheduled to begin in 1998, with subsequent emplacement of remote-handled- (RH-) TRU waste at a later date. The waste emplacement and disposal phase will continue for a 25-year period until the regulated capacity of the repository (6,200,000 ft^3 [175,600 m^3] of TRU waste) has been reached. The waste will be shipped from ten DOE facilities across the country in specially designed transportation containers, TRUPACT-IIs for CH-TRU waste and shielded road casks for RH-TRU waste, licensed by the Nuclear Regulatory Commission (NRC). The CH-TRU waste will be packaged in 55-gallon steel drums and/or Standard Waste Boxes (SWBs). An SWB is a steel container with a free volume of approximately 65 ft^3 (1.8 m^3). Figure AAC-2 shows the general arrangement of a seven-pack of drums (51.5 ft^3 [1.5 m^3]) and an SWB as received in the TRUPACT-II. The RH-TRU waste will be shipped in a shielded road cask containing a three-drum-capacity canister.

Upon receipt and inspection of the waste containers in the Waste Handling Building (WHB), the containers will be downloaded into the repository 2,150 ft (655 m) below the surface. The containers will then be transported to a disposal room (See Figure AAC-1 for room and panel arrangement). The initial seven disposal rooms are in panel 1, which is the first of eight planned panels to be excavated. Upon filling an entire panel, that panel will be closed to isolate it from the rest of the repository and the ventilation system. During the period of time it takes to fill a given panel, an additional panel will be excavated. Sequential excavation of panels will ensure that individual panels remain stable during the entire time the panel is being filled with waste.

Decontamination of the WIPP facility will commence with a detailed radiation survey of the entire site. Radioactively contaminated areas and equipment will be evaluated and decontaminated in accordance with applicable requirements. If decontamination efforts identify areas that are below radiological release criteria, routine dismantling and salvaging practices will determine the disposition of the material or equipment involved. Material and equipment that do not meet radiological release criteria will be emplaced in the access entries (panels 9 and/or 10). Upon completion of emplacement of the contaminated facility material, the entries will be closed and the repository shafts will be sealed. Final repository closure involves sealing the shafts leading to the repository. Figure AAC-3 illustrates a shaft sealing arrangement. Completion of waste disposal, which includes shaft sealing, will end disposal operations and initiate the period of active controls.

The DOE will remove the surface facilities and return the land disturbed by the WIPP activitives to a stable ecological state that will assimilate with the surrounding undisturbed ecosystem. As part of the PMS, the Hot Cell concrete structure, protected by a chain link fence, will remain as an artifact marking the WIPP site. The Hot Cell is a reinforced concrete structure measuring approximately 71 ft by 40 ft with 4.5-ft-(21.6 × 12 × 1.4 m-) thick walls. The Hot Cell foundation extends approximately 28 ft (8.5 m)

below grade and the roof is 61 ft (18.6 m) above grade. This feature and the test program supporting the PMS which will require the construction of a berm section, the erection of test monuments, and the emplacement of test markers, will impact the ability to return the land disturbed by the WIPP activitives to a stable ecological state that will assimilate with the surrounding undisturbed ecosystem. As described in this appendix, a posted access barrier will be erected around the repository footprint, affecting the return of the land disturbed by the WIPP activitives to a stable ecological state. Elevation benchmarks to support the LTM program will be located within a grid network on the surface of the withdrawn area. Finally, a portion of the mined salt, sufficient to support future construction of the Permanent Marker berm, will remain on the surface. The water supply line will be removed. At a future point in time, a water supply may have to be reestablished to support construction of the PMS. Water may be piped to the site or trucked in. Because electricity will also be required for the future construction of the PMS, the electrical supply to the site will be isolated at an incoming power pole.

Over the several decades following site restoration, activities supporting the LTM Program and evaluating the performance of the PMS testing will require occasional access to the site. These activities will be controlled by the Active Controls schedule described in Section AAC.5. Construction of the PMS will be a significant effort once again requiring the development of water, electrical, and transportation facilities at the site. Both rail and truck will be used to transport required materials to the site. This effort is anticipated to last 1-2 years.

Upon completion of the PMS, the access control program for the site shall be reevaluated and modified as required to address any changes from the effects of the PMS. When the PMS construction effort is completed, the utilities and railroad spur supporting the site will be removed and the affected terrain returned to a stable ecological state that will assimilate with the surrounding undisturbed ecosystem.

AAC.2.0 SITE DESCRIPTION

The WIPP site is located in Eddy County, in Southeastern New Mexico, 26 mi (16 km) east of Carlsbad and 14 mi (8.7 km) east of the Pecos River at its closest point. Current commercial uses of the land surrounding the site include livestock grazing, potash mining, and oil and gas production. The site-occupied land is owned by the federal government and is under the jurisdiction of the Secretary of the U.S. DOE. The LWA has withdrawn the 10,240 acres (4,144 hectares) comprising the WIPP site from "...all forms of entry, appropriation, and disposal...including without limitation the mineral leasing laws, the geothermal leasing laws, the material sale laws... and the mining laws." The underground disposal facility is constructed in a bedded salt formation 2,000 ft (610 m) thick, in the Salado Formation, 2,150 ft (655 m) below the surface. All major surface facilities are surrounded by a chain link fence enclosing approximately 35 acres (14 hectares). The boundary of the 10,240-acre (4,144 hectares) land-withdrawal area extends at least one mi (1.61 km) beyond any planned underground disposal area.

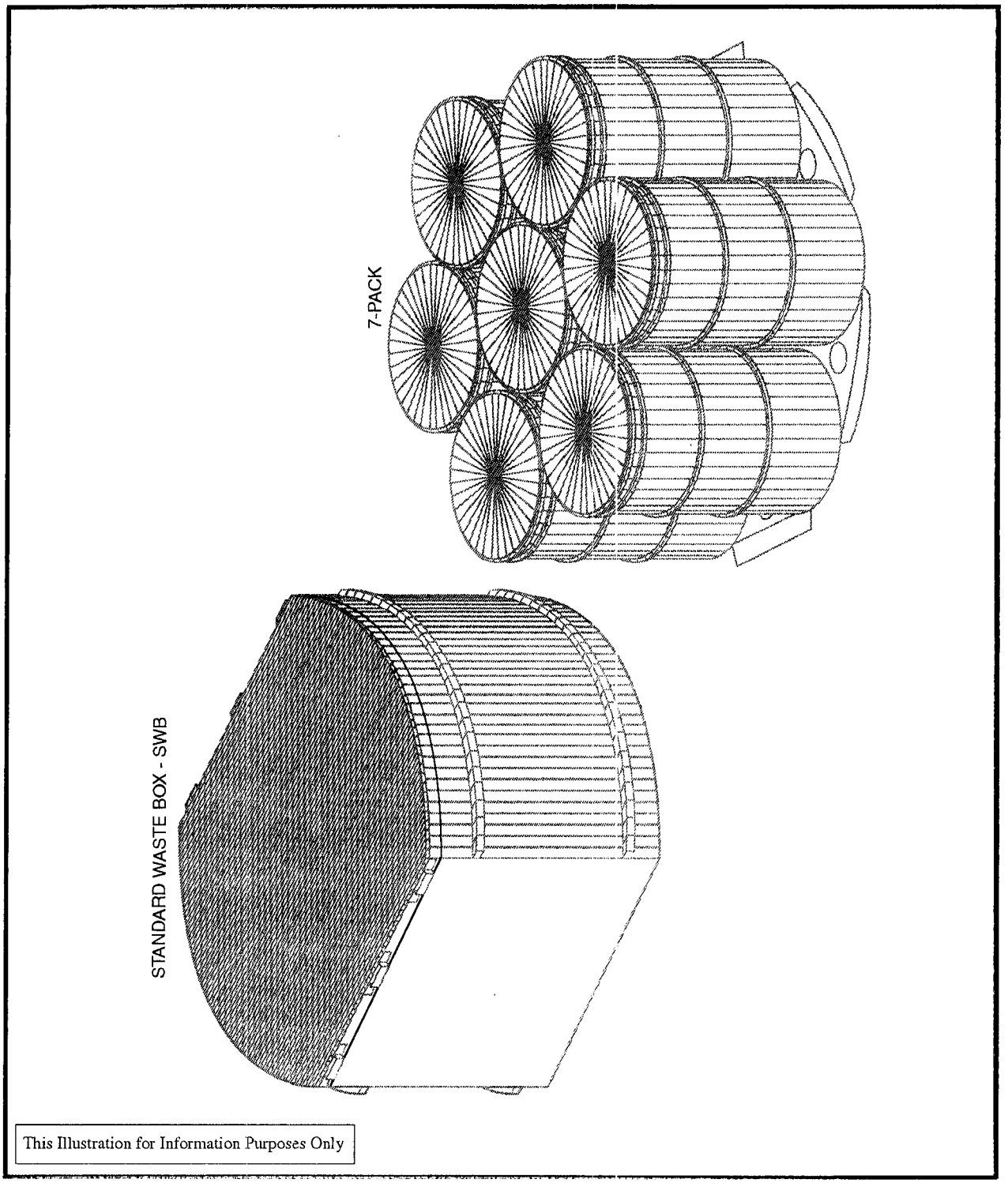

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Figure AAC-2. Standard Waste Box (SWB) with 7-Pack

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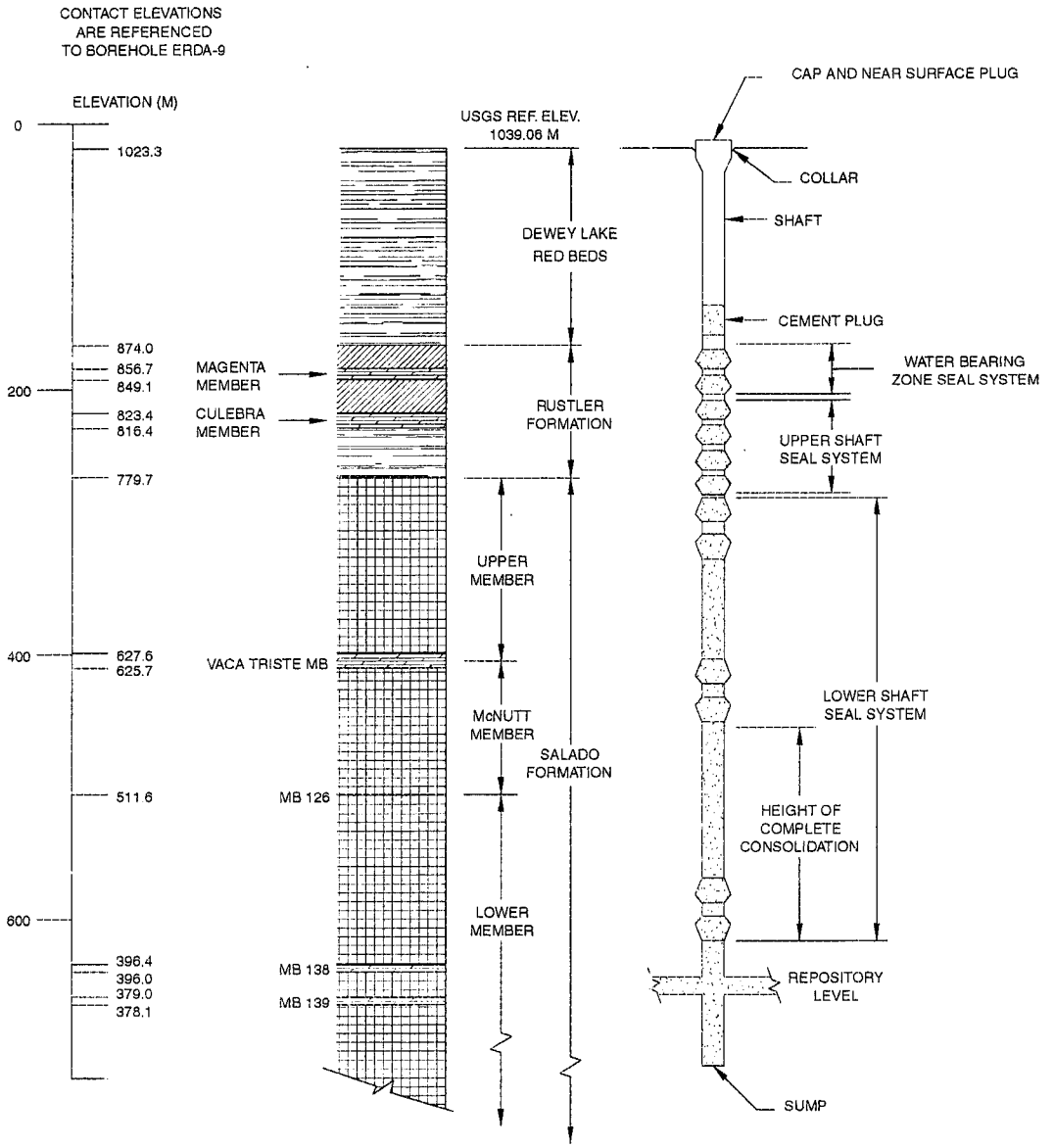

DETAILS OF THE SHAFT SEALING

FIGURE II-3

PM3

NMVP-6342-127-0

Figure AAC-3. Typical Shaft Seal System

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The WIPP facilities are comprised of surface and underground facilities interconnected by shafts. The surface appurtenances accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of TRU waste from the surface to the repository. The existing underground facilities include the TRU waste disposal area, the experimental area, and the underground maintenance and support area. Four shafts interconnect the surface facilities with the underground facilities. The waste handling shaft serves as the main operational artery for transport of waste to the repository. The salt handling shaft (SHS) provides transportation for mined material and personnel from the repository to the surface, and also functions as a secondary air inlet shaft. The air intake shaft and the exhaust air shaft ensure positive ventilation flow to the underground facilities. The exhaust air can be filtered in the unlikely event radioactive particulate material is released from containers in the repository.

The primary surface structure supporting waste handling activities is the WHB. The WHB is divided into a CH-TRU waste handling area and an RH-TRU waste handling area with a number of support areas. The CH-TRU and RH-TRU areas are designed to provide for the receipt and inspection of waste containers prior to transport to the underground facilities. TRUPACT-IIs containing CH-TRU waste are moved into the WHB through air lock doors. Once inside the CH-TRU area, the individual TRUPACTs are placed into a TRUPACT Loading Dock. At this location, waste management personnel will open the TRUPACT and remove the SWBs or seven-packs containing the waste. Rigorous monitoring and inspections for any leakage are conducted throughout the unloading sequence and transport of the waste containers to the Waste Handling Shaft.

Shielded road casks containing an RH-TRU waste canister, with each canister containing three drums of RH-TRU waste, are moved into the RH Bay. The shielded road cask is removed from its transport vehicle and loaded in the vertical position onto a road cask transfer car. The car then transports the cask to the cask unloading room. In the unloading room, the RH-TRU canister is removed from the shielded road cask and hoisted into the Hot Cell. The canister is then inspected visually and radiologically using master-slave manipulators. The canister is then lowered out of the Hot Cell into the canister shuttle car that transports the canister under the cask loading room. The canister is then hoisted into the facility cask. The facility cask is shielded with lead to protect personnel. The cask is loaded onto the facility cask transfer car and taken to the Waste Handling Shaft for downloading to the underground facilities. All the activities associated with unloading, loading, and inspecting the canister are conducted remotely through viewing windows or with the use of television cameras.

Counting room facilities and chemical laboratory facilities in the Support Building and the Safety and Emergency Services Building are available to support both surface and underground waste handling activities. In addition, the Support Building provides administrative office space, change rooms, a Central Monitoring Room, and a computer room. The Safety and Emergency Services Building contains additional office space, the major mobile fire fighting equipment, Emergency First Aid Station, the Emergency

Operations Center, and the environmental and thermoluminescent dosimetry (TLD) laboratories.

Three other major surface facilities are the Guard and Security building, the Engineering building and the Training building. The Engineering building provides office space for the Engineering Department personnel and the Engineering Drawings File Room. The Training building provides office space for members of the Training Section and classroom facilities. The Guard and Security building (GSB) provides office facilities for the WIPP Security force. This building also contains, in a hardened area, the Security Control Station with its communications facilities, an alarm monitoring station, and surveillance camera equipment. A lunch room and an auditorium are also located within the GSB.

The underground repository structures are oriented in a north-south direction. The waste disposal area will occupy approximately 120 acres (49 hectares) at the south end of the mined area. Currently, only one of eight panels is mined. The experimental area lies at the north end of the repository. This area occupies approximately 12 acres (5 hectares). No TRU waste will be disposed of in the experimental area. Four north-south excavated entries (drifts) service the waste disposal area. These drifts provide paths for the ventilation system supply and exhaust streams, for moving waste from the Waste Handling Shaft to the disposal rooms, and for moving mined salt from active mining areas to the SHS. The portions of the drifts adjacent to the eight excavated panels will also serve as two equivalent waste disposal panels (panels 9 and 10). Two of the drifts extend north of the SHS and the Air Intake Shaft to service the experimental area. Through a combination of air locks, booster fans, and damper controllers, designed differential pressures are maintained to ensure that the waste disposal area is at the lowest overall pressure with respect to other working areas within the repository. This ensures that any airborne radioactive or hazardous material will only exhaust via the ventilation exhaust path and not leak back to the mining area or the experimental area. Support facilities such as electrical substations, shops, warehouse, storage facility, parking, and lunchroom are generally located off of the entries between the experimental area and the waste disposal area.

The design capacity of the WIPP repository is 6,200,000 ft^3 (175,6000 m^3) of CH-TRU waste and 250,000 ft^3 (7,080 m^3) of RH-TRU waste. However, the LWA restricts the disposal of TRU waste, both CH and RH, to a total of 6,200,000 ft^3 (175,600 m^3). This capacity restriction must also include TRU waste derived from any decontamination activities during the disposal and decommissioning phases. As a result, prior to cessation of receipt of waste from other facilities, extensive radiation surveys will be conducted to provide information on how much waste disposal volume capacity will be required for disposal of WIPP-derived waste. The detail of these surveys is described in DOE/WIPP 95-2072, January, 1995. Based upon the survey results, receipt and emplacement of TRU waste, other than WIPP derived waste, will be terminated at an appropriate time. The waste disposal capacity remaining unfilled will then be provided to receive the derived waste that may result from the decontamination efforts at the WIPP. The WIPP's

operational policy of "start clean, stay clean" will minimize the amount of disposal capacity required near the end of the disposal phase. As the surface facilities are dismantled and cleanup of the site proceeds, contaminated material that cannot be cleaned up sufficiently to be released as uncontrolled material will be emplaced within the waste disposal area. Uncontaminated material that can be released will be salvaged or transferred to commercial storage or disposal locations.

Final activity within the repository will involve closing the waste disposal area and sealing the shafts. Upon completion of this activity, the remaining surface structures will be dismantled. All surface structures except for the concrete Hot Cell structure and a sufficient quantity of salt tailings to support construction of the Permanent Marker (PM) berm will be removed and the site regraded and planted to return the land disturbed by the WIPP activitives to a stable ecological state that will assimilate with the surrounding undisturbed ecosystem. In addition, those structures erected during the disposal phase as part of the PM testing program will also remain in place after decommissioning. This will include a section of the berm and at least one monolithic marker erected as a part of the program of long-term testing of materials planned for the PMS.

AAC.3.0 DESIGN CRITERIA

The design criteria applicable to the *WIPP Active Access Controls After Disposal Design Concept Description* were developed to meet the definition in Title 40 CFR 191.12 for controlling access to the disposal site. In addition to active access controls, the criteria also address scheduling processes to be implemented upon completion of sealing the shafts. The decontamination, decommissioning, and restoration of the land is described in DOE/WIPP 95-2072, January, 1995. *The Permanent Marker Conceptual Design Report* (Appendix PMR) addresses post-decommissioning testing activities conducted at the WIPP site. To a limited extent, the restoration of the land to its original condition will be impacted by the testing activities related to the PM system and the Hot Cell structure that will remain as an artifact of the WIPP operating surface activity.

Although the LWA establishes a 10,240-acre (4,144 hectares) area for administrative control by the Secretary of Energy in conducting activities associated with the WIPP, the actual disposal area is only approximately 120 acres (49 hectares) in extent. Access control ensures that inadvertent intrusion into this area does not occur. Deep drilling or mining are the only credible activities that can intrude. Drilling techniques in the local area do not normally include slant drilling. Where slant drilling is used, deviation from the vertical does not begin until a depth of approximately 4,000 ft (1,200 m) is attained. This depth is well below the local salt formations. The salt formations do not support slant drilling due to insufficient consolidation of the salt material. These technical facts reasonably preclude slant drilling into the repository from outside the area immediately above the repository. Therefore, it is reasonable not to extend a restrictive access control program to the entire 10,240 acres (4,144 hectares), with the accompanying cost increase and prohibition for such uses as grazing, hunting, and other public recreational activities.

The design criteria developed for the active access controls after disposal are:

1. A fence line shall be established to control access to the repository footprint area on the surface. A standard four-strand wire fence (three barbed and one unbarbed in accordance with the Bureau of Land Management (BLM) specifications) shall be erected along the perimeter of the repository surface footprint. The fence shall have gates placed approximately midway along each of the four sides. The western gate shall be 20 ft (6 m) wide. The remaining three gates shall each be 16 ft (4.9 m) wide.

2. An unpaved roadway 16 ft (5 m) wide along the perimeter of the barbed wire fence shall be constructed to provide ready vehicle access to any point around the fenced perimeter, facilitate inspection and maintenance of the fenceline, and permit visual observation of the repository footprint to the extent permitted by the lay of the land. This roadway shall connect to the paved south access road.

3. To ensure visual notification to potentially unauthorized personnel, the fence line shall be posted with signs having as a minimum a legend reading "Danger-Unauthorized Personnel Keep Out" (Title 40 CFR §264.14(c))and warning against entering the area without specific permission of the DOE (or other local authority, such as the Eddy County Sheriff's office). The signs must be legible from a distance of at least 25 ft (7.6 m). The size of the visual warning and the spacing of the warning signs shall be sufficiently large and close to ensure that one or more of the signs can be seen and read from any approach prior to an individual actually making contact with the fence line. In no case shall the spacing be greater than 300 ft (91.4 m).

4. Contractual arrangements shall be developed to ensure that periodic inspection and expedited corrective maintenance is conducted on the fence line, its associated warning signs, and the roadway.

5. Through direct DOE staffing support and/or contractual arrangements, procedures shall be established to provide routine periodic patrols and surveillance of the protected area by personnel trained in security surveillance and investigation.

6. A process will be implemented for monitoring and controlling the long term testing requirements of the PMS and implementing the periodic monitoring requirements of the LTM Program.

7. Recommendations will be developed for modifications to the active controls appropriate for access control and surveillance upon installation of the PMS.

8. Guidelines will be developed for mitigating actions to be taken to address abnormal conditions identified during periodic surveillance/inspections.

9. Reports addressing activities associated with the Active Access Controls After Disposal performance shall be prepared periodically and submitted to the appropriate regulatory and legislative authority.

Active controls convey that on-site activities are employed. Erecting a barrier around the repository footprint and establishing routine patrols of the barrier, including surveillance of the protected area, establish an active controls system. The development of a schedule to ensure the monitoring of parameters at and adjacent to the repository as related to repository performance is an additional element of active controls. The details of the monitoring program are in the *Long Term Monitoring Concept Description* (March 1994, Draft).

AAC.4.0 ACCESS CONTROLS

Title 40 CFR 191.12 defines Active Institutional Control to include four elements:

1. Controlling access to a disposal site by any means other than passive institutional controls
2. Performing maintenance operations or remedial actions at a site
3. Controlling or cleaning up releases from a site
4. Monitoring parameters related to disposal system performance

LWA has removed the WIPP site from public use as a site for mining and mineral extraction. Since any type of exploration activity would require authorization, the issuance of approval to intrude upon the repository is precluded by the LWA. The existence of the LWA as law permits meeting the requirements of the first element above by implementing low-technology barriers.

AAC.4.1 Repository Footprint Fencing

Access to an area approximately 2,780 ft by 2,360 ft (850 m by 720 m) will be controlled by a four-strand barbed wire fence. A single gate will be included along each side of the fence for access. Around the perimeter of the fence, an unpaved roadway 16 ft (4.9 m) wide will be cut to allow for patrolling of the perimeter. Figure AAC-4 is an illustration of the fence line in relation to the repository footprint. Patrolling of the perimeter is based upon the need to ensure that no mining or well drilling activity is inadvertently initiated that could threaten the integrity of the repository.

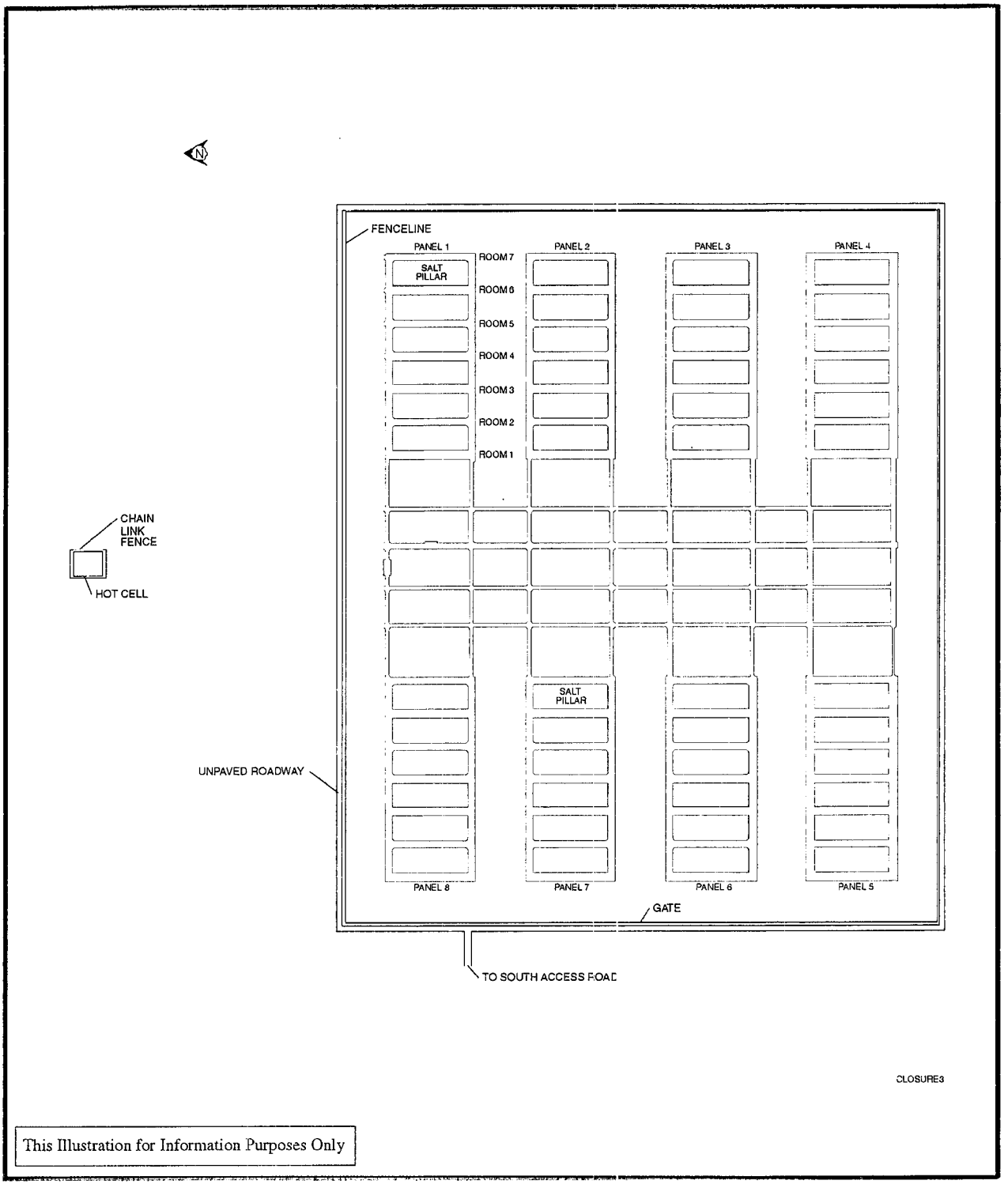
Fencing off an area larger than the disposal area footprint would not significantly reduce the risk of inadvertent intrusion, but would interfere with cattle grazing established prior to the LWA. The LWA allows the Secretary of Energy to permit grazing to continue where it was established prior to enactment of the LWA. Based upon current drilling technologies, discussions with local well drilling organizations, and observation of well drilling activities in the WIPP vicinity, it typically requires at least two to three days for a driller to setup a deep drilling rig and commence actual drilling operations. To attain the 2,150-ft (655-m) depth that would approach the repository horizon takes at least another week to 10 days. Patrolling the fenced area two to three times weekly would identify any potential drilling activity well before any breach of the repository could occur.

The risk of drilling at a location outside the disposal area surface footprint and inadvertently intruding into the disposal area is essentially zero. The most economical drilling practice is to drill vertically into the targeted formation. Local slant drilling is conducted only when the desired drill location is not available due to circumstances which the operator cannot overcome. When slant drilling practices are employed, the deviation from a vertical position directly below the drill rig does not commence until approximately 4,000 ft (1,200 m) below the surface in the local area. Slant drilling within a salt formation is not practical, because the salt is insufficiently consolidated to support the technique. According to the local office of the BLM, slant drilling in the local area does not begin until the drilling operator has reached a level below the salt formations. The lowest salt formation in the WIPP vicinity is the Castile Formation, which lies below the Salado Formation containing the WIPP repository.

Construction of access control systems using higher technology than described is not required or practicable. Likewise, continuous surveillance, whether human or electronic, is not required or practicable. The staffing levels to achieve continuous human surveillance become significant when weighed against the potential risk and the alternatives for controlling access. Continuous electronic surveillance also has significant costs of procurement, installation, testing, and maintenance. Electronic systems would require significant maintenance, both operational and corrective, and probably would not relieve the need to make routine patrols to the site. This is especially true of alarmed electronic surveillance in a location populated by a variety of wild and domestic animals that may give rise to numerous false alarms. Televised electronic surveillance combines both human and electronic technology to become extremely costly in relation to what is needed to provide reasonable assurance of continued repository integrity against inadvertent human intrusion.

AAC.4.2 Surveillance Monitoring

Although the Federal government (initially DOE) could maintain staffing to conduct periodic surveillance of the site, contractual arrangement with a local organization, such as the Eddy County Sheriff's Department, would provide some distinct advantages. Among the advantages:



NMVP-6342-128-0

Figure AAC-4. Perimeter Fenceline and Roadway

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- Sheriff's deputies are trained in patrol and surveillance activities
- Sheriff's deputies are authorized to arrest members of the general public who are found to be violating trespassing laws
- The liability associated with apprehension, attempted apprehension, or circumstances arising from attempts would remain with the Sheriff's Department
- The general area to be patrolled is already a part of the Sheriff's area of responsibility

Surveillance will consist of drive-by patrolling around the fenced perimeter two to three times per week. In the course of the patrol, particular note shall be taken of the fence integrity. In addition, the locked condition of each gate shall be checked to ensure that gate integrity is maintained and that there is no evidence of tampering. Surveillance should also include visual observation of the entire enclosed area for any signs of human activity. A routine summary of each month's surveillance activity shall be prepared documenting the day and time of each patrol and any unusual circumstances that may have been observed. This surveillance routine should continue throughout the active control period and for at least 100 years following the sealing of shafts.

Upon commencement of construction of the PMS, a routine presence at the site will once again be established and periodic surveillance will not be necessary. Once the PMS is completed, the active controls program and access control measures will be reevaluated and changes necessitated by construction of the PM system will made and implemented for the remainder of the active controls period. With construction of the PMS, easy visual inspection of the repository footprint may be curtailed. The berm is an imposing feature that would require being scaled to achieve an unobstructed view of the footprint. The DOE could defer construction of the PMS until decades after completion of decommissioning.

AAC.4.3 Maintenance and Remedial Actions

Anticipated maintenance and remedial action issues during the active control period are minimal and should encompass such issues as:

- Fence and road maintenance
- Evidence of vandalism
- Potential erection of drilling equipment
- Grass fires
- Unauthorized entry into prohibited areas

The DOE will establish contractual arrangements with local commercial and governmental organizations to provide maintenance services when called upon by the organization providing the routine patrolling service. Vandalism or unauthorized entry will be investigated by the Eddy County Sheriff's department and, upon notification of the DOE, action will be taken as the circumstances warrant. Grass fires will be addressed by the City of Carlsbad following notification that a fire exists. Normally, the Sheriff's department will make the notification if the fire is discovered by one of its units.

AAC.4.4 Control and Clean-Up Of Releases

DOE/WIPP 95-2072 (January, 1995) describes how the DOE intends to decontaminate and dismantle the surface structures. This decontamination process and disposal of the derived radioactive waste will be completed prior to the final closing of the waste disposal area and sealing the shafts. With the location of the WIPP repository 2,150 ft (655 m) below the surface and with the panels closed and shafts sealed, the potential for releases of radioactive material following the sealing of the shafts is precluded. There will be no credible pathway for releases from the repository other than human intrusion.

AAC.4.5 Monitoring Disposal System Performance

Details describing the establishment of a network of elevation benchmarks and the development of a data baseline from which to evaluate disposal system performance is described in Appendix LTM. Subsidence monitoring is the primary technology to be used. If, upon analysis of subsidence data disposal, system performance deviates from what is expected, other techniques also described in Appendix LTM may be used to assist in determining more detail regarding performance. Appendix LTM also describes the development of baselines for these other techniques.

AAC.5.0 PERIODIC ACTIVITY CONTROL

With the advent of decommissioning the WIPP and returning the land disturbed by the WIPP activitives to a stable ecological state that will assimilate with the surrounding undisturbed ecosystem, continuous occupancy for operational and security purposes will cease. However, during the active controls period after disposal (at least 100 years), there will be an ongoing need to carry out periodic activities associated with the LTM Program and evaluations of the performance of PMS features under long term testing. To ensure that these periodic activities are implemented and that their results are included in periodic reports to the appropriate regulatory and legislative authorities, a process for controlling these activities will be developed and managed from the appropriate DOE office. The essential elements of the process will include the following:

1. Development of detailed individual activities supporting the LTM

2. Development of detailed individual activities supporting the evaluation of performance of PMS features

3. Development of the individual steps and identification of responsible personnel required for the drafting, review, commenting, and approval of reports to the appropriate regulatory authority

4. Development of the individual steps and identification of responsible organizations or personnel required for the drafting, review, commenting, and approval of reports to the appropriate legislative authority

5. The identification of requirements defined from the above actions will be documented in a detailed schedule covering a period of at least 10 years

6. Review of the approved schedule at least quarterly during the first two years following completion of land restoration and implementation of Active Access Controls After Disposal

7. Semi-annual reviews of the schedule, including updating and progress reporting to the DOE, shall be documented until such time as the Federal government ceases active control of the site

Development of detailed activities supporting the LTM program shall include those elements of the Environmental Monitoring Plan (EMP) (DOE/WIPP 94-024) that are to continue for the first two years following completion of the Decontamination & Decommissioning (D & D) Plan, as stipulated in Appendix A of the C & C between the State of New Mexico and the DOE. As defined in the C & C, this includes "The level of environmental radiological surveillance developed during the operational phase..." Currently, the EMP Radiological Monitoring Program includes:

1. Effluent Monitoring - Liquid Releases
2. Effluent Monitoring - Airborne Releases
3. External Radiation
4. Airborne Particulate
5. Vegetation
6. Beef
7. Game Animals
8. Soil Sampling
9. Surface/Drinking Water
10. Groundwater
11. Aquatic Foodstuffs
12. Sediment Sampling

Appendix A of the C&C also defines elements of a minimum post-operational phase program that will be implemented for at least five years following termination of the D & D phase. This program includes:

- Intermittent operation of the state-operated high volume air sampling stations
- Four annual soil surface samples
- Four annual water samples

NOTE: The TLD requirement has been deleted from DOE/WIPP 94-024 with agreement from the State of New Mexico.

For long-term repository performance monitoring, a detailed subsidence survey will be conducted upon completion of land restoration. That survey will include, at a minimum, the 54 elevation benchmarks currently monitored. Once every ten years, an additional detailed subsidence survey will be taken and analyzed for indications of unexpected repository performance. The LTM plan describes in detail additional technologies to further evaluate repository performance should any unanticipated subsidence data be developed. Updating the ten-year schedule every six months to one year will ensure that this infrequent requirement is not lost.

To optimize the final design of the PMS, testing of various materials and berm configurations over a long period of time is a prudent and logical course of action. The detailed activities supporting the testing required to evaluate various aspects of the planned PMS design and construction will address the following topical processes and materials:

1. Evaluation of the system for unloading and moving large quantities of material from the railroad spur to the PM site

2. Performance of the railroad spur and maintenance required. This may impact a decision of whether to conduct periodic maintenance of the spur, or refurbish it at the time of initiating construction of the PMS

3. Survey of representative monuments within a 150 mi (240 km) radius of the WIPP to more extensively evaluate the climatic environmental affects on granite

4. Identification of a suitable local source of caliche and establishment of required contractual and regulatory agreements to obtain and move the caliche in the quantities required

5. Identification of a suitable local source of riprap and establishing the required contractual and regulatory agreements to obtain and move the riprap in the quantities required

6. Development of construction techniques applicable to a large berm. Determine what, if any, configuration changes may have significant impacts on the cost of construction

7. Evaluation of various berm surface materials (e.g., size of rocks, types of soil, types of vegetation) for durability and success in supporting vegetation overgrowth

8. Procurement, shipment, erection, and evaluation of various types of monument rock to assess the long-term environmental effects of wind, rain, and shifting sand on various types of monument rock (granites and

sandstones). This will provide information for development of specifications for procurement and erection of multiple monuments. In addition, concrete should be emplaced underground and tested for durability as a substitute for the granite in construction of the buried storage rooms associated with the PMS

9. Evaluation of the magnetic signature provided by sample permanent magnets buried within the berm to determine optimum locations and spacing patterns

10. Evaluation of the effects of alternative soils for use as backfill (around subsurface portions of markers) with respect to compatability with granites and sandstones. Preferable materials will function to protect the rock from attack by chemicals within the backfill material

11. Evaluation of environmental effects on the berm caused by wind, rain, and shifting sand

12. Evaluation of the effects of plant root intrusion into the berm and potential for salt dissolution and berm slumping

13. Evaluation of the effectiveness of sample reflectors buried within the berm at various distances. Evaluations should include reflectors directly buried in the berm and buried reflectors encased in concrete

Issue dates should be scheduled for distribution of periodic reports to the appropriate regulatory and legislative authorities, and completion of normal report development activities of assignment of responsibility, establishment of the scope of the reports, completion of initial drafts, draft reviews, comment resolution, and final approval. Management of the reports can then be actively addressed and adequate resources applied to ensure timely completion after effective review and comment.

All of the activities addressed above should be documented on the LTM schedule in sufficient detail to clearly convey the time of their scheduled completion and the organization responsible for conducting the activity. During quarterly and semi-annual reviews of the schedule, responsible individuals should be identified for each specific activity programmed for completion prior to the next review. Documentation of this responsibility and communication to the personnel identified should promote the timely completion of these activities and minimize the potential failure of completing any specific scheduled task.

Due to the relatively simple technology used to provide access control to the repository footprint and the Hot Cell, the range of potential abnormal occurrences is quite limited. Primarily, the abnormal occurrences will involve damage to the fencelines or roadway through vandalism, weather effects, and aging of the materials. Corrective action to

repair these effects will be accomplished by a DOE contractor. The DOE will provide the Eddy County Sheriff's department with applicable guidelines for contacting the appropriate personnel locally for making any identified repairs. Considering the properties for which access control is being provided, there is no need to provide continuous surveillance. However, arrangements should be made for daily vehicular patrols of the site until repairs are made if the damage is of a suspicious nature. If not, no increase in patrol activity should be required.

Abnormal occurrences associated with the environmental monitoring activities should be investigated under the auspices of the DOE Albuquerque Operations Office. As described above, the post-decommissioning environmental monitoring program will include both radiological and nonradiological monitoring for the first two years following land restoration and only radiological monitoring thereafter. Due to the reduced activity to support the WIPP after disposal, it is probably more cost-effective for the DOE to contract for the periodic sampling and analyses than to maintain a Carlsbad staff for that purpose. Within the contractual arrangements, immediate notification by the contractor to the Albuquerque Operations Office in the event of an abnormal occurrence should be a requirement. Appropriate guidelines for action to mitigate the effects of abnormal occurrences related to environmental monitoring should include:

- Verification of analytical results
- Increased frequency of sampling and analyses
- Determination of cause
- Investigation of additional geographical and/or parameter monitoring areas that might be affected
- Timely communication to the press regarding any potential adverse impacts and mitigating actions to be taken

The LTM provides guidance for conducting subsidence surveys every ten years following repository closure. If the surveys indicate a rate of subsidence significantly different than predicted, additional technologies may be introduced to more precisely evaluate what, if any, conditions detrimental to repository integrity have occurred. These additional technologies may include:

- Seismic Reflection/Refraction Surveys
- Gravitational Surveys
- Electromagnetic Conductivity Surveys
- Resistivity Surveys
- Ground Penetrating Radar Surveys

Currently, none of these technologies are developed to the degree of providing irrefutable evidence of the condition of the sealed repository. However, over the next few decades, while waste is being emplaced in the repository, the technology will likely advance significantly. It is also possible that images available using today's technologies will improve to a point where resolution of images of the repository acquired from grade level

will be of sufficient quality to make some assessments of repository performance. The action guidelines for abnormal occurrences associated with subsidence are the same as those proposed for the environmental monitoring program.

AAC.6.0 ARCHIVED INFORMATION

Proposed regulations require the placement of records in the archives and land record systems of local, state, Federal governments, and international archives that would likely be consulted by individuals in search of unexploited resources. A significant part of the overall system of controls is the use of passive institutional controls through the archiving of information at locations other than at the repository site. The archived information will describe the location of the repository, the nature and hazard of the waste, the geologic, geochemical, hydrologic, and other data pertinent to the containment of the waste, and the results of tests, experiments, and/or other analyses relating to excavated areas, shaft sealing, waste experiments, and analyses pertinent to the containment of waste in the repository. This information will be more extensive in volume than that available near the repository and should be widely distributed in a number of locations, including some locations worldwide.

The initial form of the information should be on archival quality paper and high-quality microfilm. Jensen (1993) describes a Scandinavian paper specification that prescribes that the paper be made of fibers from cotton, linen, and/or bleached chemical pulp with any other type pulp making up less than 5 percent of the fiber content. In addition, the pH is specified as 7.5-10 with a minimum 2 percent calcium carbonate alkaline reserve.

Specific documents that should be included in the archived information portfolio include:

1. The Final Safety Analysis Report (FSAR) and the addenda that describes the disposal phase of the WIPP

2. The Final Environmental Impact Statement (FEIS) for WIPP and the supplement(s) to the Environmental Impact Statement

3. The No-Migration Variance Petition (NMVP) and the No-Migration Determination for Disposal

4. The Resource, Conservation, and Recovery Act (RCRA) Permit Application and final Permit

5. The Compliance Certification Application (CCA) for Title 40 CFR 191 and final EPA certification

6. Environmental and ecological background data collected during the preoperational phase of WIPP and summaries of data collected during the disposal and decommissioning phases of the WIPP

7. Records of the contents of the waste containers and their disposal location within the WIPP repository

8. Drawings defining the construction and configuration of the repository and shafts

9. Drawings, procedures, and design report(s) describing how the waste was emplaced; how the rooms, entries, and panels were closed and sealed; and how the shafts and boreholes were sealed

10. Detailed maps describing the exact geographic and geologic location of the repository

Locations for this information should include public-funded organizations that may be more likely to expend the resources necessary to preserve the documents in well-controlled environments. However, the most likely strategy for long-term protection of the information is through widespread distribution. As a minimum, the information shall be submitted to the following facilities/organizations (or their equivalent) for archiving:

1. Library of Congress
2. National Archives
3. Within the States of New Mexico and Texas
   - The state archives
   - The state library
   - The city libraries of population centers exceeding 15,000 within 150 mi (241 km) of Carlsbad
4. The state libraries of the remaining 48 states
5. The local office of the BLM
6. The local office of the Bureau of Mines
7. The local office of the Bureau of Reclamation
8. The national library and national archives of the nations worldwide that possess nuclear weapons and/or operate nuclear power generating plants
9. The archive of the United Nations
10. The national archive/libraries of the signatory nations to the nuclear non-proliferation treaty
11. The U.S. Nuclear Regulatory Commission (NRC)
12. The 53 Federal Regional Depository Libraries

Location and hazards information shall be submitted to various Federal and State of New Mexico mapping agencies to ensure that the WIPP location and drilling or mining restrictions are identified on widely distributed maps used by almost all public and private organizations. These agencies include:

1. BLM
2. U.S. Geological Survey

3. Library of Congress
4. National Archives and Records Service
5. Defense Mapping Agency
6. International Boundary Commission
7. Federal Highway Administration
8. U.S Department of Transportation (DOT)
9. New Mexico State Highway Department Planning and Research Division, Cartography Section
10. One-Call System of notification of underground utilities

To ensure widespread information relative to the location of the WIPP site and the hazards associated with the emplaced waste, detailed maps and descriptions of the waste constituents should be sent to national and international professional societies of cartographers and geographers. Weitzburg (1982) suggests the following organizations and societies receive this location and hazards information:

1. The American Congress on Surveying and Mapping
2. The American Society of Cartographers
3. The Commission for the Geological Map of the World
4. The International Cartographic association
5. The American Geographical Society
6. The Association of American Geographers
7. The International Geographical Union
8. The Society of Women Geographers
9. The American Geological Institute
10. The American Geophysical Union
11. The American Society of Professional Geographers
12. The National Geographic Society
13. Mining, Oil, and Gas Professional Organizations

Many of the members of these various organizations are employed in secondary and college education, providing an opportunity for this information to become more widely disseminated among students during their formal education.

AAC.7.0 QUALITY ASSURANCE

The Quality Assurance and Quality Control (QA/QC) discipline shall be applied to the procurement of materials for and the erection of the fencelines enclosing the repository footprint and the Hot Cell. In particular, QC inspection of the placement and tensioning of the barbed wire and chain link fabric should be applied and used to provide reasonable assurance that the fencing structures will function over an extended period without significant maintenance to a number of aspects of the PM procurement and construction effort.

QA/QC will also be applied to the sampling and analyses supporting the environmental monitoring program and the LTM. DOE contractors collecting samples and laboratories conducting analyses should be qualified in accordance with guidelines prescribed in the most current edition of the *WID Quality Assurance Program Description* (WP 13-1) at the time that the contracts are awarded.

The creation and management of records included in the archived information is controlled under an approved QA program. This program has been developed in accordance with established DOE and industry guidelines. It includes procedures governing the creation, handling, and distribution of records, and QA/QC for passive controls as dealt with elsewhere.

REFERENCES

DOE/WIPP 95-2072, *Conceptual Decontamination and Decommissioning Plan*, January, 1995

Jensen, Mikael. 1993. *Conservation and Retrieval of Information - Elements of a Strategy to Inform Future Societies about Nuclear Waste Repositories*. Final Report of the Nordic Nuclear Safety Research Project KAN - 1.3. August 1993

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Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Department of Interior, July 1994

Passive Institutional Controls Conceptual Design Report, May, 1996

Title 40 Code of Federal Regulations Part 191, *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, Subpart B *Environmental Standards for Disposal*

Title 40 Code of Federal Regulations Part 264 *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,* Subpart X *Miscellaneous Units*

WP 13-1, *WID Quality Assurance Program Description*

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APPENDIX ADM

AIR DISPERSION MODELING

APPENDIX D10

AIR DISPERSION MODELING

(From the WIPP RCRA Part B Permit Application, Rev. 6)

APPENDIX D10
AIR DISPERSION MODELING

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1.0 SCOPE

The purpose of this modeling was to determine the air dispersion factors (ADF) representing the maximum concentrations of any gaseous airborne hazardous constituent that would be released from the mine air exhaust system during Waste Isolation Pilot Plant (WIPP) disposal operations. The main function of this calculation was performed by using the Environmental Protection Agency (EPA) computer-based Industrial Source Complex Long-Term (ISCLT3) air dispersion model. The model was used to predict a maximum concentration in $\mu g/m^3$, given an arbitrary input of a gas concentration of 1,000 $\mu g/m^3$. The ADF was then calculated using the following ratio:

$$\textit{Air Dispersion Factor} = \frac{\textit{maximum concentration } (\mu g/m^3)}{\textit{release concentration } (\mu g/m^3)} \qquad \text{(D10-1)}$$

2.0 BACKGROUND

The calculations and model runs were performed for the No-Migration Variance Petition (NMVP) and the Resource Conservation and Recovery Act (RCRA) Part B Permit Application. In the petition, the Department of Energy (DOE) must demonstrate that there will be no migration of hazardous constituents above heath-based levels (HBL) beyond the unit boundary. In its guidance manual, the EPA recommends that no-migration variance petitioners assess the air pathway using the ISC model. Given a concentration of a volatile organic compounds (VOC) in air released from the mine ventilation exhaust ducts, the air dispersion factor determines the resulting maximum concentration for the NMVP. This concentration is then compared to HBLs to demonstrate no-migration. In the permit application the DOE must demonstrate that there will be no release that may have an adverse effect on human health and the environment due to migration of waste constituents in the air. For the permit application the maximum concentration is used to calculate the long-term risk to the public, and then compared to acceptable risk levels. Occupational exposure is also required to be assessed in the application.

To perform the assessments above, four ADFs were determined. One ADF was determined for the maximum concentration point on the WIPP Site Boundary, two ADFs were determined for public exposure inside the WIPP Site Boundary, and one ADF was determined for the maximum worker exposure inside the Property Protection Area.

The EPA guidance on the air pathway assessment for NMVPs has specific requirements related to the ISC model run(s) for a NMVP. The model runs should:

1. estimate annual average concentrations using ISCLT3;
2. use five years of preferable on-site meteorological data, evaluate one year at a time, and use the run that produces the maximum boundary concentration;
3. include receptors up to 328 feet (100 meters) beyond the unit boundary to verify that the maximum concentration occurs at the boundary;
4. include a fine receptor grid in the maximum concentration area;
5. use Cartesian receptor grids;

6. correct for the vertical wind profile, if the source is at ground level; and
7. specify receptor heights at 5 feet (1.5 meters) (inhalation height).

Although the WIPP facility has an on-site meteorological monitoring program, the wind speed and direction data recorded under that program for the last five years do not meet EPA guidance for completeness (90 percent). As a whole, the data represent approximately 50 percent of the past five years. However, the data collected during 1993 represents approximately 70 percent coverage for that year. In addition to the on-site data, a complete set of meteorological data from the Carlsbad, New Mexico National Weather Service (NWS) Station at the Carlsbad Municipal Airport was available. The environmental conditions at the Carlsbad airport are similar to those at the WIPP facility, which is located approximately 30 miles east/southeast of the airport. Data from this station are based on hourly observations, 24 hours a day, and it is the closest NWS station to the WIPP site.

Yearly meteorological data for the Carlsbad, New Mexico NWS Station from 1990 to 1994 and the WIPP on-site meteorological station from 1993 were used during the analyses. In each model run, each set of meteorological data were used, and the run that yielded the highest concentration of concern was used to determine the next run or the ADF.

3.0 MODEL INPUT PARAMETERS

3.1 General

The ISCLT3 model is a FORTRAN computer program that requires an input file with parameters for the model run. The input file uses a keyword/parameter approach. The keywords specify the type of option or input data entered on each line of the input file and the parameters following the keyword define the specific options selected or the actual input data. The input file is divided into five functional "pathways." The pathway keywords and description are as follows:

- CO - for specifying overall job COntrol options;
- SO - for specifying SOurce information;
- RE - for specifying REceptor information;
- ME - for specifying MEteorology information; and
- OU - for specifying OUtput options.

The input parameters described below are the only ones applicable to these model runs. Also note that all parameter values are expressed in SI units unless otherwise specified.

3.2 Job Control Options

TITLEONE and TITLETWO - specify a title for the model run

MODELOPT - CONC specifies an output in concentration of a gas per unit volume of air, and RURAL specifies the facility is in a rural area.

AVERTIME - time interval for averaging long-term concentrations

POLLUTID - name or other identifier of the pollutant modeled

TERRHGTS - elevation differences between source and receptors

ELEVUNIT - elevation unit

FLAGPOLE - height of receptor above ground-level

3.3 Source Information

LOCATION - coordinates for each source
SRCPARAM - source parameters, such as emission rate (mass/time), stack height, stack temperature, exit velocity, and equivalent stack diameter

Stack Tip Downwash and Building Wake - ISC incorporates the effects of wind turbulence at the exit of the stack (exhaust duct) and near other buildings around the stack using the Building Profile Input Program (BPIP). Data representing the buildings and structures around the stack are required.

BUILDHGT - height of buildings near the exhaust stack
BUILDWID - apparent width of buildings near the exhaust stack

3.4 Receptor Information

GRIDCART - Cartesian coordinates of a grid of receptors
DISCCART - Cartesian coordinates of discrete receptors

3.5 Meteorological Information

INPUTFIL - directory and filename containing STAR data
ANEMHGHT - height of the anemometer
SURFDATA - surface meteorological station number, year data represents, and a name for the information
UAIRDATA - upper air meteorological station number, year data represents, and a name for the information
STARDATA - time interval STAR data represents
AVESPEED - median values of wind speed categories represented in the STAR data
AVETEMPS - time interval, and average temperature for each wind speed category
AVEMIXHT - time interval, average mixing height for each wind speed category and each stability class
DTHETADZ - vertical temperature gradients for each wind speed category and each stability class

3.6 Output Options

RECTABLE - print a receptor concentration table
MAXTABLE - print maximum ground-level concentrations for the number specified

4.0 INPUT PARAMETERS

4.1 Job Control Options (most are self-explanatory)

TERRHGTS - ELEV, use elevations for complex terrain as indicated on topographic

maps provided in Attachment B

ELEVUNIT - units are in feet to correspond to US Geological Survey (USGS) maps

4.2 Source Information

LOCATION - the center of the outer edge of the exhaust fan discharge duct of one main fan represents the origin (0,0) for all other coordinates. The other fan discharge coordinate is 23.6 feet (7.2 meters) north of the origin.

SRCPARAM - The "stack" in this case is the exhaust fan discharge duct, which is rectangular. The emission rate is calculated assuming that 1000 $\mu g/m^3$ (0.001 g/m^3) of any gas is released from 425,000 ft^3/min of air.

$$air\ release\ rate = (425{,}000\,ft^3/\text{min})\,x\,(1\,m^3/35.32\,ft^3)\,x\,(1\,\text{min}/60\ s)$$

$$= 200.6\ m^3/s$$

$$release\ rate\ for\ each\ fan = \frac{(200.6\ m^3/s)}{2\ fans} = 100.3\ m^3/s$$

$$emission\ rate = (0.001\ g/m^3)\ x\ (100.3\ m^3/s) = 0.1\ g/s$$

stack height = 8.2 meter
stack temperature = 288 Kelvin

Because the exhaust fans actually emit the mine air at approximately a 45° angle, the vector equivalent velocity is input as (velocity) x (SIN 45°):

$$stack\ vel. = \frac{(vol.\ flow\ rate)\,x\,(\sin 45°)}{\pi\ x\ (d/2)^2} = \frac{70.92\,m^3/s}{\pi\ x\ (4.4\ m/2)^2} = 4.66\ m/s$$

$$stack\ exit\ area = (178\,in)\ x\ (130\,in)\ x\ (m^2/1549.4\,in^2) = 14.93\,m^2$$

$$equivalent\ dia. = 2\ x\ (A/\pi)^{1/2} = 2\ x\ (14.93\ m^2/\pi)^{1/2} = 4.4\ m$$

BUILDHGT and BUILDWID - Apparent width is the width of a structure perpendicular to the 16 evenly-spaced sectors around the stack (Figure 1). For example, the apparent width of Building 413 in the northwest direction is 28.9 feet (8.8 meters).

4.3 Receptor Information

4.3.1 Receptor Grid

4.3.1.1 Coarse Receptor Grid

The first five runs (Attachment A) were coarse grid runs covering the WIPP property from the source (exhaust fans) to the WIPP Site Boundary. The receptors in these runs were generated in a Cartesian Grid of 1,312 feet (ft) by 1,312 ft (400 meters (m) by 400 m), which is the maximum number of receptors that can be used in one run to cover the property. One run was performed with the 1993 WIPP meteorological data, and the other five runs were performed with 1990 to 1994 Carlsbad meteorological data.

To determine the two ADFs for public inside the WIPP Site Boundary, the coarse grid concentrations were averaged for two areas. The two areas represent the cattle grazing leases on the WIPP property as shown in Figure D9-1 in Appendix D9 of the permit application (Appendix RA of the NMVP).

4.3.1.2 Fine Receptor Grid

To determine the WIPP Site Boundary ADF and the Property Protection Area ADF, two fine grids runs were performed. Based on the highest concentration at or beyond the WIPP Site Boundary from the six coarse grid runs, a fine grid run of 32 ft by 32 ft (10m by 10m) was performed around that point. In the other run a fine grid run of 32 ft by 32 ft (10m by 10m) was performed around the highest concentration, which was in the Property Protection Area from the six coarse runs.

4.4 Meteorological Information

INPUTFIL	- STAR file consisting of the normal frequency distribution of wind speed and wind direction, grouped by stability class. The data used in these model runs is from the Carlsbad, New Mexico Municipal Airport NWS Station.
ANEMHGHT	- self-explanatory
SURFDATA	- self-explanatory
UAIRDATA	- self-explanatory
STARDATA	- self-explanatory
AVESPEED	- self-explanatory
AVETEMPS	- 288 Kelvin for each stability class
AVEMIXHT	- 4,708 feet (1,435 meters) for each stability class and each wind speed category
DTHETADZ	- 0.01° - stability class E, 0.03° - stability class F

4.5 Output Options

MAXTABLE	- print the top 10 maximum ground-level concentrations and associated receptor coordinate and type

5.0 AIR DISPERSION FACTORS

Using equation D10-1, the four ADFs were calculated and are presented in Table D10-1 below. In conclusion, any concentration of a gas released from the exhaust ducts can be multiplied by these ADFs to determine the maximum annual average concentration at the point or area of concern.

TABLE D10-1
AIR DISPERSION FACTORS

Area	ADF
WIPP Site Boundary	1.2×10^{-4}
Grazing Lease Area - North	9.8×10^{-5}
Grazing Lease Area - South	6.7×10^{-5}
Property Protection Area	1.2×10^{-2}

BIBLIOGRAPHY

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DOE (U.S. Department of Energy). 1980. *Final Environmental Impact Statement for the Waste Isolation Pilot Plant.* DOE/EIS-0026.

DOE (U.S. Department of Energy). 1995. *Safety Analysis Report for the Waste Isolation Pilot Plant.* DOE/WIPP-95-2065.

Trinity Consultants, Inc. 1995. *Letter on Quality of WIPP On-Site Meteorological Data for ISCLT2 model runs.* Contract 75WJM66763SZ.

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ATTACHMENT A - MODEL OUTPUT LIST FILES

TABLE OF CONTENTS

Coarse Grid Run with WIPP Meteorological Data D10-10

Coarse Grid Run with 1990 Carlsbad Meteorological Data D10-34

Coarse Grid Run with 1991 Carlsbad Meteorological Data D10-58

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Coarse Grid Run with 1993 Carlsbad Meteorological Data D10-106

Coarse Grid Run with 1994 Carlsbad Meteorological Data D10-130

WIPP Site Boundary Fine Grid Run with WIPP Meteorological Data D10-154

WIPP Site Boundary Fine Grid Run with 1990 Carlsbad Meteorological Data . . . D10-190

Property Protection Area Fine Grid Run with WIPP Meteorological Data D10-226

Property Protection Area Fine Grid Run with 1990 Carlsbad Meteorological Data D10-257

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (93 WIPP Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
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SO LOCATION 2 POINT       0.00       7.20    1039.37
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SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
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SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
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RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\WP3093.STR FREE

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1993 WIPP

ME UAIRDATA 11111 1993

ME STARDATA ANNUAL

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ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

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ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

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ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

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ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

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ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCW93A.GPH 70

OU FINISHED

***********************************
*** SETUP Finishes Successfully ***
***********************************
```

1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCW93A.DAT ; **Output Print File: ADMCW93A.LST

2

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

3
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5, -2789.5, -2389.5, -1989.5, -1589.5, -1189.5, -789.5, -389.5, 10.5, 410.5,
810.5, 1210.5, 1610.5, 2010.5, 2410.5, 2810.5, 3210.5,

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8, -3069.8, -2669.8, -2269.8, -1869.8, -1469.8, -1069.8, -669.8, -269.8, 130.2,
530.2, 930.2, 1330.2, 1730.2, 2130.2, 2530.2, 2930.2,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS)							
	-3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53
10.47								
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42
1042.42								
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46
1048.51								
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46
1054.61								
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51
1054.61								
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56
1057.66								
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51
1051.56								
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46
1045.46								
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
1036.32								
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32
1039.37								
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27
1036.32								
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27
1036.32								
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22
1033.27								
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18
1030.22								
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13
1030.22								
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13
1027.18								
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03
1024.13								
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03
1018.03								

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000
90.000	.00019600	.00034000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00034000	.00000000	.00000000	.00000000	.00000000
135.000	.00019600	.00136200	.00000000	.00000000	.00000000	.00000000
157.500	.00039200	.00238300	.00000000	.00000000	.00000000	.00000000
180.000	.00195900	.00187200	.00000000	.00000000	.00000000	.00000000
202.500	.00195900	.00153200	.00000000	.00000000	.00000000	.00000000
225.000	.00215500	.00221300	.00000000	.00000000	.00000000	.00000000
247.500	.00195900	.00119100	.00000000	.00000000	.00000000	.00000000
270.000	.00078400	.00085100	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00019600	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00058800	.00017000	.00051100	.00000000	.00000000	.00000000
67.500	.00078400	.00085100	.00017000	.00000000	.00000000	.00000000
90.000	.00156700	.00102100	.00051100	.00000000	.00000000	.00000000
112.500	.00333100	.00306400	.00255300	.00000000	.00000000	.00000000
135.000	.00293900	.00425500	.00425500	.00000000	.00000000	.00000000
157.500	.00293900	.00766000	.00680900	.00000000	.00000000	.00000000
180.000	.00411400	.00697900	.00510600	.00000000	.00000000	.00000000
202.500	.00489800	.00646800	.00306400	.00000000	.00000000	.00000000
225.000	.00391800	.00459600	.00187200	.00000000	.00000000	.00000000
247.500	.00509400	.00527700	.00153200	.00000000	.00000000	.00000000
270.000	.00117600	.00170200	.00204300	.00000000	.00000000	.00000000
292.500	.00098000	.00187200	.00221300	.00000000	.00000000	.00000000
315.000	.00098000	.00102100	.00119100	.00000000	.00000000	.00000000
337.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00039200	.00034000	.00000000	.00000000	.00000000	.00000000
22.500	.00019600	.00034000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00068100	.00238300	.00000000	.00000000	.00000000
67.500	.00098000	.00085100	.00102100	.00000000	.00000000	.00000000
90.000	.00137100	.00136200	.00187200	.00000000	.00000000	.00000000
112.500	.00450600	.00391500	.00629800	.00034000	.00000000	.00000000
135.000	.00352700	.00544700	.01787200	.00442600	.00000000	.00000000
157.500	.00450600	.00425500	.01123400	.00289400	.00000000	.00000000
180.000	.00293900	.00595700	.01089400	.00340400	.00017000	.00000000
202.500	.00176300	.00459600	.00595700	.00017000	.00000000	.00000000
225.000	.00313500	.00425500	.00187200	.00017000	.00000000	.00000000
247.500	.00156700	.00340400	.00459600	.00170200	.00000000	.00000000
270.000	.00195900	.00289400	.00204300	.00170200	.00034000	.00000000
292.500	.00137100	.00153200	.00221300	.00000000	.00000000	.00000000
315.000	.00039200	.00136200	.00221300	.00051100	.00000000	.00000000
337.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00017000	.00017000	.00000000	.00000000	.00000000
22.500	.00000000	.00102100	.00119100	.00102100	.00034000	.00034000
45.000	.00039200	.00255300	.00493600	.00851100	.00153200	.00000000
67.500	.00078400	.00425500	.00595700	.00697900	.00068100	.00017000
90.000	.00313500	.00527700	.01293600	.00987200	.00119100	.00017000
112.500	.00372300	.01293600	.02706400	.01344700	.00136200	.00000000
135.000	.00372300	.01004300	.03285100	.04204300	.00306400	.00000000
157.500	.00176300	.00663800	.01855300	.01991500	.00238300	.00017000
180.000	.00274300	.00612800	.01072300	.00425500	.00051100	.00000000
202.500	.00117600	.00425500	.00731900	.00357400	.00000000	.00000000
225.000	.00019600	.00408500	.00510600	.00340400	.00136200	.00017000
247.500	.00058800	.00357400	.00595700	.01123400	.00306400	.00136200
270.000	.00058800	.00238300	.00527700	.00748900	.00357400	.00187200
292.500	.00039200	.00153200	.00221300	.00238300	.00102100	.00000000
315.000	.00000000	.00068100	.00204300	.00391500	.00136200	.00034000
337.500	.00000000	.00000000	.00034000	.00051100	.00000000	.00000000

14
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00034000	.00034000	.00000000	.00000000	.00000000
22.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00085100	.00187200	.00000000	.00000000	.00000000
67.500	.00000000	.00170200	.00272300	.00000000	.00000000	.00000000
90.000	.00000000	.00272300	.00783000	.00000000	.00000000	.00000000
112.500	.00000000	.00680900	.02314900	.00000000	.00000000	.00000000
135.000	.00000000	.01123400	.02961700	.00000000	.00000000	.00000000
157.500	.00000000	.00868100	.01038300	.00000000	.00000000	.00000000
180.000	.00000000	.00323400	.00238300	.00000000	.00000000	.00000000
202.500	.00000000	.00340400	.00068100	.00000000	.00000000	.00000000
225.000	.00000000	.00221300	.00119100	.00000000	.00000000	.00000000
247.500	.00000000	.00187200	.00442600	.00000000	.00000000	.00000000
270.000	.00000000	.00034000	.00272300	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00204300	.00000000	.00000000	.00000000
315.000	.00000000	.00085100	.00170200	.00000000	.00000000	.00000000
337.500	.00000000	.00034000	.00085100	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00051100	.00000000	.00000000	.00000000	.00000000
22.500	.00039200	.00187200	.00000000	.00000000	.00000000	.00000000
45.000	.00156700	.00374500	.00000000	.00000000	.00000000	.00000000
67.500	.00313500	.00476600	.00000000	.00000000	.00000000	.00000000
90.000	.00607400	.00748900	.00000000	.00000000	.00000000	.00000000
112.500	.01097200	.02059600	.00000000	.00000000	.00000000	.00000000
135.000	.01195100	.02348900	.00000000	.00000000	.00000000	.00000000
157.500	.01136400	.01293600	.00000000	.00000000	.00000000	.00000000
180.000	.00881700	.00561700	.00000000	.00000000	.00000000	.00000000
202.500	.00607400	.00357400	.00000000	.00000000	.00000000	.00000000
225.000	.00470200	.00493600	.00000000	.00000000	.00000000	.00000000
247.500	.00450600	.00510600	.00000000	.00000000	.00000000	.00000000
270.000	.00254700	.00272300	.00000000	.00000000	.00000000	.00000000
292.500	.00176300	.00238300	.00000000	.00000000	.00000000	.00000000
315.000	.00195900	.00238300	.00000000	.00000000	.00000000	.00000000
337.500	.00058800	.00187200	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99999

15
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.065769	.075666	.075780	.079804	.081915	.081094	.081777	.083849	.070873
2530.19	.067632	.081635	.095510	.102764	.107807	.108443	.099799	.110719	.095228
2130.19	.073869	.090523	.112253	.124712	.145173	.138825	.136338	.142826	.120694
1730.19	.079878	.099408	.125793	.161919	.185073	.199953	.199806	.204437	.159140
1330.19	.085004	.107306	.138573	.169472	.211444	.300336	.322220	.298857	.224387
930.19	.080948	.106643	.145621	.185914	.240418	.359329	.451964	.483030	.350081
530.19	.072245	.088150	.120204	.158123	.218275	.317410	.476453	.917824	.612324
130.19	.054653	.064879	.078691	.098137	.126338	.171871	.258387	.463141	1.323298
-269.81	.037627	.042552	.048406	.055372	.062816	.070488	.086707	.135155	.008444
-669.81	.026443	.026068	.033451	.035338	.036063	.046215	.054874	.037382	.007953
-1069.81	.019342	.018214	.020776	.024879	.024502	.032864	.030024	.011820	.006235
-1469.81	.014561	.014330	.016571	.019192	.020345	.019743	.013360	.007162	.004183
-1869.81	.012035	.012644	.014329	.014919	.013677	.011276	.006051	.004785	.002989
-2269.81	.009958	.011094	.011439	.011572	.009621	.007182	.004134	.003390	.002423
-2669.81	.008863	.009715	.009233	.008065	.006831	.004607	.003366	.002752	.001864
-3069.81	.007879	.007546	.007273	.006108	.004879	.003072	.002554	.001935	.001479
-3469.81	.006286	.006149	.005374	.004656	.003229	.002601	.001989	.001650	.001123

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.066410	.056593	.048034	.043285	.038518	.034008	.029928	.027224
2530.19	.082451	.067745	.056212	.049549	.043027	.037143	.033284	.030229
2130.19	.101205	.079013	.066837	.056789	.047865	.042030	.037472	.033408
1730.19	.127230	.096333	.080074	.065013	.055390	.048156	.041883	.036636
1330.19	.164793	.123308	.095632	.077998	.065039	.054529	.046222	.039642
930.19	.223003	.159887	.120366	.094147	.074690	.058938	.046259	.037427
530.19	.319253	.219602	.150175	.100331	.071171	.053443	.041806	.033791
130.19	.383190	.209957	.120484	.080131	.057873	.044206	.035118	.028769
-269.81	.124966	.111276	.080921	.059900	.045995	.036565	.029873	.024988
-669.81	.034933	.068361	.055900	.042052	.035401	.029833	.025326	.021767
-1069.81	.012542	.034125	.044029	.035685	.028957	.023784	.020545	.018336
-1469.81	.009032	.018355	.029486	.029455	.025083	.021319	.018228	.015741
-1869.81	.006659	.010426	.018769	.021687	.021414	.018801	.016506	.014526
-2269.81	.004544	.006680	.010799	.015312	.016718	.016477	.014803	.013270
-2669.81	.002962	.004742	.006755	.009889	.012624	.013419	.013210	.012050
-3069.81	.002251	.003177	.004158	.006800	.008794	.010596	.011077	.010600
-3469.81	.001605	.002434	.003479	.004744	.006831	.008440	.008778	.008703

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	1.323298	AT (	10.47,	130.19)	GC	6.	.463141	AT (	-389.53,	130.19)	GC
2.	.917824	AT (	-389.53,	530.19)	GC	7.	.451964	AT (	-789.53,	930.19)	GC
3.	.612324	AT (	10.47,	530.19)	GC	8.	.383190	AT (	410.47,	130.19)	GC
4.	.483030	AT (	-389.53,	930.19)	GC	9.	.359329	AT (	-1189.53,	930.19)	GC
5.	.476453	AT (	-789.53,	530.19)	GC	10.	.350081	AT (	10.47,	930.19)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (90 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50			
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50			
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50			
RE	GRIDCART	COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 5	1.50			
RE	GRIDCART	COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 6	1.50			
RE	GRIDCART	COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 7	1.50			
RE	GRIDCART	COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 8	1.50			
RE	GRIDCART	COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 9	1.50			
RE	GRIDCART	COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 10	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1   3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1   3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1   3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
```

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RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD90.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1990 CARLSBAD

ME UAIRDATA 11111 1990

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC90A.GPH 70

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
```

1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC90A.DAT ; **Output Print File: ADMCC90A.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

3
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5, -2789.5, -2389.5, -1989.5, -1589.5, -1189.5, -789.5, -389.5, 10.5, 410.5,
810.5, 1210.5, 1610.5, 2010.5, 2410.5, 2810.5, 3210.5,

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8, -3069.8, -2669.8, -2269.8, -1869.8, -1469.8, -1069.8, -669.8, -269.8, 130.2,
530.2, 930.2, 1330.2, 1730.2, 2130.2, 2530.2, 2930.2,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00064000	.00083000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
45.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
67.500	.00048000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00094000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00057000	.00047000	.00000000	.00000000	.00000000	.00000000
135.000	.00126000	.00083000	.00000000	.00000000	.00000000	.00000000
157.500	.00045000	.00059000	.00000000	.00000000	.00000000	.00000000
180.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
202.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
225.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
247.500	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
270.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00036000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00103000	.00213000	.00189000	.00000000	.00000000	.00000000
22.500	.00130000	.00213000	.00071000	.00000000	.00000000	.00000000
45.000	.00083000	.00177000	.00118000	.00000000	.00000000	.00000000
67.500	.00118000	.00307000	.00106000	.00000000	.00000000	.00000000
90.000	.00169000	.00284000	.00130000	.00000000	.00000000	.00000000
112.500	.00105000	.00402000	.00189000	.00000000	.00000000	.00000000
135.000	.00116000	.00556000	.00355000	.00000000	.00000000	.00000000
157.500	.00225000	.00721000	.00343000	.00000000	.00000000	.00000000
180.000	.00248000	.00520000	.00343000	.00000000	.00000000	.00000000
202.500	.00039000	.00071000	.00095000	.00000000	.00000000	.00000000
225.000	.00043000	.00095000	.00012000	.00000000	.00000000	.00000000
247.500	.00009000	.00059000	.00024000	.00000000	.00000000	.00000000
270.000	.00035000	.00047000	.00035000	.00000000	.00000000	.00000000
292.500	.00045000	.00024000	.00024000	.00000000	.00000000	.00000000
315.000	.00034000	.00130000	.00012000	.00000000	.00000000	.00000000
337.500	.00071000	.00189000	.00071000	.00000000	.00000000	.00000000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00080000	.00366000	.00816000	.00248000	.00012000	.00000000
22.500	.00035000	.00284000	.00343000	.00059000	.00000000	.00000000
45.000	.00025000	.00319000	.00118000	.00012000	.00000000	.00000000
67.500	.00036000	.00296000	.00130000	.00000000	.00000000	.00000000
90.000	.00056000	.00390000	.00343000	.00071000	.00000000	.00000000
112.500	.00067000	.00366000	.00473000	.00142000	.00000000	.00000000
135.000	.00029000	.00366000	.01017000	.00355000	.00012000	.00000000
157.500	.00069000	.00556000	.01324000	.00248000	.00035000	.00000000
180.000	.00040000	.00508000	.01206000	.00284000	.00024000	.00000000
202.500	.00034000	.00106000	.00106000	.00071000	.00000000	.00000000
225.000	.00016000	.00047000	.00047000	.00012000	.00024000	.00000000
247.500	.00030000	.00059000	.00177000	.00083000	.00071000	.00047000
270.000	.00047000	.00118000	.00225000	.00213000	.00165000	.00071000
292.500	.00031000	.00071000	.00083000	.00083000	.00024000	.00000000
315.000	.00035000	.00118000	.00095000	.00035000	.00000000	.00000000
337.500	.00033000	.00095000	.00189000	.00059000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00043000	.00461000	.00875000	.01572000	.00307000	.00059000
22.500	.00042000	.00248000	.00402000	.00449000	.00047000	.00035000
45.000	.00044000	.00284000	.00496000	.00343000	.00035000	.00012000
67.500	.00037000	.00177000	.00366000	.00201000	.00000000	.00000000
90.000	.00058000	.00307000	.00579000	.00496000	.00035000	.00000000
112.500	.00042000	.00248000	.00603000	.00378000	.00035000	.00000000
135.000	.00100000	.00556000	.01312000	.01820000	.00201000	.00059000
157.500	.00073000	.00520000	.02506000	.02376000	.00225000	.00024000
180.000	.00096000	.00496000	.01962000	.01466000	.00071000	.00047000
202.500	.00028000	.00225000	.00319000	.00366000	.00118000	.00035000
225.000	.00064000	.00201000	.00390000	.00319000	.00106000	.00024000
247.500	.00034000	.00130000	.00544000	.01253000	.00532000	.00189000
270.000	.00021000	.00307000	.00768000	.02624000	.01548000	.00662000
292.500	.00049000	.00165000	.00402000	.00922000	.00213000	.00071000
315.000	.00039000	.00213000	.00366000	.00485000	.00047000	.00012000
337.500	.00046000	.00307000	.00721000	.00969000	.00414000	.00059000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00390000	.00473000	.00000000	.00000000	.00000000
22.500	.00000000	.00130000	.00130000	.00000000	.00000000	.00000000
45.000	.00000000	.00071000	.00118000	.00000000	.00000000	.00000000
67.500	.00000000	.00118000	.00154000	.00000000	.00000000	.00000000
90.000	.00000000	.00165000	.00189000	.00000000	.00000000	.00000000
112.500	.00000000	.00154000	.00236000	.00000000	.00000000	.00000000
135.000	.00000000	.00414000	.00863000	.00000000	.00000000	.00000000
157.500	.00000000	.00721000	.01797000	.00000000	.00000000	.00000000
180.000	.00000000	.01005000	.02364000	.00000000	.00000000	.00000000
202.500	.00000000	.00284000	.00934000	.00000000	.00000000	.00000000
225.000	.00000000	.00366000	.00792000	.00000000	.00000000	.00000000
247.500	.00000000	.00236000	.01206000	.00000000	.00000000	.00000000
270.000	.00000000	.00390000	.01478000	.00000000	.00000000	.00000000
292.500	.00000000	.00461000	.01229000	.00000000	.00000000	.00000000
315.000	.00000000	.00260000	.00603000	.00000000	.00000000	.00000000
337.500	.00000000	.00154000	.00402000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00468000	.00993000	.00000000	.00000000	.00000000	.00000000
22.500	.00242000	.00520000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00201000	.00000000	.00000000	.00000000	.00000000
67.500	.00120000	.00248000	.00000000	.00000000	.00000000	.00000000
90.000	.00258000	.00390000	.00000000	.00000000	.00000000	.00000000
112.500	.00174000	.00461000	.00000000	.00000000	.00000000	.00000000
135.000	.00246000	.00745000	.00000000	.00000000	.00000000	.00000000
157.500	.00425000	.01430000	.00000000	.00000000	.00000000	.00000000
180.000	.00608000	.02352000	.00000000	.00000000	.00000000	.00000000
202.500	.00264000	.00981000	.00000000	.00000000	.00000000	.00000000
225.000	.00254000	.00674000	.00000000	.00000000	.00000000	.00000000
247.500	.00388000	.00768000	.00000000	.00000000	.00000000	.00000000
270.000	.00378000	.01312000	.00000000	.00000000	.00000000	.00000000
292.500	.00431000	.01678000	.00000000	.00000000	.00000000	.00000000
315.000	.00265000	.00827000	.00000000	.00000000	.00000000	.00000000
337.500	.00287000	.00603000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99995

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.022464	.028361	.034472	.044335	.056847	.072193	.089532	.113674	.123982
2530.19	.021706	.027825	.036289	.048397	.064506	.085263	.103321	.143887	.164025
2130.19	.021497	.028269	.037662	.048331	.072147	.094252	.128997	.178953	.210257
1730.19	.020338	.027520	.037958	.053405	.072924	.109823	.163067	.239090	.280215
1330.19	.017830	.024912	.035751	.049487	.070491	.122227	.206454	.322363	.406299
930.19	.020287	.025082	.031689	.043172	.066094	.116623	.205432	.445746	.660715
530.19	.022812	.026786	.034521	.042627	.054131	.076806	.160422	.531248	1.217078
130.19	.023551	.027818	.033536	.041513	.052964	.071434	.106884	.194960	2.262964
-269.81	.018822	.021657	.025233	.029875	.035789	.044056	.061384	.121488	.523172
-669.81	.013823	.014191	.018360	.020379	.022538	.033083	.048256	.075833	.218682
-1069.81	.010565	.010474	.012567	.016347	.018645	.028092	.039994	.062925	.145736
-1469.81	.008578	.009208	.011458	.014534	.017467	.023013	.030569	.053754	.096444
-1869.81	.007895	.008965	.010988	.012721	.014909	.018936	.024112	.044123	.069358
-2269.81	.007203	.008599	.009721	.011948	.013776	.017139	.022168	.036036	.057429
-2669.81	.006930	.008164	.009232	.010476	.012784	.015636	.021766	.032461	.044529
-3069.81	.006619	.007370	.008804	.009858	.011860	.013885	.019154	.024798	.035557
-3469.81	.006032	.007087	.007842	.009288	.010208	.013889	.016755	.022596	.026799

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.100222	.070500	.044037	.039338	.034801	.030574	.026843	.024955
2530.19	.120657	.077389	.051090	.044829	.038671	.033196	.030467	.028556
2130.19	.143723	.079188	.060532	.050928	.042671	.038511	.035514	.032549
1730.19	.170609	.088108	.072023	.057753	.050757	.045906	.041166	.036917
1330.19	.197812	.111353	.084735	.071653	.062465	.054197	.047211	.041463
930.19	.207465	.141859	.110917	.091540	.075443	.064470	.056715	.050016
530.19	.286015	.203941	.148718	.121117	.098925	.081786	.068598	.058484
130.19	.409863	.352419	.232682	.165746	.124619	.097972	.079483	.066194
-269.81	.225604	.322464	.229455	.166763	.126264	.099530	.080818	.067300
-669.81	.126210	.152287	.164296	.141260	.113140	.092062	.076270	.064401
-1069.81	.101663	.090620	.099557	.098313	.090134	.080547	.069933	.060250
-1469.81	.087050	.072617	.072669	.065999	.066279	.062950	.058367	.053647
-1869.81	.073077	.058039	.059140	.051543	.047717	.048254	.046881	.044560
-2269.81	.056408	.047125	.043377	.043766	.038914	.036567	.037192	.036585
-2669.81	.041113	.039159	.034253	.033893	.034059	.030823	.029233	.029783
-3069.81	.033470	.030403	.026559	.027766	.027440	.027522	.025211	.023402
-3469.81	.025618	.025710	.024794	.023044	.024340	.024603	.022222	.019694

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	2.262964	AT (	10.47,	130.19)	GC	6.	.445746	AT (	-389.53,	930.19)	GC
2.	1.217078	AT (	10.47,	530.19)	GC	7.	.409863	AT (	410.47,	130.19)	GC
3.	.660715	AT (	10.47,	930.19)	GC	8.	.406299	AT (	10.47,	1330.19)	GC
4.	.531248	AT (	-389.53,	530.19)	GC	9.	.352419	AT (	810.47,	130.19)	GC
5.	.523172	AT (	10.47,	-269.81)	GC	10.	.322464	AT (	810.47,	-269.81)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (91 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50.    1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1   3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1   3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1   3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
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RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD91.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1991 CARLSBAD

ME UAIRDATA 11111 1991

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC91A.GPH 70

OU FINISHED

**********************************
*** SETUP Finishes Successfully ***
**********************************
```

1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC91A.DAT ; **Output Print File: ADMCC91A.LST

2

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5, -2789.5, -2389.5, -1989.5, -1589.5, -1189.5, -789.5, -389.5, 10.5, 410.5,
810.5, 1210.5, 1610.5, 2010.5, 2410.5, 2810.5, 3210.5,

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8, -3069.8, -2669.8, -2269.8, -1869.8, -1469.8, -1069.8, -669.8, -269.8, 130.2,
530.2, 930.2, 1330.2, 1730.2, 2130.2, 2530.2, 2930.2,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS)							
	-3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53
10.47								
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42
1042.42								
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46
1048.51								
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46
1054.61								
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51
1054.61								
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56
1057.66								
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51
1051.56								
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46
1045.46								
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
1036.32								
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32
1039.37								
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27
1036.32								
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27
1036.32								
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22
1033.27								
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18
1030.22								
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13
1030.22								
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13
1027.18								
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03
1024.13								
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03
1018.03								

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

10
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD91.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1991 YEAR: 1991

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00010000	.00059000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00106000	.00000000	.00000000	.00000000	.00000000
45.000	.00027000	.00082000	.00000000	.00000000	.00000000	.00000000
67.500	.00020000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00027000	.00082000	.00000000	.00000000	.00000000	.00000000
112.500	.00025000	.00070000	.00000000	.00000000	.00000000	.00000000
135.000	.00045000	.00106000	.00000000	.00000000	.00000000	.00000000
157.500	.00037000	.00141000	.00000000	.00000000	.00000000	.00000000
180.000	.00022000	.00047000	.00000000	.00000000	.00000000	.00000000
202.500	.00004000	.00023000	.00000000	.00000000	.00000000	.00000000
225.000	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000
247.500	.00014000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00004000	.00023000	.00000000	.00000000	.00000000	.00000000
292.500	.00014000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00006000	.00035000	.00000000	.00000000	.00000000	.00000000
337.500	.00002000	.00012000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00152000	.00211000	.00129000	.00000000	.00000000	.00000000
22.500	.00115000	.00211000	.00106000	.00000000	.00000000	.00000000
45.000	.00090000	.00223000	.00164000	.00000000	.00000000	.00000000
67.500	.00107000	.00282000	.00082000	.00000000	.00000000	.00000000
90.000	.00114000	.00388000	.00117000	.00000000	.00000000	.00000000
112.500	.00086000	.00341000	.00211000	.00000000	.00000000	.00000000
135.000	.00180000	.00623000	.00294000	.00000000	.00000000	.00000000
157.500	.00206000	.00634000	.00599000	.00000000	.00000000	.00000000
180.000	.00156000	.00458000	.00446000	.00000000	.00000000	.00000000
202.500	.00034000	.00129000	.00070000	.00000000	.00000000	.00000000
225.000	.00021000	.00129000	.00023000	.00000000	.00000000	.00000000
247.500	.00031000	.00082000	.00023000	.00000000	.00000000	.00000000
270.000	.00116000	.00047000	.00059000	.00000000	.00000000	.00000000
292.500	.00017000	.00059000	.00000000	.00000000	.00000000	.00000000
315.000	.00015000	.00035000	.00012000	.00000000	.00000000	.00000000
337.500	.00052000	.00023000	.00047000	.00000000	.00000000	.00000000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD91.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1991 YEAR: 1991

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00115000	.00305000	.00587000	.00106000	.00012000	.00000000
22.500	.00036000	.00211000	.00294000	.00012000	.00000000	.00000000
45.000	.00037000	.00223000	.00141000	.00023000	.00000000	.00000000
67.500	.00052000	.00282000	.00106000	.00000000	.00000000	.00000000
90.000	.00037000	.00235000	.00223000	.00035000	.00000000	.00000000
112.500	.00042000	.00317000	.00388000	.00047000	.00023000	.00000000
135.000	.00058000	.00399000	.00893000	.00294000	.00000000	.00000000
157.500	.00027000	.00505000	.01480000	.00258000	.00012000	.00000000
180.000	.00062000	.00470000	.01081000	.00258000	.00012000	.00012000
202.500	.00017000	.00082000	.00141000	.00047000	.00000000	.00012000
225.000	.00030000	.00094000	.00106000	.00082000	.00012000	.00000000
247.500	.00028000	.00059000	.00153000	.00164000	.00047000	.00012000
270.000	.00040000	.00059000	.00200000	.00270000	.00223000	.00070000
292.500	.00078000	.00070000	.00129000	.00070000	.00012000	.00023000
315.000	.00069000	.00141000	.00153000	.00012000	.00000000	.00000000
337.500	.00023000	.00200000	.00211000	.00035000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00134000	.00564000	.01304000	.01527000	.00200000	.00035000
22.500	.00074000	.00611000	.00493000	.00364000	.00035000	.00000000
45.000	.00065000	.00505000	.00411000	.00223000	.00023000	.00000000
67.500	.00082000	.00388000	.00576000	.00223000	.00000000	.00012000
90.000	.00138000	.00458000	.00505000	.00211000	.00035000	.00000000
112.500	.00063000	.00470000	.00529000	.00317000	.00047000	.00023000
135.000	.00049000	.00623000	.00904000	.01386000	.00282000	.00012000
157.500	.00075000	.00623000	.02185000	.01903000	.00188000	.00023000
180.000	.00108000	.00717000	.01797000	.01269000	.00059000	.00012000
202.500	.00040000	.00188000	.00411000	.00458000	.00129000	.00035000
225.000	.00038000	.00164000	.00317000	.00388000	.00164000	.00035000
247.500	.00046000	.00106000	.00435000	.01269000	.00305000	.00223000
270.000	.00065000	.00176000	.00646000	.02784000	.01457000	.00916000
292.500	.00049000	.00294000	.00317000	.00928000	.00317000	.00164000
315.000	.00091000	.00352000	.00670000	.00634000	.00082000	.00023000
337.500	.00093000	.00376000	.00975000	.01480000	.00270000	.00035000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD91.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1991 YEAR: 1991

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00470000	.00611000	.00000000	.00000000	.00000000
22.500	.00000000	.00200000	.00200000	.00000000	.00000000	.00000000
45.000	.00000000	.00223000	.00141000	.00000000	.00000000	.00000000
67.500	.00000000	.00200000	.00106000	.00000000	.00000000	.00000000
90.000	.00000000	.00223000	.00094000	.00000000	.00000000	.00000000
112.500	.00000000	.00305000	.00106000	.00000000	.00000000	.00000000
135.000	.00000000	.00411000	.00341000	.00000000	.00000000	.00000000
157.500	.00000000	.00705000	.00975000	.00000000	.00000000	.00000000
180.000	.00000000	.00975000	.01809000	.00000000	.00000000	.00000000
202.500	.00000000	.00411000	.00916000	.00000000	.00000000	.00000000
225.000	.00000000	.00247000	.00646000	.00000000	.00000000	.00000000
247.500	.00000000	.00388000	.01010000	.00000000	.00000000	.00000000
270.000	.00000000	.00576000	.01797000	.00000000	.00000000	.00000000
292.500	.00000000	.00470000	.01081000	.00000000	.00000000	.00000000
315.000	.00000000	.00388000	.00634000	.00000000	.00000000	.00000000
337.500	.00000000	.00270000	.00458000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00407000	.00858000	.00000000	.00000000	.00000000	.00000000
22.500	.00238000	.00446000	.00000000	.00000000	.00000000	.00000000
45.000	.00137000	.00258000	.00000000	.00000000	.00000000	.00000000
67.500	.00193000	.00176000	.00000000	.00000000	.00000000	.00000000
90.000	.00248000	.00305000	.00000000	.00000000	.00000000	.00000000
112.500	.00159000	.00552000	.00000000	.00000000	.00000000	.00000000
135.000	.00319000	.00564000	.00000000	.00000000	.00000000	.00000000
157.500	.00544000	.01339000	.00000000	.00000000	.00000000	.00000000
180.000	.00568000	.02408000	.00000000	.00000000	.00000000	.00000000
202.500	.00352000	.00951000	.00000000	.00000000	.00000000	.00000000
225.000	.00358000	.00893000	.00000000	.00000000	.00000000	.00000000
247.500	.00376000	.01151000	.00000000	.00000000	.00000000	.00000000
270.000	.00579000	.01515000	.00000000	.00000000	.00000000	.00000000
292.500	.00469000	.01480000	.00000000	.00000000	.00000000	.00000000
315.000	.00281000	.00904000	.00000000	.00000000	.00000000	.00000000
337.500	.00281000	.00693000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99990

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.019249	.024130	.029853	.039158	.051144	.066098	.083581	.108031	.119059
2530.19	.019175	.023922	.030932	.042250	.057558	.077617	.095635	.136585	.157667
2130.19	.019873	.025281	.032618	.041267	.063551	.084606	.118548	.169107	.202014
1730.19	.020068	.026044	.034492	.046651	.062602	.097250	.148346	.224837	.269042
1330.19	.019471	.025746	.035015	.045800	.061710	.105548	.185034	.299209	.389580
930.19	.021274	.026629	.034221	.044709	.063165	.103509	.176123	.401561	.631541
530.19	.022852	.026964	.035042	.043685	.056231	.078602	.142697	.450585	1.150348
130.19	.022470	.026486	.031831	.039214	.049634	.065912	.095132	.165023	2.016856
-269.81	.018642	.021525	.025198	.030041	.036417	.045857	.068567	.129945	.493748
-669.81	.015027	.015760	.020960	.024335	.028702	.040558	.055672	.084380	.228139
-1069.81	.012844	.013333	.016271	.020679	.022824	.033409	.046633	.071240	.154415
-1469.81	.011198	.011846	.014443	.017910	.020923	.027219	.035820	.059753	.102383
-1869.81	.010099	.011277	.013557	.015354	.017784	.022463	.028363	.048599	.073632
-2269.81	.009050	.010623	.011785	.014351	.016464	.020315	.025575	.039514	.060585
-2669.81	.008569	.009935	.011141	.012588	.015241	.018445	.024628	.035264	.047059
-3069.81	.008073	.008926	.010598	.011820	.014086	.016260	.021521	.027104	.037650
-3469.81	.007327	.008564	.009447	.011095	.012159	.015944	.018760	.024544	.028652

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.098536	.071909	.048265	.043493	.038803	.034378	.030414	.028312
2530.19	.119177	.080302	.056162	.049717	.043295	.037519	.034500	.032293
2130.19	.142791	.084579	.066692	.056700	.048035	.043459	.040057	.036703
1730.19	.171203	.096164	.079623	.064657	.057012	.051584	.046266	.041500
1330.19	.202562	.121830	.094254	.080067	.069864	.060669	.052893	.046496
930.19	.223035	.155707	.122868	.101780	.084070	.072486	.064664	.057612
530.19	.304282	.221675	.163617	.136646	.113504	.094904	.080250	.068842
130.19	.405533	.395611	.268741	.194128	.147230	.116463	.094923	.079334
-269.81	.250126	.326000	.244856	.183358	.141532	.113090	.092766	.077861
-669.81	.155750	.174367	.167761	.137793	.115014	.096405	.081599	.070029
-1069.81	.121217	.110859	.115030	.104158	.091193	.079209	.069355	.061340
-1469.81	.098983	.087516	.087497	.076883	.071802	.065288	.058805	.052945
-1869.81	.080862	.069267	.070648	.061945	.055839	.053058	.049501	.045731
-2269.81	.061720	.054809	.051852	.052278	.046698	.042912	.041329	.039155
-2669.81	.044973	.044628	.040872	.040525	.040667	.036936	.034363	.033355
-3069.81	.036465	.034383	.031520	.033163	.032801	.032840	.030174	.027590
-3469.81	.028037	.028833	.028775	.027503	.028975	.029249	.026548	.023657

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	2.016856	AT (	10.47, 130.19)	GC	6.	.405533	AT (	410.47, 130.19)	GC
2.	1.150348	AT (	10.47, 530.19)	GC	7.	.401561	AT (	-389.53, 930.19)	GC
3.	.631541	AT (	10.47, 930.19)	GC	8.	.395611	AT (	810.47, 130.19)	GC
4.	.493748	AT (	10.47, -269.81)	GC	9.	.389580	AT (	10.47, 1330.19)	GC
5.	.450585	AT (	-389.53, 530.19)	GC	10.	.326000	AT (	810.47, -269.81)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

18
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (92 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1   3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1   3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1   3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
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RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD92.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1992 CARLSBAD

ME UAIRDATA 11111 1992

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC92A.GPH 70

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
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1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC92A.DAT ; **Output Print File: ADMCC92A.LST

2

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5, -2789.5, -2389.5, -1989.5, -1589.5, -1189.5, -789.5, -389.5, 10.5, 410.5,
810.5, 1210.5, 1610.5, 2010.5, 2410.5, 2810.5, 3210.5,

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8, -3069.8, -2669.8, -2269.8, -1869.8, -1469.8, -1069.8, -669.8, -269.8, 130.2,
530.2, 930.2, 1330.2, 1730.2, 2130.2, 2530.2, 2930.2,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD92.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1992 YEAR: 1992

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00025000	.00071000	.00000000	.00000000	.00000000	.00000000
22.500	.00029000	.00095000	.00000000	.00000000	.00000000	.00000000
45.000	.00035000	.00047000	.00000000	.00000000	.00000000	.00000000
67.500	.00037000	.00059000	.00000000	.00000000	.00000000	.00000000
90.000	.00042000	.00178000	.00000000	.00000000	.00000000	.00000000
112.500	.00034000	.00130000	.00000000	.00000000	.00000000	.00000000
135.000	.00052000	.00154000	.00000000	.00000000	.00000000	.00000000
157.500	.00032000	.00118000	.00000000	.00000000	.00000000	.00000000
180.000	.00039000	.00071000	.00000000	.00000000	.00000000	.00000000
202.500	.00006000	.00036000	.00000000	.00000000	.00000000	.00000000
225.000	.00019000	.00036000	.00000000	.00000000	.00000000	.00000000
247.500	.00006000	.00036000	.00000000	.00000000	.00000000	.00000000
270.000	.00006000	.00036000	.00000000	.00000000	.00000000	.00000000
292.500	.00007000	.00047000	.00000000	.00000000	.00000000	.00000000
315.000	.00004000	.00024000	.00000000	.00000000	.00000000	.00000000
337.500	.00031000	.00024000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00124000	.00261000	.00201000	.00000000	.00000000	.00000000
22.500	.00093000	.00201000	.00107000	.00000000	.00000000	.00000000
45.000	.00073000	.00273000	.00059000	.00000000	.00000000	.00000000
67.500	.00114000	.00296000	.00095000	.00000000	.00000000	.00000000
90.000	.00204000	.00616000	.00273000	.00000000	.00000000	.00000000
112.500	.00115000	.00308000	.00284000	.00000000	.00000000	.00000000
135.000	.00123000	.00403000	.00355000	.00000000	.00000000	.00000000
157.500	.00156000	.00344000	.00201000	.00000000	.00000000	.00000000
180.000	.00091000	.00332000	.00190000	.00000000	.00000000	.00000000
202.500	.00065000	.00012000	.00047000	.00000000	.00000000	.00000000
225.000	.00020000	.00083000	.00024000	.00000000	.00000000	.00000000
247.500	.00019000	.00071000	.00036000	.00000000	.00000000	.00000000
270.000	.00044000	.00071000	.00059000	.00000000	.00000000	.00000000
292.500	.00042000	.00047000	.00036000	.00000000	.00000000	.00000000
315.000	.00049000	.00130000	.00036000	.00000000	.00000000	.00000000
337.500	.00079000	.00178000	.00083000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD92.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1992 YEAR: 1992

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00067000	.00273000	.00699000	.00095000	.00024000	.00000000
22.500	.00047000	.00367000	.00391000	.00024000	.00000000	.00000000
45.000	.00050000	.00201000	.00213000	.00036000	.00000000	.00000000
67.500	.00027000	.00237000	.00237000	.00036000	.00000000	.00000000
90.000	.00035000	.00367000	.00450000	.00083000	.00000000	.00000000
112.500	.00046000	.00355000	.00533000	.00190000	.00000000	.00000000
135.000	.00045000	.00545000	.01102000	.00308000	.00024000	.00000000
157.500	.00081000	.00308000	.00984000	.00237000	.00000000	.00000000
180.000	.00047000	.00367000	.00711000	.00166000	.00000000	.00000000
202.500	.00016000	.00059000	.00142000	.00024000	.00000000	.00000000
225.000	.00029000	.00071000	.00130000	.00024000	.00000000	.00000000
247.500	.00004000	.00071000	.00118000	.00059000	.00012000	.00000000
270.000	.00050000	.00213000	.00142000	.00130000	.00083000	.00024000
292.500	.00058000	.00130000	.00154000	.00047000	.00000000	.00000000
315.000	.00046000	.00142000	.00344000	.00130000	.00000000	.00000000
337.500	.00027000	.00237000	.00438000	.00130000	.00036000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00040000	.00652000	.01244000	.01232000	.00308000	.00059000
22.500	.00046000	.00344000	.00403000	.00320000	.00024000	.00000000
45.000	.00057000	.00320000	.00296000	.00201000	.00012000	.00000000
67.500	.00054000	.00261000	.00296000	.00261000	.00012000	.00000000
90.000	.00061000	.00581000	.00462000	.00628000	.00012000	.00000000
112.500	.00063000	.00415000	.00841000	.00806000	.00095000	.00012000
135.000	.00083000	.00545000	.01600000	.01766000	.00130000	.00000000
157.500	.00103000	.00450000	.01517000	.01090000	.00012000	.00000000
180.000	.00027000	.00438000	.01161000	.01007000	.00083000	.00012000
202.500	.00009000	.00142000	.00355000	.00379000	.00059000	.00000000
225.000	.00029000	.00059000	.00379000	.00415000	.00036000	.00000000
247.500	.00010000	.00166000	.00510000	.00841000	.00462000	.00083000
270.000	.00014000	.00225000	.00652000	.02003000	.01149000	.00474000
292.500	.00022000	.00367000	.00557000	.01090000	.00379000	.00130000
315.000	.00044000	.00308000	.00640000	.01019000	.00296000	.00059000
337.500	.00039000	.00427000	.00723000	.01232000	.00510000	.00059000

14

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD92.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1992 YEAR: 1992

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00450000	.00415000	.00000000	.00000000	.00000000
22.500	.00000000	.00154000	.00036000	.00000000	.00000000	.00000000
45.000	.00000000	.00237000	.00059000	.00000000	.00000000	.00000000
67.500	.00000000	.00201000	.00190000	.00000000	.00000000	.00000000
90.000	.00000000	.00284000	.00284000	.00000000	.00000000	.00000000
112.500	.00000000	.00438000	.00332000	.00000000	.00000000	.00000000
135.000	.00000000	.00747000	.00806000	.00000000	.00000000	.00000000
157.500	.00000000	.00948000	.01505000	.00000000	.00000000	.00000000
180.000	.00000000	.00865000	.02145000	.00000000	.00000000	.00000000
202.500	.00000000	.00391000	.00960000	.00000000	.00000000	.00000000
225.000	.00000000	.00284000	.00521000	.00000000	.00000000	.00000000
247.500	.00000000	.00450000	.01066000	.00000000	.00000000	.00000000
270.000	.00000000	.00865000	.01967000	.00000000	.00000000	.00000000
292.500	.00000000	.00664000	.01612000	.00000000	.00000000	.00000000
315.000	.00000000	.00687000	.00640000	.00000000	.00000000	.00000000
337.500	.00000000	.00320000	.00403000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00298000	.00936000	.00000000	.00000000	.00000000	.00000000
22.500	.00238000	.00427000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00225000	.00000000	.00000000	.00000000	.00000000
67.500	.00134000	.00178000	.00000000	.00000000	.00000000	.00000000
90.000	.00245000	.00569000	.00000000	.00000000	.00000000	.00000000
112.500	.00214000	.00545000	.00000000	.00000000	.00000000	.00000000
135.000	.00388000	.00995000	.00000000	.00000000	.00000000	.00000000
157.500	.00524000	.01469000	.00000000	.00000000	.00000000	.00000000
180.000	.00448000	.01695000	.00000000	.00000000	.00000000	.00000000
202.500	.00396000	.00960000	.00000000	.00000000	.00000000	.00000000
225.000	.00204000	.00664000	.00000000	.00000000	.00000000	.00000000
247.500	.00322000	.00912000	.00000000	.00000000	.00000000	.00000000
270.000	.00428000	.01742000	.00000000	.00000000	.00000000	.00000000
292.500	.00555000	.01588000	.00000000	.00000000	.00000000	.00000000
315.000	.00466000	.01256000	.00000000	.00000000	.00000000	.00000000
337.500	.00208000	.00877000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99998

15
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.027330	.033317	.037275	.044599	.053435	.063734	.074869	.090264	.093142
2530.19	.026870	.033866	.042381	.051777	.063539	.077760	.087226	.115360	.123151
2130.19	.027430	.035316	.046148	.055945	.075846	.088896	.111470	.144621	.157874
1730.19	.027063	.035632	.047924	.065875	.083954	.111033	.146387	.196268	.210358
1330.19	.025298	.034050	.047210	.063034	.086327	.139039	.198620	.268633	.305086
930.19	.027814	.034676	.044291	.058955	.085737	.143986	.220988	.378586	.496048
530.19	.030140	.035674	.046296	.057874	.074715	.105428	.194937	.503573	.910924
130.19	.030035	.035614	.043138	.053703	.069015	.093696	.139984	.252262	1.649730
-269.81	.023349	.026834	.031192	.036754	.043607	.052445	.068736	.115836	.489327
-669.81	.016587	.016898	.021453	.023216	.024571	.034758	.047039	.073413	.216893
-1069.81	.012089	.011738	.013724	.017496	.019282	.028111	.039275	.061869	.144413
-1469.81	.009382	.009947	.012157	.015101	.017565	.022820	.030073	.052940	.095015
-1869.81	.008474	.009475	.011424	.012908	.014863	.018751	.023678	.043389	.067980
-2269.81	.007596	.008947	.009916	.012053	.013726	.016894	.021829	.035396	.055667
-2669.81	.007214	.008400	.009360	.010493	.012668	.015295	.021323	.031632	.043119
-3069.81	.006825	.007499	.008872	.009821	.011673	.013577	.018778	.024337	.034423
-3469.81	.006155	.007169	.007848	.009193	.010011	.013534	.016448	.022043	.026171

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.080924	.063599	.048285	.040622	.033769	.027844	.022898	.021460
2530.19	.098824	.073300	.054343	.044410	.035646	.028416	.026317	.025506
2130.19	.120068	.081346	.061650	.047699	.036674	.033436	.032015	.030172
1730.19	.147265	.093188	.069013	.049913	.044363	.041867	.038685	.035474
1330.19	.181911	.110348	.073926	.063300	.057885	.051852	.046209	.041297
930.19	.216612	.125704	.099645	.086842	.073984	.065349	.059407	.053582
530.19	.260264	.188162	.146313	.126399	.106859	.090290	.076871	.066255
130.19	.363926	.383500	.263674	.191204	.145207	.114985	.093773	.078396
-269.81	.333619	.387678	.271410	.197261	.149655	.118273	.096261	.080313
-669.81	.176695	.230217	.210681	.167564	.133585	.108747	.090223	.076301
-1069.81	.123678	.136590	.154004	.133171	.113121	.096176	.082117	.070839
-1469.81	.097529	.097535	.112426	.103736	.093047	.082255	.072549	.064259
-1869.81	.078066	.071390	.083577	.080992	.075749	.069455	.063119	.057141
-2269.81	.058823	.054619	.057091	.063902	.061754	.058448	.054522	.050406
-2669.81	.042494	.043711	.042489	.046574	.050814	.049244	.046953	.044277
-3069.81	.034225	.033264	.031560	.036201	.038842	.041689	.040476	.037742
-3469.81	.026189	.027634	.028400	.028718	.032829	.035527	.034062	.031761

17
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	1.649730	AT (	10.47,	130.19)	GC	6.	.387678	AT (	810.47,	-269.81)	GC
2.	.910924	AT (	10.47,	530.19)	GC	7.	.383500	AT (	810.47,	130.19)	GC
3.	.503573	AT (	-389.53,	530.19)	GC	8.	.378586	AT (	-389.53,	930.19)	GC
4.	.496048	AT (	10.47,	930.19)	GC	9.	.363926	AT (	410.47,	130.19)	GC
5.	.489327	AT (	10.47,	-269.81)	GC	10.	.333619	AT (	410.47,	-269.81)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (93 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1   3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1   3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1   3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
```

```
RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD93.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1993 CARLSBAD

ME UAIRDATA 11111 1993

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC93A.GPH 70

OU FINISHED

**********************************
*** SETUP Finishes Successfully ***
**********************************
```

1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC93A.DAT ; **Output Print File: ADMCC93A.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

3
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5, -2789.5, -2389.5, -1989.5, -1589.5, -1189.5, -789.5, -389.5, 10.5, 410.5,
810.5, 1210.5, 1610.5, 2010.5, 2410.5, 2810.5, 3210.5,

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8, -3069.8, -2669.8, -2269.8, -1869.8, -1469.8, -1069.8, -669.8, -269.8, 130.2,
530.2, 930.2, 1330.2, 1730.2, 2130.2, 2530.2, 2930.2,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

12
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD93.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00049000	.00047000	.00000000	.00000000	.00000000	.00000000
22.500	.00026000	.00071000	.00000000	.00000000	.00000000	.00000000
45.000	.00020000	.00035000	.00000000	.00000000	.00000000	.00000000
67.500	.00035000	.00047000	.00000000	.00000000	.00000000	.00000000
90.000	.00016000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00014000	.00083000	.00000000	.00000000	.00000000	.00000000
135.000	.00010000	.00059000	.00000000	.00000000	.00000000	.00000000
157.500	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000
180.000	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000
202.500	.00006000	.00035000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00004000	.00024000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00002000	.00012000	.00000000	.00000000	.00000000	.00000000
315.000	.00020000	.00035000	.00000000	.00000000	.00000000	.00000000
337.500	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00136000	.00213000	.00248000	.00000000	.00000000	.00000000
22.500	.00041000	.00296000	.00142000	.00000000	.00000000	.00000000
45.000	.00098000	.00201000	.00083000	.00000000	.00000000	.00000000
67.500	.00125000	.00248000	.00106000	.00000000	.00000000	.00000000
90.000	.00137000	.00473000	.00166000	.00000000	.00000000	.00000000
112.500	.00055000	.00331000	.00260000	.00000000	.00000000	.00000000
135.000	.00071000	.00390000	.00343000	.00000000	.00000000	.00000000
157.500	.00101000	.00485000	.00367000	.00000000	.00000000	.00000000
180.000	.00091000	.00296000	.00379000	.00000000	.00000000	.00000000
202.500	.00028000	.00059000	.00047000	.00000000	.00000000	.00000000
225.000	.00014000	.00035000	.00024000	.00000000	.00000000	.00000000
247.500	.00042000	.00083000	.00035000	.00000000	.00000000	.00000000
270.000	.00027000	.00047000	.00047000	.00000000	.00000000	.00000000
292.500	.00029000	.00071000	.00024000	.00000000	.00000000	.00000000
315.000	.00026000	.00024000	.00024000	.00000000	.00000000	.00000000
337.500	.00020000	.00142000	.00130000	.00000000	.00000000	.00000000

13
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD93.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00023000	.00379000	.00769000	.00142000	.00024000	.00000000
22.500	.00056000	.00296000	.00343000	.00083000	.00012000	.00000000
45.000	.00042000	.00272000	.00213000	.00024000	.00000000	.00000000
67.500	.00057000	.00308000	.00130000	.00035000	.00000000	.00000000
90.000	.00056000	.00296000	.00438000	.00095000	.00000000	.00000000
112.500	.00010000	.00166000	.00355000	.00166000	.00000000	.00000000
135.000	.00052000	.00426000	.01112000	.00402000	.00035000	.00000000
157.500	.00063000	.00414000	.01219000	.00331000	.00035000	.00000000
180.000	.00038000	.00414000	.01088000	.00402000	.00024000	.00000000
202.500	.00032000	.00106000	.00095000	.00035000	.00035000	.00000000
225.000	.00028000	.00047000	.00154000	.00012000	.00047000	.00000000
247.500	.00005000	.00083000	.00154000	.00130000	.00047000	.00035000
270.000	.00006000	.00095000	.00189000	.00189000	.00177000	.00035000
292.500	.00018000	.00095000	.00095000	.00012000	.00000000	.00000000
315.000	.00044000	.00106000	.00118000	.00047000	.00000000	.00000000
337.500	.00025000	.00201000	.00367000	.00154000	.00024000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00055000	.00627000	.01088000	.01645000	.00355000	.00130000
22.500	.00006000	.00213000	.00402000	.00544000	.00106000	.00012000
45.000	.00019000	.00225000	.00260000	.00390000	.00000000	.00000000
67.500	.00020000	.00284000	.00319000	.00272000	.00024000	.00000000
90.000	.00050000	.00450000	.00639000	.00284000	.00000000	.00012000
112.500	.00046000	.00331000	.00911000	.00710000	.00059000	.00012000
135.000	.00037000	.00450000	.02011000	.02437000	.00213000	.00000000
157.500	.00031000	.00639000	.01952000	.02047000	.00035000	.00012000
180.000	.00043000	.00651000	.01633000	.01503000	.00154000	.00035000
202.500	.00004000	.00154000	.00450000	.00414000	.00047000	.00047000
225.000	.00003000	.00118000	.00414000	.00461000	.00142000	.00024000
247.500	.00014000	.00059000	.00556000	.02082000	.00663000	.00284000
270.000	.00007000	.00248000	.00580000	.02449000	.01195000	.00876000
292.500	.00043000	.00237000	.00355000	.00450000	.00047000	.00012000
315.000	.00018000	.00189000	.00319000	.00521000	.00083000	.00035000
337.500	.00017000	.00177000	.00722000	.01633000	.00213000	.00035000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD93.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00213000	.00603000	.00000000	.00000000	.00000000
22.500	.00000000	.00237000	.00248000	.00000000	.00000000	.00000000
45.000	.00000000	.00118000	.00166000	.00000000	.00000000	.00000000
67.500	.00000000	.00166000	.00189000	.00000000	.00000000	.00000000
90.000	.00000000	.00402000	.00154000	.00000000	.00000000	.00000000
112.500	.00000000	.00556000	.00379000	.00000000	.00000000	.00000000
135.000	.00000000	.00615000	.01041000	.00000000	.00000000	.00000000
157.500	.00000000	.00816000	.01313000	.00000000	.00000000	.00000000
180.000	.00000000	.01065000	.02236000	.00000000	.00000000	.00000000
202.500	.00000000	.00509000	.00899000	.00000000	.00000000	.00000000
225.000	.00000000	.00603000	.00615000	.00000000	.00000000	.00000000
247.500	.00000000	.00532000	.01029000	.00000000	.00000000	.00000000
270.000	.00000000	.00521000	.01230000	.00000000	.00000000	.00000000
292.500	.00000000	.00331000	.00899000	.00000000	.00000000	.00000000
315.000	.00000000	.00225000	.00509000	.00000000	.00000000	.00000000
337.500	.00000000	.00201000	.00473000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00286000	.01053000	.00000000	.00000000	.00000000	.00000000
22.500	.00118000	.00461000	.00000000	.00000000	.00000000	.00000000
45.000	.00162000	.00308000	.00000000	.00000000	.00000000	.00000000
67.500	.00154000	.00343000	.00000000	.00000000	.00000000	.00000000
90.000	.00189000	.00473000	.00000000	.00000000	.00000000	.00000000
112.500	.00134000	.00473000	.00000000	.00000000	.00000000	.00000000
135.000	.00215000	.00710000	.00000000	.00000000	.00000000	.00000000
157.500	.00548000	.01881000	.00000000	.00000000	.00000000	.00000000
180.000	.00448000	.01609000	.00000000	.00000000	.00000000	.00000000
202.500	.00308000	.00935000	.00000000	.00000000	.00000000	.00000000
225.000	.00150000	.00568000	.00000000	.00000000	.00000000	.00000000
247.500	.00300000	.01053000	.00000000	.00000000	.00000000	.00000000
270.000	.00454000	.01479000	.00000000	.00000000	.00000000	.00000000
292.500	.00363000	.01100000	.00000000	.00000000	.00000000	.00000000
315.000	.00343000	.00899000	.00000000	.00000000	.00000000	.00000000
337.500	.00217000	.00722000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99986

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.025631	.031651	.037206	.046424	.058133	.072358	.084341	.100313	.102406
2530.19	.025209	.031808	.040458	.051914	.067125	.086715	.098770	.128454	.135031
2130.19	.025430	.032816	.042949	.053807	.076848	.096538	.126800	.161861	.173588
1730.19	.024731	.032689	.044113	.060826	.080780	.115448	.164823	.220882	.232365
1330.19	.022680	.030723	.042852	.058104	.081293	.134520	.213555	.305117	.338638
930.19	.024668	.030795	.039419	.053095	.078981	.135145	.224011	.435618	.554834
530.19	.026442	.031381	.040772	.051194	.066546	.095712	.191274	.548981	1.043133
130.19	.026100	.030984	.037576	.046835	.060246	.081616	.120537	.212560	2.107513
-269.81	.021046	.024313	.028445	.033790	.040518	.049485	.068268	.119985	.559448
-669.81	.015925	.016407	.021453	.023996	.026587	.036660	.048264	.079659	.232464
-1069.81	.012557	.012500	.014865	.018632	.019856	.028447	.040623	.065943	.150057
-1469.81	.010194	.010521	.012672	.015457	.017531	.023095	.031270	.055210	.097928
-1869.81	.008899	.009756	.011580	.012784	.014829	.019112	.024560	.044780	.069768
-2269.81	.007742	.008992	.009757	.011931	.013785	.017180	.022470	.036337	.056937
-2669.81	.007200	.008262	.009206	.010434	.012720	.015442	.021741	.032293	.044037
-3069.81	.006683	.007340	.008765	.009782	.011683	.013722	.019116	.024854	.035115
-3469.81	.005999	.007049	.007770	.009145	.010038	.013617	.016733	.022447	.026678

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.086425	.065443	.046732	.039948	.033760	.028307	.023706	.022647
2530.19	.105091	.074299	.053164	.044304	.036271	.029510	.027913	.027482
2130.19	.127181	.080647	.061270	.048568	.038265	.035732	.034767	.033129
1730.19	.154928	.091930	.070206	.052388	.047900	.045939	.042906	.039640
1330.19	.188465	.111991	.078083	.069225	.064396	.058250	.052230	.046834
930.19	.217861	.134353	.111231	.098412	.084486	.072567	.062719	.054704
530.19	.283730	.217953	.170873	.134607	.107551	.087926	.073275	.062229
130.19	.456576	.363636	.239411	.170887	.128759	.101428	.082436	.068764
-269.81	.182143	.251154	.196432	.149834	.116850	.093981	.077441	.065224
-669.81	.136197	.139457	.129271	.103108	.088882	.076058	.065264	.056560
-1069.81	.111315	.094418	.096192	.082941	.070374	.059801	.052663	.047461
-1469.81	.091011	.076893	.076280	.065452	.058467	.051561	.045408	.040182
-1869.81	.074277	.061481	.062096	.054281	.048090	.043906	.039793	.035956
-2269.81	.056692	.049011	.045515	.045980	.041110	.037273	.034630	.031925
-2669.81	.041327	.040100	.035938	.035484	.035852	.032658	.030050	.028228
-3069.81	.033481	.030992	.027808	.029021	.028743	.029037	.026779	.024167
-3469.81	.025738	.026035	.025526	.024067	.025411	.025839	.023471	.020874

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	2.107513	AT (	10.47,	130.19)	GC	6.	.456576	AT (	410.47,	130.19)	GC
2.	1.043133	AT (	10.47,	530.19)	GC	7.	.435618	AT (	-389.53,	930.19)	GC
3.	.559448	AT (	10.47,	-269.81)	GC	8.	.363636	AT (	810.47,	130.19)	GC
4.	.554834	AT (	10.47,	930.19)	GC	9.	.338638	AT (	10.47,	1330.19)	GC
5.	.548981	AT (	-389.53,	530.19)	GC	10.	.305117	AT (	-389.53,	1330.19)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (94 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1   3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1   3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1   3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
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RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD94.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1994 CARLSBAD

ME UAIRDATA 11111 1994

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC94A.GPH 70

OU FINISHED

**********************************
*** SETUP Finishes Successfully ***
**********************************
```

1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC94A.DAT ; **Output Print File: ADMCC94A.LST

2
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5, -2789.5, -2389.5, -1989.5, -1589.5, -1189.5, -789.5, -389.5, 10.5, 410.5,
810.5, 1210.5, 1610.5, 2010.5, 2410.5, 2810.5, 3210.5,

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8, -3069.8, -2669.8, -2269.8, -1869.8, -1469.8, -1069.8, -669.8, -269.8, 130.2,
530.2, 930.2, 1330.2, 1730.2, 2130.2, 2530.2, 2930.2,

6
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

8

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIICART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD94.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1994 YEAR: 1994

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00017000	.00086000	.00000000	.00000000	.00000000	.00000000
22.500	.00028000	.00058000	.00000000	.00000000	.00000000	.00000000
45.000	.00023000	.00115000	.00000000	.00000000	.00000000	.00000000
67.500	.00057000	.00115000	.00000000	.00000000	.00000000	.00000000
90.000	.00031000	.00158000	.00000000	.00000000	.00000000	.00000000
112.500	.00020000	.00101000	.00000000	.00000000	.00000000	.00000000
135.000	.00028000	.00058000	.00000000	.00000000	.00000000	.00000000
157.500	.00031000	.00158000	.00000000	.00000000	.00000000	.00000000
180.000	.00063000	.00144000	.00000000	.00000000	.00000000	.00000000
202.500	.00026000	.00043000	.00000000	.00000000	.00000000	.00000000
225.000	.00026000	.00043000	.00000000	.00000000	.00000000	.00000000
247.500	.00003000	.00014000	.00000000	.00000000	.00000000	.00000000
270.000	.00003000	.00014000	.00000000	.00000000	.00000000	.00000000
292.500	.00023000	.00029000	.00000000	.00000000	.00000000	.00000000
315.000	.00023000	.00029000	.00000000	.00000000	.00000000	.00000000
337.500	.00003000	.00014000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00093000	.00359000	.00244000	.00000000	.00000000	.00000000
22.500	.00089000	.00316000	.00144000	.00000000	.00000000	.00000000
45.000	.00120000	.00316000	.00115000	.00000000	.00000000	.00000000
67.500	.00125000	.00374000	.00115000	.00000000	.00000000	.00000000
90.000	.00116000	.00446000	.00302000	.00000000	.00000000	.00000000
112.500	.00119000	.00489000	.00331000	.00000000	.00000000	.00000000
135.000	.00178000	.00805000	.00633000	.00000000	.00000000	.00000000
157.500	.00121000	.00690000	.00561000	.00000000	.00000000	.00000000
180.000	.00110000	.00374000	.00374000	.00000000	.00000000	.00000000
202.500	.00001000	.00014000	.00043000	.00000000	.00000000	.00000000
225.000	.00002000	.00029000	.00029000	.00000000	.00000000	.00000000
247.500	.00068000	.00072000	.00029000	.00000000	.00000000	.00000000
270.000	.00023000	.00086000	.00043000	.00000000	.00000000	.00000000
292.500	.00032000	.00014000	.00014000	.00000000	.00000000	.00000000
315.000	.00054000	.00086000	.00058000	.00000000	.00000000	.00000000
337.500	.00041000	.00115000	.00058000	.00000000	.00000000	.00000000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD94.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1994 YEAR: 1994

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00044000	.00403000	.00748000	.00173000	.00000000	.00000000
22.500	.00076000	.00259000	.00158000	.00058000	.00000000	.00000000
45.000	.00062000	.00273000	.00187000	.00029000	.00000000	.00000000
67.500	.00068000	.00187000	.00273000	.00058000	.00000000	.00000000
90.000	.00071000	.00359000	.00690000	.00187000	.00029000	.00000000
112.500	.00079000	.00288000	.00748000	.00359000	.00000000	.00000000
135.000	.00035000	.00316000	.01308000	.00719000	.00000000	.00000000
157.500	.00054000	.00489000	.01251000	.00518000	.00000000	.00000000
180.000	.00073000	.00230000	.00762000	.00345000	.00014000	.00000000
202.500	.00013000	.00115000	.00086000	.00029000	.00014000	.00000000
225.000	.00003000	.00029000	.00101000	.00058000	.00000000	.00000000
247.500	.00003000	.00029000	.00072000	.00072000	.00014000	.00029000
270.000	.00029000	.00115000	.00244000	.00216000	.00072000	.00058000
292.500	.00041000	.00086000	.00101000	.00029000	.00000000	.00000000
315.000	.00021000	.00043000	.00144000	.00029000	.00000000	.00000000
337.500	.00017000	.00158000	.00331000	.00144000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00059000	.00417000	.01352000	.01380000	.00273000	.00043000
22.500	.00019000	.00187000	.00388000	.00460000	.00144000	.00014000
45.000	.00022000	.00216000	.00532000	.00374000	.00043000	.00014000
67.500	.00074000	.00259000	.00388000	.00374000	.00058000	.00000000
90.000	.00077000	.00288000	.00676000	.00834000	.00129000	.00000000
112.500	.00051000	.00345000	.00820000	.01050000	.00129000	.00014000
135.000	.00038000	.00374000	.01481000	.02574000	.00316000	.00101000
157.500	.00095000	.00460000	.01107000	.01308000	.00072000	.00014000
180.000	.00089000	.00403000	.01869000	.01251000	.00072000	.00014000
202.500	.00015000	.00144000	.00661000	.00345000	.00144000	.00000000
225.000	.00041000	.00086000	.00489000	.00417000	.00129000	.00043000
247.500	.00029000	.00288000	.00604000	.01107000	.00604000	.00288000
270.000	.00046000	.00144000	.00561000	.01596000	.01050000	.00374000
292.500	.00016000	.00158000	.00446000	.00417000	.00173000	.00029000
315.000	.00022000	.00216000	.00388000	.00359000	.00187000	.00029000
337.500	.00025000	.00244000	.00791000	.01107000	.00359000	.00058000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD94.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1994 YEAR: 1994

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00460000	.00690000	.00000000	.00000000	.00000000
22.500	.00000000	.00230000	.00187000	.00000000	.00000000	.00000000
45.000	.00000000	.00216000	.00086000	.00000000	.00000000	.00000000
67.500	.00000000	.00158000	.00115000	.00000000	.00000000	.00000000
90.000	.00000000	.00359000	.00331000	.00000000	.00000000	.00000000
112.500	.00000000	.00474000	.00676000	.00000000	.00000000	.00000000
135.000	.00000000	.00575000	.01395000	.00000000	.00000000	.00000000
157.500	.00000000	.00561000	.01265000	.00000000	.00000000	.00000000
180.000	.00000000	.00676000	.02631000	.00000000	.00000000	.00000000
202.500	.00000000	.00417000	.01222000	.00000000	.00000000	.00000000
225.000	.00000000	.00230000	.00561000	.00000000	.00000000	.00000000
247.500	.00000000	.00489000	.01050000	.00000000	.00000000	.00000000
270.000	.00000000	.00388000	.01035000	.00000000	.00000000	.00000000
292.500	.00000000	.00403000	.00848000	.00000000	.00000000	.00000000
315.000	.00000000	.00374000	.00403000	.00000000	.00000000	.00000000
337.500	.00000000	.00302000	.00359000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00240000	.00848000	.00000000	.00000000	.00000000	.00000000
22.500	.00140000	.00446000	.00000000	.00000000	.00000000	.00000000
45.000	.00081000	.00288000	.00000000	.00000000	.00000000	.00000000
67.500	.00115000	.00187000	.00000000	.00000000	.00000000	.00000000
90.000	.00210000	.00561000	.00000000	.00000000	.00000000	.00000000
112.500	.00145000	.00474000	.00000000	.00000000	.00000000	.00000000
135.000	.00228000	.00978000	.00000000	.00000000	.00000000	.00000000
157.500	.00402000	.01725000	.00000000	.00000000	.00000000	.00000000
180.000	.00542000	.02070000	.00000000	.00000000	.00000000	.00000000
202.500	.00266000	.01006000	.00000000	.00000000	.00000000	.00000000
225.000	.00169000	.00618000	.00000000	.00000000	.00000000	.00000000
247.500	.00261000	.01179000	.00000000	.00000000	.00000000	.00000000
270.000	.00517000	.01510000	.00000000	.00000000	.00000000	.00000000
292.500	.00307000	.01050000	.00000000	.00000000	.00000000	.00000000
315.000	.00286000	.00820000	.00000000	.00000000	.00000000	.00000000
337.500	.00203000	.00518000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = 1.00005

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.027723	.033436	.036959	.043365	.050958	.060005	.076655	.099575	.109831
2530.19	.027553	.034492	.042668	.051068	.061385	.073591	.087275	.125846	.145124
2130.19	.028253	.036123	.046864	.056592	.074429	.085548	.107947	.155584	.185865
1730.19	.028043	.036658	.048948	.066797	.084782	.109022	.139422	.206617	.247315
1330.19	.026441	.035321	.048614	.065084	.089513	.140362	.193626	.273932	.358111
930.19	.028701	.035855	.045950	.061597	.090083	.150568	.229704	.364660	.581493
530.19	.030709	.036606	.047628	.060319	.079594	.115927	.219760	.542058	1.073149
130.19	.030349	.036133	.044010	.055229	.071921	.099782	.155454	.306972	2.181532
-269.81	.023709	.027359	.031977	.037963	.045580	.055891	.075811	.145016	.537889
-669.81	.017032	.017551	.022231	.024347	.026315	.038401	.055645	.079837	.232956
-1069.81	.012528	.012358	.014552	.018752	.021489	.031883	.042912	.062593	.149783
-1469.81	.009831	.010620	.013074	.016407	.019588	.024793	.030779	.053660	.097278
-1869.81	.008953	.010123	.012266	.014111	.016078	.019441	.023261	.043827	.069050
-2269.81	.008071	.009528	.010693	.012766	.014219	.016852	.021589	.035665	.055958
-2669.81	.007633	.008893	.009844	.010847	.012711	.014843	.021080	.031655	.043255
-3069.81	.007178	.007844	.009085	.009891	.011444	.013149	.018617	.024460	.034489
-3469.81	.006411	.007331	.007920	.009071	.009692	.013152	.016348	.022053	.026336

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.092410	.069271	.048529	.040260	.033000	.026811	.021707	.020889
2530.19	.112066	.078206	.054443	.043760	.034502	.026982	.025742	.025857
2130.19	.135086	.084342	.061461	.046499	.034905	.032915	.032784	.031738
1730.19	.163671	.094676	.068067	.047677	.044068	.043437	.041278	.038597
1330.19	.198338	.111082	.071057	.063701	.061162	.056382	.051191	.046294
930.19	.228190	.122524	.102463	.094213	.082534	.071201	.061214	.053227
530.19	.266195	.201395	.165671	.129905	.103377	.084401	.070318	.059728
130.19	.370747	.329572	.220979	.159321	.120821	.095606	.077972	.065218
-269.81	.182576	.238432	.183420	.140051	.109569	.088403	.073050	.061678
-669.81	.126557	.135363	.124135	.098541	.084218	.071905	.061701	.053518
-1069.81	.101700	.089039	.092056	.079143	.066985	.056807	.049911	.044931
-1469.81	.085012	.070388	.071574	.062326	.055584	.048944	.043044	.038044
-1869.81	.069840	.055239	.057089	.050974	.045653	.041638	.037695	.034025
-2269.81	.053691	.044612	.041394	.042496	.038610	.035305	.032775	.030190
-2669.81	.039526	.036975	.032380	.032502	.033234	.030662	.028411	.026674
-3069.81	.032140	.028955	.025163	.026361	.026442	.026962	.025132	.022848
-3469.81	.024902	.024497	.023294	.021718	.023155	.023767	.021846	.019647

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	2.181532	AT (	10.47,	130.19)	GC	6.	.370747	AT (	410.47,	130.19)	GC
2.	1.073149	AT (	10.47,	530.19)	GC	7.	.364660	AT (	-389.53,	930.19)	GC
3.	.581493	AT (	10.47,	930.19)	GC	8.	.358111	AT (	10.47,	1330.19)	GC
4.	.542058	AT (	-389.53,	530.19)	GC	9.	.329572	AT (	810.47,	130.19)	GC
5.	.537889	AT (	10.47,	-269.81)	GC	10.	.306972	AT (	-389.53,	130.19)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

18
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION AT WIPP SITE BOUNDARY (93 WIPP Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -609.53 45 10.00 2974.73 11 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
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RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50			
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50			
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50			
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 4     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 9    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 10   1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 11   1.50    1.50    1.50    1.50
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RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 5  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00
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RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\WP3093.STR  FREE
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1993 WIPP
ME UAIRDATA 11111 1993
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMEW93B.GPH 70
OU FINISHED
**********************************
*** SETUP Finishes Successfully ***
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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 495 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMFW93B.DAT ; **Output Print File: ADMFW93B.LST

2
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

3
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-609.5, -599.5, -589.5, -579.5, -569.5, -559.5, -549.5, -539.5, -529.5, -519.5,
-509.5, -499.5, -489.5, -479.5, -469.5, -459.5, -449.5, -439.5, -429.5, -419.5,
-409.5, -399.5, -389.5, -379.5, -369.5, -359.5, -349.5, -339.5, -329.5, -319.5,
-309.5, -299.5, -289.5, -279.5, -269.5, -259.5, -249.5, -239.5, -229.5, -219.5,
-209.5, -199.5, -189.5, -179.5, -169.5,

*** Y-COORDINATES OF GRID ***
(METERS)

2974.7, 2984.7, 2994.7, 3004.7, 3014.7, 3024.7, 3034.7, 3044.7, 3054.7, 3064.7,
3074.7,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -609.53	-599.53	-589.53	-579.53	-569.53	-559.53	-549.53	-539.53	-529.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS)							
	-519.53	-509.53	-499.53	-489.53	-479.53	-469.53	-459.53	-449.53
-439.53								
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
1039.37								

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -429.53	-419.53	-409.53	-399.53	-389.53	-379.53	-369.53	-359.53	-349.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -339.53	-329.53	-319.53	-309.53	-299.53	-289.53	-279.53	-269.53	-259.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -249.53	-239.53	-229.53	-219.53	-209.53	-199.53	-189.53	-179.53	-169.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -609.53	-599.53	-589.53	-579.53	-569.53	-559.53	-549.53	-539.53	-529.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

12
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -519.53	-509.53	-499.53	-489.53	-479.53	-469.53	-459.53	-449.53	-439.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -429.53	-419.53	-409.53	-399.53	-389.53	-379.53	-369.53	-359.53	-349.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

14
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -339.53	-329.53	-319.53	-309.53	-299.53	-289.53	-279.53	-269.53	-259.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -249.53	-239.53	-229.53	-219.53	-209.53	-199.53	-189.53	-179.53	-169.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000
90.000	.00019600	.00034000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00034000	.00000000	.00000000	.00000000	.00000000
135.000	.00019600	.00136200	.00000000	.00000000	.00000000	.00000000
157.500	.00039200	.00238300	.00000000	.00000000	.00000000	.00000000
180.000	.00195900	.00187200	.00000000	.00000000	.00000000	.00000000
202.500	.00195900	.00153200	.00000000	.00000000	.00000000	.00000000
225.000	.00215500	.00221300	.00000000	.00000000	.00000000	.00000000
247.500	.00195900	.00119100	.00000000	.00000000	.00000000	.00000000
270.000	.00078400	.00085100	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00019600	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00058800	.00017000	.00051100	.00000000	.00000000	.00000000
67.500	.00078400	.00085100	.00017000	.00000000	.00000000	.00000000
90.000	.00156700	.00102100	.00051100	.00000000	.00000000	.00000000
112.500	.00333100	.00306400	.00255300	.00000000	.00000000	.00000000
135.000	.00293900	.00425500	.00425500	.00000000	.00000000	.00000000
157.500	.00293900	.00766000	.00680900	.00000000	.00000000	.00000000
180.000	.00411400	.00697900	.00510600	.00000000	.00000000	.00000000
202.500	.00489800	.00646800	.00306400	.00000000	.00000000	.00000000
225.000	.00391800	.00459600	.00187200	.00000000	.00000000	.00000000
247.500	.00509400	.00527700	.00153200	.00000000	.00000000	.00000000
270.000	.00117600	.00170200	.00204300	.00000000	.00000000	.00000000
292.500	.00098000	.00187200	.00221300	.00000000	.00000000	.00000000
315.000	.00098000	.00102100	.00119100	.00000000	.00000000	.00000000
337.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NC.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00039200	.00034000	.00000000	.00000000	.00000000	.00000000
22.500	.00019600	.00034000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00068100	.00238300	.00000000	.00000000	.00000000
67.500	.00098000	.00085100	.00102100	.00000000	.00000000	.00000000
90.000	.00137100	.00136200	.00187200	.00000000	.00000000	.00000000
112.500	.00450600	.00391500	.00629800	.00034000	.00000000	.00000000
135.000	.00352700	.00544700	.01787200	.00442600	.00000000	.00000000
157.500	.00450600	.00425500	.01123400	.00289400	.00000000	.00000000
180.000	.00293900	.00595700	.01089400	.00340400	.00017000	.00000000
202.500	.00176300	.00459600	.00595700	.00017000	.00000000	.00000000
225.000	.00313500	.00425500	.00187200	.00017000	.00000000	.00000000
247.500	.00156700	.00340400	.00459600	.00170200	.00000000	.00000000
270.000	.00195900	.00289400	.00204300	.00170200	.00034000	.00000000
292.500	.00137100	.00153200	.00221300	.00000000	.00000000	.00000000
315.000	.00039200	.00136200	.00221300	.00051100	.00000000	.00000000
337.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00017000	.00017000	.00000000	.00000000	.00000000
22.500	.00000000	.00102100	.00119100	.00102100	.00034000	.00034000
45.000	.00039200	.00255300	.00493600	.00851100	.00153200	.00000000
67.500	.00078400	.00425500	.00595700	.00697900	.00068100	.00017000
90.000	.00313500	.00527700	.01293600	.00987200	.00119100	.00017000
112.500	.00372300	.01293600	.02706400	.01344700	.00136200	.00000000
135.000	.00372300	.01004300	.03285100	.04204300	.00306400	.00000000
157.500	.00176300	.00663800	.01855300	.01991500	.00238300	.00017000
180.000	.00274300	.00612800	.01072300	.00425500	.00051100	.00000000
202.500	.00117600	.00425500	.00731900	.00357400	.00000000	.00000000
225.000	.00019600	.00408500	.00510600	.00340400	.00136200	.00017000
247.500	.00058800	.00357400	.00595700	.01123400	.00306400	.00136200
270.000	.00058800	.00238300	.00527700	.00748900	.00357400	.00187200
292.500	.00039200	.00153200	.00221300	.00238300	.00102100	.00000000
315.000	.00000000	.00068100	.00204300	.00391500	.00136200	.00034000
337.500	.00000000	.00000000	.00034000	.00051100	.00000000	.00000000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00034000	.00034000	.00000000	.00000000	.00000000
22.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00085100	.00187200	.00000000	.00000000	.00000000
67.500	.00000000	.00170200	.00272300	.00000000	.00000000	.00000000
90.000	.00000000	.00272300	.00783000	.00000000	.00000000	.00000000
112.500	.00000000	.00680900	.02314900	.00000000	.00000000	.00000000
135.000	.00000000	.01123400	.02961700	.00000000	.00000000	.00000000
157.500	.00000000	.00868100	.01038300	.00000000	.00000000	.00000000
180.000	.00000000	.00323400	.00238300	.00000000	.00000000	.00000000
202.500	.00000000	.00340400	.00068100	.00000000	.00000000	.00000000
225.000	.00000000	.00221300	.00119100	.00000000	.00000000	.00000000
247.500	.00000000	.00187200	.00442600	.00000000	.00000000	.00000000
270.000	.00000000	.00034000	.00272300	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00204300	.00000000	.00000000	.00000000
315.000	.00000000	.00085100	.00170200	.00000000	.00000000	.00000000
337.500	.00000000	.00034000	.00085100	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00051100	.00000000	.00000000	.00000000	.00000000
22.500	.00039200	.00187200	.00000000	.00000000	.00000000	.00000000
45.000	.00156700	.00374500	.00000000	.00000000	.00000000	.00000000
67.500	.00313500	.00476600	.00000000	.00000000	.00000000	.00000000
90.000	.00607400	.00748900	.00000000	.00000000	.00000000	.00000000
112.500	.01097200	.02059600	.00000000	.00000000	.00000000	.00000000
135.000	.01195100	.02348900	.00000000	.00000000	.00000000	.00000000
157.500	.01136400	.01293600	.00000000	.00000000	.00000000	.00000000
180.000	.00881700	.00561700	.00000000	.00000000	.00000000	.00000000
202.500	.00607400	.00357400	.00000000	.00000000	.00000000	.00000000
225.000	.00470200	.00493600	.00000000	.00000000	.00000000	.00000000
247.500	.00450600	.00510600	.00000000	.00000000	.00000000	.00000000
270.000	.00254700	.00272300	.00000000	.00000000	.00000000	.00000000
292.500	.00176300	.00238300	.00000000	.00000000	.00000000	.00000000
315.000	.00195900	.00238300	.00000000	.00000000	.00000000	.00000000
337.500	.00058800	.00187200	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -609.53	-599.53	-589.53	-579.53	-569.53	-559.53	-549.53	-539.53	-529.53
3074.73	.078429	.078223	.078015	.077806	.077595	.077381	.077167	.076950	.076731
3064.73	.078795	.078588	.078379	.078169	.077956	.077742	.077526	.077308	.077088
3054.73	.079164	.078956	.078746	.078534	.078321	.078105	.077888	.077669	.077448
3044.73	.079537	.079327	.079116	.078903	.078688	.078471	.078253	.078032	.077810
3034.73	.079912	.079701	.079489	.079275	.079058	.078840	.078620	.078399	.078175
3024.73	.080289	.080078	.079864	.079649	.079431	.079212	.078991	.078768	.078543
3014.73	.080670	.080457	.080243	.080026	.079808	.079587	.079365	.079141	.078914
3004.73	.081054	.080840	.080624	.080406	.080187	.079965	.079742	.079516	.079289
2994.73	.081441	.081226	.081009	.080790	.080569	.080346	.080121	.079894	.079665
2984.73	.081831	.081615	.081396	.081176	.080954	.080730	.080503	.080275	.080045
2974.73	.082224	.082006	.081787	.081565	.081342	.081116	.080889	.080659	.080428

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -519.53	-509.53	-499.53	-489.53	-479.53	-469.53	-459.53	-449.53	-439.53
3074.73	.076511	.076289	.076065	.075839	.075612	.075383	.075152	.074919	.074684
3064.73	.076866	.076643	.076418	.076191	.075962	.075731	.075499	.075265	.075029
3054.73	.077225	.077000	.076773	.076545	.076315	.076083	.075849	.075614	.075376
3044.73	.077586	.077360	.077132	.076902	.076671	.076437	.076202	.075965	.075727
3034.73	.077949	.077722	.077493	.077262	.077029	.076795	.076558	.076320	.076080
3024.73	.078316	.078088	.077857	.077625	.077391	.077155	.076917	.076677	.076435
3014.73	.078686	.078456	.078225	.077991	.077755	.077517	.077278	.077037	.076793
3004.73	.079059	.078828	.078595	.078359	.078122	.077883	.077642	.077399	.077154
2994.73	.079435	.079202	.078967	.078730	.078492	.078251	.078009	.077764	.077518
2984.73	.079813	.079579	.079342	.079104	.078864	.078622	.078378	.078132	.077884
2974.73	.080194	.079958	.079721	.079481	.079239	.078996	.078750	.078503	.078253

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS)							
	-429.53	-419.53	-409.53	-399.53	-389.53	-379.53	-369.53	-359.53	-349.53
3074.73	.074448	.074210	.073971	.073730	.073487	.073242	.072996	.072748	.072498
3064.73	.074792	.074552	.074311	.074069	.073824	.073578	.073330	.073080	.072829
3054.73	.075138	.074897	.074654	.074410	.074164	.073916	.073667	.073416	.073163
3044.73	.075486	.075244	.075000	.074754	.074506	.074257	.074006	.073753	.073499
3034.73	.075838	.075594	.075348	.075101	.074851	.074601	.074348	.074093	.073837
3024.73	.076192	.075946	.075699	.075450	.075199	.074947	.074692	.074436	.074178
3014.73	.076548	.076301	.076053	.075802	.075550	.075295	.075039	.074782	.074522
3004.73	.076908	.076659	.076409	.076157	.075903	.075647	.075389	.075130	.074868
2994.73	.077270	.077020	.076768	.076514	.076258	.076001	.075741	.075480	.075217
2984.73	.077634	.077383	.077129	.076874	.076616	.076357	.076096	.075833	.075568
2974.73	.078002	.077749	.077493	.077236	.076977	.076716	.076453	.076189	.075922

24
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -339.53	-329.53	-319.53	-309.53	-299.53	-289.53	-279.53	-269.53	-259.53
3074.73	.072247	.071994	.071739	.071483	.071225	.070966	.070705	.070442	.070178
3064.73	.072576	.072322	.072065	.071807	.071548	.071287	.071024	.070759	.070493
3054.73	.072908	.072652	.072394	.072134	.071873	.071610	.071345	.071079	.070811
3044.73	.073242	.072984	.072725	.072463	.072200	.071935	.071669	.071401	.071131
3034.73	.073579	.073319	.073058	.072795	.072530	.072264	.071995	.071726	.071454
3024.73	.073919	.073657	.073394	.073129	.072863	.072594	.072324	.072053	.071779
3014.73	.074260	.073997	.073732	.073466	.073197	.072927	.072656	.072382	.072107
3004.73	.074605	.074340	.074074	.073805	.073535	.073263	.072989	.072714	.072437
2994.73	.074952	.074685	.074417	.074147	.073875	.073601	.073325	.073048	.072769
2984.73	.075301	.075033	.074763	.074491	.074217	.073941	.073664	.073385	.073104
2974.73	.075654	.075383	.075111	.074837	.074562	.074284	.074005	.073724	.073441

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS)							
	-249.53	-239.53	-229.53	-219.53	-209.53	-199.53	-189.53	-179.53	-169.53
3074.73	.069912	.069645	.069376	.069105	.068833	.068560	.068285	.068008	.067730
3064.73	.070226	.069956	.069686	.069413	.069140	.068864	.068587	.068309	.068029
3054.73	.070542	.070271	.069998	.069724	.069448	.069171	.068892	.068612	.068330
3044.73	.070860	.070587	.070313	.070037	.069759	.069480	.069199	.068917	.068633
3034.73	.071181	.070906	.070630	.070352	.070073	.069792	.069509	.069225	.068939
3024.73	.071504	.071228	.070950	.070670	.070388	.070105	.069821	.069535	.069247
3014.73	.071830	.071552	.071272	.070990	.070706	.070421	.070135	.069847	.069557
3004.73	.072158	.071878	.071596	.071312	.071027	.070740	.070451	.070161	.069869
2994.73	.072489	.072206	.071922	.071637	.071349	.071060	.070770	.070478	.070184
2984.73	.072821	.072537	.072251	.071963	.071674	.071383	.071091	.070796	.070501
2974.73	.073157	.072870	.072582	.072293	.072001	.071708	.071414	.071117	.070819

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.082224	AT (	-609.53,	2974.73)	GC	6.	.081565	AT (	-579.53,	2974.73)	GC
2.	.082006	AT (	-599.53,	2974.73)	GC	7.	.081441	AT (	-609.53,	2994.73)	GC
3.	.081831	AT (	-609.53,	2984.73)	GC	8.	.081396	AT (	-589.53,	2984.73)	GC
4.	.081787	AT (	-589.53,	2974.73)	GC	9.	.081342	AT (	-569.53,	2974.73)	GC
5.	.081615	AT (	-599.53,	2984.73)	GC	10.	.081226	AT (	-599.53,	2994.73)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION AT WIPP SITE BOUNDARY (90 Carlsbad Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -209.53 45 10.00 2978.51 11 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
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RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 1	1.50			
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 2	1.50			
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 3	1.50			
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE	GRIDCART	COARSE	FLAG 4	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 4     1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5     1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6     1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7     1.50
RE GRIDCART COARSE   FLAG 8     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8     1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8     1.50    1.50    1.50    1.50
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RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
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RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 5  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
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RE GRIDCART COARSE   ELEV 6  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 6  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
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RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
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RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00
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RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\CBD90.STR (7X,6F7.5)
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1990 CARLSBAD
ME UAIRDATA 11111 1990
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMFC90B.GPH 70
OU FINISHED
**********************************
*** SETUP Finishes Successfully ***
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1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 495 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMFC90B.DAT ; **Output Print File: ADMFC90B.LST

2
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-209.5,	-199.5,	-189.5,	-179.5,	-169.5,	-159.5,	-149.5,	-139.5,	-129.5,	-119.5,
-109.5,	-99.5,	-89.5,	-79.5,	-69.5,	-59.5,	-49.5,	-39.5,	-29.5,	-19.5,
-9.5,	.5,	10.5,	20.5,	30.5,	40.5,	50.5,	60.5,	70.5,	80.5,
90.5,	100.5,	110.5,	120.5,	130.5,	140.5,	150.5,	160.5,	170.5,	180.5,
190.5,	200.5,	210.5,	220.5,	230.5,					

*** Y-COORDINATES OF GRID ***
(METERS)

2978.5,	2988.5,	2998.5,	3008.5,	3018.5,	3028.5,	3038.5,	3048.5,	3058.5,	3068.5,
3078.5,									

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -209.53	-199.53	-189.53	-179.53	-169.53	-159.53	-149.53	-139.53	-129.53
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -119.53	-109.53	-99.53	-89.53	-79.53	-69.53	-59.53	-49.53	-39.53
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -29.53	-19.53	-9.53	.47	10.47	20.47	30.47	40.47	50.47
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 60.47	70.47	80.47	90.47	100.47	110.47	120.47	130.47	140.47
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 150.47	160.47	170.47	180.47	190.47	200.47	210.47	220.47	230.47
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -209.53	-199.53	-189.53	-179.53	-169.53	-159.53	-149.53	-139.53	-129.53
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -119.53	-109.53	-99.53	-89.53	-79.53	-69.53	-59.53	-49.53	-39.53
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -29.53	-19.53	-9.53	.47	10.47	20.47	30.47	40.47	50.47
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 60.47	70.47	80.47	90.47	100.47	110.47	120.47	130.47	140.47
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 150.47	160.47	170.47	180.47	190.47	200.47	210.47	220.47	230.47
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00064000	.00083000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
45.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
67.500	.00048000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00094000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00057000	.00047000	.00000000	.00000000	.00000000	.00000000
135.000	.00126000	.00083000	.00000000	.00000000	.00000000	.00000000
157.500	.00045000	.00059000	.00000000	.00000000	.00000000	.00000000
180.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
202.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
225.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
247.500	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
270.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00036000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00103000	.00213000	.00189000	.00000000	.00000000	.00000000
22.500	.00130000	.00213000	.00071000	.00000000	.00000000	.00000000
45.000	.00083000	.00177000	.00118000	.00000000	.00000000	.00000000
67.500	.00118000	.00307000	.00106000	.00000000	.00000000	.00000000
90.000	.00169000	.00284000	.00130000	.00000000	.00000000	.00000000
112.500	.00105000	.00402000	.00189000	.00000000	.00000000	.00000000
135.000	.00116000	.00556000	.00355000	.00000000	.00000000	.00000000
157.500	.00225000	.00721000	.00343000	.00000000	.00000000	.00000000
180.000	.00248000	.00520000	.00343000	.00000000	.00000000	.00000000
202.500	.00039000	.00071000	.00095000	.00000000	.00000000	.00000000
225.000	.00043000	.00095000	.00012000	.00000000	.00000000	.00000000
247.500	.00009000	.00059000	.00024000	.00000000	.00000000	.00000000
270.000	.00035000	.00047000	.00035000	.00000000	.00000000	.00000000
292.500	.00045000	.00024000	.00024000	.00000000	.00000000	.00000000
315.000	.00034000	.00130000	.00012000	.00000000	.00000000	.00000000
337.500	.00071000	.00189000	.00071000	.00000000	.00000000	.00000000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00080000	.00366000	.00816000	.00248000	.00012000	.00000000
22.500	.00035000	.00284000	.00343000	.00059000	.00000000	.00000000
45.000	.00025000	.00319000	.00118000	.00012000	.00000000	.00000000
67.500	.00036000	.00296000	.00130000	.00000000	.00000000	.00000000
90.000	.00056000	.00390000	.00343000	.00071000	.00000000	.00000000
112.500	.00067000	.00366000	.00473000	.00142000	.00000000	.00000000
135.000	.00029000	.00366000	.01017000	.00355000	.00012000	.00000000
157.500	.00069000	.00556000	.01324000	.00248000	.00035000	.00000000
180.000	.00040000	.00508000	.01206000	.00284000	.00024000	.00000000
202.500	.00034000	.00106000	.00106000	.00071000	.00000000	.00000000
225.000	.00016000	.00047000	.00047000	.00012000	.00024000	.00000000
247.500	.00030000	.00059000	.00177000	.00083000	.00071000	.00047000
270.000	.00047000	.00118000	.00225000	.00213000	.00165000	.00071000
292.500	.00031000	.00071000	.00083000	.00083000	.00024000	.00000000
315.000	.00035000	.00118000	.00095000	.00035000	.00000000	.00000000
337.500	.00033000	.00095000	.00189000	.00059000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00043000	.00461000	.00875000	.01572000	.00307000	.00059000
22.500	.00042000	.00248000	.00402000	.00449000	.00047000	.00035000
45.000	.00044000	.00284000	.00496000	.00343000	.00035000	.00012000
67.500	.00037000	.00177000	.00366000	.00201000	.00000000	.00000000
90.000	.00058000	.00307000	.00579000	.00496000	.00035000	.00000000
112.500	.00042000	.00248000	.00603000	.00378000	.00035000	.00000000
135.000	.00100000	.00556000	.01312000	.01820000	.00201000	.00059000
157.500	.00073000	.00520000	.02506000	.02376000	.00225000	.00024000
180.000	.00096000	.00496000	.01962000	.01466000	.00071000	.00047000
202.500	.00028000	.00225000	.00319000	.00366000	.00118000	.00035000
225.000	.00064000	.00201000	.00390000	.00319000	.00106000	.00024000
247.500	.00034000	.00130000	.00544000	.01253000	.00532000	.00189000
270.000	.00021000	.00307000	.00768000	.02624000	.01548000	.00662000
292.500	.00049000	.00165000	.00402000	.00922000	.00213000	.00071000
315.000	.00039000	.00213000	.00366000	.00485000	.00047000	.00012000
337.500	.00046000	.00307000	.00721000	.00969000	.00414000	.00059000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00390000	.00473000	.00000000	.00000000	.00000000
22.500	.00000000	.00130000	.00130000	.00000000	.00000000	.00000000
45.000	.00000000	.00071000	.00118000	.00000000	.00000000	.00000000
67.500	.00000000	.00118000	.00154000	.00000000	.00000000	.00000000
90.000	.00000000	.00165000	.00189000	.00000000	.00000000	.00000000
112.500	.00000000	.00154000	.00236000	.00000000	.00000000	.00000000
135.000	.00000000	.00414000	.00863000	.00000000	.00000000	.00000000
157.500	.00000000	.00721000	.01797000	.00000000	.00000000	.00000000
180.000	.00000000	.01005000	.02364000	.00000000	.00000000	.00000000
202.500	.00000000	.00284000	.00934000	.00000000	.00000000	.00000000
225.000	.00000000	.00366000	.00792000	.00000000	.00000000	.00000000
247.500	.00000000	.00236000	.01206000	.00000000	.00000000	.00000000
270.000	.00000000	.00390000	.01478000	.00000000	.00000000	.00000000
292.500	.00000000	.00461000	.01229000	.00000000	.00000000	.00000000
315.000	.00000000	.00260000	.00603000	.00000000	.00000000	.00000000
337.500	.00000000	.00154000	.00402000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00468000	.00993000	.00000000	.00000000	.00000000	.00000000
22.500	.00242000	.00520000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00201000	.00000000	.00000000	.00000000	.00000000
67.500	.00120000	.00248000	.00000000	.00000000	.00000000	.00000000
90.000	.00258000	.00390000	.00000000	.00000000	.00000000	.00000000
112.500	.00174000	.00461000	.00000000	.00000000	.00000000	.00000000
135.000	.00246000	.00745000	.00000000	.00000000	.00000000	.00000000
157.500	.00425000	.01430000	.00000000	.00000000	.00000000	.00000000
180.000	.00608000	.02352000	.00000000	.00000000	.00000000	.00000000
202.500	.00264000	.00981000	.00000000	.00000000	.00000000	.00000000
225.000	.00254000	.00674000	.00000000	.00000000	.00000000	.00000000
247.500	.00388000	.00768000	.00000000	.00000000	.00000000	.00000000
270.000	.00378000	.01312000	.00000000	.00000000	.00000000	.00000000
292.500	.00431000	.01678000	.00000000	.00000000	.00000000	.00000000
315.000	.00265000	.00827000	.00000000	.00000000	.00000000	.00000000
337.500	.00287000	.00603000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99995

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -209.53	-199.53	-189.53	-179.53	-169.53	-159.53	-149.53	-139.53	-129.53
3078.51	.111547	.111800	.112052	.112301	.112549	.112795	.113039	.113282	.113522
3068.51	.112035	.112290	.112544	.112796	.113045	.113294	.113540	.113784	.114027
3058.51	.112527	.112784	.113040	.113294	.113545	.113796	.114044	.114290	.114535
3048.51	.113023	.113282	.113540	.113795	.114049	.114301	.114552	.114800	.115047
3038.51	.113522	.113783	.114043	.114301	.114557	.114811	.115064	.115314	.115563
3028.51	.114025	.114288	.114550	.114810	.115068	.115325	.115579	.115832	.116082
3018.51	.114531	.114797	.115061	.115323	.115584	.115842	.116099	.116353	.116606
3008.51	.115041	.115309	.115576	.115840	.116102	.116363	.116622	.116878	.117134
2998.51	.115556	.115826	.116094	.116361	.116626	.116888	.117149	.117408	.117665
2988.51	.116074	.116346	.116617	.116886	.117153	.117418	.117681	.117942	.118201
2978.51	.116596	.116871	.117144	.117415	.117684	.117951	.118217	.118480	.118741

22
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -119.53	-109.53	-99.53	-89.53	-79.53	-69.53	-59.53	-49.53	-39.53
3078.51	.113761	.113998	.114233	.114467	.114698	.114927	.115155	.115380	.115605
3068.51	.114267	.114507	.114744	.114979	.115212	.115443	.115672	.115900	.116125
3058.51	.114778	.115018	.115258	.115494	.115729	.115963	.116194	.116423	.116650
3048.51	.115292	.115534	.115775	.116014	.116252	.116486	.116719	.116950	.117179
3038.51	.115809	.116054	.116297	.116538	.116777	.117014	.117249	.117482	.117712
3028.51	.116331	.116578	.116823	.117066	.117306	.117545	.117782	.118017	.118249
3018.51	.116857	.117106	.117353	.117597	.117840	.118081	.118320	.118557	.118791
3008.51	.117386	.117637	.117886	.118133	.118378	.118620	.118861	.119099	.119336
2998.51	.117920	.118173	.118424	.118673	.118920	.119165	.119407	.119648	.119886
2988.51	.118458	.118713	.118966	.119217	.119466	.119712	.119958	.120200	.120441
2978.51	.119000	.119258	.119512	.119766	.120017	.120265	.120513	.120756	.120999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -29.53	-19.53	-9.53	.47	10.47	20.47	30.47	40.47	50.47
3078.51	.115827	.116046	.116264	.116487	.115839	.115235	.114628	.114021	.113413
3068.51	.116349	.116570	.116788	.117015	.116364	.115753	.115142	.114530	.113916
3058.51	.116876	.117100	.117319	.117547	.116889	.116275	.115659	.115042	.114423
3048.51	.117406	.117632	.117855	.118083	.117417	.116800	.116181	.115559	.114936
3038.51	.117941	.118168	.118395	.118624	.117953	.117328	.116703	.116079	.115450
3028.51	.118480	.118708	.118936	.119168	.118493	.117862	.117229	.116595	.115965
3018.51	.119023	.119254	.119480	.119717	.119035	.118400	.117762	.117123	.116483
3008.51	.119570	.119803	.120033	.120269	.119580	.118942	.118299	.117655	.117009
2998.51	.120122	.120356	.120590	.120827	.120134	.119488	.118840	.118191	.117540
2988.51	.120678	.120915	.121151	.121389	.120692	.120039	.119387	.118733	.118076
2978.51	.121239	.121477	.121714	.121955	.121251	.120595	.119937	.119277	.118616

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 60.47	70.47	80.47	90.47	100.47	110.47	120.47	130.47	140.47
3078.51	.112803	.112191	.111578	.110964	.110349	.109732	.109114	.108494	.107874
3068.51	.113302	.112685	.112067	.111448	.110828	.110206	.109584	.108959	.108334
3058.51	.113804	.113183	.112560	.111936	.111311	.110684	.110057	.109428	.108797
3048.51	.114311	.113684	.113057	.112428	.111797	.111166	.110533	.109899	.109264
3038.51	.114821	.114189	.113557	.112923	.112287	.111651	.111013	.110374	.109733
3028.51	.115329	.114698	.114061	.113422	.112781	.112139	.111496	.110852	.110206
3018.51	.115840	.115197	.114560	.113925	.113279	.112632	.111984	.111334	.110683
3008.51	.116362	.115714	.115064	.114412	.113769	.113116	.112474	.111819	.111163
2998.51	.116889	.116234	.115579	.114923	.114264	.113605	.112956	.112295	.111647
2988.51	.117418	.116759	.116099	.115437	.114773	.114108	.113442	.112774	.112106
2978.51	.117953	.117288	.116622	.115954	.115285	.114615	.113944	.113271	.112596

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 150.47	160.47	170.47	180.47	190.47	200.47	210.47	220.47	230.47
3078.51	.107252	.106630	.106006	.105381	.104757	.104130	.103504	.102876	.102247
3068.51	.107708	.107080	.106452	.105822	.105191	.104560	.103928	.103295	.102662
3058.51	.108166	.107534	.106900	.106265	.105630	.104993	.104356	.103717	.103078
3048.51	.108628	.107990	.107352	.106712	.106071	.105429	.104787	.104143	.103499
3038.51	.109092	.108450	.107806	.107162	.106516	.105869	.105221	.104572	.103923
3028.51	.109560	.108912	.108263	.107614	.106963	.106311	.105658	.105004	.104350
3018.51	.110031	.109378	.108724	.108069	.107412	.106755	.106098	.105439	.104779
3008.51	.110506	.109848	.109188	.108528	.107866	.107203	.106540	.105876	.105211
2998.51	.110985	.110321	.109656	.108990	.108323	.107655	.106986	.106316	.105646
2988.51	.111451	.110781	.110128	.109456	.108784	.108110	.107436	.106760	.106084
2978.51	.111921	.111244	.110585	.109907	.109247	.108568	.107889	.107208	.106526

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.121955	AT (	.47,	2978.51)	GC	6.	.121239	AT (	-29.53,	2978.51)	GC
2.	.121714	AT (	-9.53,	2978.51)	GC	7.	.121151	AT (	-9.53,	2988.51)	GC
3.	.121477	AT (	-19.53,	2978.51)	GC	8.	.120999	AT (	-39.53,	2978.51)	GC
4.	.121389	AT (	.47,	2988.51)	GC	9.	.120915	AT (	-19.53,	2988.51)	GC
5.	.121251	AT (	10.47,	2978.51)	GC	10.	.120827	AT (	.47,	2998.51)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION INSIDE WIPP SITE BOUNDARY (93 WIPP Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -100 22 10.00 -20.00 22 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50
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RE GRIDCART COARSE   FLAG 2    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 2    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 2    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 2    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 2    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 2    1.50    1.50
RE GRIDCART COARSE   FLAG 3    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 3    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 3    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 3    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 3    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 3    1.50    1.50
RE GRIDCART COARSE   FLAG 4    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 4    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 4    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 4    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 4    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 4    1.50    1.50
RE GRIDCART COARSE   FLAG 5    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 5    1.50    1.50
RE GRIDCART COARSE   FLAG 6    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 6    1.50    1.50
RE GRIDCART COARSE   FLAG 7    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 7    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
RE GRIDCART COARSE   FLAG 8    1.50    1.50    1.50    1.50
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RE GRIDCART COARSE   FLAG 8     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50		
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50		
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50		
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50		
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50		
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50		
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50		
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 22     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 22     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 22     1.50     1.50
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\WP3093.STR  FREE
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1993 WIPP
ME UAIRDATA 11111 1993
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMEW93A.GPH 70
OU FINISHED
**********************************
*** SETUP Finishes Successfully ***
```

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 484 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: admfW93a.dat ; **Output Print File: admfW93A.lst

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-100.0, -90.0, -80.0, -70.0, -60.0, -50.0, -40.0, -30.0, -20.0, -10.0,
.0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0,
100.0, 110.0,

*** Y-COORDINATES OF GRID ***
(METERS)

-20.0, -10.0, .0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0,
80.0, 90.0, 100.0, 110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0,
180.0, 190.0,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

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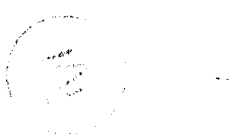
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37



*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37

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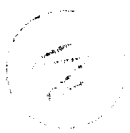
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50



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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

* SOURCE-RECEPTOR COMBINATIONS FOR WHICH CALCULATIONS MAY NOT BE PERFORMED *
LESS THAN 1.0 METER OR 3*ZLB IN DISTANCE, OR WITHIN OPEN PIT SOURCE

SOURCE ID	- - RECEPTOR LOCATION - - XR (METERS)	YR (METERS)	DISTANCE (METERS)
1	-20.0	-20.0	28.28
1	-10.0	-10.0	14.14
1	10.0	-10.0	14.14
1	-10.0	.0	10.00
1	.0	.0	.00
1	10.0	.0	10.00
1	.0	10.0	10.00
1	10.0	10.0	14.14
1	.0	20.0	20.00
1	10.0	20.0	22.36
1	20.0	20.0	28.28
1	.0	30.0	30.00
1	10.0	30.0	31.62
2	10.0	.0	12.32
2	-10.0	10.0	10.38
2	.0	10.0	2.80
2	-10.0	20.0	16.24
2	.0	20.0	12.80
2	10.0	20.0	16.24
2	.0	30.0	22.80
2	10.0	30.0	24.90
2	20.0	30.0	30.33

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000
90.000	.00019600	.00034000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00034000	.00000000	.00000000	.00000000	.00000000
135.000	.00019600	.00136200	.00000000	.00000000	.00000000	.00000000
157.500	.00039200	.00238300	.00000000	.00000000	.00000000	.00000000
180.000	.00195900	.00187200	.00000000	.00000000	.00000000	.00000000
202.500	.00195900	.00153200	.00000000	.00000000	.00000000	.00000000
225.000	.00215500	.00221300	.00000000	.00000000	.00000000	.00000000
247.500	.00195900	.00119100	.00000000	.00000000	.00000000	.00000000
270.000	.00078400	.00085100	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00019600	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00058800	.00017000	.00051100	.00000000	.00000000	.00000000
67.500	.00078400	.00085100	.00017000	.00000000	.00000000	.00000000
90.000	.00156700	.00102100	.00051100	.00000000	.00000000	.00000000
112.500	.00333100	.00306400	.00255300	.00000000	.00000000	.00000000
135.000	.00293900	.00425500	.00425500	.00000000	.00000000	.00000000
157.500	.00293900	.00766000	.00680900	.00000000	.00000000	.00000000
180.000	.00411400	.00697900	.00510600	.00000000	.00000000	.00000000
202.500	.00489800	.00646800	.00306400	.00000000	.00000000	.00000000
225.000	.00391800	.00459600	.00187200	.00000000	.00000000	.00000000
247.500	.00509400	.00527700	.00153200	.00000000	.00000000	.00000000
270.000	.00117600	.00170200	.00204300	.00000000	.00000000	.00000000
292.500	.00098000	.00187200	.00221300	.00000000	.00000000	.00000000
315.000	.00098000	.00102100	.00119100	.00000000	.00000000	.00000000
337.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00039200	.00034000	.00000000	.00000000	.00000000	.00000000
22.500	.00019600	.00034000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00068100	.00238300	.00000000	.00000000	.00000000
67.500	.00098000	.00085100	.00102100	.00000000	.00000000	.00000000
90.000	.00137100	.00136200	.00187200	.00000000	.00000000	.00000000
112.500	.00450600	.00391500	.00629800	.00034000	.00000000	.00000000
135.000	.00352700	.00544700	.01787200	.00442600	.00000000	.00000000
157.500	.00450600	.00425500	.01123400	.00289400	.00000000	.00000000
180.000	.00293900	.00595700	.01089400	.00340400	.00017000	.00000000
202.500	.00176300	.00459600	.00595700	.00017000	.00000000	.00000000
225.000	.00313500	.00425500	.00187200	.00017000	.00000000	.00000000
247.500	.00156700	.00340400	.00459600	.00170200	.00000000	.00000000
270.000	.00195900	.00289400	.00204300	.00170200	.00034000	.00000000
292.500	.00137100	.00153200	.00221300	.00000000	.00000000	.00000000
315.000	.00039200	.00136200	.00221300	.00051100	.00000000	.00000000
337.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00017000	.00017000	.00000000	.00000000	.00000000
22.500	.00000000	.00102100	.00119100	.00102100	.00034000	.00034000
45.000	.00039200	.00255300	.00493600	.00851100	.00153200	.00000000
67.500	.00078400	.00425500	.00595700	.00697900	.00068100	.00017000
90.000	.00313500	.00527700	.01293600	.00987200	.00119100	.00017000
112.500	.00372300	.01293600	.02706400	.01344700	.00136200	.00000000
135.000	.00372300	.01004300	.03285100	.04204300	.00306400	.00000000
157.500	.00176300	.00663800	.01855300	.01991500	.00238300	.00017000
180.000	.00274300	.00612800	.01072300	.00425500	.00051100	.00000000
202.500	.00117600	.00425500	.00731900	.00357400	.00000000	.00000000
225.000	.00019600	.00408500	.00510600	.00340400	.00136200	.00017000
247.500	.00058800	.00357400	.00595700	.01123400	.00306400	.00136200
270.000	.00058800	.00238300	.00527700	.00748900	.00357400	.00187200
292.500	.00039200	.00153200	.00221300	.00238300	.00102100	.00000000
315.000	.00000000	.00068100	.00204300	.00391500	.00136200	.00034000
337.500	.00000000	.00000000	.00034000	.00051100	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00034000	.00034000	.00000000	.00000000	.00000000
22.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00085100	.00187200	.00000000	.00000000	.00000000
67.500	.00000000	.00170200	.00272300	.00000000	.00000000	.00000000
90.000	.00000000	.00272300	.00783000	.00000000	.00000000	.00000000
112.500	.00000000	.00680900	.02314900	.00000000	.00000000	.00000000
135.000	.00000000	.01123400	.02961700	.00000000	.00000000	.00000000
157.500	.00000000	.00868100	.01038300	.00000000	.00000000	.00000000
180.000	.00000000	.00323400	.00238300	.00000000	.00000000	.00000000
202.500	.00000000	.00340400	.00068100	.00000000	.00000000	.00000000
225.000	.00000000	.00221300	.00119100	.00000000	.00000000	.00000000
247.500	.00000000	.00187200	.00442600	.00000000	.00000000	.00000000
270.000	.00000000	.00034000	.00272300	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00204300	.00000000	.00000000	.00000000
315.000	.00000000	.00085100	.00170200	.00000000	.00000000	.00000000
337.500	.00000000	.00034000	.00085100	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00051100	.00000000	.00000000	.00000000	.00000000
22.500	.00039200	.00187200	.00000000	.00000000	.00000000	.00000000
45.000	.00156700	.00374500	.00000000	.00000000	.00000000	.00000000
67.500	.00313500	.00476600	.00000000	.00000000	.00000000	.00000000
90.000	.00607400	.00748900	.00000000	.00000000	.00000000	.00000000
112.500	.01097200	.02059600	.00000000	.00000000	.00000000	.00000000
135.000	.01195100	.02348900	.00000000	.00000000	.00000000	.00000000
157.500	.01136400	.01293600	.00000000	.00000000	.00000000	.00000000
180.000	.00881700	.00561700	.00000000	.00000000	.00000000	.00000000
202.500	.00607400	.00357400	.00000000	.00000000	.00000000	.00000000
225.000	.00470200	.00493600	.00000000	.00000000	.00000000	.00000000
247.500	.00450600	.00510600	.00000000	.00000000	.00000000	.00000000
270.000	.00254700	.00272300	.00000000	.00000000	.00000000	.00000000
292.500	.00176300	.00238300	.00000000	.00000000	.00000000	.00000000
315.000	.00195900	.00238300	.00000000	.00000000	.00000000	.00000000
337.500	.00058800	.00187200	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.222216	1.189521	1.160668	1.164512	1.184652	1.204184	1.222966	1.240891	1.257879
180.00	1.283754	1.249361	1.219119	1.203540	1.228386	1.252902	1.276950	1.300391	1.323104
170.00	1.348213	1.313030	1.279943	1.252702	1.271748	1.302379	1.333016	1.363471	1.393562
160.00	1.415336	1.379260	1.343307	1.314602	1.313425	1.351671	1.390678	1.430208	1.469992
150.00	1.484756	1.447678	1.410153	1.378297	1.356255	1.398866	1.448436	1.499660	1.552146
140.00	1.556017	1.517758	1.478760	1.442415	1.418277	1.441429	1.504558	1.571133	1.640598
130.00	1.628485	1.588775	1.547932	1.508438	1.481075	1.474993	1.555274	1.641854	1.733975
120.00	1.701342	1.659803	1.616559	1.574385	1.540788	1.526155	1.595042	1.707753	1.830310
110.00	1.773597	1.729647	1.683175	1.637277	1.596744	1.578863	1.614689	1.761066	1.924307
100.00	1.741381	1.796891	1.746073	1.694989	1.648776	1.617727	1.621725	1.789309	2.010427
90.00	1.608979	1.738308	1.803424	1.745203	1.691144	1.649764	1.637326	1.772110	2.077041
80.00	1.458563	1.577693	1.707730	1.785825	1.721147	1.668990	1.641741	1.673053	2.097031
70.00	1.293218	1.398021	1.513495	1.639201	1.736757	1.668695	1.626088	1.626077	2.033510
60.00	1.118833	1.205525	1.301585	1.407336	1.522238	1.648854	1.574736	1.522967	1.759072
50.00	.944682	1.010898	1.083720	1.163570	1.251361	1.344994	1.453261	1.392034	1.423658
40.00	.858367	.878867	.882496	.929054	.983400	.999142	1.062658	1.273805	1.228390
30.00	.756011	.782375	.809363	.825210	.772004	.732243	.745177	.789834	1.089679
20.00	.653725	.670959	.687632	.703172	.680724	.680496	.595170	.471521	.503250
10.00	.556981	.566267	.574095	.579815	.550247	.536957	.513441	.483457	.403385
.00	.465547	.464818	.460872	.452696	.414352	.384345	.340939	.281998	.203035
-10.00	.373324	.356310	.331922	.297996	.239443	.176663	.102610	.048739	.004869
-20.00	.288197	.257509	.216454	.162422	.107067	.058804	.255871	.772106	.009054

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1.274003	1.289266	1.235893	1.179796	1.121798	1.062732	1.003397	.944519	.886952
180.00	1.345123	1.366405	1.305957	1.242323	1.176540	1.109641	1.042621	.976456	.912039
170.00	1.423265	1.452461	1.383696	1.311045	1.236064	1.159955	1.083966	1.009411	.939638
160.00	1.509914	1.549701	1.470833	1.387612	1.301451	1.214437	1.127524	1.043121	.972912
150.00	1.605609	1.659555	1.568311	1.471951	1.372644	1.272538	1.173320	1.078568	1.007727
140.00	1.712427	1.785739	1.678948	1.566203	1.450285	1.334180	1.220520	1.121051	1.043908
130.00	1.830676	1.930538	1.804295	1.671011	1.534556	1.398807	1.267296	1.166658	1.081523
120.00	1.960920	2.097628	1.945393	1.785615	1.625370	1.465837	1.319829	1.212177	1.119813
110.00	2.101557	2.289079	2.102841	1.908514	1.716258	1.527908	1.379498	1.258339	1.156437
100.00	2.255842	2.517848	2.285388	2.043751	1.804340	1.581970	1.423794	1.299171	1.189304
90.00	2.424623	2.800235	2.500512	2.190561	1.889271	1.643099	1.475119	1.330322	1.206993
80.00	2.598319	3.149501	2.752333	2.345571	1.958831	1.716557	1.523323	1.356006	1.213497
70.00	2.748115	3.574750	3.043500	2.508001	2.063106	1.793717	1.560961	1.367728	1.178338
60.00	2.851949	4.124789	3.389175	2.664995	2.189933	1.855830	1.581498	1.311532	1.053055
50.00	2.849340	4.879751	3.804641	2.832660	2.298095	1.884561	1.488543	1.111831	.865873
40.00	2.534865	6.016435	4.333626	3.084569	2.355063	1.717775	1.148562	.804859	.604234
30.00	1.471623	.000442	.604355	1.629417	2.045253	1.106030	.619992	.439520	.408313
20.00	.345729	.000676	.000352	.011077	.750117	.404347	.315704	.413885	.491487
10.00	.000889	.000308	.000379	.188312	.320818	.442107	.526602	.581765	.629444
.00	.000330	.000000	.000178	.351980	.454862	.540981	.600972	.636146	.669957
-10.00	.001734	.000000	.039682	.173429	.215109	.293281	.386997	.455324	.510914
-20.00	.010449	.000000	.032517	.194948	.236259	.245222	.272537	.323537	.370826

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	.835229	.795602	.761086	.728997
180.00	.861283	.818430	.781410	.746254
170.00	.888129	.842850	.801938	.763351
160.00	.916187	.867754	.822449	.780050
150.00	.946513	.892814	.842605	.795998
140.00	.978057	.917730	.861866	.810695
130.00	1.008913	.941805	.879601	.823541
120.00	1.037922	.963118	.895298	.833553
110.00	1.064012	.981032	.906644	.835756
100.00	1.085662	.993762	.905015	.821569
90.00	1.099998	.986808	.878241	.795698
80.00	1.077953	.940610	.834117	.755413
70.00	.993459	.864048	.768541	.697991
60.00	.875575	.755124	.675821	.620620
50.00	.710720	.614299	.555860	.538435
40.00	.497927	.488576	.498901	.523666
30.00	.454641	.500153	.528027	.542934
20.00	.535056	.559590	.570302	.571674
10.00	.638707	.635777	.624930	.609606
.00	.664295	.649660	.629844	.607801
-10.00	.530452	.536392	.533309	.524846
-20.00	.408209	.430259	.441200	.444592

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	6.016435	AT (	.00,	40.00)	GC	6.	3.574750	AT (	.00,	70.00)	GC
2.	4.879751	AT (	.00,	50.00)	GC	7.	3.389175	AT (	10.00,	60.00)	GC
3.	4.333626	AT (	10.00,	40.00)	GC	8.	3.149501	AT (	.00,	80.00)	GC
4.	4.124789	AT (	.00,	60.00)	GC	9.	3.084569	AT (	20.00,	40.00)	GC
5.	3.804641	AT (	10.00,	50.00)	GC	10.	3.043500	AT (	10.00,	70.00)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION INSIDE WIPP SITE BOUNDARY (90 Carlsbad Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -100 22 10.00 -20.00 22 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50
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RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 3     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 4     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 5     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 6     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 7     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 8     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE   FLAG 8     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 9     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10    1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11    1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12    1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13    1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14    1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15    1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50		
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50		
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50		
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50		
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50		
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50		
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50		
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 22     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 22     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 22     1.50     1.50
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 8  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 12  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 15  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 15  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 16  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 16  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 17  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 18  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 19  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 20  3410.00  3410.00
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RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\CBD90.STR (7X,6F7.5)
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1990 CARLSBAD
ME UAIRDATA 11111 1990
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMFC90A.GPH 70
OU FINISHED
**********************************
*** SETUP Finishes Successfully ***
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1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 484 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: admfc90a.dat ; **Output Print File: admfc90a.lst

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-100.0, -90.0, -80.0, -70.0, -60.0, -50.0, -40.0, -30.0, -20.0, -10.0,
.0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0,
100.0, 110.0,

*** Y-COORDINATES OF GRID ***
(METERS)

-20.0, -10.0, .0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0,
80.0, 90.0, 100.0, 110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0,
180.0, 190.0,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

* SOURCE-RECEPTOR COMBINATIONS FOR WHICH CALCULATIONS MAY NOT BE PERFORMED *
LESS THAN 1.0 METER OR 3*ZLB IN DISTANCE, OR WITHIN OPEN PIT SOURCE

SOURCE ID	- - RECEPTOR LOCATION - - XR (METERS)	YR (METERS)	DISTANCE (METERS)
1	-20.0	-20.0	28.28
1	-10.0	-10.0	14.14
1	10.0	-10.0	14.14
1	-10.0	.0	10.00
1	.0	.0	.00
1	10.0	.0	10.00
1	.0	10.0	10.00
1	10.0	10.0	14.14
1	.0	20.0	20.00
1	10.0	20.0	22.36
1	20.0	20.0	28.28
1	.0	30.0	30.00
1	10.0	30.0	31.62
2	10.0	.0	12.32
2	-10.0	10.0	10.38
2	.0	10.0	2.80
2	-10.0	20.0	16.24
2	.0	20.0	12.80
2	10.0	20.0	16.24
2	.0	30.0	22.80
2	10.0	30.0	24.90
2	20.0	30.0	30.33

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY	WIND SPEED CATEGORY					
CATEGORY	1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

ANNUAL

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00064000	.00083000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
45.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
67.500	.00048000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00094000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00057000	.00047000	.00000000	.00000000	.00000000	.00000000
135.000	.00126000	.00083000	.00000000	.00000000	.00000000	.00000000
157.500	.00045000	.00059000	.00000000	.00000000	.00000000	.00000000
180.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
202.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
225.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
247.500	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
270.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00036000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00103000	.00213000	.00189000	.00000000	.00000000	.00000000
22.500	.00130000	.00213000	.00071000	.00000000	.00000000	.00000000
45.000	.00083000	.00177000	.00118000	.00000000	.00000000	.00000000
67.500	.00118000	.00307000	.00106000	.00000000	.00000000	.00000000
90.000	.00169000	.00284000	.00130000	.00000000	.00000000	.00000000
112.500	.00105000	.00402000	.00189000	.00000000	.00000000	.00000000
135.000	.00116000	.00556000	.00355000	.00000000	.00000000	.00000000
157.500	.00225000	.00721000	.00343000	.00000000	.00000000	.00000000
180.000	.00248000	.00520000	.00343000	.00000000	.00000000	.00000000
202.500	.00039000	.00071000	.00095000	.00000000	.00000000	.00000000
225.000	.00043000	.00095000	.00012000	.00000000	.00000000	.00000000
247.500	.00009000	.00059000	.00024000	.00000000	.00000000	.00000000
270.000	.00035000	.00047000	.00035000	.00000000	.00000000	.00000000
292.500	.00045000	.00024000	.00024000	.00000000	.00000000	.00000000
315.000	.00034000	.00130000	.00012000	.00000000	.00000000	.00000000
337.500	.00071000	.00189000	.00071000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00080000	.00366000	.00816000	.00248000	.00012000	.00000000
22.500	.00035000	.00284000	.00343000	.00059000	.00000000	.00000000
45.000	.00025000	.00319000	.00118000	.00012000	.00000000	.00000000
67.500	.00036000	.00296000	.00130000	.00000000	.00000000	.00000000
90.000	.00056000	.00390000	.00343000	.00071000	.00000000	.00000000
112.500	.00067000	.00366000	.00473000	.00142000	.00000000	.00000000
135.000	.00029000	.00366000	.01017000	.00355000	.00012000	.00000000
157.500	.00069000	.00556000	.01324000	.00248000	.00035000	.00000000
180.000	.00040000	.00508000	.01206000	.00284000	.00024000	.00000000
202.500	.00034000	.00106000	.00106000	.00071000	.00000000	.00000000
225.000	.00016000	.00047000	.00047000	.00012000	.00024000	.00000000
247.500	.00030000	.00059000	.00177000	.00083000	.00071000	.00047000
270.000	.00047000	.00118000	.00225000	.00213000	.00165000	.00071000
292.500	.00031000	.00071000	.00083000	.00083000	.00024000	.00000000
315.000	.00035000	.00118000	.00095000	.00035000	.00000000	.00000000
337.500	.00033000	.00095000	.00189000	.00059000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00043000	.00461000	.00875000	.01572000	.00307000	.00059000
22.500	.00042000	.00248000	.00402000	.00449000	.00047000	.00035000
45.000	.00044000	.00284000	.00496000	.00343000	.00035000	.00012000
67.500	.00037000	.00177000	.00366000	.00201000	.00000000	.00000000
90.000	.00058000	.00307000	.00579000	.00496000	.00035000	.00000000
112.500	.00042000	.00248000	.00603000	.00378000	.00035000	.00000000
135.000	.00100000	.00556000	.01312000	.01820000	.00201000	.00059000
157.500	.00073000	.00520000	.02506000	.02376000	.00225000	.00024000
180.000	.00096000	.00496000	.01962000	.01466000	.00071000	.00047000
202.500	.00028000	.00225000	.00319000	.00366000	.00118000	.00035000
225.000	.00064000	.00201000	.00390000	.00319000	.00106000	.00024000
247.500	.00034000	.00130000	.00544000	.01253000	.00532000	.00189000
270.000	.00021000	.00307000	.00768000	.02624000	.01548000	.00662000
292.500	.00049000	.00165000	.00402000	.00922000	.00213000	.00071000
315.000	.00039000	.00213000	.00366000	.00485000	.00047000	.00012000
337.500	.00046000	.00307000	.00721000	.00969000	.00414000	.00059000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00390000	.00473000	.00000000	.00000000	.00000000
22.500	.00000000	.00130000	.00130000	.00000000	.00000000	.00000000
45.000	.00000000	.00071000	.00118000	.00000000	.00000000	.00000000
67.500	.00000000	.00118000	.00154000	.00000000	.00000000	.00000000
90.000	.00000000	.00165000	.00189000	.00000000	.00000000	.00000000
112.500	.00000000	.00154000	.00236000	.00000000	.00000000	.00000000
135.000	.00000000	.00414000	.00863000	.00000000	.00000000	.00000000
157.500	.00000000	.00721000	.01797000	.00000000	.00000000	.00000000
180.000	.00000000	.01005000	.02364000	.00000000	.00000000	.00000000
202.500	.00000000	.00284000	.00934000	.00000000	.00000000	.00000000
225.000	.00000000	.00366000	.00792000	.00000000	.00000000	.00000000
247.500	.00000000	.00236000	.01206000	.00000000	.00000000	.00000000
270.000	.00000000	.00390000	.01478000	.00000000	.00000000	.00000000
292.500	.00000000	.00461000	.01229000	.00000000	.00000000	.00000000
315.000	.00000000	.00260000	.00603000	.00000000	.00000000	.00000000
337.500	.00000000	.00154000	.00402000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00468000	.00993000	.00000000	.00000000	.00000000	.00000000
22.500	.00242000	.00520000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00201000	.00000000	.00000000	.00000000	.00000000
67.500	.00120000	.00248000	.00000000	.00000000	.00000000	.00000000
90.000	.00258000	.00390000	.00000000	.00000000	.00000000	.00000000
112.500	.00174000	.00461000	.00000000	.00000000	.00000000	.00000000
135.000	.00246000	.00745000	.00000000	.00000000	.00000000	.00000000
157.500	.00425000	.01430000	.00000000	.00000000	.00000000	.00000000
180.000	.00608000	.02352000	.00000000	.00000000	.00000000	.00000000
202.500	.00264000	.00981000	.00000000	.00000000	.00000000	.00000000
225.000	.00254000	.00674000	.00000000	.00000000	.00000000	.00000000
247.500	.00388000	.00768000	.00000000	.00000000	.00000000	.00000000
270.000	.00378000	.01312000	.00000000	.00000000	.00000000	.00000000
292.500	.00431000	.01678000	.00000000	.00000000	.00000000	.00000000
315.000	.00265000	.00827000	.00000000	.00000000	.00000000	.00000000
337.500	.00287000	.00603000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99995

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.102467	1.158826	1.221442	1.335687	1.478873	1.629453	1.786217	1.947673	2.112065
180.00	1.108006	1.166693	1.232545	1.325720	1.485780	1.655425	1.833302	2.017618	2.206207
170.00	1.110313	1.172082	1.240023	1.317314	1.481780	1.673673	1.876571	2.088318	2.306204
160.00	1.108625	1.173278	1.243332	1.323659	1.462088	1.681128	1.914168	2.159425	2.413485
150.00	1.102139	1.169359	1.242580	1.325761	1.430493	1.672364	1.941714	2.228032	2.526997
140.00	1.090064	1.159320	1.235601	1.320534	1.420285	1.640335	1.953996	2.291446	2.647181
130.00	1.071608	1.142087	1.220724	1.308417	1.412293	1.574123	1.941687	2.342966	2.770954
120.00	1.046065	1.116609	1.196473	1.286967	1.392416	1.518340	1.891523	2.373039	2.894079
110.00	1.012981	1.081949	1.161345	1.253055	1.359217	1.491089	1.782566	2.362982	3.002623
100.00	.946023	1.037508	1.114075	1.204594	1.311843	1.441171	1.629657	2.288250	3.084090
90.00	.870382	.950278	1.053997	1.139880	1.245013	1.373527	1.533482	2.112102	3.122024
80.00	.783733	.858496	.939507	1.058276	1.156421	1.282051	1.440517	1.763442	3.064848
70.00	.687611	.754665	.827817	.907427	1.045721	1.161001	1.316196	1.517582	2.832734
60.00	.585130	.641940	.703992	.772023	.846804	1.010851	1.141904	1.321118	2.208583
50.00	.481347	.526024	.574064	.626066	.683683	.748959	.913546	1.080104	1.419055
40.00	.448285	.453338	.451162	.480793	.515724	.539853	.591363	.827733	1.062451
30.00	.435156	.436432	.432954	.420929	.384346	.362097	.381464	.427686	.754075
20.00	.424749	.423508	.416431	.401472	.365341	.330117	.269820	.203071	.251146
10.00	.418483	.416601	.408721	.392685	.353464	.315500	.269236	.220799	.166939
.00	.383468	.377385	.365132	.344824	.303126	.261321	.211207	.157361	.105733
-10.00	.292492	.273326	.246593	.210869	.159542	.105825	.051661	.021203	.002275
-20.00	.207180	.176707	.138051	.090643	.048322	.016322	.165609	.539415	.007677

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	2.277956	2.443372	2.207652	1.968591	1.729608	1.493948	1.264542	1.043898	.834366
180.00	2.397167	2.587957	2.323422	2.055116	1.787310	1.524015	1.268813	1.024829	.794608
170.00	2.527712	2.749530	2.450901	2.147902	1.846122	1.550493	1.265426	.994861	.769218
160.00	2.672992	2.933516	2.593692	2.249133	1.906514	1.572536	1.252183	.950846	.794262
150.00	2.834061	3.143243	2.753217	2.357932	1.966337	1.586568	1.225357	.900772	.825806
140.00	3.014986	3.386605	2.934243	2.476148	2.024133	1.588859	1.179376	.913216	.860183
130.00	3.216894	3.669590	3.139112	2.602521	2.075820	1.573220	1.105785	.956714	.898157
120.00	3.441535	4.001420	3.369303	2.732254	2.115532	1.530689	1.076593	1.003624	.939970
110.00	3.682908	4.382370	3.619835	2.854147	2.121549	1.437962	1.138203	1.055661	.984647
100.00	3.944575	4.833965	3.901471	2.967979	2.079447	1.326708	1.184012	1.105480	1.031727
90.00	4.238219	5.401286	4.231628	3.068095	1.978955	1.359204	1.250487	1.152921	1.067722
80.00	4.547877	6.115063	4.606899	3.122836	1.768957	1.459049	1.328982	1.210057	1.104469
70.00	4.831633	7.014118	5.017674	3.085256	1.757011	1.578395	1.413924	1.268212	1.109375
60.00	5.039189	8.194150	5.446136	2.859057	1.944157	1.708555	1.501276	1.269848	1.031841
50.00	5.036280	9.822060	5.824366	2.606087	2.156241	1.842127	1.488406	1.129595	.900220
40.00	4.398587	12.252350	5.940111	2.914804	2.381149	1.790908	1.219995	.887612	.696962
30.00	2.163015	.000305	1.236609	1.604103	2.227657	1.243222	.755251	.620023	.653762
20.00	.391404	.000466	.000168	.030706	.903163	.687474	.709382	.937521	1.109186
10.00	.000770	.000212	.001068	.670649	1.048137	1.345416	1.510961	1.593307	1.671337
.00	.000172	.000018	.000290	1.272013	1.544162	1.702706	1.780133	1.801134	1.844003
-10.00	.002017	.002822	.202214	.320476	.565019	.780483	1.002190	1.154784	1.286605
-20.00	.013557	.026502	.490767	.271745	.296861	.404241	.496856	.642007	.774705

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	.683746	.655306	.630528	.607161
180.00	.705799	.675252	.648839	.623245
170.00	.729179	.697219	.667996	.639881
160.00	.754542	.720568	.688080	.657044
150.00	.783120	.745327	.709102	.674740
140.00	.814639	.771610	.730931	.692834
130.00	.847679	.799628	.753409	.711137
120.00	.882144	.827693	.777020	.729154
110.00	.917954	.856218	.799397	.741855
100.00	.954756	.884393	.812003	.739074
90.00	.990778	.897658	.802347	.728452
80.00	.995857	.875833	.780407	.708148
70.00	.944282	.830234	.742995	.674893
60.00	.869848	.758822	.683074	.625730
50.00	.754627	.661355	.600071	.596148
40.00	.598160	.627236	.672544	.739627
30.00	.773469	.873812	.934084	.966002
20.00	1.185242	1.219140	1.224944	1.212520
10.00	1.641400	1.592988	1.534444	1.471329
.00	1.775496	1.698348	1.618179	1.538657
-10.00	1.312974	1.310662	1.290192	1.258751
-20.00	.877298	.939111	.972013	.984821

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	12.252350	AT (	.00,	40.00)	GC	6.	5.940111	AT (	10.00,	40.00)	GC
2.	9.822060	AT (	.00,	50.00)	GC	7.	5.824366	AT (	10.00,	50.00)	GC
3.	8.194150	AT (	.00,	60.00)	GC	8.	5.446136	AT (	10.00,	60.00)	GC
4.	7.014118	AT (	.00,	70.00)	GC	9.	5.401286	AT (	.00,	90.00)	GC
5.	6.115063	AT (	.00,	80.00)	GC	10.	5.039189	AT (	-10.00,	60.00)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

ATTACHMENT B

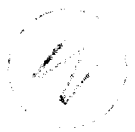
TOPOGRAPHIC MAPS

The information contained in this box is oversized or unacceptable quality and cannot be accurately digitized. To view the original please contact the DOE Carlsbad Field Office Chief Information Officer at 234-7200.

INSERT WIPP AND CARLSBAD AIRPORT TOPO MAPS HERE

ATTACHMENT C

QUALITY ASSURANCE



QUALITY ASSURANCE SUMMARY

Quality Assurance (QA) for the model runs consists of: 1) a summary of QA tests performed by the Environmental Protection Agency (EPA) on the Industrial Source Complex (ISC)2 model and 2) an independent review of the Department of Energy's (DOE's) model runs by Trinity Consultants, Inc. Both reports are attached.

The EPA QA test summary serves as the validation of the ISC2 model. For model verification, Trinity Consultants Inc. reviewed the model input and ran the input files to ensure that the data were derived and input correctly, the copy of the model code used was unchanged, and the hardware used to run the code did not influence the results of the model runs. Upon incorporation of Trinity's comments, the results of their model runs were exactly the same as those contained in this attachment.

SUMMARY OF THE QUALITY ASSURANCE AND EQUIVALENCE TESTS PERFORMED ON THE ISC2 MODELS

(From the EPA Support Center for Regulatory Air Models [SCRAM] Bulletin Board System [BBS] on April 24, 1995)

MARCH 1992

1 INTRODUCTION

This report presents a summary of the quality assurance and testing procedures that were used during the development of the ISC2 models, and summarizes the results of the ISC2 testing. A brief overview of the QA/Test Plan is presented in Section 2, followed in Section 3 by a summary of the tests performed at various stages in the software development cycle, and concluding with a discussion of the results of equivalence tests using standard EPA test data sets.

2 OVERVIEW OF QA/TEST PLAN

The ISC2 reprogramming effort included the preparation of a detailed Quality Assurance (QA) and Test Plan for the software development process as one of the earliest steps. The QA/Test Plan included a discussion of the goals of the reprogramming effort, established standard operating procedures for programming that addressed coding style, language standards, and documentation practices, and outlined a detailed test plan. The test plan stressed the importance of testing the code at each phase of the development process, including independent review of the design of individual modules, testing individual modules with standard test data, testing of groups of modules during the module integration phase, extensive system level testing, and outside review and testing of beta (draft) versions of the ISC2 software.

3 SUMMARY OF ISC2 TESTING

3.1 Module Level Testing

Individual modules were designed using structured English diagrams, or pseudo-code, to document the overall flow and structure of the program. The actual code was developed from these pseudocode files as a natural extension to executable Fortran statements. In many cases, the pseudocode remained in the actual Fortran source code files as comments to clarify the processing steps. Important modules were tested by code walkthroughs and other independent review mechanisms.

Most individual modules, particularly the calculation modules, underwent testing with standard test data once the Fortran code was written and compiled. In the absence of functioning module interfaces and data input routines, the module testing made use of the Fortran NAMELIST extension for inputting and outputting list-directed data. In this way, the input and output

variables specific to a module could be conveniently read in and written out without the need for burdensome I/O statements.

The most intensive module level testing was performed for certain modules that are involved with the more complex model computations. These included the modules that calculate the vertical term of the concentration equation, the module that solves the cubic equation for Schulman-Scire plume rise and for urban virtual distances for stabilities A and B, and the module that calculates the error function term for the finite line segment area source algorithm in the Short Term model. Using the NAMELIST test driver, the input parameters for these modules were systematically varied over the full range of possible inputs, and the results were compared with the comparable algorithms from the original ISC model. The tests of the CUBIC module were particularly intensive since the new model uses Newton's method to solve the cubic equation, which is a different method from that used in the original ISC models. This method was chosen for its efficiency, accuracy and stability over the full range of inputs, and for the better clarity of the code involved. One result of these detailed tests of the CUBIC module was the adjustment of the convergence criterion to obtain more accurate results for cases with very small plume rise. The development and testing of the error function module included an examination and comparison of several methods extracted from different models. The method used in the original ISCST model was retained, although restructured, because it appeared to be the most efficient, and gave comparable results to the other methods.

3.2 Module Integration Testing

Additional testing was performed during the module integration phase of the software development. The NAMELIST test driver approach was also used during this phase, particularly for the calculation modules. The setup processing modules were integrated and tested for each of the functional pathways using live input runstream data. This included testing of the data entry and extraction, as well as the error handling capabilities of the setup modules.

Module integration testing for the calculation modules was performed in stages, from the initial integration of the dispersion parameter modules to the full testing of the Schulman-Scire plume rise algorithms. In order to perform the latter testing, essentially all of the plume rise and dispersion parameter modules had to be integrated. The integration testing served to check the module interfaces and the flow of data.

Another important area of module integration testing involved the averaging and sorting routines of the model. In order to test these routines independent of the calculation modules, a binary concentration file of hourly results was generated by the original ISCST model to provide the raw concentration values for input to the new ISCST2 modules. In this way, all of the "bookkeeping" routines of the new model could be tested by direct comparison to the original model. As part of this testing, it was discovered that the original ISCST model contains an inconsistency between the high value by receptor and the overall maximum value summaries in the treatment of cases

with the same concentration (or deposition) value. The high value by receptor routines retain the earlier occurrence of the value, while the overall maximum 50 value routines keep the most recent occurrence. The sorting routines in the ISCST2 model consistently retain the earlier occurrence in these situations.

3.3 System Level Testing

Once all of the modules were integrated and the model input processing routines were fully functional, system level testing could be performed. System testing involved a broad range of activities. These included re-testing conditions tested under the previous stages of development, testing cases with predetermined results, systematically varying inputs to test transition points in the algorithms (especially important for the building downwash algorithms), testing normal and extreme ranges of input parameters, and testing realtime applications. An important part of this testing involved comparisons of results between the ISC2 models and the original ISC models. It was out of the need to make side-by-side comparisons for the same input data that the file conversion utility, STOLDNEW, was developed in stages.

The most intensive system level testing involved exercising the regulatory default options, since these are the most important to the user community. The building downwash algorithms were also tested intensively due to their complexity and in light of the numerous bugs associated with those algorithms in the earlier versions of ISC. The non-regulatory default options, including gradual plume rise, no BID, no stack tip downwash, and no calms processing, were also tested thoroughly. Tests were performed for both concentration calculations and deposition calculations. In addition to several realtime meteorological data sets, smaller test data sets of meteorological data were developed with variables covering a full range of possible inputs.

During the various phases of testing the models, several discrepancies were discovered between the ISC2 models and the earlier versions of ISC. Many of these discrepancies involved the building downwash algorithms, and especially the calculation of gradual momentum plume rise. Each discrepancy identified was carefully evaluated, and a resolution was reached for incorporation into the ISC2 models. An effort was also made to incorporate fixes for these discrepancies into the original ISC models, primarily for testing of the ISC2 corrections and to verify the cause and resolution of the discrepancy. The ISCST fixes are considered to be fairly complete, although they are in draft form and have not been released. Due to some fundamental flaws in the design of the ISCLT model's treatment of the direction-specific building downwash algorithms, it was not possible to complete the fixes for that model without major rewriting of the original code. Due to the number of discrepancies and the sometimes obscure nature of the causes, it is not practical to list all of them here. A brief description of some of the main problem areas was included with the original READ-ME.TXT file included with the first draft of ISC2 placed on the SCRAM BBS in September 1991. Overall, the discrepancies are not likely to effect design values significantly for most routine applications of the models for buoyant point sources or for volume sources. All values for area sources modeled with the ISCST2 model will be about 11.4 percent lower than corresponding values generated by the original

ISCST model. The most significant differences are likely to be for point sources dominated by momentum plume rise with no downwash and with Huber-Snyder downwash.

An important phase of the system testing involved automated point-by-point comparisons of the ISCST2 results with the original ISCST results for a large number of sources where the input parameters were varied systematically across a broad range of expected values. The results were compared on a point-by-point and hour-by-hour basis by a program that was developed to read the binary concentration files generated by each of the models. One of the ISC2 beta reviewers, Mark Garrison of United Engineers and Constructors, provided input data sets for this purpose that were developed during a performance evaluation of another dispersion model. Results from some of these comparisons are presented below in Section 4 of this report.

3.4 Beta Review and Testing

In addition to the system testing performed by the developers of the ISC2 code, draft versions of the models were sent to selected individuals and organizations for independent testing and beta review. The beta reviewers included EPA Regional and State modelers, as well as modelers from other Federal agencies, private industry and consulting firms. Additional system testing was being performed concurrent with the beta review. The beta reviewers were given draft versions of the models including source code, draft versions of the user's guide, and a list of specific issues for which feedback was solicited. Comments and suggestions from the beta reviewers were evaluated and incorporated into the final versions of the models where appropriate and practical.

3.5 Final Acceptance Testing

The final phase of testing for the ISC2 models is referred to as final acceptance testing. This involved review of the complete ISC2 package by EPA, and included the release of draft versions of the ISC2 models and draft user's guide to the modeling community by placing them on the SCRAM BBS. The first drafts were placed on SCRAM in September 1991, followed about two months later by revised drafts of the Short Term models, and by revised drafts of all models in early February 1992. Comments were received from several users through a special public message area in the Model Conference section of SCRAM. This final acceptance testing resulted in several bugs being identified and corrected. Additional system testing was performed concurrent with final acceptance testing. This was focused primarily on testing the lesser used options of the model and on challenging the error handling and reporting capabilities of the models. Also performed as part of the final acceptance testing were standard equivalence tests used by EPA in evaluating past changes to the models. These equivalence tests, which focus on a comparison of design values for a small number of representative sources, are summarized in the next section.

4 ISC2 EQUIVALENCE TESTS

This section describes tests that were performed on the ISC2 models to document their equivalence to the original ISC models. Two types of tests are summarized here. The first involves comparisons of predicted design values based on standard test data sets used by EPA in evaluating past changes to the models. This type of comparison is presented below for both the ISCST2 and ISCLT2 models. Another type of test for the ISCST2 model involves automated comparisons of results on a point-by-point and hour-by-hour basis using the binary concentration files generated by both models.

4.1 ISCST2 vs. ISCST Design Value Comparisons

The results of the equivalence tests involving comparisons of design values showed the ISCST2 results to be nearly identical to the ISCST (Version 90346) design values. The tests included six point sources with flat terrain, two point sources with elevated terrain, an elevated volume source, and an elevated area source. The sources were modeled using a 180 receptor polar network with one year of Pittsburgh (1964) meteorological data and one year of Oklahoma City (1984) meteorological data. All cases were modeled with both rural dispersion coefficients and with urban dispersion coefficients. The point source characteristics were as follows:

Stack Height (m)	Stack Temp. (K)	Exit Vel. (m/s)	Stack Diam. (m)	Bldg. Height (m)	Bldg. Width (m)	Elev. Terrain
35	432	11.7	2.4	NA	NA	No
35	432	11.7	2.4	34	60	No
35	432	11.7	2.4	34	30	No
35	432	11.7	2.4	34	180	No
100	416	18.8	4.6	NA	NA	No
200	425	26.5	5.6	NA	NA	No
35	432	11.7	2.4	NA	NA	Yes
200	425	26.5	5.6	NA	NA	Yes

The volume source had a release height of 35 meters, an initial lateral dimension of 14 meters and an initial vertical dimension of 16 meters. The area source had a release height of 35 meters and a width of 1000 meters. Receptor distances (in meters) for the six point sources with no terrain and for the volume and area sources were 125, 250, 400, 800, and 2000. The receptor distances for the cases with elevated terrain were 800, 2000, 4000, 7000, and 15000.

The design values examined included the highest and high-second-high 1-hour, 3-hour and 24-hour averages, and the highest annual averages. A total of 280 design values were compared. With the exception of the 24-hour Oklahoma City averages for the three building downwash sources for rural dispersion, all of the design values agreed to within a few hundredths or a few thousandths of a percent difference. The 24-hour Oklahoma City rural downwash values differed by a few tenths of percent, with the difference attributed to an error in the treatment of enhanced lateral dispersion for cases with the wake plume height less than 1.2 building heights by the original ISCST model. This difference

was resolved with the "fixed" version of the ISCST model.

4.2 ISCLT2 vs. ISCLT Design Value Comparisons

The same six point sources without elevated terrain used for the Short Term equivalence tests were also used in the Long Term model equivalence tests. The 200-meter release with elevated terrain was also examined, along with a volume source (10-meter release height and 10-meter initial lateral and vertical dispersion), and an area source (10-meter release height and 100-meter width). All sources were modeled with an annual STAR summary for the 1964 Pittsburgh data. The results of the equivalence tests for the Long Term model also showed only insignificant differences (less than 0.1 percent) between the highest annual averages from ISCLT2 and ISCLT (Version 90008) for the point sources, but showed larger differences for the area and volume sources examined. The highest annual average for the volume source for ISCLT2 was about 1.4 percent larger than the ISCLT high annual value, and the highest annual average for the area source for ISCLT2 was about 5 percent lower than the ISCLT high annual value. These differences are attributed, at least in part, to an error in the original ISCLT model in the treatment of lateral virtual distances. The differences were largest at the closer receptor distances, especially for the area source.

4.3 ISCST2 vs. ISCST Binary File Comparisons

A more intensive and complete testing of the ISCST2 model involved automated comparisons of hourly results using the binary concentration output file options of both the ISCST2 and ISCST models for a large number of source scenarios. A total of 365 different sources were included in these tests, which were broken down as follows:

100 point sources with no downwash
100 point sources with Huber-Snyder downwash
100 point sources with Schulman-Scire downwash
48 volume sources
17 area sources

The stack parameters for the point sources included a range of inputs for the release height, exit temperature, exit velocity and stack diameter covering a broad spectrum of source scenarios. These included momentum dominated plumes with no buoyancy as well as highly buoyant plumes. The volume and area source scenarios also covered a broad range of inputs, with five of the area sources including variable emission rate factors.

Receptors were located at various distances ranging from very near the source out to 100,000 meters downwind, with locations along the plume centerline and at about 10 degrees off-centerline. At each distance, receptors were placed at ground level and at two terrain elevations for the point sources. A total of 60 receptors were used for the point sources with no downwash, 54 receptors were used for the points sources with downwash, and 88 receptors were used for the volume and area sources.

The input meteorological data included 144 hours for the point sources and 24 hours for the volume and area sources. The larger number of hours for the point sources were to account for the dependence of plume rise on input meteorological conditions. The meteorological data for point sources included wind speeds at 0.5 m/s increments for the valid range of speeds for each stability category for two different mixing heights. The meteorological data for the volume and area sources also included each stability class with a smaller range of wind speeds and with two different mixing heights. Altogether, over 5 million data points were compared between the ISCST2 and ISCST models.

The results of these comparisons are presented in the following tables. The tables present the number of occurrences for various categories of the percent difference, stratified by the absolute value of the original ISCST result. Totals are given for each column, as well as for the total number of comparisons for each case and the total number of cases where both models indicated a value of 0.0. The percent differences were calculated as follows: [(New-Old)/Old]*100. Thus, a negative percent difference indicates that the ISCST2 value was less than the original or "fixed" ISCST value. Also, values in a particular column are for cases that were less than or equal to the percent difference given above the column and greater than the percent difference for the column to the left. Thus, cases under the column labeled ".20" are for cases where the percent difference was less than or equal to 0.20 percent but greater than -0.20 percent. For the ISCST2 vs. Original ISCST cases, about 92.8 percent of the cases fell into this category, while for the ISCST2 vs. "Fixed" ISCST cases, about 99.5 percent fell into this category. About 95.5 percent of the ISCST2 vs. Original ISCST occurrences fell with the range of plus or minus 2.0 percent, while about 99.5 percent of the ISCST2 vs. "Fixed" ISCST occurrences fell within this range. Most of the remaining occurrences for the ISCST2 vs. "Fixed" ISCST cases were for instances where the ISCST2 model predicted a value of 0.0 and the ISCST model predicted a very small value (less than or equal to 1.0E-6). These values are included in the upper left hand "cell" of the tables, and are indicative of slight differences in the lateral "truncation" of the plume between the two models due to rounding errors.

The results are presented in the following order:

100 Point Sources; No Downwash; Rural Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; No Downwash; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
100 Point Sources; No Downwash; Urban Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; No Downwash; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

100 Point Sources; H-S Downwash; Rural Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; H-S Downwash; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
100 Point Sources; H-S Downwash; Urban Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; H-S Downwash; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

100 Point Sources; S-S Downwash; Rural Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; S-S Downwash; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
100 Point Sources; S-S Downwash; Urban Dispersion; ISCST2 vs. Original ISCST

100 Point Sources; S-S Downwash; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

48 Volume Sources; Rural Dispersion; ISCST2 vs. Original ISCST
48 Volume Sources; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
48 Volume Sources; Urban Dispersion; ISCST2 vs. Original ISCST
48 Volume Sources; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

17 Area Sources; Rural Dispersion; ISCST2 vs. Original ISCST
17 Area Sources; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
17 Area Sources; Urban Dispersion; ISCST2 vs. Original ISCST
17 Area Sources; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

Most of the largest differences in the ISCST2 vs. Original ISCST tables are associated with point sources with plume rise dominated by momentum. The consistent differences between the area source results of about -11.4 percent are due to an error in the derivation of the equation for the finite line segment algorithm for modeling area sources in ISCST. The vast majority of occurrences for the ISCST2 vs. "Fixed" ISCST cases fall within the range of plus or minus 0.2 percent, or fall into the category of a zero ISCST2 value and a very small ISCST value. A few occurrences for the rural downwash scenarios fall outside the +/- 0.2 percent range, but most of those are still within +/- 2.0 percent. These are primarily attributable to an error in the original ISCST model that was not practical to fix. The original ISCST model occasionally uses an incorrect set of coefficients for the calculation of vertical virtual distance in the rural mode. This calculation is performed by an iterative process in both models, where an estimate of virtual distance is made based on the coefficients corresponding to the source-receptor distance, and then the value of X+Xz is checked to see if it falls within the same distance range for coefficients. The original ISCST model occasionally selects coefficients for the distance range beyond the correct range, but does not allow for stepping back to the previous distance range.

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100 POINT SOURCES; NO DOWNWASH; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	6028	474	378	316	516	233567	2774	852	796	310
.1000E-04	0	108	44	26	64	7677	623	64	70	74
.1000E-03	0	62	60	52	92	8034	691	60	110	94
.1000E-02	6	46	60	6	20	26065	930	40	108	148
.1000E-01	6	64	62	54	140	67649	1020	16	92	180
.1000	0	90	72	40	60	87815	990	0	114	206
1.000	0	46	74	68	168	132611	1472	120	218	229
10.00	0	30	72	50	168	118777	3632	348	602	123
100.0	0	38	84	36	206	66300	6836	2503	2024	498
1000.	0	42	18	68	238	25861	2805	1770	7594	4932
.1000E+05	0	42	96	36	58	4492	676	558	1722	5194
.1000E+06	0	46	20	2	12	882	650	100	302	702
.1000E+07	0	8	2	2	2	34	14	6	6	118
	0	0	0	0	0	0	0	0	0	0
TOTAL=	6040	1096	1042	756	1744	779764	23113	6437	13758	12808

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 201756

100 POINT SOURCES; NO DOWNWASH; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

	DELTA PERCENT (≤)						
RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00
.1000E-05	6494	0	0	0	0	243653	0
0	0	0	0				
.1000E-04	0	0	0	0	0	9258	0
0	0	0	0				
.1000E-03	0	0	0	0	0	9810	0
0	0	0	0				
.1000E-02	0	0	0	0	0	27865	0
0	0	0	0				
.1000E-01	0	0	0	0	0	69575	0
0	0	0	0				
.1000	0	0	0	0	0	89513	0
0	0	0	0				
1.000	0	0	0	0	0	135054	0
0	0	0	0				
10.00	0	0	0	0	0	123793	0
0	0	0	0				
100.0	0	0	0	0	0	78293	0
0	0	0	0				
1000.	0	0	0	0	0	42752	0
0	0	0	0				
.1000E+05	0	0	0	0	0	15694	0
0	0	0	0				
.1000E+06	0	0	0	0	0	10352	0
0	0	0	0				
.1000E+07	0	0	0	0	0	1894	0
0	0	0	0				
	0	0	0	0	0	0	0
0	0	0	0				
TOTAL=	6494	0	0	0	0	857506	0
0	0	0	0				

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 201292

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100 POINT SOURCES; NO DOWNWASH; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
RANGE (_=):										
.1000E-05	3862	410	296	102	274	183306	1719	279	690	626	4821
.1000E-04	0	44	74	20	20	11367	322	26	104	248	468
.1000E-03	0	42	34	16	4	21828	393	79	133	361	479
.1000E-02	0	60	30	14	80	19677	482	76	123	478	476
.1000E-01	0	50	86	26	106	49418	369	146	138	636	240
.1000	0	64	24	16	88	80097	581	148	278	637	164
1.000	0	86	92	54	86	144069	498	184	379	625	24
10.00	0	34	126	36	112	168582	952	288	668	313	8
100.0	0	54	82	56	132	86456	7436	1503	1004	146	628
1000.	0	32	58	52	132	29078	3530	2404	8544	162	1400
.1000E+05	0	44	30	6	26	3132	1258	254	1676	2500	4826
.1000E+06	0	16	0	6	4	868	248	60	386	614	590
.1000E+07	0	0	0	0	0	20	0	0	4	72	0
	0	0	0	0	0	0	0	0	0	0	0
TOTAL=	3862	936	932	404	1064	797898	17788	5447	14127	7418	14124

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 151488

100 POINT SOURCES; NO DOWNWASH; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (≤)

RANGE (≤)	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	4496	0	0	0	0	191113	0	0	0	0
.1000E-04	0	0	0	0	0	12785	0	0	0	0
.1000E-03	0	0	0	0	0	23513	0	0	0	0
.1000E-02	0	0	0	0	0	21647	0	0	0	0
.1000E-01	0	0	0	0	0	51403	0	0	0	0
.1000	0	0	0	0	0	82198	0	0	0	0
1.000	0	0	0	0	0	146157	0	0	0	0
10.00	0	0	0	0	0	171127	0	0	0	0
100.0	0	0	0	0	0	96815	0	0	0	0
1000.	0	0	0	0	0	43878	0	0	0	0
.1000E+05	0	0	0	0	0	11262	0	0	0	0
.1000E+06	0	0	0	0	0	6994	0	0	0	0
.1000E+07	0	0	0	0	0	612	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	4496	0	0	0	0	859504	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 150854

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100 POINT SOURCES; H-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	3002	280	166	24	190	147590	2243	234	102	269	4381
.1000E-04	0	26	14	0	2	6164	466	14	2	69	270
.1000E-03	0	14	26	22	16	5402	511	18	6	94	269
.1000E-02	0	38	28	14	48	22184	557	16	2	76	180
.1000E-01	0	6	42	16	80	64306	683	8	2	99	44
.1000	0	40	84	26	308	84357	644	10	0	159	6
1.000	0	28	76	100	476	128681	794	128	44	140	14
10.00	0	34	134	394	790	127305	3262	196	316	10	0
100.0	0	10	320	712	1280	95183	7968	1988	1506	106	86
1000.	0	2	442	780	452	33054	3330	2942	7956	1418	314
.1000E+05	0	0	104	50	16	3110	444	320	2776	1496	448
.1000E+06	0	0	0	0	0	22	18	6	30	24	16
.1000E+07	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
TOTAL=	3002	478	1436	2138	3658	717358	20920	5880	12742	3960	6028

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 127209

100 POINT SOURCES; H-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

	DELTA PERCENT (≤)						
	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00
2.00	10.00	100.00					
RANGE (≤):							
.1000E-05	3800	6	0	0	8	154078	0
0	0	0	0				
.1000E-04	0	0	4	0	0	7259	0
0	0	0	0				
.1000E-03	0	0	0	0	2	6477	0
0	0	0	0				
.1000E-02	0	0	0	0	0	23261	0
0	0	0	0				
.1000E-01	0	0	2	0	2	65381	0
0	0	0	0				
.1000	0	0	2	0	2	85649	0
0	0	0	0				
1.000	0	0	0	0	2	130441	52
0	0	0	0				
10.00	0	0	0	0	0	132365	48
0	0	0	0				
100.0	0	0	0	0	0	108985	6
0	0	0	0				
1000.	0	0	0	0	2	50118	0
0	0	0	0				
.1000E+05	0	0	0	0	0	9340	2
0	0	0	0				
.1000E+06	0	0	0	0	0	304	2
0	0	0	0				
.1000E+07	0	0	0	0	0	0	0
0	0	0	0				
	0	0	0	0	0	0	0
0	0	0	0				
TOTAL=	3800	6	8	0	18	773658	110
0	0	0	0				

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 126411

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100 POINT SOURCES; H-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	2219	128	38	42	186	122110	1563	0	33	359	4958
.1000E-04	0	12	4	4	26	10159	192	0	12	264	456
.1000E-03	0	4	44	12	22	20234	198	4	30	387	442
.1000E-02	0	60	0	4	2	17404	324	13	66	494	305
.1000E-01	0	12	0	12	50	46857	162	14	178	660	138
.1000	0	0	78	18	10	77437	324	30	321	561	74
1.000	0	64	82	0	0	139038	216	118	479	417	0
10.00	0	0	6	98	292	167999	526	223	528	180	0
100.0	0	6	240	330	1450	100766	7258	1536	868	6	0
1000.	0	0	516	838	542	26750	2834	2742	6078	736	0
.1000E+05	0	0	48	8	12	1430	212	132	1628	614	0
.1000E+06	0	0	0	0	0	0	4	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
TOTAL=	2219	286	1056	1366	2592	730184	13813	4812	10221	4678	6373

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 98178

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100 POINT SOURCES; H-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. 'Fixed' ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	3008	0	0	0	0	127885	0	0	0	0
.1000E-04	0	0	0	0	0	11262	0	0	0	0
.1000E-03	0	0	0	0	0	21466	0	0	0	0
.1000E-02	0	0	0	0	0	18915	0	0	0	0
.1000E-01	0	0	0	0	0	48140	0	0	0	0
.1000	0	0	0	0	0	79009	0	0	0	0
1.000	0	0	0	0	0	140435	12	0	0	0
10.00	0	0	0	0	0	169870	12	0	0	0
100.0	0	0	0	0	0	112432	0	0	0	0
1000.	0	0	0	0	0	40932	0	0	0	0
.1000E+05	0	0	0	0	0	4210	0	0	0	0
.1000E+06	0	0	0	0	0	12	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	3008	0	0	0	0	774568	24	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 97389

---

100 POINT SOURCES; S-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1218	0	0	0	0	149165	1265	744	124	58
.1000E-04	0	0	0	0	0	4206	447	56	0	38
.1000E-03	0	0	0	0	0	4092	574	70	6	46
.1000E-02	0	0	0	0	0	19946	676	44	8	32
.1000E-01	0	0	0	0	0	60717	1067	36	0	18
.1000	0	0	0	0	0	78974	1151	26	14	40
1.000	0	0	154	67	230	127990	1091	27	101	29
10.00	0	0	3060	401	1228	134599	2203	184	2403	587
100.0	0	12	2030	2337	998	96110	3964	180	6696	2220
1000.	0	0	308	332	380	46414	2198	78	1830	1928
.1000E+05	0	0	0	4	340	7322	80	12	262	726
.1000E+06	0	0	0	0	0	86	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	1218	12	5552	3141	3176	729621	14716	1457	11444	5722

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 138501

100 POINT SOURCES; S-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1384	0	0	0	0	152107	0	0	0	0
.1000E-04	0	0	0	0	0	4919	0	0	0	0
.1000E-03	0	0	0	0	0	4988	0	0	0	0
.1000E-02	0	0	0	0	0	20838	0	0	0	0
.1000E-01	0	0	0	0	0	61921	0	0	0	0
.1000	0	0	0	0	0	80236	0	0	0	0
1.000	0	0	0	0	0	129692	0	0	0	0
10.00	0	0	0	0	8	144434	0	0	0	0
100.0	0	0	0	56	20	114409	0	0	0	0
1000.	0	0	0	52	28	53572	0	0	0	0
.1000E+05	0	0	0	4	0	8826	0	0	0	0
.1000E+06	0	0	0	0	0	106	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	1384	0	0	112	56	776048	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 138335

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100 POINT SOURCES; S-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	553	16	0	0	0	143059	407	154	8	26
.1000E-04	0	0	0	0	0	8345	126	6	2	39
.1000E-03	0	0	0	0	0	19223	136	6	16	71
.1000E-02	0	0	0	0	0	15470	288	4	18	100
.1000E-01	0	0	8	0	0	44251	354	12	14	136
.1000	0	0	12	0	0	73521	416	0	6	138
1.000	0	0	88	76	152	135705	530	10	31	99
10.00	0	4	58	71	350	168349	399	14	68	12
100.0	0	0	30	46	169	113895	474	20	8	0
1000.	0	0	4	10	18	42998	148	4	0	0
.1000E+05	0	0	0	0	0	4806	20	0	0	0
.1000E+06	0	0	0	0	0	8	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	553	20	200	203	689	769630	3298	230	171	621

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 125921

100 POINT SOURCES; S-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	766	0	0	0	0	144598	0	0	0	0
.1000E-04	0	0	0	0	0	8697	0	0	0	0
.1000E-03	0	0	0	0	0	19708	0	0	0	0
.1000E-02	0	0	0	0	0	16062	0	0	0	0
.1000E-01	0	0	0	0	0	44936	0	0	0	0
.1000	0	0	0	0	0	74141	0	0	0	0
1.000	0	0	0	0	0	136707	0	0	0	0
10.00	0	0	0	0	0	169324	0	0	0	0
100.0	0	0	0	0	0	114643	0	0	0	0
1000.	0	0	0	0	0	43180	0	0	0	0
.1000E+05	0	0	0	0	0	4830	0	0	0	0
.1000E+06	0	0	0	0	0	8	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	766	0	0	0	0	776834	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 125708

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48 VOLUME SOURCES; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	370	0	0	0	0	43068	144	15	32	0
.1000E-04	0	0	0	0	0	396	42	8	24	0
.1000E-03	0	0	0	0	0	645	46	20	0	0
.1000E-02	0	0	0	0	0	974	41	41	0	0
.1000E-01	0	0	0	0	0	679	76	50	0	0
.1000	0	0	0	0	0	1067	148	4	0	0
1.000	0	0	0	0	0	5668	222	4	0	0
10.00	0	0	0	0	0	12965	471	24	0	0
100.0	0	0	0	0	0	22272	720	16	0	0
1000.	0	0	0	0	0	9884	313	0	0	0
.1000E+05	0	0	0	0	0	923	4	0	0	0
.1000E+06	0	0	0	0	0	0	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	370	0	0	0	0	98541	2227	182	56	0

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 41424

48 VOLUME SOURCES; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

	DELTA PERCENT (≤)						
	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00
2.00	10.00	100.00					
RANGE (≤):							
.1000E-05	370	0	0	0	0	43255	0
0	0	0	0				
.1000E-04	0	0	0	0	0	474	0
0	0	0	0				
.1000E-03	0	0	0	0	0	711	0
0	0	0	0				
.1000E-02	0	0	0	0	0	1056	0
0	0	0	0				
.1000E-01	0	0	0	0	0	805	0
0	0	0	0				
.1000	0	0	0	0	0	1219	0
0	0	0	0				
1.000	0	0	0	0	0	5894	0
0	0	0	0				
10.00	0	0	0	0	0	13458	0
0	0	0	0				
100.0	0	0	0	0	0	23008	0
0	0	0	0				
1000.	0	0	0	0	0	10199	0
0	0	0	0				
.1000E+05	0	0	0	0	0	927	0
0	0	0	0				
.1000E+06	0	0	0	0	0	0	0
0	0	0	0				
.1000E+07	0	0	0	0	0	0	0
0	0	0	0				
	0	0	0	0	0	0	0
0	0	0	0				
TOTAL=	370	0	0	0	0	101006	0
0	0	0	0				

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 41424

---

48 VOLUME SOURCES; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

	DELTA PERCENT (≤)						
	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00
2.00	10.00	100.00					
RANGE (≤):							
.1000E-05	192	0	0	0	0	41301	0
0	0	0	0				
.1000E-04	0	0	0	0	0	271	0
0	0	0	0				
.1000E-03	0	0	0	0	0	326	2
0	0	0	0				
.1000E-02	0	0	0	0	0	365	6
0	0	0	0				
.1000E-01	0	0	0	0	0	669	4
0	0	0	0				
.1000	0	0	0	0	0	1133	48
0	0	0	0				
1.000	0	0	0	0	0	9688	92
0	0	0	0				
10.00	0	0	0	0	0	19147	158
0	0	0	0				
100.0	0	0	0	0	0	19150	229
0	0	0	0				
1000.	0	0	0	0	0	8075	129
0	0	0	0				
.1000E+05	0	0	0	0	0	387	4
0	0	0	0				
.1000E+06	0	0	0	0	0	0	0
0	0	0	0				
.1000E+07	0	0	0	0	0	0	0
0	0	0	0				
	0	0	0	0	0	0	0
0	0	0	0				
TOTAL=	192	0	0	0	0	100512	672
0	0	0	0				

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 39808

48 VOLUME SOURCES; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

	DELTA PERCENT (≤)						
	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00
2.00	10.00	100.00					
RANGE (≤):							
.1000E-05	192	0	0	0	0	41301	0
0	0	0	0				
.1000E-04	0	0	0	0	0	271	0
0	0	0	0				
.1000E-03	0	0	0	0	0	328	0
0	0	0	0				
.1000E-02	0	0	0	0	0	371	0
0	0	0	0				
.1000E-01	0	0	0	0	0	673	0
0	0	0	0				
.1000	0	0	0	0	0	1181	0
0	0	0	0				
1.000	0	0	0	0	0	9778	0
0	0	0	0				
10.00	0	0	0	0	0	19307	0
0	0	0	0				
100.0	0	0	0	0	0	19378	0
0	0	0	0				
1000.	0	0	0	0	0	8205	0
0	0	0	0				
.1000E+05	0	0	0	0	0	391	0
0	0	0	0				
.1000E+06	0	0	0	0	0	0	0
0	0	0	0				
.1000E+07	0	0	0	0	0	0	0
0	0	0	0				
	0	0	0	0	0	0	0
0	0	0	0				
TOTAL=	192	0	0	0	0	101184	0
0	0	0	0				

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 39808

---

17 AREA SOURCES; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	2766	288	0	0	0	10514	0	0	0	0
.1000E-04	325	99	0	0	0	0	0	0	0	0
.1000E-03	239	287	2	0	0	0	0	0	0	0
.1000E-02	31	235	12	0	0	0	0	0	0	0
.1000E-01	0	399	8	0	0	0	0	0	0	0
.1000	0	461	2	0	0	0	0	0	0	0
1.000	0	594	0	0	0	0	0	0	0	0
10.00	0	1498	0	0	0	0	0	0	0	0
100.0	0	5169	0	0	0	0	0	0	0	0
1000.	0	7384	0	0	0	0	0	0	0	0
.1000E+05	0	4229	0	0	0	0	0	0	0	0
.1000E+06	0	1121	0	0	0	0	0	0	0	0
.1000E+07	0	241	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	3361	22005	24	0	0	10514	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 10514

17 AREA SOURCES; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

	DELTA PERCENT (≤)						
	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00
2.00	10.00	100.00					
RANGE (≤):							
.1000E-05	2776	0	0	0	0	10818	0
0	0	0	0				
.1000E-04	371	0	0	0	0	85	0
0	0	0	0				
.1000E-03	184	0	0	0	0	300	0
0	2	0	0				
.1000E-02	30	0	0	0	0	228	0
0	12	0	0				
.1000E-01	0	0	0	0	0	439	1
0	8	0	0				
.1000	0	0	0	0	0	433	4
0	2	0	0				
1.000	0	0	0	0	0	652	0
0	0	0	0				
10.00	0	0	0	0	0	1993	0
0	0	0	0				
100.0	0	0	0	0	0	4829	0
0	0	0	0				
1000.	0	0	0	0	0	7463	0
0	0	0	0				
.1000E+05	0	0	0	0	0	4033	0
0	0	0	0				
.1000E+06	0	0	0	0	0	1022	0
0	0	0	0				
.1000E+07	0	0	0	0	0	219	0
0	0	0	0				
	0	0	0	0	0	0	0
0	0	0	0				
TOTAL=	3361	0	0	0	0	32514	5
0	24	0	0				

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 10514

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17 AREA SOURCES; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (≤)

RANGE (≤):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1952	68	0	0	0	9188	0	0	0	0
.1000E-04	124	36	0	0	0	0	0	0	6	0
.1000E-03	49	94	0	0	0	0	0	0	4	0
.1000E-02	12	189	0	0	0	0	0	0	0	0
.1000E-01	0	509	0	0	0	0	0	0	0	0
.1000	0	749	0	0	0	0	0	0	0	0
1.000	0	938	0	0	0	0	0	0	0	0
10.00	0	3582	0	0	0	0	0	0	0	0
100.0	0	6004	0	0	0	0	0	0	0	0
1000.	0	7466	0	0	0	0	0	0	0	0
.1000E+05	0	4113	0	0	0	0	0	0	0	0
.1000E+06	0	729	0	0	0	0	0	0	0	0
.1000E+07	0	92	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	2137	24569	0	0	0	9188	0	0	10	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 9188

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17 AREA SOURCES; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (=)

RANGE (=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1960	0	0	0	0	9256	0	0	0	0
.1000E-04	124	0	0	0	0	36	0	0	6	0
.1000E-03	41	0	0	0	0	100	0	0	4	0
.1000E-02	12	0	0	0	0	201	6	0	0	0
.1000E-01	0	0	0	0	0	512	20	0	0	0
.1000	0	0	0	0	0	713	8	0	0	0
1.000	0	0	0	0	0	980	0	0	0	0
10.00	0	0	0	0	0	3623	0	0	0	0
100.0	0	0	0	0	0	6301	0	0	0	0
1000.	0	0	0	0	0	7414	0	0	0	0
.1000E+05	0	0	0	0	0	3821	0	0	0	0
.1000E+06	0	0	0	0	0	681	0	0	0	0
.1000E+07	0	0	0	0	0	85	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	2137	0	0	0	0	33723	34	0	10	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 9188

```
** This is a simple example problem for the ISC Long Term Model, ISCLT.
** This example makes use of the new area source algorithm, and corresponds
** to the same source and receptor inputs as used in the TESTST.INP file.
** To run the example type: ISCLT3EM TESTLT.INP outfil.nam
** The results for this test are in file TESTLT.OUT

CO STARTING
   TITLEONE  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW AREA SOURCE ALGORITHM
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  WINTER
   TERRHGTS  ELEV
   FLAGPOLE
   POLLUTID  OTH
   RUNORNOT  RUN
   ELEVUNIT  FEET
CO FINISHED

SO STARTING

**           SRCID  SRCTYP    XS       YS        ZS
**           -----  ------   -----    -----     -----
SO LOCATION     1    AREA     800.     400.     .0000
SO LOCATION     2    AREA      40.     360.     .0000
SO LOCATION     3    AREA     480.      20.     .0000
SO LOCATION     4    AREA     420.     260.     .0000
SO LOCATION     5    AREA     420.     180.     .0000
```

```
SO LOCATION     6    AREA     420.     100.     .0000
SO LOCATION     7    AREA     260.     340.     .0000
SO LOCATION     8    AREA      40.     100.     .0000
SO LOCATION     9    AREA      40.      20.     .0000
SO LOCATION    10    AREA     300.     360.     .0000

**           SRCID    QS       HS      XINIT    YINIT
**           -----    ----     ----    -----    -----
SO SRCPARAM     1     1.0      1.0      60.     100.
SO SRCPARAM     2     1.0      1.0      20.      20.
SO SRCPARAM     3     1.0      1.0      30.     300.
SO SRCPARAM     4     1.0      1.0      40.      40.
SO SRCPARAM     5     1.0      1.0      40.      40.
SO SRCPARAM     6     1.0      1.0      40.      40.
SO SRCPARAM     7     1.0      1.0     140.     200.
SO SRCPARAM     8     1.0      1.0     220.     100.
SO SRCPARAM     9     1.0      1.0     220.      70.
SO SRCPARAM    10    -1.0      1.0      80.      40.

SO EMISUNIT     1.000 (GRAMS/(SEC-M**2))          grams/cubic-meter

SO SRCGROUP ALL

SO FINISHED
```

```
RE STARTING
RE DISCCART     20.     60.  1.0     1.0
RE DISCCART    150.     95.  1.0     1.0
RE DISCCART    360.    100.  1.0     1.0
RE DISCCART    520.    120.  1.0     1.0
RE DISCCART    490.    240.  1.0     1.0
RE DISCCART    320.    240.  1.0     1.0
RE DISCCART    150.    260.  1.0     1.0
RE DISCCART     50.    330.  1.0     1.0
RE DISCCART     70.    390.  1.0     1.0
RE DISCCART    190.    350.  1.0     1.0
RE DISCCART    310.    370.  1.0     1.0
RE DISCCART    420.    380.  1.0     1.0
RE DISCCART     70.    460.  1.0     1.0
RE DISCCART    200.    460.  1.0     1.0
RE DISCCART    330.    470.  1.0     1.0
RE DISCCART     40.    560.  1.0     1.0
RE DISCCART    480.    660.  1.0     1.0
RE DISCCART    800.    700.  1.0     1.0
RE FINISHED


ME STARTING
   INPUTFIL  TEST.STA  FREE
   ANEMHGHT  10.
   SURFDATA  99999  1990  TESTDATA
```

```
UAIRDATA  99999  1990  TESTDATA

STARDATA  SEASON

**                  - AMBIENT AIR TEMPERATURE (DEGREES KELVIN) -

**

**                     STAB     STAB     STAB     STAB     STAB     STAB

**                     CAT 1    CAT 2    CAT 3    CAT 4    CAT 5    CAT 6

**                     -----    -----    -----    -----    -----    -----

   AVETEMPS  WINTER    283.0    283.0    283.0    283.0    283.0    283.0


**                          - MIXING LAYER HEIGHT (METERS) -

**                   S

**                   T    WS       WS       WS       WS       WS       WS

**              SEAS A    CAT 1    CAT 2    CAT 3    CAT 4    CAT 5    CAT 6

**              ---- B    -----    -----    -----    -----    -----    -----

   AVEMIXHT  WINTER 1 .225E+04 .225E+04 .225E+04 .225E+04 .225E+04 .225E+04

   AVEMIXHT  WINTER 2 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04

   AVEMIXHT  WINTER 3 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04

   AVEMIXHT  WINTER 4 .100E+04 .100E+04 .100E+04 .100E+04 .100E+04 .100E+04

   AVEMIXHT  WINTER 5 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05

   AVEMIXHT  WINTER 6 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05
```

```
**            - Roughness Length (m) -

**

**            SEAS      Z0 (m)

**            ----      -----

**

**   AVEROUGH  WINTER    0.10


ME FINISHED


**TG STARTING

**TG FINISHED


OU STARTING

   RECTABLE  SRCGRP

   MAXTABLE  10 INDSRC SRCGRP

OU FINISHED


 *** Message Summary For ISC3 Model Setup ***

 --------- Summary of Total Messages --------

A Total of           0 Fatal Error Message(s)
A Total of           2 Warning Message(s)
A Total of           0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
CO W205    12 FLAGDF: No Option Parameter Setting.  Forced by Default to ZFLAG=0.
CO W151    15 COCARD: CO ELEVUNIT card obsolescent: use RE ELEVUNIT card instead
```

```
************************************
*** SETUP Finishes Successfully ***
************************************
```

```
  *** ISCLT3 - VERSION 95250 ***     *** TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM     ***          09/07/95
                                       ***
                         ***         16:26:53

                                    PAGE    1
  *** MODELING OPTIONS USED:  CONC    RURAL  ELEV    FLGPOL DFAULT


                                                ***      MODEL SETUP OPTIONS SUMMARY
***
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - -

 **Model Is Setup For Calculation of Average CONCentration Values.
 **Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

 **Model Uses NO plume DEPLETION.

 **Model Uses RURAL Dispersion.

 **Model Uses Regulatory DEFAULT Options:
            1. Final Plume Rise.
            2. Stack-tip Downwash.
            3. Buoyancy-induced Dispersion.
            4. Default Wind Profile Exponents.
            5. Default Vertical Potential Temperature Gradients.
            6. "Upper Bound" Values For Supersquat Buildings.
            7. No Exponential Decay for RURAL Mode

 **Model Accepts Receptors on ELEV Terrain.

 **Model Accepts FLAGPOLE Receptor Heights.

 **Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0  0
                                                 Seasons/Quarters:  1  0  0  0
                                                       and Annual:  0

 **Data File Includes  4 STAR Summaries for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0  0
                                                 Seasons/Quarters:  1  1  1  1
                                                       and Annual:  0

 **This Run Includes:   10 Source(s);      1 Source Group(s); and     18 Receptor(s)

 **The Model Assumes A Pollutant Type of:  OTH

 **Model Set To Continue RUNning After the Setup Testing.

 **Output Options Selected:
```

```
          Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
          Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)

 **Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot.
Angle =      .0
                 Emission Units = (GRAMS/(SEC-M**2))                         ;
Emission Rate Unit Factor =    1.0000
                 Output Units   = GRAMS/CUBIC-METER

 **Input Runstream File: areatest.inp                                ;  **Output Print
File: areatest.out
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** AREA SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS /METER**2)	COORD (SW CORNER) X (METERS)	Y (METERS)	BASE ELEV. (METERS)	RELEASE HEIGHT (METERS)	X-DIM OF AREA (METERS)	Y-DIM OF AREA (METERS)	ORIENT. (DEG.)	INIT. SZ (METERS)	EMISSION RATE SCALAR VARY BY
1	0	.10000E+01	800.0	400.0	.0	1.00	60.00	100.00	.00	.00	
2	0	.10000E+01	40.0	360.0	.0	1.00	20.00	20.00	.00	.00	
3	0	.10000E+01	480.0	20.0	.0	1.00	30.00	300.00	.00	.00	
4	0	.10000E+01	420.0	260.0	.0	1.00	40.00	40.00	.00	.00	
5	0	.10000E+01	420.0	180.0	.0	1.00	40.00	40.00	.00	.00	
6	0	.10000E+01	420.0	100.0	.0	1.00	40.00	40.00	.00	.00	
7	0	.10000E+01	260.0	340.0	.0	1.00	140.00	200.00	.00	.00	
8	0	.10000E+01	40.0	100.0	.0	1.00	220.00	100.00	.00	.00	
9	0	.10000E+01	40.0	20.0	.0	1.00	220.00	70.00	.00	.00	
10	0	-.10000E+01	300.0	360.0	.0	1.00	80.00	40.00	.00	.00	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 , 3 , 4 , 5 , 6 , 7 , 8 , 9 , 10 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** DISCRETE CARTESIAN RECEPTORS ***
(X-COORD, Y-COORD, ZELEV, ZFLAG)
(METERS)

(	20.0,	60.0,	.3,	1.0);	(	150.0,	95.0, .3, 1.0);
(	360.0,	100.0,	.3,	1.0);	(	520.0,	120.0, .3, 1.0);
(	490.0,	240.0,	.3,	1.0);	(	320.0,	240.0, .3, 1.0);
(	150.0,	260.0,	.3,	1.0);	(	50.0,	330.0, .3, 1.0);
(	70.0,	390.0,	.3,	1.0);	(	190.0,	350.0, .3, 1.0);
(	310.0,	370.0,	.3,	1.0);	(	420.0,	380.0, .3, 1.0);
(	70.0,	460.0,	.3,	1.0);	(	200.0,	460.0, .3, 1.0);
(	330.0,	470.0,	.3,	1.0);	(	40.0,	560.0, .3, 1.0);
(	480.0,	660.0,	.3,	1.0);	(	800.0,	700.0, .3, 1.0);

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***

(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***

(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00

	C	.00000E+00	.00000E+00	.00000E+00	.00000E+00
.00000E+00	.00000E+00				
	D	.00000E+00	.00000E+00	.00000E+00	.00000E+00
.00000E+00	.00000E+00				
	E	.20000E-01	.20000E-01	.20000E-01	.20000E-01
.20000E-01	.20000E-01				
	F	.35000E-01	.35000E-01	.35000E-01	.35000E-01
.35000E-01	.35000E-01				

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
WINTER	283.0000	283.0000	283.0000	283.0000	283.0000	283.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WINTER				
	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	2250.0000	2250.0000	2250.0000	2250.0000	2250.0000	2250.0000
STABILITY CATEGORY B	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000
STABILITY CATEGORY C	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000
STABILITY CATEGORY D	1000.0000	1000.0000	1000.0000	1000.0000	1000.0000	1000.0000
STABILITY CATEGORY E	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000
STABILITY CATEGORY F	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.STA FORMAT: FREE

SURFACE STATION NO.: 99999 UPPER AIR STATION NO.: 99999

NAME: TESTDATA NAME: TESTDATA

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.25000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.25000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000						
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						

WINTER: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.25000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
270.000	.00000000	.00000000	.25000000	.00000000	.00000000	
.00000000						
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	
.00000000						
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	

```
.00000000
    337.500      .00000000     .00000000     .00000000     .00000000     .00000000
.00000000
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.STA FORMAT: FREE

SURFACE STATION NO.: 99999 UPPER AIR STATION NO.: 99999

NAME: TESTDATA NAME: TESTDATA

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000

247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

WINTER: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000
337.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.STA FORMAT: FREE

SURFACE STATION NO.: 99999 UPPER AIR STATION NO.: 99999

NAME: TESTDATA NAME: TESTDATA

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000
247.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
270.000 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
292.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
315.000 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
337.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000

WINTER: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

```
.00000000
    337.500      .00000000     .00000000     .00000000     .00000000     .00000000
.00000000

                SUM OF FREQUENCIES, FTOTAL =      1.00000
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***

INCLUDING SOURCE(S): 1 , 2 , 3 , 4 , 5 , 6 , 7 , 8 , 9 , 10 ,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF OTH IN GRAMS/CUBIC-METER **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
20.00	60.00	1.461732	150.00	95.00	6.278599
360.00	100.00	1.107130	520.00	120.00	1.776145
490.00	240.00	7.055643	320.00	240.00	1.317164
150.00	260.00	1.304899	50.00	330.00	.920154
70.00	390.00	.618355	190.00	350.00	.919853
310.00	370.00	3.915823	420.00	380.00	1.159203
70.00	460.00	.503892	200.00	460.00	.930905
330.00	470.00	8.712571	40.00	560.00	.234258
480.00	660.00	.148282	800.00	700.00	.120108

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 1 ***

** CONC OF OTH IN GRAMS/CUBIC-METER **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.106338	AT (	800.00,	700.00)	DC	6.	.005187	AT (	190.00,	350.00)	DC
2.	.018014	AT (	420.00,	380.00)	DC	7.	.004079	AT (	480.00,	660.00)	DC
3.	.012828	AT (	330.00,	470.00)	DC	8.	.003953	AT (	490.00,	240.00)	DC
4.	.009823	AT (	310.00,	370.00)	DC	9.	.003938	AT (	320.00,	240.00)	DC
5.	.006498	AT (	200.00,	460.00)	DC	10.	.003682	AT (	70.00,	460.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 2 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.378019	AT (	50.00,	330.00)	DC	6.	.008402	AT (	20.00,	60.00)	DC
2.	.074267	AT (	70.00,	390.00)	DC	7.	.004482	AT (	310.00,	370.00)	DC
3.	.044939	AT (	70.00,	460.00)	DC	8.	.003663	AT (	150.00,	95.00)	DC
4.	.013317	AT (	40.00,	560.00)	DC	9.	.002255	AT (	420.00,	380.00)	DC
5.	.012170	AT (	190.00,	350.00)	DC	10.	.001280	AT (	330.00,	470.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 3 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	6.790764	AT (	490.00,	240.00)	DC	6.	.039687	AT (	480.00,	660.00)	DC
2.	1.374194	AT (	520.00,	120.00)	DC	7.	.031461	AT (	150.00,	95.00)	DC
3.	.123926	AT (	360.00,	100.00)	DC	8.	.029688	AT (	150.00,	260.00)	DC
4.	.092051	AT (	420.00,	380.00)	DC	9.	.022130	AT (	310.00,	370.00)	DC
5.	.089242	AT (	320.00,	240.00)	DC	10.	.018005	AT (	190.00,	350.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 4 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.152196	AT (	420.00,	380.00)	DC	6.	.012970	AT (	150.00,	260.00)	DC
2.	.044282	AT (	320.00,	240.00)	DC	7.	.011296	AT (	190.00,	350.00)	DC
3.	.028833	AT (	490.00,	240.00)	DC	8.	.011080	AT (	480.00,	660.00)	DC
4.	.021732	AT (	360.00,	100.00)	DC	9.	.008672	AT (	330.00,	470.00)	DC
5.	.019270	AT (	520.00,	120.00)	DC	10.	.007012	AT (	310.00,	370.00)	DC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 5 ***

** CONC OF OTH IN GRAMS/CUBIC-METER **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.055564	AT (	420.00,	380.00)	DC	6.	.007075	AT (	360.00,	100.00)	DC
2.	.044280	AT (	320.00,	240.00)	DC	7.	.006960	AT (	480.00,	660.00)	DC
3.	.038800	AT (	490.00,	240.00)	DC	8.	.005860	AT (	150.00,	95.00)	DC
4.	.010134	AT (	150.00,	260.00)	DC	9.	.003783	AT (	310.00,	370.00)	DC
5.	.009423	AT (	330.00,	470.00)	DC	10.	.003289	AT (	520.00,	120.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 6 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.147215	AT (	520.00,	120.00)	DC	6.	.007564	AT (	330.00,	470.00)	DC
2.	.125256	AT (	360.00,	100.00)	DC	7.	.006338	AT (	310.00,	370.00)	DC
3.	.054108	AT (	490.00,	240.00)	DC	8.	.004861	AT (	20.00,	60.00)	DC
4.	.027218	AT (	420.00,	380.00)	DC	9.	.004489	AT (	480.00,	660.00)	DC
5.	.012740	AT (	150.00,	95.00)	DC	10.	.003246	AT (	150.00,	260.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 7 ***

```
 RANK       CONC      AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC      AT
  RECEPTOR (XR,YR) OF TYPE
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - - -
   1.       8.914557 AT (     330.00,     470.00)  DC          6.        .476067 AT (
 360.00,      100.00)  DC
   2.       8.621045 AT (     310.00,     370.00)  DC          7.        .399267 AT (
 190.00,      350.00)  DC
   3.       1.220750 AT (     320.00,     240.00)  DC          8.        .231648 AT (
  70.00,      460.00)  DC
   4.       1.127268 AT (     420.00,     380.00)  DC          9.        .209623 AT (
  70.00,      390.00)  DC
   5.        .667998 AT (     200.00,     460.00)  DC         10.        .115042 AT (
  50.00,      330.00)  DC

                    *** THE MAXIMUM   10  WINTER  AVERAGE CONCENTRATION    VALUES FOR
SOURCE:  8        ***

 RANK       CONC      AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC      AT
  RECEPTOR (XR,YR) OF TYPE
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - - -
   1.       3.515034 AT (     150.00,      95.00)  DC          6.        .247998 AT (
 360.00,      100.00)  DC
   2.        .919383 AT (     150.00,     260.00)  DC          7.        .247827 AT (
  70.00,      390.00)  DC
   3.        .404632 AT (     190.00,     350.00)  DC          8.        .192060 AT (
 200.00,      460.00)  DC
   4.        .348773 AT (      20.00,      60.00)  DC          9.        .165306 AT (
  70.00,      460.00)  DC
   5.        .304241 AT (      50.00,     330.00)  DC         10.        .119560 AT (
 520.00,      120.00)  DC

  *** RECEPTOR TYPES:  GC = GRIDCART
                       GP = GRIDPOLR
                       DC = DISCCART
                       DP = DISCPOLR
                       BD = BOUNDARY
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 9 ***

** CONC OF OTH IN GRAMS/CUBIC-METER

**

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	2.644321	AT (	150.00,	95.00)	DC	6.	.119259	AT (	50.00,	330.00)	DC
2.	1.076195	AT (	20.00,	60.00)	DC	7.	.100372	AT (	70.00,	390.00)	DC
3.	.286411	AT (	150.00,	260.00)	DC	8.	.078936	AT (	200.00,	460.00)	DC
4.	.185585	AT (	360.00,	100.00)	DC	9.	.070402	AT (	70.00,	460.00)	DC
5.	.150859	AT (	190.00,	350.00)	DC	10.	.067230	AT (	520.00,	120.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 10 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.000000	AT (	.00,	.00)		6.	.000000	AT (	.00,	.00)	
2.	.000000	AT (	.00,	.00)		7.	.000000	AT (	.00,	.00)	
3.	.000000	AT (	.00,	.00)		8.	.000000	AT (	.00,	.00)	
4.	.000000	AT (	.00,	.00)		9.	.000000	AT (	.00,	.00)	
5.	.000000	AT (	.00,	.00)		10.	.000000	AT (	.00,	.00)	

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR

```
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***

INCLUDING SOURCE(S): 1 , 2 , 3 , 4 , 5 , 6 , 7 , 8 , 9 , 10 ,

** CONC OF OTH IN GRAMS/CUBIC-METER

**

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	8.712571	AT (	330.00,	470.00)	DC	6.	1.461732	AT (	20.00,	60.00)	DC
2.	7.055643	AT (	490.00,	240.00)	DC	7.	1.317164	AT (	320.00,	240.00)	DC
3.	6.278599	AT (	150.00,	95.00)	DC	8.	1.304899	AT (	150.00,	260.00)	DC
4.	3.915823	AT (	310.00,	370.00)	DC	9.	1.159203	AT (	420.00,	380.00)	DC
5.	1.776145	AT (	520.00,	120.00)	DC	10.	1.107130	AT (	360.00,	100.00)	DC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

```
 *** ISCLT3 - VERSION 95250 ***     *** TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM     ***          09/07/95
                                       ***
                          ***        16:26:53

                                    PAGE  15
 *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


*** Message Summary : ISCLT3 Model Execution ***

 --------- Summary of Total Messages --------

A Total of           0 Fatal Error Message(s)
A Total of           2 Warning Message(s)
A Total of           0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
CO W205    12 FLAGDF: No Option Parameter Setting.  Forced by Default to ZFLAG=0.
CO W151    15 COCARD: CO ELEVUNIT card obsolescent: use RE ELEVUNIT card instead

   ************************************
   *** ISCLT3 Finishes Successfully ***
   ************************************
```

```
CO STARTING
   TITLEONE  Test case for long-term deposition model DEPLT
   TITLETWO  Model deposition for an urban site with no plume depletion
   MODELOPT  DFAULT  DEPOS  RURAL
   AVERTIME  WINTER
   POLLUTID  TSP
   RUNORNOT  RUN
   ERRORFIL  ERRORS.OUT
CO FINISHED

SO STARTING

   LOCATION  STACK1  POINT  0.0   0.0   0.0
** Point Source       QS    HS    TS    VS   DS
** Parameters:       ----  ----  ----  ----  ---
   SRCPARAM  STACK1  1.00  35.0  432.  11.7  2.4

   BUILDHGT  STACK1  16*34.
   BUILDWID  STACK1  36.45 34.00 25.50 15.00
             STACK1  25.50 34.00 36.45 33.33
             STACK1  36.45 34.00 25.50 15.00
             STACK1  25.50 34.00 36.45 33.33

   PARTDIAM  STACK1  10.
   MASSFRAX  STACK1  1.
   PARTDENS  STACK1  1.
```

```
SO SRCGROUP ALL

SO FINISHED



RE STARTING

RE GRIDPOLR POL ORIG    0.0     0.0

RE GRIDPOLR POL STA

RE GRIDPOLR POL DIST   300.  20000.

RE GRIDPOLR POL GDIR   36    10.0   10.0

RE GRIDPOLR POL END

RE FINISHED



ME STARTING

   INPUTFIL  BOSTON.JFD  FREE

   ANEMHGHT  10.

   SURFDATA  14739  1990  BOSTON

   UAIRDATA  14764  1990  PORTLAND

   STARDATA  WINTER


**                - AMBIENT AIR TEMPERATURE (DEGREES KELVIN) -

**

**                   STAB    STAB    STAB    STAB    STAB    STAB

**                   CAT 1   CAT 2   CAT 3   CAT 4   CAT 5   CAT 6
```

```
**                  -----   -----   -----   -----   -----   -----

   AVETEMPS  WINTER  250.00    282.77  277.51  275.99  273.72  273.40


**                        - MIXING LAYER HEIGHT (METERS) -

**                   S

**                   T    WS      WS      WS      WS      WS      WS

**            SEAS   A   CAT 1   CAT 2   CAT 3   CAT 4   CAT 5   CAT 6

**            ----   B   -----   -----   -----   -----   -----   -----

   AVEMIXHT  WINTER 1    0.      0.      0.      0.      0.      0.

   AVEMIXHT  WINTER 2    0.    502.    619.      0.      0.      0.

   AVEMIXHT  WINTER 3  370.    462.    891.   1795.      0.      0.

   AVEMIXHT  WINTER 4  385.    375.    601.    846.    802.    755.

   AVEMIXHT  WINTER 5  400.    402.    526.    490.      0.      0.

   AVEMIXHT  WINTER 6  386.    294.     58.      0.      0.      0.


**            - Roughness Length (m) -

**

**            SEAS     Z0 (m)

**            ----     -----

   AVEROUGH  WINTER    0.10
```

```
ME FINISHED


OU STARTING

   RECTABLE  SRCGRP

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
```

```
  *** ISCLT3 - VERSION 95250 ***     *** Test case for long-term deposition model
DEPLT                          ***       09/07/95
                                   *** Model deposition for an urban site with no
plume depletion            ***         16:31:32

                                  PAGE   1
  *** MODELING OPTIONS USED:  DEPOS  RURAL  FLAT          DFAULT


                                                ***      MODEL SETUP OPTIONS SUMMARY
***
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - -

 **Model Is Setup For Calculation of Total DEPOSition Values.
 **Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

 **Model Uses NO plume DEPLETION.

 **Model Uses RURAL Dispersion.

 **Model Uses Regulatory DEFAULT Options:
           1. Final Plume Rise.
           2. Stack-tip Downwash.
           3. Buoyancy-induced Dispersion.
           4. Default Wind Profile Exponents.
           5. Default Vertical Potential Temperature Gradients.
           6. "Upper Bound" Values For Supersquat Buildings.
           7. No Exponential Decay for RURAL Mode

 **Model Assumes Receptors on FLAT Terrain.

 **Model Assumes No FLAGPOLE Receptor Heights.

 **Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0
                                                Seasons/Quarters:  1  0  0  0
                                                      and Annual:  0

 **Data File Includes  1 STAR Summaries for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0
                                                Seasons/Quarters:  1  0  0  0
                                                      and Annual:  0

 **This Run Includes:    1 Source(s);      1 Source Group(s); and     72 Receptor(s)

 **The Model Assumes A Pollutant Type of:  TSP

 **Model Set To Continue RUNning After the Setup Testing.

 **Output Options Selected:
```

Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)

```
 **Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot.
Angle =      .0
                 Emission Units = GRAMS/SEC                                   ;
Emission Rate Unit Factor =    3600.0
                 Output Units   = GRAMS/M**2

 **Input Runstream File: deptest.inp                                ;  **Output Print
File: deptest.out
 **Error Message File: ERRORS.OUT
```

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** POINT SOURCE DATA ***

STACK SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS SCALAR VARY BY
STACK1	1	.10000E+01	.0	.0	.0	35.00	432.00	11.70	2.40	YES

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	STACK1 ,

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** SOURCE PARTICULATE DATA ***

*** SOURCE ID = STACK1 ; SOURCE TYPE = POINT ***

MASS FRACTION =
1.00000,

PARTICLE DIAMETER(MICRONS) =
10.00000,

PARTICLE DENSITY (G/CM**3) =
1.00000,

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: STACK1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	34.0,	36.5,	0	2	34.0,	34.0,	0	3	34.0,	25.5,	0
4	34.0,	15.0,	0								
5	34.0,	25.5,	0	6	34.0,	34.0,	0	7	34.0,	36.5,	0
8	34.0,	33.3,	0								
9	34.0,	36.5,	0	10	34.0,	34.0,	0	11	34.0,	25.5,	0
12	34.0,	15.0,	0								
13	34.0,	25.5,	0	14	34.0,	34.0,	0	15	34.0,	36.5,	0
16	34.0,	33.3,	0								

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR
***

*** ORIGIN FOR POLAR NETWORK ***
X-ORIG = .00 ; Y-ORIG = .00 (METERS)

*** DISTANCE RANGES OF NETWORK ***
(METERS)

300.0, 20000.0,

*** DIRECTION RADIALS OF NETWORK ***
(DEGREES)

10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0,
80.0, 90.0, 100.0,
110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0,
180.0, 190.0, 200.0,
210.0, 220.0, 230.0, 240.0, 250.0, 260.0, 270.0,
280.0, 290.0, 300.0,
310.0, 320.0, 330.0, 340.0, 350.0, 360.0,

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***

(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***

(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00

	C	.00000E+00	.00000E+00	.00000E+00	.00000E+00
.00000E+00	.00000E+00				
	D	.00000E+00	.00000E+00	.00000E+00	.00000E+00
.00000E+00	.00000E+00				
	E	.20000E-01	.20000E-01	.20000E-01	.20000E-01
.20000E-01	.20000E-01				
	F	.35000E-01	.35000E-01	.35000E-01	.35000E-01
.35000E-01	.35000E-01				

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN)
***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
WINTER	250.0000	282.7700	277.5100	275.9900	273.7200	273.4000

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WINTER WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	.0000	.0000	.0000	.0000	.0000	.0000
STABILITY CATEGORY B	.0000	502.0000	619.0000	.0000	.0000	.0000
STABILITY CATEGORY C	370.0000	462.0000	891.0000	1795.0000	.0000	.0000
STABILITY CATEGORY D	385.0000	375.0000	601.0000	846.0000	802.0000	755.0000
STABILITY CATEGORY E	400.0000	402.0000	526.0000	490.0000	.0000	.0000
STABILITY CATEGORY F	386.0000	294.0000	58.0000	.0000	.0000	.0000

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** AVERAGE SURFACE ROUGHNESS LENGTH (METERS) ***

WINTER .1000

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: BOSTON.JFD FORMAT: FREE

SURFACE STATION NO.: 14739 UPPER AIR STATION NO.: 14764

NAME: BOSTON NAME: PORTLAND

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

.00000000

247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

WINTER: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00138900	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00092600	.00000000	.00000000	.00000000
135.000	.00000000	.00092600	.00046300	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00046300	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00092600	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00092600	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

```
.00000000
    337.500      .00000000     .00000000     .00000000     .00000000     .00000000
.00000000
```

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: BOSTON.JFD FORMAT: FREE

SURFACE STATION NO.: 14739 UPPER AIR STATION NO.: 14764

NAME: BOSTON NAME: PORTLAND

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00046300	.00092600	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00046300	.00000000	.00000000	.00000000	.00000000
67.500	.00046300	.00046300	.00046300	.00000000	.00000000	.00000000
90.000	.00000000	.00046300	.00463000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00185200	.00000000	.00000000	.00000000
135.000	.00000000	.00092600	.00416700	.00000000	.00000000	.00000000
157.500	.00000000	.00092600	.00092600	.00000000	.00000000	.00000000
180.000	.00000000	.00092600	.00231500	.00046300	.00000000	.00000000
202.500	.00000000	.00000000	.00046300	.00000000	.00000000	.00000000
225.000	.00046300	.00000000	.00324100	.00000000	.00000000	

.00000000
247.500 .00000000 .00092600 .00370400 .00000000 .00000000
.00000000
270.000 .00000000 .00092600 .00416700 .00000000 .00000000
.00000000
292.500 .00000000 .00000000 .00231500 .00046300 .00000000
.00000000
315.000 .00000000 .00000000 .00416700 .00000000 .00000000
.00000000
337.500 .00000000 .00000000 .00138900 .00092600 .00000000
.00000000

WINTER: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00156300	.00370400	.01481500	.03101900	.00648200	.00000000
22.500	.00006400	.00185200	.00509300	.00555600	.00231500	.00046300
45.000	.00009500	.00277800	.00463000	.00694500	.00324100	.00324100
67.500	.00009500	.00277800	.00740800	.01203800	.00509300	.00092600
90.000	.00201000	.00277800	.01018600	.02037100	.00694500	.00092600
112.500	.00059000	.00324100	.00509300	.01203800	.00370400	.00000000
135.000	.00007900	.00231500	.00416700	.00648200	.00046300	.00000000
157.500	.00015800	.00463000	.00787100	.00555600	.00000000	.00000000
180.000	.00022100	.00648200	.01805600	.01203800	.00185200	.00000000
202.500	.00003200	.00092600	.00926000	.03703800	.01481500	.00138900
225.000	.00003200	.00092600	.01435200	.04907500	.03426000	.00833400
247.500	.00004800	.00138900	.01620400	.04953800	.01435200	.00231500
270.000	.00000000	.00000000	.00833400	.05046300	.01666700	.00231500
292.500	.00001600	.00046300	.00972300	.06759300	.02824100	.00926000
315.000	.00049500	.00046300	.00972300	.03472300	.01527800	

```
.00555600
    337.500      .00099000     .00092600     .00694500     .02963000     .00694500
.00277800
```

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: BOSTON.JFD FORMAT: FREE

SURFACE STATION NO.: 14739 UPPER AIR STATION NO.: 14764

NAME: BOSTON NAME: PORTLAND

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00046300	.00138900	.00601900	.00000000	.00000000	.00000000
22.500	.00000000	.00185200	.00046300	.00000000	.00000000	.00000000
45.000	.00000000	.00138900	.00092600	.00000000	.00000000	.00000000
67.500	.00000000	.00092600	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00231500	.00000000	.00000000	.00000000	.00000000
112.500	.00046300	.00138900	.00046300	.00000000	.00000000	.00000000
135.000	.00000000	.00138900	.00185200	.00000000	.00000000	.00000000
157.500	.00046300	.00000000	.00231500	.00046300	.00000000	.00000000
180.000	.00000000	.00231500	.00879700	.00000000	.00000000	.00000000
202.500	.00000000	.00138900	.00277800	.00000000	.00000000	.00000000
225.000	.00000000	.00138900	.00787100	.00092600	.00000000	

.00000000

247.500	.00000000	.00092600	.00879700	.00000000	.00000000
.00000000					
270.000	.00000000	.00231500	.00740800	.00000000	.00000000
.00000000					
292.500	.00000000	.00092600	.01574100	.00046300	.00000000
.00000000					
315.000	.00000000	.00000000	.01111200	.00000000	.00000000
.00000000					
337.500	.00000000	.00000000	.00740800	.00000000	.00000000
.00000000					

WINTER: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00101900	.00046300	.00000000	.00000000	.00000000	.00000000
22.500	.00009300	.00138900	.00000000	.00000000	.00000000	.00000000
45.000	.00006200	.00092600	.00000000	.00000000	.00000000	.00000000
67.500	.00101900	.00046300	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00098800	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00055600	.00092600	.00000000	.00000000	.00000000	.00000000
157.500	.00049400	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00018600	.00277800	.00000000	.00000000	.00000000	.00000000
202.500	.00006200	.00092600	.00000000	.00000000	.00000000	.00000000
225.000	.00015500	.00231500	.00046300	.00000000	.00000000	.00000000
247.500	.00015500	.00231500	.00000000	.00000000	.00000000	.00000000
270.000	.00009300	.00138900	.00000000	.00000000	.00000000	.00000000
292.500	.00006200	.00092600	.00000000	.00000000	.00000000	.00000000
315.000	.00055600	.00092600	.00000000	.00000000	.00000000	.00000000

.00000000

337.500	.00006200	.00092600	.00000000	.00000000	.00000000

.00000000

SUM OF FREQUENCIES, FTOTAL = 1.00006

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** THE WINTER TOTAL DEPOSITION VALUES FOR SOURCE GROUP: ALL ***

INCLUDING SOURCE(S): STACK1 ,

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR ***

** DEPO OF TSP IN GRAMS/M**2 **

DIRECTION (DEGREES)	DISTANCE (METERS) 300.00	20000.00
10.00	.228236	.001296
20.00	.322830	.001672
30.00	.392019	.002252
40.00	.450586	.002861
50.00	.383487	.002988
60.00	.191753	.002627
70.00	.078565	.002335
80.00	.205135	.002347
90.00	.331275	.002326
100.00	.496848	.002884
110.00	.660746	.003395
120.00	.597187	.003032
130.00	.457595	.002357
140.00	.360605	.001873
150.00	.306703	.001609
160.00	.265054	.001405
170.00	.261846	.001442
180.00	.258021	.001458
190.00	.170774	.000978
200.00	.083149	.000487
210.00	.065123	.000415
220.00	.070123	.000482
230.00	.059794	.000552
240.00	.034442	.000622
250.00	.028965	.000716
260.00	.083070	.000892
270.00	.136956	.001056

280.00 ¶	.125380	.000863
290.00 ¶	.113265	.000659
300.00 ¶	.093438	.000528
310.00 ¶	.071074	.000421
320.00 ¶	.057906	.000367
330.00 ¶	.053929	.000371
340.00 ¶	.060047	.000432
350.00 ¶	.096707	.000668
360.00 ¶	.132976	.000897

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

APPENDIX APS

AIR POLLUTION SOURCES

APPENDIX D15

BACKGROUND INFORMATION ON PERMITTED EMISSIONS IN THE VICINITY OF WIPP

(From the WIPP RCRA Part B Permit Application, Rev. 6)

APPENDIX D15

COMPARISON OF WIPP FACILITY EMISSIONS TO PERMITTED EMISSIONS AT SURROUNDING FACILITIES

To compare the emissions from the WIPP repository to other area sources of air contamination, the emissions from the repository as converted to tons/year as follows:

$$PE_{voc}\ (tons/year) = APE_{voc}\ (mole/panel/year) \times MW\ (g/mole) \times (1\ kg/1000\ g) \times (0.0011\ tons/kg)$$

where,

PE_{voc}	=	panel emissions, tons/year
APE_{voc}	=	average panel emissions, mole/panel/year
MW	=	molecular weight, g/mole

The average emission rates for 1 open and 9 closed panels are used to give the maximum emission rate of the repository as follows:

$$TPE_{voc} = (1 \times OPE_{voc}) + (9 \times CPE_{voc})$$

where,

TPE_{voc}	=	total panel emissions, tons/year
OPE_{voc}	=	open panel emission rate for the VOC, PE_{voc} for an open panel, tons/year
CPE_{voc}	=	closed panel emission rate for the VOC, PE_{voc} for a closed panel, tons/year

The maximum emission rates for each VOC, expressed in tons/year, are presented in Table 1. The values in Table 1 reflect no room closures in the open panel. Table 2 contains the permitted emission rates for surrounding facilities.

TABLE D15-1

REPOSITORY MAXIMUM EMISSION RATES[a]

VOC	OPE (tons/year)	CPE (tons/year)	Total Emissions (tons/year)
Carbon tetrachloride	0.196	0.0026	0.219
Chlorobenzene	0.0046	0.00006	0.0052
Chloroform	0.011	0.00013	0.0126
1,1-Dichloroethylene	0.0044	0.00005	0.0048
1,2-Dichloroethane	0.0033	0.00004	0.0037
Methylene chloride	0.13	0.0014	0.142
1,1,2,2-Tetrachloroethane	0.0054	0.00007	0.0060
Toluene	0.0060	0.00008	0.0067
1,1,1-Trichloroethane	0.14	0.0019	0.161
		TOTAL	**0.561**

a. The values presented reflect no room closures in the open panel

TABLE D15-2
SOUTHEASTERN NEW MEXICO PERMITTED EMISSION RATES

	Facility	Pollutant	Tons/yr
1.	**Navajo Refinery** 5 Miles South of Lovington on Highway 18 (505) 748-3311 **Permit # 273**	VOC's Toluene Benzene Ethyl Benzene Xylene Hex Napthalene	779.73 12.353 4.311 1.863 13.581 7.524 1.841
2.	**SPS - Cunningham Plant** 15 Miles West of Hobbs on U.S. Highway 62-180 (505) 391-3200 **Permit # 622**	No_x	20
3.	**SPS - Maddox Plant** 8 Miles West of Hobbs on U.S. Highway 62-180 (505) 391-3200 **Permit # 747**	VOC's CO N_2	8 489 4155
4.	**IMC Fertilizer, Inc.** 26 Miles SE of Carlsbad on Highway 31 (505) 887-2871 **Permit # 495-M-5**	TSP	567.2*/535.1
5.	**New Mexico Potash Corp.** 35 Miles East of Carlsbad on U.S. Highway 62-180 (505) 887-1117 **Permit # 755**	TSP	1007.8*/394.2
6.	**Navajo Refinery** 501 E. Main St. Artesia, NM 88210 (505) 748-3311 **Permit # 195-M-5**	VOC's Toluene Benzene Ethyl Benzene Xylene Hexane Napthalene HF Acid	1760.70 68.536 26.546 36.743 22.411 24.696 1.744 9.248

	Facility	Pollutant	Tons/yr
7.	**GPM - Lea Plant** 28 Miles West of Hobbs on U.S. Highway 62-180 (505) 397-5720 **Permit # 76**	SO_2 VOC's CO NO_x	818.000 45.70 789.10 2540.60
8.	**GPM - Eunice Plant** 1 Mile North 1 Mile West of Oil Center (505) 397-5591 **Permit # 44-M-5**	SO_2 VOC's CO NO_x	34,264.70 420.20 634.50 4339.90
9.	**GPM - Artesia Plant** 12 Miles East of Artesia on Hwy 82 and 3 Miles South on County Rd. 206 (505) 397-5594 **Permit # 434**	SO_2 VOC's CO NO_x	1459.00 69.20 886.50 2040.60
10.	**El Paso Natural Gas** 9 miles NW of Carlsbad, NM (505) 885-0615 **Permit # 1009**	VOC's CO NO_x	4.73 26.00 83.00
11.	**Mississippi Chemical Corp.** 18 Miles East and 2 Miles South of Carlsbad on Highway 41 (505) 887-5591 **Permit # 421**	TSP	801.5*/146.7
12.	**Western AG-Minerals Co.** 20 Miles East of Carlsbad on U.S. Highway 62-180 (505) 885-3175 **Permit # 163-M-2**	TSP PM_{10} NO_x CO	3822.0*/102.2 1834.6*/49.1 14.4*/14.4 3.6*/3.6
13.	**Anderson Ranch Station** 10,000 bbl Oil Storage Tank 15 Miles West of Lovington **Permit # 1524**	VOC's	1.5/1.36(actual)

	Facility	Pollutant	Tons/yr
14.	**Cabin Lake Compressor Sta.** 21 Miles West of Carlsbad **Permit # 1120**	NO_x CO VOC's	50.00 46.00 18.00
15.	**Lea Crude Oil Storage Fac.** 4 Miles North of Oil Center, NM **Permit # 1430**	VOC's	9.80
16.	**Thomas Station Alt. #1** Crude Oil Storage Tank 20,000 bbl Capacity 28 Miles West of Jal, NM **Permit # 1504**	VOC's	1.52
17.	**City of Hobbs** Soil Vapor Extraction Sys. Ground Water Vapor Extrac. Hobbs, NM 88240 **Permit # 1486**	VOC's Ethyl Benzene Benzene Toluene Xylene Ethyl Dichloride Ethyl Dibromide	35.400 0.200 1.800 0.920 0.500 0.070 0.013
18.	**Monument Lateral Comp. Sta.** 16 Miles Southwest of Monument, NM **Permit # 1242-Revision**	NO_x CO VOC's	14.40 18.60 0.40
19.	**Texaco, Inc.** **Bilbrey Compressor Station 1** 27 Miles Northeast of Loving **Permit # 1505**	NO_x CO VOC's	79.70*/21.50 57.80*/21.50 10.90*/7.40
20.	**Vaca Compressor Station** 20 Miles West of Jal, NM **Permit # 1448**	NO_x CO VOC's	23.60 23.60 14.80
21.	**Conoco Oil, Inc.** **Maljamar Gas Plant** Maljamar, NM **Permit # 319-M-4**	NO_x CO SO_2 VOC's	959.80 136.10 3573.40 42.70

	Facility	Pollutant	Tons/yr
22.	**Livingston Ridge Crude Oil Storage Facility** Lea County, NM **Permit # 1096-M-1**	VOC's	2.10
23.	**Shoe Bar Compressor Station** 5 Miles South of Lovington **Permit # 1472**	NO_x CO VOC's	6.70 27.40 0.20
24.	**Mike's Super Fina and Detail Shop** (Gas/Oil Station) **Soil Vapor Extraction System** Hobbs, NM **Permit # 1330**	VOC's	9.60
25.	**Grama Ridge Number 1 Compressor Station** 18 Miles Northwest of Eunice **Permit # 944-M-2**	NO_2 CO VOC's	139.20 187.40 44.40
26.	**Rattlesnake Compressor Sta.** 9 Miles South-Southwest of Jal, NM **Permit # 477-M-1**	NO_2 CO VOC's	21.20 31.80 8.01
27.	**Commanche Compressor Station** 20 Miles West of Oil Center **Permit # 1288-M-1**	NO_x CO VOC's	14.10 2.00 2.00
28.	**Texaco Oil Co., Inc.** **Bilbrey Compressor Station 2** 26 Miles Northeast of Loving **Permit # 1425**	NO_x CO VOC's	28.90 28.90 9.60
29.	**Hat Mesa Compressor Station** 24 Miles West of Oil City, NM **Permit # 1018-M-2**	NO_2 CO VOC's	245.80 245.80 16.60
30.	**Lynch Booster Compressor Sta.** 25 Miles Southwest of Hobbs **Permit # 609-M-3**	NO_2 CO SO_2 VOC's	225.70 225.70 2.80 7.90

Facility	Pollutant	Tons/yr

31.	**Asphalt Plant and Rock Crushing Plant** Loco Hills, NM **Permits # 1345 and # 1346**	TSP's NO_x CO SO_2 VOC's	29.80 59.00 22.30 37.50 25.10
32.	**WGI Compressor Station** **Notice of Intent 1542 -**	Per AQCR 702, no permit is needed if the uncontrolled emission rate of air pollutants from a particular facility is less than 10 lbs/hr or 25 tons/yr.	
33.	**127 hp Waukeska WAKC Natural Gas Engine.** **Notice of Intent 1084 -**	Per AQCR 702 and AQCR 703.1, no permit is needed if the uncontrolled emission rate of air pollutants from a particular facility is less than 10 lbs/hr or 25 tons/yr. If the uncontrolled emission rate of air pollutants from a particular facility is less than 10 tons/yr, the Notice of Intent itself serves as the complete application.	
34.	**Armstrong Construction** 3 Miles West of Hobbs **Permit # 827-M-3**	NO_x CO TSP's PM_{10} VOC's	42.25 25.10 21.20 10.20 7.30
35.	**Compressor Station** 22 Miles West of Jal **Permit # 261-M-3**	TSP's NO_x VOC's	4647.12 32.00 43.40
36.	**Portable Natural Gas Comp.** Portable with locations between Hobbs and Carlsbad **Permit # 1543**	NO_x CO VOC's	18.40 39.00 0.30
37.	**125 tph Portable Rock Crushing Facility** 6.8 Miles Southeast of Maljamar, NM **Permit # 1474**	NO_2 CO SO_2 VOC's	23.10 1.00 2.10 0.60

	Facility	Pollutant	Tons/yr
38.	**Chiso BCD Compressor Station** 20 Miles Southwest of Eunice **Permit # 1398**	NO_x CO VOC's	30.30 56.70 6.30
39.	**Mitchell Energy Technology** Geronimo Compressor Site 26 Miles South of Maljamar **Permit # 1392**	NO_x CO VOC's	6.60 27.00 1.50
40.	**TSTA Oil Producers** **Antelope Ridge Comp. Station** 22 Miles Southwest of Eunice **Permit # 1377**	NO_x CO VOC's	28.80 36.00 14.40
41.	**TSTA Oil Producers** **Antelope Ridge L.P.Comp. Sta.** 22 Miles Southwest of Eunice **Permit # 1378**	NO_x CO VOC's	30.50 31.60 13.80
42.	**Ojo Chiso No. 3 Comp. Station** 21 Miles Southwest of Eunice **Permit # 1376**	NO_x CO VOC's	9.70 16.90 4.90
43.	**Antelope Ridge Gas Plant** 20 Miles Southwest of Eunice **Permit # 401-M-3**	NO_2 CO VOC's	180.80 119.00 430.20
44.	**El Paso Natural Gas Co.** **Eunice B Compressor Station** 9 Miles Northwest of Eunice **Permit # 1009-Revision**	NO_2 CO VOC's	83.10 26.10 4.80
45.	**Llano, Inc.** **Apex Compressor Station** 8 Miles West of Hobbs **Permit # 696-M-2**	NO_x CO VOC's	168.30 93.20 23.80
46.	**Northland Sweet Booster Sta.** 17.50 Miles Southeast of Artesia, NM **Permit # 1289**	NO_x CO VOC's	20.30 30.40 10.20

	Facility	Pollutant	Tons/yr
47.	**Northland Sour Booster Sta.** 7 Miles Southeast of Artesia **Permit # 1290**	NO_x CO VOC's	15.00 22.50 7.50
48.	**Ranger Lake Booster Station** 10 Miles East of Tatum **Permit # 1136-M-1**	NO_x CO VOC's	35.10 35.10 1.40
49.	**Warren Petroleum Co.** **Monument Gas Processing Plant** 3 Miles West of Monument, NM **Permit # 110-M-2**	NO_2 CO SO_2 VOC's	2802.90 387.40 1460.00 113.70
50.	**DA Natural Gas Comp. Station** 10 Miles West of Eunice, NM **Permit # 1134**	NO_x CO VOC's	0.91 7.30 0.10
51.	**Mid-America Pipeline, Inc.** **Caprock Compressor Station** Near Caprock, NM **Permit # 920-M-1**	NO_2 CO	36.00 47.40
52.	**Texaco Oil Co., Inc.** **Eunice South** **Gas Processing Plant** 6 Miles South of Eunice **Permit # 278-M-3**	NO_x CO SO_2 VOC's	1179.80 249.50 5476.40 56.90
53.	**ENRON Gas Processing Co.** **Siete O&G Compressor Station** 30 Miles Northeast of Lovington, NM **Permit # 1203**	NO_x CO VOC's	15.90 15.90 0.40
54.	**Shoebar Compressor Station** Section 34, Range 35E, Township 16S - Lea County **Permit # 1116**	NO_x CO VOC's	5.10 5.10 2.60

	Facility	Pollutant	Tons/yr
55.	**Warren Petroleum Co.** **Eunice Gas Processing Plant** Eunice, NM **Permit # 67-M-2**	NO_x CO SO_2 VOC's	2743.50 344.75 632.80 105.00
56.	**Jal Number 3 Gas Plant** Jal, NM **Permit # 1092**	NO_x CO SO_2 VOC's	3490.80 518.40 1205.90 123.50

APPENDIX BAD

TABLES

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APPENDIX BAD

Table BAD-1. WIPP VOC Monitoring Program Data - Station VOC-1

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
09/06/91	47	0.19	JB	0.31	B	12.00		0.10	U	0.10	U
09/11/91	51	0.49	B	0.42		13.00		0.12	J	0.10	U
09/18/91	63	1.30	B	0.77		2.50	B	0.11	J	0.10	U
09/25/91	60	0.69	B	0.20		2.40		0.10	J	0.10	U
09/29/91	66	0.21	B	0.16	J	0.56		0.07	J	0.10	U
10/01/91	70	9.30	B	0.10	U	45.00		0.12	J	0.10	U
10/03/91	75	0.21	B	0.27		1.50		0.09	J	0.10	U
10/10/91	78	0.31	B	0.19	J	48.00		0.14	J	0.10	U
10/17/91	80	0.20	B	0.48		20.00		0.12	J	0.10	U
10/26/91	86	0.20	B	0.49		110.00		0.15	J	0.10	U
10/31/91	89	0.19	B	0.10	U	12.00		0.10	U	0.10	U
11/06/91	92	0.24	B	0.22		2.00		0.10	J	0.10	U
11/13/91	100	0.86	B	0.22		22.00		0.12	J	0.10	U
11/21/91	104	0.34		0.36		9.30		0.11	J	0.10	U
11/26/91	112	0.29	B	0.18	J	10.00		0.11	J	0.10	U
12/06/91	114	0.76	B	0.18	J	9.70		0.11	J	0.10	U
12/10/91	119	0.37	B	0.28		6.60		0.11	J	0.10	U
12/17/91	123	0.56	B	0.23		39.00		0.13	J	0.10	U
12/27/91	127	0.22	B	0.15	J	3.00		0.10	J	0.09	J
12/31/91	131	0.18	JB	0.14	J	1.40		0.10	J	0.10	U
02/05/92	135	0.12	JB	0.12	J	0.40		0.11	J	0.10	U
02/07/92	136	0.15	JB	0.10	U	0.58		0.12	J	0.10	U
02/08/92	138	0.17	JB	0.14	J	0.37		0.11	J	0.10	U
02/19/92	139	0.12	JB	0.13	J	0.28	J	0.10	J	0.10	U
02/27/92	140	0.15	JB	0.12	J	0.39		0.10	J	0.10	U
03/04/92	144	0.16	JB	0.14	J	0.40	B	0.10	J	0.10	U
03/16/92	148	0.16	J	0.13	J	0.33	B	0.10	J	0.10	U
03/21/92	152	0.13	JB	0.12	J	0.81	B	0.09	J	0.10	U
03/27/92	153	0.16	JB	0.10	J	0.42	B	0.10	J	0.10	U
04/02/92	168	0.13	JB	0.10	U	0.35	B	0.10	J	0.10	U
04/08/92	169	0.19	JB	0.14	J	0.51	B	0.11	J	0.10	U
04/14/92	171	0.14	JB	0.10	U	0.36	B	0.11	J	0.10	U
04/16/92	172	0.15	JB	0.10	U	0.36	B	0.11	J	0.10	U
04/20/92	174	0.12	JB	0.10	U	0.37	B	0.10	JB	0.10	U
04/25/92	176	0.11	J	0.10	U	0.29	JB	0.09	J	0.10	U
04/29/92	178	0.11	J	0.10	U	670.00	B	0.20		0.10	U

Data qualifiers:

J - indicates an estimated value and is used when mass spectral data indicate the presence of a compound, but the result is less than the specified reporting limit.

B - indicates the analyte was detected in the blank as well as in the sample.

U - indicates the compound was not detected in the sample. The report value is one-half the laboratory reporting detection limit.

JB - indicates the associated results are considered to be estimated based on findings of the WIPP data validation procedure. This qualifier is applied to analytical results when minor deviations of program quality control or documentation requirements are discovered and are not subsequently corrected by the laboratory.

Table BAD-1. WIPP VOC Monitoring Program Data - Station VOC-1 (continued)

All concentrations in parts per billion

Date	Sample	Trichloro-triflouro-ethane		Methylene Chloride		Trichloro-ethane		Carbon tetra Chloride		Trichloro-ethylene	
05/01/92	179	0.15	J	0.09	J	0.32	B	0.11	J	0.10	U
05/05/92	181	0.15	J	0.11	J	0.31	B	0.10	J	0.10	U
05/08/92	182	0.58		0.13	J	5.70	B	0.13	J	0.10	U
05/14/92	186	0.23		0.10	U	45.00	B	0.14	J	0.10	U
05/20/92	188	0.08	J	0.12	J	1.60	B	0.10	J	0.10	U
05/27/92	190	5.10		0.10	J	12.00	B	0.12	J	0.10	U
06/02/92	191	1.30		0.19	J	7.40	B	0.13	J	0.10	U
06/08/92	192	0.09	J	0.13	J	4.50	B	0.12	J	0.10	U
06/13/92	193	0.11	J	0.20		7.50	B	0.13	J	0.10	U
06/19/92	194	0.11	JB	0.10	U	5.60	B	0.11	J	0.10	U
06/25/92	199	0.13	J	0.15	J	1.40	B	0.10	J	0.10	U
06/26/92	200	4.00		0.10	U	8.40	B	0.11	J	0.10	U
06/30/92	202	0.26	B	0.10	U	1.40	B	0.12	J	0.10	U
07/08/92	203	0.18	J	0.13	J	0.55	B	0.10	J	0.10	U
07/16/92	204	0.22	B	0.10	U	1.70	B	0.12	J	0.10	U
07/24/92	205	15.00		0.10	U	2.60	B	0.10	J	0.10	U
08/01/92	206	3.60	B	0.46		31.00	B	0.11	J	0.10	U
08/04/92	207	0.84	B	0.30		0.65	B	0.11	J	0.10	U
08/12/92	214	1.60	B	0.15	J	1.70		0.11	J	0.10	U
08/14/92	217	0.37	B	0.21		4.40	B	0.12	J	0.21	
08/19/92	218	0.15	JB	0.15	J	0.72	B	0.13	J	0.08	J
08/27/92	219	0.17	JB	0.15	J	0.94	B	0.12	J	0.07	J
09/02/92	220	0.14	J	0.19	J	16.00		0.11	J	0.10	U
09/04/92	222	0.37		0.31		280.00		0.13	J	0.10	J
09/12/92	223	0.49		0.13	J	4.80		0.11	J	0.24	
09/16/92	224	0.22	B	0.13	J	21.00		0.11	J	0.07	J
09/17/92	227	0.39	B	0.16	J	2.30		0.11	J	0.10	U
09/18/92	230	0.16	J	0.15	J	2.50		0.14	J	0.10	J
09/21/92	231	0.14	J	0.68		1.30		0.14	J	0.10	J
10/08/92	232	0.13	B	1.20		130.00		0.12	J	0.10	J
10/16/92	233	0.66		0.10	U	9.40		0.11	J	0.10	U
10/22/92	234	0.10	J	0.10	U	4.30		0.10	J	0.10	U
10/29/92	236	0.34		0.16	J	16.00		0.11	J	0.12	J
11/04/92	237	0.49		0.45		8.30		0.10	J	0.12	J
11/11/92	238	0.60		0.27		3.40		0.09	J	0.07	J
11/21/92	240	0.48		0.32		4.60	J	0.07	J	0.09	J
11/26/92	243	0.11	J	0.18	J	7.90		0.10	J	0.10	U

Data qualifiers:

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JB - indicates the associated results are considered to be estimated based on findings of the WIPP data validation procedure. This qualifier is applied to analytical results when minor deviations of program quality control or documentation requirements are discovered and are not subsequently corrected by the laboratory.

Table BAD-1. WIPP VOC Monitoring Program Data - Station VOC-1 (continued)

All concentrations in parts per billion

Date	Sample	Trichloro-triflouro-ethane		methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
12/02/92	244	0.19	J	0.12	J	100.00	J	0.13	J	0.10	U
12/10/92	245	0.65		0.31		54.00		0.11	J	0.10	U
12/15/92	246	0.12	J	0.14	J	84.00		0.11	J	0.10	U
12/23/92	247	0.50		0.34		47.00		0.08	J	0.09	J
12/31/92	248	0.11	J	0.18	J	17.00		0.09	J	0.05	J
01/08/93	249	0.09	J	0.65		76.00		0.10	J	0.10	U
01/16/93	252	0.11	J	0.12	J	38.00		0.08	J	0.20	U
01/18/93	253	0.10	J	0.10	U	0.80		0.10	J	0.10	U
01/26/93	254	0.09	J	0.12	J	29.00		0.09	J	0.10	U
02/04/93	256	0.16	J	0.10	U	58.00		0.10	J	0.10	U
02/11/93	257	0.20	J	0.17	J	24.00		0.10	J	0.07	J
02/19/93	258	0.08	J	0.18	J	11.00		0.10	J	0.10	J
02/27/93	259	0.10	J	0.16	J	4.20		0.10	J	0.10	U
03/01/93	260	0.11	J	3.30		1.70		0.10	J	0.30	
03/09/93	267	2.30		0.23		3.20		0.10	J	0.10	U
03/18/93	268	0.11	J	0.17	J	3.60		0.13	J	0.10	U
03/27/93	269	0.25		0.22		9.90		0.09	J	0.10	U
04/02/93	270	0.11	J	0.37	B	3.80		0.09	J	0.03	
04/07/93	271	0.12	J	0.39	B	7.80		0.10	J	0.14	J
04/09/93	273	0.09	J	0.42	B	3.40		0.09	J	0.03	J
04/14/93	274	0.11	J	0.23		5.50		0.10	U	0.10	U
04/22/93	276	0.24		0.19	J	1.50		0.10	J	0.10	U
04/27/93	277	0.10	J	0.26	B	17.00		0.09	J	0.10	U
05/05/93	278	1.60		1.00	B	6.70		0.11	J	0.12	J
05/12/93	279	0.41	B	0.52	B	320.00		0.09	J	0.03	J
05/20/93	280	0.32	B	0.87	B	13.00		0.07	J	0.10	U
05/27/93	290	0.63	B	0.44	B	0.50		0.07	J	0.10	U
06/02/93	296	0.52		0.21	B	4.90		0.10	J	0.10	U
06/10/93	311	0.12	J	0.35	B	2.70		0.10	J	0.10	U
06/18/93	329	0.10	J	0.20	B	1.50		0.10	J	0.10	U
06/23/93	344	0.30	B	0.30	B	3.10		0.10	J	0.10	U
06/24/93	346	0.12	J	0.19	JB	2.60		0.11	J	0.04	J
06/30/93	364	0.20	J	0.40	B	4.90		0.10	J	0.10	U
07/08/93	373	0.20		0.20	B	9.00		0.10	J	0.10	U
07/16/93	385	0.18	JB	0.27	B	4.20		0.02	J	0.10	U
07/20/93	389	1.30		0.20	B	5.10		0.10	J	0.10	U

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Table BAD-1. WIPP VOC Monitoring Program Data - Station VOC-1 (continued)

All concentrations in parts per billion

Date	Sample	Trichloro-triflouro-ethane		Methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
07/28/93	391	0.10	J	0.20	B	18.00		0.10	J	0.10	J
08/05/93	397	0.10	J	0.30	B	19.00		0.10	J	0.10	U
08/13/93	399	0.29	JB	0.29	B	3.20		0.09	J	0.14	J
08/21/93	401	0.39	B	0.10	U	1.40		0.08	J	0.10	J
08/23/93	402	0.11	JB	0.08	JB	1.20		0.08	J	0.10	J
08/30/93	403	0.54	B	0.10	U	36.00		0.07	J	0.10	U
09/07/93	404	0.07	B	0.34	JB	5.80		0.20	U	0.20	U
09/16/93	406	9.80	B	0.18	JB	16.00		0.09	J	0.10	U
09/23/93	408	0.17	J	0.21	B	1.90		0.13	J	0.04	J
09/29/93	410	1.60	B	0.46	B	7.90		0.09	J	0.10	U
10/06/93	412	0.18	J	0.21	B	21.00		0.13	J	0.56	
10/12/93	415	0.06	J	0.28	B	48.00		0.10	U	0.10	U
10/20/93	417	1.20		0.23	B	1.70		0.12	J	0.10	U
10/28/93	419	0.90		0.15	J	1.90		0.07	J	0.10	U
11/05/93	423	0.52	B	0.22	B	24.00		0.09	J	0.02	J
11/07/93	424	0.25	JB	0.24	B	1.80		0.09	J	0.01	J
11/15/93	426	0.50	B	0.16	JB	1.80	Jv	0.06	J	0.01	J
11/23/93	428	0.10	U	2.80	J	4.90	J	0.66	J	2.30	J
12/01/93	431	0.17	J	0.10	U	3.00		0.07	J	0.08	J
12/09/93	433	0.11	J	0.16	JB	0.22		0.06	J	0.20	
12/16/93	437	0.46		0.36	B	1.80		0.06	J	0.09	J
12/19/93	439	0.12	J	0.21	B	0.26		0.12	J	0.10	U
12/27/93	441	0.14	J	0.24	BJv	1.90	Jv	0.14	J	0.07	J
01/06/94	443	0.60		0.25	B	1.50		0.15	J	0.10	J
01/19/94	446	0.25		0.29	B	1.80	B	0.16	J	0.08	J
02/01/94	453	4.80		0.39		1.20		0.14	J	0.10	U
02/14/94	456	2.40		0.10	U	0.44		0.13	J	0.10	U
03/03/94	461	0.10	U	0.10	U	1.10		0.10	J	0.10	U
03/16/94	466	0.10	U	1.40		1.20		0.56		0.42	
03/29/94	474	0.10	U	0.10	U	0.47		0.10	U	0.10	U
04/11/94	477	0.13	J	0.38		3.60		0.11	J	0.10	U
04/27/94	484	0.10	U	0.10	U	4.20		0.10	U	0.10	U
05/11/94	489	0.10	U	0.10	U	1.30		0.10	U	0.10	U
05/24/94	492	0.25		0.19	JB	1.90		0.11	J	0.08	J
06/07/94	498	0.11	J	0.19	JB	5.10		0.07	J	0.28	

Data qualifiers:

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JB - indicates the associated results are considered to be estimated based on findings of the WIPP data validation procedure. This qualifier is applied to analytical results when minor deviations of program quality control or documentation requirements are discovered and are not subsequently corrected by the laboratory.

Table BAD-1. WIPP VOC Monitoring Program Data - Station VOC-1 (continued)

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chrloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
06/23/94	502	0.11	J	0.45		3.50		0.06	J	0.10	U
07/06/94	508	0.29	B	0.17	J	1.30		0.05	J	0.04	J
07/19/94	510	0.25	B	1.20	B	1.80		0.10	U	0.10	U
08/01/94	518	1.20	B	1.30	B	6.30		0.10	U	0.13	J
08/18/94	522	0.10	U	2.40		1.60		0.10	U	0.10	U
09/16/94	527	0.26	JB	0.17	JB	0.10	J	0.10	U	0.10	U
09/27/94	538	0.10	U	0.26	B	0.10	U	0.10	U	0.10	U
10/11/94	547	0.22	B	0.20	JB	0.10	J	0.10	U	0.10	U
11/09/94	555	1.90	B	0.12	JB	0.10	U	0.10	U	0.10	U
11/21/94	561	0.26	B	0.23	B	0.13	J	0.10	U	0.10	U
12/08/94	568	0.24	B	0.24		0.49		0.13	J	0.20	
12/21/94	590	0.21	B	0.10	U	0.46		0.10	U	0.10	U
01/18/95	601	0.24	B	0.19	JB	0.18	J	0.10	U	0.10	U
01/30/95	602	0.26	B	0.23	B	1.40		0.10	U	0.10	U
02/15/95	606	1.90		2.30	B	4.00		2.20		3.80	
03/14/95	618	0.20	JB	0.17	JB	0.10	U	0.10	U	0.10	U
03/27/95	621	0.23	B	0.33	B	0.30		0.10	U	0.10	U
04/12/95	627	0.27	B	0.14	JB	0.14	J	0.10	U	0.10	U
04/27/95	636	0.21	B	0.24	B	0.10	J	0.10	U	0.10	U
05/10/95	647	0.10	U	0.23	B	0.10	U	0.10	U	0.10	U
06/05/95	656	0.19	JB	0.43	B	0.29		0.10	U	0.10	U
06/20/95	667	0.27	B	0.27	B	0.16	J	0.10	U	0.10	U
07/06/95	670	1.10	B	0.26	B	0.69		0.10	U	0.10	U
07/19/95	676	0.28	B	0.86	B	0.18	J	0.10	U	0.14	J
08/14/95	681	0.34	B	1.20	B	0.33		0.10	U	0.19	J
08/31/95	688	0.18	JB	0.60	B	0.43		0.10	U	0.10	J
09/13/95	691	0.17	JB	0.39	B	0.12	J	0.10	U	0.10	U
10/09/95	697	0.20	J	0.22	B	0.15	J	0.10	U	0.10	U
Minimum		0.06	J	0.08	U	0.10	U	0.02	J	0.01	J
Maximum		15.00	B	3.30	J	670.00		2.20		3.80	
Average		0.63		0.32		17.17		0.12		0.14	

Data qualifiers:

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B - indicates the analyte was detected in the blank as well as in the sample.

U - indicates the compound was not detected in the sample. The report value is one-half the laboratory reporting detection limit.

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Table BAD-2. WIPP VOC Monitoring Program Data - Station VOC-2

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
09/06/91	48	0.18	JB	0.21	B	0.31		0.09	J	0.10	U
09/11/91	52	0.23	B	0.10	U	0.21	J	0.08	J	0.10	U
09/18/91	64	0.37	B	0.13	J	0.25	J	0.09	J	0.10	U
09/25/91	59	0.20	B	0.10	U	0.18	J	0.08	J	0.10	U
09/29/91	67	0.18	JB	0.10	U	0.23	J	0.10	U	0.10	U
10/03/91	74	0.18	JB	0.10	U	0.31		0.10	U	0.10	U
10/10/91	79	0.18	JB	0.10	U	0.28	J	0.09	J	0.10	U
10/17/91	81	0.19	JB	0.10	J	0.32		0.08	J	0.10	U
10/26/91	87	0.18	JB	0.12	J	0.24	J	0.09	J	0.10	U
10/31/91	91	0.19	JB	0.27		0.22		0.10	U	0.10	U
11/06/91	93	0.19	JB	0.23		0.25	J	0.09	J	0.10	U
11/13/91	101	0.20	B	0.43		0.36		0.09	J	0.10	U
11/21/91	102	0.19	J	0.24		0.26	J	0.10	J	0.10	U
11/26/91	113	0.17	JB	0.14	J	0.68		0.09	J	0.84	
12/06/91	115	0.20	JB	0.13	J	0.21	J	0.09	J	0.10	U
12/10/91	118	0.21	B	0.22		0.33		0.09	J	0.10	U
12/17/91	124	0.19	JB	0.12	J	0.35		0.09	J	0.10	U
12/27/91	128	0.17	JB	0.10	U	0.22	J	0.09	J	0.10	U
12/31/91	132	0.18	JB	0.11	J	0.33		0.10	J	0.10	U
04/23/92	175	0.11	J	0.10	U	19.00	B	0.11	J	0.10	U
04/28/92	177	0.10	J	0.10	U	32.00	B	0.11	J	0.10	J
01/06/94	444	0.17	J	0.21	B	0.25	J	0.14	J	0.08	J
01/19/94	448	0.16	J	0.25	B	0.33	B	0.14	J	0.08	J
02/01/94	452	0.14	J	0.39	B	0.31		0.11	J	0.04	J
02/14/94	457	0.10	U	0.10	U	0.10	U	0.10	U	0.10	U
03/03/94	462	0.10	U	0.10	U	0.14	J	0.10	J	0.10	U
03/16/94	468	0.10	U	0.10	U	0.19	J	0.10	U	0.10	U
03/29/94	472	0.10	U	0.10	U	0.15	J	0.10	U	0.10	U
04/11/94	479	0.10	U	0.10	U	0.15	J	0.10	U	0.20	J
04/28/94	483	0.10	U	0.10	U	0.19	J	0.10	U	0.10	U
05/11/94	487	0.10	J	0.20	B	0.14	J	0.09	J	0.22	B
05/24/94	494	0.10	J	0.10	U	0.13	J	0.09	J	0.10	J
06/07/94	499	0.18	JB	0.10	U	0.08	J	0.03	J	0.03	J
06/23/94	505	0.09	J	0.14	J	0.12	J	0.07	J	0.15	J
07/06/94	506	0.16	J	0.31	B	0.45		0.40		0.92	
07/19/94	512	0.21	B	0.36	B	0.58		0.10	U	0.21	
07/25/94	516	0.42	B	0.60	B	0.16	J	0.08	J	0.08	J

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U - indicates the compound was not detected in the sample. The report value is one-half the laboratory reporting detection limit.

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Table BAD-2. WIPP VOC Monitoring Program Data -Station VOC-2 (continued)

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chrloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
08/01/94	519	0.20	B	0.26	B	0.13	J	0.10	U	0.10	U
08/18/95	523	0.10	U	0.10	U	0.10	U	0.10	U	0.10	U
09/21/94	533	0.19	JB	0.20	JB	0.10	J	0.10	U	0.10	U
10/10/94	544	0.21	B	0.20	JB	0.12	J	0.10	U	0.10	U
10/28/94	548	0.21	B	0.22	B	0.14	J	0.10	U	0.10	U
11/21/94	563	0.32	B	0.24	B	0.10	U	0.10	U	0.10	U
12/08/94	569	0.17	JB	0.12	J	0.10	J	0.10	U	0.10	U
12/21/95	591	0.26	B	0.23	B	0.10	U	0.10	U	0.10	U
01/05/95	593	0.27	B	0.22	B	0.10	J	0.10	U	0.10	U
01/30/95	605	0.27	B	0.21	B	0.10	J	0.10	U	0.10	U
02/15/95	608	0.10	U	0.29	B	0.10	U	0.10	U	0.10	U
03/01/95	614	0.19	JB	0.22	B	0.10	U	0.10	U	0.10	U
03/14/95	619	0.25	B	0.21	B	0.15	J	0.10	U	0.10	U
04/12/95	628	0.18	JB	0.18	JB	0.10	U	0.10	U	0.10	U
04/27/95	634	0.20	JB	0.17	JB	0.10	U	0.10	U	0.10	U
05/09/95	646	0.10	U	0.16	JB	0.10	U	0.10	U	0.10	U
05/25/95	652	0.18	JB	0.16	JB	0.10	U	0.10	U	0.10	U
06/20/95	666	0.21	B	0.47	B	0.10	U	0.10	U	0.10	U
07/06/95	668	0.18	JB	0.35	B	0.10	U	0.10	U	0.10	U
07/19/95	675	0.17	JB	0.37	B	0.10	U	0.10	U	0.10	U
08/01/95	677	0.19	JB	0.34	B	0.10	U	0.10	U	0.10	U
08/31/95	687	0.17	JB	0.21	B	0.10	U	0.10	U	0.10	U
09/13/95	689	0.16	JB	0.29	B	0.10	U	0.10	U	0.10	U
10/09/95	696	0.16	J	0.20	JB	0.10	U	0.10	U	0.10	U
11/07/95	700	0.10	U	0.11	JB	0.10	U	0.10	U	0.10	U
Minimum		0.09	J	0.10	U	0.08	J	0.03	J	0.03	J
Maximum		0.42	B	0.60	B	32.00	B	0.40		0.92	
Average		0.18		0.20		1.01		0.44		0.13	

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Table BAD-3. WIPP VOC Monitoring Program Data - Station VOC-8

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
09/06/91	39	0.32	B	0.29		1.40		0.10	U	0.10	U
09/11/91	45	3.30	B	1.50		1.80		0.11	J	0.10	U
09/17/91	57	0.39	JB	0.25		24.00		0.12	J	0.10	U
09/25/91	49	3.00	B	0.24		2.40		0.09	J	0.10	U
09/29/91	61	0.24	B	0.19	J	0.37		0.08	J	0.10	U
10/03/91	68	0.25	B	1.80		12.00		0.11	J	0.10	U
10/10/91	72	0.24	B	0.13	J	63.00		0.13	J	0.10	U
10/17/91	82	0.28	B	0.18	J	16.00		0.11		0.10	U
10/26/91	76	0.23	B	0.37		98.00		0.14	J	0.10	U
10/31/91	84	0.23	B	0.10	U	124.00		0.14	J	0.10	U
11/06/91	88	0.25	B	0.15	J	0.54		0.09	J	0.10	U
11/13/91	94	0.26	B	0.10	U	21.00		0.11	J	0.10	U
11/21/91	106	0.22		0.18	J	0.76		0.09	J	0.10	U
11/26/91	97	0.26	B	0.10	U	4.40		0.10	J	0.10	U
12/06/91	110	0.28	B	0.10	U	0.44		0.10	J	0.10	U
12/10/91	116	0.19	JB	0.73		0.66		0.11	J	0.10	U
12/17/91	120	0.52	B	0.10	U	0.35		0.09	J	0.10	U
12/27/91	125	0.18	JB	0.10	U	0.31		0.09	J	0.10	U
12/31/91	129	0.17	JB	0.10	U	0.32		0.09	J	0.10	U
08/05/92	208	0.32	B	0.76		3800.00		0.19		0.10	U
11/23/93	429	0.13	J	0.22	B	56.00		0.15	J	0.43	
12/09/93	434	0.21	J	0.77	B	2.20		0.07	J	0.15	J
12/16/93	435	0.14	J	0.30	B	4.50		0.06	J	0.12	J
12/20/93	440	0.11	J	0.18	JB	0.23		0.06	J	0.10	J
12/27/93	442	0.14	J	0.19	JB	0.47		0.13	J	0.13	J
01/06/94	445	0.17	J	0.24	B	0.72		0.17	J	0.17	J
01/19/94	450	0.46		0.44	B	0.51	B	0.15	J	0.14	J
02/01/94	455	0.25		0.22	B	0.24		0.11	J	0.13	J
02/14/94	459	0.59		0.10	U	0.26		0.13	J	0.10	U
03/03/94	463	0.16	J	2.30	B	0.25		0.10	U	0.10	U
03/15/94	470	0.10	U	0.10	U	0.24		0.10	U	0.10	U
03/29/94	473	0.10	U	0.10	U	3.30		0.10	U	0.10	U
04/11/94	478	0.10	U	0.10	U	2.20		0.10	U	0.10	U
04/28/94	485	0.10	U	0.10	U	0.28		0.10	U	0.10	U
05/11/94	488	0.10	J	0.24	B	0.25		0.08	J	0.09	JB
05/24/94	496	3.00		0.28	B	0.27		0.12	J	0.10	U
06/07/94	501	0.15	J	0.20	B	0.65		0.07	J	0.10	U

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U - indicates the compound was not detected in the sample. The report value is one-half the laboratory reporting detection limit.

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Table BAD-3. WIPP VOC Monitoring Program Data -Station VOC-8 (continued)

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Tichloro-ethylene	
06/23/94	503	0.22	B	0.14	JB	0.10	J	0.10	U	0.10	U
07/06/94	507	0.12	J	0.22	B	0.16	J	0.09	J	0.10	U
07/25/94	514	0.19	JB	0.25	B	0.10	U	0.10	U	0.10	U
08/01/94	521	0.21	B	0.19	JB	0.16	J	0.10	U	0.10	U
08/18/94	524	0.10	U	0.42		0.10	U	0.10	U	0.10	U
09/19/94	531	0.20	B	0.16	JB	0.33		0.10	U	0.28	
09/26/94	536	0.10	U	0.29	B	0.24		0.10	U	0.10	U
10/31/94	551	2.70	B	0.20	JB	4.50		0.10	U	0.20	J
11/08/94	552	0.27	B	0.20	B	0.42		0.10	U	0.10	U
11/21/94	565	0.47	B	0.25	B	0.20		0.10	U	0.10	U
12/21/94	587	0.33	B	0.21	B	4.40		0.10	U	0.10	U
01/05/95	592	0.28	B	0.27	B	3.20		0.10	U	0.10	U
01/17/95	599	0.25	B	0.17	JB	3.80		0.10	U	0.10	U
02/15/95	610	0.10	U	0.22	B	1.30		0.10	U	0.10	U
03/01/95	617	0.22	B	0.24	B	2.40		0.10	U	0.10	U
03/14/95	620	0.22	B	0.19	JB	0.11	J	0.10	U	0.10	U
03/27/95	622	0.21	B	0.40	B	0.21		0.10	U	0.10	U
04/27/95	638	0.20	JB	0.17	JB	0.10	U	0.10	U	0.10	U
05/08/95	645	0.17	J	0.35	B	0.10	U	0.10	U	0.10	U
05/25/95	653	0.20	JB	0.18	JB	0.11	J	0.10	U	0.10	U
06/05/95	659	0.73	B	0.17	JB	0.11	J	0.10	U	0.10	U
07/06/95	672	0.17	JB	0.15	JB	0.14	J	0.10	U	0.10	U
07/19/95	674	0.41	B	0.19	JB	0.11	J	0.10	U	0.10	U
08/01/95	678	0.79	B	0.18	JB	0.12	J	0.10	U	0.10	U
08/14/95	684	0.20	B	0.42	B	0.20	J	0.10	U	0.10	U
09/13/95	693	0.16	JB	0.17	JB	0.10	U	0.10	U	0.10	U
10/09/95	695	0.16	J	0.19	JB	0.10	J	0.10	U	0.10	U
11/07/95	699	0.10	U	0.12	JB	0.10	U	0.10	U	0.10	U
Minimum		0.10	J	0.10	U	0.10		0.06	J	0.09	JB
Maximum		3.30		2.30	B	3800.00		0.19	J	0.43	
Average		0.41		0.31		65.65		0.10		0.11	

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Table BAD-4. WIPP VOC Monitoring Program Data - Station VOC-9

All concentrations in parts per billion

Date	Sample	Trichloro-trifluoro-ethane		Methylene Chloride		Trichloro-ethane		Carbon Tetra-Chloride		Trichloro-ethylene	
09/06/91	42	0.20	B	0.29		8.40		0.11	J	0.10	U
09/11/91	46	2.70	B	1.50		1.80		0.12	J	0.10	U
09/24/91	65	0.45	B	0.19	J	1.30		0.11	J	0.10	U
09/25/91	58	2.50	B	0.19	J	2.10		0.09	J	0.10	U
09/29/91	62	0.21	B	0.19	J	0.27	J	0.07	J	0.10	U
10/03/91	69	0.19	B	2.90		65.00		0.13	J	0.10	U
10/10/91	73	0.15	JB	0.13	J	63.00		0.15	J	0.10	U
10/17/91	83	0.22	B	0.16	J	19.00		0.13	J	0.10	U
10/26/91	77	0.18	JB	0.34		87.00		0.17	J	0.10	U
11/06/91	85	0.28	B	0.53		0.64		0.09	J	0.10	U
11/13/91	95	0.22	B	0.24		19.00		0.11	J	0.10	U
11/21/91	108	0.23		1.10		0.66		0.09	J	0.10	U
11/26/91	98	0.28	B	0.16	J	4.80		0.10	J	0.10	U
12/06/91	111	0.28	B	0.29		0.96		0.10	J	0.30	
12/10/91	117	0.19	JB	0.86		0.61		0.10	J	0.10	U
12/17/91	121	0.48	B	0.15	J	0.33		0.10	J	0.10	U
12/27/91	126	0.19	JB	0.14	J	0.32		0.09	J	0.10	U
12/31/91	130	0.18	JB	0.54		0.34		0.09	J	0.10	U
Minimum		0.15		0.13		0.27		0.07		0.10	
Maximum		2.70		2.90		87.00		0.17		0.30	
Average		0.51		0.55		15.31		0.11		0.11	

Data qualifiers:

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U - indicates the compound was not detected in the sample. The report value is one-half the laboratory reporting detection limit.

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APPENDIX BECR

DOE/WIPP 94-021

Waste Isolation Pilot Plant Biennial Environmental Compliance Report

October 1994

United States Department of Energy
Carlsbad Area Office
Carlsbad, New Mexico

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ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AHERA	Asbestos Hazard Emergency Response Act
ALARA	As Low As Reasonably Achievable
AMR	Annual Mitigation Action Plan Report
AQCR	Air Quality Control Regulation
ASTM	American Society of Testing and Materials
BECR	Biennial Environmental Compliance Report
BLM	Bureau of Land Management
BMP	best management practice
BTU	British thermal unit
C of C	Certificate of Compliance
CAA	Clean Air Act
CAM	continuous air monitor
CAO	Carlsbad Area Office
CAS	Chemical Abstract Service
CEQ	Council of Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
CH	contact-handled
CMR	Central Monitoring Room
CMS	Corrective Measures Study
CWA	Clean Water Act
DAC	derived air concentration
DMR	Discharge Monitoring Report
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
DP	Discharge Plan
DPS	Department of Public Safety
EA	Environmental Assessment
EC&S	Environmental Compliance and Support
ECAP	Environmental Compliance Assessment Program
EDE	effective dose equivalent
EEG	Environmental Evaluation Group
EHS	extremely hazardous substance

EIA	Environmental Impact Assessment; Environmental Improvement Act
EIB	Environmental Improvement Board
EID	Environmental Improvement Division
EIS	Environmental Impact Statement
EMA	Emergency Management Act
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESH&RC	Environment, Safety, Health and Regulatory Compliance Department
FAR	Federal Acquisition Regulation
FAS	fixed air sampler
FEIS	Final Environmental Impact Statement
FFA	Federal Facility Agreement
FFCA	Federal Facility Compliance Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FLPMA	Federal Land Policy and Management Act
FONSI	Finding of No Significant Impact
FOSS	Facility Operations Shift Supervisor
FR	*Federal Register*
FSAR	Final Safety Analysis Report
FWS	U.S. Fish and Wildlife Service
GET	General Employee Training
GP	general permit
gpd	gallons per day
GR	general requirement
GWPA	Ground Water Protection Act
HAP	hazardous air pollutant
hazmat	hazardous material(s)
HCIA	Hazardous Chemicals Information Act
HEPA	high-efficiency particulate air
HMT	hazardous materials training
HMTA	Hazardous Materials Transportation Act
HMTUSA	Hazardous Materials Transportation Uniform Safety Act
HPD	Historic Preservation Division
HSWA	Hazardous and Solid Waste Amendments of 1984
HWA	Hazardous Waste Act
HWMR	Hazardous Waste Management Regulation
HWO	Hazardous Waste Operations

IATA	International Air Transport Association
ICV	inner containment vessel
L	liter
LDR	land disposal restriction
LEPC	Local Emergency Planning Committee (or Coordinator)
LWA	(Waste Isolation Pilot Plant) Land Withdrawal Act
MAP	Mitigation Action Plan
MCL	maximum contaminant level
MOC	Managing and Operating Contractor
MOU	Memorandum of Understanding
mg/L	milligrams per liter
mrem	millirem
MSDS	Material Safety Data Sheet
MVAC	motor vehicle air conditioner
NAAQS	National Ambient Air Quality Standard
NAR	North Access Road
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NMAAQS	New Mexico Ambient Air Quality Standard
NMD	No-Migration Determination
NMDG&F	New Mexico Department of Game and Fish
NMED	New Mexico Environment Department
NMSA	New Mexico Statutes Annotated
NMVP	No-Migration Variance Petition
NOD	Notice of Deficiency
NOI	Notice of Intent
NOT	Notice of Termination
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRCr	National Response Center
NRDC	Natural Resources Defense Council
NuPac	Nuclear Packaging Inc.
NWPA	Nuclear Waste Policy Act
OCA	outer containment assembly
OCV	outer containment vessel
ODC	ozone-depleting chemical

ODS	ozone-depleting substance
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
pCi/m^2-s	picocuries per square meter-second
pd	probability of detection
pfa	probability of false alarm
PL	Public Law
PM	particulate matter
ppm	parts per million
ppmw	parts per million by weight
PPP	Pollution Prevention Plan
PSD	Prevention of Significant Deterioration
PV	proposed variance
PWR	plant work request
QA	Quality Assurance
QAPP	Quality Assurance Program Plan
QAPjP	Quality Assurance Project Plan
QC	Quality Control
QSL	Qualified Supplier List
RCRA	Resource Conservation and Recovery Act
REAC/TS	Radiation Emergency Assistance Center/Training Site
RFI	RCRA Facility Investigation
RH	remote-handled
ROD	Record of Decision
RPP	Radiation Protection Program
RPR	Radiation Protection Regulation
RQ	reportable quantity
RTR	real-time radiography
SAA	satellite accumulation area
SARA	Superfund Amendments and Reauthorization Act of 1986
SARP	Safety Analysis Report for Packaging
SDWA	Safe Drinking Water Act
SEIS	Supplement Environmental Impact Statement
SERC	State Emergency Response Commission
SHPO	State Historic Preservation Officer (or Office)
SIC	Standard Industrial Classification
SIP	State Implementation Plan

SLO	State Land Office
SOP	standard operating procedure
SPCC	Spill Prevention, Control, and Countermeasures Plan
SPDV	Site and Preliminary Design Validation
SR	specific requirement
STEP	States Training and Education Program
SWA	Solid Waste Act
SWB	standard waste box
SWDA	Solid Waste Disposal Act
SWMR	Solid Waste Management Regulation
SWMU	solid waste management unit
SWPPP	Storm Water Pollution Prevention Plan
TAP	toxic air pollutant
TDOP	10-drum overpack
TDS	total dissolved solid
TLD	thermoluminescent dosimeter
TPQ	Threshold Planning Quantity
tpy	tons per year
TRAMPAC	TRUPACT-II Authorized Methods for Payload Control
TRI	Toxic Chemical Release Inventory
TRU	transuranic
TRUCON	TRUPACT-II content codes
TRUPACT-II	Transuranic Package Transporter Model II
TSCA	Toxic Substances Control Act
TSDF	treatment/storage/disposal facility
TSP	total suspended particulate
USFWS	U.S. Fish and Wildlife Service
UIC	underground injection control
UL	Underwriters Laboratories
UN	United Nations
USC	United States Code
UST	underground storage tank
USTR	Underground Storage Tank Regulation
VOC	volatile organic compound
VOST	volatile organic sampling train
WAC	Waste Acceptance Criteria
WID	Westinghouse Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

WPSO	WIPP Project Site Office, U.S. Department of Energy
WQA	New Mexico Water Quality Act
WQCC	Water Quality Control Commission
WSR	Water Supply Regulation

1.0 INTRODUCTION

This *Biennial Environmental Compliance Report* (BECR) addresses regulatory compliance at the Waste Isolation Pilot Plant (WIPP), a research and development facility designed to demonstrate the safe disposal of transuranic (TRU) radioactive waste. As required by the WIPP Land Withdrawal Act [Public Law (PL) 102-579], the BECR documents WIPP's compliance with applicable Federal laws implemented by the U.S. Environmental Protection Agency (EPA). It also addresses compliance with applicable New Mexico laws, regulations, and permit conditions.

1.1 Background of the Waste Isolation Pilot Plant (WIPP)

The WIPP project was authorized by the U.S. Department of Energy (DOE) National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (PL 96-164). This legislation mandated that DOE provide a research and development facility to demonstrate the safe disposal of radioactive waste resulting from U.S. defense activities and programs. Under this statute, the WIPP facility is exempted from regulation by the U.S. Nuclear Regulatory Commission (NRC). Initially, the WIPP mission was to include experimentation with high-level wastes, but subsequent legislation has restricted the radioactive waste to TRU waste. TRU waste is radioactive waste that contains alpha-emitting radionuclides of atomic number greater than 92 with half-lives longer than 20 years which are present in concentrations greater than 100 nanocuries per gram of waste. Most of this waste is generated from plutonium reprocessing and fabrication.

In January 1981, the DOE announced its decision to proceed with a phased development of the WIPP, to be located in Eddy County in southeastern New Mexico, 26 miles east of the City of Carlsbad. The decision called for the WIPP to be designed to accommodate approximately 6.2 million cubic feet of contact-handled (CH) TRU waste and 0.25 million cubic feet of remote-handled (RH) TRU waste. The WIPP Land Withdrawal Act (LWA) has limited the total WIPP capacity to 6.2 million cubic feet of transuranic waste.

After completing a Site and Preliminary Design Validation (SPDV) phase, the construction phase at the WIPP began in 1983. At present, surface and underground facilities to support waste handling and emplacement operations have been completed. Of the nine surface buildings, the largest structure is the Waste Handling Building, which includes areas for the receipt, inventory, inspection, and transfer of waste to the underground. The WIPP underground facility, which is 2,150 feet below the land surface in a 2,000-foot-thick bedded salt formation, consists of four shafts, the waste disposal area, the experimental area (for repository safety and mine performance studies), an equipment and maintenance facility, and connecting tunnels. Only a few waste disposal rooms have been mined at present because of the natural phenomenon of salt creep, which causes eventual room closure. Additional waste disposal rooms will be mined prior to permanent waste emplacement.

Originally, the construction phase was to have been followed by the pilot plant phase. Following the preparation of the Supplement Environmental Impact Statement (SEIS) in 1990, the DOE decided that the construction phase was to be followed by the test phase, during which tests with TRU waste would have been conducted underground at the WIPP. However, on October 21, 1993, the DOE decided not to conduct TRU waste tests underground at the WIPP facility, but to conduct enhanced laboratory tests at existing DOE facilities elsewhere. Thus, no TRU or TRU mixed waste (radioactive waste with hazardous constituents) will be sent to WIPP until after the initiation of the disposal phase. The disposal phase will be followed by the decontamination and decommissioning phase.

More detailed information on the background of the WIPP project can be found in the DOE's *Final Environmental Impact Statement, Waste Isolation Pilot Plant* (FEIS; DOE, 1980); the DOE's 1981 Record of Decision (ROD) to the FEIS (DOE, 1981); the 1990 *Final Supplement Environmental Impact Statement, Waste Isolation Pilot Plant* (SEIS; DOE, 1990a); and the 1990 ROD to the SEIS (DOE, 1990b).

1.2 Biennial Environmental Compliance Report under the WIPP Land Withdrawal Act

This BECR provides the documentation required by the 1992 LWA. The LWA specifies that:

> The Secretary shall, not later than 2 years after the date of the enactment of this Act, and biennially thereafter, submit documentation of continued compliance with the laws, regulations and permit requirements described in paragraph (1) to the Administrator, and, with the law described in paragraph (1)(C), to the State [§ 9(a)(2)].

Paragraph (1) requires that the WIPP comply with Subpart A of 40 CFR Part 191; the Clean Air Act; the Solid Waste Disposal Act (SWDA); the Safe Drinking Water Act; the Toxic Substances Control Act; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); "all other applicable Federal laws pertaining to public health and safety or the environment"; and "all regulations promulgated, and all permit requirements" under these laws. Paragraph (1)(C) requires compliance with the Solid Waste Disposal Act.

1.3 Regulatory Requirements Hierarchy

The first step in documenting regulatory compliance is the identification of all applicable regulatory requirements. This section describes the interrelationships among laws, regulations, and permit conditions and identifies the origins of the detailed regulatory requirements discussed in this report.

1.3.1 Federal/State Laws

Laws result from legislative processes at either the Federal, State, or local level. This report will summarize the purpose of each relevant law and discuss its applicability and importance to the WIPP.

1.3.2 Implementing Regulations

Once a law has been enacted, it must be implemented. Statutory authority for each new act is usually assigned to a particular agency during the legislative process. That agency is responsible for developing regulations to implement the act. At the Federal level, these regulations are first published in the *Federal Register* as "proposed" for comment from interested groups and individuals. The implementing agency must then respond appropriately to the comments and prepare the final regulations. These final regulations are again published in the *Federal Register*, along with a discussion of the comments, and are inserted into the appropriate part(s) of the Code of Federal Regulations (CFR).

New Mexico agencies use a similar process in the promulgation of regulations, with the proposed and final regulations published in the *New Mexico Register*. Many State environmental laws evolve from Federal statutes, many of which mandate that the State become authorized to administer and enforce its own regulatory program in lieu of the Federal program as long as the State regulations are no less stringent than the Federal requirements. In these cases, the State must send its "final" regulations to the U.S. Environmental Protection Agency (EPA) for approval. The EPA may approve all, part, or none of the final regulations. After EPA approval, notification of EPA's authorization of the State program is published in the *Federal Register*.

Local laws or ordinances that apply to the WIPP are limited to those under the authority of the county commission. The only local laws or ordinances applicable to the facility are zoning ordinances. These do not affect the facility's ability to protect human health and the environment. Therefore, these laws and ordinances are not included in this report.

This report identifies specific requirements from Federal/State implementing regulations that apply to the WIPP facility. In some cases where implementing regulations have not been promulgated or where a particular statute requirement is not covered by the implementing regulations, this report identifies specific requirements directly from the statute.

1.3.3 Permit Conditions

A number of Federal/State implementing regulations include permit programs. Because many implementing regulations are couched in general terms, permits and permit programs allow the regulatory agency to regulate individual facilities and stipulate site-specific conditions that must be met by a specific facility in order to meet the statutory goals of protection of the public and the environment. Thus, permits are used to regulate discharges and activities (construction, modifications, and/or operations) of a facility. This report identifies site-specific permit conditions that apply to the WIPP.

1.4 Regulatory Compliance at the WIPP

The DOE and the Westinghouse Waste Isolation Division (WID), the Managing and Operating Contractor (MOC) for the WIPP, are fully committed to conducting operations at the WIPP in such a manner as to achieve and demonstrate compliance with applicable regulations and permit conditions. Both organizations have implemented plans and procedures to achieve and maintain compliance with the regulations and have established aggressive assessment programs to validate continued successful implementation of these activities.

In a number of areas throughout this document, it is noted that procedures and manuals are in place to guide and direct WID personnel in the performance of specific job tasks which have or could have a direct impact on the compliance status in a given situation. These procedures and manuals are in place to supplement personnel training, education, and qualifications and to promote the operation of the WIPP facility in a safe and environmentally sound manner. Because this is the intended purpose of these documents, they are continually evaluated and revised to ensure that they are effective and current with respect to both regulatory and operational changes. For this reason, specific procedures and manuals are not referenced in the body of this document.

In addition, a number of reports (especially those reports which are a result of regulatory requirements) are referenced throughout the document. Due to the continual update and revision requirements for reports of this nature, they are referenced only by the report title or by the citation that requires their submittal rather than by document numbers.

1.4.1 Organizational Structure

The organizational structure of the DOE WIPP Carlsbad Area Office (CAO) and WID reflect the importance of regulatory compliance at the WIPP and the commitment of both organizations to achieving and maintaining full compliance.

The backbone of DOE CAO's organization for the WIPP consists of the Area Manager who oversees the five major branches: the Administrative Branch, the Compliance Branch, the Experimental Programs Branch, the WIPP Site Branch, and the National TRU Program Office. The Chief of the Compliance Branch is responsible for overall strategy and criteria to demonstrate and validate long-term compliance for the disposal of TRU waste and leads the preparation of the repository compliance package. The Chief of the WIPP Site Branch oversees the environment, safety, and health activities related to site operations. The Chief of the Environment, Safety, and Health Section addresses additional compliance activities and reports to the Chief of the WIPP Site Branch. The Chief of the Compliance Branch provides additional oversight in the areas of quality assurance for compliance-related activities.

WID's commitment to compliance is also represented in their organizational structure, consisting of the General Manager, the Deputy Manager, and nine department managers. The Department Manager of Environment, Safety, Health, and Regulatory Compliance reports directly to the General Manager and provides the management necessary for WID's compliance responsibilities. The Department Manager for Quality Assurance provides support to ensure that compliance activities are managed and performed in a manner consistent with WID's commitment to compliance.

1.4.2 Compliance Activities

Compliance includes a wide range of activities, ranging from the preparation of plans, procedures, reports, or permit applications to hands-on actions such as recordkeeping, monitoring, sampling and analysis, performing assessments or audits, and housekeeping. The compliance activities carried out at the WIPP to fulfill applicable regulatory requirements are identified in this report. In addition, plans and reports that have been established to maintain compliance at the WIPP are identified and discussed, and applicable manuals and procedures are mentioned.

Where appropriate, plans and procedures have been established to address compliance. Inspections and audits of related activities are conducted to demonstrate the effectiveness of these plans and procedures. WID has an aggressive Environmental Compliance Assessment Program (ECAP), which provides a comprehensive system to appraise compliance with applicable environmental statutes and requirements at the WIPP and to identify operationally feasible and environmentally sound corrective action measures for any procedural non-conformance or observation identified. The ECAP is designed around five compliance assessment processes: (1) environmental compliance appraisals, (2) environmental audits, (3) independent review group evaluations, (4) environmental event evaluations, and (5) environmental compliance status tracking and reporting.

The ECAP represents a substantial commitment by WID in compliance appraisal activities. The ECAP is expected to enhance protection of public health and the environment by discovering and eliminating any WIPP programmatic, procedural, and operational deficiencies that could lead to (1) permit violations; (2) regulatory noncompliance; (3) safety and health risks to WIPP site workers and/or the public; and (4) spills, releases, or discharges of environmental pollutants. This BECR will summarize the results of completed compliance assessments as they apply to overall WIPP compliance.

1.5 Organization of and Reporting Period for the Report

The organization of and reporting period for the BECR are discussed in the following subsections.

1.5.1 Organization of the Report

This report organizes the pertinent regulatory requirements into 14 parts, each of which corresponds to a Federal or State agency that is authorized to administer regulatory programs. Under each agency, separate chapters identify and discuss each law administered by the agency that is relevant to the WIPP facility. For example, the first part contains all pertinent regulatory programs administered by the EPA. Within this part, 10 chapters correspond to the 10 environmental laws and sets of regulations that apply to the WIPP for which the EPA is responsible (Chapters 2 through 11).

Each of the following 37 chapters summarizes a law and its implementing regulations and briefly describes their applicability to the WIPP. For ease in identifying compliance status, summary tables in each chapter provide a synopsis of WIPP's compliance with each specific requirement and a cross-reference to the more detailed discussion in the text. Each section of the text discussion summarizes a requirement and addresses its compliance status. Compliance status is identified as "achieved," "up to date," or "not applicable":

ACHIEVED — Items with the status of "achieved" are requirements that have been met and do not require any further action. They are essentially "one-time" occurrences.

Example: As a generator of hazardous waste, WIPP must obtain an EPA ID number; this requirement has been achieved.

UP TO DATE Items with the status of "up to date" are requirements that require some type of ongoing activity to maintain compliance.

Example: The DOE must file a biennial hazardous waste report; these reports are up to date.

NOT APPLICABLE Items with the status of "not applicable" were evaluated and determined not to be applicable to the WIPP either during this reporting period or throughout the duration of the project.

Example: Since the WIPP disposes of its construction and demolition debris at a landfill located on DOE property and in accordance with the applicable regulations, the requirement for obtaining a permit is not applicable.

Following the list of references, Appendix A presents an index of the specific requirements discussed in the report by regulating agency. Appendix B indexes the specific requirements in terms of their technical subject areas (for example, waste management requirements, water quality requirements, historic preservation requirements).

1.5.2 Reporting Period

This first BECR sets forth the status of WIPP compliance during the period from the Congressional approval of the WIPP LWA on October 30, 1992, to the March 31, 1994, cutoff date. Future BECRs will address the compliance status of WIPP programs and activities for the reporting period beginning April 1 and ending on March 31 two years later. The purpose for establishing a cutoff date is to provide consistency in the reporting period from year to year and to provide sufficient time to prepare and review the biennial report prior to its submittal to the EPA and the State of New Mexico.

2.0 RESOURCE CONSERVATION AND RECOVERY ACT AND SOLID WASTE DISPOSAL ACT

2.1 Summary of the Law

The Resource Conservation and Recovery Act (RCRA; 42 §§ USC 6901 et seq.) is a statute designed to provide "cradle-to-grave" control of hazardous waste by imposing management requirements on generators and transporters of hazardous wastes and on the owners and operators of treatment/storage/disposal facilities (TSDFs). RCRA applies primarily to active facilities; abandoned and inactive sites are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund; see Chapter 3).

The legislative history of RCRA was initiated in 1965 when Congress enacted the Solid Waste Disposal Act (SWDA; PL 89-72; 42 USC §§ 3251 et seq.). This law dealt with solid waste disposal and gave the States the responsibility for developing solid waste management plans. In 1970, Congress passed the Resource Recovery Act (PL 91-512) to provide the U.S. Environmental Protection Agency (EPA) with funding for resource recovery programs. The Resource Conservation and Recovery Act of 1976 (PL 94-580) completely replaced the SWDA and incorporated the intent of the Resource Recovery Act. A number of minor amendments were added during the next few years. The Hazardous and Solid Waste Amendments of 1984 (HSWA; PL 98-616) reauthorized RCRA, expanded its scope significantly, and altered many of its provisions. The term "RCRA" will be used throughout this document to refer to the reauthorized law as amended.

There are two major objectives of RCRA. The first is to promote the protection of health and the environment and to conserve material and energy resources. This objective is to be accomplished through such means as ensuring that hazardous waste management practices are conducted so as to protect human health and the environment, minimizing the generation of hazardous waste, prohibiting open dumping on the land, and requiring existing open dumps to be converted to facilities that pose no danger to the environment or health. The second objective of RCRA is to set national policy to reduce or eliminate the generation of hazardous waste as expeditiously as possible and to ensure that any hazardous waste generated be treated, stored, or disposed of so as to minimize the present and future threat to human health and the environment.

The EPA implements RCRA primarily through the 40 CFR Part 260-280 series. Parts 260-270 of Title 40 of the Code of Federal Regulations (CFR) consist of requirements and standards pertaining to solid waste, particularly hazardous waste; 40 CFR Parts 280-281 pertain to the management of underground storage tanks (USTs) containing petroleum products or hazardous chemicals.

Congress intended for the RCRA program to be implemented by States. Consequently the EPA has defined a process through which States may apply for and receive authorization to administer the RCRA program. New Mexico received authorization for the base RCRA program in

January 1985. New Mexico administers its program through the Hazardous Waste Management Regulations (HWMRs). By virtue of this authorization, New Mexico has primary authority for most aspects of the RCRA program.

The Federal Facility Compliance Act of 1992 (FFCA; 42 USC 6961) subjects the DOE to the requirements of RCRA or State hazardous waste programs. However, WIPP is not currently subject to the requirements for fees, inventory reporting, reporting the status of treatment capacity and technology (site treatment plans), or other FFCA requirements. Even though WIPP is subject to the Land Disposal Restrictions (LDRs) (and, as such, DOE has opted to obtain a variance from treatment standards prior to disposal), the WIPP will not generate or treat mixed waste subject to the requirements of the FFCA during operation. Therefore, these requirements are not addressed further in this report.

During this reporting period, WID conducted an operational readiness review (ORR) of WIPP operations and activities to verify that WIPP has completed those actions necessary to receive shipments of transuranic/mixed waste in support of Type I bin testing. This review included performance-based inspections to augment the numerous affidavit reviews performed by the ORR team. The ORR team was comprised of experienced WID staff who were removed from their duties. The team was supplemented by contract technical experts as required. The ORR affidavits that are mentioned in this document refer to signed statements that certify compliance with established acceptance criteria. These affidavits have been mentioned in this report to provide additional documentation of compliance to specific requirements. Completed affidavits and supportive documentation are handled, stored, and archived as permanent quality assurance records.

Because of the complexity of the regulations and requirements under RCRA, Table 2-1 is presented to assist the reader. This table shows the location of the RCRA-related requirements in this BECR by section and table numbers. The Federal requirements are presented in this chapter; the State RCRA-related requirements are incorporated in Chapter 25, under the New Mexico Environment Department (NMED). The conditions and requirements from the EPA's No-Migration Determination are also included in this table.

TABLE 2-1. Index of Requirements Pertaining to RCRA in the BECR

Citation	Title	BECR Section
The Resource Conservation and Recovery Act (RCRA), 42 USC §§ 6901 et seq.		
RCRA, § 3016	Inventory of Federal hazardous waste facilities	2.2.1
Regulations Implementing RCRA		
40 CFR Part 262; HWMR-7, Part III	Standards Applicable to Generators of Hazardous Waste	25.2.2
40 CFR Part 263; HWMR-7, Part IV	Standards Applicable to Transporters of Hazardous Waste	25.2.3
40 CFR Part 264; HWMR-7, Part V	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	Not applicable
40 CFR Part 265; HWMR-7, Part VI	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	25.2.4
40 CFR Part 268	Land Disposal Restrictions	2.2.2
40 CFR Part 270; HWMR-7, Part IX	EPA Administered Permit Programs: the Hazardous Waste Permit Program	25.2.5
EPA's Proposed Variance and Conditional No-Migration Determination (NMD)		
55 FR 13068, 4/6/90	Specific conditions under the proposed variance	2.3
Section VI, 55 FR 47700, 11/14/90	Specific conditions of the NMD	2.3

TABLE 2-1 (continued)

Citation	Title	BECR Section
55 FR 47700, 11/14/90	General conditions of the NMD	2.3
Requirements for and Registration of Underground Storage Tanks (USTs)		
40 CFR Part 280; USTR-1 through 14	New Mexico Underground Storage Tank Regulations	25.2.6
NMSA 74-6B-1 through 74-6B-14	New Mexico Ground Water Protection Act	28 and 25.2.2

RCRA provides direction for the management of solid and hazardous waste. It should be noted that waste defined as hazardous under RCRA (40 CFR Part 261, *Identification and Listing of Hazardous Waste*) does not include radionuclides. Thus, mixed waste, which consists of radioactive waste with hazardous constituents, is regulated under both the Atomic Energy Act (for the radionuclides) and RCRA (for the hazardous constituents).

Requirements and conditions related to the EPA's land-disposal restrictions are codified in 40 CFR Part 268 and are applicable to the WIPP facility. Under the 1984 HSWA, the land disposal of hazardous wastes not meeting EPA-imposed treatment standards is prohibited unless it can be demonstrated "to a reasonable degree of certainty" that there will be "no migration of hazardous constituents from the disposal unit . . . for as long as the wastes remain hazardous" [RCRA § 3004(d)(1)]. Section 40 CFR 268.6 allows for a variance from the land disposal restrictions when the applicant can make the required demonstration of no migration.

Because the proposed activity at the WIPP consists of placement "in or on the land," 40 CFR Part 268 applies. Consequently, the DOE submitted a petition to EPA headquarters for a no-migration variance in March 1989. On April 6, 1990, the EPA published the proposed variance for WIPP (EPA, 1990a). The EPA's decision to grant the final Conditional No-Migration Determination for WIPP (NMD) was published on November 14, 1990 (EPA, 1990b).
One section of RCRA governs the management of underground storage tanks (USTs). This portion of RCRA and the regulations specified under 40 CFR Parts 280 and 281 address USTs containing petroleum products or hazardous chemicals. (Requirements for tanks containing hazardous wastes are specified under Subpart J of 40 CFR Parts 264 and 265.) Requirements for UST management pertain to the design, construction, installation, and operation of USTs as

well as notification and corrective action requirements in the event of a release and actions required for out-of-service USTs.

The NMED has been authorized by the EPA to regulate USTs. Therefore, the State UST requirements and the compliance status for each requirement are presented in Chapter 25 of this report.

2.2 Compliance Status of the Regulatory Requirements

This section provides information on requirements of RCRA and of the EPA's regulations implementing this act. Each subsection contains a summary table with the requirement and the compliance status, and more detailed information is provided in the text.

2.2.1 Compliance with the Resource Conservation and Recovery Act

Nearly all of the requirements specified in RCRA are covered in more detail in the implementing regulations. The exception is § 3016 of the act, which requires each Federal agency to provide a biennial inventory of its TSDFs (see Table 2-2).

TABLE 2-2. The RCRA Requirements Not Covered by Implementing Regulations - Compliance Status

Citation	Requirement	Compliance Status
§ 3016	Inventory of Federal hazardous waste facilities	UP TO DATE Report filed biennially in even-numbered years [Section 2.2.1.1]

2.2.1.1 Inventory of Federal Hazardous Waste Facilities, § 3016

The DOE files the hazardous waste inventory report with the EPA and the NMED biennially (on even-numbered years) as required by § 3016 of RCRA. The most recent of these reports was submitted in 1994.

2.2.2 Compliance with the Land Disposal Restriction (LDRs), 40 CFR Part 268

This section is limited to those EPA regulations implementing RCRA that are directly applicable to the WIPP. Regulations implementing other portions of RCRA for which the State of New Mexico is authorized are found in Chapter 25.

The compliance status of each of the applicable land-disposal restrictions of 40 CFR Part 268 is summarized in Table 2-3. Detailed information is provided in the text.

TABLE 2-3. RCRA Land-Disposal Restrictions - Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 268.1	Purpose, scope, and applicability	ACHIEVED *WIPP No-Migration Variance Petition* (NMVP); No-Migration Determination (NMD) [Section 2.2.2.1]
40 CFR 268.6(a)	Submittal of petitions to allow land disposal of a waste prohibited under Subpart C of Part 268	ACHIEVED NMVP [Section 2.2.2.2]
40 CFR 268.6(b)	Requirements of demonstration of no-migration in petition	ACHIEVED NMVP [Section 2.2.2.3]
40 CFR 268.6(c)	Contents of petition	ACHIEVED NMVP [Section 2.2.2.4]

TABLE 2-3 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 268.6(d)	Submittal of petition to EPA Administrator	**ACHIEVED** NMVP [Section 2.2.2.5]
40 CFR 268.6(e)	Consistency of activities with those described in the petition and notification of EPA of changes in conditions at the unit and/or in the environment	**UP TO DATE** Westinghouse Waste Isolation Division (WID) procedure [Section 2.2.2.6]
40 CFR 268.6(f)	Activities required if hazardous constituents are found to have migrated from the repository	**NOT APPLICABLE** No waste emplaced at WIPP [Section 2.2.2.7]
40 CFR 268.6(g)	Certification in petition	**ACHIEVED** NMVP; certification signature [Section 2.2.2.8]
40 CFR 268.6(h)	Additional information requested by Administrator	**ACHIEVED** Two addenda to the NMVP [Section 2.2.2.9]
40 CFR 268.6(k)	Terms of variance	**ACHIEVED** NMD for test phase; up to November 14, 2000 [Section 2.2.2.10]

TABLE 2-3 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 268.6(n)	Non-exemption of liquid hazardous wastes containing $\geq$ 500 ppm polychlorinated biphenyls (PCBs)	**UP TO DATE** Prohibition of liquids by *WIPP Waste Acceptance Criteria* [Section 2.2.2.11]
40 CFR 268.7	Waste analysis and recordkeeping	**UP TO DATE** WID procedures [Section 2.2.2.12]
40 CFR 268.8	Landfill and surface impoundment disposal restrictions	**UP TO DATE** WIPP generated LDR waste treated prior to disposal [Section 2.2.2.13]
40 CFR 268.9	Special rules regarding wastes that exhibit a characteristic	**UP TO DATE** NMD received for test phase [Section 2.2.2.14]
40 CFR 268.10-12	Identification of waste to be evaluated by August 8, 1988; by June 8, 1989; and by May 8, 1990	**NOT APPLICABLE** No treatment standard for mixed waste; NMD received for test phase [Section 2.2.2.15]

TABLE 2-3 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 268.30	Waste-specific prohibitions--solvent wastes	**UP TO DATE** WIPP generated solvent wastes receive treatment prior to TSDF land disposal [Section 2.2.2.16]
40 CFR 268.31	Waste-specific prohibitions--dioxin-containing wastes	**NOT APPLICABLE** NMD [Section 2.2.2.17]
40 CFR 268.32	Waste-specific prohibitions--California-listed wastes	**UP TO DATE** WIPP generated California-listed wastes receive treatment prior to TSDF land disposal [Section 2.2.2.18]
40 CFR 268.33	Waste prohibitions--first-third wastes	**UP TO DATE** WIPP generated first-third wastes receive treatment prior to TSDF land disposal [Section 2.2.2.19]
40 CFR 268.34	Waste prohibitions--second-third wastes	**UP TO DATE** WIPP generated second-third wastes receive treatment prior to TSDF land disposal [Section 2.2.2.20]

TABLE 2-3 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 268.35	Waste prohibitions--third-third wastes	**UP TO DATE** WIPP generated third-third wastes receive treatment prior to TSDF land disposal [Section 2.2.2.21]
40 CFR 268.41	Treatment standards expressed as concentrations in waste extract	**UP TO DATE** WIPP provides appropriate treatment standards on the notification and/or certification forms that accompany each shipment of LDR wastes. WIPP does not treat site generated hazardous wastes [Section 2.2.2.22]
40 CFR 268.42	Treatment standards expressed as specified technologies	**UP TO DATE** WIPP provides appropriate treatment standards on the notification and/or certification forms that accompany each shipment of LDR wastes. WIPP does not treat site generated hazardous wastes [Section 2.2.2.23]

TABLE 2-3 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 268.43	Treatment standards expressed as waste concentrations	**UP TO DATE** WIPP provides appropriate treatment standards on the notification and/or certification forms that accompany each shipment of LDR wastes. WIPP does not treat site generated hazardous wastes [Section 2.2.2.24]
40 CFR 268.44	Variance from a treatment standard	**NOT APPLICABLE** No treatment standards for mixed waste [Section 2.2.2.25]
40 CFR 268.50	Prohibitions on storage of restricted wastes	**UP TO DATE** WID procedures and manuals [Section 2.2.2.26]

2.2.2.1 Purpose, Scope, and Applicability, 40 CFR 268.1

The hazardous wastes restricted from land disposal are specified in this chapter. Limited circumstances are described under which an otherwise prohibited waste may continue to be land disposed.

The requirements of 40 CFR Part 268 apply to generators and to the owners and operators of hazardous waste TSDFs. Therefore, WIPP is subject to 40 CFR Part 268. WID procedures are in place for identifying and characterizing hazardous waste generated at the facility.

With respect to WIPP as a TSDF, restricted waste may continue to be placed in a salt-bed formation when an exemption from a prohibition pursuant to a petition under 268.6 has been granted. WIPP obtained such an exemption for the test phase during which TRU mixed waste was to be tested at WIPP [i.e., the EPA's *Conditional No-Migration Determination for the WIPP Test Phase* (NMD) dated November 14, 1990]. In the wake of the DOE's decision to test TRU and TRU mixed waste only at non-WIPP facilities, some of the conditions specified in the EPA's NMD no longer apply (see Section 2.3 of this chapter).

2.2.2.2 Submittal of Petitions to Allow Land Disposal of Prohibited Waste, 40 CFR 268.6(a)

A petition may be submitted to the Administrator requesting land disposal of a waste that is prohibited under Subpart C of Part 268. The petition must demonstrate, with a reasonable degree of certainty, that there will be no migration of hazardous constituents from the unit as long as the wastes remain hazardous.

The *WIPP No-Migration Variance Petition* (NMVP) was submitted to the EPA in January 1990 and revised in March 1990 (DOE, 1990f). The EPA granted the NMD for the test phase in November 1990 (EPA, 1990b). Another petition must be prepared for the disposal phase and EPA approval obtained before TRU mixed waste may be received at WIPP.

2.2.2.3 Criteria for the Demonstration of No-Migration in Petition, 40 CFR 268.6(b)

A number of criteria for demonstrating no-migration in the petition are specified.

All criteria specified were met in the WIPP NMVP, as demonstrated by the EPA's granting of the NMD for the test phase at WIPP.

Since the NMVP and the NMD pertained only to the testing of TRU and TRU mixed waste at WIPP during the test phase, a new NMVP must be submitted to the EPA for the disposal phase at WIPP. One of the requirements that must be completed prior to the implementation of the disposal phase is the EPA's publication of a variance for this phase.

2.2.2.4 Contents of Petition, 40 CFR 268.6(c)

> *Each petition must include a monitoring plan for the monitoring program required to verify continued compliance with the conditions of the variance; baseline monitoring prior to receipt of the prohibited waste; submittal of the monitoring data to the Administrator; retention of the data on site in the operating record; and the Administrator's approval of all sampling, testing, and analytical data as well as of all estimation and monitoring techniques and the quality assurance and quality control plan for the monitoring program.*

The NMVP submitted to the EPA in March 1990 contained all topics required in such a petition. These topics included the monitoring program and plan for volatile organic compounds (VOCs) (NMVP, Section 2.8; Appendices H, I, J, and K; and Chapter 6 of the addendum to the NMVP); baseline monitoring prior to receipt of the prohibited waste (NMVP Addendum, Chapter 6); submittal of monitoring data to the Administrator (NMVP Addendum, Chapter 6); and retention of the data in the operating record on site (WID procedure). The estimation and monitoring techniques and the quality assurance/quality control (QA/QC) program for the VOC monitoring program were included in the NMVP; their approval by the Administrator is implied by the EPA's publication of the NMD. The Administrator's approval of WIPP's sampling, listing, and analytical data is predicated upon EPA approval of the annual VOC monitoring report required by the NMD (see Section 2.3).

2.2.2.5 Submittal of Petition to EPA Administrator, 40 CFR 268.6(d)

> *Each petition must be submitted to the EPA Administrator.*

In March 1989, the DOE submitted the NMVP to the EPA. In response to requests for additional information from the EPA, the DOE submitted two addenda to the NMVP, one on October 1, 1989, the other on January 22, 1990. For the convenience of commentors, the various portions of the petition and addenda were consolidated and reprinted as a single eight-volume document dated March 1990.

The EPA published its *Notice Proposing to Grant a Conditional Variance to the Department of Energy Waste Isolation Pilot Plant (WIPP) for Land Disposal Restrictions* in the *Federal Register* on April 6, 1990 (EPA, 1990a); the *Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant (WIPP)* was published on November 14, 1990 (EPA, 1990b). (See Section 2.3 for the conditions imposed on WIPP by these documents.)

2.2.2.6 Consistency of Activities with those Described in the Petition and Notification of EPA of Changes in Conditions, 40 CFR 268.6(e)

After a petition has been approved, any changes in conditions at the unit or the environment around the unit that significantly depart from the conditions described in the variance and affect the potential for migration of hazardous constituents from the unit must be reported.

A WID procedure has been prepared and implemented for reviewing changes (either planned or unplanned) in conditions at WIPP and/or the surrounding environment that may significantly depart from conditions described in the NMD and affect the potential for migration of hazardous constituents beyond the unit boundary. The purpose of this procedure is to ensure that such changes or proposed changes will trigger notification of the DOE, which will notify the EPA in accordance with 40 CFR 268.6(e) and (f). Any deliberate plans to modify or add to the procedures and conditions (e.g., experimental test plans, repository design, construction, and operations) set forth in the *WIPP Test Phase Plan: Performance Assessment* (DOE, 1990c) or the NMD constitute "planned changes." Action taken to mitigate the effects of unintentional deviations from what was modeled or predicted in the *WIPP Test Phase Plan: Performance Assessment* or the NMD are unplanned changes. Unplanned changes may be related to repository performance (e.g., revised understanding of site geology and hydrology characteristics due to new data, facility design and operations, predicted environmental impacts, modeled uncertainty analyses) or the migration of hazardous constituents.

The Administrator must be notified in writing at least 30 days prior to making any proposed change. The requirement states that the Administrator will determine whether the change invalidates the terms of the petition and will determine the appropriate response. In addition, any change must be approved by the Administrator prior to being made. If a condition at the site that was modeled or predicted in the petition does not occur as predicted, the Administrator must be notified in writing within 10 days of the discovery of the change. If conditions do not occur as modelled or predicted, the Administrator will determine any further action, including termination of waste acceptance and revocation of the petition, petition modification, or other actions.

2.2.2.7 Activities Required if Hazardous Constituents Migrate, 40 CFR Part 268.6(f)

If hazardous constituents are found to have migrated from the repository, receipt of prohibited waste at the unit must be suspended immediately, and the Administrator must be notified in writing within 10 days of the determination that a release occurred. Within 60 days of the receipt of the notification, the Administrator will determine whether the facility may continue receiving prohibited waste in the unit, whether the variance is to be revoked, and whether further examination of any migration is warranted under applicable provisions of 40 CFR Part 264 or 265.

In the event that hazardous constituents are found to have migrated from the unit, a WIPP procedure will be invoked, according to which the DOE is responsible for arranging the immediate suspension of the receipt of restricted waste. The DOE is also responsible for notifying the EPA Regional Administrator within the required time frame.

2.2.2.8 Certification in Petition, 40 CFR 268.6(g)

Each petition must include a signed certification statement indicating the completeness and accuracy of the information included.

A signed certification accompanied the submittal of the NMVP to the EPA.

2.2.2.9 Additional Information Requested by the Administrator, 40 CFR 268.6(h)

The Administrator may request additional information to evaluate the demonstration.

Additional information was requested by the EPA after the DOE submitted the original NMVP in March 1989. The additional information was provided to the EPA on October 1, 1989. Additional requests for information from the EPA resulted in the preparation and submittal of a second addendum in January 22, 1990. (See also response in Section 2.2.2.5.)

2.2.2.10 Length of Variance, 40 CFR 268.6(k)

The term of a variance granted by the EPA will be no longer than the term of the RCRA permit or up to 10 years from the date of approval for an interim-status TSDF.

The NMD provides for a 10-year term for the variance (i.e., through November 14, 2000).

2.2.2.11 Non-Exemption of Liquid Hazardous Wastes Containing PCBs, 40 CFR 268.6(n)

Liquid hazardous wastes containing $\geq$ 500 ppm of polychlorinated biphenyls (PCBs) are not eligible for an exemption under this section.

The *WIPP Waste Acceptance Criteria* (WAC; DOE, 1991b) allow only residual liquids, not to exceed 1 percent of the volume of the internal container. Furthermore, there are no plans to accept PCBs or PCB-containing wastes at WIPP.

2.2.2.12 Waste Analysis and Recordkeeping, 40 CFR 268.7

Waste analysis and recordkeeping requirements include the retention of any notices and certifications from the generator site that the waste meets the treatment standards of Subpart D and the results of the testing of the waste or of an extract of the waste to ensure that the wastes are in compliance with the treatment standards. The testing must be performed in accordance with the facility's waste analysis plan.

No treatment standards currently exist for mixed waste; therefore, no such notices and certifications are anticipated from the generator sites. Prior to the initiation of the disposal phase at WIPP, the DOE will submit a variance petition for disposal to the EPA. If the EPA grants a variance for the disposal phase, the DOE will be allowed to ship untreated TRU and TRU mixed waste to WIPP upon completion of all other pre-disposal-phase requirements.

Sampling and analysis will be conducted at the generator sites as addressed in the *Waste Analysis Plan* (DOE, 1993d), the *Waste Characterization Program Sampling and Analysis Guidance Manual* (DOE, 1992a), and the *Quality Assurance Program Plan for the Experimental Waste 2 Characterization Program* (DOE, 1991d). Sampling consists of visual examination (including weighing of individual items), real-time radiography, and headspace gas sampling of drums and

of the inner containers within the drums. Samples are analyzed for both organic and inorganic constituents. Process knowledge will also be used where possible.

The amount of sampling and analysis to be done at WIPP must be determined. However, minimizing the opening of the drums containing TRU and TRU mixed waste will minimize the potential for contamination at WIPP.

As a generator of land disposal restricted waste, WIPP provides with each shipment, the appropriate notification and/or certification forms to the TSDF accepting the waste. WID procedures provide guidance regarding compliance with the generator requirements under this part (see also Chapter 25 on compliance with 40 CFR 262.40).

2.2.2.13 Landfill and Surface Impoundment Disposal Restrictions, 40 CFR 268.8

> *Specific disposal restrictions apply to landfills and surface impoundments. Generators must make a good faith effort to locate and contract with treatment and recovery facilities prior to disposing of hazardous waste in landfills and surface impoundments.*

As a generator, WIPP has provisions in place for shipping its hazardous waste to treatment and/or recovery facilities. Surface impoundments are not used.

WIPP will not manage TRU mixed waste using surface impoundments or landfills. Thus, the disposal restrictions for landfills and surface impoundments do not apply to WIPP as a TSDF.

2.2.2.14 Special Rules Regarding Wastes Exhibiting a Characteristic, 40 CFR 268.9

> *Special rules have been promulgated regarding wastes that exhibit a characteristic. The generator of the waste must determine the EPA Hazardous Waste Number for the waste to ascertain the applicable treatment standard under Subpart D of 40 CFR Part 268.*

WIPP personnel determine the appropriate EPA Hazardous Waste Number for all hazardous waste generated at WIPP. This information is included on the manifest that is sent to the TSDF that will receive the waste.

The requirements of 40 CFR 268.9 are not applicable to WIPP as a TSDF. No treatment standards currently exist for mixed waste. A variance from these requirements similar to the NMD for the test phase at WIPP will be needed for the disposal phase.

Waste generated at WIPP will be handled in accordance with WID procedures. These procedures provide guidance regarding compliance with the generator requirements (see also Chapter 25 on compliance with 40 CFR 262.40).

2.2.2.15 Identification of Waste to be Evaluated, 40 CFR 268.10-12

> *Wastes to be evaluated for land-disposal prohibition and establishment of treatment standards were divided into three thirds. Mixed waste, which was to have been evaluated by May 8, 1990, was included in the "third third."*

No treatment standards have been devised for mixed waste. Therefore, the emplacement of any mixed waste at WIPP will require a variance from the requirement for treatment prior to shipment to WIPP. The mixed wastes expected to be received at WIPP for disposal will be listed in Part A of the RCRA permit application for the disposal phase.

2.2.2.16 Waste-Specific Prohibitions--Solvent Wastes, 40 CFR 268.30

> *Solvent wastes are prohibited from land disposal unless they are treated in accordance with the treatment standards of Subpart D.*

WIPP generated solvent wastes receive treatment prior to land disposal.

The EPA granted a variance from the treatment standards for the test phase in the NMD.

2.2.2.17 Waste-Specific Prohibitions--Dioxin-Containing Wastes, 40 CFR 268.31

> *Dioxin-containing wastes are prohibited from land disposal unless they are treated in accordance with the treatment standards of Subpart D.*

No dioxin-containing wastes are generated at WIPP.

The EPA granted a variance from the treatment standards for the test phase in the NMD.

2.2.2.18 Waste-Specific Prohibitions--California-Listed Wastes, 40 CFR 268.32

California-listed wastes are prohibited from land disposal unless they are treated in accordance with the treatment standards of Subpart D.

WIPP generated California-listed wastes receive treatment prior to land disposal.

The EPA granted a variance from the treatment standards for the test phase in the NMD.

2.2.2.19 Waste Prohibitions--First-Third Wastes, 40 CFR 268.33

First-third wastes are prohibited from land disposal unless they are treated in accordance with the treatment standards of Subpart D.

WIPP generated first-third wastes receive treatment prior to land disposal.

The EPA granted a variance from the treatment standards for the test phase in the NMD. Since mixed wastes are categorized as third-third wastes, see Section 2.2.2.21.

2.2.2.20 Waste Prohibitions--Second-Third Wastes, 40 CFR 268.34

Second-third wastes are prohibited from land disposal unless they are treated in accordance with the treatment standards of Subpart D.

WIPP generated second-third wastes receive treatment prior to land disposal.

The EPA granted a variance from the treatment standards for the test phase in the NMD. Since mixed wastes are categorized as third-third wastes, see Section 2.2.2.21.

2.2.2.21 Waste Prohibitions--Third-Third Wastes, 40 CFR 268.35

Third-third wastes are prohibited from land disposal unless they are treated in accordance with the treatment standards of Subpart D.

WIPP generated third-third wastes receive treatment prior to land disposal.

In the NMD, the EPA granted a variance from the treatment standards for the test phase at WIPP. A new variance or treatment of mixed waste will be required prior to WIPP's acceptance of TRU mixed waste at WIPP during the disposal phase.

2.2.2.22 Treatment Standards Expressed as Concentrations in Waste Extract, 40 CFR 268.41

Treated waste must meet the treatment standards expressed as concentrations in waste extract for the waste to be land disposed.

The EPA granted a variance (i.e., the NMD) from the treatment standards for mixed waste land disposal at WIPP during the test phase. A new variance will be required from the EPA prior to WIPP's acceptance of TRU mixed waste during the disposal phase.

The WIPP facility does not treat site-generated hazardous waste subject to land disposal regulations. It does, however, provide the appropriate treatment standards on the notification and/or certification forms that accompany each shipment of LDR waste. (see 2.2.2.12)

2.2.2.23 Treatment Standards Expressed as Specified Technologies, 40 CFR 268.42

Certain wastes must be treated with the technologies specified in this section for the wastes to be land disposed.

The EPA granted a variance (i.e., the NMD) from the treatment standards for mixed waste land disposal at WIPP during the test phase, when TRU mixed wastes were to have been tested at WIPP. A new variance from the EPA will be required prior to WIPP's acceptance of TRU mixed waste during the disposal phase. Therefore, these requirements are not applicable.

The WIPP facility does not treat site-generated hazardous waste subject to land disposal regulations. It does, however, provide the appropriate treatment standards on the notification and/or certification forms that accompany each shipment of LDR waste. (see 2.2.2.12)

2.2.2.24 Treatment Standards Expressed as Waste Concentrations, 40 CFR 268.43

The waste concentrations specified in this section may not be exceeded for wastes to be land disposed.

The EPA granted a variance (i.e., the NMD) from the treatment standards for mixed waste land disposal at WIPP during the test phase, when TRU mixed wastes were to have been tested at WIPP. A new variance from the EPA will be required prior to WIPP's acceptance of TRU mixed waste during the disposal phase. Therefore, these requirements are not applicable.

The WIPP facility does not treat site-generated hazardous waste subject to land disposal regulations. It does, however, provide the appropriate treatment standards on the notification and/or certification forms that accompany each shipment of LDR waste. (see 2.2.2.12)

2.2.2.25 Variance from a Treatment Standard, 40 CFR 268.44

A variance from a treatment standard may be granted by the EPA.

This requirement is not applicable as no treatment standards currently exist for mixed waste.

2.2.2.26 Prohibitions on Storage of Restricted Wastes, 40 CFR 268.50

A number of prohibitions and requirements relating to the storage of restricted wastes are specified in this section. They include storing accumulated hazardous/mixed waste for no longer than 1 year and prohibiting liquid hazardous/mixed wastes that contain PCBs at concentrations greater than or equal to 50 ppm unless the facility meets the requirements of 40 CFR 761.65(b) of the Toxic Substances Control Act (TSCA).

As a generator of hazardous waste, programs have been developed at WIPP that demonstrate compliance with the storage prohibitions for restricted waste. WIPP procedure manuals contain the procedures by which waste is identified, collected, stored, manifested, and transported off site for disposal.

This requirement does not apply to waste covered by a variance granted under 40 CFR 268.6. During the disposal phase, small amounts of TRU and TRU mixed waste may be generated at WIPP from managing the TRU waste shipped from the generator sites (i.e., "derived waste"). All such derived waste will be managed as if it were TRU mixed waste. (See also Chapter 25.)

At present, the DOE has no plans to accept PCB-containing waste at WIPP. Furthermore, the *WIPP Waste Acceptance Criteria* (DOE, 1991b) precludes the receipt of liquid waste exceeding 1 percent of the volume of a container.

2.3 Compliance with the Conditional No-Migration Determination (NMD)

On April 6, 1990, the EPA published its *Notice Proposing to Grant a Conditional Variance to the Department of Energy Waste Isolation Pilot Plant (WIPP) from Land Disposal Restrictions* in the *Federal Register* (EPA, 1990a). This was followed by the publication of the EPA's final *Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant (WIPP)* (NMD) in the *Federal Register* on November 14, 1990 (EPA, 1990b). The NMD specified eight conditions for placement of hazardous constituents at WIPP during the test phase. In addition, four general conditions were established. The NMD also stipulated that the conditions pertaining to the VOC monitoring program that were discussed in detail in the proposed variance published in April be adopted by reference and that compliance with these conditions is also mandatory.

The compliance status of each of these conditions is summarized in Table 2-4; the text provides more detailed information. Conditions 1 through 8 from the NMD are presented in Sections 2.3.1 through 2.3.10. The general conditions from the NMD are discussed in Sections 2.3.11 through 2.3.14, and the specific conditions from the proposed variance that pertain to the VOC monitoring program are contained in Sections 2.3.15 through 2.3.40.

In a DOE news release dated October 21, 1993, DOE changed its previous position of conducting tests with radioactive wastes in the WIPP underground to conducting laboratory tests at a facility other than WIPP. This change in policy is consistent with DOE's phased development approach at WIPP and will allow the DOE and the EPA to focus on disposal certification issues. Because of this policy change, a number of the requirements addressed in this document are no longer applicable to the WIPP facility (specifically those programs resultant from planned test phase operations). However, the DOE has chosen to maintain the programs necessary for compliance with a number of these requirements.

TABLE 2-4. The Conditional No-Migration Determination and the Proposed Variance - Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
EPA's Conditional No-Migration Determination (NMD), *Federal Register*, November 14, 1990, pp. 47700-47721 (55 FR 47700)		
Condition 1, IV.B.1 and VI(1)	Only testing for the purpose of determining the long-term acceptability of WIPP to be performed during the test phase	**NOT APPLICABLE** DOE decision to discontinue WIPP test phase [Section 2.3.1]
Condition 2, IV.B.2 and VI(2)	Wastes not to exceed 8,500 drums or 1 percent of repository's total capacity	**NOT APPLICABLE** DOE decision to discontinue WIPP test phase [Section 2.3.2]
Condition 3, IV.B.3 and VI(3)	Retrieval of waste if noncompliance with 40 CFR 268.6	**NOT APPLICABLE** DOE decision to discontinue WIPP test phase [Section 2.3.3]
Condition 4, IV.B.4 and VI(4)	Readily retrievable placement of waste	**NOT APPLICABLE** DOE decision to discontinue WIPP test phase [Section 2.3.4]
Condition 5, IV.B.5 and VI(5)	Installation of carbon adsorption device	**ACHIEVED** Carbon adsorption device installed [Section 2.3.5]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Condition 6, IV.B.6 and VI(6)	Implementation of air monitoring plan for VOCs	UP TO DATE VOC Monitoring Plan; WID procedures (see also Sections 2.3.15-2.3.40) [Section 2.3.6]
Condition 7(a), IV.B.7(a) and VI(7)(a)	Waste analysis: flammable mixtures of gases	UP TO DATE *Waste Analysis Plan*; WID procedure [Section 2.3.7]
Condition 7(b), IV.B.7(b) and VI(7)(b)	Waste analysis: comparison of analytical results with estimated compositions	UP TO DATE *Waste Analysis Plan*; WID procedure [Section 2.3.8]
Condition 7(c), IV.B.7(c) and VI(7)(c)	Waste analysis: maintenance of records	UP TO DATE Records maintained by WID [Section 2.3.9]
Condition 8, IV.B.8 and VI(8)	Annual report	UP TO DATE Annual reports submitted [Section 2.3.10]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
General Conditions for Compliance with the NMD (EPA, 1990b)		
General condition (GC) 1, IV.B.1	Correlation between wastes received and those described in the No-Migration Variance Petition (NMVP)	**UP TO DATE** NMVP; WID procedure [Section 2.3.11]
GC 2, VI	Notification of EPA of changes in conditions	**UP TO DATE** WID procedure [Section 2.3.12]
GC 3, VI	Suspension of receipt of restricted wastes and notification of EPA in the event of migration of hazardous constituents from the repository	**UP TO DATE** WID procedures [Section 2.3.13]
GC 4, VI	Term of petition approval	**UP TO DATE** NMD valid until November 14, 2000 [Section 2.3.14]
Additional Requirements for Air Monitoring under the Proposed Variance (PV) Published in the *Federal Register* on April 6, 1990 (EPA, 1990a)		
PV 1, IV.K	Monitoring in the exhaust shaft	**UP TO DATE** VOC Monitoring Plan; monitoring implemented July-August 1991 [Section 2.3.15]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
PV 2, IV.K	Monitoring of bin-scale experiment rooms	**UP TO DATE** VOC Monitoring Plan; monitoring implemented July-August 1991 [Section 2.3.16]
PV 3, IV.K	Monitoring of alcoves	**NOT APPLICABLE** DOE decision to discontinue WIPP test phase [Section 2.3.17]
PV 4, IV.K.1	Measurement of the leakage rate of sealed alcoves	**NOT APPLICABLE** DOE decision to discontinue WIPP test phase [Section 2.3.18]
PV 5, IV.K.1	Weekly collection of air samples	**UP TO DATE** VOC Monitoring Plan [Section 2.3.19]
PV 6, IV.K.1	Weekly monitoring at the exhaust shaft and air intake locations	**UP TO DATE** VOC Monitoring Plan [Section 2.3.20]
PV 7, IV.K.1	Monitoring frequency for the bin discharge system	**UP TO DATE** VOC Monitoring Plan; VOC Monitoring Quality Assurance Program Plan (QAPP) [Section 2.3.21]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
PV 8, IV.K.1	Increased monitoring frequency due to increased variability	**UP TO DATE** VOC Monitoring Plan [Section 2.3.22]
PV 9, IV.K.2	Routine quantification of any VOC	**UP TO DATE** VOC Monitoring Plan; VOC Monitoring QAPP [Section 2.3.23]
PV 10, IV.K.2	Standard operating procedures to identify certain other VOCs	**ACHIEVED** VOC Monitoring Plan; VOC Monitoring QAPP; WID procedure [Section 2.3.24]
PV 11, IV.K.3	Use of the average response factor for each target analyte	**ACHIEVED** VOC Monitoring Plan; VOC Monitoring QAPP [Section 2.3.25]
PV 12, IV.K.4	Use of standard operating procedures to ensure the validity of the monitoring data	**ACHIEVED** VOC Monitoring QAPP; WID manual and procedures [Section 2.3.26]
PV 13, IV.K.4	Recalibration of instruments	**UP TO DATE** VOC Monitoring QAPP [Section 2.3.27]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
PV 14, IV.K.4	Establishment and annual evaluation of the method limit of quantification for each target analyte	UP TO DATE VOC Monitoring Plan; VOC Monitoring QAPP [Section 2.3.28]
PV 15, IV.K.4	Separate determination of the method limit of quantification for the bin, alcove, and exhaust shaft monitoring locations	ACHIEVED VOC Monitoring Plan; VOC Monitoring QAPP Section 2.3.29]
PV 16, IV.K.4	Collection and analysis of recovery samples	UP TO DATE VOC Monitoring Plan; VOC Monitoring QAPP [Section 2.3.30]
PV 17, IV.K.4	Collection and analysis of duplicate samples	UP TO DATE VOC Monitoring Plan; VOC Monitoring QAPP; WID procedures [Section 2.3.31]
PV 18, IV.K.4	Validation of the completeness of the data	UP TO DATE VOC Monitoring QAPP [Section 2.3.32]
PV 19, IV.K.4	Tracking and evaluation of accuracy, precision, and completeness of the data	UP TO DATE VOC Monitoring QAPP [Section 2.3.33]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
PV 20, IV.K.4	Performance of systems audits	UP TO DATE VOC Monitoring QAPP [Section 2.3.34]
PV 21, IV.K.4	Corrective action required for improper conditions or practices	ACHIEVED VOC Monitoring QAPP [Section 2.3.35]
PV 22, IV.K.4	Establishment of specific quality assurance objectives for data acceptability	ACHIEVED VOC Monitoring QAPP [Section 2.3.36]
PV 23, IV.K.4	Corrective action required	ACHIEVED VOC Monitoring QAPP [Section 2.3.37]
PV 24, IV.K.5	Annual averaging of concentrations of targeted constituents	ACHIEVED WID procedures; annual reports [Section 2.3.38]
PV 25, IV.K.5	Submittal of annual data summaries and summaries of data accuracy, precision, and completeness for each monitoring location	ACHIEVED WID procedures; annual reports [Section 2.3.39]

TABLE 2-4 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
PV 26, IV.K.5	Maintenance of documentation on all aspects of QA/QC	ACHIEVED WID procedures [Section 2.3.40]

2.3.1 Condition 1, Testing Only of Long-Term Acceptability of WIPP

Only testing for the purpose of determining WIPP's long-term acceptability is to be performed during the test phase.

Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.2 Condition 2, Wastes Not to Exceed 8,500 Drums or 1 Percent of the Repository's Total Capacity

Waste to be emplaced during the test phase at WIPP will not exceed 8,500 drums or 1 percent of repository's total capacity.

Prior to the promulgation of the LWA, the DOE was limited to emplacing no more than 8,500 drums, or 1 percent of the total planned capacity of the WIPP, as specified by the NMD. The LWA, however, further restricts the amount of waste that may be emplaced at the WIPP during the test phase to one-half of 1 percent of the total capacity of the repository (i.e., 4,250 drums). The WIPP-related DOE documents that have been issued since the promulgation of the LWA on October 30, 1992, reflect this change and commit to emplacing no more than this latter volume of TRU waste underground. Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.3 Condition 3, Retrieval of Waste in the Event of Noncompliance with 40 CFR 268.6

If the DOE cannot demonstrate compliance with the standards of 40 CFR 268.6, all wastes emplaced in WIPP must be removed.

During the test phase, all waste emplaced in the WIPP underground waste management area was to be maintained in a manner that would ensure that wastes were readily retrievable. The DOE prepared the *Waste Retrieval Plan for the Waste Isolation Pilot Plant* (DOE, 1993b) to specify retrieval actions and to demonstrate the ability to retrieve waste. The original waste retrieval plan was issued in May, 1990. This plan has subsequently been revised and issued as Revision 1 (DOE, 1993b). The DOE would submit the required retrieval schedule in the event that it was determined that the repository could not meet the standards for long-term disposal or 6 months prior to the expiration of the petition approval. Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.4 Condition 4, Readily Retrievable Placement of Waste

> *All wastes emplaced at WIPP during the test phase must be placed in a readily retrievable manner.*

The EPA defined "readily retrievable" in the NMD as the adoption of specific measures identified in the NMVP to maintain room stability, such as room size, rock bolting, standoff walls, and the use of easily retrieved waste containers (e.g., boxes and drums). This information and the DOE's commitments to maintain the waste in a readily retrievable manner are included in the *Waste Retrieval Plan* and in Section 2.6.8 of the NMVP. This information was reviewed by the EPA during its review of the NMVP. Subsequently on March 19, 1993, the DOE submitted Revision 1 of the Waste Retrieval Plan to the EPA.

The DOE had agreed that no backfilling would be used to seal the rooms in which waste would be emplaced during the test phase; such backfilling would greatly decrease the retrievability of the emplaced waste. Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.5 Condition 5, Installation of a Carbon Adsorption Device

> *The DOE must install and operate a carbon adsorption device designed to achieve a control efficiency of 95 percent in the discharge system of the bin experiment rooms.*

A carbon adsorption control device has been installed underground as required by this condition. The efficiency of the carbon adsorption system depends upon the surface area of the carbon, the quantity of carbon used, the flow rate of air through the system, and the types and quantities of constituents to be adsorbed. Data to document that the carbon sorption system is at least 95 percent efficient in removing VOCs are maintained as part of the WIPP operating record as specified by the EPA. The following data are being collected and maintained:

- The date and time when the carbon in the control device is replaced with fresh carbon and when Volatile Organic Sampling Train (VOST) tube samples are collected for monitoring carbon breakthrough, along with records of the monitoring results;

- Engineering design analyses used to size the control device and to determine the frequency of carbon replacement; and

- A signed certification that all carbon removed from the control device is regenerated or reactivated by a process that minimizes the release of VOCs to the atmosphere or is disposed of in compliance with Federal and State of New Mexico regulations.

The bin-scale test VOC monitoring system includes three VOST tubes. Samples of carbon packed in the tubes are analyzed, and test results, along with the system mass flow data, provide a basis for estimating the lifetime of the carbon in the main sorption unit.

2.3.6 Condition 6, Implementation of the Air Monitoring Plan for VOCs

> *The DOE must implement the air monitoring plan for VOCs described in Section IV.K of the proposed variance (see also BECR Sections 2.3.15 through 2.3.40). Requirements include weekly monitoring of the five targeted VOCs, QA/QC, collection of a matrix spike and a concurrent matrix duplicate to adjust for background VOC concentrations, ±10 percent accuracy of the concentration data, a quarterly check on the calibration of the ventilation exhaust fans, and annual calibration. The five target compounds are carbon tetrachloride; methylene chloride; trichloroethylene; 1,1,1-trichloroethane; and 1,1,2-trichloro-1,2,2-trifluoroethane.*

The VOC monitoring program described in the addendum to the NMVP has been implemented at WIPP. The EPA required that this program be implemented 30 days prior to the first receipt of TRU waste at WIPP. This requirement was met during July and August of 1991. Records relating to VOC air monitoring are being maintained in the WIPP operating record and will be retained for the term of the NMD (i.e., until November 14, 2000) or for 3 years, whichever is longer, as required by this condition.

The monitoring schedule shows requirements for weekly monitoring of VOCs.

Affidavit VOC Prog. A.52.07 indicates that the DOE has committed to a full dynamic calibration of the exhaust fans annually, with quarterly checks (Section 2.4 of the affidavit). The quarterly checks consist of a Pitot tube traverse, comparing the measured value from the reference method with that of the system being tested. If the system is outside tolerance, a full dynamic calibration will be performed. The quarterly checks are performed in accordance with WID preventive maintenance procedures.

2.3.7 Condition 7(a), Waste Analysis: Flammable Mixtures of Gases

> *Three conditions were imposed relating to waste analysis. The first of these conditions is that the DOE ensure that each waste container emplaced underground at WIPP has no layer of confinement in containers that contain flammable mixtures of gases. This prohibition must be implemented by analytical testing of headspace gases from each drum/container. (The other two conditions relating to waste analysis are described in Sections 2.3.8 and 2.3.9.)*

The *Waste Analysis Plan* (DOE, 1993d) requires DOE waste generators to provide the required information to the DOE prior to the shipment of waste to WIPP. The DOE will approve shipment to WIPP of only those wastes for which the required information has been provided. Only waste meeting the criteria specified in Conditions 7(a)-(c) will be approved for shipment (Sections 2.3.7 through 2.3.9).

Waste-category-specific waste profile plans were developed for categories of waste proposed for emplacement in WIPP during the test phase. The plans specified the waste characterization activities to be performed to meet the minimal information requirements that were to be satisfied through the implementation of each plan. The minimal requirements include testing the waste containers for flammable gases. Only those waste containers tested in accordance with this condition and demonstrated to be within the EPA-specified flammability limits will be acceptable for shipment to the WIPP.

A WID procedure is in place that addresses the review of waste characterization records from the generator sites to verify that each waste container emplaced at the WIPP has no layer of confinement containing flammable mixtures of gases, as defined in the NMD [i.e., "measured concentrations (excluding methane) of 500 parts per million or greater"]. This review is conducted by WID in accordance with a WID procedure. This procedure contains a checklist which is used to verify that the data contained in the Bin Case Addendum Report (i.e., the results of bin sampling and analysis) meet the requirements of the NMD. This checklist directs the WID reviewer to ensure that the concentration of flammable VOCs in the headspace of the bin does not exceed a concentration of 500 parts per million (ppm). If the concentration of

flammable VOCs exceeds 500 ppm, the WID reviewer ensures (in accordance with the checklist) that an explicit flame test has been conducted and that the results of this test were negative (i.e., not flammable), as required by the NMD[1]. At the generator sites, all internal layers of confinement are breached while a bin of waste is loaded. As such, the only layer of confinement in a bin of waste is the bin itself. Since the bin was to have been the "container emplaced at the WIPP," a bin headspace sample would have been used to verify that the NMD flammability limit has not been exceeded. Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.8 Condition 7(b), Waste Analysis: Comparison of Analytical Results with Estimated Compositions

> *The second condition pertaining to waste analysis is that the DOE must analyze representative samples of the headspaces of containers and compare the results with the estimated compositions provided in the WIPP NMVP.*

The *Waste Analysis Plan* requires DOE waste generators to provide the required information to the DOE prior to the shipment of the waste to WIPP. The DOE will approve shipment to WIPP of only those wastes for which the required information has been provided. Only waste meeting the criteria specified in Conditions 7(a)-(c) will be approved for shipment (Sections 2.3.7 through 2.3.9).

The results of the headspace tests will be checked to ensure that the gas compositions are comparable to those described in the NMVP. A procedure is in place to ensure that waste characterization records from the generator sites are reviewed to verify that the concentrations of VOCs in the headspace of each container are less than the concentrations listed in the NMD. This review is conducted by WID in accordance with a WID procedure.

2.3.9 Condition 7(c), Waste Analysis: Maintenance of Records

> *The third condition relating to waste analysis is that waste analysis records must be maintained for the term of the NMD or for 3 years after generation, whichever is longer. Records must also be maintained during the course of any enforcement action for which they are relevant.*

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[1]However, the NRC's Certificate of Compliance (C of C) for the TRUPACT-II package prohibits the transportation of waste that exceeds the 500-ppm limit.

The waste analysis records will be maintained in the WIPP operating records throughout the 10-year term of the NMD, for 3 years, or during the course of any enforcement action for which they are relevant, whichever is longer.

2.3.10 Condition 8, Annual Report

The DOE must provide annual written reports to EPA Region VI on the status of DOE's performance assessment during the test phase.

During this reporting period, the Office of Solid Waste at EPA headquarters as well as EPA's Region VI office have been provided with two annual written reports containing a description of the tests to date and their results, modifications to the test plan, a summary of the DOE's current understanding of the repository's performance, waste characterization data from pre-test waste characterization, and an annual summary of VOC monitoring data.

2.3.11 General Condition (GC) 1, Correlation between the Wastes Emplaced by DOE at WIPP and DOE's Activities with those Described in the NMVP

The wastes to be emplaced by the DOE at WIPP and the experiments and tests conducted during the test phase must be consistent with those described in the NMVP and in the DOE's performance assessment test plan.

Wastes to have been emplaced in the WIPP during the test phase would have been consistent with those described in the NMVP. WID uses administrative controls such as procedures to ensure that project activities are consistent with those described in the NMVP. Individuals responsible for initiating changes that could be impactive are required to submit relevant information to WID. WID then ensures that the proposed change is subject to review with respect to departure from the conditions described in the WIPP NMVP. If it is determined that the change proposed is significant and may affect the potential for the migration of hazardous constituents, the EPA will be notified. Any notifications to this effect will also be provided to the NMED.

2.3.12 General Condition 2, Notification of EPA of Changes in Conditions

The DOE must notify the EPA of "any changes in conditions at the unit and/or environment that significantly depart from the conditions described in the variance and affect the potential for migration of hazardous constituents from the unit..." If the change

is planned, the EPA must be notified in writing 30 days before the change; if it is unplanned, the EPA must be notified within 10 days.

Wastes emplaced in the WIPP during the test phase would have been consistent with those described in the NMVP. WID uses administrative controls such as procedures to ensure that project activities are consistent with those described in the NMVP. The responsible individuals are required to submit relevant information to WID. WID is responsible for ensuring that the proposed change is subject to review with respect to departure from the conditions described in the WIPP NMVP. If it is determined that the proposed change is significant and may affect the potential for the migration of hazardous constituents, WID will notify the DOE, which will notify the EPA. Any notifications to this effect will also be provided to the NMED. Any unplanned change will result in notification of the EPA within 10 days.

2.3.13 General Condition 3, Suspension of Receipt of Restricted Wastes and Notification of EPA within 10 Days in the Event of Migration of Hazardous Constituents from the Repository

In the event of the migration of hazardous constituents from the repository, the DOE will suspend receipt of restricted wastes and will notify the EPA (Office of Solid Waste and EPA Region VI) within 10 days.

The NMVP demonstrates that the only credible pathway for the migration of hazardous constituents beyond the unit boundary in concentrations exceeding health-based standards is via the airborne transport of VOCs. The EPA has concurred with this demonstration in the proposed variance and in the NMD.

WID has developed a procedure to implement the determination of airborne concentrations of VOCs in the underground exhaust air stream. In addition, another WID procedure specifies the steps to be taken to notify regulatory authorities in the event of an environmental release of a hazardous material or in the event that migration of a hazardous constituent is determined to have occurred from the WIPP underground waste management area.

2.3.14 General Condition 4, Term of Petition

The term of the petition approval specified in the NMD is 10 years (i.e., until November 14, 2000).

The NMD pertains to the test phase only. Since the test phase no longer will involve the testing of TRU and TRU mixed waste at WIPP, the need for an extension is unlikely.

2.3.15 Proposed Variance Condition (PV) 1, Monitoring in the Exhaust Shaft

Monitoring in the exhaust shaft must begin 30 days prior to the emplacement of any experimental wastes underground.

This requirement is stipulated in Section 3.3 of the *VOC Monitoring Plan for the Bin-Scale Tests*. This requirement was met during July and August of 1991, when VOC monitoring was initiated at WIPP.

It should be noted that this and the rest of the requirements in this section would have been applicable only to the performance of tests on TRU mixed waste at WIPP if they had been conducted. However, the DOE has chosen to maintain the programs necessary for compliance with a number of these requirements.

2.3.16 Proposed Variance Condition 2, Monitoring of Bin-Scale Experiment Rooms

Monitoring of bin-scale experiment rooms must commence prior to emplacement of any bins containing TRU waste.

This requirement is stipulated in Section 3.3 of the *VOC Monitoring Plan for the Bin-Scale Tests*. This requirement was met during July and August of 1991, when VOC monitoring was initiated at WIPP.

2.3.17 Proposed Variance Condition 3, Monitoring of Alcoves

Monitoring of alcoves must commence prior to initiation of alcove experiments, after alcoves are sealed, and prior to purging of alcove atmosphere.

Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.18 Proposed Variance Condition 4, Leakage Rate of the Sealed Alcoves

The leakage rate of the sealed alcoves must be measured by means of injecting tracer gases into the atmosphere within each alcove and monitoring the tracer gas levels.

Due to DOE's decision to discontinue plans for radioactive waste tests in the WIPP underground, this condition is no longer applicable.

2.3.19 Proposed Variance Condition 5, Weekly Collection of Air Samples

Air samples must be collected at least weekly.

A weekly schedule for collecting air samples for the subsequent analysis of VOCs was being used at the WIPP, as indicated in Section 7.2.1 of the *VOC Monitoring Quality Assurance Program Plan* (WID, 1991a). The monitoring schedule for the first two quarters of 1993 is included in Affidavit VOC Prog. M.66.04. This schedule shows that weekly sampling of VOCs was performed.

2.3.20 Proposed Variance Condition 6, Weekly Monitoring at the Exhaust Shaft and Air Intake Locations

Exhaust shaft and air intake locations must be monitored weekly.

A weekly schedule for collecting air samples for the subsequent analysis of VOCs was being used at the WIPP, as indicated in Section 7.2.1 of the *VOC Monitoring Quality Assurance Program Plan*. Weekly collection of air samples was performed.

2.3.21 Proposed Variance Condition 7, Monitoring Frequency

In no event shall the monitoring frequency for the bin discharge system be reduced to less than 20 percent of the minimum time required for the consumption of the total working capacity of the carbon adsorption system.

This condition is reflected in Section 3.3.1 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Section 7.2.1 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.22 Proposed Variance Condition 8, Increased Monitoring Due to Increased Variability

In the event that the results of weekly air monitoring exhibit increased variability, daily air sampling must be resumed if the calculated relative standard deviation in the preceding 4-week period at the monitoring locations exceeds 75 percent for any targeted constituent.

This condition is reflected in Section 3.3.1 of the *VOC Monitoring Plan for the Bin-Scale Tests*.

2.3.23 Proposed Variance Condition 9, any VOC Routine Quantification of any VOC

Any VOC must be targeted for routine quantification if the average estimated concentration at the point of sampling is 1 ppm or more during any 4-month period and the compound is detected in at least 10 percent of the samples collected from the gas discharge system from either the room containing bins or from 50 percent of the samples collected from any alcove.

This requirement is reflected in Section 4.4 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Section 9.4.2 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.24 Proposed Variance Condition 10, Standard Operating Procedures to Identify Certain other VOCs

The DOE must implement standard operating procedures to provide positive identification of the following compounds: perchloroethylene (i.e., tetrachloroethylene), chloroform, bromoform, dichloroethane, dichloroethylene, toluene, and chlorobenzene.

This requirement is reflected in Section 4.2 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Sections 9.2.1.6 and 9.2.1.7 of the *VOC Monitoring Quality Assurance Program Plan.* To implement these plans, a standard operating procedure (SOP) is in place at the contract laboratory to provide positive identification of these nontargeted VOCs as well as of the targeted compounds, as documented in Affidavit VOC Prog. M.66.03.

2.3.25 Proposed Variance Condition 11, use of the Average Response Factor for each Target Analyte

The average response factor for each target analyte, as determined by five-point instrument calibration, must be used for quantification in high-resolution gas chromatography.

This requirement is reflected in Section 5.5 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Sections 9.2.1.5 and 9.2.2.4 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.26 Proposed Variance Condition 12, Standard Operating Procedures to Ensure the Validity of Monitoring Data

Standard operating procedures must be adopted by the DOE to ensure the validity of the monitoring data.

This requirement is reflected in Section 12.0 of the *VOC Monitoring Quality Assurance Program Plan.* A number of procedures have been issued to implement these requirements. Affidavit VOC Prog. M.66.04 examined these WID SOPs to ensure the validity of the VOC Monitoring Program data. The procedures and activities examined during this review were for sampling and analysis certification, instrument calibration checks, duplicate sampling, audit cylinder sampling, technical system audits, and data quality audits. The SOPs developed by the contract laboratory to analyze the samples and certify the canister samples were also covered by the affidavit.

2.3.27 Proposed Variance Condition 13, Recalibration of Instruments

Consistent with EPA's Method 8240 of SW-846, instruments must be recalibrated by a full five-point calibration if the response factor from the calibration check differs by more than 25 percent of the average or expected response factor.

This requirement is reflected in Section 9.2.1.5 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.28 Proposed Variance Condition 14, Establishment and Annual Evaluation of the Method Limit of Quantification for each Target Analyte

The method limit of quantification for each target analyte must be established prior to the initiation of the monitoring program and must be reevaluated annually thereafter in accordance with EPA/530-SW-90-021, "Quality Assurance and Quality Control," dated August 1990.

This requirement is reflected in Section 6.1.6 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Section 9.3.2.6 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.29 Proposed Variance Condition 15, Separate Determination of the Method Limit of Quantification for the Bin, Alcove, and Exhaust Shaft Monitoring Locations

The method limit of quantification must be determined separately for the bin, alcove, and exhaust shaft monitoring locations.

This requirement is reflected in Section 6.1.6 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Section 9.3.2.6 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.30 Proposed Variance Condition 16, Collection and Analysis of Recovery Samples

Recovery samples must be collected from audit cylinders and analyzed at a frequency of 10 percent at each monitoring location.

This requirement is reflected in Section 6.1.4 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Section 9.3.1.4 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.31 Proposed Variance Condition 17, Collection and Analysis of Duplicate Samples

Duplicate samples must be collected and analyzed at a frequency of 10 percent in each monitoring location, including the exhaust shaft.

This requirement is reflected in Section 6.1.4 of the *VOC Monitoring Plan for the Bin-Scale Tests* and in Section 9.3.1.3 of the *VOC Monitoring Quality Assurance Program Plan*. In addition, Affidavit VOC Prog. M.66.04 examined the procedures pertaining to duplicate sampling and found them to be satisfactory.

2.3.32 Proposed Variance Condition 18, Validation of the Completeness of the Data

Data completeness must be evaluated by data validation audits at a frequency not less than 5 percent.

This requirement is reflected in Sections 9.3.2.10 and 12.4 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.33 Proposed Variance Condition 19, Tracking and Evaluation of Accuracy, Precision, and Completeness

To ensure that any sampling analysis problems that may occur are detected and corrected, accuracy, precision, and completeness must be tracked and evaluated after every 10 quality control analyses.

This requirement is reflected in Section 9.3.2.9 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.34 Proposed Variance Condition 20, Performance of Systems Audits

Systems audits must be performed not only prior to the initiation of the monitoring program but also semi-annually thereafter to be consistent with good operating practice.

This requirement is reflected in Section 12.3 of the *VOC Monitoring Quality Assurance Program Plan.*

2.3.35 Proposed Variance Condition 21, Corrective Action Required for Improper Conditions or Practices

Corrective action must be taken whenever a condition or practice is found that is outside systems specifications or SOPs or that could

reasonably be expected to compromise the ability of the monitoring program to meet established quality assurance objectives for data acceptability.

This requirement is reflected in Section 11.0 of the *VOC Monitoring Quality Assurance Program Plan*.

2.3.36 Proposed Variance Condition 22, Establishment of Specific Quality Assurance Objectives

Specific quality assurance objectives must be established for data acceptability for the WIPP air monitoring program consistent with method capability and good operating practice.

This requirement is reflected in Section 9.3.2 of the *VOC Monitoring Quality Assurance Program Plan*.

2.3.37 Proposed Variance Condition 23, Corrective Action Required

Corrective action must be taken whenever quality assurance objectives for data acceptability are not being met.

This requirement is reflected in Section 11.0 of the *VOC Monitoring Quality Assurance Program Plan*.

2.3.38 Proposed Variance Condition 24, Annual Averaging of Concentrations of Targeted Constituents

To determine whether migration has occurred, concentrations of targeted constituents must be averaged over an annual time period.

Procedures addressing this requirement have been issued. The data averaged over an annual time period are included as part of the two annual reports issued to the EPA during this reporting period, which were required by Condition 8 of the NMD (see Section 2.3.10).

2.3.39 Proposed Variance Condition 25, Submittal of Annual Data Summaries and Summaries of Data Accuracy, Precision, and Completeness for each Monitoring Location

Annual data summaries and summaries of data accuracy, precision, and completeness for each monitoring location, together with calculated concentrations at the exhaust shaft and documentation of the actual method limit of detection achieved for each targeted analyte, must be submitted to the EPA.

Procedures addressing this requirement have been issued and implemented as part of a WID manual. These data were included as part of the annual reports issued to the EPA, which are required by Condition 8 of the NMD (see Section 2.3.10).

2.3.40 Proposed Variance Condition 26, Maintenance of Documentation on all Aspects of QA/QC

Documentation on all aspects of QA/QC as described in EPA/530-SW-90-021 must be maintained at WIPP.

Auditable records pertaining to the VOC Monitoring Program were examined under Affidavit VOC Prog. A.12.01. The records were found to be satisfactory.

3.0 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

3.1 Summary of the Law

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; 42 USC §§ 9601 et seq.), or "Superfund," and the Superfund Amendments and Reauthorization Act of 1986 (SARA) establish a comprehensive Federal strategy for responding to, and establishing liability for, releases of hazardous substances from a facility to the environment. The Emergency Planning and Community Right-to-Know Act (EPCRA) was enacted as a stand-alone portion under SARA. It is described in further detail in Chapter 4.

Any spills of reportable quantities of hazardous substances must be reported to the National Response Center (NRCr) under the provisions of § 103 of CERCLA, *Notices, Penalties,* and the implementing regulations in 40 CFR Part 302, *Designation, Reportable Quantities, and Notification.* Because the WIPP is not a CERCLA remediation site and is not expected to become one, most of the requirements of this act do not apply.

The WIPP is liable for any release of hazardous substances as defined in § 101 of CERCLA, *Definitions,* in quantities equal to or greater than the reportable quantities mentioned in § 102, *Reportable Quantities and Additional Designations,* and specified in 40 CFR Part 302. In the event of a release of a hazardous substance to the environment in an amount that meets or exceeds the reportable quantity for that substance, a notification of the release will be made to the appropriate agencies by WIPP personnel as required by § 103 of CERCLA.

Section 120(c) of CERCLA, *Federal Agency Hazardous Waste Compliance Docket,* establishes a docket that provides information regarding Federal facilities that manage hazardous waste or from which hazardous substances may be or have been released. This is information to be submitted to the EPA by other Federal agencies under § 103 of CERCLA or under § 3005, 3010, or 3016 of RCRA. Facilities listed under the docket must prepare a Preliminary Assessment and submit it to the EPA within 18 months of the date of publication in the *Federal Register.* If deemed necessary, a site inspection report is also due to the EPA within the same time frame.

Under 40 CFR Part 300, *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP), the organizational structures and procedures are provided for preparing for and responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants. The NCP is required by § 105 of CERCLA.

3.2 Compliance Status of the Regulatory Requirements

Table 3-1 summarizes each applicable requirement and its compliance status under CERCLA. The text provides more detail on the compliance status of each requirement.

TABLE 3-1. Comprehensive Environmental Response, Compensation, and Liability Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
§ 120, *Federal Facilities*, of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)		
CERCLA, § 120(d)	Assessment and evaluation	**UP TO DATE** Preliminary assessment due August 5, 1994 [Section 3.2.1]
40 CFR Part 300, *National Oil and Hazardous Substances Pollution Contingency Plan*		
40 CFR 300.215(b)	Emergency planning requirements	**ACHIEVED** WIPP representative on Emergency Management Advisory Board/Local Emergency Planning Committee (LEPC) [Section 3.2.2]

TABLE 3-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 300.215(e)	Material safety data sheet (MSDS) and inventory form	**ACHIEVED** List of hazardous chemicals; Emergency and Hazardous Chemical Inventory Report (Tier II Report) [Section 3.2.3]
40 CFR Part 302, *Designation, Reportable Quantities, and Notification*		
40 CFR 302.4	Designation of hazardous substances	**ACHIEVED** Spills of ethylene glycol identified as hazardous [Section 3.2.4]
40 CFR 302.5	Determination of reportable quantities (RQs)	**ACHIEVED** Spills of ethylene glycol that exceeded current RQ [Section 3.2.5]
40 CFR 302.6(a)	Notification requirements	**ACHIEVED** Ethylene glycol spills reported to National Response Center (NRCr) [Section 3.2.6]

TABLE 3-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 302.6(b)(1)	Release of mixtures or solutions	**ACHIEVED** RQ for mixture of hazardous constituents determined - see Section 3.2.5 [Section 3.2.7]
40 CFR 302.6(b)(2)	Notification of releases of radionuclides	**NOT APPLICABLE** Applicable upon receipt of TRU waste [Section 3.2.8]
40 CFR 302.6(d)	Notification of the release of heavy metals	**NOT APPLICABLE** No release of heavy metals at WIPP [Section 3.2.9]

3.2.1 Assessment and Evaluation of Federal Facilities, § 120 of CERCLA

> ***A preliminary assessment and, if warranted, a site inspection must be submitted to the EPA by each Federal facility that is included on the docket of Federal facilities that manage hazardous waste or from which hazardous substances have been released. The preliminary assessment or preliminary assessment//site inspection for a facility must be submitted to the EPA within 18 months of the publication of the notice that includes the facility on the Federal Agency Hazardous Waste Compliance docket.***

On February 5, 1993, WIPP was included as a new facility in the additions made to the Federal Agency Hazardous Waste Compliance Docket in the *Federal Register* (58 *FR* 7298). Therefore, a preliminary assessment for WIPP must be submitted to the EPA by August 5, 1994. As a

result of negotiations with the preliminary assessment coordinator of the Region VI EPA office, only a brief preliminary assessment is required of WIPP at the present time; no site inspection is needed. The brief preliminary assessment is currently in preparation.

3.2.2 Emergency Planning Requirements, 40 CFR 300.215(b)

> *A facility is subject to emergency planning requirements if an extremely hazardous substance [as defined in 40 CFR Part 355] is present at the facility in an amount equal to or in excess of the threshold planning quantity established for the substance. A Governor may designate additional facilities that will also be subject to these planning requirements. Facility owners or operators should name a facility representative who will participate in the planning process as a facility Emergency Coordinator.*

WIPP is subject to the emergency planning requirements. A WIPP representative has been designated to serve as the Emergency Coordinator for the Eddy County Emergency Management Advisory Board, which is very similar to a Local Emergency Planning Committee (LEPC). An official LEPC will be created in 1994; the current WIPP representative to the EMA Board will also represent WIPP on the LEPC. Chapter 4 also discusses this requirement.

3.2.3 Material Safety Data Sheet and Inventory Form, 40 CFR 300.215(e)

> *Each facility required to prepare or have available a material safety data sheet (MSDS) will submit either an MSDS for each hazardous chemical or a list of hazardous chemicals to the appropriate State Emergency Response Commission (SERC), LEPC, and local fire department in accordance with 40 CFR Part 370.*
>
> *Each facility will also submit an inventory form to the SERC, LEPC, and local fire department. This inventory form must contain an estimate of the maximal amount of hazardous chemicals present at the facility during the preceding year, an estimate of the average daily amount of hazardous chemicals at the facility, and the location of those chemicals.*

In lieu of MSDS, WIPP submits a list of those hazardous chemicals that are present at WIPP in amounts that exceed their respective reportable quantities.

The requirement to submit the Emergency and Hazardous Chemical Inventory report to the SERC, LEPC, and local fire department has been met. These requirements are also discussed in Chapter 4.

3.2.4 Designation of Hazardous Substances, 40 CFR 302.4

> *Hazardous substances released to the environment must be identified.*

During this reporting period, there have been three antifreeze spills from WIPP facility systems. The major ingredient of antifreeze is ethylene glycol [Chemical Abstract Service (CAS 107-21-1)]. This substance is designated as a hazardous substance under § 302.4 of CERCLA.

3.2.5 Determination of Reportable Quantities, 40 CFR 302.5

> *Reportable quantities (RQs) are established for each substance listed in Table 302.4 or in Appendix B.*

Each of the spills was determined to have exceeded the RQ for ethylene glycol (currently 1 pound). This determination was based upon the concentration of the ethylene glycol/water mixture, the data obtained from the MSDS, and the current RQ for the substance.

3.2.6 Notification Requirements, 40 CFR 302.6(a)

> *Any release of a hazardous substance in a quantity equal to or exceeding the reportable quantity determined in 40 CFR 302.5 or in 40 CFR Part 117 in any 24-hour period shall immediately be reported to the NRCr at (800) 424-8802.*

The ethylene glycol spills were reported to the National Response Center as required. [See also the *WIPP NPDES Storm Water Pollution Prevention Plan* (WID, 1993b).]

3.2.7 Releases of Mixtures or Solutions, 40 CFR 302.6(b)(1)

> *If a mixture or solution is released and the quantity of all hazardous constituents is known, notification is required when a quantity that meets or exceeds the RQ of any hazardous constituent has been released. If the quantity of one or more of the hazardous constituents is not known, notification is required when the total amount of the mixture or solution released equals or exceeds the RQ for the hazardous constituent with the lowest RQ.*

The determination of the RQs for hazardous constituents of a mixture was discussed in Section 3.2.5.

3.2.8 Notification of Releases of Radionuclides, 40 CFR 302.6(b)(2)

> *Radionuclides are subject to these notification requirements only under the following circumstances:*
>
> - *If the identity and quantity of each radionuclide in a released mixture or solution is known and the sum of the ratios (quantity released in curies/RQ for the radionuclide) for the radionuclides in the mixture or solution is equal to or greater than 1 or*
>
> - *If the quantity of each radionuclide in a released mixture or solution is known but the quantity released (in curies) of one or more of the radionuclides is unknown and the total quantity (in curies) of the mixture or solution is equal to or greater than the lowest RQ of any individual radionuclide in the mixture or solution or*
>
> - *If the identity of one or more radionuclides in a released mixture or solution is unknown and the total quantity (in curies) released is equal to or greater than either 1 curie or the lowest RQ of any known individual radionuclide in the mixture or solution, whichever is lower.*

This requirement will become applicable when WIPP receives TRU waste.

3.2.9 Notification of the Release of Heavy Metals, 40 CFR 302.6(d)

> *Notification of the release of an RQ of solid particles of antimony, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, or zinc is not required if the mean diameter released is larger than 100 micrometers except for releases of radionuclides.*

There have been no releases of heavy metals from the WIPP facility to date.

4.0 EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT

4.1 Summary of the Law

Title III of the Superfund Amendments and Reauthorization Act (SARA), otherwise known as the Emergency Planning and Community-Right-to-Know Act of 1986 (EPCRA; 42 USC §§ 11001 et seq.), authorizes a nationwide program of emergency planning as protection against accidents involving extremely hazardous substances (EHSs). The act also requires a comprehensive body of information about hazardous substances to be submitted to various State and local groups. Under Subtitle A, *Emergency Planning and Notification*, facilities such as WIPP are required to make various notifications to the State Emergency Response Commission (SERC) and the Local Emergency Planning Committee (LEPC). These notifications include notification of applicability under EPCRA, designation of a facility Emergency Coordinator, and notification of extremely hazardous substance releases to the environment. Subtitle B, *Reporting Requirements*, requires the submittal of information such as inventories of specific hazardous chemicals used or stored within a facility to the SERC, LEPC, and the fire department that has jurisdiction over the facility. Within Subtitle B, the following sections outline specific reporting requirements: (1) Section 311, *Material Safety Data Sheets*, directs the submission of a Material Safety Data Sheet (MSDS) for each hazardous chemical present or a list of hazardous chemicals present that require an MSDS; (2) Section 312, *Emergency and Hazardous Chemical Inventory Forms*, directs the annual submission of an inventory of hazardous chemicals present during the preceding year; and (3) Section 313, *Toxic Chemical Release Forms*, outlines requirements for facilities to submit a toxic chemical release report to the EPA and the resident State if toxic chemicals are used at that facility in excess of established threshold amounts.

The regulations under 40 CFR Part 355, *Emergency Planning and Notification*, established the list of extremely hazardous substances, the threshold planning quantities, and facility notification responsibilities necessary for the development and implementation of State and local emergency response plans.

The regulations of 40 CFR Part 370, *Hazardous Chemical Reporting: Community Right-to-Know*, established reporting requirements that provide the public with vital information on the hazardous chemicals in their communities, with the intent of ensuring enhanced community awareness of chemical hazards and facilitating the development of State and local emergency response plans.

In 40 CFR Part 372, *Toxic Chemical Release Reporting: Community Right-to-Know*, requirements are established for the submission of information relating to the release of toxic chemicals under Section 313.

4.2 Compliance Status of the Regulatory Requirements

Table 4-1 summarizes the applicable requirements and their compliance status under the Emergency Planning and Community Right-to-Know Act. The text provides more detail on the compliance status of each requirement.

TABLE 4-1. Emergency Planning and Community Right-to-Know Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR Part 355, *Emergency Planning Notification*		
40 CFR 355.30(a)-(b)	Emergency planning	**ACHIEVED** Notification submitted to SERC [Section 4.2.1]
40 CFR 355.30(c)	Facility Emergency Coordinator	**ACHIEVED** WIPP Emergency Coordinator; Eddy County Emergency Management Advisory Board and Local Emergency Planning Committee (LEPC) [Section 4.2.2]
40 CFR 355.30(d)	Provision of information	**ACHIEVED** Information provided to LEPC as required [Section 4.2.3]
40 CFR 355.40	Releases of extremely hazardous substances (EHSs)	**NOT APPLICABLE** No EHS releases [Section 4.2.4]

TABLE 4-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR Part 370, *Hazardous Chemical Reporting: Community Right-to-Know*		
40 CFR 370.21	Submission of MSDS or chemical list	**UP TO DATE** Revised list submitted in March and August 1993 and in March 1994 [Section 4.2.5]
40 CFR 370.25	Submission of hazardous chemical inventory form	**UP TO DATE** Inventory submitted in March 1993 and 1994 [Section 4.2.6]
40 CFR Part 372, *Toxic Chemical Release Reporting: Community Right-to-Know*		
40 CFR 372.30	Submission of the Toxic Chemical Inventory Report	**NOT APPLICABLE** Toxic chemical inventory reporting not required due to certain exemptions [Section 4.2.7]

4.2.1 Emergency Planning, 40 CFR 355.30(a)-(b)

A facility must notify the SERC that it is subject to the emergency planning requirements if there are extremely hazardous substances equal to or in excess of the threshold planning requirements.

DOE has notified the SERC that emergency planning requirements are applicable to the WIPP facility.

4.2.2 Facility Emergency Coordinator, 40 CFR 355.30(c)

> *The facility shall designate a facility representative who will participate in the local emergency planning process as a facility emergency response coordinator.*

WID has appointed a WIPP representative who acts as the Emergency Coordinator for the Eddy County Emergency Management Advisory Board, which will be replaced by an official LEPC in 1994. The same individual will serve in the LEPC as the WIPP Emergency Coordinator.

4.2.3 Provision of Information, 40 CFR 355.30(d)

> *The facility will inform the LEPC of any changes occurring at the facility that may be relevant to emergency planning.*

WIPP provides information to the LEPC regarding changes at the facility which may be relevant to emergency planning.

4.2.4 Releases of Extremely Hazardous Substances, 40 CFR 355.40

> *For releases of extremely hazardous substances under SARA Title III (40 CFR Part 355, Appendix A), the owner or operator must notify the National Response Center of any area that is likely to be affected by the release.*

There have been no releases of extremely hazardous substances from the WIPP.

4.2.5 Submission of a Material Safety Data Sheet or List of Chemicals, 40 CFR 370.21

> *Facilities must submit either an MSDS for each hazardous chemical present at the facility according to established minimum threshold schedules or a list of the hazardous chemicals for which the MSDS is required.*

The WIPP submits a list of hazardous chemicals to the SERC, the LEPC, and the local fire department whenever additional hazardous substances are received at WIPP or if significant new information is received about an item for which a list was provided. In March and August 1993, and again in March 1994, a revised list of hazardous chemicals was submitted to the appropriate organizations. The listing was comprised of extremely hazardous substances present in amounts

equal to or greater than the threshold planning quantity (TPQ) or 500 pounds, whichever was less, and all substances classified as hazardous under the Occupational Safety and Health Act Hazard Communication Standard with site inventories equal to or greater than 10,000 pounds.

4.2.6 Submission of a Hazardous Chemical Inventory, 40 CFR 370.25

> *On or before March 1 of each year, facilities must submit an inventory form containing Tier I information on hazardous chemicals present during the preceding year, or Tier II information in lieu of Tier I, with respect to any specific hazardous chemical at the facility. This inventory must be submitted to the State Emergency Response Commission, the Local Emergency Planning Committee, and the local fire department.*

The WIPP submitted the Emergency and Hazardous Chemical Inventory Report (Tier II) in March 1993 and 1994 to the SERC, LEPC, and the local fire department.

4.2.7 Submission of a Toxic Chemical Release Inventory Report, 40 CFR 372.30

> *For each toxic chemical on site in excess of the reporting threshold level, the owner or operator must submit a completed EPA Form R TO THE EPA AND THE STATE.*

During this reporting period, the WIPP was exempt from Section 313 reporting under 40 CFR 372.38, Exemptions. However, due to the promulgation of Executive Order (EO) 12856 on August 6, 1993, the WIPP is reevaluating the reporting requirements of Section 313, and examining the use of chemicals on site in regards to their relationship to the primary mission. Under section 3-304 of the EO the first report will be due on July 1, 1995, if the WIPP site meets applicable thresholds.

5.0 ATOMIC ENERGY ACT

5.1 Summary of the Law

The Atomic Energy Act of 1954 as amended (AEA; 42 USC §§ 2011 et seq.) initiated a national program for research, development, and use of atomic energy for both national defense and domestic civilian purposes. In § 161 of the AEA, the Atomic Energy Commission (succeeded by the DOE for national defense purposes) was authorized to prescribe regulations and Orders to:

> [G]overn any activity authorized pursuant to [the AEA], including standards, and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property.

The authority of the DOE to develop policies, issue Orders, and promulgate regulations addressing environmental, safety, and health protection aspects of radioactive waste and nuclear materials is derived directly from the AEA. The DOE, under the authority of the AEA, uses a system of Orders, notices, and directives to carry out the mandate to implement effective and consistent programs to protect the public, the environment, and employees from adverse consequences resulting from DOE operations.

The AEA also authorized the U.S. Nuclear Regulatory Commission (NRC) to serve a similar function for commercial nuclear facilities. Regulations promulgated by the NRC under the AEA establish standards for the management of special nuclear material and the protection of the public from radiation. Additional NRC requirements apply to the licensing, packaging, preparation, and transportation of radioactive materials. The NRC does not have regulatory authority over DOE facilities, but NRC standards and requirements are incorporated into DOE Orders. The NRC's requirements pertain to WIPP only in the transportation of TRU waste from the generator sites to WIPP (See Chapter 15).

Much of the waste to be emplaced at the WIPP is mixed (i.e., radioactive waste with hazardous constituents). This waste is subject to dual regulation: the radioactive constituents of the waste are regulated under the AEA, whereas the hazardous constituents are regulated under RCRA. Nevertheless, there may be some circumstances under which RCRA regulation of the hazardous constituents would be found to be inconsistent with AEA health and safety requirements.

The authority of the EPA to establish standards for the protection of the public and the environment from radiation is derived from the AEA, as amended; Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act (NWPA) (Public Law 97-425). The protection standards found at 40 CFR Part 191 apply to spent nuclear fuel and high-level radioactive waste as defined by the Nuclear Waste Policy Act and to TRU waste that contains more than 100 nanocuries per gram of waste of alpha-emitting TRU isotopes with half-lives greater than

20 years. These standards consist of three subparts: A, B, and C. For the purpose of this report, only subpart A is included.

Subpart A, *Standards for Management and Storage*, sets the operational term requirements limiting annual doses to members of the public from management and storage operations at disposal facilities that are operated by the DOE and are not regulated by either the NRC or by agreement States. The annual dose equivalent to any member of the public in the general environment may not exceed 25 millirem (mrem) to the whole body and 75 mrem to any critical organ.

5.2 Compliance Status of the Regulatory Requirements

The compliance status of each of the applicable requirements is summarized in Table 5-1. More detail is provided in the text.

TABLE 5-1. Atomic Energy Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR Part 191, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Waste*		
Subpart A, 40 CFR 191.03-191.04	**Standard: Annual dose equivalent of 25 mrem to whole body and 75 mrem to any critical organ**	**NOT APPLICABLE** **Will become applicable when waste receipt begins** **[Sections 5.2.1 and 6.2.2]**

5.2.1 Standard, Subpart A of 40 CFR 191.03-191.04

A standard of an annual dose equivalent of 25 mrem to the whole body and 75 mrem to any critical organ has been set for 40 CFR Part 191.

In the Second Modification to the Agreement for Consultation and Cooperation (dated August 4, 1987), the DOE and the State of New Mexico agreed that the WIPP will comply with the standards of Subpart A upon the initial receipt of waste and thereafter. However, since the

only possible pathway for releases from the facility during operations is air, the applicable NESHAPs standard under 40 CFR Part 61, Subpart H (i.e., an annual effective dose equivalent of 10 mrem), is more restrictive. See also the report prepared by the S.M. Stoller Corporation, *Verification of the Station A Alpha CAM Alarm Set Point at the Waste Isolation Pilot Plant* (dated January 17, 1991) and the letter report prepared by Cooper (dated November 2, 1992) that amended the 1991 report.

6.0 CLEAN AIR ACT

6.1 Summary of the Law

The Clean Air Act (CAA), as amended, establishes a national regulatory strategy and program to protect and enhance air quality in the United States. The CAA includes a number of standards, requirements, and permit programs to protect the quality of air in attainment areas (areas in which air pollutant emissions do not exceed the appropriate standards) and to improve it in nonattainment areas (areas that do not meet the national primary or secondary ambient air-quality standard for an air pollutant).

Congress enacted the Clean Air Act Amendments of 1990 (CAAA; PL 101-549) on November 15, 1990. The 11 titles in this public law are:

I. Provisions for Attainment and Maintenance of National Ambient Air Quality Standards
II. Provisions Relating to Mobile Sources
III. Hazardous Air Pollutants
IV. Acid Deposition Control
V. Permits
VI. Stratospheric Ozone Protection
VII. Provisions Relating to Enforcement
VIII. Miscellaneous Provisions
IX. Clean Air Research
X. Disadvantaged Business Concerns
XI. Clean Air Employment Transition Assistance.

The 11 titles of the CAAA resulted in numerous changes to the CAA and other acts and established six titles in the CAA:

I. Air Pollution Prevention and Control,
II. Emission Standards for Moving Sources,
III. General Provisions,
IV. Acid-Deposition Control (i.e., control of acid rain),
V. Operating Permits, and
VI. Stratospheric Ozone Protection.

Title I, *Air Pollution Prevention and Control*: Title I of the CAA contains requirements and standards for a number of programs that govern air pollutant emissions from stationary sources. These include the National Ambient Air Quality Standards (NAAQSs), the New Source Performance Standards (NSPS), the National Emission Standards for Hazardous Air Pollutants (NESHAPs), the Prevention of Significant Deterioration (PSD) program, and requirements for

nonattainment areas. Most of these programs are requirements for proposed new construction or for modifications of existing sources. In addition, Titles VII and IX of the CAAA established provisions relating to enforcement and requirements for CAA-related research programs, respectively.

NAAQS - A program established by Title I of the CAA (and revised by Title I of the CAAA) is the NAAQS program for the six "criteria" pollutants: sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. These standards establish the maximum levels of each pollutant allowed in the air within a particular area. The Federal NAAQSs are specified in 40 CFR 50.4 through 40 CFR 50.12, and the program is implemented under 40 CFR Part 51. The U.S. Environmental Protection Agency (EPA) has authorized the New Mexico Environment Department (NMED) to administer the NAAQS program. Therefore, the Federal NAAQSs have been superseded by the New Mexico Ambient Air Quality Standards (NMAAQSs) for the six criteria pollutants. Therefore, the two backup diesel electrical power-supply generators at WIPP are regulated under New Mexico regulations, and compliance with these regulations is discussed in Chapter 29 under the New Mexico Air Quality Act.

NSPS - The NSPS program regulates emissions from operating facilities and specifies emission standards and test methods for analyzing the emissions. This program, which was initiated by § 111 of the CAA and is implemented by 40 CFR Part 60, *Standards of Performance for New Stationary Sources*, specifies standards of performance for air pollutant emissions from different types of facilities and equipment. Pollutants that are regulated under the NSPS include sulfur dioxide, nitrogen oxides, particulate matter, visible emissions (opacity), carbon monoxide, volatile organic compounds (VOCs), and lead. Since the EPA has authorized the NMED to administer the NSPS program, the NMED requirements supersede the Federal requirements. Therefore, emissions from the backup generators at WIPP are regulated under the State program, which is discussed in Chapter 29.

NESHAPs - Hazardous air pollutant emissions are regulated under § 112 of the CAA (Title III of the CAAA) as implemented by 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants (NESHAPs)*. Before the CAA was amended in 1990, Subpart A of NESHAPS listed only eight hazardous air pollutants (HAPs). These pollutants are asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride. The CAAA (§ 301) added 181 HAPs, bringing the list of HAPs regulated under Subpart A to 189. De minimis levels for all the HAPs have been proposed under § 112(g) as referenced by the proposed rule *Hazardous Air Pollutants: Proposed Regulations Governing Constructed, Reconstructed or Modified Major Sources* dated April 1, 1994 (59 FR 15504).

In 1993, the WIPP completed a Hazardous Air Pollutant (HAP) Emission Inventory (WID, 1993c) The HAP inventory was developed as a baseline document to calculate maximum potential hourly and annual emissions of criteria pollutants, all 189 regulated NESHAP pollutants, and the New Mexico toxic air pollutants (TAPs) specified under New Mexico Air Quality Control Regulations (AQCRs) 751 and 702, Part III. Emission estimates were used to determine if the WIPP is required to obtain air permits under State or Federal regulations.

Based on HAPs inventory calculations, WIPP operations are significantly below the 10-ton per year (tpy) emission limit for any individual HAP or the 25-tpy limit for combined HAPs emissions established in Subpart A. Thus, the WIPP does not have any NESHAP Subpart A permitting or reporting requirement at this time. However, 40 CFR 61.09(a)(1) requires that the EPA be notified of WIPP's anticipated date of initial startup of the source no more than 60 days or less than 30 days before that date.

The HAPs inventory is updated annually to evaluate regulatory changes and to monitor the use of HAPs and TAPs at the site. The WIPP Chemical Inventory Database is used to evaluate chemical use at the site. Using chemical inventory data, WIPP personnel evaluate potential replacement chemicals and minimize the use of materials that are regulated under NESHAPs as much as possible.

After consultation with the NMED Air Quality Bureau, a determination was made that the WIPP was required to obtain a permit under AQCR 702 for the operation of two back-up diesel electrical power-supply generators. A State permit is required when criteria pollutants exceed the State threshold levels of 10 pounds per hour or 25 tons per year. For the compliance status with the State permit programs, see Chapter 29.

With regard to radionuclide emissions at the WIPP, only Subpart H of NESHAPs applies due to the nature of wastes to be received at the WIPP. No radium-containing TRU wastes are currently identified for disposal at the WIPP. Subpart H of 40 CFR Part 61, *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*, pertains to non-radon radionuclide emissions from DOE facilities. The NESHAP for radionuclides is an effective dose equivalent (EDE) of 10 millirem (mrem) per year to any member of the public. A NESHAPs application must be filed if the anticipated EDE will exceed 1 percent of the standard. The DOE and the EPA have agreed that the WIPP will be regulated under NESHAPs through the disposal phase at the WIPP [see the NESHAPs Memorandum of Understanding (MOU) between the EPA and the DOE, draft # 6, dated September 7, 1993].

In the *WIPP Final Safety Analysis Report* (FSAR) (DOE, 1990d), doses from radionuclide emissions anticipated from WIPP were calculated to be less than 1 percent of the allowable EDE of 10 mrem per year to any one member of the public. The DOE

documented the expected emission levels in a data package submitted to the EPA. An emissions monitoring system was installed to comply with NESHAPs and to meet confirmatory monitoring requirements. Emissions monitoring test results will be used to verify compliance after receipt of TRU waste at WIPP.

PSD Program - The PSD program, like many of the other programs under the CAA, is designed for proposed new construction or the modification of existing facilities. It pertains to any proposed new or modified facility to be located in an attainment area, particularly if the facility could impact the air quality in a national park, wilderness area, monument, seashore, or other areas of special national or regional natural, recreational, scenic, or historic value. Because the WIPP does not emit over 100 tpy of any criteria pollutant, the WIPP is not categorized as a major source, and the PSD program does not apply.

Title II, *Emission Standards for Moving Sources*: Although most of the requirements under the CAA pertain to stationary sources, the requirements under Title II of the CAA and the CAAA pertain to mobile sources and establish standards for motor vehicles and fuel. Many of these requirements are aimed at automobile manufacturers and petroleum companies (e.g., Part A of Title II, *Motor Vehicle Emission and Fuel Standards*). Federal agency fleets are covered in § 248 of the CAA. Federal agencies that operate fleets in nonattainment areas for ozone and/or carbon monoxide are required to use clean-fuel vehicles and must use clean alternative fuels when operating in the nonattainment area. At present, the requirements for Federal agency fleets under Title II are not applicable to the WIPP because it is not located in a nonattainment area.

Title III, *General Provisions*: Title III of the CAA provides general provisions for the administration of the CAA and pertains to all titles. The provisions stipulated under Title III include administration, Federal procurement, suits, audits, and air-quality monitoring and modeling. It does not add additional programs. Title III of the CAA (VIII of the CAAA) also requires that the EPA perform a comprehensive analysis of the impact of the CAAA.

Title IV, *Acid Deposition Control*: Title IV of the CAA and the CAAA is aimed primarily at utilities and power plants that emit large quantities of sulfur dioxide and/or nitrogen oxides. It seeks to reduce emissions of sulfur dioxide and nitrogen oxides in order to decrease the acid-rain problem in the United States. It is not applicable to WIPP.

Title V, *Permits*: Most of the other permitting programs under the CAA are designed primarily for proposed new construction or the modification of existing facilities. Title V of the CAA and the CAAA as promulgated in 40 CFR Part 70, *State Operating Permit Programs*, identifies the operating permit requirements for major stationary sources. Those facilities required by the State or by the EPA to have an operating permit will be expected to submit an operating permit application, a compliance plan, and periodic compliance reports.

Currently the State of New Mexico has no approved operating permit program in place. The State submitted an Operating Permit State Implementation Plan (SIP) to the EPA on November 15, 1993. On May 19, 1994, the EPA proposed to grant interim approval to the NMED for its operating permit program (59 FR 26158). If approved, the interim approval will go into effect for up to 2 years.

The SIP identifies two new regulations to implement the requirements of 40 CFR Part 70. New Mexico Air Quality Control Regulation (AQCR) 770 adopts and adds to the provisions of 40 CFR Part 70, and AQCR 771 establishes permit fees for emissions for the New Mexico Operating Permit Program (see also Chapter 29). The Federal program (40 CFR Part 70) regulates and requires permits for both area and major sources. At this time, emission limits for those area sources required to have an operating permit have not been established; therefore, the major-source emission thresholds are used to determine which facilities require operating permits for both area and major sources under 40 CFR Part 70 and AQCRs 770 and 771. The HAP inventory was also used to determine if the WIPP is a major source as defined in 40 CFR Part 70 and AQCR 771. A facility is considered a "major source" and is required to obtain an operating permit if the facility emits 100 tons per year (tpy) of criteria pollutants, 10 tpy of any single HAP, or 25 tpy of any combination of HAPs. Based on HAP inventory emission calculations, the WIPP is not a major source and is not required to obtain a Federal CAA operating permit.

Title VI, *Stratospheric Ozone Protection*: Title VI of the CAA and the CAAA places restrictions on and phases out the use of ozone-depleting chemicals, particularly chlorofluorocarbons (CFCs). It is implemented by 40 CFR Part 82, *Protection of Stratospheric Ozone*. These regulations are designed to phase out the use of Class I and Class II substances. Class I substances are CFCs, halons, carbon tetrachloride, methyl chloroform, hydrobromofluorocarbons (HBFCs), and methyl bromide. Class II substances are hydrochlorofluorocarbons, which generally have a lower ozone-depleting potential than do CFCs. The production of most Class I substances will be prohibited as of January 1, 1996 (January 1, 2001, for methyl bromide, as indicated in 58 FR 69235). Proposed legislation indicates that, effective January 1, 2010, the use of Class II substances will be prohibited unless the substance has been used, recovered, and recycled; is used and entirely consumed in producing other chemicals; or is used as a refrigerant in appliances that were manufactured prior to January 1, 2020 (58 FR 15014). By January 1, 2030, the manufacture of all Class II substances will also be prohibited (58 FR 65018).

Implementing regulations pertaining to labeling requirements and the use and disposal of Class I substances during the service, repair, or disposal of appliances and industrial process refrigeration have been published in the *Federal Register*. Recycling equipment registrations and training certification have been received from all WIPP refrigerant recycling contractors. Effective February 16, 1993, the distribution or sale of any Class I substance identified as nonessential was implemented. Nonessential products include safety horns, wall-mounted

alarms, CFC-containing cleaning fluids for electronic or photographic equipment, and CFC-containing aerosol products or other pressurized dispensers.

Most of the requirements pertaining to ozone-depleting substances (ODSs) such as CFCs are applicable primarily to manufacturers of the chemicals, products containing the chemicals, or products in which ODSs are used during the manufacturing process. However, these regulations are applicable to WIPP in that these products will no longer be available after the time specified in the regulations; therefore, replacement products must be found. It is anticipated that the most significant impact on WIPP will be in finding appropriate solvents and warning devices that do not make use of ODSs.

Any container in which Class I or Class II substances (including waste) will be transported must have a warning label as required by 40 CFR 82.106, *Warning Statement Requirements*. However, the *WIPP Waste Acceptance Criteria* (WAC; DOE, 1991b) require that each generator site document that all aerosol cans included in the waste packages intended for WIPP have been punctured (because the WAC allows no pressurized containers to be transported in the TRUPACT-II containers) and that all such containers are empty; thus, wastes destined for the WIPP will not include containers with Class I or Class II substances. Therefore, the labeling requirements for Class I and Class II substances are not applicable to TRU wastes destined for WIPP.

6.2 Compliance Status of the Regulatory Requirements

Table 6-1 summarizes each applicable requirement and its compliance status under the Clean Air Act. Following the table, the text provides more detail on the compliance status of each requirement.

TABLE 6-1. Clean Air Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
Clean Air Act as amended, § 118, *Control of Pollution from Federal Facilities*		
§ 118	Control of pollution from Federal facilities	See Chapters 6 and 29 [Section 6.2.1]

TABLE 6-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Subpart H of 40 CFR Part 61, *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*		
40 CFR 61.96	NESHAPs application for radionuclides	**ACHIEVED** *Radionuclide Emission Data Package for the WIPP* [Section 6.2.2.1]
40 CFR 61.93(a),(b)	EPA approval of any alternative methods for monitoring/sampling for radionuclide emissions and air flow rate that differ from those specified under NESHAPs	**UP TO DATE** Not deemed to be required for confirmatory sampling [Section 6.2.2.2]
40 CFR 61.93(b) and Appendix B, Method 114, § 4.10	NESHAPs Quality Assurance Project Plan (QAPjP)	**ACHIEVED** *NESHAPs QAPjP*, 1993 [Section 6.2.2.3]
40 CFR 61.09(a)(1)	EPA notification under NESHAPs, pre-startup	**UP TO DATE** Notifications: June 1991; update required before receipt of TRU waste [Section 6.2.2.4]
40 CFR 61.09(a)(2)	EPA notification under NESHAPs, post-startup	**NOT APPLICABLE** Will be required after receipt of TRU waste [Section 6.2.2.5]
40 CFR 61.94	NESHAPs annual report	**NOT APPLICABLE** Will be required prior to receipt of TRU waste [Section 6.2.2.6]

TABLE 6-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
National Emission Standards for Hazardous Air Pollutants for Non-Radionuclides		
40 CFR Part 61, Subpart A	General NESHAPs requirements	See Chapter 29
40 CFR Part 70, *State Operating Permit Programs, if applicable*[1]		
40 CFR 70.3(a)(3)	Operating permit application from area sources under NESHAPs	**NOT APPLICABLE** No area-source thresholds established yet by the EPA or NMED [Section 6.2.3.1]
40 CFR 70.5(c)(8)	Compliance plan for 40 CFR Part 70 sources as part of operating permit application	**NOT APPLICABLE** Will be required if operating permit application is requested [Section 6.2.3.2]
40 CFR 70.5(c)(8)(iv) and 70.6(a)(3)(iii)(A)	Semiannual operating permit reports and progress reports on compliance plan	**NOT APPLICABLE** Will be required if operating permit is needed [Section 6.2.3.3]

[1]Applicability of 40 CFR Part 70: "A State program with whole or partial approval under this part must provide for permitting of at least the following sources: ...(3) Any source, including an area source, subject to a standard or other requirement under section 112 of the Act..." [40 CFR 70.3(a)].

TABLE 6-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
CAA, § 112, National Emission Standards for Hazardous Air Pollutants		
CAA, § 112(r)(6)(K)	Risk management plan/hazard assessment, if applicable	**NOT APPLICABLE** Low levels of emissions and exemptions (HAPs inventory, Tier II report, and *WIPP Final Safety Analysis Report*) [Section 6.2.3.4]
40 CFR Part 82, *Protection of Stratospheric Ozone*		
40 CFR 82.40	Restrictions on repairing and servicing motor vehicle air conditioners (MVACs)	**ACHIEVED** Off-site certified service technicians used on all Government Service Administration (GSA) vehicles [Section 6.2.4.1]
40 CFR 82.54(c) and 82.104(a)	Prohibition of nonessential Class I ozone-depleting substances (ODSs)	**UP TO DATE** Non-essential ODSs removed from purchase lists; substitute products being evaluated and used to replace ODSs [Section 6.2.4.2]
40 CFR 82.66	Ban on nonessential products containing Class I substances	**UP TO DATE** Substitute products [Section 6.2.4.3]

TABLE 6-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 82.84	Federal procurement requirements	NOT APPLICABLE Substitute products [Section 6.2.4.4]
40 CFR 82.86	Reporting requirements	NOT APPLICABLE Substitute products [Section 6.2.4.5]
40 CFR Part 82, Subpart E	Labeling of products and containers containing Class I or Class II ODS	NOT APPLICABLE Aerosol cans in waste packages punctured and containers drained to less than 1% residual liquid; label requirement not applicable [Section 6.2.4.6]
40 CFR 82.102	Applicability	NOT APPLICABLE Manufacturers: see also Section 6.2.4.6 [Section 6.2.4.7]
40 CFR 82.106	Required warning statements	NOT APPLICABLE Manufacturers; see also Section 6.2.4.6 [Section 6.2.4.8]
40 CFR 82.108 and 82.112	Placement of warning statement and prohibition of removal of the label bearing the warning statement	NOT APPLICABLE Manufacturers; see also Section 6.2.4.6 [Section 6.2.4.9]

TABLE 6-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 82.122	Certification, recordkeeping, and notice requirements	**UP TO DATE** Labels applied to containers as required [Section 6.2.4.10]
40 CFR 82.150	Service, maintenance, and repair of appliances using refrigerants	**ACHIEVED** EPA certification requirements met by contractors' recycling appliances at WIPP [Section 6.2.4.11]
40 CFR 82.154	Prohibitions	**ACHIEVED** Contractors responsible for management of appliances; no appliances sold at WIPP [Section 6.2.4.12]
40 CFR 82.156	Required practices	**UP TO DATE** Certified contractors and equipment; self-contained equipment; same-day repair of leaks [Section 6.2.4.13]

6.2.1 Control of Pollution from Federal Facilities, CAA § 118

Each department of the executive, legislative, and judicial branches of the Federal government having jurisdiction over any property or facility or engaged in any activity resulting in or that may result in the discharge of air pollutants and each employee thereof is subject to and must comply with all Federal, State, interstate, and local requirements respecting the control and abatement of air pollution in the same manner and to the same extent as any nongovernmental entity.

The DOE complies with all Federal and State requirements pertaining to the release of air pollutants that apply to WIPP. Compliance with Federal and State air-quality requirements are described in this chapter and in Chapter 29, respectively.

6.2.2 National Emission Standards for Hazardous Air Pollutants (NESHAPs), 40 CFR 61, Subpart H

The NESHAP for radionuclides other than radon from DOE facilities is an effective dose equivalent (EDE) of 10 mrem/year.

Subpart H, *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities,* of 40 CFR Part 61 requires that facilities owned or operated by the DOE that emit any radionuclides other than radon-222 and radon-220 into the air are subject to this regulation.

After receipt of waste, WIPP could emit radionuclides other than radon-222 and radon-220 and therefore would be subject to the emissions standard specifying that no member of the public may receive an EDE of 10 mrem/year in any year. Information on modeling for radionuclide emissions that was published in the *WIPP Final Safety Analysis Report* of May 1990 (DOE, 1990d) indicates that individuals could receive a maximum effective dose of 0.0017 mrem/year from routine operations at WIPP during disposal phase operations. In May 1994, additional modeling was performed for NESHAPs compliance using the CAP-88 code, which resulted in an estimated EDE of 4.04E-04 mrem/year. These calculated values are well below 1 percent of the regulatory limit of 10 mrem/year; thus, only confirmatory sampling will be required to comply with Subpart H. If radionuclide emissions are routinely found to exceed 1 percent of the standard (i.e., 0.1 mrem/year), it may be necessary to develop a continuous monitoring program, file a NESHAPs application for approval by the EPA, and/or report monthly instead of annually, at the discretion of the EPA. However, no source term exists at or is planned for WIPP that could cause normal operations to exceed the 1-percent emission limit. Thus, any projected emissions exceeding the 1-percent level would be the result of an extremely unlikely accident scenario.

6.2.2.1 NESHAPs Application for Radionuclides, 40 CFR 61.96

The submittal of a NESHAPs application is required prior to construction or modification of any DOE facility that will emit radionuclides to the air.

An application under NESHAPs would ordinarily be required prior to receipt of radioactive waste at WIPP. However, if the estimated annual EDE is less than 1 percent of the standard,

no application is required. Since the estimated EDE was well below this number, no application was required for compliance with Subpart H of NESHAPs at WIPP. Therefore, the application that had been prepared was converted to a data package (*Radionuclide Emission Data Package for the Waste Isolation Pilot Plant*) in November 1990 and transmitted to the EPA for their information in February 1991 (WID, 1990). An application will be required only if confirmatory monitoring reveals that the emissions may have reached or exceeded 1 percent of the standard. If radionuclide emissions are routinely found to exceed 1 percent of the standard (i.e., 0.1 mrem/year), it may be necessary to develop a continuous monitoring program, file a NESHAPs application for approval by the EPA, and/or report monthly instead of annually, at the discretion of the EPA. However, no source term exists at or is planned for WIPP that could cause normal operations to exceed the 1-percent emission limit. Thus, any projected emissions exceeding the 1-percent level would be the result of an extremely unlikely accident scenario.

6.2.2.2 EPA Approval of any Alternative Methods Used, 40 CFR 61.93(a),(b)

EPA approval is required for any alternative methods for monitoring/sampling for radionuclide emissions and air-flow rate that differ from those specified under NESHAPs.

In accordance with the draft MOU between the EPA and the DOE (draft 6), it is DOE policy to implement the requirements of Subpart H of 40 CFR Part 61 at WIPP until closure of the facility. Accordingly, the WID has evaluated the criteria stipulated in Subpart H and determined that the technology used at WIPP is consistent with EPA-approved methods. The WIPP employs a single-point, anisokinetic sampling technology for performing the required periodic confirmatory measurements rather than using an isokinetic system. The technology being used more accurately measures potential emissions in the WIPP mine atmosphere but is not an EPA-approved sampling methodology. Because calculated emissions are less than 1 percent of the 10-mrem standard, the WIPP is required to perform confirmatory sampling only. For demonstrating compliance with Subpart H, the DOE is taking the position that EPA approval of a single-point anisokinetic sampling technology is not required for confirmatory sampling. However, the EPA is authorized to review WIPP's confirmatory sampling methodology as part of the data package review. The EPA can make a determination that the sampling methods being used are adequate for periodic confirmatory measurements.

Specially designed shrouded aerosol sampling probes provide representative aerosol sampling even though they operate anisokinetically with respect to the effluent stream velocity. The shrouded probe is a unique design developed by Texas A&M University personnel specifically for sampling air in the underground shafts at WIPP. Texas A&M personnel examined the need for an alternative to isokinetic sampling in the 14-foot-diameter underground exhaust shaft in order to meet the criterion of 50-percent collection efficiency for a 10-micron diameter. The shrouded probe has been evaluated as a successful alternative to isokinetic sampling in the

underground exhaust shaft. Documents that support the use of anisokinetic sampling and sampling locations in the exhaust air streams at WIPP include reports by Newton et al. (1987), Anand and McFarland (1988), Turner et al. (1988), and McFarland et al. (1989). The DOE has discussed the use of single-point anisokinetic sampling technology with EPA Region VI and does not anticipate that the EPA will determine that approval of an alternative sampling technology is required prior to the emplacement of TRU waste at WIPP. Based on the results of the Texas A&M studies on the single-point anisokinetic probe, this technology provides a representative sample of the WIPP underground environment.

6.2.2.3 NESHAPs Quality Assurance Project Plan, 40 CFR 61.93(b) and Appendix B, Method 114, Section 4.10

A NESHAPs Quality Assurance Project Plan (QAPjP) is required for facilities subject to Subpart H of NESHAPs.

The draft *Quality Assurance Project Plan for Sampling Emissions of Radionuclides to the Ambient Air at the Waste Isolation Pilot Plant* was completed on August 30, 1993, and submitted to the DOE on September 3, 1993 (WID, 1993d). The NESHAPs QAPjP must be approved by the EPA and implemented at WIPP prior to the receipt of TRU waste.

6.2.2.4 NESHAPs Pre-Startup Notification, 40 CFR 61.09(a)(1)

The EPA will be notified of planned startup between 30 and 60 days prior to startup.

On June 10 and June 26, 1991, DOE sent pre-startup notification letters to the EPA Administrator and the EPA Region VI office, respectively, to inform them of the pending startup of WIPP, which was anticipated between July 17 and August 2, 1991. When startup was delayed, another letter of notification (not dated) was sent from DOE to the EPA Region VI office, indicating that the window for startup had shifted to August 30 to September 30, 1991. Again, startup was delayed. Because of the DOE's agreement to comply with NESHAPs requirements until closure of WIPP, notification of the EPA will be required prior to receipt of TRU waste at WIPP.

6.2.2.5 NESHAPs Post-Startup Notification, 40 CFR 61.09(a)(2)

The EPA will be notified of actual startup of WIPP within 15 days after that date.

When the DOE opens WIPP for emplacement of radioactive waste, it will notify the EPA within 15 days after startup. Until that time, this requirement does not apply to WIPP.

6.2.2.6 NESHAPs Annual Report, 40 CFR 61.94

A NESHAPs annual report must be submitted by June 30th for facilities subject to Subpart H of NESHAPs.

After DOE opens WIPP for the emplacement of radioactive waste, it will file a NESHAPs report by June 30th every year as long as the facility is subject to these regulations. This requirement will no longer be applicable after closure of WIPP, when the radiation protection standards of Subpart B (40 CFR Part 191) will go into effect.

6.2.3 State Operating Permit Programs, 40 CFR Part 70 and Draft AQCRs 770 and 771

The new requirements for operating permits include a provision that State programs must provide for permitting of "any source, including an area source [i.e., a source of the pollutant that is not a major source], subject to a standard or other requirement under § 112 of the [Clean Air] Act" [see Section 70.3(a)(3)], which is the section on NESHAPs. Based on emission calculations in the 1993 HAPs Inventory, emissions at the WIPP are below "major source" and NESHAP emission limits. Thus, the permitting and reporting requirements contained in 40 CFR Part 70 and AQCRs 770 and 771 are not applicable at this time. The HAPs Inventory is updated annually to evaluate regulatory changes and to monitor the use of HAPs and toxic air pollutants (TAPs; defined in New Mexico AQCRs 751 and 702, Part III) at the site. The WIPP Chemical Inventory Database is used to evaluate chemical use at the site. Using chemical inventory data, WIPP personnel evaluated potential replacement chemicals to minimize the use of materials regulated under the NESHAPs and TAP programs.

Because the State does not yet have an operating permit program in place, the Federal requirements for an operating permit program are summarized here.

6.2.3.1 Operating Permit Application, 40 CFR 70.3(a)(3)

Upon approval of its operating permit program, the State may require the submittal of operating permit applications from area sources under NESHAPs.

Based on the 1993 WIPP HAPs Inventory, HAP emissions from the facility are below current operating-permit threshold levels, and an operating permit is not required for WIPP. Submittal of an application is not applicable at this time.

6.2.3.2 Compliance Plan, 40 CFR 70.5(c)(8)

Submittal of a compliance plan is required as part of the operating permit application for 40 CFR 70 sources.

Based on the 1993 WIPP HAPs Inventory, HAP emissions from the facility are below current operating-permit threshold levels, and an operating permit is not required for WIPP. If a determination is made at a later date that an operating permit application is required for the facility, a compliance plan will be part of the application as specified.

6.2.3.3 Semiannual Operating Permit Reports and Progress Reports on the Compliance Plan, 40 CFR 70.5(c)(8)(iv) and 70.6(a)(3)(iii)(A)

Semiannual operating permit reports and progress reports on the compliance plan will be filed, if applicable.

Based on the 1993 WIPP HAPs Inventory, HAP emissions from the facility are below current operating-permit threshold levels, and an operating permit is not required for WIPP. The WIPP will be required to submit these reports if and when WIPP is considered to be subject to the operating permit program.

6.2.3.4 Risk Management Plan/Hazard Assessment, CAA, § 112(r)

A risk management plan/hazard assessment must be prepared, if applicable.

The list of regulated substances for accidental release prevention under § 112(r) of the CAA and the threshold quantities for these substances have been finalized in 40 CFR Part 68, *Chemical Accident Prevention Provisions* (59 FR 4478). However, the requirements for evaluating the need for and the preparation of a risk management plan were published separately as a proposed rule (Subpart B of 40 CFR Part 68) in October 1993 (*Risk Management Programs for Chemical Accidental Release Prevention*, 58 FR 54190). Since the requirements for risk management programs have not yet been finalized, they do not currently apply to WIPP. However, in order to take a proactive approach with Subpart B of 40 CFR Part 68 when these regulations become finalized, three documents were used to determine whether emissions from WIPP exceed the

regulatory threshold level of any of the chemicals listed in the final rule. The three documents are the WIPP HAPs inventory, the *WIPP Tier II Emergency and Hazardous Chemical Inventory Report* required under the Emergency Planning and Community Right-to-Know Act (EPCRA), and the *WIPP Final Safety Analysis Report* (FSAR). It was found that, of the 162 substances and gases listed in the final rule, none meets or exceeds the final threshold levels. Sulfuric acid, which was included in the proposed list, is not included in the final list, and the final threshold quantity for sulfur dioxide (SO_2) is 5000 pounds, which is considerably greater than the SO_2 emissions released as a combustion byproduct from the operation of the backup diesel generators and the emergency diesel fire pump. Therefore, WIPP is not currently required to develop a risk management plan to evaluate accidental releases from the site.

6.2.4 Protection of Stratospheric Ozone, 40 CFR Part 82

A number of requirements have been imposed that relate to chlorofluorocarbons (CFCs) and other ozone-depleting substances (ODSs). Most of these requirements pertain directly to manufacturers; however, because of the planned phase-out of these materials, the regulations will also impact users of these materials.

6.2.4.1 Restrictions on Repairing and Servicing Motor Vehicle Air Conditioners (MVACs), 40 CFR 82.40

> *Effective August 13, 1992, no person repairing or servicing motor vehicles for consideration may perform any service on a motor vehicle air conditioner (MVAC) involving the refrigerant for the air conditioner without using approved refrigerant recycling equipment and unless he/she has been properly trained and certified by a technician certification program approved by the Administrator.*

No government vehicles are serviced, repaired, or maintained by WIPP employees or contractors. The WID Purchasing Department has indicated that no work has been performed on MVACs owned by the Government Service Administration (GSA) since the effective date of the regulations. The vendors have verified that they have not serviced these vehicles.

All equipment owned or used by the vendors that service these vehicles has been approved, and all the service technicians who perform such work are certified to work on MVACs.

6.2.4.2 Prohibition of Nonessential Class I Ozone-Depleting Substances (ODSs), 40 CFR 82.54(c) and 82.104(a)

Nonessential Class I ODSs are being phased out and will no longer be sold or distributed in the United States as of January 17, 1994. The Class I ODSs currently consist of the chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform.

A list of the ODSs used at WIPP is included in the current WIPP emissions inventory. As WIPP personnel continue to define the actual use of products containing ODSs, waste minimization personnel will continue to obtain substitute products to reduce ODS emissions from WIPP.

6.2.4.3 Ban on Nonessential Products Containing Class I Substances, 40 CFR 82.66

The following products that release a Class I substance were identified as being nonessential and are subject to the prohibitions specified under 40 CFR 82.64:

- *Personal safety horns;*
- *Wall-mounted alarms used in factories or other work areas;*
- *Any plastic flexible or packaging foam product which is manufactured with or contains a CFC;*
- *Any aerosol product or other pressurized dispenser that contains a CFC including but not limited to household, industrial, automotive, and pesticide uses except lubricants, coatings, or cleaning fluids for electrical or electronic equipment that contain no CFCs other than CFC-11, CFC-12, or CFC-113 for solvent purposes; and*
- *Document preservation sprays that contain no other CFC than CFC-113.*

The deadlines set under 40 CFR 82.64 pertain to selling or distributing nonessential products. However, the items have been listed because no purchase of nonessential products shall be made by government entities after October 24, 1994. An inventory of ODSs on site, dated September 17, 1993, was reviewed. No personal safety horns, wall-mounted alarms, or plastic flexible or packaging foam was listed on the inventory list, and the WIPP warehouse has verified that no plastic or packaging foam is present on site.

WIPP has an inventory of aerosol products used at the site. Substitute products are being investigated.

A number of cleaning fluids used at the site are listed on the September 17th inventory list. An inventory list dated October 26, 1992, shows that substitute products are being identified and are replacing ODSs.

No document preservation sprays are used at WIPP.

6.2.4.4 Federal Procurement Requirements, 40 CFR 82.84

Each department, agency, and instrumentality of the United States shall conform its procurement regulations to the requirements and policies of Title VI of the CAA by October 24, 1994. Each such regulation shall provide, at a minimum, the following:

- *In place of Class I or Class II substances or of products made with or containing such substances, safe alternatives identified under 42 USC § 7671(k) (or products made with or containing such alternatives) shall be substituted to the maximum extent practicable.*

- *Consistent with the phaseout schedules for ODS, no purchase shall be made of Class II substances, or products containing Class II substances, for the purpose of any use prohibited under 42 USC § 7671(d)(c).*

- *All active or new contracts involving the performance of any service or activity subject to 42 USC § 7671(g) or 7671(h) or regulations promulgated thereunder include, or be modified to include, a condition requiring the contractor to ensure compliance with all requirements of those sections and regulations.*

- *No purchase shall be made of products whose sale is prohibited under 42 USC § 7671(h), except when they will be used by persons certified under § 609 to service vehicles, and no purchase shall be made of nonessential products as defined under 42 USC § 7671(i).*

- *Proper labeling under 42 USC § 7671(j) shall be a specification for the purchase of any product subject to that section.*

For agencies subject to the Federal Acquisition Regulation (FAR), 48 CFR Part 1, amendment of the FAR, consistent with this subpart, shall satisfy the requirement of this section.

Since the procurement regulations do not become effective until October 24, 1994, the requirements are included for planning purposes. A comparison of the inventory list dated September 17, 1993, with that dated October 26, 1992, indicates that efforts are being made to identify substitute products to replace ODSs.

6.2.4.5 Reporting Requirements, 40 CFR 82.86

No later than 1 year after October 22, 1993, each agency, department, and instrumentality of the United States shall certify to the Office of Management and Budget that its procurement regulations have been amended in accordance with this section.

Certification by the GSA that the FAR has been amended in accordance with this section shall constitute adequate certification for purposes of all agencies subject to the FAR.

The procurement regulations become effective on October 24, 1994. See also response to Section 6.2.4.5.

6.2.4.6 Labeling of Products and Containers Containing Class I or Class II Ozone-Depleting Substances, 40 CFR Part 82, Subpart E

Warning statements are required on containers of and products containing or manufactured with certain ODSs.

Federal procurement regulations require that proper labeling be a specification for the purchase of any product. The labeling requirements apply primarily to manufacturers. However, it should be noted that this requirement could impact transporters of TRU waste to WIPP if the waste contains any Class I or Class II ODSs and if the waste is transported across State boundaries. Containers holding any such waste must be labeled in compliance with Subpart E of 40 CFR Part 82.

6.2.4.7 Applicability, 40 CFR 82.102

These requirements apply to substances designated as Class I or Class II substances as of February 11, 1993, beginning on May 15, 1993. The requirements of this subpart apply to the following containers and products except those products manufactured prior to May 15, 1993, provided that the manufacturer submits documentation to the EPA upon request showing that the product was manufactured prior to that date. The requirements apply to:

- *All containers in which a Class I or Class II substance is stored or transported,*
- *All products containing a Class I substance, or*
- *All products directly manufactured with a process that uses a Class I substance, unless otherwise exempted.*

Beginning on January 1, 2010, or 1 year after any determination between May 15, 1993 and January 1, 2010, if suitable substitute products or manufacturing processes are found, the requirements of this subpart shall apply to the following:

- *All products containing a Class II substance or*
- *All products manufactured with a process that uses a Class II substance*

Federal procurement regulations require that proper labeling shall be a specification for the purchase of any product. The labeling requirements apply primarily to manufacturers. (See also Section 6.2.4.6.)

6.2.4.8 Required Warning Statements, 40 CFR 82.106

Unless otherwise exempted by this subpart, each container or product identified in § 82.102(a) or (b) shall bear the following warning statement, meeting the requirements of this subpart for placement and form:

WARNING: Contains [or Manufactured with, if applicable] [*insert name of substance*], a substance which harms public health and environment by destroying ozone in the upper atmosphere.

Exemptions from the warning label requirement are:

- *Products in which trace quantities of a controlled substance remain as a residue or impurity*
- *Products manufactured using methyl chloroform or CFC-113 by persons who can demonstrate and certify a 95 percent reduction in overall usage from their 1990 calendar year usage of methyl chloroform or CFC-113 as solvents during a 12-month period ending within 60 days of such certification or during the most recently completed calendar year*
- *Products that are otherwise not subject to the requirements of this subpart that are being repaired, using a process that uses a controlled substance.*

Federal procurement regulations require that proper labeling shall be a specification for the purchase of any product. The labeling requirements apply primarily to manufacturers. (See also Section 6.2.4.6.)

6.2.4.9 Placement of Warning Statement and Prohibition on Removal of the Label Bearing the Warning Statement, 40 CFR 82.108 and 82.112

The warning statement shall be "clearly legible and conspicuous." The manner in which the label may be placed on the container is described. Removal of the label bearing the warning statement is prohibited.

The warning statement is primarily the responsibility of the manufacturer. The prohibition on removing the label bearing the warning statement applies primarily to the manufacturer and subsequent wholesalers. (See also Section 6.2.4.6.)

6.2.4.10 Certification, Recordkeeping, and Notice Requirements, 40 CFR 82.122

On or after May 15, 1993, no person may modify, remove, or interfere with any warning statement required by this subpart, except as described in § 82.112.

All appliances and products containing CFCs should have a label from the manufacturer. It is WIPP policy that warning labels not be removed or tampered with. If a label is damaged, it will be replaced.

6.2.4.11 Service, Maintenance, and Repair of Appliances using Refrigerants, 40 CFR 82.150

This subpart applies to any person servicing, maintaining, or repairing appliances except for MVACs. This subpart also applies to persons disposing of appliances, including MVACs. In addition, this subpart applies to refrigerant reclaimers, appliance owners, and manufacturers of appliances and recycling and recovery equipment.

Although no WIPP employees service, maintain, or repair appliances, these regulations apply to WIPP because the facility owns appliances and WIPP is responsible for the disposal of appliances. WIPP policy is that appliances will be sold intact or refrigerants must be removed from all appliances by a certified recycling contractor.

6.2.4.12 Prohibitions, 40 CFR 81.154

Prohibitions are specified for persons who maintain, service, repair, or dispose of appliances who may vent or otherwise release into the environment any Class I or Class II substance used as refrigerant in such equipment. De minimis releases associated with good faith attempts to recycle or recover refrigerants are not subject to this prohibition. No person may dispose of appliances except for small appliances, MVACs, and MVAC-like appliances unless the required practices described in 40 CFR 82.156 are observed and equipment that is certified for that type of appliance is used. Prohibitions are also specified regarding recycling or recovery equipment.

Prohibitions also exist for the sale of Class I or Class II substances consisting wholly or in part of used refrigerants.

It is a violation of this subpart to accept a signed statement pursuant to 40 CFR 82.156(f)(2) if the person knew or had reason to know that such a signed statement is false.

No WIPP employees service, repair, or maintain appliances on site. Before disposing of appliances, refrigerant is evacuated by a contractor/technician. No WIPP employees perform work on regulated appliances, and no recycling or recovery equipment is owned by the facility. Only small appliances have been disposed of by WIPP personnel since the regulation took effect on July 13, 1993. All contractors have submitted a signed statement to the EPA that ensures compliance with and knowledge of applicable regulations and is included in equipment certification form. Recycling and reclamation appliances containing refrigerants used at the WIPP are owned by certified contractors. No recycling or reclamation appliances have been altered since their certification.

No Class I or II substances are sold or distributed from WIPP.

The technician writes and signs all "Work Performed" narratives on the Plant Work Request at WIPP. The technician is always accompanied by an electrician from Work Control who is responsible for the verification of the "Work Performed" statements.

6.2.4.13 Required Practices, 40 CFR 82.156

Effective July 13, 1993, any person opening appliances other than MVACs must evacuate the refrigerant to a system receiver or to a recovery or recycling machine as specified. At least one piece of certified, self-contained recovery equipment must be available at his/her place of business.

Leaks in appliances containing refrigerant must be repaired as specified.

The contractors have indicated that this is done; Plant Work Requests verify that this requirement is met. All recovery equipment owned/used by the contractors at WIPP is certified. All maintenance, service, and repair on applicable appliances is performed by one of the certified contractors, who have verified on the Equipment Certification Form that they have complied with these regulations.

All equipment owned/used by the contractors at WIPP is self contained. All applicable requirements of this section are being met.

To date, there have been no leaks in the commercial refrigeration units used by the WIPP cafeteria. A leak was detected in 41-B-890B; it was repaired the same day the leak was detected.

6.3 Compliance Status of Permit Conditions

Table 6-2 summarizes the applicable permits and the status of the permit conditions. Currently, only the permit for the backup diesel electrical power-supply generators and a permit for open burning are required for WIPP under the Clean Air Act; those permits are discussed in Chapter 29. An operating permit, to be issued by the State or the EPA, may ultimately be required because WIPP is an area source of several pollutants under the NESHAPs program; however, no such permit is currently required.

TABLE 6-2. Permits Required Under the Clean Air Act - Status of Compliance with Permit Conditions

CITATION	REQUIREMENTS	COMPLIANCE STATUS
§ 109	NAAQS permit	See Chapter 29
40 CFR Part 70	Operating permit conditions to be determined, if applicable	**NOT APPLICABLE** Threshold values for area sources requiring operating permits not yet established by EPA or NMED [See Section 6.2.3]

6.3.1 Applicability of Operating Permit Requirements, 40 CFR Part 70

The EPA and the State are required to establish a threshold value for area sources that emit HAPs in amounts that are less than the 10-tpy limit for a single HAP or the 25-tpy limit for combined HAPs emissions. Those facilities that emit HAPs at rates that meet or exceed the threshold values will be regulated under the operating permit program; those area sources with emissions that are lower than the threshold values will not be required to file an operating-permit application. Until the threshold values are promulgated, area sources are considered to be exempt from the operating permit requirements. Specific operating-permit conditions for a given facility will be specified in the individual permit.

7.0 FEDERAL WATER POLLUTION CONTROL ACT OF 1972 ("CLEAN WATER ACT")

7.1 Summary of the Law

The Federal Water Pollution Control Act of 1972 (33 USC §§ 1251 et seq.) is usually referred to as the "Clean Water Act" (CWA). The major program under this act is the National Pollutant Discharge Elimination System (NPDES). This program, discussed in § 402 of the CWA, regulates the discharge of pollutants into navigable waters of the United States. The regulations implementing the NPDES that are relevant to the WIPP project are found in 40 CFR Part 122, *EPA Administered Permit Programs: the National Pollutant Discharge Elimination System*, which contains definitions and basic application requirements, standard permit conditions, and monitoring and reporting requirements for the NPDES program. However, because there are no point-source discharges into navigable waters at WIPP, the facility is not required to obtain a standard NPDES permit.

In 1990, an NPDES storm water permit program was added to the CWA [§ 402(p)] to govern the discharge of pollutants into precipitation runoff. The EPA has determined that the NPDES storm water regulations found in 40 CFR Part 122.26 are applicable to WIPP because a potential exists for storm water runoff to contact regulated pollutants. The NPDES storm water permit program involves three types of permits: general, individual, and group. To obtain a permit, a facility submits either a Notice of Intent for a general permit, an individual application for an individual permit, or an application as part of a group of applicants for a group permit. The EPA planned to cover most industrial discharges under general permits and issued the *Final NPDES General Permits for Storm Water Discharges Associated with Industrial Activity* in the *Federal Register* on September 9, 1992. These general permits cover facilities that discharge effluents associated with industrial activities in 11 states that do not have authorized NPDES programs, including New Mexico.

Of the other regulations that implement the NPDES program, only 40 CFR 122.21, *NPDES Permit Assessment for Sewage Sludge*, and 40 CFR Part 459, *Photographic Point Source Category*, could apply to WIPP. In order to meet the requirements of 40 CFR Part 122.21(c)(2), the DOE filed an NPDES sewage sludge information package with EPA Region VI, requesting a determination as to whether the facility will be required to obtain an NPDES sewage-sludge discharge permit. Based on the determination made by the Regional Director, the DOE may be required to submit a Notice of Intent (NOI) to obtain a sludge-discharge permit. However, WIPP is exempt from regulation under 40 CFR Part 459 because photographic wastes are collected and transported off-site to a licensed facility for disposal.

Another implementing regulation under the CWA that is applicable to the WIPP project is 40 CFR Part 112, *Oil Pollution Prevention*, which includes criteria and guidelines for the preparation and implementation of a facility's Spill Prevention, Control, and Countermeasures

(SPCC) Plan. The *WIPP Spill Prevention, Control, and Countermeasures Plan* (SPCC Plan) was first issued in November 1988 and is currently undergoing its third revision.

7.2 Compliance Status of the Regulatory Requirements

Table 7-1 summarizes the regulatory requirements and their compliance status under the Clean Water Act. The text gives more detail on the compliance status for each requirement.

TABLE 7-1. Clean Water Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR Part 112, *Oil Pollution Prevention*		
40 CFR 112.3	Requirements for preparation and implementation of spill prevention, control, and countermeasures (SPCC) plans	**ACHIEVED** WIPP SPCC Plan [Section 7.2.1]
40 CFR 112.5	Amendment of SPCC plans by owners and operators	**UP TO DATE** WIPP SPCC Plan [Section 7.2.2]
40 CFR Part 122, *EPA-Administered Permit Programs: the National Pollutant Discharge Elimination System (NPDES)*		
40 CFR 122.1(b)(1)	NPDES permits for the discharge of pollutants from any point source into waters of the United States	**NOT APPLICABLE** No NPDES permit required because of lack of process- or point-source discharges at WIPP [Section 7.2.3]

TABLE 7-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 122.21(c)(2)	NPDES permit assessment for sewage sludge	**ACHIEVED** Information package submitted to the EPA for NPDES sewage-sludge permit determination by the deadline (February 19, 1994) [Section 7.2.4]
40 CFR 122.26(a)	Requirement for a storm water discharge permit	**ACHIEVED** General permit obtained, # NMR00A021 [Section 7.2.5]
40 CFR 122.26(c)	Application requirement for storm water discharges associated with industrial activity	**NOT APPLICABLE** Requirement superseded by issuance of EPA's NPDES General Permits and filing of Notice of Intent for WIPP [Section 7.2.6]

7.2.1 SPCC Plan Requirements, 40 CFR 112.3

Requirements for the preparation and implementation of SPCC plans are specified under the "Oil Pollution Prevention" regulations of 40 CFR Part 112.

The *WIPP Spill Prevention, Control, and Countermeasures (SPCC) Plan* was issued in November 1988.

7.2.2 Amendment of the SPCC Plan by the Owner/Operator, 40 CFR 112.5

Requirements for amending SPCC plans by the owners/operators of a facility are specified under the "Oil Pollution Prevention" regulations of 40 CFR Part 112.

The WIPP SPCC Plan undergoes an annual review and revision as needed to reflect changes in facility activities and emergency equipment (WID, 1993a).

7.2.3 NPDES Permit Requirement, 40 CFR 122.1(b)(1)

> *The NPDES program requires permits for the discharge of pollutants from any point source into waters of the United States.*

There are no point-source discharges into navigable water from WIPP. Therefore, the facility is not required to obtain a standard NPDES permit.

7.2.4 NPDES Permit Assessment, 40 CFR 122.21(c)(2)

> *Any "treatment works treating domestic sewage" commencing operations after the promulgation of an applicable standard for sewage sludge use or disposal shall submit an application to the director at least 180 days prior to the date proposed for commencing operations.*

The WIPP stabilization sewage lagoon began operating in June 1985. Sludge was disposed of in 1993 during the facility expansion. This expansion included the construction of two new lined evaporation ponds and the subsequent draining and lining of the primary evaporation pond. All sludges were removed from the primary evaporation pond prior to the installation of the synthetic liner. This was the first removal of sludge in the 9-year operation of the facility, and it is anticipated that sludge removal will be necessary approximately twice prior to final facility closure.

The sewage sludge permitting regulations were promulgated on February 19, 1993, and became effective on February 19, 1994 (i.e., the submittal of a sewage sludge application was due on the latter date). WID personnel worked closely with NMED and EPA personnel in complying with these new regulations and satisfied all their applicable requirements. Therefore, the 180-day prenotification period is not applicable here.

Consultation with the NMED Surface Water Bureau and the EPA Region VI Water Management Division provided a determination for land disposal of the sewage sludges. Dried sludges were removed from the primary evaporation pond and mixed with top soils at a reclamation site near the construction landfill. Sludges were used as a soil additive to implement the best management practices (BMPs) identified in the *WIPP National Pollutant Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan* (WIPP PPP) (WID, 1993b).

7.2.5 Requirement for NPDES Permit for Storm Water Discharges, 40 CFR 122.26(a)

Storm water discharges are regulated by the EPA under the NPDES program. The EPA requires an NPDES permit for facilities that could discharge contaminated storm water runoff to waters of the United States.

The WIPP site is regulated by NPDES Storm Water General Permit # NMR00A021.

Evaluation of NPDES storm water compliance options for the WIPP began in July 1991. On April 2, 1992, the EPA published the final *NPDES Application Deadlines, General Permit Requirements and Reporting Requirements for Storm Water Discharges Associated with Industrial Activity*, which established the new general permit rules for minimal sampling and analytical requirements. The EPA published the *Final NPDES General Permits for Storm Water Discharges Associated with Industrial Activity* (hereafter referred to as the "NPDES General Permits") in the *Federal Register* on September 9, 1992. These general permits established NOI requirements, prohibitions, requirements to develop and implement storm water pollution prevention plans, and requirements to conduct site inspections for facilities with discharges that are authorized by the permit. In addition, these permits established monitoring requirements for certain classes of facilities.

This requirement is addressed in the WIPP PPP. No sampling was required for the submittal of the NPDES General Permits NOI; the WIPP has little existing NPDES storm water monitoring data.

The NPDES storm water rules require compliance sampling of discharges resulting from any storm event that is greater than 0.1 inch in magnitude. The WIPP uses BMPs such as retention basins designed to contain two consecutive 24-hour storm events, the covering of material storage areas, and the reclamation of disturbed sites to eliminate storm water contact with regulated pollutants. By design, it is anticipated that regulated discharges at WIPP will be required to complete compliance sampling only if a storm event results in a discharge from a retention basin. If sampling is required, it will be conducted as required by the NPDES General Permits.

7.2.6 Application Requirement for Storm Water Discharges Associated with Industrial Activity, 40 CFR 122.26(c)

The implementing regulations in Part 122 require the submittal of an application for a storm water NPDES permit.

This requirement was superseded by the issuance of EPA's *Final NPDES General Permits for Storm Water Discharges Associated with Industrial Activity* (57 FR 41236, September 9, 1992),

which replaces the requirement for the submittal of an application with the filing of an NOI for obtaining a general permit. The NOI for WIPP was submitted to the EPA on September 26, 1992 (see Section 7.3.1).

7.3 Compliance Status of Permit Conditions

Table 7-2 summarizes specific conditions and their compliance status under the EPA's *Final NPDES General Permits for Storm Water Discharges Associated with Industrial Activity*. These general permits were published in the *Federal Register* on September 9, 1992. All applicable requirements are specified in Part IV and Appendix B of the NPDES General Permits.

TABLE 7-2. NPDES General Permits - Summary of Permit Condition Compliance Status

CITATION	CONDITION	COMPLIANCE STATUS
CWA, *Final NPDES General Permits for Storm Water Discharges Associated with Industrial Activity* (57 FR 41236, September 9, 1992)		
IV(A); Appendix B, II(A)	Notice of Intent (NOI) to file for general permit	**ACHIEVED** Filed on September 26, 1992 [Section 7.3.1]
IV(A)(4)	Notice of Termination (NOT)	**NOT APPLICABLE** Containment of storm water discharges not demonstrated [Section 7.3.2]
IV(B)(1); Appendix B, III(A)	Prohibition on non-storm water discharges	**ACHIEVED** Discharges: either exempt, non-regulated, or contained [Section 7.3.3]

TABLE 7-2 (continued)

CITATION	CONDITION	COMPLIANCE STATUS
IV(B)(2); Appendix B, III(B)	Releases of reportable quantities of hazardous substances and oil	**UP TO DATE** Three releases of ethylene glycol reported; WIPP PPP, Section 3.3, addresses necessary actions [Section 7.3.4]
IV(C); Appendix B, Part IV	Storm water pollution prevention plan	**ACHIEVED** WIPP PPP [Section 7.3.5]
IV(C)(1); Appendix B, IV(D)(1)	Pollution prevention team	**ACHIEVED** Identified in WIPP PPP, Section 2.2 [Section 7.3.6]
IV(C)(2); Appendix B, IV(D)(2)	Identification of potential pollution sources	**ACHIEVED** WIPP PPP, Chapter 3.0 [Section 7.3.7]
IV(C)(2); Appendix B, IV(D)	Site assessments	**ACHIEVED** Summarized in WIPP PPP, Chapter 3.0. [Section 7.3.8]
IV(C)(3); Appendix B, IV(D)(3)	Measures and controls (including recordkeeping and internal reporting)	**ACHIEVED** Identified in WIPP PPP, Chapter 4.0. [Section 7.3.9]

TABLE 7-2 (continued)

CITATION	CONDITION	COMPLIANCE STATUS
IV(C)(4); Appendix B, IV(D)(4)	Comprehensive site compliance evaluations	**UP TO DATE** Initial site inspection; WIPP PPP, Chapter 3.0 [Section 7.3.10]
IV(D)(1); Appendix B, IV(D)(7)	Requirements for storage, processing, and handling areas for EPCRA § 313 "water priority chemicals"	**NOT APPLICABLE** No reporting under § 313 of EPCRA required [Section 7.3.11]
IV(D)(2); Appendix B, IV(D)(8)	Enclosure or covering of outdoor salt piles	**NOT APPLICABLE** Runoff diverted to evaporation basins; no discharge to waters of the U.S. possible, WIPP PPP, Chapter 4.0 [Section 7.3.12]
IV(D)(3); Appendix B, IV(D)(5)	Notification to municipal large and medium separate storm water systems	**NOT APPLICABLE** Storm water not discharged through a large or medium separate system [Section 7.3.13]
IV(E); Appendix B, Part IV and XI(C)(vi)	Monitoring and reporting requirements	**NOT APPLICABLE** Required monitoring described in WIPP PPP, Chapter 5.0 [Section 7.3.14]

TABLE 7-2 (continued)

CITATION	CONDITION	COMPLIANCE STATUS
IV(G); Appendix B, IV(A)(1)	Deadline for plan preparation and compliance	ACHIEVED WIPP PPP issued March 31, 1993; implementation of BMP completed by October 1, 1993, compliance date [Section 7.3.15]

7.3.1 NOI to File for a General Permit, IV(A) and Appendix B, II(A)

In the EPA's NPDES General Permit, a provision was made that a facility should file an NOI to file for a general storm water discharge permit rather than submit a formal application for the permit.

The NOI to obtain an NPDES general storm water permit was submitted to the EPA on September 26, 1992. The EPA issued a general permit to WIPP on December 31, 1992 (# NMR00A021).

7.3.2 Notice of Termination (NOT), IV(A)(4)

A facility may submit an NOT if no storm water discharges will be released.

Although the WIPP has implemented BMPs that are designed to make WIPP a zero-discharge facility, this requirement is currently not applicable because the facility has the potential to discharge storm water that could contact regulated pollutants. If WIPP can demonstrate that the storm water discharges can be effectively contained, an NOT may be filed as specified under Condition IV(A)(4) of the NPDES General Permits. If the NOT is approved by the EPA, coverage of WIPP under the *NPDES General Permits for Storm Water Discharges Associated with Industrial Activity* will cease.

7.3.3 Prohibition on Non-Storm Water Discharges, IV(B)(1) and Appendix B, III(A)

The EPA prohibits the release of non-storm water discharges under the storm water discharge NPDES permit.

In 1989, an internal audit identified 63 potential non-storm water discharges. A comprehensive sampling program was initiated, and non-storm water discharges have now been characterized, either by chemical analysis or by process knowledge. Of these, 49 were either air-conditioner condensate discharges or fire-water testing discharges, both of which are exempt from the general permit rules. Nine of the 14 remaining discharges are non-regulated because they are below applicable regulatory limits or are collected in containers and not allowed to be discharged to the ground. The remaining five will be contained by engineering controls. Four of these five discharges are oily condensates from the Main Compressor Building. A Plant Work Request (PWR) has been submitted to hard-pipe all four oily condensate discharges into a container. The one remaining discharge is an oily condensate discharge (less than 1 gallon per day) from a small compressor at the Air Intake Shaft. A PWR has been written to collect this discharge in a small container. All condensate discharges will be collected and disposed of as wastes in accordance with the applicable regulatory criteria.

7.3.4 Releases of Reportable Quantities of Hazardous Substances and Oil, IV(B)(2) and Appendix B, III(B)

Releases of reportable quantities of hazardous substances and oil must be reported.

Three spills (ethylene glycol) at WIPP have been reported to the National Response Center. All spills were immediately contained and cleaned up in accordance with the WIPP spill response procedure. All contaminated soils were drummed, manifested, and transported to an off-site disposal facility.

Section 3.3 of the WIPP PPP (WID, 1993b) addresses the actions that must be taken in the event of a reportable spill, including notification of the National Response Center; modification of the PPP within 14 days to provide a description of the release; the circumstances leading to, and the date of the release; measures to prevent recurrence and to respond to such releases; and notification of the EPA.

7.3.5 Storm Water Pollution Prevention Plan, IV(C) and Appendix B, Part IV

Regulated facilities with a general permit must have prepared and implemented a storm water pollution prevention plan.

The WIPP PPP describes how the BMPs and other requirements of the NPDES storm water regulations are being implemented at the WIPP. Requirements addressed include the identification of a pollution prevention team, the potential pollution sources, and past spills and leaks.

7.3.6 Pollution Prevention Team, IV(C)(1) and Appendix B, IV(D)(1)

A pollution prevention team is required for permitted facilities. This team must be addressed in the facility's PPP.

The WIPP Pollution Prevention Team is composed of representatives from organizations within the DOE and the Westinghouse Waste Isolation Division (WID) who are knowledgeable about the facility and its operations and who will provide structure and direction to the storm water management program. The members of the Pollution Prevention Team and their functional area responsibilities are identified in Section 2.2 of the PPP.

7.3.7 Identification of Potential Pollution Sources, IV(C)(2) and Appendix B, IV(D)(2)

Potential sources of pollution must be identified at the permitted facility.

A site inspection was conducted to look for illicit connections into either the WIPP sewage system or into storm water diversion swales. The 4-day site inspection focused on all surface facility operations, the status of existing BMPs, materials handling practices, materials storage areas, and storm water flow patterns and volumes. The inspection revealed seven areas that could contribute pollutants to storm water runoff. These seven areas are identified and discussed in Chapter 3.0, ***Assessment***, of the PPP.

Storm water flows were evaluated using NMED and EPA methodology. Because the NMED guidelines for calculating runoff coefficients are more stringent, they were chosen to calculate storm water runoff from the WIPP. Meetings were held with the EPA Region VI Storm Water Section and with the NMED Ground Water and Surface Water Bureaus to evaluate compliance alternatives.

As described in the PPP, three different material inventories were used to complete the materials inventory assessment: the WIPP Stores Stock Inventory, the MSDS Inventory, and the

Hazardous Air Pollutants Inventory. Several site walkarounds were then conducted to examine material storage practice and to identify the operations and storage areas with potential to come into contact with storm water.

The three ethylene glycol spills that were reported to the National Response Center are described in the PPP.

Non-storm water discharges, described in the PPP, are discussed in Section 7.3.3 above. The existing monitoring data are also described in the PPP, and the locations of the data are specified. An identification of potential risks from discharges was not performed because all non-storm water discharges are either exempted, contained, or not regulated.

7.3.8 Site Assessments, IV(C)(2) and Appendix B, IV(D)

A site assessment for storm water discharge sources must be included in a facility's PPP.

A summary of the site assessment is provided in Chapter 3.0 of the PPP. This summary identifies the potential pollutant sources that require additional controls or BMPs to ensure compliance with the requirements (see also Section 7.3.7 above).

7.3.9 Measures and Controls, IV(C)(3) and Appendix B, IV(D)(3)

Measures and controls (including recordkeeping and internal reporting) must be addressed in the PPP.

The measures and controls for discharges are described in the PPP. In Chapter 4.0, BMPs and implementation of these practices are specified for eight management areas, which include the seven areas identified in Section 7.3.7 and the solid waste management units (SWMUs) located in the rest of the 16-section withdrawal area. Included in the discussion are sections on good housekeeping, maintenance, and visual inspections; the WIPP SPCC Plan; management of runoff and of sediment and erosion controls; employee training; compliance reporting; annual site compliance evaluations; and recordkeeping.

7.3.10 Comprehensive Site Compliance Evaluations, IV(C)(4) and Appendix B, IV(D)(4)

Comprehensive site compliance evaluations are mandatory for a permitted facility and must be discussed in the facility's PPP.

Comprehensive site inspections are discussed in Chapter 3.0 of the PPP. The initial internal site assessment is described, along with the periodic site compliance evaluation. The CWA Coordinator is responsible for conducting quarterly site compliance evaluations. The NPDES program, including site operation and materials management, is reviewed annually. In addition, the NPDES storm water permit program is evaluated periodically as part of the WIPP Environmental Compliance Assessment Program. The PPP will be revised annually to reflect changes in compliance strategy, regulations, team members, etc.

During the inspections, material handling and storage areas and other potential sources of pollution are visually inspected for evidence of actual or potential pollutant discharges. Guidelines for housekeeping, maintenance, and visual inspections are provided in a Westinghouse manual. WID personnel conduct self assessments in accordance with a WIPP procedure, which outlines the requirements for evaluating good housekeeping practices and for making visual inspections. In addition, WID personnel conduct quarterly walkarounds to assess compliance with the storm water regulations at the site and develop corrective action plans to mitigate any issues that may arise from these assessments.

7.3.11 Requirements for Storage, Processing, and Handling Areas for EPCRA § 313 "Water Priority Chemicals," IV(D)(1) and Appendix B, IV(D)(7)

The EPA specifies requirements for storage, processing, and handling areas for EPCRA § 313 "water priority chemicals."

This section is not applicable because WIPP has not been required to submit a report under § 313 of EPCRA during this reporting period due to certain exemptions (see Chapter 4.0).

7.3.12 Enclosure or Covering of Outdoor Salt Piles, IV(D)(2) and Appendix B, IV(D)(8)

The EPA's NPDES General Permit requires that outdoor salt piles be enclosed or covered. This requirement applies only to storage pile runoff discharged to waters of the United States.

The outdoor salt piles at WIPP are situated on an impervious, compacted, caliche liner which eliminates potential discharge to waters of the United States. Any storm water runoff is diverted to the caliche-lined evaporation basin. Storm water that collects in the evaporation basin usually evaporates within 24 hours. Furthermore, the moisture contained in the mined salt quickly forms a hard crust over the surface of the pile, which reduces wind-borne particulates. As rain falls on the salt pile, this protective crust becomes thicker and more impervious, which further reduces salt particulate discharges. Because no waters are diverted to waters of the United States, closure or enclosure of the salt piles is not required.

7.3.13 Notification to Municipal Large and Medium Separate Storm Water Systems, IV(D)(3) and Appendix B, IV(D)(5)

The NPDES General Permits require that the permitted facility notify the owners/operators of any municipal large and medium separate storm water systems that service the facility in the event of a discharge.

This requirement is not applicable at WIPP because storm water is not discharged through a large or medium separate storm water system.

7.3.14 Monitoring and Reporting Requirements, IV(E) and Appendix B, Part IV and XI (C)(vi)

Monitoring and reporting requirements required are described in the NPDES General Permits and differ for different types of facilities.

As discussed in the PPP, all regulated storm water discharges are or will be contained within retention basins or controlled by practices such as diversion berms, reclamation, or material covers. Therefore, the need for compliance sampling at WIPP is not anticipated.

As indicated by the PPP, a Discharge Monitoring Report (DMR) is required only if a discharge has occurred. In the event of a discharge, the DMR, along with sampling results, will be submitted to the EPA on the appropriate DMR form by October 28 of the appropriate year.

7.3.15 Compliance Deadlines, IV(G) and Appendix B, IV(A)(1)

The NPDES General Permits require that the permitted facility complete the development of the Pollution Prevention Plan by the regulatory deadline of April 1, 1993, and require compliance with the terms of the plan by October 1, 1993.

As required by the NPDES General Permit for WIPP, the WIPP PPP was issued on March 31, 1993 (WID, 1993b). As described in Chapter 5 of the PPP, the implementation of BMPs such as retention basins, reclamation of disturbed sites in Zone 1, and the covering of material storage areas was completed by the regulatory deadline of October 1, 1993. The BMPs are inspected on a quarterly basis.

8.0 SAFE DRINKING WATER ACT

8.1 Summary of the Law

The Safe Drinking Water Act of 1974 (SDWA; 42 USC §§ 300f et seq.), as amended, provides the regulatory strategy for protecting public water supply systems and underground sources of drinking water. As defined in the implementing regulations in 40 CFR Part 141, *National Primary Drinking Water Regulations*, these are systems that provide water for human consumption and that have at least 15 connections or regularly serve at least 25 people.

The SDWA also protects underground sources of drinking water from underground injection of contaminated fluids. Underground injection, defined as "subsurface emplacements of fluids by well injections" in § 1421(d) of the SDWA, is governed by the Underground Injection Control (UIC) program described in Subpart C of 40 CFR Part 144. The nearest potential underground source of drinking water to the WIPP is the Dewey Lake Red Bed Formation, a perched water table located approximately 3.5 miles south of the site. The lack of ground water in the Dewey Lake Red Bed Formation at the WIPP site has been interpreted to imply a lack of a hydrogeologic connection with the portions of the formation south of the site that do contain ground water.

The EPA delegated authority for ensuring compliance with the SDWA's National Primary Drinking Water Standards by approving the New Mexico Environmental Improvement Board's (EIB's) New Mexico Water Supply Regulations, WSR 3. (See Chapter 31, New Mexico Water Supply Regulations.)

8.2 Compliance Status of the Regulatory Requirements

The WIPP Land Withdrawal Act specifically requires compliance with the SDWA. The relevant requirements from the SDWA are summarized in Table 8-1, along with the compliance status of each. More detail is presented in the text.

The New Mexico EIB has authority to administer the SDWA in New Mexico. The EIB's Water Supply Regulations contain the State compliance criteria and general operating requirements for the owners and operators of water-supply systems. These regulations and the compliance status at WIPP are covered in Chapter 31.

TABLE 8-1. Safe Drinking Water Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR Part 142, *National Primary Drinking Water Regulations Implementation*		
40 CFR 142.4	State program requirements	See Chapter 31, New Mexico Water Supply Regulations [Section 8.2.1]
40 CFR Part 144, *Underground Injection Control*		
40 CFR 144(C)	Underground injection control (UIC)	**NOT APPLICABLE** No TRU waste or other disposal at WIPP using UIC [Section 8.2.2]

8.2.1 State Program Requirements, 40 CFR 142.4

All applicable requirements in this section are covered in the State program for the SDWA. See Chapter 31, which addresses the New Mexico Water Supply Regulations.

8.2.2 Underground Injection Control, 40 CFR 144(c)

The EPA has established a number of requirements for facilities that dispose of wastes by means of underground injection.

None of the hazardous waste currently generated at WIPP is injected underground, nor will TRU waste be disposed of by underground injection at WIPP. Therefore, the EPA's requirements for underground injection requirements for underground injection control (UIC) do not apply to WIPP.

9.0 TOXIC SUBSTANCES CONTROL ACT

9.1 Summary of the Law

Prior to the passage of the Toxic Substances Control Act (TSCA; 15 USC §§ 2601 et seq.), significant gaps existed in the Federal government's authority to test and regulate problem chemicals. The Clean Air Act, the Clean Water Act, and other laws dealt with chemical substances only when they entered the environment as wastes (e.g., as emissions to the air or discharges into the water). In many cases, controls could not be easily fashioned or required without severe economic consequences. Other statutes, such as the Occupational Safety and Health Act and the Consumer Product Safety Act, deal only with one phase of the chemical's existence (worker exposure or direct consumer exposure) and have no authority to address environmental hazards. Whereas both of these statutes were clearly needed, the life cycle of a chemical, from production to ultimate disposal, provides many opportunities for release to the environment, resulting in human exposure, and Federal authority to deal with the overall cycle was fragmented. The TSCA legislation imposed on new toxic substances, which requires testing before the chemicals reach the production phase, helped to overcome this difficulty.

TSCA has two main features: it regulates the production, use, distribution, and disposal of new, potentially toxic chemical substances, where necessary, and it regulates potential hazards from toxic chemicals. TSCA requires that tests be conducted on new chemical substances before significant human or environmental exposure can occur.

The act applies primarily to commercial manufacturers, importers, and processors of toxic chemicals. The WIPP is not a manufacturer or a processor of chemical products; therefore, most of the provisions of TSCA do not apply. However, three sections of this act pertain to existing commercial toxic substances, rather than to the development of new chemicals. These sections deal with asbestos, indoor radon abatement, and polychlorinated biphenyls (PCBs).

9.1.1 Asbestos Hazard Emergency Response Act of 1986

Because of the potential for serious health hazards associated with asbestos, Congress amended TSCA in 1986 by adding Title II, *The Asbestos Hazard Emergency Response Act* (AHERA). AHERA requires the EPA to establish a comprehensive regulatory framework of inspection, management, planning, operations and maintenance activities, and appropriate abatement responses for controlling asbestos-containing materials in schools. Under AHERA, EPA promulgated its "AHERA-in-Schools Rule" on October 17, 1987. The 1988 AHERA amendments provided additional time for local educational agencies to submit asbestos management plans to the State governors and to begin the implementation of these plans.

Under AHERA, the EPA was also required to conduct a study to determine the extent of danger to human health posed by asbestos in public and commercial buildings and the means to respond

to such danger. This study has been submitted to Congress. At the present time, the EPA does not recommend a regulatory program modeled on AHERA for public and commercial buildings.

9.1.2 Indoor Radon Abatement

The Title III TSCA amendment, *Indoor Radon Abatement*, was added to address the national long-term goal "with respect to radon levels in buildings, that the air within the buildings in the United States should be as free of radon as the ambient air outside of buildings." One of the goal-driven requirements that Title III sets forth in § 309, *Study of Radon in Federal Buildings*, directs each Federal department or agency that owns a Federal building to conduct a study to determine the extent of radon contamination in such buildings. The WIPP has responded to this requirement.

9.1.3 Polychlorinated Biphenyls (PCBs)

Section 6(e) of TSCA, *Polychlorinated Biphenyls*, directed the EPA to phase out PCB manufacture and use according to a statutorily mandated timetable. This timetable directed the EPA to promulgate rules for the disposal and marking of PCBs within 6 months of the enactment of TSCA: by 1 year after the passage of this act, no one was allowed to manufacture, process, distribute, or use any PCB in the United States except in "a totally enclosed manner." Furthermore, unless the EPA did not find any unreasonable risk of injury to public health or the environment, no one was allowed to manufacture PCBs at all after 2 years, or to distribute them after 2 1/2 years after TSCA's passage.

The regulations in 40 CFR Part 761, *Environmental Protection Agency Regulations for Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions for Polychlorinated Biphenyls under the Toxic Substances Control Act*, implement the PCB provisions of TSCA. This part applies to all parties who manufacture, process, distribute in commerce, use, or dispose of PCBs or PCB items. The purpose of these regulations is to establish prohibitions of, and requirements for, the manufacture, processing, distribution in commerce, use, disposal, storage, and marking of PCBs and PCB items. DOE policy now prohibits the use of PCB items or equipment in DOE-installed equipment at facilities such as WIPP. However, prior to the enactment of TSCA prohibiting PCBs, these chemicals were used in fluids of electrical systems all over the country, including DOE sites. Therefore, surveys have been done at DOE sites to identify any PCB or PCB-containing equipment and to eliminate the fluids and equipment in accordance with EPA standards. Requirements for storage and disposal of PCBs have also been established under TSCA (e.g., see 40 CFR 761.60, *Disposal Requirements*, and 40 CFR 761.65, *Storage for Disposal*).

9.2 Compliance Status of the Regulatory Requirements

Table 9-1 summarizes the applicable regulatory requirements and their compliance status under TSCA. The text gives more detail on the compliance status of each requirement.

TABLE 9-1. Toxic Substances Control Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
Title II, *Asbestos Hazard Emergency Response Act*		
TSCA, §§ 201 et seq.	Hazards of friable asbestos-containing material	**ACHIEVED** Asbestos-containing material restricted at WIPP [Section 9.2.1]
Title III, *Indoor Radon Abatement*		
TSCA, § 309	Study of radon in Federal buildings	**ACHIEVED** Study conducted [Section 9.2.2]
40 CFR Part 761, *EPA Regulations for Manufacturing Processing, Distribution in Commerce, and Use Prohibitions for Polychlorinated Biphenyls under the Toxic Substances Control Act*		
40 CFR 761.20	Prohibition of PCBs	**ACHIEVED** Survey and removal of PCB-contaminated equipment; PCBs prohibited at WIPP [Section 9.2.3]

TABLE 9-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 761.60	Disposal requirements for PCBs	NOT APPLICABLE PCBs prohibited from TRU waste to be received at WIPP from generator sites [Section 9.2.4]

9.2.1 Hazards of Friable Asbestos-Containing Materials, TSCA, §§ 201 et seq.

> *Because of the hazards to human health inherent in friable asbestos-containing materials, Congress specified a number of requirements pertaining to asbestos specified in Title II of TSCA.*

Asbestos is a restricted material at the WIPP. Therefore, in accordance with WIPP's Hazard Communication Program, asbestos-free insulating material must be used throughout the facility when insulation is being replaced or installed. The removal of any previously installed material that might contain asbestos requires the coordination of WID safety and compliance personnel.

9.2.2 Study of Radon in Federal Buildings, TSCA, § 309

> *Each Federal agency that owns a building must conduct a study of radon contamination in the building(s).*

The DOE conducted an indoor radon study in response to this requirement and submitted the findings in *Results of the U.S. Department of Energy Indoor Radon Study* (DOE, 1990e).

9.2.3 Prohibition of PCBs, 40 CFR 761.20

> *No person may use any PCB or any PCB item regardless of concentration in any way other than in a totally enclosed manner within the United States.*

The DOE has conducted surveys of electrical equipment, such as transformers, that could house PCB-containing fluids. Such a survey was conducted at WIPP. Any equipment containing PCBs

was identified and has been replaced by non-PCB-containing equipment. All PCB-containing equipment identified was disposed of in accordance with the regulations described in Section 9.2.4.

9.2.4 Disposal Requirements for PCBs, 40 CFR 761.60

> *In most circumstances, PCBs must be incinerated as stipulated in 40 CFR 761.70 or placed in chemical-waste landfills that meet the requirements of 40 CFR 761.75 and that have been approved as a landfill for PCBs by the EPA.*

Any DOE equipment identified at WIPP that contained PCB fluids was decontaminated as described in the regulations and disposed of as required.

The WIPP WAC states that only those wastes identified in the RCRA Part A and Part B applications as acceptable for emplacement at WIPP may be shipped to WIPP. As indicated in Chapter K of the *WIPP RCRA Permit Application* (Rev. 3), there are currently no plans to ship PCB-contaminated wastes from the generator sites to WIPP.

10.0 FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT

10.1 Summary of the Law

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA; 7 USC §§ 136 et seq.) authorizes the EPA to regulate the registration, certification, use, storage, disposal, transportation, and recall of pesticides. Section 18 of FIFRA authorizes the EPA to exempt State and Federal agencies from any provision of the act if emergency conditions requiring an exemption have been determined to exist, and the regulations of 40 CFR Part 166, *Exemption of Federal and State Agencies for Use of Pesticides under Emergency Conditions*, provide guidelines for urgent, non-routine situations that require the use of pesticides and for which exemptions may be authorized. Sections 19(a) and 25(a) of FIFRA authorize the EPA to establish regulations and procedures regarding the disposal or storage of packages and containers of pesticides and the disposal or storage of excess amounts of such pesticides. The regulations of 40 CFR Part 165, *Regulations for the Acceptance of Certain Pesticides and Recommended Procedures for the Disposal and Storage of Pesticides and Pesticides Containers*, established procedures for the acceptance, disposal, or storage of packages and containers of pesticides and for the disposal or storage of excess amounts of such pesticides. The standards of FIFRA are considered mandatory for DOE facilities. All uses and applications of restricted-use pesticides at WIPP are conducted only by commercial pesticide applicators who are under contract with WID and are required to meet Federal and State standards (see also Chapter 38).

10.2 Compliance Status of the Regulatory Requirements

The two major requirements of FIFRA and the compliance status of each are summarized in Table 10-1. More detail is provided in the text.

TABLE 10-1. Federal Insecticide, Fungicide and Rodenticide Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 152.15	Registration of pesticide products	NOT APPLICABLE Pesticide applications done by contractors; pesticides and contracts reviewed by WID safety and regulatory compliance personnel [Section 10.2.1]
40 CFR 165.8-.11	Recommended procedures for disposal or storage of pesticides	UP TO DATE General-use product stored at WIPP complies with storage instructions on label [Section 10.2.2]

10.2.1 Registration of Pesticide Products, 40 CFR 152.15

No person may distribute or sell any pesticide product that is not registered under FIFRA. The pesticide must be registered if the person who distributes or sells the substance knows that it will be used as a pesticide.

Restricted-use pesticides are neither stored at WIPP, nor are they applied by WIPP personnel. All applications of restricted-use pesticides are conducted according to existing contract(s) negotiated with pesticide applicators; WID safety and regulatory compliance personnel review all pesticide application contracts before they are awarded. The DOE requires that any pesticide contractor be licensed with the State as a certified pesticide applicator and submit a list of pesticides utilized and their respective EPA numbers to WID prior to awarding the contract. The current agreement requires that the applicator perform scheduled quarterly applications and respond to unscheduled "special situations" such as occurrences of wasp swarming and ant infestation. Before an application is performed, the contractor submits information consisting of the application date, location, method of application, the generic pesticide name, and a Material Safety Data Sheet (MSDS) for review by WID, which confirms that adequate protective equipment is available and that the pesticides to be used are not on the EPA restricted-pesticide

list. After the application, the contractor must submit such information to WID as the type and amount of pesticide used and the dilution factor.

CINCH, a general-use wasp and hornet killer used on site by WIPP personnel, is properly registered with the State of New Mexico.

10.2.2 Recommended Procedures for the Disposal or Storage of Packages and Containers of Pesticides, 40 CFR Part 165

Recommendations for the storage and disposal of pesticides are specified in 40 CFR 165.8 through 165.11.

WIPP currently makes a general-use wasp and hornet killer available to its personnel. The product is stored in the warehouse according to label instructions. Used, empty cans are discarded by WIPP personnel into satellite accumulation area containers and managed as hazardous waste.

Because WIPP personnel do not use, store, or dispose of restricted-use pesticides on site, the majority of these requirements are not applicable. All restricted-use pesticide applications are made by contractors, who are responsible for storing and disposing of pesticides off site.

All applications of restricted-use pesticides at WIPP are performed by commercial, State-licensed applicators. The DOE requires applicators under contract to comply with the requirements of the New Mexico Pesticide Control Act and the implementing regulations set forth by the New Mexico State University Board of Regents. More information on the State requirements is provided in Chapter 38.

11.0 NOISE CONTROL ACT OF 1972

11.1 Summary of the Law

In the Noise Control Act of 1972 (42 USC §§ 4901 et seq.), the EPA declared its policy of promoting an environment for all Americans that is free from noise jeopardizing public health or welfare. According to the act's policy clause in § 2(a)(3), the primary responsibility for noise control is vested in State and local governments. Federal regulation is deemed essential only for commercial noise sources requiring national uniformity of treatment (e.g., aircraft noise). However, Federal agencies are directed to carry out the programs within their control in a manner that furthers the act's policy. Each agency having jurisdiction over any property or facility, or engaged in any activity resulting or which may result in the emission of noise, shall comply with Federal, State, interstate, and local requirements regarding the control and abatement of environmental noise "to the fullest extent consistent with their authority." Facilities under the DOE are required to comply with the Occupational Safety and Health Administration (OSHA) regulations that address occupational noise exposure standards under 29 CFR Part 1910, *Occupational Safety and Health Standards*.

The regulations under 29 CFR 1910.95, *Occupational Noise Exposure*, define the permissible noise exposure levels to which employees may be subjected. The regulations also include requirements for the development and implementation of a monitoring program, the establishment and maintenance of an audiometric testing program, the measurement of noise, the provision of personal hearing-protection equipment when necessary, and the administration of a hearing conservation program.

11.2 Compliance Status of the Regulatory Requirement

Table 11-1 summarizes the applicable requirement and its compliance status. More information is provided in the text.

TABLE 11-1. Noise Control Act of 1972 - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
29 CFR 1910, *Occupational Safety and Health Standards*		
29 CFR 1910.95	Compliance with hearing protection standards	**ACHIEVED** Testing, controls, equipment, training, procedures, and contracted specialist in place; Hearing Conservation Program [Section 11.2.1]

11.2.1 Compliance with Hearing Protection Standards, 29 CFR 1910.95

Employers must take measures to protect the hearing of employees.

The DOE administers a full program in accordance with the Noise Control Act and the implementing regulations. Program activities include the following: a hearing conservation program; an audiometric testing program; administrative and engineering controls (e.g., noise mufflers in the area of underground exhaust fans; posted signs); noise measurement (e.g., sound meters, dosimetry); and the provision of personal hearing-protection equipment (e.g., ear plugs, ear muffs). Furthermore, the DOE maintains a certified ear, nose, and throat specialist on contract, requires hearing protection training for WIPP employees, and has developed procedures such as the Hearing Conservation Program. The WIPP Safety Manual and the Occupational Health Manual and their implementing procedures address the requirements of and activities conducted under this program.

12.0 NATIONAL ENVIRONMENTAL POLICY ACT

12.1 Summary of the Law

The National Environmental Policy Act (NEPA; 42 USC §§ 4321 et seq.) establishes policy, sets goals, and provides means for carrying out the policy. Congress created the Council on Environmental Quality (CEQ) to administer the NEPA program. Within NEPA are (1) "action-forcing" provisions to ensure that Federal agencies act according to the letter and spirit of the act and (2) NEPA requirements for identifying reasonable courses of action, along with the environmental consequences of all proposed actions, for all major Federal actions under consideration. The purpose of NEPA is not to generate paperwork but to foster action. The NEPA process is intended to help public officials (1) make decisions based on understanding possible environmental consequences to actions and (2) take the appropriate steps to protect, restore, and improve the environment. Because public involvement in the decision-making process is mandated, NEPA has often been referred to as a "public disclosure law."

The CEQ's regulations in 40 CFR Parts 1500 through 1508 implement § 102(2) of NEPA, informing Federal agencies about what they must do to comply with the procedures and to achieve the goals of NEPA. These regulations outline specific requirements with regard to the integration of the NEPA process early in a process to ensure timely planning and decision-making, the preparation of environmental impact statements (EISs) or Environmental Assessments (EAs), public review and solicitation of comments on EISs, decisions with respect to an EIS or EA, and the implementation of the decisions.

12.2 Compliance Status of the Regulatory Requirements

Table 12-1 summarizes the regulatory requirements and their compliance status under NEPA. Additional information is provided in the text.

TABLE 12-1. National Environmental Policy Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR Parts 1500-1508	Provision of environmental information to public officials and private citizens; use as a decision-making tool; need for Environmental Impact Statements (EISs), Environmental Assessments (EAs), and categorical exclusions	**UP TO DATE** Final Environmental Impact Statement (FEIS) and FEIS Record of Decision (ROD); Final Supplement Environmental Impact Statement (SEIS) and SEIS ROD; numerous categorical exclusions [Section 12.2.1]

12.2.1 Provision of Environmental Information to Public Officials and Private Citizens, 40 CFR Parts 1500-1508.

Environmental information must be made available to the public before decisions are made and actions are taken and must include a detailed statement on environmental impacts of major Federal actions significantly affecting the quality of the human environment.

Pursuant to the requirements of NEPA, the DOE published the *Final Environmental Impact Statement* (FEIS) for the WIPP in 1980 (DOE, 1980). The FEIS analyzed and compared the environmental impacts of various alternatives for demonstrating the safe disposal of TRU waste resulting from national defense activities. Based on the environmental analyses in the FEIS, the DOE published a Record of Decision (ROD) to the FEIS in 1981 to proceed with the phased development of the WIPP (DOE, 1981). This ROD noted that the FEIS would be supplemented as appropriate if new environmental data resulted from the Site and Preliminary Design Validation (SPDV) program or from other WIPP activities.

Consistent with this commitment, the DOE prepared additional NEPA documentation to address changes in the proposed action and the development of new geologic and hydrologic information. Changes addressed in the 1990 *Final Supplement Environmental Impact Statement* (SEIS) (DOE, 1990a) included alterations in the composition of the waste inventory, the transportation of waste to the WIPP, conducting a test phase at WIPP, and management of mixed waste (TRU waste with hazardous constituents). The DOE published a ROD to the SEIS in 1990 (DOE, 1990b). One of the commitments made in this second ROD was that the DOE will prepare another Supplemental Environmental Impact Statement (and ROD) prior to initiating the disposal phase at WIPP.

In order to ensure compliance with NEPA as administered by the CEQ and by the DOE (see also Chapter 14), Westinghouse Waste Isolation Division (WID) personnel prepared the WIPP NEPA Compliance Program. This program consists of the *NEPA Compliance Plan* and implementing procedures.

13.0 ATOMIC ENERGY ACT AND THE U.S. DEPARTMENT OF ENERGY

13.1 Summary of the Law

The Atomic Energy Act of 1954 as amended (AEA; 42 USC §§ 2011 et seq.) established a national program for research, development, and use of atomic energy for national defense and civilian purposes. Section 161 of the AEA authorized the Atomic Energy Commission (AEC) to establish rules, regulations, and orders to govern any activity regulated under the AEA to protect health and minimize hazards to life or property. Activities included standards and restrictions pertaining to the design, location, and operation of facilities.

The AEC has been succeeded by two organizations: the U.S. Department of Energy (DOE) for national defense and the U.S. Nuclear Regulatory Commission (NRC) for domestic civilian purposes (see Chapter 15 for the compliance status of NRC-related requirements). Thus, the AEA gave the DOE its authority to develop policies, issue Orders, and promulgate regulations that address environmental, safety, and health protection aspects of radioactive waste and nuclear materials. The radioactive constituents of the TRU waste to be shipped to WIPP are regulated under the AEA by a DOE system of Orders, notices, and directives which carries out the AEA mandate to implement effective and consistent programs to protect the public, the environment, and workers from adverse consequences from DOE operations. Thus, TRU waste[1] is regulated under the AEA and, by extension, by the DOE system.

Regulation of mixed waste is more complex. Radioactive waste and constituents are not regulated by the U.S. Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA): in fact, RCRA specifically excludes "source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended" [§ 1004(27) of RCRA; see also § 1006(a)]. Therefore, TRU mixed waste is subject to dual regulation under the AEA and RCRA: the radioactive constituents are regulated under the AEA, whereas the hazardous constituents are regulated under RCRA.

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[1]The AEA defined "transuranic waste" as

> . . .material contaminated with elements that have an atomic number greater than 92, including neptunium, plutonium, americium, and curium, and that are in concentrations greater than 10 nanocuries per gram, or in such other concentrations as the Nuclear Regulatory Commission may prescribe to protect the public health and safety [AEA, § 11(ee)].

In 1982, TRU waste was redefined as having half lives greater than 20 years and concentrations greater than 100 nanocuries per gram of waste. (Wastes with TRU concentrations between 10 and 100 nanocuries per gram have been reclassified as low-level wastes.)

13.2 Compliance Status of the Regulatory Requirements

As indicated in the previous section, the DOE has used a system of Orders, notices, and directives to implement its programs under the AEA and to ensure compliance with other statutes and regulations. These implementing documents are not considered to be at the same levels as are those in the Code of Federal Regulations (CFR).

The DOE has recently issued regulations in the 10 CFR series in addition to the regulations that pertain to NEPA (see Chapter 14). On December 14, 1993, 10 CFR Part 835, *Occupational Radiation Protection*, was published in the *Federal Register*. These regulations became effective on January 13, 1994.

Because radioactive waste has not yet been received at WIPP, these regulations are not applicable. However, a number of programs are in place at WIPP to meet the requirements upon receipt of TRU waste.

14.0 NATIONAL ENVIRONMENTAL POLICY ACT AND THE U.S. DEPARTMENT OF ENERGY

14.1 Summary of the Law

As discussed in Chapter 12, the National Environmental Policy Act (NEPA) establishes policy, sets goals, and provides a process for carrying out the policy. The NEPA process requires the identification of reasonable courses of action, along with the environmental consequences of all proposed actions, for all major Federal actions under consideration The NEPA process is intended to help public officials make decisions based on understanding possible environmental consequences to actions and to take the appropriate steps to protect, restore, and improve the environment. The establishment of this national policy ensures that consideration is given to environmental values and factors in Federal planning and decision making. The U.S. Department of Energy's (DOE) policy is to comply fully with the letter and spirit of NEPA.

The Council on Environmental Quality (CEQ) regulations in 40 CFR Parts 1500-1508 implement § 102(2) of NEPA and inform Federal agencies as to what they must do to comply with the procedures and achieve the goals of NEPA. These parts provide regulations applicable to and binding on all Federal agencies for implementing the procedural provisions of NEPA. The DOE adopted the CEQ regulations and established 10 CFR Part 1021, *National Environmental Policy Act Implementing Procedures*, to implement the procedural provisions of NEPA pursuant to the CEQ regulations. By issuing its guidelines as regulations published in the CFR, the DOE ensures that its NEPA procedures are more accessible to the public.

The implementing procedures in 10 CFR Part 1021 detail requirements for the preparation and circulation of NEPA documents, including the Environmental Impact Statement (EIS) and the Supplemental Environmental Impact Statement (SEIS), the related Records of Decision (RODs), the Mitigation Action Plan (MAP), and the Environmental Assessment (EA). The DOE requires that a MAP be prepared for the implementation of any commitments made in an EIS/ROD for mitigation of environmental impacts associated with an action. A MAP is also required of any Finding of No Significant Impact (FONSI) to an EA that contains mitigative actions prior to initiating the proposed action.

Subpart D, *Typical Classes of Actions*, of this part lists typical types of actions that require NEPA documentation and those that are categorically excluded from the need to prepare an EIS or an EA. Classes of actions that the DOE has determined do not individually or cumulatively have a significant effect on the human environment are *categorical exclusions*. The classes of actions identified in Subpart D are: (1) *Categorical Exclusions Applicable to General Agency Actions*, such as routine administrative actions; (2) *Categorical Exclusions Applicable to Specific Agency Actions*, such as installation of data-processing equipment; (3) *Classes of Actions That Normally Require EAs but Not Necessarily EISs*, such as field demonstration projects for

wetlands mitigation; and (4) *Classes of Actions That Normally Require EISs*, such as the siting, construction, and operation of a facility, such as the WIPP, for the disposal of TRU waste.

14.2 Compliance Status of the Regulatory Requirements

Table 14-1 summarizes the regulatory requirements and their compliance status under the DOE's *National Environmental Policy Act Implementing Procedures* in 10 CFR Part 1021. Additional detail is presented in the text.

TABLE 14-1. DOE's National Environmental Policy Act Implementing Procedures, 10 CFR Part 1021 - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
10 CFR Part 1021, *Implementing Procedures*		
10 CFR Part 1021	Supplements and clarifies the requirements contained in 40 CFR Parts 1500-1508; adds requirement for Mitigation Action Plans (MAPs); delineates specific categorical exclusions for use by the DOE	**UP TO DATE** Final Environmental Impact Statement (FEIS) and FEIS Record of Decision (ROD) issued in 1980 and 1981, respectively; Final Supplement Environmental Impact Statement (SEIS) and SEIS ROD issued in 1990; MAP issued in July 1991, with annual MAP reports submitted in July 1992 and 1993; numerous categorical exclusions; WIPP NEPA Compliance Program [Section 14.2.1]

14.2.1 Implementing Procedures, 10 CFR Part 1021

DOE's regulations that implement NEPA (10 CFR Part 1021) supplement and clarify the requirements contained in 40 CFR Parts 1500-1508 (see also Chapter 12). The DOE regulations add a requirement for Mitigation Action Plans (MAPs) for EISs, supplemental EISs, and

RODs. They also delineate specific categorical exclusions for DOE facilities.

In 1980, the DOE published the *Final Environmental Impact Statement* (FEIS) for the WIPP (DOE, 1980). The FEIS analyzed and compared the environmental impacts of various alternatives for demonstrating the safe disposal of TRU waste resulting from DOE national defense-related activities. The FEIS for the WIPP project includes responses to the comments received in writing and at the public hearings, as is required.

Based on the environmental analyses presented in the FEIS, the DOE published a Record of Decision (ROD) in 1981 to proceed with the phased development of the WIPP. The ROD was published in the *Federal Register* on January 28, 1981 (DOE, 1981). A number of mitigative commitments were specified.

Since publication of the FEIS in 1980, new geological and hydrological information led to changes in the understanding of the hydrogeological characteristics of the WIPP site as they relate to the long-term performance of the underground waste repository. In addition, there have been changes in the information and assumptions used to analyze the environmental impacts in the FEIS. Consequently, the Final Supplement Environmental Impact Statement (SEIS), which updated the environmental record established in 1980 by evaluating the environmental impacts associated with new information, new circumstances, and proposal modifications, was published in 1990 (DOE, 1990a).

Based on the analysis presented in the SEIS, the SEIS ROD accepted the proposed action in the SEIS to proceed with the phased WIPP development. The DOE published the SEIS ROD in the *Federal Register* on June 22, 1990 (DOE, 1990b). A number of mitigative commitments were specified in the ROD, including the commitment to prepare another supplemental Environmental Impact Statement prior to the initiation of the disposal phase at WIPP.

The DOE issued the *Mitigation Action Plan for the Records of Decision for the Waste Isolation Pilot Plant* (DOE, 1991e) on July 10, 1991. This document addresses the mitigative commitments stated in the RODs to the 1980 FEIS and the 1990 SEIS and discusses mitigative actions, organizations responsible for implementing these actions, and the status of each commitment. The Annual Mitigation Report (AMR) is prepared annually to track the status of each commitment that has not yet been closed. To date, AMRs have been issued in July 1992 and July 1993; the July 1994 AMR is currently in preparation.

Numerous categorical exclusions have been used at WIPP in accordance with 10 CFR Part 1021. The determination that a given project falls under a categorical exclusion as identified by the DOE is based upon a NEPA checklist that assists in the proper selection and application of NEPA documentation. The methods used are based upon the WIPP NEPA Compliance

Program, which contains the *WIPP NEPA Compliance Plan*, two procedures for implementing NEPA at WIPP, and a training module that will be used to train appropriate personnel.

The WIPP NEPA Compliance Program is in the final technical review stage. It has been audited by personnel from Westinghouse Environmental Affairs and DOE-Headquarters and is considered to be a model NEPA program. The NEPA Compliance Program is consistent with other WIPP and Sandia National Laboratories procedures, including those relating to procurement, engineering, and work control.

15.0 ATOMIC ENERGY ACT AND THE U.S. NUCLEAR REGULATORY COMMISSION

15.1 Summary of the Law

As discussed in Chapter 13, the Atomic Energy Act of 1954 as amended (AEA; 42 USC §§ 2011 et seq.) gives the U.S. Nuclear Regulatory Commission (NRC) its authority to develop policies, issue orders, and promulgate regulations that address environmental, safety, and health protection aspects of radioactive waste and nuclear materials in the civilian sector. Regulations promulgated by the NRC under the AEA appear in the first portion of Title 10 of the Code of Federal Regulations (CFR) and establish standards for the management of nuclear material and the protection of the public against radiation. Additional NRC requirements apply to the licensing, packaging, preparation, and transportation of radioactive materials.

15.2 Compliance Status of the Regulatory Requirements

Generally, the NRC does not have regulatory authority over the DOE. The only portion of the NRC's implementing regulations that applies to WIPP is 10 CFR Part 71, *Packaging and Transportation of Radioactive Material*. These regulations pertain to the NRC's certification of packaging such as the Transuranic Package Transporter Model II (TRUPACT-II) shipping container designed to transport TRU wastes from the generator sites to WIPP. The compliance status of each of the applicable NRC regulatory requirements is summarized in Table 15-1. Details are provided in the text.

TABLE 15-1. Atomic Energy Act and the U. S. Nuclear Regulatory Commission (NRC) - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
10 CFR Part 71, *Packaging and Transportation of Radioactive Material*		
10 CFR 71.12	General license: NRC-approved package Note: The NRC issued the DOE a certificate of compliance for the TRUPACT-II instead of a license.	**ACHIEVED** *TRUPACT-II Certificate of Compliance (C of C) No. 9218, Section 14.* [Section 15.2.1]

TABLE 15-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
10 CFR 71.31-71.39	Contents of application and package description, evaluation, and QA	**ACHIEVED** *TRUPACT-II Safety Analysis Report for Packaging (SARP)* [Section 15.2.2]
10 CFR 71.41	Demonstration of compliance	**ACHIEVED** TRUPACT-II SARP, Section 1.2 [Section 15.2.3]
10 CFR 71.43 and 71.45	Requirements for all packages	**ACHIEVED** TRUPACT-II SARP, Sections 2.4 and 2.5 [Section 15.2.4]
10 CFR 71.47	External radiation standards for all packages	**ACHIEVED** TRUPACT-II SARP, Section 5.0 [Section 15.2.5]
10 CFR 71.51	Additional requirements for Type B packages	**ACHIEVED** TRUPACT-II SARP, Section 4.0 [Section 15.2.6]
10 CFR 71.55-71.61	Requirements for all fissile material packages	**ACHIEVED** TRUPACT-II SARP, Section 6.0 [Section 15.2.7]
10 CFR 71.63	Special requirements for plutonium shipments in excess of 20 Ci/shipment	**ACHIEVED** TRUPACT-II SARP, Section 1.2 and Appendix 1.3.7 [Section 15.2.8]

TABLE 15-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
10 CFR 71.71	Tests under normal conditions of transport	ACHIEVED TRUPACT-II SARP, Section 2.6 [Section 15.2.9]
10 CFR 71.73	Tests under hypothetical accident conditions	ACHIEVED TRUPACT-II SARP, Section 2.7 [Section 15.2.10]
10 CFR 71.81	Compliance with general requirements (71.00-.6a), operating controls and procedures (71.81-.99), and quality assurance requirements (71.101-.137)	ACHIEVED TRUPACT-II SARP, Sections 7.0, 8.0, and 9.0 [Section 15.2.11]
10 CFR 71.83	Assumptions as to unknown properties: assume credible values that will cause the maximum nuclear reactivity	ACHIEVED TRUPACT-II SARP, Appendix 1.3.7 [Section 15.2.12]
10 CFR 71.85	Preliminary determinations of integrity of packaging, pressure testing, and marking	ACHIEVED TRUPACT-II SARP, Section 8.1 [Section 15.2.13]
10 CFR 71.87	Routine determinations prior to each shipment	ACHIEVED TRUPACT-II SARP, Section 7.0 [Section 15.2.14]
10 CFR 71.89	Any special opening instructions for the consignee	ACHIEVED TRUPACT-II SARP, Section 7.2 [Section 15.2.15]

TABLE 15-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
10 CFR 71.91	Records to be kept at least 3 years after shipment	**UP TO DATE** WID record-keeping procedures in place for TRUPACT-II containers [Section 15.2.16]
10 CFR 71.93	Inspections and tests to be performed or allowed to be performed by the NRC	**ACHIEVED** NRC inspections during and after fabrication [Section 15.2.17]
10 CFR 71.95	Reports regarding (1) any decreased effectiveness of an authorized packaging during use and (2) details of any defects with safety significance	**UP TO DATE** Records maintained by TRUPACT-II Maintenance Engineer; no reports to date [Section 15.2.18]
10 CFR 71.97	Advance notification of shipment of nuclear waste as described	**UP TO DATE** TRANSCOM satellite tracking system for advance notification [Section 15.2.19]
10 CFR 71.101-71.137	NRC quality assurance requirements	**ACHIEVED** NRC inspection of WID's QA program [Section 15.2.20]

15.2.1 General License, 10 CFR 71.12

A general license is issued to any licensee of the NRC to transport licensed material in a package for which a license, certificate of compliance, or other approval has been issued by the NRC.

The TRUPACT-II container is approved for use under the general license provisions of 10 CFR 71.12 [Certificate of Compliance (C of C) No. 9218, Section 14]. The DOE is registered with the NRC as a user. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II packaging meets the applicable requirements of 10 CFR §71.12.

15.2.2 Contents of Application and Package Description/Evaluation, 10 CFR 71.31-71.39

The required contents of an application are described. The application must include a package description/evaluation and description of the packaging and proposed contents as described in 10 CFR 71.33 and must demonstrate that the package meets the appropriate NRC standards. In addition, the quality assurance (QA) program for the design, fabrication, assembly, testing, maintenance, repair, modification, and use of the package must be described, along with established codes and standards. Any additional information requested by the NRC must be provided.

The *Safety Analysis Report for Packaging* (SARP) for the TRUPACT-II packaging describes the design, specifications, and safety evaluation in accordance with the NRC's requirements (DOE, 1989a). The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II is in compliance with all applicable requirements of 10 CFR §71.31-71.39.

15.2.3 Demonstration of Compliance, 10 CFR 71.41

The tests specified in 10 CFR 71.71 and 71.73 must be performed on the package to demonstrate compliance under normal conditions and hypothetical accident conditions, respectively.

Section 1.2 of the TRUPACT-II SARP describes the analysis and testing to demonstrate compliance with both normal and hypothetical accident conditions of transport. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.41.

15.2.4 Standards for all Packages, 10 CFR 71.43 and 71.45

Standards for all packages must be met. These include general standards such as size, seals and fastening devices, materials and construction of the package, valves, temperature, and prohibition

of continuous venting during transport as well as lifting and tie-down standards.

Sections 2.4 and 2.5 of the TRUPACT-II SARP describe the packaging features, including tie-downs. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.43 and 71.45.

15.2.5 External Radiation Standards for all Packages, 10 CFR 71.47

A package must be designed and prepared for shipment so that the radiation level at any external surface of the package does not exceed 200 millirem per hour and the transport index does not exceed 10.

Section 5.0 of the TRUPACT-II SARP discusses the fact that the TRUPACT-II has no special shielding; the contents are limited to less than 200 millirem per hour at the surface of the payload containers. The NRCs issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.47.

15.2.6 Additional Requirements for Type B Packages, 10 CFR 71.51

Type B packages must be designed, constructed, and prepared for shipment so as to prevent loss or disposal of radioactive material, significant increase in external radiation levels, or substantial reduction in the effectiveness of the packaging (see also Section 15.2.1.9) during normal transport. In addition, release of krypton-85 may not exceed 10,000 curies in 1 week, release of other radioactive material may not exceed a total amount A_2 in 1 week, and no external radiation dose rate may exceed 1 rem per hour at 1 meter from the external surface of the package during hypothetical accident conditions. Compliance with these requirements must not be predicated upon the use of filters or of a mechanical cooling system.

Section 4.0 of the TRUPACT-II SARP discusses containment design and an acceptance criterion (a leak rate of less than 1×10^{-7} standard cubic centimeters per second). The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.51.

15.2.7 Requirements for all Fissile Material Packages, 10 CFR 71.55-71.61

All packages used to ship fissile material must be designed and constructed in accordance with 10 CFR 71.41 through 71.51. In addition, each package must be designed and constructed and its contents so limited that the contents will remain subcritical during normal and accident transportation conditions and that the packaging will remain effective during normal transportation conditions. Specific standards for Fissile Class I, II, and III packages are described in 10 CFR 71.57, 71.59, and 71.61, respectively. A Fissile Class I package must be designed and constructed and its contents so limited that (1) any number of undamaged packages would be subcritical in any arrangement and with optimal interspersed hydrogenous moderation and (2) 250 packages, if each were subjected to the tests specified in 10 CFR 71.73, would be subcritical if stacked together in any arrangement, closely reflected on all sides by water, and with optimal interspersed hydrogenous moderation.

Section 6.0 of the TRUPACT-II SARP discusses criticality; the contents are controlled to limit the amount of fissile material that may be shipped. The TRUPACT-II is a Fissile Class I package. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.55-71.61.

15.2.8 Special Requirements for Plutonium Shipments, 10 CFR 71.63

Plutonium in excess of 20 curies per package must be shipped as a solid and must be packaged in a separate inner container placed within outer packaging that meets the requirements of 10 CFR 71.41 through 71.77. In addition, the restrictions limiting plutonium under normal and accident conditions must be met.

Section 1.2 of the TRUPACT-II SARP describes the double containment feature of the TRUPACT-II; Appendix 1.3.7 of the TRUPACT-II SARP requires the contents to be in a non-dispersable form. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.63.

15.2.9 Tests Under Normal Conditions of Transport, 10 CFR 71.71

The behavior of each package design under tests and conditions simulating normal transportation conditions must be evaluated. The tests include free drop, compression, and penetration tests. Conditions include heat, cold, change in external pressure (reduced and increased), vibration, and water spray.

Section 2.6 of TRUPACT-II SARP describes the analysis and/or tests performed to demonstrate compliance with the normal conditions of transport. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.71.

15.2.10 Tests Under Hypothetical Accident Conditions, 10 CFR 71.73

Evaluation of a package for hypothetical accident conditions is based upon the sequential application of tests in the order specified to determine their cumulative effect on a package or array of packages. Tests include free drop, puncture, thermal, and immersion as specified in 10 CFR 71.73.

Section 2.7 of TRUPACT-II SARP describes the analysis and/or tests performed to demonstrate compliance with the hypothetical accident conditions of transport. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.73.

15.2.11 Compliance with Operating Controls and Procedures, 10 CFR 71.81

A licensee who is subject to this part and who transports licensed material must comply with requirements of the general provisions (71.00-71.6a), operating controls and procedures (71.81-71.99), and quality assurance requirements (71.101-71.137).

Sections 7.0, 8.0, and 9.0 of the TRUPACT-II SARP describe acceptance and maintenance, operating instructions, and quality assurance. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.81.

15.2.12 Assumptions Regarding Unknown Properties, 10 CFR 71.83

When the isotopic abundance, mass, concentration, degree of irradiation, degree of moderation, or other relevant property of fissile material in a package is not known, the fissile material will be packaged as if the unknown properties have credible values that will cause the maximum nuclear reactivity.

Section 6.0 of the TRUPACT-II SARP assumes the worst case for the criticality assumptions; Appendix 1.3.7 limits the amount of fissile material that may be shipped in the TRUPACT-II packaging. The NRC's issuance of C of C No. 9218 confirms that the TRUPACT-II meets the applicable requirements of 10 CFR §71.83.

15.2.13 Preliminary Determination of Integrity of Packaging, Pressure Testing, and Marking, 10 CFR 71.85

Prior to the first use of any packaging for the shipment of licensed material, the licensee shall ensure the integrity of the packaging, conduct pressure testing, and mark the packaging as required.

Prior to the first use of the TRUPACT-II packaging for the shipment of TRU waste, the integrity of the packaging will be ensured, pressure testing will be conducted as required, and the packagings will be marked with the TRUPACT-II model number, gross weight, and the package identification number assigned by the NRC. Section 8.1 of the TRUPACT-II SARP describes preliminary determinations.

15.2.14 Routine Determinations Prior to each Shipment, 10 CFR 71.87

Prior to each shipment of licensed material, the licensee must ensure that the package and its contents satisfy the applicable requirements of this part and the license. These routine determinations include appropriateness and integrity of packaging; closure devices; liquid containment; pressure relief devices; loading and closure procedures; moderator/neutron absorbers, if appropriate; lift/tie-down devices; external radiation levels (on external surfaces of the package and around vehicle); and accessible package surface temperatures.

Routine Westinghouse Waste Isolation Division (WID) procedures and Operating and Maintenance Instructions are in place to ensure that these requirements are met. Section 7.0 of the TRUPACT-II SARP describes routine determinations.

15.2.15 Special Opening Instructions, 10 CFR 71.89

Any special opening instructions must be sent or otherwise made available to the consignee prior to delivery of a package.

WIPP has provided copies of its procedures for handling an empty TRUPACT-II packaging to each waste-generating site that may ship wastes to WIPP. These procedures provide the requirements and foundations for each site to develop its own procedure(s), taking local facilities and needs into account. Section 7.2 of the TRUPACT-II SARP describes opening the TRUPACT-II.

15.2.16 Maintenance of Records, 10 CFR 71.91

A record of each shipment of licensed material must be kept at least 3 years after shipment. The records to be kept include identification of the packaging by model number, verification of integrity of the packaging, coolant information, type and quantity of licensed material, specific information regarding irradiated fissile material, date of shipment, any special controls, name and address of transferee and of recipient, and results of the determinations required by 10 CFR 71.87. Records demonstrating the quality of packaging must also be retained.

Each WID procedure pertaining to the TRUPACT-II identifies the specific records required for retention. Retention times are also identified for each record. Records are retained at the working location and submitted to the WIPP Records Center for safe and retrievable storage.

15.2.17 NRC Inspections and Tests, 10 CFR 71.93

The licensee or certificate holder shall allow the NRC to inspect the licensed material, packaging, premises, and facilities in which the material or packaging is used, provided, constructed, listed, stored, or shipped; perform (and allow the NRC to perform) tests deemed necessary by the NRC; and notify the NRC at least 45 days prior to the fabrication of a package to be used to ship licensed

material that exceeds the allowed heat load (5 kilowatts) or the maximal normal operating pressure (15 psi gauge).

The DOE has and will continue to allow NRC to inspect or conduct tests, or will perform those tests deemed necessary by the NRC, on TRU waste transportation packages. The TRUPACT C of C requires DOE to meet Subpart G requirements (see Sections 15.2.11 through 15.2.19). Currently there are no TRUPACT-IIs in production. At least 45 days prior to the resumption of construction, the DOE will notify the NRC as required by the TRUPACT C of C.

15.2.18 Reports Regarding Decreased Effectiveness or Defects with Safety Significance, 10 CFR 71.95

Within 30 days, the licensee will report the following to the NRC: (1) any instance in which there was decreased effectiveness of any authorized packaging during use and (2) details of any defects with safety significance in packaging after first use and the means used to prevent recurrence.

The packaging maintenance program is defined and detailed in a WID procedure that addresses such topics as control of material, spare parts, and nonconformance reports. Maintenance records are maintained by the TRUPACT-II Maintenance Engineer. No conditions causing decreased effectiveness have occurred to date.

15.2.19 Advance Notification of Shipment of Nuclear Waste, 10 CFR 71.97

Advance written notification of a shipment of nuclear waste will be provided to the governor of any State to be traversed by the shipment. Notification must be provided at least 7 days or 4 days before the beginning of the 7-day period during which departure of the shipment is expected if notification is by mail or by messenger, respectively. The information required by 10 CFR 71.97(d) will be provided.

Advance notification to State officials will be made using the TRANSCOM satellite tracking system. Operations personnel and designated State officials will be notified regarding WIPP shipments and other selected high-visibility shipments. State officials designated for receipt of this information have been provided with the requisite TRANSCOM computer software and have been trained in its use.

15.2.20 NRC Quality Assurance Requirements, 10 CFR 71.101-71.137

Subpart H of 10 CFR Part 71 (71.101-71.137) established the NRC quality assurance (QA) requirements for packagings. The QA requirements pertain to design, purchase, fabrication, handling, shipping, storage, cleaning, assembly, inspections, testing, operation, maintenance, repair, and modification of components of packaging that are important for safety. The requirements address the licensee's QA organization (71.103); QA program (71.105); package design control (71.107); procurement document control (71.109); instructions, procedures, and drawings (71.111); document control (71.113); control of purchased material, equipment, and services (71.115); identification and control of material parts and components (71.117); control of special processes (71.119); internal inspections (71.121); test control (71.123); control of measuring and test equipment (71.125); handling, storage, and shipping control (71.127); inspection test and operating status (71.129); nonconforming materials, parts, or components (71.131); corrective action (71.133); QA records (71.135); and audits (71.137).

The *WID QA Plan for Procurement, Use, Maintenance and Repair of TRUPACT-II* (WID, 1991b) addresses the 18 criteria specified within Annex 2 of the NRC's Regulatory Guide 7.10, promulgated by the Office of Nuclear Regulatory Research. The title of this document is *Establishing Quality Assurance Programs for Packaging Used in the Transport of Radioactive Material.* The NRC has inspected the WID's QA program and found that it meets the requirements of 10 CFR 71, Subpart H.

15.3 Compliance Status of the Certificate of Compliance

The NRC has issued C of C No. 9218 to the DOE for the TRUPACT-II container and registered the DOE as a user. A number of conditions are specified in the C of C. The conditions from the latest revision of the C of C (dated November 19, 1992) are summarized in Table 15-2. Additional detail is presented in the text.

TABLE 15-2. The U. S. Nuclear Regulatory Commission's Certificate of Compliance (C of C) for the TRUPACT-II Container - Compliance Status of Conditions and Restrictions

CITATION	CONDITION OR RESTRICTION	COMPLIANCE STATUS
Description of TRUPACT-II		
C of C, p. 1, 5(2), para. 1	Overall specifications for the TRUPACT-II	**ACHIEVED** TRUPACT-II SARP, Section 1.2.1.1 and Appendix 1.3.2 [Section 15.3.1]
C of C, p. 1, 5(2), para. 1	Weight specifications	**ACHIEVED** TRUPACT-II SARP, Section 1.2.1.2 and Appendix 1.3.2 [Section 15.3.2]
C of C, p. 1, 5(2), para. 2	Outer containment assembly specifications	**ACHIEVED** TRUPACT-II SARP, Section 1.2.1.1 [Section 15.3.3]
C of C, p. 1, 5(2), para. 3, ICV	Inner containment vessel specifications	**ACHIEVED** TRUPACT-II SARP, Section 1.2.1.1.2 and Appendix 1.3.2 [Section 15.3.4]

TABLE 15-2 (continued)

CITATION	CONDITION OR RESTRICTION	COMPLIANCE STATUS
Packaging - Drawings		
C of C, p. 2, 5(a)(3), para. 1	Packaging construction	**ACHIEVED** TRUPACT-II SARP, Appendix 1.3.2 [Section 15.3.5]
C of C, p. 2, 5(a)(3), para. 2	Positioning of contents within packaging	**ACHIEVED** TRUPACT-II SARP, Appendix 1.3.2 [Section 15.3.6]
Contents - Type and Form of Material		
C of C, p. 2, 5(b)(1)	Allowable materials	**UP TO DATE** TRUPACT-II SARP, Appendix 1.3.7, *TRUPACT-II Authorized Methods for Payload Control* (TRAMPAC); *WIPP Waste Acceptance Criteria* (WAC) [Section 15.3.7]
C of C, p. 2, 5(b)(1)	Explosives, corrosives, nonradioactive pyrophorics, and pressurized containers prohibited	**UP TO DATE** TRAMPAC; WAC [Section 15.3.8]
C of C, p. 2, 5(b)(1)	Radioactive pyrophorics not to exceed 1 percent by weight within a drum, standard waste box (SWB), or bin	**UP TO DATE** TRAMPAC; WAC [Section 15.3.9]

TABLE 15-2 (continued)

CITATION	CONDITION OR RESTRICTION	COMPLIANCE STATUS
C of C, p. 2, 5(b)(1)	Free liquids not to exceed 1 percent by volume within a drum, SWB, or bin	UP TO DATE TRAMPAC; WAC [Section 15.3.10]
C of C, p. 2, 5(b)(1)	Flammable organics limited to 500 ppm in headspace of any drum, SWB, or bin	UP TO DATE TRAMPAC; WAC [Section 15.3.11]
Contents - Maximal Quantity of Material per Package		
C of C, p. 2, 5(b)(2), para. 1	Maximum allowable weight	UP TO DATE TRAMPAC; WAC [Section 15.3.12]
C of C, p. 2, 5(b)(2), para. 2	Maximal number of payload containers per package and authorized packaging configurations	UP TO DATE TRAMPAC; WAC [Section 15.3.13]
C of C, p. 2, 5(b)(2), para. 3	Amount of allowable fissile material	UP TO DATE TRAMPAC; WAC [Section 15.3.14]
C of C, p. 2, 5(b)(2), para. 4	Allowable decay heat	UP TO DATE TRUPACT-II SARP, Section 1.2.3.33; TRUPACT-II Content Codes (TRUCON) [Section 15.3.15]

TABLE 15-2 (continued)

CITATION	CONDITION OR RESTRICTION	COMPLIANCE STATUS
	Fissile Class	
C of C, p. 2, 5(c)	Fissile Class I	**UP TO DATE** TRUPACT-II SARP, Section 6.0 [Section 15.3.16]
C of C, p. 3, 6	Restrictions of form, properties, and other parameters	**UP TO DATE** TRAMPAC; WAC [Section 15.3.17]
C of C, p. 3, 7	Shipping category designations	**UP TO DATE** TRUCON [Section 15.3.18]
C of C, p. 3, 8	Labeling requirements	**UP TO DATE** TRAMPAC; WAC [Section 15.3.19]
C of C, p. 3, 9	Pre-shipping venting or aspirating requirements	**UP TO DATE** TRAMPAC; WAC; TRUCON [Section 15.3.20]
C of C, p. 3, 10	Requirements of Subpart G of 10 CFR Part 71	**UP TO DATE** WID QA program [Section 15.3.21]

TABLE 15-2 (continued)

CITATION	CONDITION OR RESTRICTION	COMPLIANCE STATUS
C of C, p. 3, 10(a)	Preparation of packages for shipment and operations	UP TO DATE TRUPACT-II SARP, Section 7.0 [Section 15.3.22]
C of C, p. 3, 10(b)	Testing and maintenance of packaging	UP TO DATE TRUPACT-II SARP, Section 8.0 [Section 15.3.23]
C of C, p. 3, 11	Contents of each package	UP TO DATE TRAMPAC; WAC [Section 15.3.24]
C of C, p. 3, 12	Leak testing	UP TO DATE TRUPACT-II SARP, Section 8.0 [Section 15.3.25]
C of C, p. 3, 13	Removal of free-standing water	UP TO DATE TRUPACT-II SARP, Section 7.0 [Section 15.3.26]
C of C, p. 3, 14	Approval of TRUPACT-II	ACHIEVED NRC'S C of C No. 9218 [Section 15.3.27]

TABLE 15-2 (continued)

CITATION	CONDITION OR RESTRICTION	COMPLIANCE STATUS
C of C, p. 3, 15	Expiration date: August 31, 1994	UP TO DATE Will submit application to the NRC for timely renewal prior to expiration [Section 15.3.28]

15.3.1 Overall Specifications for the TRUPACT-II, Certificate of Compliance (C of C), p. 1, 5(2), para. 1

The TRUPACT-II consists of an unvented, 1/4-inch-thick stainless steel inner containment vessel (ICV) positioned within an outer containment assembly (OCA).

The OCA is an unvented 1/4-inch-thick stainless steel outer containment vessel (OCV) with a 10-inch-thick layer of polyurethane foam and a 1/4- to 3/8-inch-thick outer stainless steel shell.

The package is a right circular cylinder with outside dimensions of about 94 inches in diameter and 122 inches in height.

The TRUPACT-II packaging is composed of the ICV positioned within the OCA. As shown in the drawings in Appendix 1.3.2 of the TRUPACT-II SARP and discussed in Section 1.2.1.1 of that document, the ICV is unvented and is fabricated primarily of 1/4-inch Type 304 stainless steel. The OCA is also unvented and is bounded by a 1/4- to 3/8-inch-thick Type 304 stainless steel shell. Within the outer shell of the OCA is the OCV, which has a 3/16-inch-thick Type 304 stainless steel shell. Between the outer shell of the OCA and the outer shell of the OCV is a layer of polyurethane foam to provide insulation and absorb energy; this layer is up to 9 13/16 inches thick.

The TRUPACT-II is a right cylinder. The OCA is 94 3/8 inches in diameter and 121 3/4 inches high (Section 1.2.1.1.1 of the TRUPACT-II SARP).

15.3.2 Overall Weight, C of C, p. 1, 5(2), para. 1

The package weighs no more than 19,250 pounds when loaded, with the maximal allowable contents of 7,265 pounds.

According to Section 1.2.1.2 of the SARP, the maximum gross shipping weight of the TRUPACT-II package is 19,250 pounds. The maximal payload weight is 7,265 pounds.

15.3.3 Outer Containment Assembly of the TRUPACT-II, C of C, p. 1, 5(2), para. 2

The OCA has a domed lid secured to the OCA body with a locking ring.

The OCV containment seal is provided by a butyl rubber O-ring (bore seal).

The OCV is equipped with a seal test port and a vent port.

As shown and described in Section 1.2.1.1 of the TRUPACT-II SARP, the OCA has a domed lid which is secured to the body of the OCA with a locking ring assembly. The containment O-ring is made of butyl rubber. The location of the OCV seal test port and the vent port are shown in Appendix 1.3.2 of the TRUPACT-II SARP (Sheet 2 of Drawing 2077-500 SNP).

15.3.4 Inner Containment Vessel of the TRUPACT-II, C of C, p. 1, 5(2), para. 3

The ICV is a right circular cylinder with domed ends. Its outside dimensions are approximately 73 inches in diameter and 98 inches high.

The lid is secured to the ICV body with a locking ring.

The containment seal is provided by a butyl rubber O-ring (bore seal).

The ICV is equipped with a seal test port and vent port. Aluminum spacers are placed in the top and bottom domed ends of the ICV during shipping. The cavity available for the contents is a cylinder of approximately 73 inches in diameter and 75 inches in height.

The ICV is a right cylinder with domed ends. According to Section 1.2.1.1.2 of the TRUPACT-II SARP, the ICV has a maximal external diameter of 76 5/16 inches, a minimal

external diameter of 73 1/8 inches, and an overall external length of 99 inches when the lid is installed on the body of the ICV. The lid is secured to the body with a locking ring. Two main O-rings are enclosed between the mating lid and body of the OCV: the upper main O-ring is made of butyl rubber and serves a containment function; the lower (test) seal is made of neoprene or ethylene propylene and allows a vacuum to be established on the exterior side of the containment O-ring for helium and pressure-rise leakage-rate testing.

The locations of the ICV seal test port and the vent port are shown in Appendix 1.3.2 of the TRUPACT-II SARP (Sheet 3 of Drawing 2077-500SNP). The upper and lower aluminum spacer assemblies are shown on Sheet 6 of this same set of drawings in Appendix 1.3.2 of the SARP.

A cylindrical cavity is available for the contents to be placed in the ICV. The dimensions of the cavity are a minimal and maximal diameter of 72 7/16 and 73 7/8 inches (Section 1.2.1.1.2 of the TRUPACT-II SARP) and a height of 74 5/8 inches (Appendix 1.3.2 of the SARP, Drawing 2077-500SNP, Sheet 2).

15.3.5 Drawings Showing Construction of TRUPACT-II, C of C, p. 2, 5(a)(3), para. 1

The packaging is constructed in accordance with Nuclear Packaging Inc. (NuPac) drawing # 2077-500SNP, Sheets 1-11 (Rev. K).

The 11 sheets of Drawing #2077-500SNP are included in the TRUPACT-II SARP. The TRUPACT-II packages are constructed in accordance with these drawings.

15.3.6 Drawings Showing Position of Contents in TRUPACT-II, C of C, p. 2, 5(a)(3), para. 2

The contents are positioned within the packaging in accordance with NuPac drawings # 2077-007SNP (Rev. C) and 2077-008 SNP, Sheets 1 and 2 (Rev. C).

NuPac Drawings 2077-007SNP (one sheet) and 2077-008SNP (two sheets) are included in Appendix 1.3.8 of the TRUPACT-II SARP. The drum assemblies or standard waste boxes (SWBs) are positioned within the package as shown in these drawings.

15.3.7 Physical Form of Allowable Material and Receptacles, C of C, p. 2, 5(b)(1)

Only dewatered, solid, or solidified TRU wastes are allowed. They must be packaged in 55-gallon drums, SWBs, or bins.

According to Section 3.2.1.2 of the *WIPP Waste Acceptance Criteria* (WAC) (DOE, 1991b), standard 55-gallon metal drums, SWBs, 55-gallon drums overpacked in an SWB, and an experimental bin overpacked in an SWB are authorized for shipping contact-handled TRU wastes in a TRUPACT-II packaging. The prohibition of free liquids is discussed in Section 15.3.10 of this BECR. (See also Section 5 of Appendix 1.3.7 to the TRUPACT-II SARP.)

15.3.8 Prohibition of Explosives, Corrosives, Nonradioactive Pyrophorics, and Pressurized Containers, C of C, p. 2, 5(b)(1)

Explosives, corrosives, nonradioactive pyrophorics, and pressurized containers are prohibited.

Section 3.3.4 of the WAC prohibits the acceptance of explosives or pressurized canisters at WIPP. The WAC stipulates that any nonradioactive pyrophoric materials must be rendered safe by mixing them with chemically stable materials (e.g., concrete, glass) or by processing them to remove their hazardous properties; thus, they will be rendered nonpyrophoric prior to shipment to WIPP (Section 3.3.3). (See also Section 5 of Appendix 1.3.7 to the TRUPACT-II SARP.)

Corrosive wastes are prohibited on two counts. They are prohibited on the basis of the definition of corrosive waste used in the WAC (i.e., aqueous materials with a pH less than 2 or higher than 12.5[1]). Furthermore, since corrosive wastes are aqueous by definition, they are prohibited as free-standing liquids (see Section 15.3.10).

15.3.9 Restriction of Radioactive Pyrophorics, C of C, p. 2, 5(b)(1)

Radioactive pyrophorics must not exceed 1 percent by weight within a drum, SWB, or bin.

Section 3.3.3 of the WAC restricts pyrophoric forms of radionuclides to 1 percent by weight of the waste in each waste container with the stipulation that such waste be dispersed in the waste. (See also Section 5 of Appendix 1.3.7 to the TRUPACT-II SARP.)

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[1] The WAC definition of corrosive wastes differs from that of RCRA since the latter includes aqueous materials with a pH of 2 or of 12.5 in its definition of corrosive waste under 40 CFR 261.22(a)(i).

15.3.10 Restriction of Free Liquids, C of C, p. 2, 5(b)(1)

Free liquids must not exceed 1 percent by volume within a drum, SWB, or bin.

Section 3.3.2 of the WAC stipulates that liquid waste will not be emplaced at WIPP and that the total liquid in a waste container will not equal or exceed 1 volume percent of the payload container. (See also Section 4 of Appendix 1.3.7 to the TRUPACT-II SARP.)

15.3.11 Restriction of Flammable Organics, C of C, p. 2, 5(b)(1)

Flammable organics are limited to 500 ppm in the headspace of any drum, SWB, or bin.

Section 3.4.7.2 of the WAC limits the total concentration of potentially flammable volatile organic compounds (VOCs) to 500 ppm in the headspace of a waste package; this value includes error measurement.

15.3.12 Maximal Allowable Weight, C of C, p. 2, 5(b)(2), para. 1

Contents must not exceed 7,265 pounds including shoring and secondary containers, with no more than 1,000 pounds per 55-gallon drum and 4,000 pounds per SWB.

Section 3.4.1.2 of the WAC specifies the following weight limits for waste package assemblies transported in the TRUPACT-II package:

1,000 lbs per drum
1,450 lbs per drum overpacked in an SWB
4,000 lbs per SWB
7,265 lbs per TRUPACT-II payload
19,250 lbs per TRUPACT-II payload, including the weight of the TRUPACT-II packaging

15.3.13 Maximal Number of Payload Containers Per Package and Authorized Configurations, C of C, p. 2, 5(b)(2), para. 2

The maximal number of payload containers per package and authorized packaging configurations are:

14 55-gal drums
2 SWBs
2 SWBs, each containing one bin
2 SWBs, each containing four 55-gal drums
1 10-drum overpack (TDOP) containing ten 55-gal drums
1 TDOP containing one SWB
1 TDOP containing one bin within an SWB
1 TDOP containing four 55-gal drums within an SWB.

According to the WAC (Section 3.2.2.2), the authorized loading configurations for shipment in the TRUPACT-II package are standard 55-gallon metal drums in two seven-pack configurations or two SWBs. Up to four drums or one experimental bin may be overpacked in an SWB. If only one seven-pack or one SWB of waste is scheduled for shipment in the TRUPACT-II, a dunnage seven-pack or SWB must be added to the package for transport, as specified in Appendix 1.3.7 of the TRUPACT-II SARP. In addition, drums, SWBs and experimental bins may be overpacked in a TDOP for shipment within the TRUPACT-II.

15.3.14 Amount of Allowable Fissile Material, C of C, p. 2, 5(b)(2), para. 3

Fissile material must not exceed 325 grams Pu-239 equivalent, with no more than 200 grams Pu-239 equivalent per 55-gal drum or 325 grams Pu-239 equivalent per SWB (for Pu-239 equivalent, see Appendix 1.3.7 of the TRUPACT-II SARP).

Section 3.4.2.1 of the WAC specifies that the fissile or fissionable radionuclide content of contact-handled TRU waste packages will not exceed the following values, in Pu-239 fissile-gram equivalents:

- 200 grams per 55-gallon drum
- 5 grams per cubic foot in boxes, up to a 350-gram maximum.

However, the TRUPACT-II package limit for the SWB cited in the WAC is less than 325 grams. Thus, the sum of the fissile equivalents of all waste packages in the entire payload of a quantity including two times the error may not exceed 325 grams (see the calculational methods described in Appendix 1.3.7 of the TRUPACT-II SARP).

15.3.15 Allowable Decay Heat, C of C, p. 2, 5(b)(2), para. 4

Decay heat must not exceed the values given in Tables 6.1 through 6.3 of the TRUPACT-II Content Codes (TRUCON) (DOE, 1989b).

According to Section 3.4.6.2 of the WAC, there are two thermal limits for decay heat: the total decay heat from radioactive decay of the radioisotopes within an individual payload container and the total decay heat from all payload containers in a TRUPACT-II package. The total decay heat limits per TRUPACT-II for each shipping category are presented in Table 1.2.3.33 of the TRUPACT-II SARP. In determining whether or not a waste package or group of waste packages meets the limits, the error must be added to the measured value. The design limit for the TRUPACT-II is 40 watts.

15.3.16 Fissile Class, C of C, p. 2, 5(c)

The C of C identifies the TRUPACT-II as a Fissile Class I package.

The C of C identified the TRUPACT-II as a Fissile Class I packaging. Therefore, the requirements specified in 10 CFR 71.57 must be met.

15.3.17 Restrictions of Form, Properties, and other Parameters, C of C, p. 3, 6

The physical form, chemical properties, chemical compatibility, configuration of the payload containers and contents, isotopic inventory, fissile content, decay heat, weight and center of gravity, and radiation dose rate must be determined and limited in accordance with the TRUPACT-II Authorized Methods for Payload Control (TRAMPAC) (TRUPACT-II SARP, Appendix 1.3.7).

The methods for determining and controlling the physical form of the wastes are visual examination, real-time radiography (RTR), records and data-base information, and sampling (SARP, Appendix 1.3.7, Section 4). The chemical properties of the waste (SARP, Appendix 1.3.7, Section 5) are determined by the allowable chemical constituents within a given waste type and are restricted so that all the payload containers are safe for handling and transport. Chemical compatibility (SARP, Appendix 1.3.7, Section 6; see also SARP Appendix 2.10.12) within the waste and between the waste and the packaging ensures that no chemical process will occur that might pose a threat to the safe transport of the payload in the TRUPACT-II package. The configuration of the payload container and content is controlled as described in Section 8

of the SARP's Appendix 1.3.7; this section also describes specifications for filter vents and pre-shipping venting and aspiration requirements.

The isotopic inventory for each payload container and the fissile content are discussed in Section 9 of the TRAMPAC. Decay heat is discussed in Section 10 of the TRAMPAC.

The allowable weights for individual payload containers and for the total payload are presented in Section 11 of the TRAMPAC, along with methods of determining and controlling weight. The methods for determining the center of gravity of the loaded TRUPACT-II package are also described in this section for 55-gallon drums and for SWBs.

External radiation dose rates are presented in Section 12 of the TRAMPAC. These rates may not exceed 200 mrem per hour at the surface of the payload container and 10 mrem per hour at 2 meters (see also Section 5.0 of the TRUPACT-II SARP).

15.3.18 Shipping Category Designations, C of C, p. 3, 7

Each drum, SWB, or bin must be assigned a shipping category in accordance with Table 5 from TRUCON (Rev. 6) or tested for gas generation and must meet the acceptance criteria in accordance with Attachment 2.0 to Appendix 1.3.7 of the TRUPACT-II SARP.

Section 1.2.3.2 of the TRUPACT-II SARP discusses the payload shipping categories developed specifically for the TRUPACT-II package. The primary difference among the categories is their potential for gas generation and internal bagging configuration. For waste with an adequate margin of safety, an analytical prediction suffices. Wastes without such a margin of safety require testing as described in Section 1.23.3.12 and Attachment 2 to Appendix 1.3.7 of the TRUPACT-II SARP.

15.3.19 Labeling Requirements, C of C, p. 3, 8

Each drum, SWB, or bin must be labeled to indicate its shipping category. All drums, SWBs, or bins within a package must be of the same shipping category.

As described in Section 3.4.8 of the WAC, each waste package will be labeled with the shipping category after all payload parameters have been verified. Furthermore, all waste packages within a single TRUPACT-II package must belong to the same shipping category (WAC, Section 3.6.1.2). (See also Section 13.1 of Appendix 1.3.7 to the TRUPACT-II SARP.)

15.3.20 Pre-Shipment Venting or Aspirating Requirements, C of C, p. 3, 9

Each drum, SWB, bin, or TDOP must be equipped with filtered vents prior to shipment in accordance with Appendix 1.3.7 to the TRUPACT-II SARP; drums not equipped with filtered vents during storage must be aspirated before shipment; the minimal aspiration time may be determined from Tables 7.1 through 9.3 in TRUCON.

Section 3.4.7.2 of the WAC stipulates that all payload containers, including any overpacks, must be vented with filters that meet the specifications described in the TRUPACT-II SARP. At least one filter will be used per drum, two per overpacked experimental bin in an SWB, and two per SWB. Any rigid drum liners will be filtered or punctured. (See also Section 8.1 of Appendix 1.3.7 and Appendix 3.6.11 to the TRUPACT-II SARP.)

15.3.21 Requirements of Subpart G of 10 CFR Part 71, C of C, p. 3, 10

Compliance with the requirements of Subpart G of 10 CFR Part 71 is required.

Subpart G invokes Subpart H, *Quality Assurance*. (See Section 15.2.20.)

15.3.22 Preparation of Packages for Shipment and Operations, C of C, p. 3, 10(a)

Each package must be prepared for shipment and operated in accordance with procedures described in Section 7, "Operating Procedures," of the TRUPACT-II SARP.

Section 7 of the TRUPACT-II SARP contains procedures for loading and unloading the TRUPACT-II container and for preparing an empty packaging for transport. In addition, the payload assembly criteria are presented in Section 13 of Appendix 1.3.7 to the TRUPACT-II SARP.

15.3.23 Testing and Maintenance of Packages, C of C, p. 3, 10(b)

Each package must be tested and maintained in accordance with procedures described in Section 8, Acceptance Tests and Maintenance Program, of the TRUPACT-II SARP.

The required acceptance tests and the maintenance program are included in Section 8 of the TRUPACT-II SARP. The acceptance tests are those tests that must be performed prior to the first use of the TRUPACT-II and include visual inspection and structural and pressure, leakage, component, and thermal acceptance tests. (No shielding is provided in the TRUPACT-II container; therefore shielding integrity tests are not appropriate.) The maintenance program consists of procedures and tests used to ensure the continuation of proper performance of the TRUPACT-II packaging. It comprises structural and pressure tests; leak tests and subsystems maintenance of fasteners; the ICV; the OCA; seal areas and grooves; and valves, rupture discs, and gaskets on the containment vessel. No shielding or thermal inspections or tests are necessary to ensure continued performance of the TRUPACT-II container.

15.3.24 Contents of Packages, C of C, p. 3, 11

The contents of each package must be in accordance with Appendix 7.4.1, "Payload Control Procedures," of the TRUPACT-II SARP.

The payload control procedure appears in Appendix 7.4.3 and is summarized in Section 13 of Appendix 1.3.7 of the TRUPACT-II SARP. Section 3.6.1.2 of the WAC specifies that the payload control procedures provided in Section 7.4.3 of the TRUPACT-II SARP will be followed for shipping contact-handled TRU waste in the TRUPACT-II package.

15.3.25 Leak Testing, C of C, p. 3, 12

Prior to each shipment, lid and vent port seals on inner and outer containment vessels must be leak tested to 1 x 10^{-7} standard cubic centimeter per second in accordance with Section 7 of the TRUPACT-II SARP.

The assembly verification leak test and other leak tests that must be performed on the TRUPACT-II package are described in Appendix 7.4.2 and Section 8 of the TRUPACT-II SARP. All such mandatory tests will be run on each package prior to shipment.

15.3.26 Removal of Free-Standing Water, C of C, p. 3, 13

All free-standing water must be removed from the ICV cavity and the OCV cavity before shipment.

The operating procedures of Section 7 of the TRUPACT-II package include instructions for inspecting for free-standing water and removing it from the package (i.e., Sections 7.1.2.3.2,

7.1.2.3.3, and 7.1.2.3.6 through 7.1.2.3.9). These procedures must be used for loading the TRUPACT-II container.

15.3.27 Approval of the TRUPACT-II Packaging, C of C, p. 3, 14

The TRUPACT-II packaging must be approved for use under general license provisions of 10 CFR 71.12.

See Section 15.2.1.

15.3.28 Expiration Date, C of C, p. 3, 15

The expiration date of this C of C is August 31, 1994.

In order to use the TRUPACT-II packaging for shipping TRU waste, the C of C must be updated prior to its expiration date of August 31, 1994. This will be accomplished by submitting an application for timely renewal to the NRC.

16.0 HAZARDOUS MATERIALS TRANSPORTATION ACT

16.1 Summary of the Law

The Hazardous Materials Transportation Act (HMTA; 49 USC §§ 1801 et seq.), as amended, is the major transportation-related statute that affects the DOE. The objective of the HMTA is "to improve the regulatory and enforcement authority of the Secretary of Transportation to protect the Nation adequately against risks to life and property which are inherent in the transportation of hazardous materials in commerce." The HMTA provides for safe intra- and inter-state transportation of hazardous materials (including nuclear materials).

The Hazardous Materials Transportation Uniform Safety Act (HMTUSA; PL 101-615) was enacted on November 16, 1990. This public law, which amends the HMTA, required the U.S. Department of Transportation (DOT) to set standards for designating routes for the transportation of hazardous materials, establish regulations on training standards for all hazardous materials transportation workers, issue safety permits to motor carriers for certain hazardous materials, and perform a railroad transportation safety study for certain highly radioactive materials. DOT is also required to participate in international forums dealing with recommendations or legislation relating to mandatory standards and requirements pertaining to the transportation of hazardous materials and to consult with interested agencies to facilitate consistency in international law with respect to hazardous materials transportation. In addition, HMTUSA requires registration and an annual registration fee for shippers and carriers of certain hazardous materials such as radioactive materials and establishes planning and training grants to the States for developing, improving, and implementing emergency plans.

In the Second Modification to the Agreement for Consultation and Cooperation, dated August 4, 1987, the DOE agreed to comply with all applicable DOT regulations and corresponding regulations of the U.S. Nuclear Regulatory Commission (NRC). The following regulations are applicable to WIPP.

49 CFR Part 171, *General Information, Regulations, and Definitions*, sets forth the DOT requirements that are applicable to the transportation of hazardous materials and the packaging used in the transportation of those materials.

49 CFR Part 172, *Hazardous Materials Table, Special Provisions, Hazardous Materials Communications Requirements and Emergency Response Information Requirements*, lists and classifies the materials that the DOT has designated as hazardous for the purpose of transportation and describes the communications regulations that apply when those materials are shipped.

In 49 CFR Part 173, *Shippers - General Requirements for Shipments and Packagings*, the DOT defines hazardous materials for the purpose of transportation; establishes requirements in preparing materials for shipment; sets forth inspection, testing, and retesting responsibilities

concerning containers built, repaired, or conditioned for use in the transportation of hazardous materials; sets forth requirements for transporting radioactive material; classifies materials having more than one hazard; and describes criteria for instructing those responsible for preparing hazardous materials for shipment.

In 49 CFR Part 175, *Carriage by Aircraft*, the DOT prescribes additional requirements to those in Parts 171, 172, and 173 concerning the transportation of hazardous material by air.

In 49 CFR Part 177, *Carriage by Public Highway*, the DOT sets forth requirements to promote the uniform enforcement of law to minimize danger to life and property in the transportation of hazardous materials by public highway.

49 CFR Part 178, *Specifications for Packagings*, describes manufacturing and testing specifications for packaging and containers used for the transportation of hazardous materials.

16.2 Compliance Status of the Regulatory Requirements

Table 16-1 summarizes the regulatory requirements and their compliance status under the Hazardous Materials Transportation Act. The text gives more detail on the compliance status for each requirement.

TABLE 16-1. Hazardous Materials Transportation Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
49 CFR Part 171, *General Information, Regulations, and Definitions*		
49 CFR 171.2	General requirements	**UP TO DATE** Being addressed in *Transportation Management Plan* and WID procedures [Section 16.2.1]

TABLE 16-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
49 CFR 171.3	Transport of hazardous material requiring manifests, labeling, and shipper/generator and transporter identification	**UP TO DATE** Being addressed in *Transportation Management Plan* [Section 16.2.2]
49 CFR 171.14	Materials poisonous by inhalation; segregation requirements	**UP TO DATE** Being addressed in *Transportation Management Plan* [Section 16.2.3]
49 CFR 171.15/16	Notice and report of hazardous material incidents	**UP TO DATE** Being addressed in *Transportation Management Plan* [Section 16.2.4]
49 CFR Part 172, *Hazardous Materials Table, Special Provisions, Hazardous Materials Communication Requirements and Emergency Response Information Requirements*		
49 CFR 172.101	Hazardous materials table	**UP TO DATE** Addressed in WID procedure [Section 16.2.5]
Subpart C, 49 CFR 172.200-.205	Shipping paper requirements	**UP TO DATE** Addressed in WID procedure [Section 16.2.6]

TABLE 16-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Subpart D, 49 CFR 172.300-.338	Marking of hazardous materials/substances for transport	**UP TO DATE** Addressed in WID procedure [Section 16.2.7]
Subpart E, 49 CFR 172.400-.450	Labeling of hazardous materials/substances for transport	**UP TO DATE** Addressed in WID procedure [Section 16.2.8]
Subpart F, 49 CFR 172.500-.560	Placarding of hazardous materials/substances for transport	**UP TO DATE** Addressed in WID procedure [Section 16.2.9]
Subpart G, 49 CFR 172.600	Emergency response	**UP TO DATE** Addressed in WID procedure [Section 16.2.10]
Subpart H, 49 CFR 172.700-.704	Training requirements for the transportation of hazardous materials	**UP TO DATE** Training conducted and attended by appropriate personnel [Section 16.2.11]
49 CFR Part 173, *Shippers - General Requirements for Shipments and Packagings*		
Subpart A, 49 CFR 173.12	General requirements for shipments and packagings	**UP TO DATE** Addressed in WID procedure [Section 16.2.12]

TABLE 16-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Subpart B, 49 CFR 173.21-.40	Preparation of hazardous materials for transport	**UP TO DATE** Addressed in WID procedure [Section 16.2.13]
Subpart C, 49 CFR 173.50-.63	Definitions, classification, and packaging of Class 1 materials	**NOT APPLICABLE** Addressed in WID procedure [Section 16.2.14]
Subpart D, 49 CFR 173.115-.156	Classification, packing group assignments, and exceptions for hazardous materials other than Classes 1 and 7	**UP TO DATE** Addressed in WID procedure [Section 16.2.15]
Subpart E, 49 CFR 173.158-.230	Non-bulk packaging of hazardous materials other than Classes 1 and 7	**UP TO DATE** Addressed in WID procedure [Section 16.2.16]
Subpart I, 49 CFR 173.401-.478	Transportation of radioactive materials (including empty packaging)	**UP TO DATE** Addressed in WID procedures [Section 16.2.17]
49 CFR Part 175, *Carriage by Aircraft*		
49 CFR 175	Transportation of hazardous material by aircraft	**UP TO DATE** Addressed in WID Procedure [Section 16.2.18]
49 CFR Part 177, *Carriage by Public Highway*		

TABLE 16-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
49 CFR 177.800, .816, and .825	Training responsibilities and requirements for Class 7 material	**UP TO DATE** Training conducted and attended by appropriate personnel [Section 16.2.19]
49 CFR Part 178, *Specifications for Packagings*		
49 CFR 178	Packagings and containers used for transportation of hazardous materials	**UP TO DATE** Certificate of Compliance (C of C) for TRUPACT-II packaging [Section 16.2.20]

16.2.1 General Requirements, 49 CFR 171.2

General requirements regarding the offering or acceptance of hazardous material for transportation in commerce are described. Material to be shipped must be properly classed, described, packaged, marked, labeled, and in condition for shipment.

General requirements for the shipment of hazardous material are being addressed in the draft WID *Transportation Management Plan* and in Westinghouse Waste Isolation Division (WID) procedures. The *Transportation Management Plan* is being developed from the *TRUPACT-II Transportation Management Plan* (DOE, 1993a) in order to broaden the scope of the existing document. The plan will identify the WID organizations and positions that are responsible for ensuring compliance with the HMTA. The completion and certification of several worksheets (e.g., "Shipping Request," "Shipment Worksheet for Ground Transportation," and "Shipment Worksheet for Air Transportation") ensure compliance through careful documentation of all required actions.

16.2.2 Hazardous Waste, 49 CFR 171.3

Requirements for the shipment of hazardous wastes include the preparation of manifests or other shipping papers, motor vehicle marking and placarding, waste packaging and labeling, and identification numbers for the generators and the transporters.

Manifests, marking and placarding, and other labeling requirements are being addressed in the WID *Transportation Management Plan*. Completion of step-by-step worksheets ensure the proper execution of these tasks in shipping hazardous wastes from WIPP to an off-site treatment/storage/disposal facility (TSDF).

16.2.3 Transitional Provisions for Implementing Requirements Based on the United Nations (UN) Recommendations, 49 CFR 171.14

This subchapter provides an orderly transition to the new requirements incorporated as part of a comprehensive revision to this subchapter based on the UN Recommendations. Specified are requirements for new explosives, materials that are poisonous by inhalation, and infectious substances.

A WID procedure addresses materials that are poisonous by inhalation. Prescribed methods for shipping poisonous-by-inhalation materials will be included in the *Transportation Management Plan*.

16.2.4 Immediate Notice of Certain Hazardous Materials Incidents and Detailed Hazardous Materials Incident Reports, 49 CFR 171.15-171.16

Section 171.15 specifies the requirements of immediate notification by each carrier who transports hazardous materials (including hazardous wastes) and is involved in a hazardous material incident during the course of transportation. Section 171.16 specifies the requirements for the submission of a written hazardous materials incident report by the carrier.

Requirements for transportation emergency notifications are specified in the *Transportation Management Plan*. This plan and WID procedures define reportable incident and reporting requirements, including the identification of organizations and other entities that receive reports.

16.2.5 Table of Hazardous Materials, 49 CFR 172.101

The Hazardous Materials Table designates all materials listed as hazardous for the purpose of transporting those materials.

These requirements are covered in a WID procedure that is directed to any "... material, including its mixtures and solutions that...is listed in the Appendix to 49 CFR 172.101, *List of Hazardous Substances and Reportable Quantities.*"

16.2.6 Shipping Papers, Subpart C, 49 CFR 172.200-172.205

This subpart describes the requirements for the provision of shipping papers by persons who offer hazardous material for transportation. The shipping papers must include a description of the hazardous material, shipper's certification, and a hazardous waste manifest.

Requirements concerning shipping papers, including manifests, for hazardous materials, are described in a WID procedure. Each required record is identified and defined by forms attached to this procedure.

16.2.7 Marking, Subpart D, 49 CFR 172.300-172.338

Marking requirements for the transportation of hazardous materials or substances are described in this subpart.

According to a WID procedure, the Transportation Engineer marks and labels the shipment in accordance with either Subparts D and E of 49 CFR Part 172 or the International Air Transport Association (IATA) 7.1 and 7.2.

16.2.8 Labeling, Subpart E, 49 CFR 172.400-172.450

This subpart describes the requirements for the labeling of packages or containment devices by persons who offer hazardous material for transport.

According to a WID procedure, the Transportation Engineer marks and labels the shipment in accordance with either Subparts D and E of 49 CFR Part 172 or IATA 7.1 and 7.2.

16.2.9 Placarding, Subpart F, 49 CFR 172.500-172.560

This subpart describes the requirements for the placarding of hazardous material by persons who offer hazardous material for transport.

According to a WID procedure, the Transportation Engineer ensures that the vehicle that will transport hazardous waste from WIPP is properly placarded.

16.2.10 Emergency Response Information, Subpart F, 49 CFR 172.600

This subpart describes the requirements for the provision of emergency response information during transportation and at facilities where hazardous materials are loaded for transportation, stored incidental to transportation, or otherwise handled during any phase of transportation.

According to a WID procedure, the Transportation Engineer delivers the shipping papers and the *Carrier/Driver Instructions, Emergency Response Plan during Transportation*, to the driver and releases the shipment. This plan specifies driver actions to be taken in the event of an incident during transportation.

16.2.11 Training Requirements, Federal/State Relationship, and Applicability and Responsibility for Training and Testing, 49 CFR 172.700-.702 and 172.704

These sections prescribe minimal training requirements for the transportation of hazardous materials and specify requirements that TSDF owners or operators must meet to ensure that their hazardous materials (hazmat) employees are trained in a systematic program. The following requirements are included: States may impose more stringent training requirements under certain conditions; the training curriculum must include general awareness and familiarization, hazardous material recognition and identification, function-specific topics, and safety and emergency response information; and current hazmat employee training records must be maintained and contain specific training documentation including certification of training.

WIPP employees having job duties that require them to attend the Hazardous Material Training Course (HMT-102) have done so or work under the direct supervision of another trained hazmat

employee. Through the training programs, hazmat employees become familiar with the applicable hazardous material regulations, are able to recognize and identify hazardous materials, are knowledgeable of function-specific hazardous material regulations, and are knowledgeable of emergency response information and hazardous material communications requirements. The WIPP provides each hazmat employee with initial and recurrent training in accordance with established schedules. Each employer maintains records of current training, inclusive of the preceding 2 years. The training records are maintained in accordance with existing requirements.

16.2.12 General Requirements for Shipments and Packagings, Subpart A, 49 CFR 173.1-173.12

This subpart includes the requirements for preparing hazardous materials for shipment by air, highway, rail, or water and definitions and classifications of hazardous materials for transportation purposes.

A WID procedure specifies that shipments of hazardous materials must comply with these requirements.

16.2.13 Preparation of Hazardous Materials for Transportation, Subpart B, 49 CFR 173.21-173.40

This subpart describes the requirements for the preparation of hazardous materials for transportation. The shipper's responsibilities are described and include the classification and description of hazardous material and the determination that the packaging or container is an authorized packaging and that it has been manufactured, assembled, and marked properly.

According to WID procedures, the Transportation Engineer and the generator determine who will perform the packaging and where the packaging will be performed. Personnel packaging hazardous materials must be familiar with the packaging requirements for these materials, commensurate with the complexity of the packaging and the degree, nature, and quantity of hazard. The Transportation Engineer prepares a written work instruction for the packaging of the material, if required. WID personnel package the hazardous material.

16.2.14 Definitions, Classification, and Packaging for Class 1 Materials, Subchapter C, 49 CFR 173.50-173.63

Definitions, classifications, and requirements for packaging of Class 1 materials (explosives) are described.

A WID procedure includes two worksheets (a shipment worksheet for ground transportation and one for air transportation) and a shipper's declaration of dangerous goods. A hazardous waste manifest or bill-of lading is used for ground transport. All actions that would be required for the classification and packaging of Class 1 materials are included in these worksheets. However, Class 1 materials are not used, packaged, or shipped from the WIPP; therefore, this section does not apply.

16.2.15 Definitions, Classification, Packaging Group Assignments, and Exceptions for Hazardous Materials other than Class 1 and Class 7, Subpart D, 49 CFR 173.115-173.156

Definitions, classifications, packing group assignments, and exceptions for hazardous materials, including flammable, non-flammable, poisonous and non-poisonous gases, flammable liquids and solids, and toxic material are specified.

A WID procedure includes two worksheets (a shipment worksheet for ground transportation and one for air transportation) and a shipper's declaration of dangerous goods. All actions required for the classification and packaging of hazardous materials other than Classes 1 and 7 are included in these worksheets.

16.2.16 Non-Bulk Packaging Requirements for Hazardous Materials other than Class 1 and Class 7, Subpart E, 49 CFR 173.158-173.230

Non-bulk packaging requirements for hazardous materials other than Class 1 and Class 7 materials are described. Specific requirements are described in 49 CFR 173.158 through 173.198 for nitric acid; wet batteries; corrosive non-explosive smoke bombs; chemical kits; gallium; hydrogen fluoride; mercury; smokeless powder for small arms; aircraft hydraulic power unit fuel tanks; paint, paint-related material, adhesives, and ink; refrigerating machines; liquid pyrophoric materials; barium azide; nitrocellulose-based film; highway or rail fuses; lithium batteries and cells; matches; pyrophoric solids, metals, or alloys; white or

yellow phosphorus; certain Group 1 poisonous materials; mixtures of bromoacetone, methyl bromide, chloropicrin, and methyl chloride or of chloropicrin and methyl chloride or of chloropicrin and compressed gas; hydrogen cyanide; infectious substances; and nickel carbonyl.

A WID procedure indicates that the Transportation Engineer classifies the shipment with the information provided in the shipping request by completing the shipment worksheet. If required, the requestor and/or the Transportation Engineer obtain additional information to classify the shipment properly. The Transportation Engineer determines the packaging requirements.

16.2.17 Radioactive Materials, Subpart I, 49 CFR 173.401-173.478

This subpart sets forth requirements for the transportation of radioactive materials by carriers and shippers and includes requirements for package design, package testing, empty radioactive materials packaging, and NRC-approved packages.

A WID procedure identifies both general and specific requirements to be implemented at WIPP. Other procedures provide instructions for shipping empty TRUPACT-II containers from WIPP by truck and for shipping radioactive materials to WIPP from the generator sites. The procedures also show how packaging requirements are determined, including verification that the quantity and form of material to be shipped meet the requirements of the Certificate of Compliance and/or tested parameters of the intended package.

More detail is specified in Chapter 15 under the NRC's regulations implementing transportation requirements under the Atomic Energy Act.

16.2.18 Carriage by Aircraft, 49 CFR Part 175

This part describes requirements that must be observed with respect to the transportation of hazardous materials in air craft. Included are provisions relating to unacceptable hazardous materials shipments; acceptance and inspection of shipments; discrepancy reports; notification of the pilot in command; shipping papers; keeping and replacement of labels; reporting hazardous materials incidents; quantity limitation; orientation, securing, and location of cargo containing hazardous materials; compatibility of packages; damaged shipments; and specific regulations applicable according to the classification of the material, including special

limitations and requirements for Class 7 (i.e., radioactive) materials.

A WID procedure provides guidance for shipping hazardous materials by air. Hazardous materials shipped from WIPP are in accordance with the International Air Transport Association (IATA).

The transportation options studied in the Comparative Transportation Alternatives Study did not consider transportation of TRU wastes to WIPP by air.

16.2.19 Training Responsibilities and Requirements for Class 7 (Radioactive) Materials, 49 CFR 177.800, 177.816, and 177.825

These sections set forth requirements for training, including the following: a carrier may not transport or cause to be transported hazardous material by motor vehicle unless each of its hazmat employees has received the appropriate specialized training. Each of the carrier's hazmat employees must have the appropriate State-issued commercial driver's license with the proper endorsement and must have in his/her immediate possession a certificate of training that includes a proper statement of authentication.

All transportation of radioactive or mixed waste will be contracted to a local carrier. The carrier's employees have been properly trained, and their records include all certification information. The carrier's drivers all possess a commercial driver's license with either a tank vehicle or hazardous material endorsement, and each is trained and certified to transport highway route-controlled-quantity radioactive materials. Each driver has a properly authenticated training certificate in his/her possession.

16.2.20 Specifications for Packagings, 49 CFR Part 178

This part contains prescribed manufacturing and testing specifications and inspection requirements for packaging and for containers used for the transportation of hazardous materials.

WIPP quality assurance procedures define the methodology by which specified criteria are verified. The TRUPACT-II container has been developed to transport contact-handled TRU waste to WIPP from the generator sites. The specifications for this packaging and conditions of the Certificate of Compliance granted by the NRC are described in more detail in Chapter 15. All the hazardous material shipped from WIPP is packaged in performance-oriented packaging in accordance with 49 CFR and United Nations packing standards and regulations.

17.0 MATERIALS ACT OF 1947

17.1 Summary of the Law

The Materials Act of 1947 (30 USC §§ 601 et seq.) establishes policy that directs the Bureau of Land Management (BLM) of the U.S. Department of the Interior (DOI) to prescribe rules and regulations for the disposal of mineral material resources (including, but not limited to, sand, stone, gravel, pumice, cinders, and clay) on public lands under the BLM's jurisdiction at fair market value while ensuring that adequate measures are taken to protect the environment and to minimize damage to public health and safety during the authorized removal of such minerals. Under the act, no mineral material shall be disposed of if the Secretary of the Interior determines that the aggregate damage to public lands and resources would exceed the benefits to be derived from the proposed sale or free use of the material.

The policy of the Materials Act of 1947 is addressed in the 1992 Waste Isolation Pilot Plant Land Withdrawal Act (LWA). In the LWA, the DOE was given statutory authority and responsibility for the management of the withdrawn land at WIPP consistent with the Materials Act of 1947 and other applicable laws such as the Federal Land Policy and Management Act and the Public Rangelands Improvement Act (see Chapters 18 and 19, respectively). Furthermore, the LWA directs the DOE to produce a WIPP land management plan to provide for the disposal of salt tailings subject to the Materials Act of 1947 and the act's implementing regulations.

The regulations in 43 CFR Part 3600, *Mineral Materials Disposal: General*, implement the Materials Act of 1947 and establish procedures for the exploration, development, and disposal of mineral material resources as well as for the protection of the environment of the public lands under permit or contract for sale or free use. These regulations are applicable to the WIPP because of the need to dispose of excess salt tailings extracted from the withdrawal area.

17.2 Compliance Status of the Regulatory Requirement

Table 17-1 summarizes the single applicable requirement and its compliance status under the Materials Act of 1947. The text provides more detail on the compliance status of the requirement.

TABLE 17-1. Materials Act of 1947 - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
43 CFR Part 3600, *Mineral Materials Disposal: General*		
43 CFR 3601.1-3	Protection of environment: disposal of salt tailings	UP TO DATE Addressed in the *WIPP Land Management Plan* [Section 17.2.1]

17.2.1 Environmental Protection During Disposal of Mineral Material, 43 CFR 3601.1-3

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Authorized land managers must take steps to prevent unnecessary or undue environmental degradation resulting from mineral material disposal operations.

Salt from the underground mining operations at WIPP is brought to the surface and stored in the salt pile just north of the surface facilities. This salt storage pile has the capacity to store the 2 million tons of material projected to be excavated during the lifetime of the WIPP project. There is also an inactive salt storage pile at WIPP. This salt pile is a result of the Site and Preliminary Design Validation (SPDV) phase.

According to the planned actions addressed in the *WIPP Land Management Plan* (DOE, 1993c), salt tailings extracted from the withdrawal area that are not needed for backfill at WIPP will be disposed of in accordance with the requirements of §§ 2 and 3 of the Materials Act of 1947. These requirements specify that if the appraised value of the salt exceeds $1,000, disposal will be performed by the highest responsible qualified bidder by competitive bidding and publication of notice of the proposed disposal as described in § 2 of the Materials Act. If the appraised value of the salt is $1,000 or less, it may be disposed of at the discretion of the Secretary. Any money received from the disposal of the salt will be disposed of in the same manner as money received from the sale of public lands (Materials Act, § 3).

18.0 FEDERAL LAND POLICY AND MANAGEMENT ACT

18.1 Summary of the Law

One of the objectives of the Federal Land Policy and Management Act (FLPMA; 43 USC §§ 1701-1782) is to ensure that

> ". . . public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use."

Title II under FLPMA, *Land Use Planning; Land Acquisition and Disposition*, directs the Secretary of the Interior to prepare and maintain an inventory of all public lands and to develop and maintain, with public involvement, land-use plans regardless of whether subject public lands have been classified as withdrawn, set aside, or otherwise designated. Under Title V, *Rights-of-Way*, the Secretary of the Interior is authorized to grant, issue, or renew rights-of-way over, upon, under, or through public lands.

The policy and commitment of the FLPMA are addressed in the 1992 Waste Isolation Pilot Plant Land Withdrawal Act (LWA). The LWA gave the DOE statutory authority and responsibility for the management of the withdrawn land consistent with FLPMA and other applicable laws such as the Public Rangelands Improvement Act and the Taylor Grazing Act (see also Chapters 19 and 20, respectively). Furthermore, the LWA directed the DOE to produce a WIPP land-management plan to provide for grazing, hunting and trapping, wildlife habitat, the disposal of salt tailings, and mining, subject to the applicable implementing regulations of FLPMA.

A process was established in the implementing regulations of 43 CFR Part 1600, *Planning, Programming, Budgeting*, for the development, approval, maintenance, amendment, and revision of resource management plans for public lands administered by the Bureau of Land Management (BLM). This part states that the objective of resource management planning is to guide and control future management actions and the development of subsequent more detailed and limited scope plans for resources and uses consistent with the principles of Title II of FLPMA. The DOE must develop and maintain a land management plan consistent with the processes and requirements for resource management plans as described in these regulations.

Other regulations implementing FLPMA established procedures for the orderly and timely processing of applications, grants, permits, amendments, assignments, and terminations for rights-of-way and permits over, upon, under, or through public lands. In particular, 43 CFR Part 2800, *Rights-of-Way, Principles and Procedures*, provides guidelines for the use of right-of-way and temporary-use permit areas and establishes requirements for the submission and

processing of right-of-way grant/reservation and temporary-use permit applications. These regulations remain applicable to the WIPP because of the necessity to establish rights-of-way for the construction and phased operation of this facility.

18.2 Compliance Status of the Regulatory Requirements

Table 18-1 summarizes each applicable requirement and its compliance status under FLPMA. The text provides more detail on the compliance status of each requirement.

TABLE 18-1. Federal Land Policy and Management Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
43 CFR Part 1600, *Planning, Programming, Budgeting*		
43 CFR 1610.1	Resource management planning guidance	**ACHIEVED** *WIPP Land Management Plan* [Section 18.2.1]
43 CFR 1610.2	Public participation	**ACHIEVED** Public review of *WIPP Land Management Plan*, 30 days [Section 18.2.2]
43 CFR 1610.3-2	Consistency of management plan with applicable laws	**ACHIEVED** *WIPP Land Management Plan* [Section 18.2.3]

TABLE 18-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
43 CFR Part 2800, *Rights-of-Way, Principles and Procedures*		
43 CFR 2801.2(a)	Common terms and conditions of right-of-way reservations and temporary-use permits: • Compliance with regulations • Non-discrimination • Repair of roads, fences, trails • Fire prevention and suppression	**ACHIEVED** Compliance status in BECR; non-discrimination policy; repairs as needed; fire-fighting equipment, personnel, and agreement [Section 18.2.4]
43 CFR 2801.2(b)	Mandatory conditions for right-of-way reservations and temporary-use permits: • Restoration • Air- and water-quality standards • Scenic, cultural, and environmental values • Local inhabitants • State standards that are more stringent than the Federal ones	**UP TO DATE** *Final Environmental Impact Statement* (FEIS); *WIPP Land Management Plan*; *Final Supplement Environmental Impact Statement* (SEIS) and SEIS for disposal; no local inhabitants who rely on biota of the area for subsistence; operation and maintenance in accordance with reservations (see Section 18.3); and permit conditions met (see other chapters in BECR) [Section 18.2.5]
43 CFR 2802.2	Application requirements for a right-of-way reservation or temporary-use permit	**ACHIEVED** Several reservations and permits obtained (see Sections 18.3 and 35.3) [Section 18.2.6]

18.2.1 Resource Management Planning Guidance, 43 CFR 1610.1

Guidance in preparing resource management plans may be provided to the District and Area BLM Managers by the Director and State Director of the BLM.

Since the land that is the subject of the *Waste Isolation Pilot Plant (WIPP) Land Management Plan* (DOE, 1993c) was transferred to the DOE, the plan was prepared by Westinghouse Waste Isolation Division (WID) personnel at the request of the DOE. However, considerable input to the plan was obtained from BLM personnel, particularly from the BLM office in Carlsbad. Therefore, the *WIPP Land Management Plan* represents a joint effort between BLM and WID personnel. The plan parallels the general guidelines used in the development of BLM's Area Resource-Management Plan.

18.2.2 Public Participation, 43 CFR 1610.2

The public shall be provided an opportunity to review and comment on land management plans.

Public meetings were held in Carlsbad and Hobbs, New Mexico, and members of the public were given 30 days to review and comment on the *WIPP Land Management Plan*. A copy of the draft plan was also sent to the State Land Office, the Environmental Evaluation Group (EEG), and the New Mexico Environment Department (NMED) for their review. The comments obtained were incorporated as appropriate into the final document.

18.2.3 Consistency of Management Plans, 43 CFR 1610.3-2

Land-use plans shall be consistent with the purposes, policies, and programs of Federal laws and regulations that apply to public lands.

As a requirement of the LWA, the *WIPP Land Management Plan* was developed for the withdrawal area consistent with FLPMA. The plan was drafted by WID personnel in consultation with the BLM and the State of New Mexico and was submitted to Congress in October 1993. The development of this plan parallels the general guidelines used in formulating the BLM's Area Resource-Management Plan.

18.2.4 Common Terms and Conditions of Right-of-Way Reservations and Temporary-Use Permits, 43 CFR 2801.2(a)

By accepting a right-of-way reservation or a temporary-use permit, the applicant agrees and consents to comply with the following terms and conditions in addition to those terms and conditions that are specified in the reservation(s) or permit(s). The common terms and conditions are:

- *To comply with all applicable State and Federal laws and the implementing regulations to the extent practicable;*
- *To protect employees and applicants for employment who will be or are involved in the construction, operation, maintenance, and termination of the authorized use against discrimination because of race, creed, color, sex, or national origin and to ensure that all subcontracts include an identical provision;*
- *To rebuild and repair roads, fences, and established trails that may be destroyed or damaged by the construction, operation, or maintenance of the project and to build and maintain suitable crossings for existing roads and significant trails that intersect the project; and*
- *To prevent and suppress fires on or in the immediate vicinity of the right-of-way areas.*

Compliance with all applicable State and Federal laws and their implementing regulations is discussed throughout this document. See the specific regulations and the compliance status section of each for more detailed information.

The DOE and its contractors have a non-discrimination policy in effect for their employees and for hiring. In addition, contracts and subcontracts awarded by the DOE and by its contractors include such a non-discrimination clause.

Any roads, fences, or established trails destroyed or damaged by the construction, operation, or maintenance of any of the structures for which WIPP has received a right-of-way reservation or temporary-use permit are repaired as required.

WIPP maintains fire-fighting equipment. Some of the WIPP emergency response personnel are trained in fire-fighting methods. WIPP also has an agreement with the Carlsbad Fire Department to provide fire-fighting service if necessary.

18.2.5 Conditions to be Incorporated within all Right-of-Way Reservations and Temporary-Use Permits, 43 CFR 2801.2(b)

All right-of-way reservations and temporary-use permits must contain requirements to ensure:

- *Restoration, revegetation, and curtailment of land erosion;*
- *Compliance with applicable air- and water-quality standards;*
- *Protection of scenic, aesthetic, cultural, and environmental values as well as Federal property and public health and safety;*
- *Protection of the interests of local inhabitants who rely on the fish, wildlife, and biota of the area for subsistence;*
- *Maintenance and operation of facilities on the prescribed location in a manner that is consistent with the reservation or permit; and*
- *Compliance with any State standards for public health and safety; environmental protection; and siting, construction, operation, and maintenance that are more stringent than the Federal standards.*

Each area that is the subject of a right-of-way reservation will be reclaimed and revegetated as described in the *WIPP Land Management Plan*.

Compliance with applicable air- and water-quality standards is discussed in Chapters 6 through 8, 29, and 30 of this report. See these chapters for more specific information pertaining to the air- and water-quality standards.

Protection of scenic, aesthetic, cultural, and environmental values was addressed in the *WIPP Final Environmental Impact Statement* (FEIS) (DOE, 1980) and in the *Supplement Environmental*

Impact Statement (SEIS) (DOE, 1990a). A second SEIS will be prepared prior to the initiation of disposal of TRU waste at WIPP; any changes in these values or in the potential impact of WIPP operations on these values will be addressed in this document.

The people who live in the vicinity of WIPP are ranchers. There are no local inhabitants who rely on fish, wildlife, or other biota of the area for subsistence. Therefore, this condition does not apply to WIPP.

Each "facility" (road, pipeline, railroad, etc.) is maintained and operated in accordance with the stipulations provided in the respective right-of-way reservation. See Section 18.3 for more specific information.

State standards or permit conditions imposed by the State are being met. For example, see Section 29.3 on the air-quality permit issued to WIPP by the NMED.

18.2.6 Requirements for Applications for Right-of-Way Reservations and Temporary-Use Permits, 43 CFR 2802.2

Parties seeking a right-of-way reservation or temporary-use permit involving the use of public lands shall file an application for the reservation or permit with either the Area Manager, the District Manager, or the State Director having jurisdiction over the affected public lands.

To date, several right-of-way reservations and land-use permits have been granted to the DOE. These reservations and permits are listed below.

Right-of-way Reservation No. NM 53809 for a water pipeline was granted on August 17, 1983, and is still active. There is no expiration date. (See Section 18.3.2.)

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Right-of-way Reservation No. NM 55676 for the north access road at WIPP was granted on August 24, 1983, and is still active. There is no expiration date. (See Section 18.3.3.)

Right-of-way Reservation No. NM 55699 for the railroad spur at WIPP was granted on September 27, 1983, and is still active. There is no expiration date. (See Section 18.3.4.)

Right-of-way Reservation No. NM 63136 for dosimetry and aerosol sampling sites was granted on July 31, 1986, and is still active. There is no expiration date. (See Section 18.3.5.)

Right-of-way Reservation No. NM 65801 for seven subsidence monuments was granted on November 7, 1986, and is still active. There is no expiration date. (See Section 18.3.6.)

Right-of-way Reservation No. NM 82245 for the installation of a survey monument was granted on December 13, 1989, and is still active. The permit expires on December 13, 2019. (See Section 18.3.7.)

Right-of-way Reservation No. NM 77921 for an aerosol sampling site was granted on August 18, 1989, and is still active. The permit will expire on August 18, 2019. (See Section 18.3.8.)

Free-Use Caliche Permit No. NM-FU-91183 was renewed on August 18, 1993, and is still active. The permit expires on August 18, 1994. (See Section 18.3.9.)

A right-of-way permit for a high-volume air sampler has also been issued to WIPP. Because this permit was issued by the New Mexico Commissioner of Public Lands, it is discussed in more detail in Section 35.3.

18.3 Compliance Status of the Permit Conditions

Table 18-2 summarizes the conditions in the right-of-way reservations and the temporary-use permit awarded to WIPP by the BLM. The table also includes the compliance status. The text provides more detail on the compliance status of each reservation or permit condition.

TABLE 18-2. Federal Land Policy and Management Act - Summary of Permit Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
Common Conditions (CC) of Right-of-Way Reservations		

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
CC 1	Control and jurisdiction of DOE	**ACHIEVED** DOE jurisdiction and control [Section 18.3.1]
CC 2	Right of access and use	**ACHIEVED** DOE and BLM and authorized personnel [Section 18.3.1]
CC 3	Products or resources on lands within the right-of-way	**NOT APPLICABLE** Superseded by WIPP Land Withdrawal Act [Section 18.3.1]
CC 4	Compliance with 43 CFR Part 2800	See Sections 18.2.4 through 18.2.6 [Section 18.3.1]
CC 5	BLM seeding requirements for BLM Roswell District	**UP TO DATE** Sites prioritized for reclamation and reseeding [Section 18.3.1]
Right-of-Way Reservation No. NM 53809, *Water Pipeline*		
Sec. 13; Standard Stipulations (SS) 1, 2, 5, 6, 8	Preconstruction and construction conditions	**ACHIEVED** Notification and construction activities [Section 18.3.2.1]

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Sec. 13E	Water access for livestock	**ACHIEVED** Water tap on pipeline installed [Section 18.3.2.2]
SS 3	Road construction	**ACHIEVED** Only essential roads; traffic confined to authorized right of way [Section 18.3.2.3]
SS 4	Posting of BLM number	**ACHIEVED** BLM No. NM 53809 posted [Section 18.3.2.4]
SS 7	Gates or cattleguards on public lands	**UP TO DATE** Gates and cattleguards on public lands not locked [Section 18.3.2.5]
Right-of-Way Reservation No. NM 55676, *North Access Road*		
SS 2	Polychlorinated biphenyls (PCBs)	**NOT APPLICABLE** All PCB-containing fluids and equipment removed from WIPP; no known PCB spills at WIPP [Section 18.3.3.1]
SS 3-5	SS for the construction of overhead electric distribution lines	**ACHIEVED** All stipulations met [Section 18.3.3.2]

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
SS 6	Posting of BLM serial number	**ACHIEVED** BLM No. NM 55676 posted [Section 18.3.3.3]
Term/Condition (T/C) 7	Damage or injury to private property	**UP TO DATE** Personal responsibility of DOE and DOE contractor employees [Section 18.3.3.4]
T/C 7 and 8	Actions required upon abandonment, relinquishment, or expiration of right-of-way reservation	**NOT APPLICABLE** Right-of-way reservation active [Section 18.3.3.5]
Amendment (April 22, 1988)	Fencing	**ACHIEVED** Fencing standards met [Section 18.3.3.6]
Right-of-Way Reservation No. NM 55699, *Access Railroad*		
SS 1-4, 7, 9, 11	Preconstruction and construction requirements for railroad spur	**ACHIEVED** Agreement among BLM, DOE, and Corps of Engineers [Section 18.3.4.1]
SS 5	Reseeding upon completion of construction	**ACHIEVED** BLM seeding requirements for Roswell District [Section 18.3.4.2]

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
SS 6	Abandonment of the site	NOT APPLICABLE Site not abandoned [Section 18.3.4.3]
SS 8	Responsibility for damage or injury to private property	See Section 18.3.3.4 [Section 18.3.4.4]
SS 10	Access to water for livestock	ACHIEVED Water taps and related equipment provided by DOE [Section 18.3.4.5]
SS 12	Removal of caliche and/or other mineral material	ACHIEVED Free-use caliche permit in effect (see Section 18.3.9) [Section 18.3.4.6]
SS 13 W	Application for free-use permits	ACHIEVED Free-use permit application filed; permit granted by BLM (see also Section 18.3.9) [Section 18.3.4.7]
Amendment	Notification of BLM regarding the access road parallel to the railroad	ACHIEVED BLM notified [Section 18.3.4.8]
Right-of-Way Reservation No. NM 63136, *Dosimetry and Aerosol Sampling Sites*		

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Attachment A	Establishment of dosimeter stations and air samplers	**ACHIEVED** Aerosol samplers installed; operated and maintained by WID personnel [Section 18.3.5.1]
Amendment	Air monitoring and data collection site	**ACHIEVED** Trailer, tower, and instruments installed as agreed [Section 18.3.5.2]
Right-of-Way Reservation No. NM 65801, *Seven Subsidence Monuments*		
Right-of-way reservation	No unique conditions	See Section 18.3.1 [Section 18.3.6]
Right-of-Way Reservation No. NM 82245 for Two Subsidence Monuments		
#1	Construction and maintenance of the monuments	**ACHIEVED** Installed as described in application [Section 18.3.7.1]
#3	Security and maintenance of the monuments	**UP TO DATE** DOE responsible for security; WID maintains monuments [Section 18.3.7.2]
#5	Rehabilitation of the land	**NOT APPLICABLE** Right-of-way active [Section 18.3.7.3]

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Right-of-Way Reservation No. NM 77921, *Aerosol Sampling Site*		
#1	Construction, operation, and maintenance	**ACHIEVED** Constructed, operated, and maintained as described in application [Section 18.3.8.1]
#3	Security and operation of aerosol sampling station	**UP TO DATE** DOE responsible for security; WID operates and maintains station [Section 18.3.8.2]
#5	Rehabilitation of the land occupied by the aerosol sampling station	**NOT APPLICABLE** See Section 18.3.7.3 [Section 18.3.8.3]
Letter from El Paso Natural Gas Company	Use of the abandoned concrete slab	**ACHIEVED** Discussions with El Paso Natural Gas Company personnel [Section 18.3.8.4]
Free-Use Permit No. NM-FU3-91183 for Use of Caliche		
Approval of request to mine 35,000 cubic yards of caliche	Withdrawal of caliche	**UP TO DATE** WIPP still removing allotted caliche [Section 18.3.9.1]

TABLE 18-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Attachment 2, Reclamation	Reclamation of caliche borrow pit	NOT APPLICABLE Withdrawal area to be recontoured to a slope of 3:1 [Section 18.3.9.2]

18.3.1 Common Conditions of the Right-of-Way Reservations

Several conditions are common to all the right-of-way reservations awarded to WIPP by the BLM. These common conditions are:

(1) That the subject of the reservation be under the control and jurisdiction of the DOE;

(2) That right of access and use is reserved to DOE personnel and those authorized by DOE and to BLM personnel and their authorized permittees, licensees, and leasees;

(3) That any products or resources on lands within the right-of-way remain under the jurisdiction of the issuing agency;

(4) That all applicable regulations under 43 CFR Part 2800 be followed; and

(5) That the BLM seeding requirements for the Roswell district be met.

The subjects of each of the right-of-way reservations are under the control and jurisdiction of the DOE. Right of access and use of these structures is reserved to the DOE and the BLM and their authorized personnel.

In October 1992, the WIPP LWA was passed. This legislation transferred WIPP lands from the U. S. Department of the Interior to the DOE. These lands were also withdrawn from all forms of entry, appropriation, and disposal under the public land laws, including the mineral leasing laws.

The applicable portions of 43 CFR Part 2800 and the compliance status of each are described in Sections 18.2.4 through 18.2.6. They are also summarized in Table 18-1.

Reclamation of disturbed areas is an ongoing project at WIPP and is performed as described in the *WIPP Land Management Plan* (DOE, 1993c). Seeding is conducted in accordance with the requirements for the BLM Roswell district.

18.3.2 Right-of-Way Reservation No. NM 53809, Water Pipeline

The conditions specified for the water-pipeline right-of-way reservation are described in Section 18.3.2, along with the compliance status of each condition. Since the pipeline was built approximately 10 years ago, the conditions required for its construction are not discussed individually.

The reservation was awarded on August 17, 1983, and extends to perpetuity.

18.3.2.1 Pre-Construction and Construction Conditions for the Water Pipeline, Section 13 and SS Nos. 1, 2, 5, 6, 8

Pre-construction notification and conditions for construction (e.g., minimization of blading and clearing of vegetation; protection of scenic values; permits; livestock barriers) were specified in the right-of-way reservation and in the Standard Stipulations for Pipeline and Underground Cable Rights of Way in the Roswell District, BLM.

All conditions were met when the water pipeline was constructed.

18.3.2.2 Livestock Water, Section 13.E

The DOE has agreed to provide water access (taps) off the waterline for livestock in the area. The DOE will also provide water meters and all necessary materials, equipment, and labor to install new water troughs in the four sections specified.

The DOE installed a water tap on the water pipeline for use by ranchers. The tap is located 0.6 mile south of the intersection of the DOE north access road (NAR) and Highway 62/180.

18.3.2.3 Road Construction, SS No. 3

Roads will not be constructed where terrain features allow vehicles to maneuver without the aid of such construction. All vehicular traffic and construction activities will be confined to the authorized right-of-way.

No roads have been constructed where the terrain allows vehicles to maneuver adequately. All traffic is confined to the authorized right-of-way.

18.3.2.4 Posting of the BLM Number Assigned to This Right-of-Way, SS No. 4

The grantee will post the BLM serial number assigned to this right-of-way in a conspicuous place where the right-of-way intersects existing roads or highways. If the right-of-way parallels existing roads, the BLM number will be posted where the right-of-way first crosses the public lands and where it leaves the public lands.

The BLM number assigned to this right-of-way (i.e., NM 53809) is posted as required.

18.3.2.5 Gates or Cattleguards on Public Lands, SS No. 7

Gates or cattleguards on public lands will not be locked or closed to the public.

Gates and cattleguards on public lands are not locked and remain open to the public.

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18.3.3 Right-of-Way Reservation No. NM 55676, North Access Road

The conditions specified for the NAR right-of-way reservation are described in this section, along with the compliance status of each condition. Since the road was built approximately 10 years ago, the conditions required for its construction are not discussed individually.

This reservation was awarded on August 24, 1983, and extends to perpetuity.

18.3.3.1 Polychlorinated Biphenyls (PCBs), SS No. 2

Any PCBs shall be used in a totally enclosed manner in accordance with the provisions of the Toxic Substances Control Act. Any release of PCBs in excess of the reportable quantity shall be reported as required under the Comprehensive Environmental Response, Compensation, and Liability Act, with a copy of any report required by the Federal or State agency being provided to the Authorized Officer within 5 working days of the occurrence of the spill or release.

As described in Chapter 9, all PCB-containing equipment and fluids have been removed from the WIPP site and have been disposed of in accordance with the regulations. No PCBs are allowed on site. No release or spill of PCBs or PCB-containing fluids is known to have ever occurred at WIPP. Therefore, these conditions do not apply at WIPP.

18.3.3.2 Standard Stipulations for the Construction of Overhead Electric Distribution Lines, SS Nos. 3-5

Upon DOE's request, BLM authorized the DOE to install an auxiliary electrical line and 10-13 poles along the right-of-way for the NAR. This authorization was accompanied by standard stipulations for overhead electrical distribution lines in the Roswell District. The standard stipulations for the construction of power lines included a prohibition of clearing or blading of the right-of-way unless agreed to in writing by the Authorized Officer, construction of the power lines to ensure the safety of raptors, and minimization of damage to existing fences and other improvements on public lands.

All stipulations for the construction of power lines were met.

18.3.3.3 Posting of BLM Serial Number, SS No. 6

The BLM serial number assigned to this authorization (i.e., NM 55676) shall be posted in a permanent, conspicuous manner where the power line crosses roads and at all serviced facilities. Numbers must be at least 2 inches high and will be affixed to the pole nearest the road crossing and at the facilities served.

The BLM Serial Number (NM 55676) is posted as required.

18.3.3.4 Damage or Injury to Private Property, Term/Condition No. 7

The DOE and/or its authorized agents will be responsible for any damage or injury to private property, including livestock, and will financially reimburse the allottee for any such loss in accordance with applicable law.

In the event that the vehicle of an employee of the DOE or a DOE contractor injures or kills livestock near the WIPP site or causes other damage to private property, that employee is responsible for reimbursing the owner of the livestock or property.

18.3.3.5 Actions Required Upon Abandonment, Relinquishment, or Expiration of Right-of-Way Reservation, Terms/Conditions, Nos. 7 and 8

Upon cancellation, relinquishment, or expiration of the reservation, the holder of the reservation will comply with those abandonment procedures prescribed by the BLM Authorized Officer. All surface structures (poles, lines, transformers, etc.) will be removed within 180 days of abandonment, relinquishment, or termination of use of the reservation or of the use of the serviced facility or facilities. This will not apply where the power line extends service to an active adjoining facility or facilities.

These conditions will be met upon termination of the reservation or abandonment of the site by the DOE.

18.3.3.6 Fencing, Amendment (April 22, 1988)

The DOE requested that it be allowed to install fencing on the east and west sides of the WIPP NAR for a distance of 12.125 miles to allow for a safe travel route when entering or leaving the site via Highway 62/180. The BLM allowed this installation, subject to the BLM fencing standards.

The BLM fencing standards were met in installing the fence along the NAR.

18.3.4 Right-of-Way Reservation No. NM 55699, Railroad

The conditions specified for the railroad right-of-way reservation are described in this section, along with the compliance status of each condition. Since the railroad spur at WIPP was constructed a number of years ago, the conditions pertaining to the construction of the spur are not discussed individually.

This right-of-way reservation was awarded on September 27, 1983, and extends to perpetuity.

18.3.4.1 Preconstruction and Construction Requirements for the Railroad Spur, SS Nos. 1-4, 7-9, and 11

The preconstruction and construction conditions for the railroad spur were listed in the "Special Stipulation for WIPP Railroad Access." These conditions include preconstruction notification and a prework conference, notification of any anticipated changes, notification of grazing permittees or lessees prior to entering public lands on grazing allotments, barriers and fences for livestock, road or stock trail crossings, mitigation of cultural resources, and installation of fences.

Agreement was reached among members of the BLM, the DOE, and the Army Corps of Engineers with respect to the DOE's meeting all preconstruction and construction requirements.

18.3.4.2 Reseeding Upon Completion of Construction, SS No. 5

The right-of-way must be reseeded upon completion of railroad construction according to BLM seeding requirements for the Roswell District.

The right-of-way was reseeded upon completion of railroad construction in accordance with the BLM seeding requirements for the Roswell District.

18.3.4.3 Abandonment of the Site, SS No. 6

If the WIPP is abandoned for any reason, the railroad bed will be ripped and returned as much as possible to its original terrain. The area will be reseeded as discussed in Section 18.3.4.2.

If the site is abandoned, these actions will be conducted. Until such time, these conditions are not applicable.

18.3.4.4 Responsibility for Damage or Injury to Private Property, SS No. 8

See Section 18.3.3.4.

18.3.4.5 Access to Water for Livestock, SS No. 10

The DOE will provide a water tap and a livestock watering facility in one section, a livestock drinker and related pipeline in a second section, and a water pipeline to tie into an existing water tub in a third. This action is separate and apart from the railroad reservation and will be implemented after completion of the Cooperative Agreement among the DOE, the BLM, and the rancher.

Water taps and related equipment have been provided by the DOE. See also Section 18.3.2.2.

18.3.4.6 Removal of Caliche and/or other Mineral Material, SS No. 12

The grantee and its subcontractor will remove caliche and/or other mineral material from BLM-approved sites only. The DOE will submit a pit development and rehabilitation plan to the BLM for its approval before removing any caliche.

An application for a free-use caliche permit was submitted to the BLM by the DOE. The permit was awarded by the BLM (see also Section 18.3.9).

18.3.4.7 Application for Free-Use Permits, SS No. 13

The DOE will sign applications for BLM free-use permits for the borrowing of caliche, sand, gravel, and other construction materials in quantities that may be reasonably required for this project. WIPP contractors will be responsible for locating the source; obtaining, completing, and processing the applications; and complying with all BLM requirements.

The DOE submitted an application to the BLM for a free-use permit for caliche. The permit was granted by the BLM. (See also Section 18.3.9.)

18.3.4.8 Notification of the BLM Regarding the Access Road Parallel to the Railroad, Amendment

An access road parallel to the railroad was deemed necessary. Since the existing access road, constructed in conjunction with the railroad, is located within 75 feet of the railroad centerline (i.e., within the railroad right-of-way), no new right-of-way was required. However, notification to the BLM was needed.

The BLM was notified as specified.

18.3.5 Right-of-Way Reservation No. NM 63136, Dosimetry and Aerosol Sampling Sites

The conditions specified for the right-of-way reservation for the aerosol sampling site are described in this section, along with the compliance status of each condition. The reservation was awarded on July 31, 1986, and amended in August 1988. The reservation is to remain in effect for 25 years (i.e., until July 31, 2011).

18.3.5.1 Establishment of Dosimeter Stations and Air Samplers, Attachment A

The reservation allowed the installation of 21 thermoluminescent dosimeters (TLDs) and four aerosol sampling stations at 20 and two locations, respectively. The DOE and its operating contractor are technically and financially responsible for the installation, maintenance, and operation of these monitoring systems.

Air samplers have been installed. WID personnel operate and maintain the monitoring system. The environmental dosimetry program that used the TLDs was discontinued in 1990 on the basis of two studies performed, one internally, the other by University of Michigan personnel for the Environmental Evaluation Group (EEG). Both studies concluded that the environmental dosimetry program could be discontinued because it measures gamma or x-ray radiation rather than alpha radiation, such as that emitted by TRU material, and because it is much less sensitive than other sampling programs used at WIPP.

18.3.5.2 Air Monitoring and Data Collection Site, Amendment

Right-of-way reservation No. 63136 was modified to allow an air monitoring and data collection site.

An instrumentation trailer (8 feet by 16 feet), a 10-meter-tall meteorological tower, and various environmental monitoring instruments were installed as agreed to between the DOE and the BLM. The installation required clearing an area of vegetation, constructing a concrete foundation for the trailer and tower, burying instrumentation wires, and constructing an access road. The 0.25-acre area was enclosed by a chain-link security fence as specified in the request to amend the right-of-way reservation.

18.3.6 Right-of-Way Reservation for Subsidence Monuments, No. NM 65801

No unique conditions were specified for the right-of-way reservation for seven geological subsidence monuments. Therefore, only the common conditions described in Section 18.3.1 apply and have been met.

The right-of-way reservation was awarded on November 7, 1986. It is to be held in perpetuity.

18.3.7 Right-of-Way Reservation for Two Subsidence Monuments, No. NM 82245

The conditions of the right-of-way reservation for two subsidence monuments are described in this section, along with the compliance status of each condition.

The reservation was granted on December 13, 1989. It has a 30-year term and is renewable.

18.3.7.1 Construction and Maintenance of the Monuments, #1

The monuments will be constructed and maintained in accordance with the details specified in the application submitted on December 4, 1989.

Two concrete survey monuments were installed on the right-of-way. The monuments are approximately 18 inches in diameter and 36 inches deep. Installation of the monuments was performed as described in the application.

18.3.7.2 Security and Maintenance of the Monuments, #3

The DOE is responsible for the security and maintenance of the monuments.

The DOE is responsible for the security of the monuments. WID maintains the monuments.

18.3.7.3 Rehabilitation of the Land, #5

Upon cancellation or termination of this reservation, the DOE will rehabilitate the land. All structures, improvements, debris, etc., will be removed. All disturbed surfaces will be reseeded in accordance with BLM specifications using Seed Mixture 2.

Upon cancellation or termination of this right-of-way reservation, the DOE will ensure that the land is rehabilitated as specified. All structures, improvements, and debris will be removed and all disturbed surfaces reseeded with pure live seed (Seed Mixture 2) containing no weeds as specified in the *BLM Seeding Requirements in the Roswell District*. Until the reservation is cancelled or terminated, these conditions are not applicable.

18.3.8 Right-of-Way Reservation for an Aerosol Sampling Site, No. NM 77921 (NM 77860)

The conditions for the right-of-way reservation for an aerosol sampling site are discussed in this section, along with the compliance status of each condition. Right-of-way reservation No. NM 77921 was granted on August 18, 1989. (It was originally granted as No. NM 77860, but the number was subsequently changed because it had already been issued.) The reservation was made for a 30-year term and is renewable.

18.3.8.1 Construction, Operation, and Maintenance, #1

The facility will be constructed, operated, and maintained in accordance with the details specified in the application submitted on July 31, 1989.

The application (dated July 13, 1989) specified that a 6-foot metallic stand would be positioned on an existing concrete pad, an electrical hookup would be made to an existing power line, and a chain-link security fence would be emplaced. It also indicated that the monitoring station

would be used throughout the life of the project and would be operated throughout each year of the project. These conditions have been met.

18.3.8.2 Security and Operation of the Aerosol Sampling Station, #3

The DOE will be responsible for the security and day-to-day operation of the facility.

The DOE is responsible for the security of the aerosol sampling station. WID personnel operate and maintain the station.

18.3.8.3 Rehabilitation of the Land Occupied by the Aerosol Sampling Station, #5

The conditions specified (and the response to the conditions) specified are identical to those described in Section 18.3.7.3. See this section for specific information pertaining to rehabilitation of the land upon cancellation or termination of a right-of-way reservation.

18.3.8.4 Use of the Abandoned Concrete Slab

A concrete slab was present at the location of the right-of-way land. The slab had been owned by the El Paso Natural Gas Company. WID personnel requested the use of the slab for radiation monitoring. El Paso Natural Gas Company personnel stated that the slab could be used if their personnel in Jal, New Mexico, were notified prior to initiating construction and if the BLM gave its consent.

Discussions were held with personnel from the El Paso Natural Gas Company. No additional conditions were specified, and notifications were made as requested by El Paso Natural Gas.

The BLM's issuance of this right-of-way reservation consists of its tacit approval of use of the concrete slab.

18.3.9 Caliche Free-Use Permit, NM-FU3-91183

The conditions specified under this permit are discussed in this section, along with the compliance status of each condition. The permit was renewed on August 18, 1993, and expires on August 18, 1994.

18.3.9.1 Withdrawal of Caliche

Under this permit, WIPP is entitled to withdraw 35,000 cubic yards of caliche.

The WIPP has not yet finished withdrawing the allotted 35,000 cubic yards of caliche from the borrow pit as allowed by the permit. It is anticipated that this activity will have been completed by the time the permit expires on August 18, 1994.

18.3.9.2 Reclamation of the Caliche Borrow Pit

Upon completion of its withdrawal of caliche from the caliche borrow pit, the DOE will perform reclamation and other closure activities, including reseeding, as specified under the permit.

WIPP and BLM personnel have agreed that the only closure activity to be performed by the DOE is to recontour the slope of the withdrawal area to a 3:1 slope. The reason for the other conditions being cancelled (e.g., reseeding the area) is that the pit is a community borrow pit; several other parties are removing caliche from the pit and will continue to do so past the expiration date of the WIPP caliche free-use permit.

19.0 PUBLIC RANGELANDS IMPROVEMENT ACT

19.1 Summary of the Law

Congress has recognized that vast segments of public rangelands produce less than their potential for livestock, wildlife habitat, recreation, forage, and water and soil conservation benefits. The 1978 Public Rangelands Improvement Act (43 USC §§ 1901 et seq.) was enacted to address the concerns that such rangelands could remain in such an unsatisfactory condition and that some areas could decline further under existing levels of management.

With the passage of this act, Congress reaffirmed a national policy and commitment to:

- Inventory and identify current public rangeland conditions and trends;
- Manage, maintain, and improve the condition of public rangelands so that they become as productive as is feasible; and
- Continue the policy of protecting wild free-roaming horses and burros while facilitating the removal and disposal of excess wild free-roaming horses and burros that pose a threat to themselves, their habitat, and other rangeland values.

This policy and commitment are echoed in other statutes that address public-land use and management. One such act, the Federal Land Policy and Management Act (FLPMA), directs the Secretary of the Interior to prepare and maintain an inventory of all public lands and to develop and maintain land-use plans with public involvement regardless of whether the public lands have been classified as withdrawn, set aside, or otherwise designated (see Chapter 18). Another statute, the Waste Isolation Pilot Plant Land Withdrawal Act (LWA), transferred jurisdiction over, and statutory authority and responsibility for, the management of the withdrawn lands at WIPP from the U.S. Department of the Interior to the DOE. Section 4 of the LWA, *Establishment of Management Responsibilities*, directs the DOE to conduct the management of grazing consistent with such laws as the Public Rangelands Improvement Act, the Taylor Grazing Act (Chapter 20), and other applicable laws such as Title IV, *Range Management*, of FLPMA (Chapter 18).

The implementing regulations under Subchapter D, *Range Management*, 43 CFR Part 4100, *Grazing Administration - Exclusive of Alaska*, provide uniform guidance for the administration of grazing on public lands. The objectives of these regulations include the following: orderly use, improvement, and development; enhancement of productivity by prevention of overgrazing and soil deterioration; and provision of inventory and categorization of public rangelands on the basis of range conditions and trends. The regulations specify that grazing on administered public lands must be managed in accordance with applicable land-use plans. These plans must set forth program constraints and the general management practices needed to achieve the management objectives.

19.2 Compliance Status of the Regulatory Requirement

Table 19-1 summarizes the applicable requirement and its compliance status under the Public Rangelands Improvement Act. The text discusses the compliance status of the requirement in more detail.

TABLE 19-1. Public Rangelands Improvement Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
43 CFR Part 4100, *Grazing Administration - Exclusive of Alaska*		
43 CFR 4100.0-8	Land-use plan, including grazing management	UP TO DATE Authorized range-management activities ongoing; *WIPP Land Management Plan.* [Section 19.2.1]

19.2.1 Management of Grazing Per Land-Use Plan, 43 CFR 4100.0-8

Grazing on administered public lands shall be managed under the principle of multiple use and sustained yield and must be in accordance with the applicable land-use plan.

As addressed in the *WIPP Land Management Plan* (DOE, 1993c), the DOE's intent is to continue current range-management practices with no immediate changes. Grazing will continue on the withdrawn lands as it has since the inception of the WIPP project. Range-management plans include (1) continued management of two affected grazing allotments under multiple-use management and sustained yield; (2) continued vegetative monitoring, which will include collecting data on actual livestock use, wildlife use, and degree of use of key forage species; and (3) continued monitoring studies to determine range condition and trends. In accordance with the *WIPP Land Management Plan*, the Bureau of Land Management (BLM) will administer all range management activities.

20.0 TAYLOR GRAZING ACT

20.1 Summary of the Law

Although the United States does not and cannot hold property for private or personal purposes, it controls public lands under constitutional grant, acting through Congress. Control over public lands is in the hands of Congress; with this power, Congress may prohibit or fix the terms under which public lands may be used.

The Taylor Grazing Act of 1934 (43 USC §§ 315 et seq.) was enacted by Congress for the purpose of establishing a means for Federal management of public lands used for grazing. The intent of Congress was to aid the livestock industry by defining grazing rights and to protect these rights by regulation. This act is intended to prohibit injury to public grazing lands from unregulated grazing and directs the orderly use of and improvement to public grazing lands by establishing grazing districts and a grazing permit system.

The Waste Isolation Pilot Plant Land Withdrawal Act of 1992 (LWA) withdrew public lands and transferred jurisdiction over WIPP site lands from the U.S. Department of the Interior (DOI) to the DOE. As a result of the LWA, the DOE was given statutory authority and responsibility for the management of the withdrawn land consistent with the Federal Land Policy and Management Act (see Chapter 18) and other applicable laws such as the Taylor Grazing Act. Under the LWA, the DOE may allow grazing to continue where it was established before the enactment of the LWA, consistent with the applicable implementing regulations of the Taylor Grazing Act such as 43 CFR Part 4100, *Grazing Administration - Exclusive of Alaska*, although the Bureau of Land Management (BLM) continues to administer the grazing-permit program and collects the grazing fee. The WIPP withdrawal area affects two grazing allotments (i. e., land designated and managed for the grazing of livestock).

The implementing regulations of 43 CFR Part 4100 provide uniform guidance for the administration of grazing on public lands exclusive of Alaska. The objectives of these regulations are as follows: orderly use, improvement, and development of public grazing lands; enhancement of grazing land productivity by the prevention of overgrazing and soil deterioration; stabilization of the livestock industry dependent upon the public range; and provision of inventory and categorization of public rangelands on the basis of range conditions and trends. These objectives must be consistent with land-use plans, multiple use, sustained yield, environmental values, and other general objectives as stated by the Taylor Grazing Act.

20.2 Compliance Status of the Regulatory Requirements

Table 20-1 summarizes the two applicable regulatory requirements and their compliance status under the Taylor Grazing Act. The text gives more detail on the compliance status of each requirement.

TABLE 20-1. Taylor Grazing Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
43 CFR Part 4100, *Grazing Administration*		
43 CFR 4100.0-8	Management of grazing lands under principles of multiple use and sustained yield and in accordance with applicable land-use plans	**UP TO DATE** Bureau of Land Management (BLM) authorized to manage ongoing grazing activities; *WIPP Land Management Plan* [Section 20.2.1; see also Section 19.2.1]
43 CFR 4120.2	Preparation of allotment management plan	**ACHIEVED** BLM authorized to manage land use for two allotments [Section 20.2.2]

20.2.1 Management of Grazing Lands, 43 CFR 4100.0-8

Grazing on public lands shall be managed under the principles of multiple use and sustained yield in accordance with applicable land-use plans.

In accordance with the *WIPP Land Management Plan* (DOE, 1993c), the BLM will ensure that range management activities are carried out under the authority of the Taylor Grazing Act of 1934, the Federal Land Policy and Management Act (FLPMA, Chapter 18), and the Public Rangelands Improvement Act (Chapter 19). The principles of multiple use and sustained yield are basic to the management of these activities. The DOE's intent is to continue current

management practices with no immediate changes in current operations. (See also Section 19.2.1.)

20.2.2 Allotment Management Plans, 43 CFR 4120.2

An allotment management plan shall be prepared in careful and considered consultation, cooperation, and coordination with BLM personnel, the landowners involved, the district grazing advisory board, and any other affected interests.

The WIPP withdrawal area affects two grazing allotments administered by the BLM: the Livingston Ridge and Antelope Ridge. Portions of both allotments lie within the withdrawal area. No formal grazing system has been implemented for the Livingston Ridge; however, a recent review by the BLM of actual-use data indicates that there is pasture rotation, with some pastures being rested for at least a portion of the growing season. The Antelope Ridge allotment is leased to a livestock rancher; in consultation with the BLM, an allotment management plan has been developed for this allotment. The plan includes a five-pasture rotation system, with some pastures being rested for full years and others receiving growing-season rest. WIPP is contained within an area of 300 acres within the Antelope Range allotment that is posted against trespass and fenced to prevent grazing. This 300-acre area is the only portion of the withdrawal area that is not currently used for livestock activity.

21.0 BALD AND GOLDEN EAGLE PROTECTION ACT

21.1 Summary of the Law

The Bald and Golden Eagle Protection Act (16 USC § 668-668d) makes it unlawful to take (i.e., capture, kill, or destroy), possess, molest, or disturb bald eagles (*Haliaeetus leucocephalus*) and golden eagles (*Aquila chrysaetos*), alive or dead, their nests, or their eggs anywhere in the United States. A permit must be obtained from the U.S. Department of the Interior to relocate any nest that interferes with resource development or recovery operations. The Bald and Golden Eagle Protection Act is implemented by several parts under CFR Title 50, Subchapter B, *Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants*. These implementing regulations are found in 50 CFR Parts 13, 17, 21, and 22.

The regulations in 50 CFR Part 13, *General Permit Procedures*, provide uniform rules, conditions, and procedures for the application for and the issuance, denial, suspension, revocation, and general administration of all permits issued pursuant to 50 CFR Subchapter B. The provisions in this part are in addition to other regulations such as the Migratory Bird Treaty Act (Chapter 22) and the Endangered Species Act (Chapter 23) and apply to all permits issued under these regulations, including 50 CFR Parts 17, 21, and 22.

The regulations of 50 CFR Part 17, *Endangered and Threatened Wildlife and Plants*, which also implement the Endangered Species Act and are discussed in Chapter 23, could apply to WIPP because of the potential for the presence of the endangered bald eagle. The regulations in this part outline permit requirements for activities involving endangered wildlife and identify those species of wildlife and plants recognized as endangered or threatened with extinction.

The purpose of the regulations in 50 CFR Part 21, *Migratory Bird Permits*, is to supplement the general permit regulations of Part 13 of Subchapter B with respect to permits for the taking, possession, transportation, sale, purchase, barter, importation, exportation, and banding or marking of migratory birds. Section 21.22 of 50 CFR Part 21 outlines the requirements and procedures for permitting the banding or marking of bald and golden eagles. The requirements under 50 CFR Part 21 are discussed in Chapter 22.

The purpose of the regulations in 50 CFR Part 22, *Eagle Permits*, is to govern the taking, possession, and transportation of bald and golden eagles for scientific, educational, and depredation-control purposes and for the religious purposes of Indian tribes. The import, export, purchase, sale, or barter of bald or golden eagles, their parts, nests, or eggs is not permitted by any regulation of Subchapter B.

21.2 Compliance Status of the Regulatory Requirements

Table 21-1 summarizes some of the applicable requirements and their compliance status under the Bald and Golden Eagle Protection Act. The text provides more detail on the compliance status of these requirements.

TABLE 21-1. Bald and Golden Eagle Protection Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR Part 13, *General Permit Procedures*		
50 CFR 13.11	Permit application procedures	**NOT APPLICABLE** No nesting eagles at WIPP [Section 21.2.1]
50 CFR Part 22, *Eagle Permits*		
50 CFR 22.11	General permit requirements	**NOT APPLICABLE** No nesting eagles at WIPP [Section 21.2.2]
50 CFR 22.25	Permits to take golden eagle nests	**NOT APPLICABLE** No nesting eagles at WIPP [Section 21.2.3]

21.2.1 Permit Application Procedures, 50 CFR 13.11

Applicants must submit separate applications for each permit on prescribed forms and must follow prescribed forwarding instructions.

At present, no bald or golden eagles are nesting on the WIPP site. WIPP personnel will file an application for an eagle permit as required if the need for such a permit is perceived. Other permit requirements under 50 CFR Part 13, which would become applicable were a need to arise to disturb or relocate a bald or golden eagle, are discussed in Chapter 22.

21.2.2 General Permit Requirements, 50 CFR 22.11

> *No person shall take, possess, or transport any bald or golden eagle, living or dead, or the parts, nest, or eggs of such birds except as authorized under terms of a valid issued permit.*

WIPP personnel will apply for a permit and will comply with the permit conditions if such a permit is ever needed.

21.2.3 Permits to Take Golden Eagle Nests, 50 CFR 22.25

> *Persons desiring to take golden eagle nests during a resource-development or recovery operation must file a permit application in accordance with prescribed procedures. The nests may be taken only when they are inactive.*

At present, no golden eagles are nesting on the WIPP site. If it becomes necessary to move or remove a golden eagle nest, a permit application will be filed. All permit conditions will be met, and the nest(s) will be moved only when inactive.

22.0 MIGRATORY BIRD TREATY ACT

22.1 Summary of the Law

The Migratory Bird Treaty Act (16 USC §§ 703-712) is intended to protect birds that have common migratory flyways between the United States and Canada, Mexico, Japan, and Russia. The act stipulates that it is unlawful "at any time, by any means or in any manner, to pursue, hunt, take, capture, kill, or attempt to take, capture, or kill . . . any migratory bird, any part, nest, or eggs of any such bird" unless specifically authorized by the Secretary of the Interior by direction or through regulations permitting and governing these actions. Although WIPP is not located within a major migration corridor, there is the potential for migratory birds to be present on WIPP lands.

The regulations in 50 CFR Part 13, *General Permit Procedures*, provide uniform rules, conditions, and procedures for the application for and the issuance, denial, suspension, revocation, and general administration of all permits issued pursuant to 50 CFR Subchapter B, *Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants*. The provisions in this part are in addition to other regulations, including 50 CFR Parts 17, 21, and 22, and apply to all permits issued under these regulations.

The regulations of 50 CFR Part 17, *Endangered and Threatened Wildlife and Plants*, also implement the Migratory Bird Treaty Act and could apply to WIPP because of the potential for the presence of migratory endangered and threatened species of birds at the WIPP. These regulations, discussed in Chapter 23, outline the requirements for permits for activities involving endangered wildlife and identify those species of wildlife that are recognized as endangered or threatened with extinction.

Under the Migratory Bird Treaty Act, the DOE is required to consult annually with the U. S. Fish and Wildlife Service (FWS) with respect to impacts on migratory game birds[1] and crows resulting from the hunting activities permitted on WIPP lands. Hunting privileges for the public within the withdrawal area will continue, except for the areas that are posted against trespass. These hunting activities, whether conducted out of or within the withdrawal area, are subject to regulations implementing the Migratory Bird Treaty Act (i.e., 50 CFR Part 20, *Migratory Bird Hunting*), which regulate the harvest of migratory birds by specifying the mode of harvest, hunting seasons, possession limits, and so on. Furthermore, because certain migratory birds which have been federally recognized and listed as endangered or threatened, such as bald eagles and peregrine falcons, could be present on WIPP lands, the Bald and Golden Eagle Protection

[1]Migratory game birds are migratory birds that belong to the following families: Anatidae (ducks, geese, brant, and swans); Columbidae (doves and pigeons); Gruidae (little brown cranes); Rallidae (rails, coots, and gallinules); and Scolopacidae (woodcock and snipe).

Act (Chapter 21) and the Endangered Species Act (Chapter 23) may also apply, along with their implementing regulations.

The regulations in 50 CFR Part 21, *Migratory Bird Permits*, supplement the general permit regulations of Part 13 of this subchapter with respect to permits for the taking, possession, transportation, sale, purchase, barter, importation, exportation, and banding or marking of migratory birds. The portion that is relevant to WIPP is § 21.22, which outlines the requirements and procedures for obtaining permits to band or mark birds. Part 21 also provides certain exceptions to the permit requirements for public, scientific, or educational institutions and establishes depredation orders that provide limited exceptions to the Migratory Bird Treaty Act.

The purpose of the regulations in 50 CFR 22, *Eagle Permits*, is to govern the taking, possession, and transportation of bald and golden eagles for scientific, educational, and depredation-control purposes and for the religious purposes of Indian tribes. Compliance with these regulations is discussed in Chapter 21.

22.2 Compliance Status of the Regulatory Requirements

The compliance status of each of the applicable regulatory requirements under the Migratory Bird Treaty Act is summarized in Table 22-1. More detail is provided in the text.

TABLE 22-1. Migratory Bird Treaty Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR Part 13, *General Permit Procedures*		
50 CFR 13.11	Permit application procedures	**ACHIEVED** Application submitted to the U.S. Fish and Wildlife Service (FWS) [Section 22.2.1]

TABLE 22-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR 13.12	Information requirements for permit applications	**ACHIEVED** Prescribed information included in application [Section 22.2.2]
50 CFR 13.44	Display of permit	**ACHIEVED** Permit displayed [Section 22.2.3]
50 CFR 13.45	Filing of reports	**ACHIEVED** Annual report submitted to FWS [Section 22.2.4]
50 CFR 13.46	Maintenance of records	**UP TO DATE** Maintained for at least 5 years [Section 22.2.5]
50 CFR 13.47	Inspection requirement	**NOT APPLICABLE** No inspections requested to date [Section 22.2.6]
50 CFR 13.48	Compliance with permit conditions (see also Sections 22.2.12 and 22.3.1)	**UP TO DATE** All conditions met (see also Sections 22.2.12 and 22.3.1) [Section 22.2.7]
50 CFR 13.50	Acceptance of liability	**UP TO DATE** No action required [Section 22.2.8]

TABLE 22-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR Part 20, *Migratory Bird Hunting*		
50 CFR Part 20, Subpart C	Compliance with applicable hunting regulations	**UP TO DATE** Hunting allowed in some areas in compliance with applicable regulations [Section 22.2.9]
50 CFR Part 21, *Migratory Bird Permits*		
50 CFR 21.22(a)	Permit for banding or marking migratory birds	**ACHIEVED** Federal permit #22478 for banding obtained [Section 22.2.10]
50 CFR 21.22(b)	Application procedures for banding or marking permits	**ACHIEVED** Prescribed information submitted to FWS [Section 22.2.11]
50 CFR 21.22(c)	Additional permit conditions	**UP TO DATE** Permit conditions met [Section 22.2.12]
50 CFR 21.22(d)	Term of permit	**UP TO DATE** Less than 3 years [Section 22.2.13]

TABLE 22-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR 21.27	Special-purpose permits	NOT APPLICABLE No action required [Section 22.2.14]
50 CFR 21.28	Falconry permits	NOT APPLICABLE No falconry activities anticipated at WIPP [Section 22.2.15]
50 CFR 21.41	Depredation permits	NOT APPLICABLE No need for a depredation permit anticipated for WIPP [Section 22.2.16]

22.2.1 Permit Application Procedures, 50 CFR 13.11

Applicants must submit a separate application on the prescribed form for each permit and must follow the prescribed forwarding instructions.

The prescribed information has been submitted to the FWS.

22.2.2 Information Requirements for Permit Applications, 50 CFR 13.12

Applicants must provide current information such as organizational affiliation, reason(s) for the permit application, and certification of familiarity with 50 CFR Part 13.

The prescribed permit applications and supporting information have been submitted to the FWS.

22.2.3 Display of Permit, 50 CFR 13.44

Any permit issued under 50 CFR Part 13 will be displayed for inspection upon the request of the Director, his/her agent, or any other person that relies upon the existence of the permit.

The permits are permanently displayed on the door of the freezer in which tissue samples are held at WIPP.

22.2.4 Filing of Reports, 50 CFR 13.45

Recipients of a permit may be required to file reports of the activities conducted under the permit. Any such report must be filed by March 31 for the preceding calendar year ending December 31 or for any portion of the year during which the permit was in force.

Annual reports are submitted to the FWS.

22.2.5 Maintenance of Records, 50 CFR 13.46

From the date of issuance of a permit, the recipient of the permit must maintain complete and accurate records of any taking, possession, transportation, sale, purchase, barter, exportation, or importation of plants obtained from the wild or wildlife covered under the permit. The records must be kept current and must include the names and addresses of any persons involved in the transfer of the plant or wildlife as well as the date of the transaction and any other appropriate information. The records must be legible or reproducible and written in English and must be maintained for 5 years from the date of expiration of the permit.

All applicable records are held for at least 5 years from the date of expiration of the permit.

22.2.6 Inspection Requirement, 50 CFR 13.47

Any person holding a permit under this subpart shall allow the Director's agent to enter his/her premises at any reasonable hour

to inspect any wildlife or plant held or to inspect, audit, or copy any permits, books, or records required under Subpart B.

The Director's agent has not yet requested such an inspection. Should an inspection be requested, full cooperation will be given.

22.2.7 Compliance with Permit Conditions, 50 CFR 13.48

Any person holding a permit under this subpart or acting under the authority of the permittee must comply with all conditions of the permit and with all applicable laws and regulations governing the permitted activity.

Conditions described in the permit have been met. See also Sections 22.2.12 and 22.3.1.

22.2.8 Acceptance of Liability, 50 CFR 13.50

Any person holding a permit under Subpart B assumes all liability and responsibility for the conduct of any activity conducted under the authority of the permit.

The recipients of the permits under Subpart B at WIPP are fully aware of their liabilities and assume responsibility for their activities.

22.2.9 Compliance with Applicable Migratory Bird Hunting Regulations, 50 CFR 20, Subpart C

Hunters of migratory game birds and crows must comply with open-season requirements, including the avoidance of prohibited hunting methods.

Hunting privileges for the public will continue within the withdrawal area, except in areas posted against trespass, in accordance with applicable hunting regulations.

22.2.10 Application for Banding or Marking Permit, 50 CFR 21.22(a)

Persons intending to capture migratory birds for banding or marking must have obtained a permit acquired in accordance with prescribed permit regulations.

A permit (#22478) for banding at WIPP has been granted by the FWS. See also Section 22.3.1.

22.2.11 Application Procedures for Banding or Marking Permits, 50 CFR 21.22(b)

Information to be provided in banding or marking permit applications includes, but is not limited to, the State in which authorization is desired; the species to be banded or marked; and the name and address of the public, scientific, or educational institution that will be recipients of salvaged specimens.

This information was included in the application for the permit.

22.2.12 Additional Permit Conditions, 50 CFR 21.22(c)

In addition to the general permit conditions described in 50 CFR Part 13 (see Sections 22.2.1 through 22.2.8), the following conditions will be met:

- *Only official numbered leg bands issued by the Fish and Wildlife Service will be used to band migratory birds.*
- *All traps or nets used to capture migratory birds for banding or marking will have a tag attached with the name and address of the permittee and the permit number.*
- *The holder of a permit may salvage birds killed or found dead. All such dead birds salvaged under the authority of a banding or marking permit must be donated and transferred to a public, scientific, or educational institution at least every 6 months or within 60 days of the expiration or revocation of the permit unless a special permit that authorizes possession for a longer period of time has been issued.*

- *The permittees must keep accurate records of their operations and must file reports as required.*

The additional permit conditions are met at WIPP.

22.2.13 Term of Permit, 50 CFR 21.22(d)

The term of a banding or marking permit shall not exceed 3 years from the date of issuance or renewal. The expiration date is designated on the permit unless the permit has been amended or revoked.

Permit #22478 does not exceed the 3-year term. The permit was reissued to WID personnel on May 19, 1993, and will expire on June 30, 1995.

22.2.14 Special-Purpose Permits, 50 CFR 21.27

Permits may be issued for special-purpose activities related to migratory birds or their parts, nests, or eggs that are otherwise outside the scope of the standard permits of this part.

No special-purpose permits have been needed at WIPP to date. Should such a permit be deemed necessary, all appropriate requirements will be met as specified under this section.

22.2.15 Falconry Permits, 50 CFR 21.28

A falconry permit is required before any person may take; possess; transport; sell; purchase; barter; or offer to sell, purchase, or barter raptors for falconry purposes.

No falconry activities are anticipated at WIPP. Therefore, this permit is not applicable.

22.2.16 Depredation Permits, 50 CFR 21.41

A depredation permit is required before any person may take, possess, or transport migratory birds for depredation control.

No need for a depredation permit to control migratory birds is anticipated at WIPP. Therefore, this permit does not apply.

22.3 Compliance Status of Permit Conditions

Table 22-2 summarizes the conditions imposed by the FWS for the permit issued. The text provides more detail on the compliance status of the permit conditions.

TABLE 22-2. Migratory Bird Treaty Act - Summary of Permit Compliance Status

CITATION	CONDITION	COMPLIANCE STATUS
Permit No. 22478	Authorization to capture and band or mark birds; excluded for waterfowl, eagles, and endangered or threatened species	**UP TO DATE** No waterfowl, eagles, or endangered species captured, banded, or marked at WIPP [Section 22.3.1]

22.3.1 Permit No. 22478

Permit No. 22478 authorizes the WID employee specified to capture and band or mark all species of birds except waterfowl, eagles, or endangered or threatened species.

Permit No. 22478 provides authority to capture and band or mark all species of birds except waterfowl, eagles, or endangered or threatened species. No waterfowl, eagles, or endangered or threatened species have been captured, marked, or banded at WIPP.

23.0 ENDANGERED SPECIES ACT

23.1 Summary of the Law

The Endangered Species Act (16 USC §§ 1531 et seq.) was enacted in 1973 to prevent the extinction of many species of animals and plants. This act provides strong measures to help alleviate the loss of species and their habitats and places restrictions on a wide range of activities involving endangered and threatened animals and plants to help ensure their continued survival. With limited exceptions, this act prohibits activities using these protected species unless authorized by a permit from the U.S. Fish and Wildlife Service (FWS). Under § 1536 of the act and the implementing regulations in 50 CFR Part 402, *Interagency Cooperation--Endangered Species Act, as Amended,* the U.S. Environmental Protection Agency (EPA) is prohibited from authorizing activities likely to jeopardize the continued existence of any threatened or endangered species or its critical habitat. A biological assessment and "formal consultation," followed by the issuance of a "biological opinion" by the FWS, may be required for any species that is determined to be in potential jeopardy.

The FWS lists five threatened or endangered species of plants and animals that could occur at the WIPP site: the Lee pincushion cactus (*Coryphantha sneedi var. leei*); the gypsum wild buckwheat (*Eriogonum gypsophilum*); the peregrine falcon (*Falco peregrinus anatum*); the bald eagle (*Haliaeetus leucocephalus*); and a fish, the Pecos gambusia (*Gambusia nobilis*). However, the FWS has determined that WIPP activities will have no adverse impacts on these species. In addition, no critical habitat for terrestrial endangered species has been identified at the WIPP site. Consequently, neither formal consultation nor biological opinion processes have been required for the WIPP project by the FWS under § 1536.

The regulations in 50 CFR Part 13, *General Permit Procedures,* provide uniform rules, conditions, and procedures for the application for and the issuance, denial, suspension, revocation, and general administration of all permits issued pursuant to 50 CFR Subchapter B, *Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants.* The provisions in this part are in addition to other regulations and apply to all permits issued under them, including 50 CFR Parts 17, 21, and 22.

The regulations of 50 CFR Part 17, *Endangered and Threatened Wildlife and Plants*, implement the Endangered Species Act as well as the Bald and Golden Eagle Protection Act (see Chapter 21) and could apply to WIPP because of the potential for the presence of the endangered animal and plant species identified above. The regulations in this part outline the requirements for permits for activities involving endangered wildlife and identify those species of wildlife and plants recognized as endangered or threatened with extinction.

Other Federal regulations that implement the Endangered Species Act and that apply to the WIPP include the implementing regulations in 50 CFR Parts 21 and 22. The purpose of the regulations

in 50 CFR Part 21, *Migratory Bird Permits*, is to supplement the general permit regulations of Part 13 of Subchapter B with respect to permits for the taking, possession, transportation, sale, purchase, barter, importation, exportation, and banding or marking of migratory birds, including those listed as threatened or endangered. Compliance with these regulations is discussed in Chapter 22.

The regulations in 50 CFR Part 22, *Eagle Permits*, govern the taking, possession, and transportation of the endangered bald eagle for scientific, educational, and depredation-control purposes and for the religious purposes of Indian tribes. Requirements under these regulations are discussed in Chapter 21.

23.2 Compliance Status of the Regulatory Requirements

Table 23-1 summarizes regulatory requirements and their compliance status under the Endangered Species Act. The text gives more detail on the compliance status of each requirement.

TABLE 23-1. Endangered Species Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR Part 13, *General Permit Procedures*		
50 CFR 13.11	Permit application procedures	**NOT APPLICABLE** No work anticipated with endangered or threatened species [Section 23.2.1]

TABLE 23-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
50 CFR Part 17, *Endangered and Threatened Wildlife and Plants*		
50 CFR 17.22, 17.32, 17.52, and 17.62	Application for permits for scientific purposes or for the enhancement of propagation or survival of endangered or threatened species	**NOT APPLICABLE** No work anticipated with endangered or threatened species [Section 23.2.2]
50 CFR Part 402, *Interagency Cooperation - Endangered Species Act, as Amended*		
50 CFR 402.12	Biological assessment to evaluate effects of proposed actions on designated species	**NOT APPLICABLE** Determination of no adverse impacts; see Section 23.2.4 [Section 23.2.3]
50 CFR 402.14	Formal consultation with the FWS to determine whether any action will affect listed species	**ACHIEVED** Determination of no adverse impacts [Section 23.2.4]

23.2.1 Permit Application Procedures, 50 CFR 13.11

Applicants must submit separate applications for each permit on prescribed forms and must follow prescribed forwarding instructions.

No permit is required because activities involving endangered species are not conducted at WIPP. Other requirements related to permits under 50 CFR Part 13, which would become applicable only if activities involving endangered species were initiated, are summarized and discussed in Chapter 22.

23.2.2 Application for Endangered or Threatened Species Permit, 50 CFR 17.22 (a)(1), 17.32, 17.52, and 17.62

Applicants for permits for using endangered or threatened species of wildlife or plants for scientific purposes, enhancement of propagation or survival, or for incidental taking must submit an application as prescribed.

To date, taking endangered or threatened wildlife or plants for these purposes, which would require a permit from the FWS, has not been necessary. It is not expected that such a permit will be needed in the future.

23.2.3 Biological Assessment of Impacts on Recognized Species, 50 CFR 402.12

A biological assessment may be required to determine whether construction activities will jeopardize the continued existence of endangered species or the critical habitat of any such species.

On May 29, 1980, the FWS determined that construction of the WIPP would have no adverse impacts on recognized endangered or threatened species. In addition, no critical habitat for terrestrial endangered species has been identified at the WIPP site. Consequently, no biological assessment has been required for the WIPP.

23.2.4 Formal Consultation with the FWS Regarding Impacts on Recognized Species, 50 CFR 402.14

Formal consultation with the FWS to determine whether construction activities will jeopardize the continued existence of endangered species or its critical habitat is required.

On May 29, 1980, the FWS determined that construction of the WIPP would have no adverse impacts on recognized endangered or threatened species. In addition, no critical habitat for terrestrial endangered species has been identified at the WIPP site. Consequently, no formal consultation has been required for the WIPP.

24.0 NATIONAL HISTORIC PRESERVATION ACT

24.1 Summary of the Law

The National Historic Preservation Act (NHPA; 16 USC §§ 470 et seq.) was enacted to protect the nation's cultural resources in conjunction with the States, local governments, Indian tribes, and private organizations and individuals. The policy of the Federal government includes (1) providing leadership in preserving the prehistoric and historic resources of the nation; (2) administering federally owned, administered, or controlled prehistoric resources for the benefit of present and future generations; (3) contributing to the preservation of nonfederally owned prehistoric and historic resources; and (4) assisting State and local governments and the National Trust for Historic Preservation in expanding and accelerating their historic preservation programs and activities. The act also established the National Register of Historic Places ("National Register"). At the State level, the State Historic Preservation Officer (SHPO) coordinates the State's participation in implementating the NHPA.

Section 106 of NHPA requires that a Federal agency head who has jurisdiction over a Federal, federally assisted, or federally licensed undertaking take into account the effects of the agency's undertaking on historic properties included in or eligible for the National Register. Furthermore, the "Section 106 process" requires that the Federal agency head afford the Advisory Council on Historic Preservation ("the Council") a reasonable opportunity to comment on the undertaking prior to initiating the undertaking. Through the Section 106 process, the Council seeks to accommodate historic preservation concerns with the needs of Federal undertakings. The Council encourages this accommodation through consultation among the Federal agency, the SHPO, and other interested parties during the early stages of planning.

The NHPA has been amended by two acts. The Archaeological and Historic Preservation Act (16 USC §§ 469 et seq.) directs Federal agencies to recover and preserve historic and archaeological data that would otherwise be lost as a result of Federal construction or program activities. This statute applies to known cultural resources on WIPP lands or those that may be recorded in the future.

The other act amending the NHPA is the Archaeological Resources Protection Act (16 USC §§ 470aa et seq.). This statute sets forth the requirements for obtaining a permit from the U.S. Department of the Interior (DOI) for the excavation or removal of archaeological resources from public or Indian lands. The act's implementing regulations in 43 CFR Part 7, *Protection of Archaeological Resources*, establish uniform definitions, standards, and procedures to be followed by all Federal land managers in providing protection for archaeological resources located on public lands. The statute and regulations apply to known cultural resources on WIPP lands or those that may be recorded in the future.

Since 1976, cultural resource investigations have recorded 98 archaeological sites and numerous isolated artifacts within the 16-square-mile area enclosed by the WIPP site boundary. Thirty-

three sites recorded within the central 4-square-mile area were determined eligible for inclusion on the National Register as an archaeological district. Investigations since 1980 have recorded an additional 14 individual sites outside the central 4-square-mile area that are considered eligible for inclusion on the National Register. The NHPA's implementing regulations in 36 CFR Part 800, *Protection of Historic and Cultural Properties*, contain provisions for the development of a treatment plan by a Federal agency that identifies historic properties that are likely to be discovered during the implementation of an undertaking and how they will be managed.

24.2 Compliance Status of the Regulatory Requirements

Table 24-1 summarizes the regulatory requirements and their compliance status under the National Historic Preservation Act. The text gives more detail on the compliance status of each requirement.

TABLE 24-1. National Historic Preservation Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
36 CFR Part 800, *Protection of Historic and Cultural Properties*		
36 CFR 800.5	Assessment of effects on historic properties	**ACHIEVED** Determination of No Adverse Effect obtained (May 1980) [Section 24.2.1]
36 CFR 800.11 (W)	Development of plan for treatment of historic property	**ACHIEVED** *WIPP Mitigation Plan* submitted to State Historic Preservation Officer (SHPO) and to the Council; SHPO determined No Adverse Effect from WIPP activities in May 1980 [Section 24.2.2]

TABLE 24-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
43 CFR Part 7, *Protection of Archaeological Resources*		
43 CFR 7.5	Application for permit to excavate and/or remove archaeological resources	NOT APPLICABLE No excavations or removal of archaeological sites slated [Section 24.2.3]

24.2.1 Assessment of Effects on Historic Properties, 36 CFR 800.5

In consultation with the SHPO, the Federal agency official with jurisdiction over an undertaking is responsible for assessing the effect of an undertaking on affected historic properties, obtaining the SHPO's concurrence when the effect is not considered adverse, and notifying and submitting summary documentation to the Council.

The DOE submitted documentation to the New Mexico SHPO describing excavation activities and the avoidance of any potential historical sites. A determination of No Adverse Effect from WIPP activities on historic properties was made by the SHPO in May 1980. Similar documentation was submitted to the Council.

24.2.2 Development of a Plan for the Treatment of Historical Property Discovered During a Federal Agency Undertaking, 36 CFR 800.11

After a determination by the Federal agency official presiding over an undertaking that the potential for the discovery of historical property exists, the agency official may develop a plan for the treatment of such properties if discovered and include this plan in any documentation prepared to comply with 36 CFR 800.5.

A mitigation plan describing excavation activities at WIPP and the avoidance of historical sites was submitted to the New Mexico SHPO. A determination of No Adverse Effect from WIPP activities on cultural resources was made by the SHPO in May 1980. A similar mitigation plan

was submitted to the Council. The Council concurred that the *WIPP Mitigation Plan* is appropriate to protect cultural resources. The *WIPP Land Management Plan* (DOE, 1993c) also outlines objectives and planned actions for the management of cultural resources within the withdrawal area.

24.2.3 Application for Permits and Information Collection, 43 CFR 7.5

> *Any person proposing to excavate and/or remove archaeological resources from public lands and to carry out activities associated with such excavation and/or removal shall apply for a permit for the proposed work and shall not begin the proposed work until a permit has been issued.*

Avoidance of known archaeological sites will remain as the primary mitigation measure. No known archaeological sites have been slated for excavation.

25.0 NEW MEXICO HAZARDOUS WASTE ACT

25.1 Summary of the Law

The purpose of the Hazardous Waste Act (HWA; §§ 74-4-1 through 74-4-14 NMSA 1978) is to maintain the quality of New Mexico's environment; to confer optimal health, safety, comfort, and economic and social well being on its inhabitants; and to protect the proper utilization of its lands. The Hazardous Waste Act established the program for hazardous waste management and control in the State of New Mexico. Since its initial enactment in 1977, it has been amended substantially three times (in 1981, 1987, and 1989) to make its provisions more consistent with the 1980 and 1984 amendments to RCRA (see Chapter 2). The major provisions of the HWA were taken directly from Subtitles C (*Hazardous Waste Management*) and I (*Regulation of Underground Storage Tanks*) of RCRA.

On January 11, 1985, the State of New Mexico received authorization from the EPA to administer the Federal hazardous waste program, effective January 25, 1985. Additional authorizations that expanded the scope of the initial authorization were granted by the EPA and became effective on April 10, 1990; July 25, 1990; and December 4, 1992. However, New Mexico's authorization for hazardous waste management does not currently extend to the regulations promulgated by the EPA pursuant to the Hazardous and Solid Waste Amendments of 1984 (HSWA).

A State may adopt Federal regulations by reference to those regulations without specifying each of the requirements and provisions of the Federal regulations. On January 11, 1991, the State of New Mexico adopted the entire body of 40 CFR Parts 260 through 266 and Parts 268 through 270 of the EPA's regulations implementing Subtitle C with only a few substitutions and minor exceptions. Table 25-1 shows the correspondence between the Federal and State implementing regulations. The Federal regulations through July 1, 1990, were adopted into the New Mexico Hazardous Waste Management Regulations (HWMR).

On July 11, 1990, the EPA published its acceptance of New Mexico's revised hazardous waste program, effective July 25, 1990. This authorization allows the State of New Mexico to regulate the hazardous constituents of mixed waste under the revised Hazardous Waste Act except for those changes in the regulations made by the EPA subsequent to the authorization. Therefore, this authorization allows the State to regulate the hazardous constituents of the mixed waste to be sent to the WIPP except for changes in the regulations that have been made by the EPA and that have not yet received EPA's authorization in the State program.

On July 23, 1992, New Mexico submitted an application for additional program approvals. The EPA published an immediate final rule on October 5, 1992, in which the decision was made to grant final authorization to New Mexico for the additional program modifications unless adverse comments were received. In the event that no such comments were received, the final authorization would become effective on December 4, 1992.

TABLE 25-1. Correspondence between the Federal Regulations Implementing the Resource Conservation and Recovery Act (RCRA) and the State Regulations Implementing the New Mexico Hazardous Waste Act (HWA)

Implementing Regulations under RCRA	Hazardous Waste Management Regulations (HWMRs) under HWA	Adoptions, Modifications, and Exceptions	BECR Sections
40 CFR Part 260	Section 101	Adopts Part 260 into Part I by reference	—
	Section 102	Modifies several definitions; deletes Sections 260.1(b)(6), 260.22, and 260.30 through 260.33; provides NMED 24-hour emergency-response telephone number	—
40 CFR Part 261	Section 201	Adopts Part 261 into Part II by reference	—
40 CFR Part 262	Section 301	Adopts Part 262 into Part III by reference	Section 25.2.2
40 CFR Part 263	Section 401	Adopts Part 263 into Part IV by reference	Section 25.2.3
	Section 402	Deletes Section 263.20(e)	
40 CFR Part 264	Section 501	Adopts Part 264 into Part V by reference	Not applicable
	Section 501	Deletes Sections 264.149 and 264.150	
40 CFR Part 265	Section 601	Adopts Part 265 into Part VI by reference	Section 25.2.4
	Section 602	Deletes Sections 265.149 and 265.150	
40 CFR Part 266	Section 701	Adopts Part 266 into Part VII by reference	Not applicable

TABLE 25-1 (continued)

Implementing Regulations under RCRA	Hazardous Waste Management Regulations (HWMRs) under HWA	Adoptions, Modifications, and Exceptions	BECR Sections
40 CFR Part 268	Section 801	Adopts Part 268 into Part VIII by reference	Section 2.2.2
40 CFR Part 270	Section 901	Adopts Part 270 into Part IX by reference	Section 25.2.5
	Section 902	Adds New Mexico permitting procedures	
—	Section 1001	Requires compliance with applicable laws	Section 25.2.1
	Section 1002	Effectuates HWA	
	Section 1003	Replaces 40 CFR Part 124 with Section 902 of the HWMRs	
	Section 1004	Severability	
	Section 1005	Effect of stay or invalidation of Federal regulations incorporated by reference	
	Section 1006	Amendment of prior regulations	
	Section 1007	Saving clause	

The State's HWMRs are applicable to WIPP on three counts. First, WIPP is a generator of hazardous waste and is thus required to comply with the RCRA requirements of 40 CFR Part 262 (Part III of the New Mexico HWMRs). As long as WIPP ships its hazardous waste off-site to an EPA-approved TSDF within 90 days, no RCRA permit is required for this activity. Second, when WIPP receives waste from the generator sites, WIPP will be responsible for subcontracting the transporter. This activity will be regulated under the transporter requirements of 40 CFR Part 263 (Part IV of the HWMRs). Third, WIPP will be a disposal, storage, and/or treatment facility for TRU mixed waste, which mandates that WIPP receive a RCRA permit.

The permit will be received from both the NMED and the EPA because the former is not yet authorized for HSWA requirements or for other recent changes made by the EPA in the Federal regulations.

After the State of New Mexico received authorization from the EPA to regulate mixed waste in July 1990, the NMED informed WIPP that the RCRA Part A permit application was due on January 22, 1991, with the Part B application due on February 28, 1991. WIPP submitted its Part A permit application to the NMED and to Region VI of the EPA on January 22, 1991. The Part B permit application was submitted to the NMED on February 26, 1991, and to the EPA Region VI office on February 27, 1991. Since then, three revisions of the permit application have been submitted to the regulatory agencies to provide additional information required and to inform the agencies of changes. The latest revision was completed and submitted in January 1993.

In August 1993, the NMED and the EPA issued a draft RCRA permit for the WIPP, which consisted of six modules. The first five were prepared by the NMED, and the sixth module, based on requirements related to HSWA, was prepared by the EPA. The permit application was based on conducting tests on TRU mixed wastes at WIPP during the test phase. Although DOE decided not to test TRU waste at WIPP during the test phase, DOE has requested that the NMED and the EPA continue the current permitting process.

The New Mexico permitting procedures from Section 902 of HWMR-7 and the miscellaneous provisions covered in Sections 1001 through 1007 of HWMR-7 have been added to the requirements in the Federal regulations. Furthermore, since the New Mexico Underground Storage Tank Regulations (USTRs) differ from the Federal regulations specified in 40 CFR Part 280, these State regulations are also discussed in detail in this chapter (see Section 25.2.6). The UST section includes the results of the environmental compliance assessment that was performed for the UST program at WIPP.

25.2 Compliance Status of Regulatory Requirements

There are two regulatory requirements in the HWA and the implementing HWMRs that do not have direct counterparts in the Federal regulations. Section 25.2.1 discusses one requirement from the HWA that is unique and is not in the State implementing regulations. It also includes a discussion of the New Mexico USTR requirements and their compliance status at WIPP.

25.2.1 Compliance Status of the Hazardous Waste Regulatory Requirement

The New Mexico requirement pertaining to hazardous waste management that differs from the Federal regulations is summarized in Table 25-2, along with a summary of the compliance status of the requirement at WIPP. Additional information is presented in the text.

TABLE 25-2. New Mexico Hazardous Waste Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
New Mexico Hazardous Waste Management Regulations (HWMR-7)		
HWMR-7, Section 1001	Compliance with other regulations	ACHIEVED See other chapters in this report [Section 25.2.1.1]

25.2.1.1 Compliance with other Regulations, Section 1001 of HWMR-7

Compliance with the HWMRs does not relieve a person of the obligation to comply with other applicable State and Federal regulations.

Compliance with the other Federal and State regulations that apply to WIPP is discussed in the other chapters of this BECR.

25.2.2 Compliance with Regulations for Hazardous Waste Generators, 40 CFR Part 262 (HWMR-7, § 301)

Table 25-3 summarizes the applicable regulatory requirements for hazardous waste generators under Part III of HWMR-7, which corresponds to the Federal implementing regulations of 40 CFR Part 262. Because the HWMRs adopt the Federal implementing regulations by reference, the citations given in this table are from the Federal regulations (40 CFR Part 262). The compliance status of each requirement is included. The text provides more detail.

TABLE 25-3. New Mexico Hazardous Waste Management Regulations (HWMRs) for Hazardous Waste Generators - Compliance Status

Citation	Requirement	Compliance Status
40 CFR 262.11 (HWMR-7, § 301)	Hazardous waste determination	**ACHIEVED** WID procedures [Section 25.2.2.1]
40 CFR 262.12 (HWMR-7, § 301)	EPA identification number	**ACHIEVED** NM 4890139088 [Section 25.2.2.2]
40 CFR 262.20 (HWMR-7, § 301)	Manifest requirements	**UP TO DATE** WID procedures; *WIPP Waste Minimization Plan* [Section 25.2.2.3]
40 CFR 262.21 (HWMR-7, § 301)	Acquisition of manifests	**UP TO DATE** State-specific or uniform manifest used [Section 25.2.2.4]
40 CFR 262.22 (HWMR-7, § 301)	Number of copies	**UP TO DATE** Uniform manifest [Section 25.2.2.5]
40 CFR 262.23 (HWMR-7, § 301)	Use of the manifest	**UP TO DATE** WID procedures [Section 25.2.2.6]
40 CFR 262.30 (and 49 CFR Parts 173, 178, and 179) (HWMR-7, § 301)	DOT packaging requirements	**UP TO DATE** WID procedures [Section 25.2.2.7]

TABLE 25-3 (continued)

Citation	Requirement	Compliance Status
40 CFR 262.31 (and 49 CFR Part 172) (HWMR-7, § 301)	Labeling requirements	**UP TO DATE** WID procedures [Section 25.2.2.8]
40 CFR 262.32 (and 49 CFR Part 172) (HWMR-7, § 301)	Marking requirements	**UP TO DATE** WID procedures [Section 25.2.2.9]
40 CFR 262.33 (and 49 CFR Part 172) (HWMR-7, § 301)	Placarding requirements	**UP TO DATE** WID procedures [Section 25.2.2.10]
40 CFR 262.34(a) (HWMR-7, § 301)	90-day or less accumulation time	**ACHIEVED** WID procedures [Section 25.2.2.11]
40 CFR 262.34(a)(1)(i) (HWMR-7, § 301)	Compliance with Subpart I of 40 CFR Part 265 for waste placed in containers	**UP TO DATE** WID procedures [Section 25.2.2.12]
40 CFR 262.34(a)(1)(ii) (HWMR-7, § 301)	Accumulation of hazardous wastes in tanks	**NOT APPLICABLE** Hazardous waste not accumulated in tanks at WIPP [Section 25.2.2.13]
40 CFR 262.34(a)(1)(iii) (HWMR-7, § 301)	Compliance with Subpart W of 40 CFR Part 265 for wastes placed on drip pads	**NOT APPLICABLE** No drip pads at WIPP [Section 25.2.2.14]

TABLE 25-3 (continued)

Citation	Requirement	Compliance Status
40 CFR 262.34(a)(2) (HWMR-7, § 301)	Marking each container with the date of initial accumulation of waste	**UP TO DATE** WID procedures [Section 25.2.2.15]
40 CFR 262.34(a)(3) (HWMR-7, § 301)	Marking each container as hazardous waste	**UP TO DATE** WID procedures [Section 25.2.2.16]
40 CFR 262.34(a)(4) (HWMR-7, § 301)	Compliance with Subpart C of 40 CFR 265 for preparedness and prevention	**UP TO DATE**
	Compliance with Subpart D of 40 CFR Part 265 for contingency plans and emergency procedures	**ACHIEVED** *WIPP Contingency Plan*
	Compliance with 40 CFR 265.16 regarding personnel training	**UP TO DATE** Formal personnel training
	Compliance with 40 CFR 268.7(a)(4) regarding a waste analysis plan for prohibited waste under the land disposal restrictions (LDRs)	**NOT APPLICABLE** No treatment or land disposal at WIPP for WIPP-generated wastes [Section 25.2.2.17]
40 CFR 262.34(b) (HWMR-7, § 301)	Extension of the 90-day storage period due to unforeseen, temporary, and uncontrollable circumstances	**ACHIEVED** January 1991 [Section 25.2.2.18]

TABLE 25-3 (continued)

Citation	Requirement	Compliance Status
40 CFR 262.34(c)(1) (HWMR-7, § 301)	Restrictions and requirements for satellite accumulation areas (SAAs), including: • Limit of 55 gallons of hazardous or 1 quart of acutely hazardous waste [listed in 40 CFR 261.33 (e)] at or near point of generation	**UP TO DATE** WID procedures in place governing the SAAs at WIPP [Section 25.2.2.19]
40 CFR 262.34(c)(1)(i) (HWMR-7, § 301)	• Compliance with 40 CFR 265.171, *Condition of Containers* • Compliance with 40 CFR 265.172, *Compatibility of Waste with Container* • Compliance with 40 CFR 265.173(a) pertaining to keeping hazardous waste containers closed during storage	**UP TO DATE** WID procedures [Section 25.2.2.20]
40 CFR 262.34(c)(1)(ii) (HWMR-7, § 301)	• Labeling of container as "hazardous waste"	**UP TO DATE** WID procedures [Section 25.2.2.21]

TABLE 25-3 (continued)

Citation	Requirement	Compliance Status
40 CFR 262.34(c)(2) (HWMR-7, § 301)	• Management of waste exceeding the 55-gallon (hazardous) or 1-quart (acutely hazardous) waste limit, including required compliance within 3 days and marking container(s) containing the excess waste with the date on which excess waste began accumulating	**UP TO DATE** WID procedures [Section 25.2.2.22]
40 CFR 262.40 (HWMR-7, § 301)	Recordkeeping requirements	**UP TO DATE** WID procedures [Section 25.2.2.23]
40 CFR 262.41 (HWMR-7, § 301)	Generator–biennial report	**UP TO DATE** Biennial report submitted in March 1994 [Section 25.2.2.24]
40 CFR 262.42 (HWMR-7, § 301)	Exception reporting if copy of manifest is not returned to the generator within the specified period of time	**NOT APPLICABLE** No exception report required to date. [Section 25.2.2.25]
40 CFR 262.43 (HWMR-7, § 301)	Additional reporting	**NOT APPLICABLE** No additional reports requested [Section 25.2.2.26]

25.2.2.1 Hazardous Waste Determination, 40 CFR 262.11 (HWMR-7, § 301)

The generator of solid waste is required to determine whether the waste is hazardous as defined under 40 CFR Parts 260 and 261.

Nonradioactive hazardous waste is currently generated from maintenance, construction, and laboratory operations at WIPP. Nonradioactive hazardous waste generated at WIPP is characterized through process knowledge and/or waste sampling and analysis. Procedures to meet these requirements have been implemented. Procedures are also in place for the characterization of mixed waste.

25.2.2.2 EPA Identification Number, 40 CFR 262.12 (HWMR-7, § 301)

An EPA identification number is required for each generator of hazardous waste.

The DOE has obtained a generator identification number for the WIPP. It is NM4890139088.

25.2.2.3 Manifest Requirements, 40 CFR 262.20 (HWMR-7, § 301)

Compliance with the manifest requirements is mandatory for shipping hazardous waste off site. One of the requirements is that the generator have a waste minimization program in place.

Nonradioactive hazardous waste generated at the WIPP is manifested appropriately when it is transported off site. Records are maintained in the operating files for 3 years. Procedures are in place that address these requirements. The Westinghouse Waste Isolation Division (WID) is responsible for implementing these procedures. A waste minimization program is in place.

25.2.2.4 Acquisition of Manifests, 40 CFR 262.21 (HWMR-7, § 301)

The generator must obtain a manifest from the appropriate source.

The WIPP obtains a manifest from consignment States which require a manifest. If the consignment State does not require a specific manifest, a uniform hazardous waste manifest is used. The WIPP uses the current revision of EPA form 8700-22.

25.2.2.5 Number of Copies, 40 CFR 262.22 (HWMR-7, § 301)

The manifest shall consist of sufficient copies to provide two for the generator and one each for the transporter and owner or operator of the facility.

The manifests used by WIPP contain at least the number of copies to fulfill this requirement. The manifest form currently used contains six copies.

25.2.2.6 Use of the Manifest, 40 CFR 262.23 (HWMR-7, § 301)

The generator must sign the manifest certification by hand, obtain the handwritten signature of the initial transporter and date of acceptance on the manifest, and retain one copy. The generator must give the transporter the remaining copies of the manifest.

Other requirements of this regulation pertain to shipments by water, rail, or to a designated facility in an authorized State which has not yet obtained authorization to regulate that particular waste as hazardous.

WID procedures are in place that address compliance with applicable parts of this regulation. Hazardous waste generated at WIPP is sent to TSDFs in States with authorized hazardous-waste programs.

25.2.2.7 Packaging Requirements, 40 CFR 262.30 (HWMR-7, § 301)

EPA and DOT packaging requirements must be met before shipping hazardous waste off site.

A WID procedure is in place that addresses these requirements. WID is responsible for providing oversight and technical assistance in implementing this procedure.

25.2.2.8 Labeling Requirements, 40 CFR 262.31 (HWMR-7, § 301)

EPA and DOT labeling requirements must be met before shipping hazardous waste off site.

A WID procedure is in place that addresses these requirements. WID is responsible for providing oversight and technical assistance in implementing this procedure.

25.2.2.9 Marking Requirements, 40 CFR 262.32 (HWMR-7, § 301)

EPA and DOT marking requirements must be met before shipping hazardous waste off site.

A WID procedure is in place that addresses these requirements. WID is responsible for providing oversight and technical assistance in implementing this procedure.

25.2.2.10 Placarding Requirements, 40 CFR 262.33 (HWMR-7, § 301)

EPA and DOT placarding requirements must be met before shipping hazardous waste off site.

A WID procedure is in place that addresses these requirements. WID is responsible for providing oversight and technical assistance in implementing this procedure.

25.2.2.11 Accumulation Time, 40 CFR 262.34(a) (HWMR-7, § 301)

Accumulation time is limited to 90-day storage of hazardous wastes for a non-permitted facility.

Waste is accumulated in containers in satellite accumulation areas (SAAs) and subsequently moved to the Hazardous Waste Staging Area at WIPP. At this point, the 90-day storage requirement comes into effect. WID procedures are in place that address this requirement for hazardous wastes generated at WIPP and shipped off site to an approved TSDF. WID is responsible for providing oversight and technical assistance in implementing this procedure. Records are maintained at WIPP that document compliance with the 90-day deadline.

25.2.2.12 Compliance with Subpart I of 40 CFR Part 265, 40 CFR 262.34(a)(1)(i) (HWMR-7, § 301)

Compliance with Subpart I of 40 CFR Part 265 is required for waste placed in containers. The requirements of this subpart pertain to the condition of containers, compatibility of waste with the containers, closing containers during storage, inspections, the

location of containers holding ignitable or reactive waste, and the segregation of incompatible wastes. Documentation that the unit is emptied at least once every 90 days is also required.

WID procedures are in place that address compliance with Subpart I of 40 CFR Part 265 (see also Sections 25.2.4.53 through 25.2.4.58). These procedures provide for weekly inspections of containers and segregation of incompatible wastes. The hazardous waste storage area is located more than 50 feet from the WIPP property line for compliance with the requirements for ignitable or reactive waste (40 CFR 265.176). Records are maintained at WIPP that document compliance with the 90-day deadline.

25.2.2.13 Accumulation of Hazardous Wastes, 40 CFR 262.34 (a)(1)(ii) (HWMR-7, § 301)

Except as provided in paragraphs (d), (e), and (f) of this section, a generator may accumulate hazardous waste on site for 90 days or less without a permit or without having interim status, provided that the waste is placed in tanks, and the generator complies with Subpart J of 40 CFR Part 265.0, except §265.197(c) and §265.200.

Hazardous waste is not accumulated in tank systems at WIPP; therefore, this regulation does not apply.

25.2.2.14 Compliance with Subpart W of 40 CFR Part 265, 40 CFR 262.34(a)(1)(iii) (HWMR-7, § 301)

Compliance with Subpart W of 40 CFR Part 265 for wastes placed on drip pads is required.

No drip pads are required at WIPP for hazardous waste accumulation. Therefore, these requirements do not apply.

25.2.2.15 Marking with Date of Initial Accumulation, 40 CFR 262.34(a)(2) (HWMR-7, § 301)

Each container of hazardous waste must be clearly marked with the date of initial accumulation of the waste, and the label must be visible for inspection.

Each container of hazardous waste is labeled with the date of the initial accumulation of the waste as described in WID procedures. Weekly container inspections confirm that this requirement is being met.

25.2.2.16 Marking as Hazardous Waste, 40 CFR 262.34(a)(3) (HWMR-7, § 301)

Each hazardous waste container in an SAA must be labeled or marked as hazardous waste.

Each hazardous waste container in each SAA is clearly labeled as hazardous waste as described in WID procedures. Weekly inspections are performed to verify proper labeling of containers.

25.2.2.17 Compliance with Emergency Response, Training, and Waste Analysis Plan Requirements, 40 CFR 262.34(a)(4) (HWMR-7, § 301)

Compliance with Subparts C (preparedness and prevention) and D (contingency plans and emergency procedures) of 40 CFR Part 265 and with Sections 40 CFR 265.16 (personnel training) and 268.7(a)(4) (waste analysis plan for prohibited waste under the land disposal restrictions) is required.

40 CFR Part 265, Subpart C, Preparedness and Prevention: WIPP is maintained and operated to minimize the possibility of fire, explosions, or any unplanned release of hazardous waste to the environment. Inspections of waste handling areas and equipment are conducted periodically in accordance with procedures in place. Any corrective actions needed are initiated via Plant Work Requests (PWRs).

WID has prepared a contingency plan which provides a list of emergency equipment at WIPP, along with a description and statement of capabilities of the equipment and the cognizant organization responsible for ensuring that the equipment is available and operable.

The following communication and alarm systems are available at the WIPP site: two-way communication by the public address system and its intercom phones and paging channels, an intra-plant telephone system, mine phones, local and facility-wide alarm systems, pagers and plectrons, and portable two-way radios. Inspection procedures are in place for the communication and alarm systems and the fire protection equipment and include provisions for testing and maintenance to ensure that equipment will be operable in an emergency. Spill control and decontamination equipment are inspected weekly, and the results are recorded on an inspection form.

Adequate aisle space is provided in the hazardous waste storage area at WIPP to allow for potential emergency response activities.

The DOE has established Memoranda of Understanding (MOUs) with off-site emergency response agencies for fire fighting, medical assistance, and law enforcement. An example is the mutual aid agreement between the City of Hobbs and the DOE, which provides for mutual ambulance, medical, fire, rescue, and hazardous material response services. All outside agencies with which MOUs have been made have received copies of the *WIPP RCRA Contingency Plan* and the *WIPP Emergency Plan.*

40 CFR Part 265, Subpart D, Contingency Plan and Emergency Procedures: A contingency plan has been developed for the WIPP site and is maintained at all controlled document locations. The purpose of the document is to define responsibilities, provide guidance for the coordination of activities, and minimize hazards to human health and the environment from fires, explosions, or any sudden or non-sudden release of hazardous waste or hazardous waste constituents. The *WIPP RCRA Contingency Plan* describes actions that must be taken in response to fires, explosions, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents to air, soil, or water. It describes agreements with local authorities; lists names, addresses, and phone numbers of persons qualified to act as Emergency Coordinators; provides a list of emergency equipment at the facility; and includes an evacuation plan.

Copies of the *WIPP RCRA Contingency Plan* have been provided to all outside agencies with which WIPP has agreements for assistance in an emergency situation. A copy of the plan is maintained at WIPP controlled document locations. WID has the distribution list for the plan and is responsible for updating the controlled copies.

The plan will be reviewed and revised if necessary whenever applicable regulations are revised; if the plan fails in an emergency; if the facility changes in a way that materially increases the potential for fires, explosions, or releases of hazardous waste or hazardous waste constituents or changes the response necessary in an emergency; or if the list of Emergency Coordinators or the list of emergency equipment changes.

A RCRA Emergency Coordinator is on site at WIPP 24 hours a day, 7 days a week. The coordinator is responsible for coordinating all emergency response measures. The primary RCRA Emergency Coordinator is the Facility Operations Shift Supervisor (FOSS).

Emergency Coordinators are thoroughly familiar with the *WIPP RCRA Contingency Plan.* The plan has provisions that meet the emergency procedure requirements such as communication of an emergency situation to employees, notification of the appropriate agency if assistance is needed, identification of hazardous materials, assessment of hazards, and notification of any incident that requires implementation of the *WIPP RCRA Contingency Plan.*

40 CFR 265.16, Personnel Training: Formal training at WIPP is conducted in accordance with a WID training procedures manual. Training includes General Employee Training (GET), other classroom training, and on-the-job training. Training is conducted by certified instructors. Certification requirements are established in a WID procedure.

The GET 101 course provides detailed training in such areas as communications, alarm systems, and emergency response. A WID procedure requires all personnel to attend GET 101 within 30 days of employment. WID employees must attend a refresher class annually. Other classroom training is offered for personnel in certain job categories that involve the management of hazardous waste, such as maintenance and waste operations. Annual refreshers are provided. Maintenance personnel are trained to provide repair and replacement services. Inspections are a part of job-specific training and emergency response personnel training.

WID maintains a listing of all hazardous waste management job titles, the names of employees assigned by job title to hazardous waste management jobs, and job descriptions that identify RCRA-related duties. Records on active and inactive personnel are kept in accordance with WID documents.

40 CFR 268.7(1)(4), Waste Analysis for Treating Prohibited Wastes in Tanks or Containers: This requirement for a waste analysis plan for the treatment of wastes prohibited from land disposal in tanks or containers is not applicable to WIPP as WIPP-generated hazardous waste is neither treated nor land disposed at this facility.

25.2.2.18 Extension of Storage Period, 40 CFR 262.34(b) (HWMR-7, § 301)

The 90-day storage period may be extended due to unforeseen, temporary, and uncontrollable circumstances.

WID procedures provide instruction for the shipment of hazardous waste off site prior to the 90-day deadline. However, on January 11, 1991, a 30-day extension was requested of the State because of the unexpected need for a new profile sheet for waste nickel-cadmium batteries. The approved TSDF for WIPP waste informed WID of this need 5 days before the expiration of the 90-day storage period for the batteries. The extension was granted on January 15, 1991. The hazardous waste was shipped off site within the 30-day extension period.

25.2.2.19 Restrictions and Requirements, 40 CFR 262.34(c)(1) (HWMR-7, § 301)

There are a number of restrictions and requirements for satellite accumulation areas. These include the limit of 55 gallons of hazardous or 1 quart of acutely hazardous waste [listed in 40 CFR

261.33(e)] and the requirement that the satellite accumulation area be located at or near the point of generation of the waste.

WID procedures are in place and weekly inspections are conducted to verify that the 55-gallon limit per SAA is not exceeded. None of the SAAs has a capacity that exceeds 55 gallons, and no acutely hazardous waste is generated at WIPP. The SAAs are located at or near the points of generation of the hazardous waste. In addition, WID procedures define the requirements for placing waste in an SAA. These procedures define the responsibilities of the waste generator.

25.2.2.20 Compliance with 40 CFR 265.171, 265.172, and 165.173(a), 40 CFR 262.34(c)(1)(i) (HWMR-7, § 301)

These requirements for hazardous waste generators from 40 CFR Part 265 pertain to the condition of the containers (265.171), compatibility of the waste with the container (265.172), and the necessity to keep the containers closed when not actually adding waste to or removing it from the containers [265.173(1)]. In addition, a container holding hazardous waste must not be opened, handled, or stored in a manner that could rupture the container or cause it to leak.

WID procedures are in place to ensure that containers used to hold hazardous waste in SAAs are in good condition. If a container is found to be damaged, it is repaired, or the waste is removed and transferred to another container. If the container is repaired, the date and nature of the repair are included in the area log. All SAA inspection reports on file at WIPP indicate that the requirement for containers holding hazardous waste to be kept in good condition is met. Weekly inspections confirm that this requirement is being met. No special liners are used in the waste containers. Procedures are in place that address waste/container compatibility and the requirement that containers be closed except when waste is being added or removed. Inspections are conducted on a regular basis to ensure compliance with these regulations for containers.

A WID procedure addresses the requirement that containers not be opened, handled, or stored in a manner that could cause the container to rupture or leak by requiring that containers be inspected before and after transportation from the SAA to the staging area. [See also Sections 25.2.4.53 through 25.2.4.58.]

25.2.2.21 Labeling of Container as "Hazardous Waste," 40 CFR 262.34(c)(1)(ii) (HWMR-7, § 301)

Labeling of each hazardous waste container as "hazardous waste" is required.

WID procedures are in place, and inspections are conducted regularly to verify that each container of hazardous waste is clearly labeled as hazardous waste. Weekly inspections are performed to verify proper labeling of containers.

25.2.2.22 Management of Waste, 40 CFR 262.34(c)(2) (HWMR-7, § 301)

If waste accumulates in one of the SAAs in excess of the 55-gallon or 1-quart limit, the container(s) containing the excess waste must be marked with the date on which excess waste began accumulating, and compliance with the 55-gallon or 1-quart limit must be restored within 3 days.

WID procedures are in place that address the 55-gallon limit in the SAAs. No acutely hazardous wastes are generated at WIPP. WID personnel verify that no SAA waste container is overfilled and that any waste generated at an SAA in excess of the 55-gallon limit is removed within 3 days in accordance with the regulations.

25.2.2.23 Recordkeeping Requirements, 40 CFR 262.40 (HWMR-7, § 301)

Manifests, test results, waste analyses, and reports must be kept on site for at least 3 years.

WID procedures are in place that address these requirements. Required records are maintained by WID on site for a minimum of 3 years, after which they may be retained on site until closure or microfiched and stored indefinitely.

WID is responsible for recordkeeping oversight.

25.2.2.24 Generator-Biennial Report, 40 CFR 262.41 (HWMR-7, § 301)

Each generator of hazardous waste that ships the waste off site to an approved TSDF must file a report to the EPA by March 1 of every even-numbered year, including a description of the results of waste minimization efforts.

WID procedures have been prepared to respond to these requirements. Implementation of these procedures with regard to biennial reporting is the responsibility of WID. The results of waste-minimization activities are included in the hazardous-waste generator biennial report. The most recent report was submitted in March 1994.

25.2.2.25 Exception Reporting, 40 CFR 262.42 (HWMR-7, § 301)

Exception reporting is required if a copy of the manifest is not returned to the generator within 35 days of the date of acceptance of the hazardous waste by the transporter.

A WID procedure addresses exception reporting. At this time, no exception reporting has been required.

25.2.2.26 Additional Reporting, 40 CFR 262.43 (HWMR-7, § 301)

The Administrator, as he/she deems necessary, may require generators to furnish additional reports concerning the quantities and disposition of wastes identified or listed in 40 CFR Part 261.0.

No additional reports have been requested to date.

25.2.3 Compliance with Standards Applicable to Transporters of Hazardous Waste, 40 CFR Part 263 (HWMR-7, § 401)

The standards and requirements specified under 40 CFR Part 263 are not applicable to WIPP because of DOE's decision to eliminate testing of TRU mixed wastes at WIPP. However, the requirements will become applicable when the generator sites begin shipping TRU mixed wastes to WIPP because WID will subcontract transportation of the wastes to a trucking and/or a rail company.

A summary of the requirements for transporters of hazardous or mixed wastes and the compliance status of each requirement is described in Table 25-4. Additional information is provided in the text.

TABLE 25-4. New Mexico Hazardous Waste Management Regulations (HWMRs) for Transporters of Hazardous/Mixed Waste, 40 CFR Part 263 - Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 263.10(a) (HWMR-7, § 401)	Compliance with DOT regulations	**UP TO DATE** *Dawn Enterprises Management Plan*, 6/17/93 [Section 25.2.3.1]
40 CFR 263.11 (HWMR-7, § 401)	EPA identification number	**ACHIEVED** NMD 986669604 [Section 25.2.3.2]
40 CFR 263.20-263.22 (HWMR-7, § 401)	Compliance with the manifest system and recordkeeping	**UP TO DATE** *Dawn Enterprises Management Plan*, 6/17/93 [Section 25.2.3.3]
40 CFR 263.30 (HWMR-7, § 401)	Immediate action after hazardous waste discharges	**NOT APPLICABLE** *Dawn Enterprises Management Plan*, Section 6.0 [Section 25.2.3.4]
40 CFR 263.31 (HWMR-7, § 401)	Discharge cleanup	**NOT APPLICABLE** Dawn's subcontract with RAMP Industries [Section 25.2.3.5]

25.2.3.1 Compliance with Department of Transportation (DOT) Regulations, 40 CFR 263.10(a) (HWMR-7, § 401)

Transporters of hazardous/mixed waste must comply with all applicable DOT regulations.

Dawn Enterprises was to have transported TRU waste to WIPP from the generator sites during the Test Phase that was originally planned for WIPP. The *Dawn Enterprises Management Plan* (Revision X, date June 17, 1993) incorporates the applicable DOT regulations from the Title 49 series of the Code of Federal Regulations.

Any transporter hired to ship TRU and TRU mixed waste from the generator sites to WIPP must comply with the DOT regulations.

25.2.3.2 EPA Identification Number, 40 CFR 263.11 (HWMR-7, § 401)

The transporter must have an EPA identification number from the EPA Administrator.

Dawn Enterprises was contracted to transport TRU and TRU mixed waste from the generator sites to WIPP during the test phase originally planned for WIPP. Their EPA identification number is NMD 986669604. Any transporter hired to ship TRU and TRU mixed waste to WIPP must have an EPA identification number.

25.2.3.3 Compliance with the Manifest System and with Recordkeeping Requirements, 40 CFR 263.20-263.22 (HWMR-7, § 401)

The transporter must comply with all relevant manifest and recordkeeping requirements.

The *Dawn Enterprises Management Plan* indicates that they will comply with requirements of the manifest system and specifies that the following records are maintained as required: "audits, management assessments, inspection reports/checklists, purchase orders, maintenance reports, NDE reports, training, and copies of Hazardous Waste Manifests." Any transporter hired to ship TRU and TRU mixed waste to WIPP must comply with these requirements.

25.2.3.4 Immediate Action after Hazardous Waste Discharges, 40 CFR 263.30 (HWMR-7, § 401)

The transporter will take appropriate immediate action in the event of a discharge of hazardous waste (or hazardous constituents) during transportation.

Section 6 of the *Dawn Enterprises Management Plan* describes emergency response after a hazardous materials spill. The section specifies immediate actions to be taken by the transporter

to protect human health and the environment, such as notifying the local authorities, diking the discharge area, and notifying the National Response Center (by telephone) and the DOT (in writing). Any transporter that ships TRU and TRU mixed waste to WIPP must have these capabilities. Due to DOE's decision not to conduct the test phase at WIPP, no waste has been shipped to WIPP to date; no mixed waste discharges have occurred.

25.2.3.5 Discharge Cleanup, 40 CFR 263.31 (HWMR-7, § 401)

> *A transporter must clean up any hazardous waste discharge that occurs during transportation or must take any action(s) required by Federal, State, or local officials to render the discharge nonhazardous to human health and the environment.*

In the event of a hazardous waste constituent discharge during transportation, Dawn Enterprises has a subcontract in place with RAMP Industries to handle any cleanup activities required. Any transporter of TRU and TRU mixed waste to WIPP must be capable of ensuring adequate cleanup of any hazardous or mixed waste released to the environment during a transportation incident or accident. Due to DOE's decision not to conduct the test phase at WIPP, no waste has been shipped to WIPP to date; no mixed waste discharges have occurred. (See also Section 25.2.3.4.)

25.2.4 Compliance Status of the Regulatory Requirements for Interim-Status Treatment/Storage/Disposal Facilities (TSDFs), 40 CFR Part 265 (HWMR-7, §§ 601 and 602)

The WIPP is an interim-status facility. All applicable requirements for a TSDF are described in this section.

Table 25-5 summarizes each of the applicable requirements under 40 CFR Part 265 and provides the compliance status of each. The text that follows the table provides additional detail.

TABLE 25-5. New Mexico Hazardous Waste Management Regulations (HWMRs) for Interim-Status TSDFs, 40 CFR Part 265 - Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.10 (HWMR-7, § 601)	Applicability	[Section 25.2.4.1; see also Sections 25.2.4.2 through 25.2.4.9]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.11 (HWMR-7, § 601)	EPA identification number	**ACHIEVED** NM4890139088 [Section 25.2.4.2]
40 CFR 265.12 (HWMR-7, § 601)	Required notices to the off-site source(s)	**NOT APPLICABLE** None to date [Section 25.2.4.3]
40 CFR 265.13 (HWMR-7, § 601)	General waste analysis	**UP TO DATE** *WIPP Waste Analysis Plan*; *Waste Characterization Sampling and Analysis Guidance Manual*; *Quality Assurance Program Plan for the Experimental Waste Characterization Program* [Section 25.2.4.4]
40 CFR 265.14 (HWMR-7, § 601)	Security	**ACHIEVED** 8-foot-high chain-link fence, 24-hour surveillance system, and signs in Spanish and English posted at 50-foot intervals [Section 25.2.4.5]
40 CFR 265.15 (HWMR-7, § 601)	General inspection requirements	**UP TO DATE** Inspection procedures; inspection logs [Section 25.2.4.6]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.16 (HWMR-7, § 601)	Personnel training	**UP TO DATE** Procedures, manuals, and employer records [Section 25.2.4.7]
40 CFR 265.17 (HWMR-7, § 601)	General requirements for ignitable, reactive, or incompatible wastes	**UP TO DATE** *WIPP Waste Acceptance Criteria*; no incompatible wastes identified [Section 25.2.4.8]
40 CFR 265.18 (HWMR-7, § 601)	Location standards	**NOT APPLICABLE** Allows WIPP to be used as a TSDF [Section 25.2.4.9]
40 CFR 265.31 (HWMR-7, § 601)	Maintenance and operation of facility	**UP TO DATE** *WIPP Waste Acceptance Criteria* and *WID Contingency Plan* [Section 25.2.4.10]
40 CFR 265.32 (HWMR-7, § 601)	Required equipment	**UP TO DATE** WID procedures [Section 25.2.4.11]
40 CFR 265.33 (HWMR-7, § 601)	Testing and maintenance of equipment	**UP TO DATE** WID procedures [Section 25.2.4.12]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.34 (HWMR-7, § 601)	Access to communications or alarm system	**UP TO DATE** Public address system, intercom, phones, telephones, alarm systems, pagers and plectrons, portable two-way radios [Section 25.2.4.13]
40 CFR 265.35 (HWMR-7, § 601)	Required aisle space	**UP TO DATE** Adequate aisle space to be maintained [Section 25.2.4.14]
40 CFR 265.37 (HWMR-7, § 601)	Arrangements with local authorities	**ACHIEVED** MOUs in place with local authorities [Section 25.2.4.15]
40 CFR 265.51 (HWMR-7, § 601)	Purpose and implementation of the contingency plan	**ACHIEVED** *WIPP Contingency Plan* in place to minimize hazards [Section 25.2.4.16]
40 CFR 265.52 (HWMR-7, § 601)	Content of the contingency plan	**ACHIEVED** *WIPP Contingency Plan* [Section 25.2.4.17]
40 CFR 265.53 (HWMR-7, § 601)	Copies of contingency plan	**ACHIEVED** Copy provided to each outside agency with an agreement to provide emergency assistance to WIPP [Section 25.2.4.18]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.54 (HWMR-7, § 601)	Amendment of contingency plan	**UP TO DATE** *WIPP Contingency Plan* [Section 25.2.4.19]
40 CFR 265.55 (HWMR-7, § 601)	Emergency Coordinator	**ACHIEVED** Facility Operations Shift Supervisor [Section 25.2.4.20]
40 CFR 265.56 (HWMR-7, § 601)	Emergency procedures	**UP TO DATE** *WIPP Contingency Plan* [Section 25.2.4.21]
40 CFR 265.71 (HWMR-7, § 601)	Use of manifest system	**NOT APPLICABLE** WID procedures; no shipments to date [Section 25.2.4.22]
40 CFR 265.72 (HWMR-7, § 601)	Manifest discrepancies	**NOT APPLICABLE** WID procedures; no shipments to date [Section 25.2.4.23]
40 CFR 265.73 (HWMR-7, § 601)	Operating record	**UP TO DATE** WID procedures [Section 25.2.4.24]
40 CFR 265.74 (HWMR-7, § 601)	Availability, retention, and disposition of records	**UP TO DATE** WID procedures [Section 25.2.4.25]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.75 (HWMR-7, § 601)	TSDF biennial report	**NOT APPLICABLE** WID procedures [Section 25.2.4.26]
40 CFR 265.76 (HWMR-7, § 601)	Unmanifested waste report	**NOT APPLICABLE** No waste shipments to date [Section 25.2.4.27]
40 CFR 265.77 (HWMR-7, § 601)	Additional reports	**NOT APPLICABLE** No additional reporting to date [Section 25.2.4.28]
40 CFR 265.90 (HWMR-7, § 601)	Applicability of the ground-water monitoring system	**NOT APPLICABLE** Ground-water monitoring waiver [Section 25.2.4.29]
40 CFR 265.91 (HWMR-7, § 601)	Ground-water monitoring system	**NOT APPLICABLE** Ground-water monitoring waiver [Section 25.2.4.30]
40 CFR 265.92 (HWMR-7, § 601)	Sampling and analysis	**NOT APPLICABLE** Ground-water monitoring waiver [Section 25.2.4.31]
40 CFR 265.93 (HWMR-7, § 601)	Preparation, evaluation, and response	**NOT APPLICABLE** Ground-water monitoring waiver [Section 25.2.4.32]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.94 (HWMR-7, § 601)	Recordkeeping and reporting	**NOT APPLICABLE** Ground-water monitoring waiver [Section 25.2.4.33]
40 CFR 265.110 (HWMR-7, § 601)	Applicability of the closure/post-closure requirements	**UP TO DATE** *RCRA Compliance Manual* [Section 25.2.4.34]
40 CFR 265.111 (HWMR-7, § 601)	Closure performance standard	**UP TO DATE** *RCRA Compliance Manual* [Section 25.2.4.35]
40 CFR 265.112 (HWMR-7, § 601)	Closure plan; amendment of plan	**UP TO DATE** *RCRA Compliance Manual* [Section 25.2.4.36]
40 CFR 265.113 (HWMR-7, § 601)	Time allowed for closure	**UP TO DATE** *RCRA Compliance Manual* [Section 25.2.4.37]
40 CFR 265.114 (HWMR-7, § 601)	Disposal or decontamination of equipment, structures, and soils	**UP TO DATE** *RCRA Compliance Manual* [Section 25.2.4.38]
40 CFR 265.115 (HWMR-7, § 601)	Certification of closure	**NOT APPLICABLE** *RCRA Compliance Manual* [Section 25.2.4.39]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.116 (HWMR-7, § 601)	Survey plat	NOT APPLICABLE Clean closure [Section 25.2.4.40]
40 CFR 265.117 (HWMR-7, § 601)	Postclosure care and use of property	NOT APPLICABLE Clean closure [Section 25.2.4.41]
40 CFR 265.118 (HWMR-7, § 601)	Postclosure plan; amendment of plan	NOT APPLICABLE Clean closure [Section 25.2.4.42]
40 CFR 265.119 (HWMR-7, § 601)	Postclosure notices	NOT APPLICABLE Clean closure [Section 25.2.4.43]
40 CFR 265.120 (HWMR-7, § 601)	Certification of completion of postclosure care	NOT APPLICABLE Clean closure [Section 25.2.4.44]
40 CFR 265.142 (HWMR-7, § 601)	Cost estimate for closure	NOT APPLICABLE Exemption as Federal facility [Section 25.2.4.45]
40 CFR 265.143 (HWMR-7, § 601)	Financial assurance for closure	NOT APPLICABLE Exemption as Federal facility [Section 25.2.4.46]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.144 (HWMR-7, § 601)	Cost estimate for postclosure care	**NOT APPLICABLE** Exemption as Federal facility [Section 25.2.4.47]
40 CFR 265.145 (HWMR-7, § 601)	Financial assurance for postclosure care	**NOT APPLICABLE** Exemption as Federal facility [Section 25.2.4.48]
40 CFR 265.146 (HWMR-7, § 601)	Use of a mechanism for financial assurance of both closure and postclosure care	**NOT APPLICABLE** Exemption as Federal facility [Section 25.2.4.49]
40 CFR 265.147 (HWMR-7, § 601)	Liability requirements	**NOT APPLICABLE** Exemption as Federal facility [Section 25.2.4.50]
40 CFR 265.148 (HWMR-7, § 601)	Incapacity of owners or operators, guarantors, or financial institutions	**NOT APPLICABLE** Exemption as Federal facility [Section 25.2.4.51]
40 CFR 265.149 [HWMR-5, § 602(A)]	Use of State-required mechanisms	**NOT APPLICABLE** Omission from State regulations and exemption as Federal facility [Section 25.2.4.52]
40 CFR 265.150 [HWMR-5, § 602(B)]	State assumption of responsibility	**NOT APPLICABLE** Omission from State regulations and exemption as Federal facility [Section 25.2.4.53]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.171 (HWMR-7, § 601)	Condition of containers	**UP TO DATE** WID procedures [Section 25.2.4.54]
40 CFR 265.172 (HWMR-7, § 601)	Compatibility of waste with containers	**UP TO DATE** WID procedures [Section 25.2.4.55]
40 CFR 265.173 (HWMR-7, § 601)	Management of containers	**UP TO DATE** WID procedures; training [Section 25.2.4.56]
40 CFR 265.174 (HWMR-7, § 601)	Inspections	**UP TO DATE** WID procedures [Section 25.2.4.57]
40 CFR 265.176 (HWMR-7, § 601)	Special requirements for ignitable or reactive waste	**UP TO DATE** *Waste Acceptance Criteria for WIPP* [Section 25.2.4.58]
40 CFR 265.177 (HWMR-7, § 601)	Special requirements for incompatible wastes	**UP TO DATE** WID procedures [Section 25.2.4.59]
40 CFR 265.190-265.445 (HWMR-7, § 601)	Tank systems; surface impoundments; waste piles; land treatment; incinerators; thermal treatment; chemical, physical, and biological treatment; underground injection; and drip pads	**NOT APPLICABLE** None of these used at WIPP [Section 25.2.4.60]

TABLE 25-5 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 265.1032 (HWMR-7, § 601)	Standards (air emission) for process vents	NOT APPLICABLE No process vents at WIPP [Section 25.2.4.61]
40 CFR 265.1052-265.1062 (HWMR-7, § 601)	Air emission standards for equipment leaks	NOT APPLICABLE [Section 25.2.4.62]

25.2.4.1 Applicability, 40 CFR 265.10 (HWMR-7, § 601)

The regulations in Subpart B apply to owners and operators of all hazardous waste facilities, except as § 265.1 provides otherwise.

The portions of Subpart B applicable to the WIPP are identified in §§ 265.11 through 265.18 as discussed in Sections 25.2.4.2 through 25.2.4.9 below.

25.2.4.2 EPA Identification Number, 40 CFR 265.11 (HWMR-7, § 601)

Each TSDF must have an EPA identification number.

The EPA identification number for WIPP is NM4890139088.

25.2.4.3 Required Notices, 40 CFR 265.12 (HWMR-7, § 601)

Notices required are notification of the Regional Administrator at least 4 weeks in advance of the date of arrival of waste from a foreign source and notification of a new owner or operator of the requirements under 40 CFR Parts 265 and 270.

Before transferring ownership or operation of the facility, the DOE and/or WID will notify the new owner or operator in writing of the requirements of this part and those of Part 270.

25.2.4.4 General Waste Analysis, 40 CFR 265.13 (HWMR-7, § 601)

A detailed chemical and physical analysis of a representative sample of the wastes is required before a TSDF may treat, store, or dispose of waste. The owner/operator of the TSDF must inspect and, if necessary, analyze the waste received to ensure that it matches the identity of the waste described in the accompanying manifest. The owner/operator must follow a written waste analysis plan to ensure compliance with these requirements.

General waste analysis is addressed in the *WIPP Waste Analysis Plan* (DOE, 1993d). Sampling and analysis is conducted in accordance with the *Waste Characterization Program Sampling and Analysis Guidance Manual* (DOE, 1992a). All activities are performed in accordance with the *Quality Assurance Program Plan for the Experimental Waste Characterization Program* (DOE, 1991d). Characterization methods consist of process knowledge; visual examination (including weighing of individual items); real-time radiography; and headspace gas sampling of drums, the inner container in drums, and bins.

25.2.4.5 Security, 40 CFR 265.14 (HWMR-7, § 601)

Security measures are required to prevent the possibility of unknowing and/or unauthorized entry by persons or livestock onto the active portion of the facility. A 24-hour surveillance system or barrier is required, and the facility must be posted.

The WIPP is enclosed within an 8-foot-high chain-link fence, and 24-hour surveillance is conducted by guards trained to minimize unauthorized entry onto the facility. Signs with the legend "Danger--Unauthorized Personnel Keep Out" in both Spanish and English are posted at 50-foot intervals. The perimeter fence, gates, and signs are inspected daily for evidence of tampering or structural damage in accordance with a WIPP procedure.

25.2.4.6 General Inspection Requirements, 40 CFR 265.15 (HWMR-7, § 601)

The owner/operator must inspect the facility for malfunctions, deterioration, operator errors, and discharges that cause actual or potential releases of hazardous constituents to the environment or a threat to human health. A written schedule must be developed and followed for inspecting all monitoring, safety, and emergency equipment; security devices; and operating/structural equipment

needed to prevent, detect, or respond to environmental or human health hazards. The inspections must be recorded in an inspection log or summary and kept for at least 3 years.

The WID implements inspection procedures for all monitoring, safety, and emergency equipment; security devices; and operating and structural equipment. Written schedules have been developed that indicate the frequency of routine inspections. Inspections may be conducted more frequently than indicated but are not performed less frequently.

Each group develops procedures that outline the types of problems that will be examined during inspections of its equipment and systems and maintains its own inspection information.

Completed inspection sheets include a signature, date, and time of inspection; observations made; and the date and nature of any repairs or other remedial actions. All log sheets are maintained for at least 3 years.

25.2.4.7 Personnel Training, 40 CFR 265.16 (HWMR-7, § 601)

Personnel training must be provided to facility personnel within 6 months of their employment or new assignment; personnel must not work in unsupervised positions until the training has been completed. The training program must be designed to ensure that facility personnel can respond effectively to an emergency. The program must be directed by a person trained in hazardous waste management procedures. The job title for each position at the facility that is related to hazardous waste management, the name of the employee filling the position, a written description of the training required, and records that document that the training and/or job experience has been completed are also required. These records must be kept until closure for current personnel and for at least 3 years for former employees.

Formal training is conducted in accordance with a training manual. The training includes both GET for all WIPP employees, other classroom training, and on-the-job training. Training policy indicates that WIPP training will be conducted by certified instructors. Certification requirements are established in a WID procedure.

GET 101 provides detailed training in such areas as communications, alarm systems, and emergency response. A WID procedure requires all personnel to attend GET 101 within 30 days of employment. A refresher class must be attended annually. Other classroom training is offered for personnel in certain job categories. Annual refresher courses are provided.

Maintenance personnel are trained to provide repair and replacement services. Inspections are a part of job-specific training and emergency response personnel training.

WID maintains a listing of all hazardous waste management job titles, names of employees assigned by job title to hazardous waste management jobs, and job descriptions that identify RCRA duties. Records on active and inactive personnel are kept in accordance with WID documents.

25.2.4.8 General Requirements for Ignitable, Reactive, or Incompatible Wastes, 40 CFR 265.17 (HWMR-7, § 601)

Precautions must be taken to prevent accidental ignition or reaction of ignitable or reactive waste. Any mixture or commingling of incompatible wastes must be conducted to avoid the generation of extreme heat or pressure, fire or explosion, violent reaction, uncontrolled toxic airborne materials, uncontrolled flammable fumes or gases, damage to the structural integrity of the device or facility, or threat to human health or the environment.

WIPP is precluded from accepting ignitable, corrosive, or reactive waste as specified in the *Waste Acceptance Criteria*. In an analysis of the compatibility of the waste categories with each other and with waste containers, no incompatibilities were identified.

"No Smoking" signs have been placed conspicuously at the Hazardous Waste Staging Area and at all SAAs where there could be a hazard from ignitable or reactive wastes. A WID procedure requires a weekly inspection to verify that legible "No Smoking" signs are posted near the SAAs. A WID procedure also prohibits combining incompatible wastes generated at WIPP.

25.2.4.9 Location Standards, 40 CFR 265.18 (HWMR-7, § 601)

No hazardous waste may be emplaced in such structures as a salt-bed formation or an underground mine except at the DOE Waste Isolation Pilot Plant in New Mexico.

WIPP is specified in this requirement as the only facility of this type that may be used for the placement of hazardous waste.

25.2.4.10 Maintenance and Operation of Facility, 40 CFR 265.31 (HWMR-7, § 601)

Facilities must be maintained and operated to minimize the possibility of fire, explosions, or any unplanned release of hazardous constituents to air, soil, or surface water that could threaten human health or the environment.

Section 1 of the *WID Contingency Plan* address this requirement. In addition, the *Waste Acceptance Criteria* document prohibits the receipt of explosive or otherwise reactive waste, liquids, non-radioactive pyrophoric or other ignitable wastes, or compressed gases at WIPP as a TSDF. Inspection of waste-handling areas and equipment are conducted as described by WID procedures. Corrective actions are initiated via Plant Work Requests.

25.2.4.11 Required Equipment, 40 CFR 265.32 (HWMR-7, § 601)

All facilities must be equipped with an internal communications or alarm system for immediate emergency instruction; devices to summon external emergency assistance; fire extinguishers and fire-control, spill-control, and decontamination equipment; and water or foam equipment, sprinklers, or water-spray systems.

WID has prepared a contingency plan which provides a list of emergency equipment at WIPP, along with a description and statement of capabilities of the equipment and the cognizant organization responsible for ensuring that the equipment is available and operable. Procedures are in place for providing guidance to WIPP personnel for testing emergency equipment.

25.2.4.12 Testing and Maintenance of Equipment, 40 CFR 265.33 (HWMR-7, § 601)

All facility communications or alarm systems and fire-control, spill-control, and decontamination equipment must be tested and maintained as needed to ensure its proper operation during an emergency.

The WID maintains inspection procedures in place for communication and alarm systems and for fire protection equipment that include provisions for testing and maintenance to ensure that the equipment will be operable in an emergency. Spill control and decontamination equipment are inspected weekly and the results recorded on an inspection form.

25.2.4.13 Access to Communications or Alarm Systems, 40 CFR 265.34 (HWMR-7, § 601)

Immediate access to a communications or internal alarm system is required for all personnel involved when handling hazardous waste. If just one employee is ever on the premises during operations, he/she must have immediate access to a device (e.g., telephone) for summoning external emergency assistance.

The following communication and alarm systems are available at the WIPP site: two-way communication by the public address system and its intercom phones and paging channels, an intra-plant telephone system, mine phones, local and facility-wide alarm systems, pagers and plectrons, and portable two-way radios. The WIPP RCRA Contingency Plan provides an inspection schedule for this equipment and describes the location of alarms, telephones, etc., at WIPP. All SAA inspection reports on file at WIPP indicate that this requirement is met for hazardous wastes generated at WIPP. There is more than one employee at the site at all times.

25.2.4.14 Required Aisle Space, 40 CFR 265.35 (HWMR-7, § 601)

Aisle space must be maintained to allow the unobstructed movement of personnel and of fire-protection, spill-control, and decontamination equipment to any area of facility operation unless aisle space is not needed for these purposes.

A procedure is in place to address the areas of the WIPP where mixed waste containers will be maintained so that adequate aisle space will be provided for emergency response.

25.2.4.15 Arrangements with Local Authorities, 40 CFR 265.37 (HWMR-7, § 601)

Arrangements with local authorities must be made for the provision of emergency services if needed. Requirements include familiarizing the local authorities with the layout of the facility, properties of hazardous waste to be handled, possible evacuation routes, and other information needed for emergency responses.

The RCRA Contingency Plan addresses this requirement. The DOE has established MOUs with all appropriate off-site emergency response agencies for fire fighting, medical assistance, and law enforcement. Examples include a MOU with the Guadalupe Medical Center Emergency Radiological Treatment Center for the WIPP, which provides for the treatment of radiologically contaminated personnel, and a mutual aid agreement between the City of Hobbs and the DOE,

which provides for mutual ambulance, medical, fire, rescue, and hazardous material response services. All outside agencies with which MOUs have been made have received copies of the RCRA Contingency Plan and the *WIPP Emergency Plan* (WID, 1992). The official MOUs are in the process of being revised.

25.2.4.16 Purpose and Implementation of the Contingency Plan, 40 CFR 265.51 (HWMR-7, § 601)

Each owner/operator must have a contingency plan for his/her TSDF. The contingency plan must be designed to minimize hazards to human health or the environment from fires, explosions, or unplanned releases of hazardous constituents to the environment. The provisions of the plan must be carried out whenever a fire, explosion, or release of hazardous constituents could threaten human health or the environment.

The RCRA Contingency Plan has been developed for the WIPP. It is maintained at all controlled document locations. The purpose of the document is to define responsibilities; provide guidance for coordination of activities; and minimize hazards to human health and the environment from fires, explosions, or any unplanned release of hazardous waste or hazardous waste constituents.

25.2.4.17 Content of the Contingency Plan, 40 CFR 265.52 (HWMR-7, § 601)

The contingency plan must describe the actions to be taken by facility personnel in response to fires, explosions, or any unplanned releases of hazardous constituents to the environment. The plan must describe arrangements agreed to by local authorities and emergency response units and must list the current names, addresses, and phone numbers (work and home) of all Emergency Coordinators. All emergency equipment must be listed, along with the location, description, and capabilities of all equipment. An evacuation plan for facility personnel must be included.

The RCRA Contingency Plan describes actions that must be taken in response to fires, explosions, or any unplanned or sudden or non-sudden release of hazardous waste or hazardous waste constituents to air, soil, or water and describes agreements with local authorities. It also lists the names, addresses, and phone numbers of persons qualified to act as Emergency Coordinators, provides a list of emergency equipment at the facility, and includes an evacuation

plan. The project also maintains the *WIPP Spill Prevention, Control, and Countermeasures (SPCC) Plan* (WID, 1993a).

The RCRA Contingency Plan also describes the agreements between WIPP and local police and fire department, hospitals, contractors, and State and local emergency response teams. The MOUs in place are currently being revised.

An evacuation plan for WIPP personnel is included in the RCRA Contingency Plan as required.

25.2.4.18 Copies of the Contingency Plan, 40 CFR 265.53 (HWMR-7, § 601)

Copies of the contingency plan and all revisions to the plan must be maintained at the facility and submitted to all local police and fire departments, hospitals, and State and local emergency response teams that may be called upon to provide emergency services.

Copies of the RCRA Contingency Plan are maintained at WIPP. A copy of the plan is maintained at controlled document locations. WID maintains a distribution list for the plan and is responsible for updating the controlled copies. Copies of the RCRA Contingency Plan have been provided to all outside agencies with which WIPP has agreements for assistance in an emergency situation.

25.2.4.19 Amendment of Contingency Plan, 40 CFR 265.54 (HWMR-7, § 601)

The contingency plan must be reviewed and immediately revised, if necessary, whenever applicable regulations are revised; the plan fails in an emergency; the facility changes in a way that increases the potential for fire, explosions, or release of hazardous waste; or the list of Emergency Coordinators or emergency equipment changes.

As described in the RCRA Contingency Plan, the plan will be reviewed and revised if necessary whenever applicable regulations are revised; the plan fails in an emergency; the facility changes in a way that materially increases the potential for fires, explosions, or releases of hazardous waste or hazardous waste constituents or changes the response necessary in an emergency; the list of Emergency Coordinators changes; or the list of emergency equipment changes.

25.2.4.20 Emergency Coordinator, 40 CFR 265.55 (HWMR-7, § 601)

At least one employee (on the facility premises or on call) must be designated as the Emergency Coordinator, with the responsibility for coordinating all emergency response measures. The Emergency Coordinator must be familiar with the contingency plan, all operations and activities at the facility, the location and characteristics of waste handled, location of all facility records, and the facility layout. The Emergency Coordinator must have the authority to commit the resources needed to carry out the contingency plan.

A RCRA Emergency Coordinator is on site at the WIPP facility 24 hours a day, 7 days a week. The coordinator is responsible for coordinating all emergency response measures. The primary RCRA Emergency Coordinator is the Facility Operations Shift Supervisor (FOSS). The FOSS is the coordinator who will be on duty at the time of any incident that requires implementation of the RCRA Contingency Plan.

Persons qualified to act as the RCRA Emergency Coordinator are listed in the RCRA Contingency Plan. These employees have the requisite experience and authorization power to perform their role as Emergency Coordinator.

25.2.4.21 Emergency Procedures, 40 CFR 265.56 (HWMR-7, § 601)

In the event of an imminent or actual emergency situation, the Emergency Coordinator or designee must notify facility personnel via internal alarms or communications systems and must notify State or local agencies if their help is needed. A release, fire, or explosion mandates that the Emergency Coordinator obtain appropriate information, assess possible hazards, make any notifications required, prevent the spread or reoccurrence of the incident, monitor if necessary, recover waste, and record details regarding the incident in the facility's operating record. The owner or operator must note specific information about any incident that requires the contingency plan to be implemented. This information must be recorded in the facility's operating record. A written report must be submitted to the Regional EPA office and the NMED within 15 days of the incident. The State Emergency Response Commission (SERC) must be contacted rather than the NMED in the event of any spill incident that may endanger human health or the environment.

WIPP Emergency Coordinators are thoroughly familiar with the RCRA Contingency Plan. The plan has provisions that meet the emergency procedure requirements such as communicating information about the emergency to employees, notifying appropriate agencies to obtain assistance, identifying hazardous materials, assessing hazards, and making the necessary notifications. The appropriate agencies include the Local Emergency Planning Committee (LEPC), the Carlsbad Police Department, the Carlsbad Fire Department, and the Eddy County Sheriff.

Each department at WIPP is responsible for the cleanup of spills in its area. Disposal of the released material is the responsibility of WID.

All emergency equipment listed in the contingency plan is kept clean and fit for its intended use.

As described in the RCRA Contingency Plan, a daily log is maintained in the Central Monitoring Room (CMR) at WIPP. The FOSS signs into the log before beginning his/her duty shift. All incidents, regardless of whether or not they activate the RCRA Contingency Plan, are recorded in the CMR log, along with routine maintenance activities.

The RCRA Contingency Plan addresses the requirement that the SERC be notified in the event of a spill that would endanger human health or the environment. The SERC will contact the NMED if their assistance is needed.

25.2.4.22 Use of Manifest System, 40 CFR 265.71 (HWMR-7, § 601)

If a facility receives hazardous constituents accompanied by a manifest, the owner or operator or designee must sign and date each copy of the manifest to certify receipt of the waste, note any significant discrepancies in the manifest, return at least one copy of the manifest to the transporter, send a copy of the manifest to the generator within 30 days, and retain a copy of the manifest for at least 3 years.

A WID procedure provides guidance on the proper management and retention of hazardous waste manifests. Another WID procedure provides instructions for receiving, surveying, and inspecting TRUPACT II containers at WIPP, which includes proper disposition of the hazardous waste. Further, the *Waste Acceptance Criteria for the Waste Isolation Pilot Plant* requires generator sites to provide a manifest for shipments of transuranic mixed waste. This requirement will become applicable when the WIPP facility receives a waste shipment.

25.2.4.23 Manifest Discrepancies, 40 CFR 265.72 (HWMR-7, § 601)

Manifest discrepancies are differences between the quantity or type of hazardous waste designated in the manifest and that actually received. Upon discovering a significant discrepancy, the owner or operator must try to reconcile the discrepancy with the generator or transporter. If not resolved within 15 days, the owner or operator must notify the Regional Administrator.

A WID procedure provides instruction and guidance for handling manifest discrepancies. The generator will be notified of all discrepancies, and the discrepancy will be recorded in the "remarks" section of the appropriate form. If the discrepancy cannot be resolved within 15 days, it will be reported in writing to the NMED. This requirement will become applicable when the WIPP facility receives a waste shipment.

25.2.4.24 Operating Record, 40 CFR 265.73 (HWMR-7, § 601)

The owner/operator must keep a written operating record at the facility. Information relating to the type and amount of hazardous waste, its location and quantity at each location, cross references to specific manifest documents and records and the results of waste analyses, summary reports and details of all incidents requiring implementation of the contingency plan, records and results of inspections, monitoring and analytical data and any corrective actions taken, and closure cost estimates must be included. In addition, records pertaining to an off-site treatment, land disposal, or storage facility must be kept in the operating record.

A WID procedure establishes guidelines for maintaining the written operating record. It incorporates applicable conditions of the No-Migration Determination for the WIPP (EPA, 1990b). The information that must be recorded and maintained at the facility, such as the location of each mixed-waste container within the repository and inspection records and results, is specified. These records are maintained at various locations at the facility by different organizations according to the type of record and point of generation.

25.2.4.25 Availability, Retention, and Disposition of Records, 40 CFR 265.74 (HWMR-7, § 601)

All records required under this part, including plans, must be retained and made available for inspection by EPA designees. The retention period for all records required under this part is automatically extended during the course of any unresolved enforcement action or as requested by the Administrator. Records of waste disposal locations and quantities must be submitted to the appropriate agencies upon closure of the facility.

This requirement is addressed in a WID procedure that establishes guidelines for maintaining a written operating record. The procedure includes provisions for furnishing all records upon request to the EPA and NMED, as well as provisions for submitting a copy of waste emplacement locations and quantities to appropriate State and Federal regulators. In the event of an enforcement action, records will be retained indefinitely.

25.2.4.26 TSDF Biennial Report, 40 CFR 265.75 (HWMR-7, § 601)

The owner or operator of a TSDF must submit a copy of a biennial report to the Regional Administrator by March 1 of each even-numbered year using EPA Form 8700-13B.

A WID procedure establishes guidelines for the preparation and submittal of a biennial report for a facility that operates as a generator and a TSD. The procedure indicates that all information needed to meet this requirement shall be provided, including a description and the quantity of each mixed waste received during the reporting year and the method and date of treatment, storage, or disposal at the facility. The TSDF biennial report is not required until after TRU mixed waste is received at WIPP.

25.2.4.27 Unmanifested Waste Report, 40 CFR 265.76 (HWMR-7, § 601)

A report must be submitted to the Regional Administrator for any hazardous waste accepted for treatment, storage, or disposal that is not accompanied by a hazardous waste manifest.

According to the *Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, a hazardous waste manifest shall be transmitted with each shipment of TRU mixed waste to WIPP. Therefore, no mixed waste will be accepted that is not accompanied by a hazardous waste manifest. No waste shipments have been received at WIPP to date.

25.2.4.28 Additional Reports, 40 CFR 265.77 (HWMR-7, § 601)

Additional reports required of the owner or operator of a TSDF by the Regional Administrator are reports relating to releases, fire, or explosions; ground-water contamination and monitoring data; facility closure; and air emissions under Subparts AA and BB of this part.

Releases, fires, and explosions will be reported as specified in the WIPP Contingency Plan. Whenever it becomes necessary to partially close WIPP, the DOE will notify the NMED, in writing, at least 60 days prior to the date on which such partial or final closure will commence, as specified by WID procedure. Subparts AA and BB do not apply at WIPP; therefore no reporting is required at WIPP under these subparts.

25.2.4.29 Applicability of the Ground-Water Monitoring System, 40 CFR 265.90 (HWMR-7, § 601)

A ground-water monitoring system is required by the owner or operator of a surface impoundment, landfill, or land treatment facility used to manage hazardous waste. All or part of the ground-water monitoring requirements may be waived if the owner/operator can demonstrate a low potential for migration of hazardous constituents from the facility via the uppermost aquifer to water supply wells or to surface water. The demonstration, in writing, must be certified by a qualified geologist or geotechnical engineer.

A ground-water monitoring waiver was prepared and is located at WIPP. This waiver contains the information to demonstrate that a very low potential for migration of hazardous waste or hazardous constituents from the WIPP site via ground water exists. This information was also provided to the EPA in the *WIPP No-Migration Variance Petition* (DOE, 1990f).

25.2.4.30 Ground-Water Monitoring System, 40 CFR 265.91 (HWMR-7, § 601)

The ground-water monitoring system required of landfills managing hazardous waste is described in detail.

A ground-water monitoring waiver was prepared and is located at the WIPP facility. This waiver obviates the need for a ground-water monitoring system at WIPP.

25.2.4.31 Sampling and Analysis, 40 CFR 265.92 (HWMR-7, § 601)

Sampling and analytical requirements for the ground-water monitoring system are described in detail.

A ground-water monitoring waiver was prepared and is located at WIPP. This waiver obviates the need for a ground-water monitoring system at WIPP.

25.2.4.32 Preparation, Evaluation, and Response, 40 CFR 265.93 (HWMR-7, § 601)

The owner or operator must prepare an outline of a ground-water quality assessment program, describing a more comprehensive ground-water monitoring program than that described in previous sections of this part.

A ground-water monitoring waiver was prepared and is located at WIPP. This waiver obviates the need for the ground-water quality assessment program described in this section.

25.2.4.33 Recordkeeping and Reporting, 40 CFR 265.94 (HWMR-7, § 601)

Recordkeeping and reporting of the results of ground-water monitoring is required.

A ground-water monitoring waiver was prepared and is located at WIPP. This waiver obviates the need for recordkeeping and reporting the results of ground-water monitoring.

25.2.4.34 Applicability of the Closure/Postclosure Requirements, 40 CFR 265.110 (HWMR-7, § 601)

Closure and postclosure requirements apply to the owners and operators of all hazardous and mixed-waste management facilities.

These requirements will apply to WIPP as a TSDF for mixed waste. Although closure and post-closure are planned after the implementation of the disposal phase at WIPP, plans for closure and postclosure are addressed in the *RCRA Compliance Manual*.

25.2.4.35 Closure Performance Standard, 40 CFR 265.111 (HWMR-7, § 601)

A closure performance standard is required to minimize the need for further maintenance; to control, minimize, or eliminate the post-closure escape of hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the environment; and to comply with the other closure requirements of this subpart.

Closure will be deemed complete when all hazardous waste and hazardous waste residues have been removed from the units, all equipment and structures associated with the operation of the units have been decontaminated, and unit closure certification has been submitted to and approved by the NMED.

25.2.4.36 Closure Plan; Amendment of Plan, 40 CFR 265.112 (HWMR-7, § 601)

The owner/operator of a hazardous or mixed-waste management facility must have a written closure plan. The plan, approved by the Regional Administrator or designee, may be amended subject to the Regional Administrator's approval.

WIPP has prepared a written closure plan to satisfy the RCRA closure plan requirement. The plan includes, but is not limited to, the following:

1) A description of how each hazardous waste management unit at the facility will be closed in accordance with the closure performance standard (see Section 25.2.4.34) and

2) A description of how final closure of the facility will be conducted.

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Should it become necessary to amend the closure plan at the WIPP, the DOE will submit a written notification of, or request for, a permit modification describing any change in operation, facility design, or storage/disposal designs that affect the closure plan. Partial and final closure activities are outlined in WID procedures.

The requirements for the removal of wastes and decontamination or dismantling of equipment are addressed by WID procedure.

25.2.4.37 Time Allowed for Closure, 40 CFR 265.113 (HWMR-7, § 601)

Within 90 days after receipt of the final volume of hazardous mixed waste at a hazardous waste management unit or facility, the owner or operator must treat, remove, or dispose of all hazardous/mixed wastes on site in accordance with the approved closure plan. Partial or final closure activities must be complete in accordance with the approved closure plan within 180 days of receipt of the final volume of waste. An extension of time may be allowed if the owner/operator can demonstrate that the activities required will take longer than the allotted time period and has taken and will continue to take all steps necessary to prevent threats to human health and the environment from the unclosed but nonoperational facility.

The time allowed for closure is addressed in the RCRA Compliance Manual. Milestone schedules for final and partial closure are included on the closure plan. The WIPP has applied for a variance from the 180-day closure requirement.

25.2.4.38 Disposal or Decontamination of Equipment, Structures, and Soils, 40 CFR 265.114 (HWMR-7, § 601)

During the partial and final closure periods, all contaminated equipment, structures, and soils must be properly disposed of or decontaminated. By removing all hazardous constituents during closure, the owner/operator may become a mixed or hazardous waste generator and must handle all such waste in accordance with the requirements of 40 CFR Part 262.

The regulatory requirements for the disposal or decontamination of equipment, structures, and soils are addressed in WID procedures. This section is broken down into four subsections, which include the removal of hazardous waste residues; the decontamination of equipment, structures, and soils; personnel decontamination; and sampling and quality assurance.

25.2.4.39 Certification of Closure, 40 CFR 265.115 (HWMR-7, § 601)

Within 60 days of the completion of closure of each landfill unit and within 60 days of completion of final closure, the owner/operator must submit a certification that the hazardous or mixed waste unit has been closed in accordance with the

specifications in the approved closure plan. The certification must be sent to the Regional Administrator by registered mail and must be signed by the owner/operator and by an independent registered professional engineer.

DOE will submit the Certification of Closure to the Secretary of the NMED within 60 days of completion of closure activities.

25.2.4.40 Survey Plat, 40 CFR 265.116 (HWMR-7, § 601)

The owner/operator must submit a survey plat to the Regional Administrator and the authority with jurisdiction over local land use no later than the submittal of the certification of closure. The survey plat must indicate the location and dimensions of landfill cells or other hazardous waste disposal units with respect to permanently surveyed benchmarks. The plat must be prepared and certified by a professional land surveyor.

A survey plat may not be required for WIPP because the facility will be decontaminated at closure.

25.2.4.41 Postclosure Care and use of Property, 40 CFR 265.117 (HWMR-7, § 601)

Postclosure care for each hazardous/mixed-waste unit must begin after completion of closure and continue for 30 years after that date. All postclosure care must be performed in accordance with the postclosure plan for the facility.

Postclosure care and use of property may not be required for WIPP because the facility will be decontaminated at closure.

25.2.4.42 Postclosure Plan; Amendment of Plan, 40 CFR 265.118 (HWMR-7, § 601)

The owner/operator of a hazardous or mixed-waste management facility must have a written postclosure plan. The plan, approved by the Regional Administrator or designee, may be amended subject to the Regional Administrator's approval.

A postclosure plan may not be required for WIPP because the facility will be decontaminated at closure.

25.2.4.43 Postclosure Notices, 40 CFR 265.119 (HWMR-7, § 601)

A record of the type, location, and quantity of hazardous/mixed wastes disposed of within each unit must be submitted to the Regional Administrator and the authority with jurisdiction over local land use no later than 60 days after submittal of the certification of closure. Within the same timeframe, the owner/operator must also record a notation in the deed to the facility that the facility has been used to manage hazardous/mixed wastes and that the record of type, location, and quantity of waste disposal has been filed; the owner/operator must also certify that this notation has been recorded as required.

Postclosure notices may not be required for WIPP because the facility will be decontaminated at closure.

25.2.4.44 Certification of Completion of Postclosure Care, 40 CFR 265.120 (HWMR-7, § 601)

Within 60 days of the completion of postclosure of each landfill unit and within 60 days of completion of final post-closure, the owner/operator must submit a certification that the hazardous or mixed-waste unit has been closed in accordance with the specifications in the approved postclosure plan. The certification must be sent to the Regional Administrator by registered mail and must be signed by the owner/operator and by an independent registered professional engineer.

Postclosure certification may not be required for WIPP because the facility will be decontaminated at closure.

25.2.4.45 Cost Estimate for Closure, 40 CFR 265.142 (HWMR-7, § 601)

The owner/operator must provide a detailed written estimate of the cost of closing the facility.

As a Federal facility, WIPP is exempt from the requirement to provide cost estimates for closure actions.

25.2.4.46 Financial Assurance for Closure, 40 CFR 265.143 (HWMR-7, § 601)

The owner/operator of each facility must establish financial assurance for closure of the facility.

As a Federal facility, WIPP is exempt from the requirement to provide financial assurance for closure actions.

25.2.4.47 Cost Estimate for Postclosure Care, 40 CFR 265.144 (HWMR-7, § 601)

The owner/operator of each TSDF must provide a detailed written cost estimate for postclosure monitoring and maintenance of the facility.

As a Federal facility, WIPP is exempt from the requirement to provide a cost estimate for postclosure care.

25.2.4.48 Financial Assurance for Postclosure Care, 40 CFR 265.145 (HWMR-7, § 601)

The owner/operator of a hazardous or mixed waste disposal unit must establish financial assurance for postclosure care of the disposal unit(s).

As a Federal facility, WIPP is exempt from the requirement to provide financial assurance for postclosure care.

25.2.4.49 Use of a Mechanism for Financial Assurance of both Closure and Postclosure Care, 40 CFR 265.146 (HWMR-7, § 601)

The owner/operator may satisfy the requirements for financial assurance by using a mechanism such as a trust fund, security bond, letter of credit, etc.

As a Federal facility, WIPP is exempt from the requirement to provide mechanisms for financial assurance of both closure and postclosure care.

25.2.4.50 Liability Requirements, 40 CFR 265.147 (HWMR-7, § 601)

An owner/operator of a TSDF must demonstrate financial responsibility for bodily injury and property damage from accident occurrences arising from operations of the TSDF.

As a Federal facility, WIPP is exempt from the requirement to provide liability insurance.

25.2.4.51 Incapacity of Owners or Operators, Guarantors, or Financial Institutions, 40 CFR 265.148 (HWMR-7, § 601)

An owner/operator must notify the Regional Administrator by certified mail of the commencement of a bankruptcy proceeding that names him/her as a debtor within 10 days after commencement of the proceeding. In the event of bankruptcy of the guarantors or financial institutions, the owner/operator must establish financial assurance of liability coverage within 60 days after the event.

As a Federal facility, WIPP is exempt from the requirement to provide financial status information.

25.2.4.52 Use of State-required Mechanisms, 40 CFR 265.149 [HWMR-7, § 602(A)]

For a facility located in a State with financial assurance requirements but where the EPA administers the requirements of this subpart on closure and post-closure, an owner/operator may use State-required financial mechanisms to meet these requirements.

As a Federal facility, WIPP is exempt from the requirement to provide financial status information. Furthermore, this Federal requirement under 40 CFR Part 265 is specifically omitted from the State regulations under § 602(A) of HWMR-7.

25.2.4.53 State Assumption of Responsibility, 40 CFR 265.150 [HWMR-7, § 602(B)]

If a State assumes responsibility for an owner/operator's compliance with the closure, post-closure, or liability requirements of this part, the owner/operator will be in compliance if the Regional Administrator determines that the State's assumption of responsibility is adequate.

As a Federal facility, WIPP is exempt from the requirement to provide financial status information. Furthermore, this Federal requirement under 40 CFR Part 265 is specifically omitted from the State regulations under § 602(B) of HWMR-7.

25.2.4.54 Condition of Containers, 40 CFR 265.171 (HWMR-7, § 601)

If a container holding hazardous or mixed waste is not in good condition or begins to leak, the waste within it must be transferred to a container that is in good condition, or the waste must be managed in another way that complies with the requirements in this part.

Containers must be in good condition (no visible deterioration) in accordance with WID procedures. The date and nature of repairs performed on a container or other remedial action is included in the Area Log.

All SAA inspection reports on file at WIPP indicate that this requirement is met for hazardous wastes generated at WIPP.

25.2.4.55 Compatibility of Waste with Containers, 40 CFR 265.172 (HWMR-7, § 601)

A container made of or lined with materials that will not react with and are compatible with the waste to be stored within it must be used.

No special liners are placed in waste containers to hold hazardous wastes generated at WIPP, but measures are taken to ensure that the containers to be used are compatible with the waste generated. These measures are described in WID procedures.

A chemical compatibility analysis of the waste forms to be sent to WIPP as a TSDF and the container materials to be used was conducted. Each generator and storage site has produced a comprehensive list of all possible chemicals present in its waste. Low carbon steel and

polyethylene were added to evaluate chemical compatibility between the waste materials and the container materials. Potential incompatibilities were analyzed using EPA-600/2-80-076, *A Method for Determining the Compatibility of Hazardous Waste*.

25.2.4.56 Management of Containers, 40 CFR 265.173 (HWMR-7, § 601)

A container holding hazardous or mixed waste must be kept closed during storage except when it is necessary to add or remove waste. Containers holding hazardous or mixed waste must not be opened, handled, or stored so as to rupture the container or cause it to leak.

A WID procedure prohibits opening containers located in the SAAs at WIPP except to add or sample the WIPP-generated hazardous waste.

The requirement that hazardous waste containers not be opened, handled, or stored in a manner that would threaten the integrity of the containers is addressed in the WID procedure that requires that containers be inspected before and after transportation from the SAA to the Hazardous Waste Staging Area.

TRU mixed waste shipped to WIPP will be contained in sealed containers. WID procedures do not provide for accessing containers. None of the procedures directs or allows the removal of lids from the containers.

All TRU mixed-waste-handling operators are thoroughly trained in the safe use of TRU mixed-waste handling and transport equipment to minimize the potential for rupture or leak of a container.

25.2.4.57 Inspections, 40 CFR 265.174 (HWMR-7, § 601)

Areas in which containers holding hazardous or mixed wastes are stored must be inspected at least weekly to ensure that there are no leaks or other signs of deterioration caused by corrosion or other factors.

WID procedures are in place that ensure that the regulatory requirements for inspections are met. Inspections of containers holding hazardous waste are performed weekly, as described in WID procedures. All inspection report files are maintained by WID.

25.2.4.58 Special Requirements for Ignitable or Reactive Waste, 40 CFR 265.176 (HWMR-7, § 601)

Containers holding ignitable or reactive waste must be located at least 15 meters (50 feet) from the facility's property line.

All storage containers holding hazardous waste are located more than 15 meters from the property line at WIPP.

The *Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (DOE, 1991b) is designed to ensure that ignitable or reactive waste will not be accepted at the WIPP. It states that explosives, compressed gases, or non-radionuclide pyrophorics are not allowed. It also says that residual liquids and radionuclides in pyrophoric form are limited to less than 1 percent by volume and weight, respectively.

25.2.4.59 Special Requirements for Incompatible Wastes, 40 CFR 265.177 (HWMR-7, § 601)

Incompatible wastes must not be placed in the same container and must be segregated. Hazardous waste must not be placed in an unwashed container that previously held incompatible waste or material.

A WID procedure prohibits mixing WIPP-generated hazardous wastes with materials that may be incompatible. The procedure includes a list of incompatible wastes that may be generated on site.

WID procedures prohibit placing hazardous waste in any unwashed container that previously held an incompatible material. WID procedures also specify that a storage container holding a hazardous waste that is incompatible with any waste or other materials stored nearby must be separated or protected from the other materials by means of a dike, berm, wall, or other barrier or device. WID procedures state that chemicals/materials must be compatible with any waste materials, container materials, and TRUPACT-II materials. A chemical compatibility analysis of the waste forms and container materials has been performed.

25.2.4.60 Tank Systems; Surface Impoundments; Waste Piles; Land Treatment; Landfills; Incinerators; Thermal Treatment; Chemical, Physical, and Biological Treatment; Underground Injection; and Drip Pads, 40 CFR 265.190-265.445 (HWMR-7, § 601)

Requirements are specified for tank systems; surface impoundments; waste piles; land treatment; incinerators; thermal treatment; chemical, physical, and biological treatment; underground injection; and drip pads.

None of these regulatory requirements is applicable to WIPP because none of these systems will be used at this facility.

25.2.4.61 Air Emission Standards for Process Vents, 40 CFR 265.1032 (HWMR-7, § 601)

Air emission standards have been set for TSDFs with process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping operations managing hazardous wastes with organic concentrations of at least 10 parts per million by weight (ppmw).

WIPP does not have process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping operations managing hazardous wastes with organic concentrations of at least 10 ppmw. Therefore, the requirements in Subpart AA of 40 CFR Part 265 (265.1032 through 265.1035) do not apply.

25.2.4.62 Air Emission Standards for Equipment Leaks, 40 CFR 265.1052-265.1062 (HWMR-7, § 601)

Air emission standards have been promulgated for leaks from TSDF equipment that contains or contacts hazardous wastes with organic concentrations of at least 10 percent by weight.

The air emissions standards for equipment leaks do not apply at WIPP because the types of equipment listed, such as pumps in light liquid service and compressors, are not used at WIPP. Therefore, none of the standards and requirements of 40 CFR Part BB (265.1050 through 265.1064) pertains to WIPP.

25.2.5 Compliance with the Hazardous/Mixed Waste Permit Program, 40 CFR Part 270 (HWMR-7, §§ 901 and 902)

The requirements of 40 CFR Part 270 pertain to general RCRA permitting requirements for TSDFs and include provisions for submitting applications, standard permit conditions, and monitoring and reporting requirements. The compliance status of each applicable requirement is summarized in Table 25-6; detailed information is provided in the text.

TABLE 25-6. The New Mexico Hazardous/Mixed Waste Permit Program, 40 CFR Part 270 - Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 270.1 (HWMR-7, § 901)	Purpose and scope of the RCRA permit program regulations	**UP TO DATE** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* [Section 25.2.5.1]
40 CFR 270.10 (HWMR-7, § 901)	General application requirements	**ACHIEVED** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* [Section 25.2.5.2]
40 CFR 270.11 (HWMR-7, § 901)	Signatories to permit applications and reports	**ACHIEVED** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* [Section 25.2.5.3]
40 CFR 270.13 (HWMR-7, § 901)	Contents of Part A of the permit application	**ACHIEVED** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* [Section 25.2.5.4]

TABLE 25-6 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 270.14 (HWMR-7, §§ 901 and 902)	Contents of Part B: general requirements	**ACHIEVED** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* [Section 25.2.5.5]
40 CFR 270.15 (HWMR-7, § 901)	Specific Part B information requirements for containers	**ACHIEVED** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant*, Chapters D and F [Section 25.2.5.6]
40 CFR 270.23 (HWMR-7, § 901)	Specific Part B information requirements for miscellaneous units	**ACHIEVED** *RCRA Part B Permit Application for the Waste Isolation Pilot Plant*, Chapter D, Section 9 [Section 25.2.5.7]
40 CFR 270.30 (HWMR-7, § 901)	Conditions applicable to all permits	**NOT APPLICABLE** Will be applicable when a permit is issued [Section 25.2.5.8]
40 CFR 270.31 (HWMR-7, § 901)	Requirements for recording and reporting of monitoring results	**NOT APPLICABLE** Will be applicable when a permit is issued [Section 25.2.5.9]

TABLE 25-6 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
40 CFR 270.42 (HWMR-7, §§ 901 and 902)	Permit modification at the request of the permittee	NOT APPLICABLE Will be applicable when a permit is issued [Section 25.2.5.10]
40 CFR 270.71 (HWMR-7, § 901)	Operation during interim status	UP TO DATE Interim status achieved by timely filing of Part A; compliance with interim-status requirements [Section 25.2.5.11]
40 CFR 270.72 (HWMR-7, § 901)	Changes during interim status	UP TO DATE WID procedure [Section 25.2.5.12]

25.2.5.1 Purpose and Scope of the RCRA Permit Program Regulations, 40 CFR 270.1 (HWMR-7, § 901)

The purpose and scope of the RCRA permit program regulations are defined, and the regulations are summarized.

Prior to the receipt of TRU mixed waste, WIPP must retain interim status or be permitted as a mixed-waste facility. The DOE contends (with the concurrence of the EPA) that WIPP is an interim-status facility. As required for an interim-status facility, the DOE submitted a RCRA permit application to the EPA and to the NMED for the test phase. This application will be revised, amended, or rewritten and resubmitted prior to the disposal phase at the express request of the Secretary of the NMED. The DOE is in the process of preparing a revised permit application but will not submit it until it has been formally requested.

25.2.5.2 General Application Requirements, 40 CFR 270.10 (HWMR-7, § 901)

General application requirements include the requirement that an interim-status facility submit a RCRA Part A permit application within 6 months after the date of publication of regulations requiring its compliance with 40 CFR Part 265. Submittal of the Part B application is required at least 6 months from the date of request. The permit application must be considered complete before a permit may be issued, which includes providing all applicable information described in 40 CFR 270.13 through 270.29, using the appropriate application form. Records must be kept of all data used to complete permit applications (including updates) for at least 3 years from the date of signature on the application.

On July 25, 1990, the NM Environmental Improvement Division (EID; now renamed as the New Mexico Environment Department, NMED) received the EPA's final authorization for the State's mixed-waste program. In a letter to DOE dated August 27, 1990, the EID required the submittal of Parts A and B of the *RCRA Permit Application for the Waste Isolation Pilot Plant* by January 22 and February 28, 1991, respectively. The DOE submitted the Part A portion of the application to the EID and to the Regional EPA office in Dallas, Texas, on January 22, 1991. The Part B portion was submitted to the EID and the EPA Regional Office on February 26 and February 27, 1991, respectively.

The RCRA permit application for the Test Phase was prepared to meet all applicable requirements specified in 40 CFR 270.13 through 270.29. The appropriate form was used for Part A; no form has been generated for Part B. Three revisions of the application have been sent to the regulatory agencies, the latest being the January 1993 revision.

A record of all data used to complete the application for the test phase is being maintained at WIPP. It will be kept for at least 3 years from the date of the signature in the application.

25.2.5.3 Signatories to Permit Applications and Reports, 40 CFR 270.11 (HWMR-7, § 901)

Signatories to permit applications shall be by a senior executive officer with responsibility for overall operations for a Federal agency and/or a responsible corporate officer for a corporation. Reports and plans required by permits (e.g., the annual waste minimization plan) and other information requested shall be signed by a duly authorized representative. Any person signing one of

these documents is required to make the certification statement specified in 40 CFR 270.11(d). (See also Section 2.2.3.3.)

The requirement calling for signatories to permit applications is met on pages 9 and 10 in Part A of the *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* for the test phase.

No reports have been required yet since WIPP is not yet acting as a TSDF for mixed waste, but the proper signatories will be provided in these documents. The certification statement, which was submitted with the *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* for the test phase, will appear as required in reports requested by the appropriate regulatory agency.

25.2.5.4 Contents of Part A of the Permit Application, 40 CFR 270.13 (HWMR-7, § 901)

The contents required for Part A of the RCRA permit application include the activities mandating a RCRA permit, identification of the facility and operator, SIC codes, status of the facility, a scale drawing and photographs of the facility, description of processes to be used, a specification of the hazardous wastes/constituents and the estimated quantity of such wastes, a listing of all permits received or applied for and other environmental permits, a topographic map, and a brief description of the nature of the business.

Part A of the *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* contains all of the information required by 40 CFR 270.13. The *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* has been reviewed by the NMED and was determined to be administratively complete.

25.2.5.5 Contents of Part B: General Requirements, 40 CFR 270.14 (HWMR-7, §§ 901 and 902)

The general requirements for Part B of a RCRA permit application include a facility description, chemical and physical analyses of the hazardous waste to be handled, a copy of relevant plans (e.g., waste analysis plan; contingency plan; closure plan) security procedures and equipment, inspection schedule, procedures/structures/equipment to minimize hazards and releases, traffic patterns, geologic data, training program, ground-water

monitoring information and data, and information regarding solid waste management units.

The *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* for the test phase has been reviewed by the NMED and has been determined to be administratively complete.

25.2.5.6 Specific Part B Information Requirements for Containers, 40 CFR 270.15 (HWMR-7, § 901)

Specific Part B information requirements for containers include a detailed description of the containment system; a demonstration to show that the wastes contain no free liquids; drawings or data showing ignitable, reactive or incompatible wastes; and procedures used for incompatible wastes.

The requirement calling for specific container information is met in Chapters D and F of the *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* for the test phase. The *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* was determined to be administratively complete by the NMED.

25.2.5.7 Specific Part B Information Requirements for Miscellaneous Units, 40 CFR 270.23 (HWMR-7, § 901)

Specific Part B information requirements for miscellaneous units include a detailed description of the unit; detailed hydrologic, geologic, and meteorologic assessments and land-use maps for the region surrounding the site; information on potential exposure pathways to hazardous constituents and the potential magnitude and nature of such exposures; a report on the effectiveness of any treatment methodology proposed; and any additional information requested for evaluating the compliance of the unit with the environmental protection standards of 40 CFR 264.601.

The requirement calling for specific miscellaneous unit information is met in Section 9 of Chapter D of the *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* for the test phase. The *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* was determined to be administratively complete by the NMED.

25.2.5.8 Conditions Applicable to all Permits, 40 CFR 270.30 (HWMR-7, § 901)

Conditions applicable to all permits are specified and include duty to comply, duty to reapply, minimization of releases, proper operation and maintenance, permit actions, property rights, duty to provide information, inspection and entry, monitoring and records, signatory requirements, and reporting requirements.

This requirement will become applicable when a permit is issued by the NMED and the EPA.

25.2.5.9 Requirements for Recording and Reporting of Monitoring Results, 40 CFR 270.31 (HWMR-7, § 901)

Requirements for recording and reporting monitoring results will be specified in the RCRA permit.

These requirements for recording and reporting monitoring results are met and discussed in Section 9e of Chapter D of the *RCRA Part B Permit Application for the Waste Isolation Pilot Plant* for the test phase, which was determined to be administratively complete by the NMED. These requirements will become applicable when a permit is issued by the NMED and the EPA.

25.2.5.10 Permit Modification at the Request of the Permittee, 40 CFR 270.42 (HWMR-7, §§ 901 and 902)

After a RCRA permit has been finalized, the permittee may request that it be modified. Three classes of modifications are identified in Appendix I to 40 CFR 270.42. Class 1, the least significant of the permit modifications, covers minor modifications such as the correction of typographical errors; changes to conform with agency guidelines or regulations; or procedural changes that increase the frequency of monitoring, reporting, sampling, or maintenance activities. Class 1 modifications require notification of the Director within 7 days after the change has been made; all persons on the facility mailing list must be notified within 90 calendar days after the Director approves the request.

Class 2 modifications are more extensive and significant and apply to changes needed to allow timely response to common variations in the types and quantities of wastes managed, technological advancements, and changes in the regulations (e.g., changes in

emergency procedures or removal of equipment from the emergency equipment list). They require that the permittee submit a modification request to the Director, announce a 60-day comment period, notify all persons on the facility mailing list, publish the notice in a major local newspaper of general circulation, and hold a public meeting.

Class 3 modifications are the most significant and potentially impactive and substantially alter the facility or its operation (e.g., extending the closure period or a final compliance date; creating a new landfill or other type of unit or increasing the capacity of a pre-existing one). The notification and other requirements are similar to those for Class 2 modifications.

Permit modification will not be applicable at WIPP until after a RCRA permit has been finalized for this facility.

25.2.5.11 Operation During Interim Status, 40 CFR 270.71 (HWMR-7, § 901)

During interim status, the facility shall not treat, store, or dispose of hazardous waste or employ processes not specified or exceed the design capabilities described in Part A of the permit application. The facility will comply with all applicable standards described in 40 CFR Part 265.

The WIPP has waste analysis and waste acceptance criteria in place to ensure that all waste managed at the facility is within the bounds specified in the Part A permit application. Further, the WIPP has programs and procedures in place that address compliance with the applicable interim-status standards of 40 CFR Part 265. (See Section 25.2.4.)

25.2.5.12 Changes During Interim Status, 40 CFR 270.72 (HWMR-7, § 901)

Changes that may be made during interim status are treatment, storage, or disposal of new wastes; increases in the design capacity of processes used or changes in the processes used; changes in ownership or operational control; changes made in accordance with an interim-status corrective action order; or the addition of newly regulated units if and only if a revised Part A permit application is submitted and approved by the Director. Such changes may not be made if reconstruction of the facility results

(i.e., the capital investment in the changes to the facility may not exceed 50 percent of the capital cost of a comparable, entirely new, hazardous waste management facility).

Until a final RCRA permit is issued, WIPP will remain subject to the interim-status requirements stipulated under 40 CFR Part 265. The WIPP has submitted the required permit application and has a process in place to manage and make appropriate notifications should design or operation processes change; however, no notifications will be issued at this time, until the Secretary of the NMED requests revisions. Any changes to the disposal facility which cannot be made under the guidelines of interim status will be deferred until a permit is issued, or proposed changes will be submitted to NMED for review and approval as required by the interim status provisions. Once a permit is issued, the DOE can propose modifications to the permit to the NMED for approval.

25.2.6 Compliance Status of the Underground Storage Tank (UST) Regulatory Requirements

This section of the report will examine the New Mexico UST requirements as they pertain to the WIPP. Compliance status is summarized in Table 25-7, and additional detail is provided in the text that follows the table.

TABLE 25-7. New Mexico Underground Storage Tank Regulations (USTRs) - Compliance Status Summary

CITATION	REQUIREMENT	COMPLIANCE STATUS
Part I, *General Provisions*		
USTR, Sec. 103	Applicability	**UP TO DATE** Two USTs at WIPP, one for diesel fuel, the other for unleaded fuel [Section 25.2.6.1]
Part II, *Registration of Tanks*		
USTR, Sec. 200	Existing tanks	**ACHIEVED** Two registered USTs [Section 25.2.6.2]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 201	Transfer of ownership	**NOT APPLICABLE** Original ownership [Section 25.2.6.3]
USTR, Sec. 202	New UST system	**ACHIEVED** Registration for two new USTs: transmitted on June 18, 1992 [Section 25.2.6.4]
USTR, Sec. 203	Substantially modified UST systems	**NOT APPLICABLE** No system modifications made [Section 25.2.6.5]
USTR, Sec. 204	Notification of spill or release	**NOT APPLICABLE** No releases during this period [Section 25.2.6.6]
USTR, Sec. 205	Emergency repairs and tank replacement	**NOT APPLICABLE** No emergencies requiring repair or tank replacement [Section 25.2.6.7]
USTR, Sec. 206	Application forms	**ACHIEVED** Proper application forms used [Section 25.2.6.8]
USTR, Sec. 207	Registration certificate	**ACHIEVED** Certificate displayed [Section 25.2.6.9]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Part III, *Annual Fee*		
USTR, Sec. 300	Payment of fee	**ACHIEVED** Fees paid annually by January 31 [Section 25.2.6.10]
USTR, Sec. 301	Amount of fee	**ACHIEVED** $200.00 paid per year ($100 per UST) [Section 25.2.6.11]
USTR, Sec. 302	Late payment penalties	**NOT APPLICABLE** No late payments made [Section 25.2.6.12]
Part IV, *UST Systems: Design, Construction, Installation and Certification*		
USTR, Sec. 400(a)	Performance standards to ensure that new UST systems tanks are properly designed and constructed	**ACHIEVED** ASTM and UL standards met by fiberglass-reinforced plastic tanks [Section 25.2.6.13]
USTR, Sec. 400(b)	Piping to be properly designed and constructed	**ACHIEVED** Fiberglass-reinforced plastic piping [Section 25.2.6.14]
USTR, Sec. 400(c)(1)(i)	Spill prevention equipment	**ACHIEVED** Spill catchment basin [Section 25.2.6.15]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 400(c)(1)(ii)	Overfill prevention equipment	**ACHIEVED** Model 310 extractor vent valve [Section 25.2.6.16]
USTR, Sec. 400(d)	Installation of tanks and piping	**ACHIEVED** Installer's oath on NMED tank registration form [Section 25.2.6.17]
USTR, Sec. 400(e)	Certificate of installation	**ACHIEVED** Certification of inspector; NMED UST Bureau representative present at installation of new UST systems [Section 25.2.6.18]
USTR, Sec. 401(a)	Upgrading of existing UST systems	**NOT APPLICABLE** Two new USTs installed on February 10, 1992 [Section 25.2.6.19]
USTR, Sec. 401(b)	Upgrading requirements for steel tanks	**NOT APPLICABLE** Single wall fiberglass-reinforced plastic tanks replaced with double-walled plastic tanks on February 10, 1992 [Section 25.2.6.20]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 401(c)	Upgrading requirements for metal piping	**NOT APPLICABLE** Metal piping replaced with fiberglass-reinforced plastic piping on February 10, 1992 [Section 25.2.6.21]
USTR Sec. 401(d)	Spill and overfill protection equipment	**ACHIEVED** Current spill and overfill protection equipment meets 1998 deadline [Section 25.2.6.22]
USTR, Sec. 402	Certification of compliance with notification requirements	**ACHIEVED** All required notifications made [Section 25.2.6.23]
Part V, *General Operating Requirements*		
USTR, Sec. 500(a)	Spill and overflow control	**ACHIEVED** WIPP procedure [Section 25.2.6.24]
USTR, Sec. 501(a)	Corrosion protection	**ACHIEVED** Rubber boots covering all metal fittings [Section 25.2.6.25]
USTR, Sec. 501(b)	Inspections of cathodic protection systems	**NOT APPLICABLE** No cathodic protection required [Section 25.2.6.26]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 501(c)	Inspections of impressed-current cathodic protection systems	**NOT APPLICABLE** No cathodic protection required for fiberglass-reinforced systems [Section 25.2.6.27]
USTR, Sec. 501(d)	Records of operation of the cathodic protection system	**NOT APPLICABLE** No cathodic protection required for fiberglass-plastic systems [Section 25.2.6.28]
USTR, Sec. 502	Compatibility	**ACHIEVED** Fiberglass-reinforced plastic system compatible with both diesel and unleaded fuel [Section 25.2.6.29]
USTR, Sec. 503(a)	Repairs allowed	**NOT APPLICABLE** No repairs performed on the UST system [Section 25.2.6.30]
USTR, Sec. 503(b)	Repairs to fiberglass-reinforced plastic tanks	**NOT APPLICABLE** No major repairs performed on the UST system [Section 25.2.6.31]
USTR, Sec. 503(c)	Replacement or repair of pipe sections and fittings	**NOT APPLICABLE** No repairs conducted on the pipes or fittings. [Section 25.2.6.32]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 503(d)	Tightness testing after repairs	**NOT APPLICABLE** No repairs conducted on the tanks or piping [Section 25.2.6.33]
USTR, Sec. 503(e)	Testing of any repaired cathodically protected UST system	**NOT APPLICABLE** No cathodic protection required [Section 25.2.6.34]
USTR, Sec. 503(f)	Records of all repairs	**UP TO DATE** Records of all repairs maintained for life of the UST system [Section 25.2.6.35]
USTR, Sec. 504(a)	Reporting requirements	**ACHIEVED** All required reports submitted [Section 25.2.6.36]
USTR, Sec. 504(b)	Recordkeeping requirements	**ACHIEVED** All required records maintained [Section 25.2.6.37]
USTR, Sec. 504(c)	Availability and maintenance of records	**ACHIEVED** Records maintained at the site [Section 25.2.6.38]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 505(a)	Inspections, monitoring, and testing of USTs	**ACHIEVED** NMED personnel allowed to inspect, sample, and monitor the UST system [Section 25.2.6.39]
USTR, Sec. 505(c)	Inspections of UST installations, repairs or modifications, or removals or system closures	**ACHIEVED** NMED representative present at installation of new UST system [Section 25.2.6.40]
Part VI, *Release Detection*		
USTR, Sec. 600(a)	General requirements of all UST systems	**ACHIEVED** Interstitial monitoring system installed [Section 25.2.6.41]
USTR, Sec. 600(b)	Notification of releases	**ACHIEVED** No releases to date [Section 25.2.6.42]
USTR, Sec. 600(c)	Schedule for required release detection	**ACHIEVED** UST system designed so no release detection for piping is required; interstitial monitoring used for tanks [Section 25.2.6.43]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 600(d)	Failure to comply with release-detection requirements	**NOT APPLICABLE** Release-detection equipment used [Section 25.2.6.44]
USTR, Sec. 601(a)	Requirements for tanks of petroleum UST systems	**ACHIEVED** Interstitial monitoring used [Section 25.2.6.45]
USTR, Sec. 601(b)	Requirements for piping of petroleum UST systems	**ACHIEVED** See Sections 25.2.6.47 and 25.2.6.48 [Section 25.2.6.46]
USTR, Sec. 601(b)(1)	Requirements for pressurized piping	**NOT APPLICABLE** USTs under suction piping [Section 25.2.6.47]
USTR, Sec. 601(b)(2)	Requirements for suction piping	**ACHIEVED** Engineering drawings confirm compliance with this requirement [Section 25.2.6.48]
USTR, Sec. 602	Requirements for hazardous substance UST systems	**NOT APPLICABLE** No UST systems used for hazardous substances at the WIPP [Section 25.2.6.49]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 603	Methods of release detection for tanks	**ACHIEVED** Interstitial monitoring used [Section 25.2.6.50]
USTR, Sec. 603(a)	Inventory control	**ACHIEVED** Inventory control used as contingency method only [Section 25.2.6.51]
USTR, Sec. 603(b)	Manual tank gauging	**NOT APPLICABLE** [Section 25.2.6.52]
USTR, Sec. 603(c)	Tank tightness testing	**NOT APPLICABLE** Tank tightness testing not necessary when interstitial monitoring is used [Section 25.2.6.53]
USTR, Sec. 603(d)	Automatic tank gauging	**NOT APPLICABLE** Interstitial monitoring used [Section 25.2.6.54]
USTR, Sec. 603(e)	Vapor monitoring	**NOT APPLICABLE** Interstitial monitoring used [Section 25.2.6.55]
USTR, Sec. 603(f)	Ground-water monitoring	**NOT APPLICABLE** Ground-water variance [Section 25.2.6.56]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 603(g)	Interstitial monitoring	**ACHIEVED** Release from any portion of the tank that regularly contains product detected by interstitial monitoring [Section 25.2.6.57]
USTR, Sec. 603(h)	Other methods of detecting releases	**NOT APPLICABLE** Interstitial monitoring used [Section 25.2.6.58]
USTR, Sec. 604	Methods of release detection for piping	**NOT APPLICABLE** Release detection for piping not required because of design [Section 25.2.6.59]
USTR, Sec. 605	Release detection recordkeeping	**ACHIEVED** Required records maintained [Section 25.2.6.60]
Part VII, *Release Reporting, Investigation, and Confirmation*		
USTR, Sec. 700	Reporting of suspected releases	**NOT APPLICABLE** No releases to date [Section 25.2.6.61]
USTR, Sec. 701	Investigation of off-site impacts	**NOT APPLICABLE** Offsite-impact information not requested by NMED [Section 25.2.6.62]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 702	Release investigation and confirmation steps	**NOT APPLICABLE** No releases to date [Section 25.2.6.63]
USTR, Sec. 703(a)	Reporting and cleanup of large spills and overfills	**NOT APPLICABLE** No large spills or overfills [Section 25.2.6.64]
USTR, Sec. 703(b)	Reporting and cleanup of small spills and overfills	**ACHIEVED** Small spills and overfills properly controlled and cleaned up [Section 25.2.6.65]
Part VIII, *Out-of-Service UST Systems and Closure*		
USTR, Sec. 800	Temporary closure	**NOT APPLICABLE** No temporary closure [Section 25.2.6.66]
USTR, Sec. 801(a)	Permanent closure and changes-in-service	**ACHIEVED** NMED notified before closure of old UST systems [Section 25.2.6.67]
USTR, Sec. 801(b)	Permanent closure of a tank	**ACHIEVED** Old UST system emptied, cleaned, and removed for permanent closure [Section 25.2.6.68]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR, Sec. 801(c)	Change in service	**NOT APPLICABLE** No change in service for UST systems [Section 25.2.6.69]
USTR, Sec. 802(a)	Assessing the site	**ACHIEVED** Site assessed prior to permanent closure of old UST systems [Section 25.2.6.70]
USTR, Sec. 802(b)	Corrective action	**UP TO DATE** UST area assessed before change in service [Section 25.2.6.71]
USTR, Sec. 803	Applicability to previously closed UST systems	**NOT APPLICABLE** No UST systems at WIPP closed before December 22, 1988 [Section 25.2.6.72]
USTR, Sec. 804	Closure records	**ACHIEVED** Tank closure; records maintained at the WIPP site [Section 25.2.6.73]
Part IX, *Financial Responsibility*		
USTR, Sec. 900	Applicability	**NOT APPLICABLE** Federal and State government entities exempt [Section 25.2.6.74]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
Part X, *Administrative Review*		
USTR, Sec. 1000	Informal review	**NOT APPLICABLE** Provision not invoked at WIPP [Section 25.2.6.75]
USTR, Sec. 1001	Review by Director	**NOT APPLICABLE** Provision not invoked at WIPP [Section 25.2.6.76]
Part XI, *Miscellaneous*		
USTR, Sec. 1100	Compliance with other regulations	See Chapters 2 through 24 and 25 through 38 for compliance with applicable Federal and State regulations, respectively. [Section 25.2.6.77]
USTR, Sec. 1101	Construction	**NOT APPLICABLE** [Section 25.2.6.78]
USTR, Sec. 1102	Severability	**NOT APPLICABLE** [Section 25.2.6.79]
Part XII, *Corrective Action for Petroleum UST Systems*		
USTR Sec. 1200(A)	Cleanup requirements for releases from petroleum UST systems	**NOT APPLICABLE** No releases during this period [Section 25.2.6.80]

TABLE 25-7 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
USTR Sec. 1200(B)-1222	Additional corrective action requirements for petroleum UST systems	**NOT APPLICABLE** No corrective actions necessary for current UST system [Section 25.2.6.81]
Part XIII, *Corrective Action for Hazardous Substance UST Systems*		
USTR Secs. 1300-1320	Corrective action for hazardous substance UST systems	**NOT APPLICABLE** No hazardous substance USTs at WIPP [Section 25.2.6.82]
Part XIV, *Certification for Tank Installers*		
USTR Secs. 1400-1417	Certification of tank installers and repairers	**ACHIEVED** Required certification information maintained [Section 25.2.6.83]
Part XV, *Ground Water Protection Act Regulations*		
USTR Sec. 1505	Priorities	**NOT APPLICABLE** [Section 25.2.6.84]
USTR Sec. 1508	Minimum site assessment	**NOT APPLICABLE** [Section 25.2.6.85]

25.2.6.1 Applicability, USTR Section 103; 40 CFR 280.10

Any owner or operator of an UST that contains a hazardous substance or petroleum product must meet the standards set by the New Mexico Environmental Improvement Board (EIB) in the New Mexico Underground Storage Tank Regulations (USTRs).

The WIPP has two 8,000-gallon USTs. One contains unleaded gasoline, and the other contains diesel fuel.

25.2.6.2 Existing Tanks, USTR Section 200

The owner of any UST must register such tank or tanks with the Underground Storage Tank section of the NMED within 3 months after April 14, 1988, the effective date of this Part II as first adopted, except that any owner who has filed the form of notice entitled "Notification for Underground Storage Tanks," prescribed by the EPA and described in 40 CFR Part 280, is not required to register a tank for which a notice has been filed, provided that the information provided is still current.

Registration becomes effective upon receipt of the first year's annual fee described in Sections 25.2.6.10 and 25.2.6.11. Registration must by renewed annually by payment of the annual fee until the permanent closure of the tank.

Both of the USTs at WIPP are registered with the Underground Storage Tank Bureau section of the NMED.

25.2.6.3 Transfer of Ownership, USTR Section 201

If ownership of the UST system changes, the new owner must re-register the tank with the division within 30 days of ownership transfer, using a form provided by the division.

This section is not applicable since ownership of the tanks has not been transferred.

25.2.6.4 New UST System, USTR Section 202

The owner must notify the division in writing at least 30 days before any new tank or UST system is installed and must register any new tank or UST system with the division prior to placing it in service.

Proper notification was provided to the NMED prior to the February 10, 1992, installation of the new UST system. The application for the new system was submitted on June 18, 1992, and the USTs were placed into service shortly thereafter.

25.2.6.5 Substantially Modified UST Systems, USTR Section 203

When an existing UST system is substantially modified or replaced, the owner must notify the division in writing of such modification or replacement at least 30 days prior to the modification or replacement. Emergency repairs or replacements made as described in Section 25.2.6.7 are exempt from these notification requirements.

Proper notification was provided to the NMED prior to the February 10, 1992, installation of the new UST system. The application for the new system was submitted on June 18, 1992, and the USTs were placed into service shortly thereafter.

25.2.6.6 Notification of Spill or Release, USTR Section 204

Notice of any known or suspected release from a UST system, any spill, or any other emergency situation must be given to the NMED by telephone within 24 hours. The owner or operator making the report shall provide the information specified under Section 204(A).

Written notice describing the spill, release, or suspected release and any investigation or follow-up action taken or to be taken must be mailed or delivered to the NMED within 7 days of the incident. The written notice shall verify the prior oral notification as to each of the items of information listed in subsection A and provide any appropriate additions or corrections to the information contained in the prior oral notification.

No releases have occurred during this reporting period. However, if this should occur, WIPP procedures discuss the requirements for the proper handling of spills and releases.

25.2.6.7 Emergency Repairs and Tank Replacement, USTR Section 205

Immediate repairs or replacement of an UST system may be made in the event an emergency situation presents a threat to the public health, provided notice is given to the NMED as described in Section 25.2.6.6.

No such emergency repair or replacement of an UST system has been necessary at WIPP to date.

25.2.6.8 Application Forms, USTR Section 206

All USTs must be registered on application forms provided by the NMED unless the EPA form ("Notification for Underground Storage Tanks") has been submitted to the NMED and all information contained therein is still accurate. An application submitted by a municipal, State, or other public facility must be signed by either a principal executive officer, ranking elected official, or other duly authorized employee.

The New Mexico UST registration form is used to register the USTs at WIPP. It has been submitted under the name of the DOE WIPP Project Manager, who is the principal executive officer for DOE at WIPP.

25.2.6.9 Registration Certificate, USTR Section 207

Upon submittal of a complete registration application or the EPA form and payment of the annual fee, the NMED shall issue a validated registration certificate which is current and valid and must be displayed on the premises of the UST system at all times. In the event that any information provided on the registration form or the EPA form changes or is no longer accurate, the change must be reported to the NMED on the appropriate form within 30 days.

The registration certificate from the NMED is displayed.

25.2.6.10 Payment of Fee, USTR Section 300

An annual per-tank fee shall be paid to the NMED no later than January 31 for each current calendar year or portion of a year that a tank is in use. A tank shall be deemed "in use" until notice is received by the NMED that the tank has been removed or otherwise permanently closed in a manner acceptable to the division.

The annual fee for a new tank placed in service after January 31 for any calendar year after 1989 shall be paid within 30 days after the tank is placed in service. The annual fees shall be designated to the Hazardous Waste and Underground Storage Tank Fund.

The annual fee per UST at WIPP is paid by January 31 for each calendar year. The fee for the replacement tanks accompanied the application that was transmitted to the NMED on February 10, 1992.

25.2.6.11 Amount of Fee, USTR Section 301

The annual fee for each UST is $100.00 per tank.

The annual fee paid for each UST at WIPP is $100, or $200 for both tanks.

25.2.6.12 Late Payment Penalties, USTR Section 302

In the event that the annual fee is not paid when due, a late fee of $5.00 or 5 percent of the unpaid fee, whichever is greater, and interest charges at the rate of 1.5 percent per month shall be imposed and shall accumulate until the annual fee and all accrued late fees and interest charges are paid.

No late payment penalties have been incurred.

25.2.6.13 Performance Standards for Tanks in New UST Systems, USTR Section 400(a); 40 CFR 280.20(a)

Each tank must be properly designed and constructed, and any portion underground must be protected from corrosion by a nationally recognized association or independent testing laboratory

as specified. Each tank must be constructed of fiberglass-reinforced plastic; steel, with cathodic protection; or steel-fiberglass-reinforced-plastic composite. The tank may be constructed of metal without additional corrosion protection if the conditions apply as described in Section 400(a)(4) of the USTRs.

The tanks are designed and constructed of fiberglass-reinforced plastic in accordance with Underwriters Laboratories Standard 1316, *Standard for Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products*, and with the American Society for Testing and Materials (ASTM) Standard D4021-86, *Standard Specification for Glass-Fiber-Reinforced Polyester Underground Petroleum Storage Tanks.*

25.2.6.14 Design and Construction of Piping, USTR Section 400(b); 40 CFR 280.20(b)

The piping that routinely contains regulated substances and is in contact with the ground must be properly designed, constructed, and protected from corrosion in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory as specified. The piping is constructed of fiberglass-reinforced plastic; or steel, with cathodic protection; or metal without additional corrosion protection measures provided that the piping is installed at a non-corrosive site and records are maintained that demonstrate the noncorrosivity of the site for the remaining life of the piping. The piping construction and corrosion protection are determined by the implementing agency to be designed to prevent the release or threatened release of any stored regulated substance in a manner that is no less protective of human health and the environment.

The piping is constructed of fiberglass-reinforced plastic as designed by the Xerxes Corporation in accordance with the appropriated standards.

25.2.6.15 Spill Prevention Equipment, USTR Section 400(c)(1)(i); 40 CFR 280.20(c)(1)(i)

Owners and operators must use spill prevention equipment that will prevent the release of product to the environment when the transfer hose is detached from the fill pipe (for example, a spill catchment basin).

The WIPP's UST system uses a spill catchment basis.

25.2.6.16 Overfill Prevention Equipment, USTR Section 400(c)(1)(ii); 40 CFR 280.20(c)(1)(ii)

Overfill-prevention equipment must be used that will automatically shut off flow into the tank when the tank is no more than 95 percent full; alert the transfer operator when the tank is no more than 90 percent full by restricting the flow into the tank or triggering a high-level alarm; or restrict the flow 30 minutes prior to overfilling, alert the operator with a high-level alarm 1 minute before overfilling, or automatically shut off flow into the tank so that none of the fittings located on top of the tank is exposed to product due to overfilling. Owners and operators may use alternative equipment if it is determined by the implementing agency to be no less protective of human health and the environment than the equipment specified above or if the UST system is filled by transfers of no more than 25 gallons at one time.

The model 310 extractor vent valve is used to automatically shut off the flow into the tank when the tank is no more than 95 percent full. This valve is a permanent part of the system.

25.2.6.17 Installation of Tanks and Piping, USTR Section 400(d); 40 CFR 280.20(d)

All tanks and piping must be properly installed in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory and in accordance with the manufacturer's instructions.

The installer (Cline Pump Co.) certified on the NMED application that the methods used to install the tanks and piping comply with the requirements. Cline Pump has supplied the WIPP with copies of qualified certification.

25.2.6.18 Certificate of Installation, USTR Section 400(e); 40 CFR 280.20(e)

All owners and operators must ensure that one or more of the specified methods of certification, testing, or inspection was used to demonstrate compliance with Section 25.2.6.17 by providing a certification of compliance on the UST notification form required

by USTR Part II. The allowable methods of certification for the installer are: certification by the tank and piping manufacturers; certification or licensing by the implementing agency; inspection and certification of the installation by a registered professional engineer with education and experience in UST system installation, inspection and approval by the implementing agency, or the presence of a representative from the UST Bureau of the NMED at the installation; completion of all work listed on the manufacturer's installation checklists; or compliance with another method for ensuring compliance with this section that is determined by the implementing agency to be no less protective of human health and the environment.

Cline Pump Company is certified by the NMED. The installation of the new systems was inspected and approved by an NMED representative who was present during the installation.

25.2.6.19 Upgrading Existing UST Systems, USTR Section 401(a); 40 CFR 280.21(a)

All existing UST systems must be upgraded to meet the new performance standards (see Sections 25.2.6.13 through 25.2.6.18), the requirements described in Sections 25.2.6.20 through 25.2.6.22, or the closure requirements described in Sections 25.2.6.66 through 25.2.6.73 by December 22, 1998.

The UST system formerly used at the WIPP has been replaced. The new system meets the new performance standards (see Sections 25.2.6.13 through 25.2.6.18); therefore, upgrading is not appropriate at this time.

25.2.6.20 Tank Upgrading Requirements, USTR Section 401(b); 40 CFR 280.21(b)

Steel tanks must be upgraded to have an interior lining and/or cathodic protection.

The new tanks are constructed of fiberglass-reinforced plastic and are not constructed of steel. (See Section 25.2.6.19.)

25.2.6.21 Piping Upgrading Requirements, USTR Section 401(c); 40 CFR 280.21(c)

Metal piping that routinely contains regulated substances and is in contact with the ground must be cathodically protected.

The piping for the UST system at WIPP is made of double-walled fiberglass-reinforced plastic. (See Section 25.2.6.19.)

25.2.6.22 Spill and Overfill Prevention Equipment, USTR Section 401(d); 40 CFR 280.21(d)

To prevent spilling and overfilling associated with the transfer of product to the UST system, all existing UST systems must comply with the new UST system spill and overfill prevention equipment requirements specified in USTR Section 400(c).

Spill and overfill prevention equipment has been incorporated into the new UST system as described in Sections 25.2.6.15 and 25.2.6.16.

25.2.6.23 Certificate of Compliance and Notification Requirements, USTR Section 402; 40 CFR 280.22

In the registration application required by USTR Part II, all owners and operators of new UST systems must certify compliance with the installation requirements of USTR Section 400(e), cathodic protection requirements for steel tanks and piping under Sections 400(a) and (b), financial responsibility under USTR Part IX, and release detection under Sections 601 and 602. The owners and operators must also ensure that the installer certifies that the methods used to install the tanks and piping comply with the requirements in Section 400(d).

The notification requirements pertain to the person who sells a tank intended to be used as an UST.

As outlined in the registration form, the certification requirements were met. The cathodic protection requirements are not applicable since neither the tank nor the piping is made of steel. The financial responsibility requirements are not applicable because WIPP is owned by the DOE. The notification requirements apply only to the person who sold the tank to be used as an UST and therefore do not apply to WIPP.

25.2.6.24 Spill and Overflow Control, USTR Section 500; 40 CFR 280.30

Owners and operators must ensure that any releases due to spilling or overfilling do not occur, that the volume available in the tank is greater than the volume of product to be transferred to the tank before the transfer is made, and that the transfer operation is monitored constantly to prevent overfilling and spilling. Any spills or overfills must be reported, cleaned up, and investigated in accordance with USTR Sections 204 and 703.

The new tanks are equipped with spill and overfill protection equipment. WIPP procedures are in place that govern the transfer of product to the tanks and that specify requirements for reporting, cleaning up, and investigating spills or overfills.

25.2.6.25 Operation and Maintenance of Corrosion Protection, USTR Section 501(a); 40 CFR 280.31(a)

All corrosion protection systems must be operated and maintained to continuously provide corrosion protection to the metal components of that portion of the tank and piping that routinely contain regulated substances and are in contact with the ground.

The corrosion protection consists of rubber boots around the metal fittings.

25.2.6.26 Inspections of Cathodic Protection System, USTR Section 501(b); 40 CFR 280.31(b)

All UST systems equipped with cathodic protection systems must be inspected for proper operation by a qualified cathodic protection tester in accordance with requirements regarding the frequency of inspections and specific inspection criteria.

Cathodic protection is required only for steel tanks and metal parts. The metal fittings in the UST system are protected by rubber boots. Therefore, cathodic protection is not required.

25.2.6.27 Inspections of Impressed-Current Cathodic Protection Systems, USTR Section 501(c); 40 CFR 280.31(c)

UST systems with impressed-current cathodic protection systems must be inspected every 60 days to ensure that the equipment is running properly.

No cathodic protection systems are required for fiberglass-reinforced plastic systems.

25.2.6.28 Records of Operation of the Cathodic Protection System, USTR Section 501(d); 40 CFR 280.31(d)

For UST systems using cathodic protection, records of the operation of the cathodic protection system must be maintained in accordance with 40 CFR 280.34 to demonstrate compliance with the performance standards in this section. These records must provide the results of inspections.

No cathodic protection is required for fiberglass-reinforced plastic UST systems. Therefore, this requirement does not apply.

25.2.6.29 Compatibility, USTR Section 502; 40 CFR 280.32

Owners and operators must use an UST system made of or lined with materials that are compatible with the substance stored in the UST system.

Fiberglass-reinforced plastic is compatible with unleaded and diesel fuel.

25.2.6.30 Repairs Allowed, USTR Section 503(a); 40 CFR 280.33(a)

Repairs to UST systems must be properly conducted in accordance with a code of practice developed by a nationally recognized association or an independent testing laboratory.

As of March 31, 1994, no major repairs have been required.

25.2.6.31 Repairs to Fiberglass-Reinforced Plastic Tanks, USTR 503(b); 40 CFR 280.33(b)

Repairs to fiberglass-reinforced plastic tanks may be made by the manufacturer's authorized representatives or in accordance with a code of practice developed by a nationally recognized association or an independent testing laboratory.

As of March 31, 1994, no major repairs have been required.

25.2.6.32 Repairs of Pipe Sections and Fittings, USTR Section 503(c); 40 CFR 280.33(c)

Metal pipe sections and fittings that have released product as a result of corrosion or other damage must be replaced. Fiberglass pipes and fittings may be repaired in accordance with the manufacturer's specifications.

No repairs have been conducted on the pipes or fittings.

25.2.6.33 Tightness Testing after Repairs, USTR Section 503(d); 40 CFR 280.33(d)

Repaired tanks and piping must be tightness tested in accordance with USTR Sections 603(d) and 604(b) within 30 days after the date of the completion of the repair except as provided in this section.

No repairs have been conducted on the tanks or piping.

25.2.6.34 Testing of Repaired Cathodically Protected UST System, USTR Section 503(e); 40 CFR 280.33(e)

Within 6 months following the repair of any cathodically protected UST system, the cathodic protection system must be tested in accordance with USTR Sections 501(b) and (c) to ensure that it is operating properly.

The current UST system does not require cathodic protection.

25.2.6.35 Records of all Repairs, USTR Section 503(f); 40 CFR 280.33(f)

UST system owners and operators must maintain records of each repair for the remaining operating life of the UST system to demonstrate compliance with the requirements of this section.

No repairs have been performed on the current system. However, when UST system repairs are necessary, the records will be maintained at WIPP for the life of the UST system.

25.2.6.36 Reporting, USTR Section 504(a); 40 CFR 280.34(a)

Owners and operators must submit the following information to the NMED: registration of all UST systems, including certification of installation for new UST systems (USTR, Part II); reports of all releases (including suspected releases, spills, and overfills) and confirmed releases; corrective actions planned or taken; and a notification before permanent closure or change in service.

The information in this requirement has been submitted to the NMED. Spill, overfill, and release reporting requirements are addressed by WIPP procedures.

25.2.6.37 Recordkeeping Requirements, USTR Section 504(b); 40 CFR 280.34(b)

Owners and operators must maintain the following information: a corrosion expert's analysis of site corrosion potential if corrosion protection equipment is not used, documentation of operation of corrosion protection equipment, documentation of UST system repairs, recent compliance with release detection requirements, and the results of the site investigation required prior to permanent closure.

The rubber boots are considered adequate to meet the corrosion protection requirements since the tank and piping consist of fiberglass-reinforced plastic. Metal flex elbow fittings are contained within the rubber boots, which separate them from contact with the ground.

WIPP procedures specify the retention time for record of UST system repairs.

A WIPP procedure addresses the retention of monitoring results. Correspondence WD 93:00280 contains the tank closure form as an attachment.

25.2.6.38 Availability and Maintenance of Records, USTR Section 504(c); 40 CFR 280.34(c)

The applicable records must be kept either at the UST site and immediately available for inspections by the NMED or at a readily available alternative site and be provided to the NMED upon request.

The UST records are maintained at the WIPP site.

25.2.6.39 Inspections, Monitoring, and Testing of USTs, USTR Section 505(a)

Any owner or operator of an UST shall, upon the request of the director or authorized NMED representatives, furnish information relating to the UST(s), conduct monitoring or testing, and allow the NMED representative to have access to the USTs and to copy all records relating to such tanks at all reasonable times. NMED officers, employees, or representatives will be allowed to inspect the UST system(s) and obtain samples of its contents and to conduct monitoring or testing of the tanks and its associated equipment or the surrounding soils, air, surface water, or ground water.

NMED personnel are allowed to inspect the UST systems at any reasonable time. They are also allowed to sample the contents of the USTs. Monitoring or testing of the tanks and associated equipment and contents or the surrounding soils, air, or surface or ground water may also be performed.

25.2.6.40 Inspections of UST Installations, Repairs or Modifications, or Removals or System Closures, USTR Section 505(c)

The owner and operator must allow the Director or authorized NMED representatives to be present at and inspect all UST system installations, replacements, repairs, substantial modifications, installations of leak detection systems, and UST system closures. To ensure that the inspector has an opportunity to be present during the steps in these procedures which are important to the prevention of releases, the owner or operator must give the NMED oral notice of the dates on which critical junctures in the installation, repair, substantial modification, or closure of the UST

system are to take place. Oral notice must be given at least 24 hours in advance of the commencement of the procedure. The inspector may require that critical junctures be performed from Monday through Friday during regular business hours.

A representative of the NMED UST Bureau was present at the installation of the new UST systems on February 10, 1992.

25.2.6.41 General Requirements for all UST Systems, USTR Section 600(a); 40 CFR 280.40(a)

Owners and operators of new and existing UST systems must provide a method, or combination of methods, of release detection that can detect a release from any portion of the tank and the connected underground piping that routinely contains product; is installed, calibrated, operated, and maintained in accordance with the manufacturer's instructions, including routine maintenance and service checks for operability or running condition; meets the performance requirements; and must be capable of detecting the leak rate or quantity specified for that method in the corresponding section of the rule with a probability of detection (pd) of 0.95 and a probability of false alarm (pfa) of 0.05.

The UST system uses interstitial monitoring to detect for releases. There are sensors between the walls at the lowest end of the piping and tank. Interstitial monitoring is adequate because it can detect a release through the inner wall in any portion of the double-walled tank and/or piping that regularly contains product.

25.2.6.42 Notification of Releases, USTR Section 600(b); 40 CFR 280.40(b)

When a release detection method operated in accordance with the performance standards in USTR Sections 603 and 604 indicates that a release may have occurred, owners and operators must notify the NMED in accordance with USTR Section 204 and Part VII.

No releases or suspected releases have occurred with the current UST system.

25.2.6.43 Schedule for Required Release Detection, USTR Section 600(c); 40 CFR 280.40(c)

Owners and operators of all UST systems must comply with the release-detection requirements of this part by December 22 of the year listed in a table.

New UST systems were installed on February 10, 1992. The new systems meet the release-detection requirements of this part.

25.2.6.44 Failure to Comply with Release-Detection Requirements, USTR Section 600(d); 40 CFR 280.40(d)

Any existing UST system that cannot apply a release-detection method that complies with the requirements of this part must complete the closure procedures for the system by the date indicated in USTR Section 600(c) (Section 25.2.6.43).

The new UST system at WIPP uses a release-detection method that complies with the requirements of this part. Therefore, Section USTR 600(d) does not apply to the WIPP UST systems.

25.2.6.45 Requirements for Tanks of Petroleum UST Systems, USTR Section 601(a); 40 CFR 280.41(a)

Tanks must be monitored at least every 30 days for releases using one of the methods listed in USTR Sections 603(d)-(h) (see Sections 25.2.6.54 through 25.2.6.58) except that UST systems that meet the performance standards and the monthly inventory control requirements may use tank tightness testing at least every 5 years until December 22, 1998, or until 10 years after the tank is installed or upgraded, whichever is later; UST systems that do not meet the performance standards may use monthly inventory controls and annual tank tightness testing until December 22, 1998, when the tank must be upgraded or permanently closed; and tanks with a capacity of 550 gallons or less may use weekly tank gauging.

The interstitial monitoring system meets the release-detection requirement. Should the interstitial system become inoperable, monthly inventory controls will be used. In this contingency situation, tank tightness testing will be performed every 5 years.

25.2.6.46 Requirements for Piping of Petroleum UST Systems, USTR Section 601(b); 40 CFR 280.41(b)

Underground piping that routinely contains regulated substances must be monitored for releases in a manner that meets the requirements for pressurized or suction piping.

See Section 25.2.6.48, which specifies the requirements for suction piping as used in the UST systems at WIPP.

25.2.6.47 Requirements for Pressurized Piping, USTR Section 601(b)(1); 40 CFR 280.41(b)(1)

Underground piping that conveys regulated substances under pressure must be equipped with an automatic line leak detector and have an annual line-tightness test or have monthly monitoring conducted.

This requirement is not applicable since the current UST system operates under suction piping.

25.2.6.48 Requirements for Suction Piping, USTR Section 601(b)(2); 40 CFR 280.41(b)(2)

Underground piping that conveys regulated substances under suction must either have a line tightness test conducted at least every 3 years in accordance with USTR Section 604(b) or use a monthly monitoring method conducted in accordance with USTR § 604(c). No release detection is required for suction piping that is designed and constructed to meet the following standards: the below-grade piping operates at less than atmospheric pressure; the below-grade piping is sloped so that the contents of the pipe will drain back into the storage tank if the suction is released; only one check valve is included in each suction line; the check valve is located directly below and as close as practical to the suction

pump; and a method is provided that allows compliance with this section to be readily determined.

No release detection is required on the piping since the system was designed and constructed to meet each of the above requirements.

25.2.6.49 Requirements for Hazardous Substance UST Systems, USTR Section 602; 40 CFR 280.42

A number of release-detection requirements are specified for UST systems that contain hazardous substances.

WIPP has no UST systems that contain hazardous substances. Therefore, these requirements do not apply to this facility.

25.2.6.50 Methods of Release Detection for Tanks, USTR Section 603; 40 CFR 280.43

A number of requirements for the acceptable release-detection methods are specified. The release-detection methods described are: inventory control, manual tank gauging, tank-tightness testing, automatic tank gauging, vapor monitoring, ground-water monitoring, interstitial monitoring, and other methods.

See Sections 25.2.6.51 through 25.2.6.59.

25.2.6.51 Inventory Control, USTR Section 603(a); 40 CFR 280.43(a)

Product inventory control (or another test of equivalent performance) must be conducted monthly to detect a release of at least 1.0 percent of flow-through plus 130 gallons on a monthly basis in the following manner: inventory volume measurements for regulated substance inputs, withdrawals, and the amount still remaining in the tank are recorded each operating day; the equipment used is capable of measuring the level of product over the full range of the tank's height to the nearest one-eighth of an inch; the regulated substance inputs are reconciled with delivery receipts by measurement of the tank inventory volume before and after delivery; deliveries are made through a drop tube that extends to within 1 foot of the tank bottom; product dispensing is metered

and recorded within the local standards for meter calibration or an accuracy of 6 cubic inches for every 5 gallons of product withdrawn; and the measurement of any water level in the bottom of the tank is made to the nearest one-eighth of an inch at least once a month.

Inventory control is a "contingency" method used only if the interstitial monitoring system fails. If this situation arises, there is a WIPP procedure addressing the requirements for using this method. Compliance with the requirement for a drop tube extending to within 1 foot of the tank bottom has been verified through discussions with the installing organization. The stick reading can measure to the nearest one-eighth of an inch.

25.2.6.52 Manual Tank Gauging, USTR Section 603(b); 40 CFR 280.43(b)

Manual tank gauging must meet the following requirements: tank liquid level measurements are taken at the beginning and ending of a period of at least 36 hours during which no liquid is added to or removed from the tank; level measurements are based on an average of two consecutive stick readings at both the beginning and ending of the period; the equipment used is capable of measuring the level of product over the full range of the tank's height to the nearest one-eighth of an inch; a leak is suspected and subject to the requirements of USTR Part VII if the variation between beginning and ending measurements exceeds the weekly or monthly standards in the table provided.

This requirement is not applicable since the UST system uses interstitial monitoring as the primary method of release detection.

25.2.6.53 Tank Tightness Testing, USTR Section 603(c); 40 CFR 280.43(c)

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Tank tightness testing (or another test of equivalent performance) must be capable of detecting a 0.1-gallon-per-hour leak rate from any portion of the tank that routinely contains product while accounting for the effects of thermal expansion or contraction of the product, vapor pockets, tank deformation, evaporation or condensation, and the location of the water table.

Tank tightness testing is not required to be performed for the current UST setup. If the interstitial monitoring method fails, tank tightness testing will be performed every 5 years as part of the inventory control method.

25.2.6.54 Automatic Tank Gauging, USTR Section 603(d); 40 CFR 280.43(d)

Equipment for automatic tank gauging that tests for the loss of product and conducts inventory control must meet the following requirements: the automatic product level monitor test can detect a 0.2-gallon-per-hour leak rate from any portion of the tank that routinely contains product, and inventory control (or another test of equivalent performance) is conducted in accordance with the requirements of USTR Section 603(a).

This method is not applicable for the current UST system. See Sections 25.2.6.51, 25.2.6.53, and 25.2.6.57.

25.2.6.55 Vapor Monitoring, USTR Section 603(e); 40 CFR 280.43(e)

Testing or monitoring for vapors within the soil gas of the excavation zone must meet the following requirements: the materials used as backfill are sufficiently porous (e.g., gravel, sand, crushed rock) to readily allow diffusion of vapors from releases into the excavation area; the stored regulated substance (e.g., gasoline), or a tracer compound placed in the tank system, is sufficiently volatile to result in a vapor level that is detectable by the monitoring devices located in the excavation zone in the event of a release from the tank; the measurement of vapors by the monitoring device is not rendered inoperative by the ground water, rainfall, soil moisture, or other known interferences so that a release could go undetected for more than 30 days; the level of background contamination in the excavation zone will not interfere with the method used to detect releases from the tank; the vapor monitors are designed and operated to detect any significant increase in concentration above background of the regulated substance stored in the tank system, a component or components of that substance, or a tracer compound placed in the tank system; in the UST excavation zone, the site is assessed to establish the number and positioning of monitoring wells that will detect releases within the excavation zone from any portion of the tank that

routinely contains product; and monitoring wells are clearly marked and secured to avoid unauthorized access and tampering.

This method is not applicable for the current UST system. See Sections 25.2.6.51, 25.2.6.53, and 25.2.6.57.

25.2.6.56 Ground-Water Monitoring, USTR Section 603(f); 40 CFR 280.43(f)

Testing or monitoring for liquids in the ground water must meet the following requirements: the regulated substance stored is immiscible in water and has a specific gravity of less than 1; ground water is never more than 20 feet from the ground surface, and the hydraulic conductivity of the soil(s) between the UST system and the monitoring wells or devices is not less than 0.01 cm/sec (e.g., the soil should consist of gravels, coarse to medium sands, coarse silts, or other permeable materials); the slotted portion of the monitoring well casing must be designed to prevent the migration of natural soils or filter pack into the well and to allow the entry of regulated substances on the water table into the well under both high and low ground-water conditions; monitoring wells shall be sealed from the ground surface to the top of the filter pack; monitoring wells or devices intercept the excavation zone or are as close to it as is technically feasible; the continuous monitoring devices or manual methods used can detect the presence of at least one-eighth of an inch of free product on top of the ground water in the monitoring wells; within and immediately below the UST system excavation zone, the site is assessed to ensure compliance with the first five requirements of this section and to establish the number and positioning of the monitoring wells or devices that will detect releases from any portion of the tank that routinely contains product; and monitoring wells are clearly marked and secured to avoid unauthorized access and tampering.

The WIPP site has a variance from ground-water requirements. See Sections 25.2.6.51, 25.2.6.53, and 25.2.6.57.

25.2.6.57 Interstitial Monitoring, USTR Section 603(g); 40 CFR 280.43(g)

Interstitial monitoring between the UST system and a secondary barrier immediately around or beneath it may be used, but only if the system is designed, constructed, and installed to detect a leak from any portion of the tank that routinely contains product and also meets one of the following requirements: for double-walled UST systems, the sampling or testing method can detect a release through the inner wall in any portion of the tank that routinely contains product; for UST systems with a secondary barrier within the excavation zone, the sampling or testing method used can detect a release between the UST system and the secondary barrier; the secondary barrier around or beneath the UST system consists of artificially constructed material that is sufficiently thick and impermeable (at least 10^{-6} cm/sec for the regulated substance stored) to direct a release to the monitoring point and permit its detection; the barrier is compatible with the regulated substance stored so that a release from the UST system will not cause a deterioration of the barrier, allowing a release to pass through undetected; for cathodically protected tanks, the secondary barrier must be installed so that it does not interfere with the proper operation of the cathodic protection system; the ground water, soil moisture, or rainfall will not render the testing or sampling method used inoperative so that a release could go undetected for more than 30 days; the site is assessed to ensure that the secondary barrier is always above the ground water and is not located in a 25-year flood plain, unless the barrier and monitoring designs are for use under such conditions; monitoring wells are clearly marked and secured to avoid unauthorized access and tampering; and, for tanks with an internally fitted liner, an automated device can detect a release between the inner wall of the tank and the liner, and the liner is compatible with the substance stored.

The interstitial monitoring system is the primary method of release detection for the UST system. The as-built engineering drawings verify that this method can detect a release through the inner wall in any portion of the tank that routinely contains product.

25.2.6.58 Other Methods of Detecting Releases, USTR Section 603(h); 40 CFR 280.43(h)

Any other method may be used if it can detect a 0.2-gallon-per-hour leak rate or a release of 150 gallons within a month with a probability of detection of 0.95 and a probability of false alarm of 0.05, and it has been approved by the NMED.

The WIPP does not use any methods of release detection other than the ones described in Sections 25.2.6.51 and 25.2.6.57.

25.2.6.59 Methods of Release Detection of Piping, USTR Section 604; 40 CFR 280.44

Each method of release detection for piping used to meet the requirements of USTR Section 601 must be conducted in accordance with specific requirements for automatic line leak detectors, line tightness testing, or applicable tank methods.

Since the system meets the requirements of USTR Section 601(b)(2), line leak detectors are not required.

25.2.6.60 Release Detection Recordkeeping, USTR Section 605; 40 CFR 280.45

All UST system owners and operators must maintain records in accordance with USTR Section 504 that demonstrate compliance with all applicable requirements in Part VI. All written performance claims pertaining to any release detection system used, and the manner in which these claims have been justified or tested by the equipment manufacturer or installer, must be maintained for 5 years, or for another reasonable period of time determined by the NMED, from the date of installation. The results of any sampling, testing, or monitoring must be maintained for at least 1 year, or for any reasonable period of time determined by the NMED, except that the results of tank tightness testing conducted in accordance with USTR Section 603(c) must be retained until the next test is conducted. Written documentation of all calibration, maintenance, and repair of release-detection equipment permanently located on site must be maintained for at least 1 year after the servicing work has been completed or for any reasonable time period determined by the NMED. Any schedules

of required calibration and maintenance provided by the release-detection equipment manufacturer must be retained for 5 years from the date of installation.

The WID Purchasing Department maintains the manufacturer's equipment and performance claims records. The Records Inventory and Disposition Schedule (RIDS) discusses the maintenance of these records. The RIDS adequately addresses the record retention requirements of this section. According to the manufacturer of the tanks, no calibration or maintenance is required for the current configuration. However, if modifications are made, these functions will need to be performed.

25.2.6.61 Reporting of Suspected Releases, USTR Section 700; 40 CFR 280.50

Owners and operators of UST systems must report suspected releases to the NMED within 24 hours and follow the procedures in USTR Section 702 for any of the following conditions:

- *The discovery by owners and operators or others of released regulated substances at the UST site or in the surrounding area*
- *Unusual operating conditions*
- *Monitoring results from a release detection method that indicate that a release may have occurred unless the monitoring device is found to be defective and is immediately repaired and subsequent monitoring does not confirm the initial results or, in the case of inventory control, a second month of data does not confirm the initial result.*

No releases or suspected releases have occurred from the current UST system. Should a suspected release occur, a WIPP procedure outlines the required steps above.

25.2.6.62 Investigation of Off-Site Impacts, USTR Section 701; 40 CFR 280.51

When required by the NMED, owners and operators of UST systems must follow the procedures in USTR Section 702 to determine if the UST system is the source of off-site impacts.

NMED has not requested off-site impact information.

25.2.6.63 Release Investigation and Confirmation Steps, USTR Section 702; 40 CFR 280.52

Unless corrective action is initiated in accordance with USTR Parts XII and XIII, owners and operators must immediately investigate and confirm all suspected releases of regulated substances that require reporting under USTR Section 700 within 7 days using a system test and/or a site check as described in more detail in this part of the regulations. If a leak in the UST system is found to exist, the system must be repaired, replaced, or upgraded as needed.

WID procedures indicate the appropriate testing, investigating, reporting, and corrective action to be taken if a release of regulated substances is suspected. To date, there have been no leaks in the current UST system.

25.2.6.64 Reporting and Cleanup of Large Spills and Overfills, USTR Section 703(a); 40 CFR 280.53(a)

Owners and operators of UST systems must contain and immediately clean up a spill or overfill and report it to the NMED within 24 hours. Corrective action must be initiated in accordance with USTR Section 204. If a spill or overfill of a petroleum product results in a release to the environment that exceeds 25 gallons [or a hazardous substance spill results in a release to the environment that equals or exceeds its reportable quantity under CERCLA (40 CFR Part 302)], corrective action must be initiated in accordance with USTR Part XII or XIII.

There have been no large spills or overfills with the current UST setup. WID procedures address the requirements with respect to petroleum UST systems (i.e., as specified in USTR Part XII). No hazardous substances are contained in UST systems at WIPP; therefore, USTR Part XIII does not apply.

25.2.6.65 Reporting and Cleanup of Small Spills and Overfills, USTR Section 703(b); 40 CFR 280.53(b)

Owners and operators of UST systems must contain and immediately clean up a spill or overfill of a petroleum product that is less than 25 gallons and a spill or overfill of a hazardous substance that is less than the reportable quantity. If cleanup cannot be accomplished within 24 hours, owners and operators must immediately notify the implementing agency.

Small spills and overfills have been properly contained and cleaned up. WID procedures address this requirement with respect to petroleum UST systems. No UST systems are used to contain hazardous substances at WIPP.

25.2.6.66 Temporary Closure, USTR Section 800; 40 CFR 280.70

When an UST system is temporarily closed, owners and operators must continue operation and maintenance of corrosion protection in accordance with USTR Section 501 and any release detection in accordance with USTR Part VI. USTR Parts VII, XII, and XIII and Section 204 must be complied with if a release is suspected or confirmed. However, release detection is not required as long as the UST system is empty. When an UST system is temporarily closed for 3 months or more, the vent lines must be left open and functioning, and all other lines, pumps, manways, and axillary equipment must be capped and secured.

Documentation of the original tank closures was submitted to NMED. No temporary closure took place.

25.2.6.67 Permanent Closure and Changes in Service, USTR Section 801(a); 40 CFR 280.71(a)

At least 30 days before beginning either permanent closure or a change in service, owners and operators must notify the NMED unless such action is in response to corrective action.

The closure documentation for the old UST systems was submitted to the NMED within the 30-day requirement for beginning permanent closure.

25.2.6.68 Permanent Closure of a Tank, USTR Section 801(b); 40 CFR 280.71(b)

To permanently close a tank, the owners and operators must empty and clean it by removing all liquids and accumulated sludges. The tanks must be either removed from the ground or filled with an inert solid material.

The closure documentation for the old UST system is maintained at the WIPP site. These USTs were emptied, cleaned, and removed from the ground as required.

25.2.6.69 Change in Service, USTR Section 801(c); 40 CFR 280.71(c)

Before a change in service in which the use of a UST system is continued for the storage of a nonregulated substance, owners and operators must empty and clean the tank by removing all liquid and accumulated sludge and conduct a site assessment in accordance with USTR Section 802.

There was no change in service for the old UST system.

25.2.6.70 Assessing the Site, USTR Section 802(a); 40 CFR 280.72(a)

Before permanent closure or a change in service is completed, owners and operators must measure for the presence of a release where contamination is most likely to be present at the UST site as required under this subsection.

The UST site was assessed prior to permanent closure of the old UST system. The closure documentation for the old UST systems is maintained at the WIPP site.

25.2.6.71 Corrective Action, USTR Section 802(b); 40 CFR 280.72(b)

If contaminated soils, contaminated ground water, or free product as a liquid or vapor are discovered, owners and operators must begin corrective action in accordance with USTR Parts XII or XIII.

The WIPP has procedures in place which address the required actions to take if a release or suspected release is identified. See 25.2.6.80 for further information.

25.2.6.72 Applicability to Previously Closed UST Systems, USTR Section 803; 40 CFR 280.73

When directed by the NMED, the owner and operator of an UST system permanently closed before December 22, 1988, must assess the excavation zone and close the UST system if releases from the UST may pose a current or potential threat to human health and the environment.

No UST systems at WIPP were permanently closed before December 22, 1988.

25.2.6.73 Closure Records, USTR Section 804; 40 CFR 280.74

Owners and operators must maintain records in accordance with USTR Section 504 that demonstrate compliance with closure requirements under this part. The results of the excavation zone assessment required in USTR Section 802 (Section 25.2.6.70) must be maintained for at least 3 years after completion of permanent closure or change in service.

A tank closure for the old UST systems was submitted to NMED. The records are maintained at WIPP.

25.2.6.74 Applicability of Financial Responsibility, USTR Section 900; 40 CFR 280.90

State and Federal government entities whose debts and liabilities are the debts and liabilities of a State or the United States are exempt from the requirements of USTR Part IX, "Financial Responsibility."

As the owner of WIPP, the DOE is exempt from the financial responsibility requirements of this part because DOE is a Federal government entity whose debts and liabilities are the debts and liabilities of the United States.

25.2.6.75 Informal Review, USTR Section 1000

Any owner or operator of an UST who disagrees with a decision made by NMED personnel pursuant to the USTRs may have the decision reviewed by submitting a written request for informal

review to the NMED. The request must be postmarked within 15 days of the date of the decision. The grounds for the petitioner's objection must be specified.

This provision has not been invoked at WIPP.

25.2.6.76 Review by the Director on Written Memoranda, USTR Section 1001

Within 20 days after the NMED has made a determination under USTR Section 1000, the petitioner may appeal the determination to the NMED Director by requesting a review on written memoranda in writing. The grounds for the objection to the determination must be specified. The request must be accompanied by all written information, documentation, and arguments that the petitioner wants the Director to consider.

This provision has not been invoked at WIPP.

25.2.6.77 Compliance with other Regulations, USTR Section 1100

Compliance with the USTRs does not relieve a person of the obligation to comply with other applicable State and Federal regulations.

Compliance with the other applicable Federal and State regulations is discussed elsewhere in this document (see Chapters 2 through 24 and 25 through 38, respectively).

25.2.6.78 Construction, USTR Section 1101

The USTRs shall be liberally construed to effectuate the purpose of the New Mexico Hazardous Waste Act.

The USTRs are liberally construed to effectuate the purpose of the New Mexico Hazardous Waste Act with respect to the sections in this act that pertain to managing UST systems containing hazardous (i.e., regulated) substances.

25.2.6.79 Severability, USTR Section 1102

If any part, section, or application of the USTRs is held invalid, the remainder (or its application to other situations or persons) shall not be affected.

No action is required.

25.2.6.80 Cleanup Requirements for Releases from Petroleum UST Systems, USTR Section 1200(A)

All releases must be cleaned up through soil remediation, ground- and surface-water remediation, and any other appropriate procedures in a manner protective of health, public welfare, and the environment.

No releases have occurred with the current UST system to date.

25.2.6.81 Additional Corrective Action Requirements for Petroleum UST Systems, USTR Sections 1200(B)-1222

Additional corrective action requirements specify types of releases, notification and reporting requirements, types of actions required for remediation and reclamation involving specific releases, and provisions for monitoring.

No releases have occurred during this reporting period. Consequently, these requirements are not applicable to WIPP, and no action is required. WID procedures are in place to address them, however, should corrective actions involving petroleum USTs become necessary in the future.

25.2.6.82 Corrective Action for Hazardous Substance UST Systems, USTR Sections 1300-1320 (Part XIII)

Requirements for corrective actions for hazardous substance UST systems are specified in this part of the USTRs.

There are no hazardous substance UST systems at WIPP. Furthermore, it is very unlikely that such systems would be installed at this facility. Therefore, Part XIII of the USTRs (Sections 1300-1320) does not apply to WIPP.

25.2.6.83 Certification Requirements for Tank Installers and Repairers, USTR Sections 1400-1417 (Part XIV)

Certification by the NMED is required for all individuals and companies that install or repair UST systems in New Mexico. Certification is based on field experience, training, and a written and an on-site examination.

Documentation of certification of the contractor that installed the new UST systems at WIPP is retained at the WIPP.

25.2.6.84 Priorities, USTR Section 1505

NMED priorities for corrective action at sites contaminated by releases of regulated substances from USTs are established in this section.

If a release is detected from the UST systems at WIPP, the action to be taken by the NMED will depend on the extent and nature of the release.

See Section 25.2.6.85 for the requirements for a minimum site assessment.

25.2.6.85 Minimum Site Assessment, USTR Section 1508

Owners and operators are strictly liable for the NMED's costs of taking corrective action at a site unless the owner or operator has conducted a minimum site assessment as required by these regulations. To complete such an assessment, the owner and operator must report, investigate, and confirm the release pursuant to USTR Part VII and determine the immediate extent, magnitude, and impact of contamination by conducting investigations and reporting to the NMED (USTR Sections 1203 through 1206). The owner or operator shall include with the report of the on-site investigation a copy of any insurance policies which are in effect on the date of the report and any policies in existence at the time

the release may have occurred. The NMED shall notify the owner or operator of any inadequacies in the report within 30 days of its receipt of the on-site investigation report. The owner or operator shall, within 15 days of such notice of inadequacy, modify the report and resubmit it to the NMED for review and written approval. If the modified report does not meet the requirements of USTR Section 1205, the owner and operator shall be deemed not to have conducted a minimum site assessment.

If a minimum site assessment is deemed necessary, it will be prepared and submitted to meet the requirements specified. The transmittal of insurance policies is not required for a Federal facility; therefore, the report would not be accompanied by a copy of such policies.

26.0 NEW MEXICO SOLID WASTE ACT

26.1 Summary of the Law

With the enactment of the Solid Waste Act (SWA) in 1990, the Legislature of the State of New Mexico authorized and directed the establishment of a comprehensive and integrated solid waste management program at both the State and local levels. This legislation directs the planning and regulation of the reduction, storage, collection, transportation, and disposal of solid waste and authorizes the establishment of a system of permits for the construction, operation, and, if applicable, closure and postclosure maintenance of solid waste facilities.

The SWA is implemented by the New Mexico Solid Waste Management Regulations (SWMRs). These regulations are applicable to WIPP because of the presence of a construction landfill and infectious wastes at the facility.

26.2 Compliance Status of the Regulatory Requirements

Table 26-1 summarizes the applicable requirements and their compliance status under the State of New Mexico's Solid Waste Act. The text provides more detail on the compliance status of each requirement.

TABLE 26-1. New Mexico Solid Waste Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
Solid Waste Management Regulations (SWMR-3), § 104	Applicability of regulations	UP TO DATE Landfill on WIPP site [Section 26.2.1]
SWMR-3, § 106	General requirements	UP TO DATE Landfill managed as required [Section 26.2.2]

Table 26-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
SWMR-3, § 107	Prohibited acts	**UP TO DATE** Wastes specified that are excluded from the landfill [Section 26.2.3]
SWMR-3, § 109	Recordkeeping and annual reports	**UP TO DATE** Documentation process in place [Section 26.2.4]
SWMR-3, §§ 201, 202, 209, 210	Permit application requirements	**NOT APPLICABLE** Landfill exempt [Section 26.2.5]
SWMR-3, Part IV	Solid waste facility operation requirements	**UP TO DATE** Operated as required [Section 26.2.6]
SWMR-3, Part V	Closure and postclosure requirements	**NOT APPLICABLE** Landfill exempt [Section 26.2.7]
SWMR-3, Part VI	Operator certification	**NOT APPLICABLE** Landfill exempt [Section 26.2.8]
SWMR-3, § 706(C)	Storage and containment requirements for infectious waste	**UP TO DATE** Storage and containment procedures established [Section 26.2.9]

Table 26-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
SWMR-3, § 706(D)	Operational requirements for infectious waste treatment, storage, and disposal facilities	**ACHIEVED** Operational procedures established [Section 26.2.10]
SWMR-3, § 706(E)	Treatment and disposal of infectious waste	**ACHIEVED** Off-site incineration or steam sterilization used [Section 26.2.11]
SWMR-3, § 706(F)	Requirements for infectious waste transporters	**NOT APPLICABLE** Transport by off-site contractor [Section 26.2.12]
SWMR-3, § 711	Manifest requirements (to accompany each load of infectious waste)	**UP TO DATE** Manifest provided [Section 26.2.13]

26.2.1 Applicability of Regulations, SWMR-3, § 104

Subpart 104 specifies that these regulations apply to all transporters of solid waste and to owners and operators of storage, transfer, processing, transformation, recycling, or disposal facilities.

A construction landfill is located on the WIPP site. The landfill is used only for nonhazardous waste from construction activities; no hazardous wastes or materials are allowed.

26.2.2 General Requirements for Processing and Disposal of Solid Waste, SWMR-3, § 106

All solid waste must be processed or disposed of by means in accordance with Environmental Improvement Board regulations, including recycling, composting, transformation, or landfilling. Generators of solid waste must provide containers for the solid waste except for construction and demolition debris, yard refuse, and white goods.

The construction landfill is managed in accordance with applicable State and Federal requirements. The requirements and rules of operation are described in a WIPP procedure that provides guidelines for the operation of the construction landfill in a manner that is protective of human health and the environment and ensures compliance with applicable local, State, and Federal laws and regulations. Because the landfill is limited to construction debris and nonhazardous solid waste, no containers are provided.

26.2.3 Prohibited Acts, SWMR-3, § 107

Subpart 107 specifies prohibited acts including the following: disposal of solid waste in places other than a permitted solid waste facility; disposal of regulated waste such as special waste, hazardous waste, radioactive materials, and petroleum waste; disposal of bulk liquids; and disposal of any solid wastes that are known to be harmful to the environment or hazardous to public health or safety.

The following wastes are excluded from the WIPP landfill:

- Radioactive materials
- Hazardous or other regulated materials, including petroleum products
- Liquids, or containers that contain liquids
- Any recyclable materials as determined by the Westinghouse Waste Isolation Division (WID).

Construction debris that may be disposed of in the landfill are timers, pipes, excavation soil (if not contaminated with hazardous materials/wastes), concrete, packing materials, sheet metal, glass, and wood.

26.2.4 Recordkeeping and Annual Reports, SWMR-3, § 109

Operators of solid waste facilities shall make and maintain records during the active life of the facility. Operators shall submit annual reports to the Secretary of the New Mexico Environment Department (NMED) within 45 days after each anniversary date of any permit or other approval given.

The records required are found on the WID Construction Debris Disposal Form (WP Form 1633), which requires the name, company, date, description and estimated volume of debris, and signatures of the landfill user and of the landfill custodian. No permit is required (see Section 26.2.5). Therefore, an annual report is not necessary.

26.2.5 Permit Application Requirements, SWMR-3, §§ 201, 202, 209, 210

Any person seeking a permit to construct, operate, or modify a solid waste facility must file an application.

This landfill is exempted from permit application requirements because it receives construction debris only and because it is located at the same site where the construction debris is generated. Therefore, a permit is not required for this landfill.

26.2.6 Solid Waste Facility Operation, SWMR-3, Part IV

A solid waste facility must be operated so that it does not cause a public nuisance or create a potential hazard to public health or welfare.

The construction landfill is operated according to WID procedures that ensure protection of public health and welfare.

26.2.7 Landfill Closure and Postclosure Requirements, SWMR-3, Part V

Part V of the SWMRs specifies a number of landfill closure and postclosure requirements including the installation of a final cover, preparing and implementing a land-use plan, a schedule for completing all closure work, an approved postclosure care and monitoring plan, and annual reports.

This landfill is exempted from these requirements because it receives construction debris only and because it is located at the same site (i.e., WIPP) where the construction debris is generated. Therefore, closure and postclosure requirements are not applicable.

26.2.8 Operator Certification, SWMR-3, Part VI

Part VI of SWMR-3 provides requirements for operator certification: certification of operators is required as of January 31, 1994. The amount and type of personnel training and experience are specified for landfills and for other types of facility.

This landfill is exempted from these requirements because it receives construction debris only and because it is located at the same site (i.e., WIPP) where the construction debris is generated. Therefore, operator certification is not required.

26.2.9 Storage and Containment of Infectious Waste, SWMR-3, § 706(C)

Subpart 706 (C) specifies infectious waste storage and containment requirements, including waste segregation; specifications for container integrity; container labeling and marking; and storage and containment area access, integrity, and marking.

The following practices are ongoing at WIPP:

- Access to the collection and storage area is limited to trained medical personnel who are vaccinated against hepatitis.
- Special containers are easily identifiable through the use of enclosed red-lined bio-hazard bags.
- All sharps are sealed in containers that are leak-proof, puncture-proof, and tamper-proof. These containers are then enclosed in plastic bio-hazard bags.
- All containment bags are clearly identifiable with red lining as specified by 29 CFR 1910.145(f)(4).
- No infectious waste containers are reused.

- Storage and containment areas are in an enclosed, clearly marked environment.
- No compaction or grinding devices are used to reduce the volume of infectious waste.

26.2.10 Infectious Waste Treatment, Storage, and Disposal Facilities, SWMR-3, § 706(D)

Section 706(D) specifies operational requirements for infectious waste treatment, storage, and disposal facilities. Included is a requirement for the preparation and maintenance of a management plan that identifies the type of waste generated or handled; the segregation, packaging, labeling, collection, storage, and transportation procedures to be implemented; the treatment or disposal methods to be used; the transporter and disposal facility to be used; and the person responsible for the management of the infectious waste.

The WID Transportation Manual and the Occupational Health Manual address the operational requirements for infectious waste as specified in this part.

26.2.11 Treatment and Disposal of Infectious Waste, SWMR-3, § 706(E)

Several methods are specified for the treatment and disposal of infectious waste. These methods include controlled incineration, heat sterilization, discharge to a sewage treatment system, and landfilling.

The method of treatment and disposal is incineration or steam sterilization at an off-site facility. Transportation is provided by an off-site subcontractor. Transfer is monitored by WID personnel.

26.2.12 Infectious Waste Transporters, SWMR-3, § 706(F)

Requirements for the transportation of infectious waste are specified in this section.

WIPP does not transport infectious waste. Transportation is accomplished by an off-site subcontractor.

26.2.13 Manifest Requirements, SWMR-3, § 711

A manifest must accompany each shipment of infectious waste. Each manifest must include information on the waste generator, transporter, waste treatment facility, the type of waste, and any special instructions.

Medical waste shipments are accompanied by a shipment manifest that includes the required information.

27.0 NEW MEXICO ENVIRONMENTAL IMPROVEMENT ACT

27.1 Summary of the Law

The enactment of the New Mexico Environmental Improvement Act (EIA; §§ 74-1-1 through 74-1-10 NMSA 1978) created the Environmental Improvement Board (EIB) to promulgate regulations and standards to protect health and safety and the environment. The EIA also created the Environmental Improvement Division, now known as the New Mexico Environment Department (NMED). The act directs the NMED to assume responsibility for environmental management and protection in order to ensure an environment that confers optimal health, safety, comfort, and economic and social well-being on its inhabitants. In carrying out its responsibilities, the NMED is directed to maintain, develop, and enforce regulations and standards in areas including water supply, liquid waste, air quality, radiation control, health and safety, hazardous wastes, and underground storage tanks. As discussed in Chapters 25 through 31 of this report, many of these regulations and standards are applicable to WIPP. These include the Hazardous Waste Act and the implementing hazardous waste management and underground storage tank regulations (Chapter 25), the Solid Waste Act (Chapter 26), the Ground Water Protection Act (Chapter 28), the Air Quality Control Act (Chapter 29), the Water Quality Act (Chapter 30) and Water Supply Regulations (Chapter 31).

27.2 Compliance Status of the Law

The DOE will continue to comply with all applicable New Mexico environmental regulations and standards as demonstrated in the following chapters.

28.0 NEW MEXICO GROUND WATER PROTECTION ACT

28.1 Summary of the Law

The Ground Water Protection Act (GWPA; § 74-6B NMSA 1978) was enacted in 1990 in response to the threat facing public health and safety and the environment from pollution of ground-water resources from leaking underground storage tanks (USTs). The purpose of this act includes the provision of substantive direction that allows the State of New Mexico to take corrective action at sites contaminated by leakage from USTs.

The GWPA is implemented by the regulations of the New Mexico Environment Department (NMED), NMED-92-1, *Ground Water Protection Act Corrective Action Fund Regulations*. These regulations provide guidelines for the payment or reimbursal of the costs of a minimum site assessment and corrective action and specify the requirements for owners or operators of leaking USTs.

The GWPA is also implemented by the Ground Water Protection Act Regulations that are provided in the New Mexico Underground Storage Tank Regulations (USTR) as Part XV. These regulations are discussed in Chapter 25. WIPP has installed two new UST systems that meet the new standards and requirements for USTs. Procedures are in place for routine operations regarding the tanks and for dealing with any spills or releases from the UST systems. Two sections in Chapter 25 (Sections 25.2.6.84 and 25.2.6.85) deal specifically with the applicable New Mexico Ground Water Protection Act Regulations.

28.2 Compliance Status of the Regulatory Requirement

Table 28-1 summarizes the general regulatory requirement and its compliance status under the implementing regulation of the New Mexico Ground Water Protection Act. See also Sections 25.2.2.84 and 25.2.2.85 for the applicable portions of the Ground Water Protection Act Regulations.

TABLE 28-1. New Mexico Ground Water Protection Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
New Mexico Environment Department 92-1, *Ground Water Protection Act Corrective Action Fund Regulations*		
NMED 92-1	Reimbursement of costs from corrective actions for spills/releases from USTs	**NOT APPLICABLE** No spills or leaks from new UST systems [Section 28.2.1]

28.2.1 Corrective Action for Spills/Releases from USTs, NMED-92-1

The owners or operators of USTs that release a regulated substance must take appropriate corrective action. The NMED will reimburse certain costs associated with performing a minimum site assessment and other corrective actions taken for spills or releases from USTs.

NMED-92-1 provides a vehicle for reimbursing the owners and operators of leaking UST systems with some of the costs spent on corrective action and minimum site assessments performed. As a Federal agency, it is doubtful that the DOE would seek to be reimbursed for any such corrective actions taken at WIPP.

29.0 NEW MEXICO AIR QUALITY CONTROL ACT

29.1 Summary of the Law

The New Mexico Air Quality Control Act (§§ 74-2-1 through 74-2-22 NMSA 1978), based primarily on the Clean Air Act (CAA; see Chapter 6), is not generally more stringent than the CAA except in areas of air pollution prevention that have not been preempted by the CAA and are not precluded by the limiting provisions of the Air Quality Control Act. The Air Quality Control Act is implemented by the Air Quality Control Regulations (AQCRs).

Under 40 CFR Part 70, operating permits are required for both area and major sources. The New Mexico Environment Department (NMED) will implement the Federal requirements under AQCR 770, and AQCR 771 will contain the fee structure for the operating permit program. However, these AQCRs have not yet been issued. At this time, emission limits for area sources have not been established, and major source emission thresholds are being used to determine which facilities require operating permits for both area and major sources under 40 CFR Part 70.

29.2 Compliance Status of the Regulatory Requirements

Table 29-1 summarizes the compliance status of the AQCR requirements that are potentially applicable to WIPP. The text provides more detail on the compliance status of each requirement. It should be noted that AQCRs 770 and 771 will deal with the State operating permit program; however, these AQCRs have not yet been issued and, therefore, are not included in this section. Furthermore, based on major source emission thresholds, emissions from WIPP are significantly below the emission levels that require the submittal of an operating permit application.

TABLE 29-1. Air Quality Control Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENTS	COMPLIANCE STATUS
New Mexico Air Quality Control Regulations (AQCRs)		
Air Quality Control Regulation (AQCR) 301	Regulations to control open burning	**ACHIEVED** Open-burning permit (see also Section 29.3.1) [Section 29.2.1]
AQCR 401	Regulations to control smoke and visible emissions	**ACHIEVED** [Section 29.2.2]
AQCR 507	Oil-burning equipment--particulate matter	**NOT APPLICABLE** Oil-burning equipment below rated heat capacity of regulated equipment [Section 29.2.3]
AQCR 605	Oil-burning equipment--sulfur dioxide	**NOT APPLICABLE** Oil-burning equipment below rated heat capacity of regulated equipment [Section 29.2.4]
AQCR 606	Oil-burning equipment--nitrogen dioxide	**NOT APPLICABLE** Oil-burning equipment below rated heat capacity of regulated equipment [Section 29.2.5]
AQCR 700	Permit fees	**ACHIEVED** Fee sent with permit application (see AQCR 702) [Section 29.2.6]

TABLE 29-1 (continued)

CITATION	REQUIREMENTS	COMPLIANCE STATUS
AQCR 702	Permits	**ACHIEVED** Application for permit for generators filed July 13, 1993; permit issued on December 7, 1993 (see Section 29.3.2) [Section 29.2.7]
AQCR 703.1	Annual emission inventory from permitted facility or if more than 1 ton of lead or 10 tons of particulates, SO_2, NO_2, CO, or volatile organic compounds (VOCs) are emitted from the facility in any calendar year	**UP TO DATE** Requirement for the submittal of 1993 emission data from diesel generators completed by submittal of sampling compliance plan (see Section 29.3.2) [Section 29.2.8]
AQCR 710	Stack height requirements	**ACHIEVED** Stack height approved by State [Section 29.2.9]
AQCR 751	NESHAPs - radionuclides (40 CFR Part 61, Subpart H) NESHAPs - other HAPs (40 CFR Part 61, Subpart A)	**NOT APPLICABLE** Radionuclides (Subpart H): not present; EPA-regulated; see Chapter 6 Other HAPs (Subpart A): WID HAPs inventory: HAP emissions not present or significantly below regulatory limits [Section 29.2.10]
AQCR 752	Application for registration of toxic air pollutants (TAPs)	**NOT APPLICABLE** WID HAPs inventory: emissions of TAPs significantly below threshold levels for registration application [Section 29.2.11]

TABLE 29-1 (continued)

CITATION	REQUIREMENTS	COMPLIANCE STATUS
AQCR 801	Excess emissions during malfunction, startup, shutdown, or scheduled maintenance	**UP TO DATE** Any excess emissions that occur to be reported in accordance with AQCR 801 [Section 29.2.12]
AQCR 901	Controlling emissions leaving New Mexico	**ACHIEVED** Emissions do not exceed NAAQS [Section 29.2.13]
AQCR 1001	Sampling equipment	**UP TO DATE** Addressed in AQCR 702 permit [Section 29.2.14]

29.2.1 Regulations to Control Open Burning, AQCR 301

Open burning is allowed for the instruction and training of fire-fighting and -rescue personnel when a permit is obtained from the NMED.

The DOE has applied for, and received, a permit to allow open burning for fire-fighter training. More specific information about the permit is provided in Section 29.3.1.

29.2.2 Regulations to Control Smoke and Visible Emissions, AQCR 401

No person owning or operating stationary combustion equipment shall permit, cause, or allow visible emissions from stationary combustion equipment to equal or exceed an opacity of 20 percent. No emissions of smoke with an opacity greater than 30 percent shall be released into the open air for any period greater than 10 seconds from any diesel-powered vehicle operating below 8000 feet mean sea level. Opacity emissions shall be determined using Method 9 described in Appendix A of 40 CFR Part 60 (minimum time period for taking opacity readings: 10 minutes).

Opacity measurements are not required for the backup diesel generators because no opacity measurements are specifically required under the permit (see Section 29.3.2). However, opacity testing has been performed on the generators and was found to be less than the 20-percent opacity limit.

Other diesel equipment is present on site that does not require a permit under AQCR 702 because this equipment represents such a small source of emissions. The inventory on the equipment was submitted to the NMED with the permit application for the backup generators. The emissions from this diesel equipment fall well below the permit thresholds; however, the equipment is scheduled for opacity testing. Method 9 will be used with at least 10-minute opacity readings.

29.2.3 Oil-Burning Equipment--Particulate Matter, AQCR 507

Standards have been established for particulate-matter emissions from oil-burning equipment with a rated heat capacity exceeding 250 million British thermal units (BTUs) per hour.

No oil-burning equipment at WIPP exceeds this rated heat capacity. The rated heat capacity of each of the generators is only 139.6 million BTUs per hour.

29.2.4 Oil-Burning Equipment--Sulfur Dioxide, AQCR 605

Standards have been established for sulfur dioxide emissions from oil-burning equipment with a rated heat capacity exceeding 1 million million (i.e., 10^{12}) BTUs per hour.

No oil-burning equipment at WIPP exceeds this rated heat capacity. The rated heat capacity of each of the two generators is only 139.6 million BTUs per hour (i.e., 1.4×10^8 BTUs per hour).

29.2.5 Oil-Burning Equipment--Nitrogen Dioxide, AQCR 606

Standards have been established for nitrogen dioxide emissions from oil-burning equipment with a rated heat capacity of 10^{12} BTUs per hour.

No oil-burning equipment at WIPP exceeds this rated heat capacity. The rated heat capacity of each of the two generators is only 139.6 million BTUs per hour (i.e., 1.4×10^8 BTUs/hour).

29.2.6 Permit Fees, AQCR 700

Permit fees must be paid with the submittal of a permit application.

The only permits required at WIPP under the AQCRs are for open burning and for the generators (see also Sections 29.2.6, 29.3.1, and 29.3.2). The permit fee for the diesel generators ($10,100) was submitted with the permit application in July 1993.

29.2.7 Permits, AQCR 702

A permit is required for facilities that emit criteria pollutants or toxic air pollutants at rates that meet or exceed the threshold levels specified in AQCR 702.

Preliminary calculations for the backup diesel generator emissions exceed the hourly thresholds for nitrogen dioxide that require the submittal of a permit application under AQCR 702. Therefore, the WIPP submitted an AQCR 702 permit application to the NMED for the diesel generators, which was received by the State on July 13, 1993. The WIPP received notification from the State on August 24, 1993, that modeling information was needed to complete the application. The information was submitted within the 10-day window specified by the State. The State has since concurred that the permit application is complete. The permit was issued by the NMED on December 7, 1993 (see Section 29.3).

29.2.8 Annual Emission Inventory, AQCR 703.1

An annual emission inventory is required annually for any stationary source permitted under AQCR 702 (except for those sources that are permitted only for TAP emissions). Other sources that are required to file an annual emission inventory are those that must file a Notice of Intent under AQCR 703.1 or that emit in excess of 1 ton of lead or 10 tons of total suspended particulates, particulate matter with an aerodynamic diameter of 10 μ or less (i.e., PM_{10}), sulfur dioxide, nitrogen dioxide, carbon monoxide, or volatile organic compounds (VOCs) in any calendar year including and subsequent to 1990.

The requirement for the 1994 submittal of an annual emission inventory was fulfilled by the submittal of the 1993 diesel generator emission data to the NMED in the sampling compliance plan. WIPP will file annual inventories if the NMED should determine that such annual reports are required.

29.2.9 Stack Height Requirements, AQCR 710

Stack height requirements must be met.

WIPP meets the requirement for stack height. The State has approved WIPP's calculations and modeling.

29.2.10 National Emission Standards for Hazardous Air Pollutants (NESHAPs), AQCR 751

NESHAPs requirements must be met.

The State is authorized to administer the NESHAPs program except for radionuclide emissions. Therefore, the EPA regulates these emissions under Subpart H of 40 CFR Part 61 (see Chapter 6). The State is currently performing an inventory of hazardous air pollutant (HAP) emissions within New Mexico, particularly of the 181 HAPs that were added to the list in the Clean Air Act Amendments of 1990. After the inventory has been completed, the State will begin the process of promulgating regulations to control these emissions. WIPP will be required to comply with these new regulations for any HAPs emitted from a major or an area source.

In 1993, the WIPP completed a HAPs emission inventory (WID, 1993c) The HAP inventory included calculations of the maximal potential hourly and annual emissions of criteria pollutants, all 189 regulated NESHAP pollutants, and the New Mexico toxic air pollutants (TAPs) specified under New Mexico Air Quality Control Regulations (AQCR) 751 and Part III of 702. Emission estimates were used to determine if the WIPP is required to obtain any air permits under State or Federal regulations. Based on the HAPs inventory calculations, WIPP operations are significantly below the 10-ton per year (tpy) emission limit for any individual HAP or the 25-tpy limit for combined HAPs emissions established in Subpart A of NESHAPs. Thus, the WIPP does not have any NESHAP Subpart A permitting or reporting requirement at this time. However, 40 CFR 61.09(a)(1) requires that the EPA be notified of WIPP's anticipated date of initial startup of the source no more than 60 days or less than 30 days before that date.

29.2.11 Application for Registration, AQCR 752

An application for the registration of toxic air pollutants (TAPs) must be submitted to the State if any are or could be emitted at levels that meet or exceed the levels specified in Appendix A of AQCR 752.

As indicated in Section 29.2.10, the WIPP HAPs emission inventory that was completed in 1993 included calculations of the maximal potential hourly and annual emissions of the New Mexico

TAP identified under AQCR 751 and Part III of 702. Emission estimates were used to determine if the WIPP is required to obtain air permits under State or Federal regulations. Based on HAPs inventory calculations, WIPP operations are significantly below the emission limit specified for any TAP; therefore, WIPP is not required to register any air pollutant emissions under AQCR 752.

29.2.12 Excess Emissions During Malfunction, Startup, Shutdown, or Scheduled Maintenance, AQCR 801

Excess emissions during malfunction, startup, shutdown, or scheduled maintenance must be minimized.

Special attention will be paid during startup, shutdown, scheduled maintenance, and any malfunction of the generators to ensure that emissions are minimized. The release of excess emissions is unlikely, however, because a redundant system is in place, and the second backup generator will be used to reduce potential emissions. If excess emissions occur, reporting will be performed as required by AQCR 801.

29.2.13 Controlling Emissions Leaving New Mexico, AQCR 901

Emissions leaving New Mexico must not exceed the standards and regulations of the receiving State.

Emissions calculations and modeling that have been completed reveal that the emissions do not exceed the NAAQs.

29.2.14 Sampling Equipment, AQCR 1001

Sampling equipment on stacks or other openings through which emissions are released to the atmosphere will be used as required.

The sampling equipment required for measuring emissions from the WIPP backup diesel generators was specified by the State in § 3(b) of the permit. Sampling ports, safe sampling platforms, safe access to sampling platforms, and utilities for sampling and testing equipment have been provided. A 0.25-inch stainless steel sampling line adjacent to the sampling ports which extends down to within 4 feet above ground level has been installed as required by the permit. This sampling line provides access for future audits by the NMED (see Section 29.3.2).

29.3 Compliance Status of Permit Conditions

Two permits issued under the AQCRs are in place at WIPP: the open-burning permit and the permit for the backup diesel generators, which was issued to WIPP on December 7, 1993. The permit conditions and the compliance status of each are summarized in Table 29-2. More detailed information is provided in the text.

TABLE 29-2. Air Quality Permits at WIPP - Summary of Regulatory Compliance Status

CONDITION	REQUIREMENTS	COMPLIANCE STATUS
Open-Burning Permit		
Conditions	Application and permit	**ACHIEVED** Permit obtained [Section 29.3.1]
Air Quality Permit No. 310-M-2 for the Two Backup Diesel Generators		
Condition 1	Construction and operation	**UP TO DATE** Equipment installed and operated [Section 29.3.2.1]
Condition 2	Emission rates (NO_2, CO_2, SO_2, and particulate matter)	**UP TO DATE** Compliance tests [Section 29.3.2.2]
Conditions 3-4	Compliance test methods	**UP TO DATE** Completion of compliance tests and submittal of the final *Emission Sampling Report* to the NMED in March 1994 [Section 29.3.2.3]

TABLE 29-2 (continued)

CONDITION	REQUIREMENTS	COMPLIANCE STATUS
Condition 5	Revisions and modifications	**NOT APPLICABLE** Revised permit application and NMED inspections [Section 29.3.2.4]
Condition 6	Notification to subsequent owners	**NOT APPLICABLE** Notification to new owner/operator and to NMED [Section 29.3.2.5]
Condition 7	Right to access property and review records	**UP TO DATE** NMED request to inspect and/or to receive records [Section 29.3.2.6]
Condition 8	Posting of the permit	**ACHIEVED** Posting of permit [Section 29.3.2.7]
Condition 9	Recordkeeping	**UP TO DATE** Records retained; WID procedure [Section 29.3.2.8]
Condition 10	Reporting	**UP TO DATE** Reports and notifications to NMED [Section 29.3.2.9]
Additional condition, p. 8	Permit cancellations	**NOT APPLICABLE** Submittal of new permit application [Section 29.3.2.10]

TABLE 29-2 (continued)

CONDITION	REQUIREMENTS	COMPLIANCE STATUS
Additional condition, p. 8	Notice of intent and emission inventory	UP TO DATE See Section 29.2.8 [Section 29.3.2.11]

29.3.1 Conditions of Open-Burning Permit, Application and Permit

Open burning is allowed monthly for up to 1 year. Up to 500 gallons of propane, diesel, gasoline, wood products, and standard automotive vehicles are to be burned; plywood and tires are excluded. All burning must take place during the time period of 3 hours after sunrise to 1 hour before sunset. The direction of the wind at the burning site must be such that the smoke is generally carried away from public roads and areas of human habitation. All burning must cease whenever an air stagnation advisory is issued for the area by the U.S. Weather Service. All material to be burned must be as dry as possible, and the amount of dirt on the material must be minimized. No natural or synthetic rubber or petroleum products shall be burned. All applicable restrictions, codes, and ordinances shall be met.

All conditions specified in the application and in the permit are met. The permit is valid from March 1, 1994, to March 1, 1995.

29.3.2 Permit for Backup Diesel Generators, Permit No. 310-M-2

The conditions specified by Air Quality Permit No. 310-M-2 for the backup diesel generators at WIPP are described in this section.

29.3.2.1 Construction and Operation, Condition 1

The plant [i.e., the diesel generators] shall be constructed and operated as described in the permit application dated June 18, 1993, and with the air quality monitoring information that was submitted on September 22, 1993, unless modified by the

conditions of this permit. The facility consists of two Caterpillar diesel generators with a rated capacity of 1500 horsepower. Only one Caterpillar diesel engine may operate at one time, and the sum of hours of operation for both engines shall not exceed 480 hours per year. Changes in plans, specifications, and other representations provided in the application documents shall not be made if they change the method of emissions control or in the character of the emissions or if they would increase the discharge of emissions. Any such proposed change must be submitted as a proposal revision or modification of the permit accordance with the condition described in Section 29.3.2.4.

The equipment described in the permit application was installed and is operated in accordance with the application and with the terms and conditions of the permit.

29.3.2.2 Emission Rates, Condition 2

The NMED has specified maximal emission rates for nitrogen oxide, carbon monoxide, sulfur dioxide, and particulate matter (see Table 29-3). The rates specified are in terms of pounds per hour and tons per year from each engine and from the facility (i.e., both engines).

The amounts of emissions were based upon calculations for the equipment installed. The equipment is operated and maintained in accordance with the manufacturer's specification.

TABLE 29-3. Allowable Emission Rates from the Diesel Generator Engines at WIPP

Pollutant	Allowable Emission Rates			
	Allowable Emission Rates from Each Diesel Engine		Total Allowable Rates from Both Diesel Engines	
	Pounds per Hour	Tons per Year	Pounds per Hour	Tons per Year
Nitrogen dioxide	46.3	5.6	46.3	11.2
Carbon monoxide	10.1	1.2	10.1	2.4
Sulfur dioxide	3.1	0.4	3.1	0.8
Particulate matter	3.3	0.4	3.3	0.8

29.3.2.3 Compliance Test Methods, Conditions 3-4

Initial compliance tests for all four pollutants described for Condition 2 (Section 29.3.2) are required for one of the diesel generators. Compliance tests may be reimposed if noncompliance is indicated or if the tests were technically unsatisfactory. The tests shall be conducted within 60 days after achieving the maximal production rate at which the generator will normally be operated. If the maximal production rate does not occur within 120 days of source startup, the tests must be conducted no later than 180 days after the initial startup of the source.

The tests shall be conducted in accordance with EPA Reference Methods 1-4, Method 5 (particulate matter), Method 6 (sulfur dioxide), Method 7(A-E) (nitrogen dioxide), and Method 10 (carbon monoxide) contained in 40 CFR Part 60, Appendix A, and with the requirements of 40 CFR 60.8(f). The oxygen in the stack gas shall be determined by using EPA Method 3.

The NMED shall be notified of the date and time of compliance testing at least 30 days before the planned test date so that the NMED may have an observer present during testing. The permittee will arrange a pretest meeting with the NMED at least 30 days prior to the anticipated test date and shall observe the pre-testing and testing procedures described in detail under this condition. These requirements include submitting a written test protocol to the NMED at least 1 week prior to the testing date for approval and providing appropriate equipment and access to the NMED observer for sampling. Several parameters (i.e., engine revolutions per minute, exhaust static pressure, exhaust manifold temperature, fuel consumption, and horsepower as indicated by kilowatt output] shall be monitored and recorded during the test and the results included with the test report. Flow straighteners shall be installed where necessary to prevent cyclonic flow in the stack. The tests shall be conducted at 90 percent of full load or greater and at additional loads as specified by NMED personnel at the test or pre-test meeting.

Two copies of the compliance test report must be submitted to the NMED within 30 days after completion of testing.

Compliance with these conditions was achieved. The compliance test report (*Emission Sampling Report, Backup Diesel Generator*) was submitted to the NMED Air Quality Bureau on March 6, 1994, and was approved on May 12, 1994.

29.3.2.4 Revisions and Modifications, Condition 5

Any future changes shall be preceded by the submittal of a permit application to the NMED in accordance with AQCR 702. No modifications shall be made prior to the issuance of the revised permit.

There have been no revisions or modification to the equipment or its operation.

29.3.2.5 Notification to Subsequent Owners, Condition 6

If there is any change in control or ownership of the diesel generators, the permittee shall notify the succeeding owner of the permit and its conditions and shall notify the NMED of the change in ownership within 15 days of the change.

There has been no change in ownership or control of the permitted equipment.

29.3.2.6 Right to Access Property and Review Records, Condition 7

The NMED will be given the right to enter the facility at all reasonable times to verify the terms and conditions of the permit. Upon receipt of a verbal or written request from any authorized representative of the NMED, the company will produce any records or information necessary to demonstrate that the terms and conditions of the permit are being met.

Upon request, NMED representatives will be allowed non-restricted entry to the site and will be provided with appropriate records and information.

29.3.2.7 Posting of the Permit, Condition 8

A copy of the permit will be posted and in view of the plant site at all times. It will be made available to NMED personnel for inspection upon request.

A copy of the permit is posted in the office of the Facility Operations Shift Supervisor.

29.3.2.8 Recordkeeping, Condition 9

DOE will maintain an operational log in which the date, time, and hours of operation will be recorded for each engine. The records will be maintained on site for at least 2 years from the time of recording and will be made available to NMED personnel upon request.

Completion and maintenance of operational logs are carried out as prescribed by WID procedure.

29.3.2.9 Reporting, Condition 10

The permittee will notify the NMED in writing or provide the NMED with the following information:

- *The anticipated date of the initial startup of each new or modified emission source at least 30 days prior to that date*
- *The actual date of the initial startup of each new or modified source within 15 days after the startup date*
- *The date when each new or modified source reaches the maximal production rate at which it will operate within 15 days after that date*
- *Any change of operators within 15 days after the change*

- *Any necessary update or correction no more than 60 days after the operator knows or should have known of the condition necessitating the update or correction of the permit.*

Notice of the initial startup of each source was submitted to the Air Quality Bureau in December 1993. Subsequent reports will be filed as needed.

29.3.2.10 Permit Cancellations (Permit, p. 8)

The NMED will cancel the permit automatically if any source ceases operation for at least 5 years or if the construction or modification of a source is not initiated within 2 years from the date of issuance or if work on construction or modification is suspended for a total of 1 year.

If the generator ceases operation for at least 5 years and is to be reactivated, a new permit application will be filed. The generators will not be operated until the permit has been issued.

29.3.2.11 Notice of Intent and Emission Inventory (Permit, p. 8)

Requirements related to Notice of Intent and emission inventory are contained in AQCR 703.1.

See Section 29.2.8, which pertains to compliance with AQCR 703.1.

30.0 NEW MEXICO WATER QUALITY ACT

30.1 Summary of the Law

With the enactment of the New Mexico Water Quality Act (WQA; 74-6-1 through 74-6-17 NMSA 1978), a mechanism was provided at the State level to establish water-quality standards that are consistent with the Federal Clean Water Act (CWA). The State act created the Water Quality Control Commission (WQCC) and directed the WQCC, as the State's water-pollution-control agency for all purposes of the CWA, to adopt a comprehensive water quality management program and water quality standards. The *New Mexico Water Quality Control Commission Regulations* include water-quality standards for ground and surface water and regulations regarding discharges to surface-water courses and ground water. Pursuant to the regulations of § 3-109, *Director Approval, Disapproval, Modification, or Termination of Proposed Discharge Plans*, the discharge plan submitted by the DOE for the discharge of 23,000 gallons per day (gpd) of sewage effluent and up to 1,500 gpd of nonhazardous brine water from the WIPP was approved in 1992.

30.2 Compliance Status of the Regulatory Requirements

Table 30-1 summarizes the regulatory requirements and their compliance status under the New Mexico Water Quality Act. Following the table, the text gives more detail on the compliance status for each requirement.

TABLE 30-1. New Mexico Water Quality Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
WQCC 82-1, *New Mexico Water Quality Control Commission Regulations*		
WQCC 82-1, § 1-201	Notice of Intent (NOI) to discharge	**ACHIEVED** NOI filed as required [Section 30.2.1]

TABLE 30-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
WQCC 82-1, § 1-202	Filing of plans and specifications—sewerage systems	**ACHIEVED** Submitted to New Mexico Environment Department (NMED) [Section 30.2.2]
WQCC 82-1, § 1-203	Notification of discharge—removal: requirements for notification, corrective action, and reporting in the event of an unauthorized discharge of oil or other water contaminant that could have adverse effects	**UP TO DATE** *RCRA Contingency Plan* [Section 30.2.3]
WQCC 82-1, § 2-101	General discharge limitations and sampling/analytical requirements	**UP TO DATE** Specified in NMED Discharge Plan Approval [Section 30.2.4]
WQCC 82-1, § 3-104	Authorization only of effluent(s)/leachate(s) as specified in discharge plan	**UP TO DATE** Authorization granted [Section 30.2.5]
WQCC 82-1, § 3-106	Application for discharge plan approval	**ACHIEVED** Application sent to NMED [Section 30.2.6]

TABLE 30-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
WQCC 82-1, § 3-107	Monitoring, reporting, and other requirements	**UP TO DATE** Monitoring reports filed [Section 30.2.7]
WQCC 82-1, § 3-108	Public notice and participation	**ACHIEVED** Public notice published [Section 30.2.8]
WQCC 82-1, § 3-109	Director approval, disapproval, modification, or termination of proposed discharge plans	**UP TO DATE** Discharge Plan to be revised if necessary [Section 30.2.9]
WQCC § 91-1	Water quality standards for interstate and intrastate streams in New Mexico	**NOT APPLICABLE** No streams affected by WIPP [Section 30.2.10]

30.2.1 Notice of Intent to Discharge, WQCC 82-1, § 1-201

Any party intending to make a new water contaminant discharge or to alter the character or location of an existing water contaminant discharge, unless the discharge is being made or will be made into a community sewer system or subject to the Liquid Waste Disposal Regulations adopted by the New Mexico Environmental Improvement Board, shall file a notice with the Water Pollution Control Bureau of the New Mexico Environment Department (NMED).

Notices of Intent to discharge have been filed as required. The latest filing occurred on January 8, 1992.

30.2.2 Filing of Plans and Specifications - Sewerage Systems, WQCC 82-1, § 1-202

Any party proposing to construct a sewerage system or proposing to modify any sewerage system in a manner that will change the quantity or quality of the discharge from the system substantially must file plans and specifications for the construction or modification with the Water Pollution Control Bureau of the NMED.

Sewerage system plans and specifications were included in the transmittal of the Discharge Plan application to the NMED.

30.2.3 Notification of Discharge - Removal, WQCC 82-1, § 1-203

Requirements for reporting, notifications, and corrective action with respect to any discharge from any facility of oil or other water contaminant, in such quantity as may with reasonable probability injure or be detrimental to human health, animal or plant life, or property, or unreasonably interfere with the public welfare or the use of property are specified.

In the event of an unauthorized discharge of oil or other potentially harmful water contaminants, notification and reporting will be performed and corrective action taken according to WID procedures and the *RCRA Contingency Plan*. The discharge will be reported to the Chief of the Groundwater Bureau of the NMED within 24 hours. A written report will be submitted within 7 days, as required under this regulation.

30.2.4 General Requirements, WQCC 82-1, § 2-101

General discharge limitations and sampling/analytical requirements for the discharge of effluents to a watercourse must be met.

These limitations and requirements are specified in the NMED's Discharge Plan Approval DP-831. The discharge limitations and the sampling/analytical requirements are met. Reports are submitted quarterly to the NMED.

30.2.5 Discharge Plan Required, WQCC 82-1, § 3-104

No party shall cause or allow effluent or leachate to discharge so that it may move directly or indirectly into ground water unless the discharge meets the requirements of a discharge plan approved by the Director. When a plan has been approved, discharges must be consistent with the terms and conditions of the plan.

The discharge of 1,500 gallons per day of nonhazardous brine water at WIPP is authorized by NMED Discharge Plan Approval DP-831.

30.2.6 Application for Discharge Plan Approval, WQCC 82-1, § 3-106

Any party who intends to begin discharging any listed water contaminants or any toxic pollutant so that they may move directly or indirectly into ground water must submit a discharge plan as required.

The Discharge Plan application was submitted to the NMED on November 14, 1991. The NMED approved the Discharge Plan on January 16, 1992; it will expire on January 16, 1997.

30.2.7 Monitoring, Reporting, and other Requirements, WQCC 82-1, § 3-107

Requirements include notification of the NMED of any facility expansion, production increase, or process modifications that would result in the discharge of water contaminants.

Monitoring reports are filed quarterly according to the following schedule: January 16, April 16, July 16, and October 16.

30.2.8 Public Notice and Participation, WQCC 82-1, § 3-108

Within 30 days of filing of a proposed discharge plan, or modification or renewal of an approved discharge plan, the NMED must ensure that the public and affected governmental agencies are notified.

The NMED published public notice of the Discharge Plan on December 15, 1991. No comments were received from the public.

30.2.9 Director Approval, Disapproval, Modification, or Termination of Proposed Discharge Plans, WQCC 82-1, § 3-109

If the monitoring data submitted indicate that these regulations are being or may be violated or that the standards in WQCC 82-1, § 3-102, "Standards for Ground Water of 10,000 mg/L TDS [total dissolved solid] Concentration or Less," are being or will be exceeded in ground water at any place of withdrawal for the present or reasonably foreseeable future due to the discharge, it may be necessary to modify the discharge plan.

If the monitoring data submitted indicate that the Discharge Plan conditions or the standards are being or will be exceeded, it may be necessary to revise the Discharge Plan.

Since the approval of discharge may not exceed 7 years from the date of issuance of the Discharge Plan approval, it will be necessary to find an alternative means of disposal for the nonhazardous brine solution currently being discharged.

30.2.10 Water Quality Standards for Interstate and Intrastate Streams in New Mexico, WQCC 91-1

The State has set a number of water-quality standards for interstate and intrastate streams in New Mexico.

The water-quality standards for interstate and intrastate streams in New Mexico do not apply to WIPP because there are no streams, either intermittent or permanent, that will be affected by WIPP.

30.3 Compliance Status of the Permit Requirements

Table 30-2 summarizes the specific and general requirements from the Discharge Plan for WIPP and their compliance status. Additional information is provided in the text.

TABLE 30-2. New Mexico Water Quality Act - Summary of Compliance Status of Permit Requirements

CITATION	REQUIREMENT	COMPLIANCE STATUS
Approval DP-831, *New Mexico Discharge Plan for the WIPP*		
DP-831 Specific Requirement (SR) #1	Monitoring and quarterly reports	**UP TO DATE** Monitoring conducted and reports submitted quarterly [Section 30.3.1]
DP-831 SR #2	Submittal of water quality analysis with quarterly report	**UP TO DATE** Analysis submitted quarterly [Section 30.3.2]
DP-831 SR #3	Quarterly sampling of each evaporation lagoon	**UP TO DATE** Sampling and results reported quarterly [Section 30.3.3]
DP-831 SR #4	Maintenance of berms protecting the lagoon system from precipitation runoff and runon	**UP TO DATE** Performed quarterly [Section 30.3.4]
DP-831 SR #5	Completion of proposed evaporation ponds	**ACHIEVED** Completed July 16, 1993 [Section 30.3.5]

TABLE 30-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
DP-831 General Requirement (GR)-- Recordkeeping	Records to be kept and made available to the NMED upon request	**UP TO DATE** Information recorded and available [Section 30.3.6]
DP-831 GR - Inspection and Entry	Allowing inspections, entry, sampling, and monitoring by NMED personnel	**UP TO DATE** Activities allowed on site [Section 30.3.7]
DP-831 GR - Duty to Provide Information	Providing information relevant to discharge plan/records required by Discharge Plan that has been requested by NMED	**UP TO DATE** [Section 30.3.8]
DP-831 GR - Spills, Leaks, and Other Unauthorized Discharges	Reporting and remediation of any spills, leaks, and any other unauthorized discharges	**UP TO DATE** Reports to be made if unauthorized discharges occur; no reporting required to date [Section 30.3.9]
DP-831 GR - Retention of Records	Retention of all monitoring information, discharge plan reports, and data used to complete the discharge plan application for at least 5 years	**UP TO DATE** Documentation being retained [Section 30.3.10]

TABLE 30-2 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
DP-831 GR - Modifications and/or Amendments	Notification of NMED of any modifications or additions to the wastewater disposal system; approval by NMED required prior to increasing the quantity or concentration of constituents in waste water above those approved in the plan	**UP TO DATE** Approval to be obtained as required [Section 30.3.11]

30.3.1 Requirements for Monitoring and Quarterly Reports, DP-831 Specific Requirement (SR) #1

The applicant shall monitor the quantity of brine water pumped into the evaporation ponds monthly and submit a quarterly report to the Ground Water Section's Office.

The monitoring required by the NMED Discharge Plan Approval (DP-381) has been conducted as required. The results have been submitted in the quarterly Discharge Monitoring Reports required by the Discharge Plan, which are prepared in accordance with a Westinghouse Waste Isolation Division (WID) procedure.

30.3.2 Requirement for Water Quality Analysis Submitted with Quarterly Report, DP-831 SR #2

A water quality analysis shall be submitted with the quarterly report mentioned above in SR #1.

Water quality analyses have been submitted with the quarterly reports.

30.3.3 Requirement that the Evaporation Lagoon be Sampled and the Results Reported, DP-831 SR #3

Each evaporation lagoon shall be sampled quarterly for total dissolved solids (TDS) and the results submitted in the quarterly report.

Each evaporation lagoon has been sampled quarterly. The results have been reported in the quarterly reports.

30.3.4 Requirement for Berm Maintenance, DP-831 SR #4

Berms protecting the lagoon system shall be maintained to protect it from precipitation runoff and runon.

Maintenance of the berms is performed quarterly.

30.3.5 Requirement for Completion of Proposed Evaporation Ponds, DP-831 SR #5

The applicant has 18 months from the date of approval to complete construction of the proposed evaporation ponds. The applicant can discharge brine waters into the existing salt pile evaporation pond until the new evaporation ponds are completed.

The evaporation ponds were completed by July 16, 1993, as required.

30.3.6 General Requirement, *Recordkeeping*, DP-831

The discharger must maintain a written record of ground-water and wastewater quality analyses at the facility. The information must be recorded and made available to the NMED upon request.

Monitoring, reporting, and recordkeeping requirements are met as specified in the Discharge Plan.

30.3.7 **General Requirement, *Inspection and Entry*, DP-831**

The discharger shall allow the NMED Secretary or her authorized representative, upon the presentation of credentials, to enter the discharger's facility during regular business hours or at other reasonable times under the conditions of this discharge plan.

NMED personnel are allowed on site to conduct inspections, sampling, and monitoring during normal business hours.

30.3.8 **General Requirement, *Duty to Provide Information*, DP-831**

The discharger shall furnish to the NMED, within a reasonable time frame specified by the NMED, any relevant information which it may request to determine whether cause exists for modifying, terminating, and/or renewing this discharge plan or to determine compliance with this plan. The discharger shall furnish to the NMED, upon request, copies of records required to be kept by this discharge plan.

No requests have been received from the NMED to provide information relevant to the Discharge Plan. Similarly, the NMED has not requested copies of the records to be maintained under the terms of the Discharge Plan.

30.3.9 **General Requirement, *Spills, Leaks, and other Unauthorized Discharges*, DP-831**

Any unauthorized discharges must be reported to the NMED and remediated as required. This requirement applies to all seeps, spills, and/or leaks discovered from the sewerage lagoons or that may directly or indirectly leave the boundaries of the WIPP site.

Any spills, leaks, and other unauthorized discharges will be reported to NMED and remediated in accordance with WIPP procedures.

30.3.10 General Requirement, *Retention of Records*, DP-831

The discharger shall retain records of all monitoring information, including all calibration and maintenance records, copies of all reports required by this discharge plan, and records of all data used to complete the application for this discharge plan, for a period of at least 5 years from the date of the sample collection, measurement, report, or application.

All monitoring information, analytical results, discharge plan reports, and data used to complete the discharge plan application will be retained for at least 5 years.

30.3.11 General Requirement, *Modifications and/or Amendments*, DP-831

The discharger must notify the NMED of any modifications or additions to the applicant's wastewater disposal system, including any increase in wastewater flow rate and wastewater storage and disposal management changes to the system as approved under this discharge plan. The discharger shall obtain the NMED's approval, as a discharge plan modification, prior to any increase in the quantity or concentration of constituents in the wastewater above those approved in this plan.

If any modifications or additions to the wastewater disposal system are planned for WIPP that would increase the quantity and/or the concentration of constituents in the waste water above those approved in the discharge plan, the NMED will be notified. No work will be initiated until the NMED approves the modification or addition.

31.0 NEW MEXICO WATER SUPPLY REGULATIONS

31.1 Summary of the Regulations

Like the Safe Drinking Water Act (SDWA), the New Mexico Water Supply Regulations (WSRs) provide a regulatory strategy for protecting public water-supply systems within the State. The WSRs identify the various categories of water-supply systems and establish operating requirements for each system. The WSRs establish the maximum contaminant levels (MCLs) for water-supply systems and implement monitoring and analytical requirements for each system.

31.2 Compliance Status of the Regulatory Requirements

The New Mexico Environment Department (NMED) notified the WIPP on September 9, 1992, that the WIPP water-line system is considered a public water supply and classified the system as a non-transient, non-community water supply for reporting and testing under the requirements of the SDWA. The DOE has corresponded with the NMED since the original letter of September 9, 1992, which identified the WIPP as a non-transient, non-community water supply system, to obtain a determination of the specific SDWA sampling requirements for the site. This direction was requested because the WIPP obtains raw water from the Double Eagle Water Line, which is owned and operated by the City of Carlsbad.

On March 11, 1994, the NMED Carlsbad Field Office provided specific direction on the type of SDWA sampling required for the WIPP water supply system. The letter references Part III, § 310, of the New Mexico Water Supply Regulations, which states:

> When a public water system supplies water to one or more other public water supply systems, the Department may modify the compliance sampling requirements imposed by the regulations to the extent that the interconnection of the systems justifies treating them as a single system for compliance sampling purposes.

The NMED went on to determine that "since the Carlsbad Municipal Public Water Supply (WSS# 206-08) provides WIPP with its water and since Carlsbad already tests the various constituents at each Double Eagle wellfield source, WIPP is exempted from taking these samples." The NMED then determined that the WIPP is required to obtain entry-point system samples including lead, copper, and total coliform bacteria.

The specific requirements that are applicable to WIPP and the compliance status of each are summarized in Table 31-1. More detailed information is provided in the text.

TABLE 31-1. New Mexico Water Supply Regulations (WSR-3) - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
WSR 3, § 107(A)(1)	Use of chlorinated materials as disinfectants or oxidants	**ACHIEVED** Chlorination of raw water from Carlsbad [Section 31.2.1]
WSR 3, § 202(A)	Maximum contaminant levels (MCLs) for inorganic chemicals	**ACHIEVED** Preliminary sampling of inorganics: below MCLs [Section 31.2.2]
WSR 3, § 205(A)	MCL for total coliform bacteria	**UP TO DATE** Monthly sampling: below MCL [Section 31.2.3]
WSR 3, § 208(I)	Cross connections	**UP TO DATE** Inspections, corrective actions [Section 31.2.4]
WSR 3, § 301(E)	Certification of sampling personnel	**ACHIEVED** Certification of personnel involved with sampling [Section 31.2.5]
WSR 3, § 302(A)	Compliance sampling of coliforms	**UP TO DATE** At least one sample of total coliform bacteria collected per month; WIPP Water Sampling Plan in WID procedure [Section 31.2.6]

TABLE 31-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
WSR 3, § 305(A)(2)	Requirements for organic chemicals other than total trihalomethanes	**NOT APPLICABLE** No analyses for organic compounds required by NMED [Section 31.2.7]
WSR 3, § 309	Laboratories	**ACHIEVED** Contracts with laboratories; QA/QC [Section 31.2.8]
WSR 3, § 310	Sampling of consecutive public water-supply systems	**ACHIEVED** Modified sampling requirements [Section 31.2.9]
WSR 3, § 401(A)	Reporting requirements	**UP TO DATE** Submittal of analytical reports [Section 31.2.10]
WSR 3, § 403(A)	Record maintenance	**UP TO DATE** Maintenance of analytical results as quality records [Section 31.2.11]
WSR 3, § 404(B)	Public notice requirements pertaining to lead	**UP TO DATE** Results of analyses for lead to be posted at WIPP [Section 31.2.12]

31.2.1 Use of Chlorinated Materials as Disinfectants or Oxidants, WSR 3, § 107(A)(1)

The EPA Administrator has identified several options for chlorinated materials to be used as alternate or supplemental disinfectants or oxidants as the best technology, treatment techniques, or other means that are generally available for achieving compliance with the maximum contaminant level (MCL) for total trihalomethanes.

Raw water received at WIPP from the Carlsbad water-supply systems is chlorinated with sodium hypochlorite (NaClO).

31.2.2 Maximum Contaminant Levels (MLCs) for Inorganic Chemicals, WSR 3, § 202(A)

The NMED requires that the water-supply entry point at WIPP be sampled for lead and copper. The MCLs for lead and copper are 0.05 and 1.3 mg/L, respectively.

The sampling of inorganic chemicals required at WIPP is in progress. The results of previous analyses suggest that the concentrations of the inorganic chemicals of concern will fall below the respective MCLs.

31.2.3 MCL for Total Coliform Bacteria, WSR 3, § 205(A)

The MCL for total coliform bacteria is based on the presence or absence of total coliforms in a sample rather than on coliform density. For a system that collects fewer than 40 samples per month, the system is in compliance with the total coliform MCL if no more than one sample collected during the month is total coliform positive.

Analyses for total coliform bacteria (i.e., *Escherichia coli*) are being performed at WIPP on a monthly basis. The laboratory submits the results to WIPP and to the NMED. To date, the MCL for total coliforms has been met.

31.2.4 Cross Connections, WSR 3, § 208(I)

No physical connection between a public water supply and any water-supply source not regulated by the NMED is allowed unless the public water-supply system is protected by a backflow prevention device that has been reviewed by the NMED and is listed by an appropriate listing agency.

WIPP personnel are working with the City of Carlsbad to prepare and implement a WIPP Waterline Cross-Connection Plan. Inspections of the system's cross connections are under way. Corrective actions are being implemented as needed.

31.2.5 Certification of Sampling Personnel, WSR 3, §301(E)

All persons who collect compliance samples for water-supply samples must possess a current Sampling Certificate issued by the Secretary of the NMED. Sampling Certificates are issued only to persons who have successfully completed an approved training course and have passed an examination that is administered periodically by the NMED. Sampling Certificates are issued for up to 3 years.

All WIPP personnel who are involved with water-supply sampling to ensure compliance with the WSRs have completed the New Mexico water-sampling training course and have received Sampling Certificates.

31.2.6 Compliance Sampling of Coliforms, WSR 3, § 302(A)

Public water-supply systems must collect total coliform samples at sites that are representative of water throughout the distribution system according to their approved written sampling plan.

The minimal number of samples required per month is based on the population served by the system. Only one sample per month is required by a water-supply system that serves an average daily population of 25 to 1,000.

Samples are collected at a site that is representative of water throughout the distribution system, which is described in the WIPP Water Sampling Plan. This plan is contained within a WID

procedure and has been approved by the NMED. It is currently being revised to incorporate the lead and copper monitoring requirements from the Discharge Plan Approval.

Fewer than 1,000 people are served by the water-supply system at WIPP. Therefore at least one sample is collected per month for total coliform bacteria analysis.

31.2.7 Requirements for Organic Chemicals other than Total Trihalomethanes, WSR 3, § 305(A)(2)

For community water systems using only ground-water sources, analysis for organic insecticides and herbicides shall be completed by those systems that have been specified by the NMED.

The NMED does not require that WIPP sample for insecticides, herbicides, or any other organic compound(s).

31.2.8 Laboratories, WSR 3, § 309

Compliance samples may be considered only if they have been analyzed by a laboratory that is acceptable to the NMED.

WIPP has contracts in place with two off-site EPA-certified laboratories to complete all microbiological and inorganic analyses required by the NMED for WIPP. Both laboratories have undergone quality assurance/quality control (QA/QC) review and approval. Each laboratory has an approved Quality Assurance Project Plan (QAPjP) in place and is listed on the WIPP Qualified Supplier List (QSL).

31.2.9 Sampling of Consecutive Public Water-Supply Systems, WSR 3, § 310

When a public water-supply system provides water to one or more other public water-supply systems, the NMED may modify the compliance sampling requirements imposed by these regulations. Any modified compliance sampling shall be conducted in accordance with the schedule specified by the NMED.

The water-supply system at WIPP receives its water from the public water-supply system of the City of Carlsbad. Carlsbad is responsible for all well-source sampling. Therefore, the NMED has modified the compliance sampling requirements for WIPP and requires sampling only for

lead, copper, and total coliform bacteria. The schedule mandated by the NMED for sampling is presented in Table 31-2.

TABLE 31-2. Required Sampling at WIPP for Compliance with the Safe Drinking Water Act and the New Mexico Water Supply Regulations

Contaminant	Frequency of Water-Supply Sampling
Lead and copper (for water systems for populations of 501 to 3,300)	Initial sampling requires 20 sample sites for two 6-month periods beginning on July 1, 1993; requirements may be reduced when action levels are met for two consecutive sampling periods.
Total coliform bacteria	Once per month

31.2.10 Reporting Requirements, WSR 3, § 401(A)

Unless a shorter period is specified, the water supplier shall provide a copy of the results and data required to the appropriate NMED field office within 10 days after analysis.

Analytical reports for inorganic chemicals are submitted to the appropriate NMED field office within 10 days of their receipt by WID personnel. The analytical laboratory that analyzes total coliform bacteria sends a copy of the results and data directly to WIPP and to the appropriate NMED field office.

31.2.11 Record Maintenance, WSR 3, § 403(A)

A water supplier shall retain the appropriate records on or near the premises of the public water-supply system. Records of bacteriological and chemical analyses shall be kept for at least 5 and 10 years, respectively. The information that must be retained includes the date, place, and time of sampling; the name of the person who collected the sample; identification of the sample; date of analysis and name of the laboratory and person who performed the analysis; the analytical method used; and the results of the analysis.

All applicable records pertaining to the sampling and analysis and the analytical results are maintained as quality records by WID.

31.2.12 Public Notice Requirements Pertaining to Lead, WSR 3, § 404(B)

> *Notice pertaining to lead concentrations in drinking water shall be given to persons served by the system. For non-transient, non-community water systems, notice may be given by continuous posting. If posting is used, the notice shall be posted in a conspicuous place in the area served by the system, and the posting shall continue for 3 months.*

On March 11, 1994, the NMED provided a determination that copper and lead sampling is required at WIPP. Sampling is expected to occur in April 1994. Upon receipt of the analytical results pertaining to lead, the analytical results (i.e., the lead concentrations) will be posted at WIPP. Because WIPP is the end user of the WIPP water-supply system, no other public notice is required.

32.0 NEW MEXICO HAZARDOUS CHEMICALS INFORMATION ACT

32.1 Summary of the Law

The New Mexico Hazardous Chemicals Information Act (HCIA; §§ 74-4E-1 through 74-4E-9 NMSA 1978) was enacted to ensure that current information on the nature and location of hazardous chemicals is available to Local Emergency Planning Committees (LEPCs), emergency responders, and the public as required by Title III. The HCIA created the State Emergency Response Commission (SERC) and directs facility owners or operators to notify the New Mexico Department of Public Safety under certain conditions, including the presence of extremely hazardous substances at or above a specified quantity at a facility and the release of any chemical substance that has occurred at or above reportable quantities determined by the State. The HCIA specifies reports to be submitted to the State, including toxic chemical release and hazardous material inventory reports.

32.2 Compliance Status of the Regulatory Requirements

Table 32-1 summarizes each applicable requirement and its compliance status under the Hazardous Chemical Information Act. The text provides more detail on the compliance status of each requirement.

TABLE 32-1. Hazardous Chemicals Information Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
Hazardous Chemicals Information Act, §§ 74-4E-1 to 74-4E-9 NMSA 1978		
§ 74-4E-5(A)(1)	Notification to the State that an extremely hazardous substance, at or above a specified quantity, is present at a facility	**UP TO DATE** Notifications and revised listing submitted [Section 32.2.1]
§ 74-4E-5(A)(2)	Notice of release of chemical substance(s) when release is at or above the reportable quantity of the substance	**UP TO DATE** Notification of releases of ethylene glycol submitted [Section 32.2.2]

TABLE 32-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
§ 74-4E-5(A)(3)	Submittal of an inventory form covering each hazardous material on or before March 1 of each year	**UP TO DATE** Chemical inventory submitted in March 1993 and 1994 [Section 32.2.3]
§ 74-4E-5(A)(4)	Submittal of Toxic Chemical Release Inventory (TRI) forms to Public Safety Department for facilities employing at least 10 employees and with SIC code between 20-39 classification	**NOT APPLICABLE** TRI reporting not currently required due to certain exemptions [Section 32.2.4]

32.2.1 Notice of Extremely Hazardous Substance, § 74-4E-5(A)(1)

Facility owners or operators must notify the State safety department that an extremely hazardous substance, at or above the threshold planning quantity, is present at a facility.

The requirement to notify the SERC of the WIPP's being subject to emergency planning requirements has been met.

The WIPP submits a list of hazardous chemicals to the SERC, the LEPC, and the local fire department whenever additional substances are received or if significant new information is received about an item for which a list was provided. In March and August 1993 and March 1994, a revised list of hazardous chemicals was submitted to these organizations. The listing comprised extremely hazardous substances present in amounts equal to or greater than the Threshold Planning Quantity (TPQ) or 500 pounds, whichever is less, and all substances classified as hazardous under the Occupational Safety and Health Act Hazard Communication Standard with site inventories equal to or greater than 10,000 pounds.

32.2.2 Notice of Release of Chemical Substance(s), § 74-4E-5(A)(2)

Facility owners or operators must notify the State safety department of the release of a chemical substance when the release is at or above the reportable quantity of the substance.

During this reporting period, there were three ethylene glycol spills at WIPP that exceeded the reportable quantity of 1 pound. These were reported to the SERC and the LEPC.

32.2.3 Hazardous Material Inventory, § 74-4E-5(A)(3)

Facility owners or operators must submit to the State an inventory form containing Tier II information on or before March 1 of each year.

The WIPP submitted the Emergency and Hazardous Chemical Inventory Report (Tier II Report) in March 1993 and 1994 to the SERC, the LEPC, and the local fire department.

32.2.4 Toxic Chemical Release Inventory, § 74-4E-5(A)(4)

Facility owners or operators employing at least 10 employees and with a SIC code between 20 and 39 must submit a toxic chemical release form on or before July 1 of each year to the State safety department.

During this reporting period, the WIPP was exempt from submitting a Toxic Chemical Release Inventory report because of the use of toxic chemicals at WIPP and the exemptions described in 40 CFR 372.38, *Exemptions*.

33.0 NEW MEXICO EMERGENCY MANAGEMENT ACT

33.1 Summary of the Law

The New Mexico Emergency Management Act (EMA; §§ 74-4B-1 through 74-4B-14 NMSA 1978) was enacted to ensure the adequacy of hazardous material emergency management capabilities in the State to protect the health and safety of New Mexico citizens and the environment. The act delineates those State agencies that are responsible for responding to hazardous material accidents and providing for control and management of such accidents. Furthermore, the act provides for the formulation of a comprehensive hazardous materials emergency management plan.

33.2 Compliance Status of the Regulatory Requirements

Table 33-1 summarizes each applicable requirement and its compliance status under the EMA. The text provides more detail on the compliance status of each requirement.

TABLE 33-1. New Mexico Emergency Management Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
Emergency Management Act, §§ 74-4B-1 - 74-4B-14 NMSA 1978		
§ 74-4B-2	Findings and purpose	**NOT APPLICABLE** State responsibilities [Section 33.2.1]
§ 74-4B-4	State responsibility for management of accidents; immunity from liability; cooperative agreements; private property	**NOT APPLICABLE** State responsibilities [Section 33.2.2]
§ 74-4B-5	State Police Emergency Response Officer; procedure for notification; cooperation with other State agencies and local governments	**UP TO DATE** WID procedures [Section 33.2.3]

TABLE 33-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
§ 74-4B-6	Emergency Management Task Force: powers and duties	NOT APPLICABLE State responsibilities [Section 33.2.4]
§ 74-4B-6.1	Creation and duties of the Hazardous Materials Emergency Response Administrator	NOT APPLICABLE State responsibilities [Section 33.2.5]
§ 74-4B-10	Responsibility for cleanup by owner, shipper, or carrier of the hazardous material	UP TO DATE WID procedures [Section 33.2.6]

33.2.1 Findings and Purpose, § 74-4B-2

The purpose of the EMA is to ensure that adequate hazardous materials emergency management capabilities exist in the State, delineate the State agencies that are responsible for responding to and controlling and managing a hazardous materials accident, and provide for the formulation of a comprehensive statewide hazardous materials emergency management plan.

These are State responsibilities. No action is required at WIPP by this subsection.

33.2.2 State Responsibility for Management of Accidents; Immunity from Liability; Cooperative Agreements; Private Property, § 74-4B-4

The State government has the primary responsibility for managing an accident. The EMA does not waive or alter immunity from liability. The State may enter into cooperative agreements with county and municipal governments for accident management. The State may enter into such agreements with the Federal government, Indian tribes and pueblos, and bordering States for assistance in managing accidents. When an accident has occurred or appears

imminent, responsible State personnel or authorized persons are authorized to enter any buildings or premises to determine whether emergency management procedures should be implemented.

These are State responsibilities. No action is required at WIPP under this subsection.

33.2.3 State Police Emergency Response Officer; Procedure for Notification; Cooperation of other State Agencies and Local Governments, § 74-4B-5

State Police Emergency Response Officers shall be designated, trained, and available to answer an emergency response call from the first responder. The responsibilities of these officers and of the State Police Emergency Response Center are described. Any driver of a vehicle carrying hazardous materials involved in an accident which may cause injury to persons or property or any owner, shipper, or carrier of hazardous materials involved in an accident who has knowledge of such accident or any owner or person in charge of any building, premises, or facility where such an accident occurs shall immediately notify the New Mexico State Police Division of the Public Safety Department by the quickest means of communication available.

Should an accident involving hazardous materials occur, the New Mexico State Police Division of the Public Safety Department will be notified by the driver, owner, shipper, or carrier of the waste as outlined in a Westinghouse Waste Isolation Division (WID) procedure and the *RCRA Contingency Plan*.

WIPP personnel will contact the State Emergency Response Commission (SERC) in the event of a spill that could endanger human health or the environment. The SERC will, in turn, contact the NMED if their assistance is needed.

33.2.4 Emergency Management Task Force: Powers and Duties, § 74-4B-6

The composition and responsibilities of the Emergency Management Task Force are described.

These are State responsibilities. No action is required at WIPP under this subsection.

33.2.5 Creation and Duties of the Hazardous Materials Emergency Response Administrator, § 74-4B-6.1

The creation and responsibilities of the Hazardous Materials Emergency Response Administrator are described in this subsection.

These are State responsibilities. No action is required at WIPP under this subsection.

33.2.6 Clean-up, § 74-4B-10

Nothing in the EMA shall be construed to relieve hazardous materials owners, shippers, or carriers of their responsibilities and liability in the event of an accident. Such persons shall assist the State as requested in responding to an accident and are responsible for restoring the scene of the accident to the satisfaction of the State.

An occurrence involving a TRUPACT II container that is not within the confines of the WIPP does not fall under WID responsibility. The correct line of action for an on-site occurrence that can be cleaned up by site personnel is covered in a WID procedure. However, in the event of an on-site occurrence that is not handled by site personnel, a clean-up contractor will be obtained.

If an off-site occurrence takes place involving a TRUPACT-II container, the DOE will take responsibility for cleaning up the scene of the accident to the State's satisfaction.

34.0 NEW MEXICO PREHISTORIC AND HISTORIC SITES PRESERVATION ACT

34.1 Summary of the Law

The provisions of the Congressional National Historic Preservation Act (NHPA) are furthered by law in the State of New Mexico. The act currently in place is the New Mexico Prehistoric and Historic Sites Preservation Act (§§ 18-8-1 through 18-8-8 NMSA 1978). The purpose of this act is the acquisition, stabilization, restoration, or protection of significant prehistoric and historic sites by the State of New Mexico and corporations. This act is administered by the State Historic Preservation Officer (SHPO) in consultation with the Cultural Properties Review Committee.

The Prehistoric and Historic Sites Preservation Act is implemented by Historic Preservation Division (HPD) Rule 89-2, which established procedures for acquiring, stabilizing, restoring, or protecting significant prehistoric and historic sites. Rule 89-2 also established procedures and guidelines to evaluate alternatives to programs and projects requiring the use of land from significant prehistoric and historic sites and to determine whether all possible planning has been implemented to preserve and protect such sites. Detailed requirements for a long-term management plan for any site acquired, stabilized, restored, or protected are included under this rule.

34.2 Compliance Status of the Regulatory Requirements

The WIPP is not bound by the New Mexico statutes and regulations regarding cultural properties because of the facility's location on federally managed land. However, WIPP personnel contract for archeological surveys and consult with the SHPO each time an action is proposed that would impact a previously undisturbed area. Prior to the transfer of the 16 sections of WIPP from the Department of the Interior to the DOE, the Bureau of Land Management was consulted on all cultural resource issues and, through their programmatic agreement with the SHPO, arranged clearances and work approvals.

During this reporting period, there were no projects proposed that required BLM or SHPO concurrence, therefore, these requirements are not addressed further in this report.

35.0 NEW MEXICO STATE IMPLEMENTATION OF THE FEDERAL LAND POLICY AND MANAGEMENT ACT

35.1 Summary of the Law

The Federal Land Policy and Management Act (FLPMA) was enacted to ensure that "public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use." Under the FLPMA, the Secretary of the Interior is authorized to grant, issue, or renew rights-of-way over, upon, under, or through public lands.

The spirit and purpose of the Congressional legislation to protect and preserve the quality of public lands is furthered by law in the State of New Mexico. In 1912, the Legislature of the State of New Mexico created the State Land Office (SLO) and directed that the Office's executive officer, the Commissioner of Public Lands (the Commissioner), execute jurisdiction over, and provide for the management, care, control and disposition of, public lands owned and subsequently acquired by the State. The Commissioner was authorized to grant rights-of-way and easements over, upon, or across State lands for highways, power lines, mining, or other purposes. The Commissioner's authority related to rights-of-way and easements is currently promulgated in New Mexico Statute 19-7-57.

The regulation of right-of-way and easement grants is addressed in the State Land Office's Rule 10, *Relating to Easements and Rights-of-Way*, which outlines the requirements for applying for and maintaining a right-of-way grant.

35.2 Compliance Status of the Regulatory Requirements

Table 35-1 summarizes the applicable requirements under SLO Rule 10 and the compliance status of each requirement. The text provides more detail on the compliance status of the requirements.

TABLE 35-1. New Mexico Implementation of the Federal Land Policy and Management Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
State Land Office Rule No. 10, *Relating to Easements and Rights-of-Way*		
SLO Rule 10.006	Application requirements and fees	**ACHIEVED** Permit issued [Section 35.2.1]
SLO Rule 10.009	Conditions	**ACHIEVED** Right of way: 40 feet wide [Section 35.2.2]
SLO Rule 10.010	Damage bond	**NOT APPLICABLE** Requirement waived for government agencies [Section 35.2.3]
SLO Rule 10.011	Survey plat	**ACHIEVED** Plat included in application [Section 35.2.4]
SLO Rule 10.012	Construction reports for ruins, artifacts, or monuments found	**NOT APPLICABLE** No artifacts found on right-of-way [Section 35.2.5]
SLO Rule 10.013	Affidavit of completion	**ACHIEVED** Affidavit of completion submitted [Section 35.2.6]

TABLE 35-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
SLO Rule 10.017	Renewal of right-of-way grants	**NOT APPLICABLE** 35-year term of permit currently deemed adequate [Section 35.2.7]
SLO Rule 10.019	Reclamation and restoration	**NOT APPLICABLE** Right-of-way to be reclaimed and revegetated after use [Section 35.2.8]

35.2.1 Application Requirements and Fees, SLO Rule 10.006

Written application for right-of-way grants (reservations) shall be made upon the proper forms. The application shall be made under oath and be accompanied by the payment of appropriate fees. The application will contain a legal description of the lands to be crossed and a plat (see Section 35.2.4).

The proper application form and the fees required were submitted as required. The application included the legal description of the lands to be crossed and a survey plat.

Permit No. RW-22789 was issued for a high-volume air sampler for the period of October 3, 1985, through October 3, 2020.

35.2.2 Conditions, SLO Rule 10.009

The minimum width of a right-of-way or easement granted under these rules shall be 30 feet.

As described in the application and survey plat, the right-of-way covers a 40-foot-wide strip of land.

35.2.3 Damage Bond, SLO Rule 10.010

The applicant must file a bond with the Commissioner before the right-of-way may be issued. The bond must compensate the State or other appropriate party for any damage done to improvements or other property. The Commissioner may waive this requirement if the applicant is a governmental agency that is prohibited from posting a security bond, the applicant is not immune to suit or is otherwise required by law to pay such damages, or meets other conditions specified.

The DOE is a governmental agency that is required by law to pay compensation for any such damages. Therefore, the requirement for a damage bond was waived.

35.2.4 Survey Plat, SLO Rule 10.011

Specific requirements for the survey plat are described in SLO Rule 10.011

A survey plat was included in the application. The plat met all requirements specified in SLO Rule 10.011.

35.2.5 Construction Reports, SLO Rule 10.012

The holder of a right-of-way shall notify the Commissioner immediately in the event that any historic or prehistoric ruin, monument, or artifact of historical, archeological, or scientific value is discovered upon the right-of-way. The holder of the right-of-way shall refrain from further disturbing the area until the Commissioner has been notified and inspection and clearance have been performed by the proper authorities if deemed necessary by the Commissioner.

No ruins, monuments, or artifacts of historical, archeological, or scientific value were discovered upon the right-of-way.

35.2.6 Affidavit of Completion, SLO Rule 10.013

Upon the completion of construction of any right-of-way, the applicant shall promptly file an affidavit of completion with the Commissioner. Failure to file such an affidavit in accordance with this section shall subject the right-of-way to cancellation in accordance with the provisions of these rules.

The DOE submitted an Affidavit of Completion to the State Land Office certifying the completion of construction and the location of the high-volume air sampler.

35.2.7 Renewal of Right-of-Way Reservations, SLO Rule 10.017

An application may be submitted for a renewal of the reservation prior to the expiration date of any right-of-way.

Permit No. RW-22789 (see Section 35.3) was granted for a term of 35 years. If the right-of-way will still be needed after the expiration date, an application will be submitted as required. However, it is likely that the 35-year period will be adequate.

35.2.8 Reclamation and Restoration, SLO Rule 10.019

Any person who enters upon State land to survey or construct a right-of-way shall take all steps necessary to preserve and protect the natural environmental conditions of the land, including reclaiming disturbed areas by leveling or terracing and revegetation. Revegetation shall include the establishment of suitable grasses and forbs. The grantee of any right-of-way shall consult with the Commissioner's designee regarding reclamation prior to undertaking same and shall abide by all directives of the designee.

The DOE will ensure that all reclamation and revegetation activities requested by the Commissioner or by his/her designee will be performed. Until these activities have been initiated, these requirements do not apply to WIPP.

35.3 Compliance Status of the Permit Conditions

The Commissioner granted Right-of-Way Permit No. RW-22789 to WIPP for a high-volume air sampler. The term of the permit is 35 years (October 3, 1985, through October 3, 2020). Table 35-2 summarizes the applicable permit conditions and the compliance status of each condition. The text provides more detail on the compliance status of the permit conditions.

TABLE 35-2. State Land Office Right-of-Way Permit No. RW-22789 - Summary of Permit Compliance Status

CITATION	CONDITION	COMPLIANCE STATUS
Right-of-Way Permit No. RW-22789 for a High-Volume Air Sampler		
Term/Condition #3	Disposal of brush and other debris	**ACHIEVED** Appropriate disposal of brush and other debris [Section 35.3.1]
Term/Condition #4	Depth of pipelines	**NOT APPLICABLE** No pipelines on right of way [Section 35.3.2]
Term/Condition #5	Prevention of destruction or injury to improvements or livestock	**UP TO DATE** Care taken to avoid damage to improvements or livestock [Section 35.3.3]
Term/Condition #6	Purpose of right-of-way	**UP TO DATE** Used only for high-volume air sampler [Section 35.3.4]

TABLE 35-2 (continued)

CITATION	CONDITION	COMPLIANCE STATUS
Term/Condition #7	Existing rights	**NOT APPLICABLE** No other leases or rights-of-way known for area [Section 35.3.5]
Term/Condition #8	Leases for mineral resources	**NOT APPLICABLE** [Section 35.3.6]
Term/Condition #9	Compliance with all applicable regulations and requirements	**UP TO DATE** See entire BECR for compliance status [Section 35.3.7]
Term/Condition #10	Non-use of the right-of-way	**UP TO DATE** Right-of-way used periodically [Section 35.3.8]
Term/Condition #13	Protection and preservation of natural environmental conditions	**UP TO DATE** Protection of land; best acceptable reclamation practices to be used [Section 35.3.9]
Term/Condition #14	Reclamation of all disturbed areas	**NOT APPLICABLE** Seed mixes of indigenous plants to be used for revegetation [Section 35.3.10]

35.3.1 Disposal of Brush and other Debris, Term/Condition #3

In clearing the right-of-way, the grantee agrees to dispose of brush and other debris so as not to interfere with the movement of livestock of State grazing lessees.

All brush and other debris were disposed of appropriately.

35.3.2 Depth of Pipelines, Term/Condition #4

All pipelines placed on the right-of-way lands under this permit must be buried at least 20 inches deep.

This right-of-way was not obtained for a pipeline. Therefore, this condition is not applicable.

35.3.3 Prevention of Destruction or Injury to Improvements or Livestock, Term/Condition #5

The grantee agrees to carefully avoid causing destruction or injury to any improvements or livestock lawfully upon the premises, to close all gates immediately after passing through them, and to make prompt payment of all reasonable and just damages for any injury or destruction arising from constructing or maintaining the right-of-way.

The DOE carefully avoids causing destruction or injury to any improvements or livestock that are lawfully upon the premises. Gates are closed as soon as possible.

35.3.4 Purpose of Right-of-Way, Term/Condition #6

The right-of-way granted is for the sole purpose of providing egress from and ingress to a high-volume air sampler. The right-of-way may not be used for any other purpose and may not be re-assigned by the grantee.

The right-of-way granted under this permit is used only for accessing the high-volume air sampler.

35.3.5 Existing Rights, Term/Condition #7

The rights granted under Permit RW-22789 are subject to valid existing rights.

No existing leases or rights-of-way of record are known.

35.3.6 Leases for Mineral Resources, Term/Condition #8

The Commissioner reserves the right to execute leases for oil and gas, coal and minerals; to sell or dispose of same; and to grant rights-of-way and easements related to such leasing.

The land subject to the conditions of Permit RW-22789 (i.e., T 19 S, R 27 E, Section 13) is not part of the land that was withdrawn from the U. S. Department of the Interior and transferred to the DOE under the WIPP Land Withdrawal Act (i.e., several sections under T 22 S, R 31 E). Therefore, this term remains applicable although no action is required by WIPP personnel.

35.3.7 Compliance with all Applicable Regulations and Requirements, Term/Condition #9

The grantee and its employees, agents, and contractors shall fully comply with all laws, regulations, and requirements of any governmental authority or agency in all matters that affect the premises and operations pertaining to such issues as conservation, sanitation, aesthetics, pollution, cultural properties, fire, or ecology.

This entire BECR addresses compliance with all such laws, regulations, and requirements at WIPP.

35.3.8 Non-Use of the Right-of-Way, Term/Condition #10

If the right-of-way granted is not used for a period that exceeds 1 year without the prior written permission of the Commissioner, the right-of-way will be considered abandoned. Non-use for shorter periods will require that the grantee prove that there was no intent to abandon the right-of-way.

The right-of-way is used periodically to collect samples and to maintain the sampler.

35.3.9 Protection and Preservation of Natural Environmental Conditions, Term/Condition #13

The grantee agrees to preserve and protect the natural environmental conditions of the land encompassed in this permit and to take such reclamation or corrective actions necessary to protect the land from pollution, erosion, or other forms of environmental degradation.

The land encompassed in this permit is being preserved and protected. In addition, a contemporary reclamation program and a corresponding long-range plan have been implemented at WIPP. When the right-of-way for the high-volume air sampler is to be reclaimed, WIPP personnel will use the best acceptable reclamation practices. (See also Section 35.3.10.)

35.3.10 Reclamation of all Disturbed Areas, Term/Condition #14

The grantee agrees to reclaim all disturbed areas by grading, leveling, or terracing and to landscape these areas at its own expense. Landscaping will include the planting of native grasses, shrubs, or other vegetation so as to return disturbed areas to their natural state and prevent erosion caused by water and/or wind.

The seed mixes to be used to revegetate the area will reflect those species that are indigenous to the vicinity, with priority given to those species of plants that are conducive to soil stabilization and to the needs of livestock and wildlife. (See also Section 35.3.9.) This section is not applicable to WIPP during this reporting period.

36.0 NEW MEXICO STATE IMPLEMENTATION OF THE BALD AND GOLDEN EAGLE PROTECTION ACT

36.1 Summary of the Law

The Bald and Golden Eagle Protection Act makes it unlawful to take (i.e., capture, kill, or destroy), possess, molest, or disturb living or dead bald eagles (*Haliaeetus leucocephalus*) or golden eagles (*Aquila chrysaetos*), their parts, their nests, or their eggs anywhere in the United States. A permit must be obtained from the U.S. Department of the Interior to relocate any nest that interferes with resource development or recovery operations. In addition, a permit may be obtained that authorizes taking, possessing, or transporting eagles or their parts, nests, or eggs.

Chapter 17 of the New Mexico statutes establishes rules and regulations to protect raptors. In particular, § 17-2-14, *Hawks, vultures and owls, taking, possessing, trapping, destroying, maiming or selling prohibited; exception by permit; penalty,* authorizes the Director of the Department of Game and Fish to issue permits to allow any person to take, possess, trap, ensnare, or destroy any bird protected by this section. Permits may be granted for several purposes, including scientific purposes, in accordance with the law and the State Game Commission's regulations. In addition, §§ 17-2-37 through 17-2-46, the Wildlife Conservation Act, also further the purpose of the Bald and Golden Eagle Protection Act with respect to the bald eagle as an endangered species (see Chapter 37).

36.2 Compliance Status of the Regulatory Requirements

At present, no bald or golden eagles are nesting on the WIPP site. Therefore, a permit regarding bald or golden eagles is not needed. If it becomes necessary, a permit application will be submitted, and all applicable permit requirements will be met.

37.0 NEW MEXICO WILDLIFE CONSERVATION ACT, IMPLEMENTING THE ENDANGERED SPECIES ACT

37.1 Summary of the Law

The Endangered Species Act was enacted in 1973 to prevent the extinction of many species of animals and plants. The act provides strong measures to help alleviate the loss of species and their habitats. It places restrictions on a wide range of activities involving endangered and threatened animals and plants to help ensure their continued survival. With limited exceptions, the act prohibits activities using these protected species unless authorized by a permit from the U.S. Fish and Wildlife Service (FWS).

The intent of the Congressional endangered species legislation is furthered in the State of New Mexico by the Wildlife Conservation Act, which was enacted in 1974. The current sections of the State's act reside in §§ 17-2-37 through 17-2-46 NMSA 1978. The act directs that endangered species of wildlife that are indigenous to New Mexico should be managed and maintained and, to the extent possible, their numbers enhanced within the carrying capacity of the habitat. The State is directed to assist in the management of endangered and threatened species of wildlife, including those that are federally listed.

Protection under the Wildlife Conservation Act extends to species, genera, and families that are listed in § 17-2-3, *Protected wildlife species and game fish defined*. Thus, protection under the Wildlife Conservation Act is extended to game birds such as all members of the family Phasianidae (quail, partridges, and pheasants) and game fish such as all members of the family Ictaluridae (catfish).

Section 17-2-41, *Endangered Species*, states that "except as otherwise provided in this act, it is unlawful to take, possess, transport, export, process, sell or offer for sale, or ship" any species or subspecies of wildlife that appears on the following lists: (1) wildlife indigenous to the State determined to be endangered within the State as set forth by regulations of the Game Commission of the State of New Mexico ("the Commission") and (2) the Federal lists of endangered species as set forth in the Endangered Species Act to the extent that such lists are adopted by regulations of the Commission. In § 17-2-42, *Management Programs*, the Director of the State Department of Game and Fish is directed to perform the following: (1) establish programs deemed necessary by the Commission for the management of endangered species; (2) work with Federal and State entities or with private individuals in the administration and management of programs for the management of endangered species; (3) authorize by permit the taking, possession, transportation, or shipment of species deemed to need management for purposes including scientific and educational; and (4) authorize by permit the removal, capture, and destruction of endangered species where necessary to prevent damage to property or to protect human health.

The intent of the congressional legislation protecting migratory game birds under the Migratory Bird Treaty Act is also addressed in Chapter 17 of the New Mexico statutes. In particular, § 17-2-3, *Protected wildlife species and game fish defined*, specifies that all of the migratory bird family Anatidae (waterfowl) is protected. The hunting, taking, capturing, killing, or possession or the attempt to hunt, take, capture, or kill species of this family is regulated by the Commission. In addition, the Wildlife Conservation Act also implements portions of the Migratory Bird Treaty Act with respect to migratory game birds that are recognized as endangered species.

The Commission's Regulation No. 564, *Governing the Removal, Capture or Destruction of Endangered Species*, was adopted in 1975. This regulation specifies that any person who does not possess a permit and who removes, captures, or destroys any wildlife species classified as endangered by Commission regulations, other than those listed in 50 CFR Part 17, *Endangered and Threatened Wildlife and Plants*, must report any such incident to the New Mexico Department of Game and Fish.

The Commission's Regulation No. 682, *Amending the Listing of Endangered Species and Subspecies of New Mexico*, lists endangered wildlife in the State. Amendment 1 to this regulation adopts the Federal list of endangered species specified in 50 CFR Part 17.

The amended listing of endangered wildlife of New Mexico, which was issued in November 1990, lists a number of endangered or threatened species that could be found at WIPP and were specified in the WIPP FEIS (DOE, 1980) or the SEIS (DOE, 1990a). These include nine species of fish, three species of reptiles, and five species of birds, which are listed in Table 37-1.

The Commission's Regulation No. 705, *Regulation for the Taking and Possession of Protected Wildlife for Scientific and Educational Purposes*, contains the requirements for obtaining and using State permits and authorizations for taking and possessing wildlife for scientific and educational purposes. Permits and authorizations are issued to individuals rather than to parties or organizations; however, a permittee may have qualified subpermittees. "Protected wildlife" is defined as all wild species of mammals, birds, reptiles, amphibians, and fishes and endangered mollusks and crustaceans taken by a non-resident of New Mexico or as pikas, marmots, and game, furbearing, and endangered mammals; all birds except rock doves, European starlings, and house sparrows; horned lizards if sacrificed, retained, and/or transported out of State; endangered reptiles; bullfrogs and endangered amphibians; game and endangered fishes; and endangered mollusks and crustaceans taken by a resident.

TABLE 37-1. Endangered and Threatened Species in the State of New Mexico that May Occur at WIPP

COMMON NAME	SCIENTIFIC NAME
Fish	
Blue sucker	*Cycleptus elongatus*
(Rio Grande) bluntnose shiner	*Notropis simus simus*
Bigscale logperch	*Percina macrolepida*
Gray redhorse	*Moxostoma congestum*
Greenthroat darter	*Etheostoma lepidum*
Mexican tetra	*Astyanax mexicanus*
Pecos gambusia (F)[1]	*Gambusia nobilis*
Pecos pupfish	*Cyprinodon pecosensis*
(Pecos) bluntnose shiner	*N. simus pecosensis*
Reptiles	
Plain-bellied water snake	*Nerodia erythrogaster*
Western ribbon snake	*Thamnophis proximus*
(Dunes) sagebrush lizard	*Sceleroporus graciosus arenicolous*
Birds	
Aplomado falcon	*Falco femoralis*
Peregrine falcon (F)	*Falco peregrinus*
Bald eagle (F)	*Haliaeetus leucocephalus*
Baird's sparrow	*Ammodramus bairdii*
Varied bunting	*Passerina versicolor*

37.2 Compliance Status of the Regulatory Requirements

Table 37-2 summarizes each applicable requirement and its compliance status under the State of New Mexico's Wildlife Conservation Act. The text provides more detail on the compliance status of each requirement. It should be noted that a number of these requirements apply to WIPP because of the potential for the occurrence of recognized endangered or threatened species on WIPP lands.

[1]The presence of "(F)" after a common name indicates that this species is also on the Federal list of endangered or threatened species.

TABLE 37-2. New Mexico Wildlife Conservation Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
State Game Commission Regulation No. 564, *Governing the Removal, Capture, or Destruction of Endangered Species*		
Regulation No. 564	Report of unpermitted removal, capture, or destruction of endangered species	**NOT APPLICABLE** No endangered species removed from, captured, or destroyed at WIPP [Section 37.2.1]
State Game Commission Regulation No. 682, *Amending the Listing of Endangered Species and Subspecies of New Mexico*		
Regulation No. 682 	Recognition of State-listed endangered wildlife	**ACHIEVED** Consultation with Game and Fish Department [Section 37.2.2]
State Game Commission Regulation No. 705, *Regulation for the Taking and Possession of Protected Wildlife for Scientific and Educational Purposes*		
Regulation No. 705, Chapter 2	Requirements for obtaining a permit	**ACHIEVED** Two permits obtained at WIPP (see Section 37.3) [Section 37.2.3]
Regulation 705, Chapter 5	Year-end reports	**UP TO DATE** Submitted annually by March 31 [Section 37.2.4]

37.2.1 Report of Unpermitted Removal, Capture, or Destruction of Endangered Species, Regulation No. 564

Persons without an authorized State permit who remove, capture, or destroy a State-listed endangered species must provide detailed information on such incident(s) to the State Game and Fish Department within 30 days.

No incidents requiring reports have occurred. Several permits and authorizations have been issued for various activities involving the taking of wildlife that are neither endangered nor threatened. These permits and authorizations specify that endangered wildlife shall not be taken during these activities (see Section 37.3).

37.2.2 Recognition of State-Listed Endangered Wildlife, Regulation No. 682

The State-listed endangered species that could be present at WIPP and/or affected by WIPP activities must be identified.

In 1989, the DOE consulted with the New Mexico Department of Game and Fish (NMDG&F) regarding the State-listed endangered species in the vicinity of the WIPP site. At that time, the State Game and Fish Department communicated to the DOE their opinion of which State-listed endangered species "occur or are likely to occur at the WIPP site." The species identified were listed in Regulation 657 dated January 9, 1988, and included the following species: Mississippi kite, bald eagle, peregrine falcon, least tern, willow flycatcher, Bell's vireo, Baird's sparrow, and the sagebrush lizard. The NMDG&F subsequently concurred that proposed WIPP activities would probably have no significant impacts on State-listed species in the area. Since 1989, Regulation 682 was updated on November 30, 1990, with Amendment No. 1 issued on July 25, 1991. The list in the updated version of Regulation No. 682 does not include the Mississippi kite.

37.2.3 Permit Application and Requirements to Conduct Activities Authorized Under this Regulation, Chapter 2 of Regulation No. 705

A person must complete and submit a permit or authorization application; after receipt of the permit, permittees and subpermittees must comply with written permit requirements.

To date, two permits for banding birds and taking protected birds (with specific methods for taking protected birds and fishes) have been issued to Westinghouse Waste Isolation Division (WID) personnel. More detail on these permits is provided in Section 37.3.

37.2.4 Year-End Reports, Chapter 5 of Regulation No. 705

An annual report is generally required for permits issued by the Department of Game and Fish. The permits must be filed by March 31.

Annual reports are submitted that describe the activities conducted under each permit issued by the NMDG&F.

37.3 Compliance Status of the Permit Conditions

Table 37-3 summarizes the conditions imposed by the NMDG&F for each of the two permits issued. The text provides more detail on the compliance status of each permit condition.

TABLE 37-3. New Mexico Wildlife Conservation Act - Summary of Permit Compliance Status

CITATION	CONDITION		COMPLIANCE STATUS
Permit No. 1961	(1)	Authorization for live capture and banding of protected birds; excluded for waterfowl, eagles, resident gallinaceous species of gamebirds, and federally endangered or threatened species	ACHIEVED Only authorized birds captured and/or banded; no endangered or threatened species salvaged; disposition of wildlife as required under permit
	(2)	Salvaged endangered or threatened species salvaged to be reported	
	(3)	Disposition of wildlife	[Section 37.3.1]

TABLE 37-3 (continued)

CITATION	CONDITION	COMPLIANCE STATUS
Permit No. 1894	Live trapping; authorization for quail, catfish, and unprotected vertebrates; nonlethal methods for catfish; report for salvaging endangered or threatened vertebrates	ACHIEVED No gill nets used; no more than 50 catfish taken under permit; nonlethal methods used for catfish; no endangered or threatened vertebrates salvaged Quail permit limit exceeded and reported [Section 37.3.2]

37.3.1 Permit No. 1961

Permit No. 1961 authorizes the designated permittee and subpermittees to live-capture, band, and release all protected species of birds except for waterfowl, eagles, resident gallinaceous game birds, and endangered or threatened species. Salvage of any dead, injured, or otherwise incapacitated members of an endangered or threatened species must be reported to the NMDG&F within 14 days. The ultimate disposition of all protected wildlife that is not released is to the Carnegie Museum of Natural History, New Mexico State University, or the University of Arizona.

Permit No. 1961 was issued for the period of April 2, 1993, through March 31, 1994. No waterfowl, eagles, resident gallinaceous game birds, or endangered or threatened species have been live-captured, banded, or salvaged. The ultimate disposition of any protected species allowable under this permit resides in the Carnegie Museum of Natural History, New Mexico State University, or the University of Arizona, as specified in the permit.

37.3.2 Permit No. 1894

Permit No. 1894 authorizes the permittee and subpermittees specified to use live traps, trotlines, and nets (except gill nets) to obtain specimens and to salvage dead, injured, or otherwise incapacitated vertebrates. The authorized WID personnel may take up to 30 specimens of quail, 50 channel/flathead catfish, and unprotected vertebrates as needed in Eddy and Lea counties. Nonlethal methods must be used to take the catfish. Any endangered or threatened species salvaged must be reported to the NMDG&F within 14 days. WIPP is the ultimate disposition location for all specimens retained under this permit.

Permit No. 1894 was issued for the period of April 1, 1993, through March 31, 1994. No gill nets have been used to obtain specimens. The allowable number of specimens of 50 channel/flathead catfish has not been exceeded. Methods used to capture the catfish are not lethal to these fish or to other aquatic vertebrates. No endangered or threatened species have been salvaged.

On February 3, 1994, the WID notified the NMDG&F that the WIPP had exceeded by seven the harvest allotment of 30 quail that is provided in Permit No. 1894. This occurred when the additional quail died in a trap. The WID immediately notified the NMDG&F, and an investigation was initiated. Results of the investigation were reviewed by the NMDG&F enforcement headquarters staff. On March 28, 1994, the NMDG&F notified the WID that no citations would be issued and that no further action would be required.

38.0 NEW MEXICO PESTICIDE CONTROL ACT

38.1 Summary of the Law

The Pesticide Control Act (§§ 76-4-1 through 76-4-30 NMSA 1978) is administered and enforced by the New Mexico State Department of Agriculture under the direction of the Board of Regents of New Mexico State University, Las Cruces, New Mexico. This act provides for the registration, labeling, distribution, storage, transportation, application, use, and disposal of pesticides and pesticide-related devices. It also provides for the licensing of pesticide dealers, consultants, applicators, and operators of pesticide apparatus and imposes penalties to protect the environment and the public health and welfare.

The Pesticide Control Act is implemented by two regulatory orders of the Board of Regents of New Mexico State University. Regulatory Order No. 4, *Regulatory Orders of the Board of Regents of New Mexico State University* (dated September 16, 1978), describes State requirements for the storage of pesticides and the disposal of pesticide wastes. Regulatory Order No. 5, *Definitions, Licensing, Equipment Inspection, Record Keeping of Pesticides by Regulated Applicants* (dated November 2, 1979), describes requirements for licensing and for applying pesticides in New Mexico and applies to all activities involving the distribution and use of pesticides in the State.

38.2 Compliance Status of the Regulatory Requirements

The compliance status of each of the major requirements of the implementing regulations of the Pesticide Control Act is summarized in Table 38-1. Additional detail is provided in the text.

TABLE 38-1. New Mexico Pesticide Control Act - Summary of Regulatory Compliance Status

CITATION	REQUIREMENT	COMPLIANCE STATUS
New Mexico Pesticide Control Act, Regulatory Order No. 4, *Regulatory Order of the Board of Regents of New Mexico State University*		
Section 5	Storage of pesticides and disposal of pesticide wastes	**ACHIEVED** General-use wasp and hornet killer stored on site [Section 38.2.1; see also 10.2.2]

TABLE 38-1 (continued)

CITATION	REQUIREMENT	COMPLIANCE STATUS
New Mexico Pesticide Control Act, Regulatory Order No. 5, *Definitions, Licensing, Equipment Inspections, Record Keeping of Pesticides by Regulated Applicators*		
Section 6	License classifications	**NOT APPLICABLE** Subcontractor: categories 3A, 3B, 7A, 7B, 7D [Section 38.2.2]
Section 10	Protective equipment	**ACHIEVED** Review by WID personnel [Section 38.2.3]
Section 11	Application of pesticides	**UP TO DATE** Review by WID personnel [Section 38.2.4]

38.2.1 Storage of Pesticides and Disposal of Pesticide Wastes, Section 5 of Regulatory Order No. 4

Requirements for storing pesticides and for disposing of pesticide wastes and pesticide containers are described in Section 5 of Regulatory Order No. 4 to the New Mexico Pesticide Control Act.

All restricted-use pesticides are brought on site by the contractor who has been hired to apply them. Storage and disposal of restricted-use pesticides and their containers are the responsibility of the contractors who are licensed by the State and knowledgeable of applicable requirements (see also Section 10.2.2). One general-use pesticide, "CINCH" Wasp and Hornet Killer, is stored at WIPP. "CINCH" is properly stored in accordance with the product label. Used, empty aerosol cans are managed as hazardous waste.

38.2.2 License Classification, Section 6 of Regulatory Order No. 5

There are 17 categories of licenses granted by the State of New Mexico. Each one represents the type and scope of the specific certification examinations that must be taken by commercial, non-commercial, and public applicators and by pest-management consultants for their licenses.

The applicator who is contracted to apply pesticides at WIPP is licensed under the following categories:

3A - Ornamental Pest Control	7A - Structural Pest Control
3B - Turf Pest Control	7B - Rodent Control
	7D - Termite Control

38.2.3 Protective Equipment, Section 10 of Regulatory Order No. 5

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All licensed certified applicators must make available properly decontaminated protective equipment which is in proper working order and must advise their employees of its use to meet the safety requirements of the pesticide labeling.

All pesticide application contracts are reviewed and approved by Westinghouse Waste Isolation Division (WID) personnel before the contract is awarded. Provisions in the contract require that WID personnel approve the use of all pesticides prior to application on site. In addition, the applicator is required to submit records of the date of application, specific location, application method, quantity applied, and weather conditions at time of application.

38.2.4 Application of Pesticides, Section 11 of Regulatory Order No. 5

A licensed certified applicator shall apply only those pesticides registered for use in New Mexico under his/her license application. Any person who applies pesticides must follow the directions, rates, and precautions that are stated on the approved label and labeling. Restricted-use pesticides shall be applied only by licensed certified applicators or persons under their direct supervision.

WID personnel review the application method and pesticide(s) to be used by the contractor before the application to ensure that the method is appropriate and that no pesticides on the EPA's restricted list will be used.

A copy of the contractor's current license is maintained by the WID.

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APPENDIX A

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43 CFR 1610.3-2	Consistency of management plan with applicable laws	18.2.3
43 CFR Part 2800	**Rights-of-Way, Principles and Procedures**	**18.2**
43 CFR 2801.2(a)	Common terms and conditions of right-of-way reservations and temporary-use permits: • Compliance with regulations • Non-discrimination • Repair of roads, fences, trails • Fire prevention and suppression	18.2.4
43 CFR 2801.2(b) W	Mandatory conditions for right-of-way reservations and temporary-use permits: • Restoration • Air- and water-quality standards • Scenic, cultural, and environmental values • Local inhabitants • State standards that are more stringent than the Federal ones	18.2.5
43 CFR 2802.2	Application requirements for a right-of-way reservation or temporary-use permit	18.2.6
CC 1	**Common Conditions (CC) of Right-of-Way Reservations**	**18.3**
CC 1	Control and jurisdiction of DOE	18.3.1
CC 2	Right of access and use	18.3.1
CC 3	Products or resources on lands within the right-of-way	18.3.1
CC 4	Compliance with 43 CFR Part 2800	18.3.1
CC 5	BLM seeding requirements for BLM Roswell District	18.3.1
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 53809, Water Pipeline**	**18.3**

Citation	Requirement	BECR Section
Sec. 13; Standard Stipulations (SS) 1, 2, 5, 6, 8	Preconstruction and construction conditions	18.3.2.1
Sec. 13E	Water access for livestock	18.3.2.2
SS 3	Road construction	18.3.2.3
SS 4	Posting of BLM number	18.3.2.4
SS 7	Gates or cattleguards on public lands	18.3.2.5
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 55676, North Access Road**	**18.3**
SS 2	Polychlorinated biphenyls (PCBs)	18.3.3.1
SS 3-5	SS for the construction of overhead electric distribution lines	18.3.3.2
SS 6	Posting of BLM serial number	18.3.3.3
Term/Condition (T/C) 7	Damage or injury to private property	18.3.3.4
T/C 7 and 8	Actions required upon abandonment, relinquishment, or expiration of right-of-way reservation	18.3.3.5
Amendment (April 22, 1988)	Fencing	18.3.3.6
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 55699, Access Railroad**	**18.3**
SS 1-4, 7, 9, 11	Preconstruction and construction requirements for railroad spur	18.3.4.1
SS 5	Reseeding upon completion of construction	18.3.4.2
SS 6	Abandonment of the site	18.3.4.3
SS 8	Responsibility for damage or injury to private property	18.3.4.4
SS 10	Access to water for livestock	18.3.4.5
SS 12	Removal of caliche and/or other mineral material	18.3.4.6
SS 13	Application for free-use permits	18.3.4.7
Amendment	Notification of BLM regarding the access road parallel to the railroad	18.3.4.8

Citation	Requirement	BECR Section
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 63136, Dosimetry and Aerosol Sampling Sites**	**18.3**
Attachment A	Establishment of dosimeter stations and air samplers	18.3.5.1
Amendment	Air monitoring and data collection site	18.3.5.2
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 65801, Seven Subsidence Monuments**	**18.3**
Right-of-way reservation	No unique conditions	18.3.6
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 82245 for Two Subsidence Monuments**	**18.3**
#1	Construction and maintenance of the monuments	18.3.7.1
#3	Security and maintenance of the monuments	18.3.7.2
#5	Rehabilitation of the land	18.3.7.3
Sec. 13; Standard Stipulations	**Right-of-Way Reservation No. NM 77921, Aerosol Sampling Site**	**18.3**
#1	Construction, operation, and maintenance	18.3.8.1
#3	Security and operation of aerosol sampling station	18.3.8.2
#5	Rehabilitation of the land occupied by the aerosol sampling station	18.3.8.3
Letter from El Paso Natural Gas Company	Use of the abandoned concrete slab	18.3.8.4
Sec. 13; Standard Stipulations	**Free-Use Permit No. NM-FU3-91183 for Use of Caliche**	**18.3**
Approval of request to mine 35,000 cubic yards of caliche	Withdrawal of caliche	18.3.9.1
Attachment 2, Reclamation	Reclamation of caliche borrow pit	18.3.9.2
43 CFR Part 4100	**Grazing Administration - Exclusive of Alaska**	**19.2**
43 CFR 4100.0-8	Land-use plan, including grazing management	19.2.1
43 CFR Part 4100	**Grazing Administration**	**20.2**

Citation	Requirement	BECR Section
43 CFR 4100.0-8	Management of grazing lands under principles of multiple use and sustained yield and in accordance with applicable land-use plans	20.2.1; see also 19.2.1
43 CFR 4120.2	Preparation of allotment management plan	20.2.2
50 CFR Part 13	**General Permit Procedures**	**21.2**
50 CFR 13.11	Permit application procedures	21.2.1
50 CFR Part 22	**Eagle Permits**	**21.2**
50 CFR 22.11	General permit requirements	21.2.2
50 CFR 22.25	Permits to take golden eagle nests	21.2.3
50 CFR Part 13	**General Permit Procedures**	**22.2**
50 CFR 13.11	Permit application procedures	22.2.1
50 CFR 13.12	Information requirements for permit applications	22.2.2
50 CFR 13.44	Display of permit	22.2.3
50 CFR 13.45	Filing of reports	22.2.4
50 CFR 13.46	Maintenance of records	22.2.5
50 CFR 13.47	Inspection requirement	22.2.6
50 CFR 13.48	Compliance with permit conditions (see also Sections 22.2.12 and 22.3.1)	22.2.7
50 CFR 13.50	Acceptance of liability	22.2.8
50 CFR Part 20	**Migratory Bird Hunting**	**22.2**
50 CFR Part 20, Subpart C	Compliance with applicable hunting regulations	22.2.9
50 CFR Part 21	**Migratory Bird Permits**	**22.2**
50 CFR 21.22(a)	Permit for banding or marking migratory birds	22.2.10
50 CFR 21.22(b)	Application procedures for banding or marking permits	22.2.11
50 CFR 21.22(c)	Additional permit conditions	22.2.12
50 CFR 21.22(d)	Term of permit	22.2.13
50 CFR 21.27	Special-purpose permits	22.2.14

Citation	Requirement	BECR Section
50 CFR 21.28	Falconry permits	22.2.15
50 CFR 21.41	Depredation permits	22.2.16
Permit No. 22478	**Authorization to capture and band or mark birds**	**22.3**
50 CFR Part 13	**General Permit Procedures**	**23.2**
50 CFR 13.11	Permit application procedures	23.2.1
50 CFR Part 17	**Endangered and Threatened Wildlife and Plants**	**23.2**
50 CFR 17.22, 17.32, 17.52, and 17.62	Application for permits for scientific purposes or for the enhancement of propagation or survival of endangered or threatened species	23.2.2
50 CFR Part 402	**Interagency Cooperation - Endangered Species Act, as Amended**	**23.2**
50 CFR 402.12	Biological assessment to evaluate effects of proposed actions on designated species	23.2.3
50 CFR 402.14	Formal consultation with the FWS to determine whether any action will affect listed species	23.2.4
Advisory Council on Historic Preservation		
36 CFR Part 800	**Protection of Historic and Cultural Properties**	**24.2**
36 CFR 800.5	Assessment of effects on historic properties	24.2.1
36 CFR 800.11	Development of plan for treatment of historic property	24.2.2
43 CFR Part 7	**Protection of Archaeological Resources**	**24.2**
43 CFR 7.5	Application for permit to excavate and/or remove archaeological resources	24.2.3
New Mexico Environment Department		
40 CFR Part 262 (HWMR-7, § 301)	**Standards applicable to generators of hazardous waste**	**25.2.2**
40 CFR 262.11	Hazardous waste determination	25.2.2.1

Citation	Requirement	BECR Section
40 CFR 262.12	EPA identification number	25.2.2.2
40 CFR 262.20	Manifest requirements	25.2.2.3
40 CFR 262.21	Acquisition of manifests	25.2.2.4
40 CFR 262.22	Number of copies	25.2.2.5
40 CFR 262.23	Use of the manifest	25.2.2.6
40 CFR 262.30	DOT packaging requirements	25.2.2.7
40 CFR 262.31	Labeling requirements	25.2.2.8
40 CFR 262.32	Marking requirements	25.2.2.9
40 CFR 262.33	Placarding requirements	25.2.2.10
40 CFR 262.34(a)	90-day or less accumulation time	25.2.2.11
40 CFR 262.34(a)(1)(i)	Compliance with Subpart I of 40 CFR Part 265 for waste placed in containers	25.2.2.12
40 CFR 262.34(a)(1)(ii)	Accumulation of hazardous wastes in tanks	25.2.2.13
40 CFR 262.24(a)(1)(iii)	Compliance with Subpart W of 40 CFR Part 265 for wastes placed on drip pads	25.2.2.14
40 CFR 262.34(a)(2)	Marking each container with the date of initial accumulation of waste	25.2.2.15
40 CFR 262.34(a)(3)	Marking each container as hazardous waste	25.2.2.16
40 CFR 262.34(a)(4)	Compliance with Subparts C and D of 40 CFR 265, 40 CFR 265.16, and 40 CFR 268.7(a)(4) for preparedness/prevention, contingency plans/emergency procedures, training, and waste analysis plans	25.2.2.17
40 CFR 262.34(b)	Extension of the 90-day storage period due to unforeseen, temporary, and uncontrollable circumstances	25.2.2.18
40 CFR 262.34(c)(1)(i)	Restrictions and requirements for satellite accumulation areas	25.2.2.19, 25.2.2.20
40 CFR 262.34(c)(1)(ii)	Labeling of container as "hazardous waste"	25.2.2.21
40 CFR 262.34(c)(2)	Management of waste exceeding the 55-gallon or 1-quart limit	25.2.2.22
40 CFR 262.40	Recordkeeping requirements	25.2.2.23
40 CFR 262.41	Generator--biennial report	25.2.2.24

Citation	Requirement	BECR Section
40 CFR 262.42	Exception reporting if copy of manifest is not returned to generator within the specified time period	25.2.2.25
40 CFR 262.43	Additional reporting	25.2.2.26
40 CFR Part 263 (HWMR-7, § 401)	**Standards Applicable to Transporters of Hazardous Waste**	**25.2.3**
40 CFR 263.10(a)	Compliance with DOT regulations	25.2.3.1
40 CFR 263.11	EPA identification number	25.2.3.2
40 CFR 263.20 - 263.22	Compliance with the manifest system and recordkeeping	25.2.3.3
40 CFR 263.30	Immediate action after hazardous waste discharges	25.2.3.4
40 CFR 263.31	Discharge cleanup	25.2.3.5
40 CFR Part 265 (HWMR-7, § 601)	**Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities**	**25.2.4**
40 CFR 265.10	Applicability	25.2.4.1
40 CFR 265.11	EPA identification number	25.2.4.2
40 CFR 265.12	Required notices to the off-site source(s)	25.2.4.3
40 CFR 265.13	General waste analysis	25.2.4.4
40 CFR 265.14	Security	25.2.4.5
40 CFR 265.15	General inspection requirements	25.2.4.6
40 CFR 265.16	Personnel training	25.2.4.7
40 CFR 265.17	General requirements for ignitable, reactive, or incompatible wastes	25.2.4.8
40 CFR 265.18	Location standards	25.2.4.9
40 CFR 265.31	Maintenance and operation of facility	25.2.4.10
40 CFR 265.32	Required equipment	25.2.4.11
40 CFR 265.33	Testing and maintenance of equipment	25.2.4.12
40 CFR 265.34	Access to communications or alarm system	25.2.4.13
40 CFR 265.35	Required aisle space	25.2.4.14

Citation	Requirement	BECR Section
40 CFR 265.37	Arrangements with local authorities	25.2.4.15
40 CFR 265.51	Purpose and implementation of the contingency plan	25.2.4.16
40 CFR 265.52	Content of the contingency plan	25.2.4.17
40 CFR 265.53	Copies of contingency plan	25.2.4.18
40 CFR 265.54	Amendment of contingency plan	25.2.4.19
40 CFR 265.55	Emergency Coordinator	25.2.4.20
40 CFR 265.56	Emergency procedures	25.2.4.21
40 CFR 265.71	Use of manifest system	25.2.4.22
40 CFR 265.72	Manifest discrepancies	25.2.4.23
40 CFR 265.73	Operating record	25.2.4.24
40 CFR 265.74	Availability, retention, and disposition of records	25.2.4.25
40 CFR 265.75	TSDF biennial report	25.2.4.26
40 CFR 265.76	Unmanifested waste report	25.2.4.27
40 CFR 265.77	Additional reports	25.2.4.28
40 CFR 265.90	Applicability of the ground-water monitoring system	25.2.4.29
40 CFR 265.91	Ground-water monitoring system	25.2.4.30
40 CFR 265.92	Sampling and analysis	25.2.4.31
40 CFR 265.93	Preparation, evaluation, and response	25.2.4.32
40 CFR 265.94	Recordkeeping and reporting	25.2.4.33
40 CFR 265.110	Applicability of the closure/post-closure requirements	25.2.4.34
40 CFR 265.111	Closure performance standard	25.2.4.35
40 CFR 265.112	Closure plan; amendment of plan	25.2.4.36
40 CFR 265.113	Time allowed for closure	25.2.4.37
40 CFR 265.114	Disposal or decontamination of equipment, structures, and soils	25.2.4.38
40 CFR 265.115	Certification of closure	25.2.4.39
40 CFR 265.116	Survey plat	25.2.4.40

Citation	Requirement	BECR Section
40 CFR 265.117	Postclosure care and use of property	25.2.4.41
40 CFR 265.118	Postclosure plan; amendment of plan	25.2.4.42
40 CFR 265.119	Postclosure notices	25.2.4.43
40 CFR 265.120	Certification of completion of postclosure care	25.2.4.44
40 CFR 265.142	Cost estimate for closure	25.2.4.45
40 CFR 265.143	Financial assurance for closure	25.2.4.46
40 CFR 265.144	Cost estimate for postclosure care	25.2.4.47
40 CFR 265.145	Financial assurance for postclosure care	25.2.4.48
40 CFR 265.146	Use of a mechanism for financial assurance of both closure and postclosure care	25.2.4.49
40 CFR 265.147	Liability requirements	25.2.4.50
40 CFR 265.148	Incapacity of owners or operators, guarantors, or financial institutions	25.2.4.51
40 CFR 265.149 [HWMR-7, § 602(A)]	Use of State-required mechanisms	25.2.4.52
40 CFR 265.150 [HWMR-7, § 602(B)]	State assumption of responsibility	25.2.4.53
40 CFR 265.171	Condition of containers	25.2.4.54
40 CFR 265.172	Compatibility of waste with containers	25.2.4.55
40 CFR 265.173	Management of containers	25.2.4.56
40 CFR 265.174	Inspections	25.2.4.57
40 CFR 265.176	Special requirements for ignitable or reactive waste	25.2.4.58
40 CFR 265.177	Special requirements for incompatible wastes	25.2.4.59
40 CFR 265.190-.445	Tank systems; surface impoundments; waste piles; land treatment; incinerators; thermal treatment; chemical, physical, and biological treatment; underground injection; and drip pads	25.2.4.60
40 CFR 265.1032	Standards (air emission) for process vents	25.2.4.61
40 CFR 265.1052-.1062	Air emission standards for equipment leaks	25.2.4.62

Citation	Requirement	BECR Section
40 CFR Part 270 (HWMR-7, § 901)	**EPA Administered Permit Programs: the Hazardous Waste Permit Program**	**25.2.5**
40 CFR 270.1	Purpose and scope of the RCRA permit program regulations	25.2.5.1
40 CFR 270.10	General application requirements	25.2.5.2
40 CFR 270.11	Signatories to permit applications and reports	25.2.5.3
40 CFR 270.13	Contents of Part A of the permit application	25.2.5.4
40 CFR 270.14 (HWMR-7, §§ 901 and 902)	Contents of Part B: general requirements	25.2.5.5
40 CFR 270.15	Specific Part B information requirements for containers	25.2.5.6
40 CFR 270.23	Specific Part B requirements for miscellaneous units	25.2.5.7
40 CFR 270.30	Conditions applicable to all permits	25.2.5.8
40 CFR 270.31	Requirements for recording and reporting of monitoring results	25.2.5.9
40 CFR 270.42 (HWMR-7, §§ 901 and 902)	Permit modification at the request of the permittee	25.2.5.10
40 CFR 270.71 (HWMR-7, §§ 901 and 902)	Operation during interim status	25.2.5.11
40 CFR 270.72	Changes during interim status	25.2.5.12
§§ 74-1-1 through 74-1-10	**New Mexico Environmental Improvement Act**	**27.1; see Chapters 25, 26, and 28-31**
New Mexico Environment Department (NMED) 92-1	**New Mexico Environment Department Ground Water Protection Act Corrective Action Fund Regulations**	**28.1**
NMED 92-1	Reimbursement of costs from corrective actions for spills/releases from underground storage tanks	28.2.1
AQCRs	**New Mexico Air Quality Control Regulations**	**29.1**
AQCR 301	Regulations to control open burning	29.2.1
AQCR 401	Regulations to control smoke and visible emissions	29.2.2

Citation	Requirement	BECR Section
AQCR 507	Oil-burning equipment -- particulate matter	29.2.3
AQCR 605	Oil-burning equipment -- sulfur dioxide	29.2.4
AQCR 606	Oil-burning equipment -- nitrogen dioxide	29.2.5
AQCR 700	Permit fees	29.2.6
AQCR 702	Permits	29.2.7; 29.3
AQCR 703.1	Annual emission inventory	29.2.8
AQCR 710	Stack height requirements	29.2.9
AQCR 751	NESHAPs - radionuclides NESHAPs - other HAPs	29.2.10
AQCR 752	Application for registration of toxic air pollutants	29.2.11
AQCR 801	Excess emissions during malfunction, startup, shutdown, or scheduled maintenance	29.2.12
AQCR 901	Controlling emissions leaving New Mexico	29.2.13
AQCR 1001	Sampling equipment	29.2.14
Open-burning permit, Conditions	Application and permit	29.3.1
Air Quality Permit No. 310-M-2, Condition 1	Construction and operation	29.3.2.1
Condition 2	Emission rates	29.3.2.2
Condition 3-4	Compliance test methods	29.3.2.3
Condition 5	Revisions and modifications	29.3.2.4
Condition 6	Notification to subsequent owners	29.3.2.5
Condition 7	Right to access property and review records	29.3.2.6
Condition 8	Posting of the permit	29.3.2.7
Condition 9	Recordkeeping	29.3.2.8
Condition 10	Reporting	29.3.2.9
Additional Condition, p. 8	Permit cancellations	29.3.2.10
Additional Condition, p. 8	Notice of intent and emission inventory	29.3.2.11

Citation	Requirement	BECR Section
Approval DP-831	**New Mexico Discharge Plan for the WIPP**	**30.3**
DP-831 Specific Requirement (SR) #1	Monitoring and quarterly reports	30.3.1
DP-831 SR #2	Submittal of water quality analysis	30.3.2
DP-831 SR #3	Quarterly sampling of each evaporation lagoon	30.3.3
DP-831 SR #4	Maintenance of berms	30.3.4
DP-831 SR #5	Completion of proposed evaporation ponds	30.3.5
DP-831 General Requirement (GR)--Recordkeeping	Records to be kept and made available to the NMED upon request	30.3.6
DP-831 GR--Inspection and Entry	Allowing inspections, entry, sampling, and monitoring by NMED personnel	30.3.7
DP-831 GR--Duty to Provide Information	Providing information relevant to discharge plan/records required by Discharge Plan that has been requested by NMED	30.3.8
DP-831 GR--Spills, Leaks, and Other Unauthorized Discharges	Reporting and remediation of any spills, leaks, and other unauthorized discharges	30.3.9
DP-831 GR--Retention of Records	Retention of all monitoring information, discharge plan reports, and data needed for discharge plan application	30.3.10
DP-831 GR--Modifications and/or Amendments	Notification of NMED of any modifications or additions to the wastewater disposal system; approval by NMED required prior to increasing the quantity or concentration of constituents in waste water above those approved in the plan	30.3.11 W
HWMR-7	**New Mexico Hazardous Waste Management Regulations**	**25.2.1**
HWMR-7, § 1001	Compliance with other regulations	25.2.1.1
USTR	**New Mexico Underground Storage Tank Regulations**	**25.2.6**
USTR Sec. 103	Applicability	25.2.6.1
USTR Sec. 200	Existing tanks	25.2.6.2
USTR Sec. 201	Transfer of ownership	25.2.6.3

Citation	Requirement	BECR Section
USTR Sec. 202	New UST system	25.2.6.4
USTR Sec. 203	Substantially modified UST systems	25.2.6.5
USTR Sec. 204	Notification of spill or release	25.2.6.6
USTR Sec. 205	Emergency repairs and tank replacement	25.2.6.7
USTR Sec. 206	Application forms	25.2.6.8
USTR Sec. 207	Registration certificate	25.2.6.9
USTR Sec. 300	Payment of fee	25.2.6.10
USTR Sec. 301	Amount of fee	25.2.6.11
USTR Sec. 302	Late payment penalties	25.2.6.12
USTR Sec. 400(a)	Performance standards to ensure that new UST systems tanks are properly designed and constructed	25.2.6.13
USTR Sec. 400(b)	Piping to be properly designed and constructed	25.2.6.14
USTR Sec. 400(c)(1)(i)	Spill prevention equipment	25.2.6.15
USTR Sec. 400(c)(1)(ii)	Overfill prevention equipment	25.2.6.16
USTR Sec. 400(d)	Installation of tanks and piping	25.2.6.17
USTR Sec. 400(e)	Certificate of installation	25.2.6.18
USTR Sec. 401(a)	Upgrading of existing UST systems	25.2.6.19
USTR Sec. 401(b)	Upgrading requirements for steel tanks	25.2.6.20
USTR Sec. 401(c)	Upgrading requirements for metal piping	25.2.6.21
USTR Sec. 401(d)	Spill and overfill protection equipment	25.2.6.22
USTR Sec. 402 (by reference to 40 CFR 280.22)	Certification of compliance and notification requirements	25.2.6.23
USTR Sec. 500(a)	Spill and overflow control	25.2.6.24
USTR Sec. 501(a)	Corrosion protection	25.2.6.25
USTR Sec. 501(b)	Inspections of cathodic protection systems	25.2.6.26
USTR Sec. 501(c)	Inspections of impressed-current cathodic protection systems	25.2.6.27
USTR Sec. 501(d)	Records of operation of the cathodic protection system	25.2.6.28

Citation	Requirement	BECR Section
USTR Sec. 502	Compatibility	25.2.6.29
USTR Sec. 503(a)	Repairs allowed	25.2.6.30
USTR Sec. 503(b)	Repairs to fiberglass-reinforced plastic tanks	25.2.6.31
USTR Sec. 503(c)	Replacement or repair of pipe sections and fittings	25.2.6.32
USTR Sec. 503(d)	Tightness testing after repairs	25.2.6.33
USTR Sec. 503(e)	Testing of any repaired cathodically protected UST system	25.2.6.34
USTR Sec. 503(f)	Records of all repairs	25.2.6.35
USTR Sec. 504(a)	Reporting requirements	25.2.6.36
USTR Sec. 504(b)	Recordkeeping requirements	25.2.6.37
USTR Sec. 504(c)	Availability and maintenance of records	25.2.6.38
USTR Sec. 505(a)	Inspections, monitoring, and testing of USTs	25.2.6.39
USTR Sec. 505(c)	Inspections of UST installations, repairs or modifications, or removals or system closures	25.2.6.40
USTR Sec. 600(a)	General requirements of all UST systems	25.2.6.41
USTR Sec. 600(b)	Notification of releases	25.2.6.42
USTR Sec. 600(c)	Schedule for required release detection	25.2.6.43
USTR Sec. 600(d)	Failure to comply with release-detection requirements	25.2.6.44
USTR Sec. 601(a)	Requirements for tanks of petroleum UST systems	25.2.2.45
USTR Sec. 601(b)	Requirements for piping of petroleum UST systems	25.2.6.46
USTR Sec. 601(b)(1)	Requirements for pressurized piping	25.2.6.47
USTR Sec. 601(b)(2)	Requirements for suction piping	25.2.6.48
USTR Sec. 602	Requirements for hazardous substance UST systems	25.2.6.49
USTR Sec. 603	Methods of release detection for tanks	25.2.6.50
USTR Sec. 603(a)	Inventory control	25.2.6.51

Citation	Requirement	BECR Section
USTR Sec. 603(b)	Manual tank gauging	25.2.6.52
USTR Sec. 603(c)	Tank tightness testing	25.2.6.53
USTR Sec. 603(d)	Automatic tank gauging	25.2.6.54
USTR Sec. 603(e)	Vapor monitoring	25.2.6.55
USTR Sec. 603(f)	Ground-water monitoring	25.2.6.56
USTR Sec. 603(g)	Interstitial monitoring	25.2.6.57
USTR Sec. 603(h)	Other methods of detecting releases	25.2.6.58
USTR Sec. 604	Methods of release detection for piping	25.2.6.59
USTR Sec. 605	Release detection recordkeeping	25.2.6.60
USTR Sec. 700	Reporting of suspected releases	25.2.6.61
USTR Sec. 701	Investigation of off-site impacts	25.2.6.62
USTR Sec. 702	Release investigation and confirmation steps	25.2.6.63
USTR Sec. 703(a)	Reporting and cleanup of large spills and overfills	25.2.6.64
USTR Sec. 703(b)	Reporting and cleanup of small spills and overfills	25.2.6.65
USTR Sec. 800	Temporary closure	25.2.6.66
USTR Sec. 801(a)	Permanent closure and changes in-service	25.2.6.67
USTR Sec. 801(b)	Permanent closure of a tank	25.2.6.68
USTR Sec. 801(c)	Change in service	25.2.6.69
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New Mexico Department of Public Safety		
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HCIA § 74-4E-5(A)(2)	Notice of release of chemical substance(s) when release is at or above the reportable quantity of the substance	32.2.2
HCIA § 74-4E-5(A)(3)	Submittal of an inventory form covering each hazardous material	32.2.3
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§ 74-4B-1 - 74-4B-14, NMSA 1978	**Emergency Management Act**	**33.1**
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§ 74-4B-5	State Police Emergency Response Officer; procedure for notification; cooperation with other State agencies and local governments	33.2.3
§ 74-4B-6	Emergency Management Task Force: powers and duties	33.2.4
§ 74-4B-6.1	Creation and duties of the Hazardous Materials Emergency Response Administrator	33.2.5
§ 74-4B-10	Responsibility for clean-up by owner, shipper, or carrier of the hazardous material	33.2.2.6
New Mexico Commissioner of Public Lands		
State Land Office (SLO) Rule No. 10	**Relating to easements and Rights-of-Way**	**35.1**

Citation	Requirement	BECR Section
SLO Rule 10.006	Application requirements and fees	35.2.1
SLO Rule 10.009	Conditions	35.2.2
SLO Rule 10.010	Damage bond	35.2.3
SLO Rule 10.011	Survey plat	35.2.4
SLO Rule 10.012	Construction reports for ruins, artifacts, or monuments found	35.2.5
SLO Rule 10.013	Affidavit of completion	35.2.6
SLO Rule 10.017	Renewal of right-of-way grants	35.2.7
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TC #4	Depth of pipelines	35.3.2
TC #5	Prevention of destruction or injury to improvements or livestock	35.3.3
TC #6	Purpose of right-of-way	35.3.4
TC #7	Existing rights	35.3.5
TC #8	Leases for mineral resources	35.3.6
TC #9	Compliance with all applicable regulations and requirements	35.3.7
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New Mexico Department of Game and Fish		
50 CFR 13	**General Permit Procedures**	**37.1**
50 CFR 13.48	Compliance with permit conditions	37.3
50 CFR 21	**Migratory Bird Permits**	**37.1**
50 CFR 21.22(a)	Permit for banding or marking migratory birds	37.3

Citation	Requirement	BECR Section
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Permit No. 1961	(1) Authorization for live capture and banding of protected birds (2) Salvaged endangered or threatened species to be reported (3) Disposition of wildlife	37.3.1
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New Mexico Department of Agriculture		
Regulatory Order No. 4	**Regulatory Order of the Board of Regents of New Mexico State University**	**38.1**

Citation	Requirement	BECR Section
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Regulatory Order No. 5	**Definitions, Licensing, Equipment Inspections, Record Keeping of Pesticides by Regulated Applicators**	**38.1**
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APPENDIX B

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CAA, § 112(r)(6)(K)	Risk management plan/hazard assessment, if applicable	6.2.3.4
CAA, § 118	Control of pollution from Federal facilities	6.21; Chapters 6 and 29
40 CFR Part 61	**National Emission Standards for Hazardous Air Pollutants (NESHAPs)**	**6.1**
40 CFR Part 61, Subpart A	General NESHAPs requirements for nonradioactive emissions	See Chapter 29
40 CFR Part 61, Subpart H	**National Emission Standards for Emissions of Radionuclides Other Than Radon from DOE Facilities**	**6.1**
40 CFR 61.96	NESHAPs application for radionuclides	6.2.2.1
40 CFR 61.93(a),(b)	EPA approval of any alternative methods for monitoring/sampling for radionuclide emissions and air flow rate that differ from those specified under NESHAPs	6.2.2.2
40 CFR 61.93(b) and Appendix B, Method 114, § 4.10	NESHAPs Quality Assurance Project Plan	6.2.2.3
40 CFR 61.09(a)(1)	EPA notification under NESHAPs, pre-startup	6.2.2.4
40 CFR 61.09(a)(2)	EPA notification under NESHAPs, post-startup	6.2.2.5
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CITATION	REQUIREMENT	BECR SECTION
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40 CFR Part 82	**Protection of Stratospheric Ozone**	**6.1**
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
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§74-4B-4	State responsibility for management of accidents; immunity from liability; cooperative agreements; private property	33.2.2
§ 74-4B-5	State Police Emergency Response Officer; procedure for notification; cooperation with other State agencies and local governments	33.2.3
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CITATION	REQUIREMENT	BECR SECTION
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40 CFR Part 165	**Regulations for the Acceptance of Certain Pesticides and Recommended Procedures for the Disposal and Storage of Pesticides and Pesticides Containers**	**10.1**
40 CFR 165.8-.11	Recommended procedures for disposal or storage of pesticides	10.2.2
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CITATION	REQUIREMENT	BECR SECTION
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HCIA § 74-4E-5(A)(2)	Notice of release of chemical substance(s) when release is at or above the reportable quantity of the substance	32.2.2
HCIA § 74-4E-5(A)(3)	Submittal of an inventory form covering each hazardous material	32.2.3
HCIA § 74-4E-5(A)(4)	Submittal of Toxic Chemical Release Inventory forms	32.2.4
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Regulatory Order No. 5	**New Mexico Pesticide Control Act: Definitions, Licensing, Equipment Inspections, Record Keeping of Pesticides by Regulated Applicators**	**38.1**
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Section 10	Protective equipment	38.2.3
Section 11	Application of pesticides	38.2.4
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
43 CFR 2801.2(b)	Mandatory conditions for right-of-way reservations and temporary-use permits: • Restoration • Air- and water-quality standards • Scenic, cultural, and environmental values • Local inhabitants • State standards that are more stringent than the Federal ones	18.2.5
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
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43 CFR 4120.2	Preparation of allotment management plan	20.2.2
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SLO Rule 10.009	Conditions	35.2.2
SLO Rule 10.010	Damage bond	35.2.3
SLO Rule 10.011	Survey plot	35.2.4
SLO Rule 10.012	Construction reports for ruins, artifacts, and monuments	35.2.5
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SLO Rule 10.017	Renewal of right-of-way grants	35.2.7
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TC #6	Purpose of right-of-way	35.3.4
TC #7	Existing rights	35.3.5
TC #8	Leases for mineral resources	35.3.6
TC #9	Compliance with all applicable regulations and requirements	35.3.7
TC #10	Non-use of the right-of-way	35.3.8

CITATION	REQUIREMENT	BECR SECTION
TC #13	Protection and preservation of natural environmental conditions	35.3.9
TC #14	Reclamation of all disturbed areas	35.3.10
Radiation Protection Legislation		
10 CFR Part 71	**Packaging and Transportation of Radioactive Material**	**15.1**
10 CFR 71.12	General license: NRC-approved package Note: The NRC issued the DOE a certificate of compliance for the TRUPACT-II instead of a license.	15.2.1
10 CFR 71.31-71.39	Contents of application and package description, evaluation, and QA	15.2.2
10 CFR 71.41	Demonstration of compliance	15.2.3
10 CFR 71.43 and 71.45	Requirements for all packages	15.2.4
10 CFR 71.47	External radiation standards for all packages	15.2.5
10 CFR 71.51	Additional requirements for Type B packages	15.2.6
10 CFR 71.55-71.61	Requirements for all fissile material packages	15.2.7
10 CFR 71.63	Special requirements for plutonium shipments in excess of 20 Ci/shipment	15.2.8
10 CFR 71.71	Tests under normal conditions of transport	15.2.9
10 CFR 71.73	Tests under hypothetical accident conditions	15.2.10
10 CFR 71.81	Compliance with general requirements (71.00-6a), operating controls and procedures (71.81-71.99), and quality assurance requirements (71.101-71.137)	15.2.11

CITATION	REQUIREMENT	BECR SECTION
10 CFR 71.83	Assumptions as to unknown properties: assume credible values that will cause the maximum nuclear reactivity	15.2.12
10 CFR 71.85	Preliminary determinations of integrity of packaging, pressure testing, and marking	15.2.13
10 CFR 71.87	Routine determinations prior to each shipment	15.2.14
10 CFR 71.89	Any special opening instructions for the consignee	15.2.15
10 CFR 71.91	Records to be kept at least 3 years after shipment	15.2.16
10 CFR 71.93	Inspections and tests to be performed or allowed to be performed by the NRC	15.2.17
10 CFR 71.95	Reports regarding (1) any decreased effectiveness of an authorized packaging during use and (2) details of any defects with safety significance	15.2.18
10 CFR 71.97	Advance notification of shipment of nuclear waste as described	15.2.19
10 CFR 71.101-71.137	NRC quality assurance requirements	15.2.20
40 CFR Part 191 (W)	**Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Waste**	**5.1**
Subpart A, 40 CFR 191.03-191.04	Standard annual dose equivalent	5.2.1
Plant and Animal Preservation Legislation		
50 CFR Part 13	**General Permit Procedures**	**21.2**
50 CFR 13.11	Permit application procedures	21.2.1

CITATION	REQUIREMENT	BECR SECTION
50 CFR Part 22	**Eagle Permits**	**21.2**
50 CFR 22.11	General permit requirements	21.2.2
50 CFR 22.25	Permits to take golden eagle nests	21.2.3
50 CFR Part 13	**General Permit Procedures**	**22.2**
50 CFR 13.11	Permit application procedures	22.2.1
50 CFR 13.12	Information requirements for permit applications	22.2.2
50 CFR 13.44	Display of permit	22.2.3
50 CFR 13.45	Filing of reports	22.2.4
50 CFR 13.46	Maintenance of records	22.2.5
50 CFR 13.47	Inspection requirement	22.2.6
50 CFR 13.48	Compliance with permit conditions (see also Sections 22.2.12 and 22.3.1)	22.2.7
50 CFR 13.50	Acceptance of liability	22.2.8
50 CFR Part 20	**Migratory Bird Hunting**	**22.2**
50 CFR Part 20, Subpart C	Compliance with applicable hunting regulations	22.2.9
50 CFR Part 21	**Migratory Bird Permits**	**22.2**
50 CFR 21.22(a)	Permit for banding or marking migratory birds	22.2.10
50 CFR 21.22(b)	Application procedures for banding or marking permits	22.2.11
50 CFR 21.22(c)	Additional permit conditions	22.2.12
50 CFR 21.22(d)	Term of permit	22.2.13
50 CFR 21.27	Special-purpose permits	22.2.14
50 CFR 21.28	Falconry permits	22.2.15
50 CFR 21.41	Depredation permits	22.2.16

CITATION	REQUIREMENT	BECR SECTION
Permit No. 22478	Authorization to capture and band or mark birds	22.3
50 CFR Part 13	**General Permit Procedures**	**23.2**
50 CFR 13.11	Permit application procedures	23.2.1
50 CFR Part 17	**Endangered and Threatened Wildlife and Plants**	**23.2**
50 CFR 17.22, 17.32, 17.52, and 17.62	Application for permits for scientific purposes or for the enhancement of propagation or survival of endangered or threatened species	23.2.2
50 CFR Part 402	**Interagency Cooperation - Endangered Species Act, as Amended**	**23.2**
50 CFR 402.12	Biological assessment to evaluate effects of proposed actions on designated species	23.2.3
50 CFR 402.14	Formal consultation with the FWS to determine whether any action will affect listed species	23.2.4
50 CFR 13	**General Fish & Wildlife Permit Procedures**	**36.1, 37.1**
50 CFR 13.48	Compliance with permit conditions	37.3
50 CFR 17	**Endangered and threatened wildlife and plants**	**36.1, 37.1**
§ 17-2-14; §§ 17-2-37 through 17-2-46	**New Mexico State implementation of the Bald and Golden Eagle Protection Act**	**36.1**
§§ 17-2-37 through 17-2-46	**New Mexico Wildlife Conservation Act implementing the Endangered Species Act**	**37.1**
Regulation No. 564	**State Game Commission Regulation, *Governing the Removal, Capture, or Destruction of Endangered Species***	**37.2**

CITATION	REQUIREMENT	BECR SECTION
Regulation No. 564	Report of unpermitted removal, capture, or destruction of endangered species	37.2.1
Regulation No. 682	**State Game Commission Regulation No. 682, *Amending the Listing of Endangered Species and Subspecies of New Mexico***	**37.2**
Regulation No. 682	Recognition of State-listed endangered wildlife	37.2.2
Regulation No. 705	**State Game Commission Regulation, *Regulation for the Taking and Possession of Protected Wildlife for Scientific and Educational Purposes***	**37.2**
Regulation No. 705, Chapter 2	Requirements for obtaining a permit	37.2.3 37.3
Regulation No. 705, Chapter 5	Year-end reports	37.2.4
NMDG&F permits	**New Mexico Department of Game and Fish Permits**	**37.3**
Permit No. 1961	Authorization for live capture and banding of protected birds, reporting of salvaged endangered or threatened wildlife, and disposition of wildlife	37.3.1
Permit No. 1894	Live trapping; authorization for quail, catfish, and unprotected species; nonlethal methods for catfish; report for salvaging endangered or threatened vertebrates	37.3.2
Waste Management Legislation		
RCRA § 3016	Inventory of Federal hazardous waste facilities	2.2.1.1
HWMR-7, § 1001	New Mexico Hazardous Waste Management Regulations, HWMR-7	25.2.1.1
40 CFR Part 262 (HWMR-7, § 301)	**Standards applicable to generators of hazardous waste**	**25.2.2**

CITATION	REQUIREMENT	BECR SECTION
40 CFR 262.11	Hazardous waste determination	25.2.2.1
40 CFR 262.12	EPA identification number	25.2.2.2
40 CFR 262.20	Manifest requirements	25.2.2.3
40 CFR 262.21	Acquisition of manifests	25.2.2.4
40 CFR 262.22	Number of copies	25.2.2.5
40 CFR 262.23	Use of the manifest	25.2.2.6
40 CFR 262.30	DOT packaging requirements	25.2.2.7
40 CFR 262.31	Labeling requirements	25.2.2.8
40 CFR 262.32	Marking requirements	25.2.2.9
40 CFR 262.33	Placarding requirements	25.2.2.10
40 CFR 262.34(a)	90-day or less accumulation time	25.2.2.11
40 CFR 262.34(a)(1)(i)	Compliance with Subpart I of 40 CFR Part 265 for waste placed in containers	25.2.2.12
40 CFR 262.34(a)(1)(ii)	Accumulation of hazardous wastes in tanks	25.2.2.13
40 CFR 262.34(a)(1)(iii)	Compliance with Subpart W of 40 CFR Part 265 for wastes placed on drip pads	25.2.2.14
40 CFR 262.34(a)(2)	Marking each container with the date of initial accumulation of waste	25.2.2.15
40 CFR 262.34(a)(3)	Marking each container as hazardous waste	25.2.2.16
40 CFR 262.34(a)(4)	Compliance with Subparts C and D of 40 CFR 265 and with 40 CFR 265.26 and 268.7	25.2.2.17
40 CFR 262.34(b)	Extension of the 90-day storage period due to unforeseen, temporary, and uncontrollable circumstances	25.2.2.18
40 CFR 262.34(c)(1)(i)	Restrictions and requirements for satellite accumulation areas	25.2.2.19 25.2.2.20
40 CFR 262.34(c)(1)(ii)	Labeling of container as "hazardous waste"	25.2.2.21

CITATION	REQUIREMENT	BECR SECTION
40 CFR 262.34(c)(2)	Management of waste exceeding the 55-gallon or 1-quart limit	25.2.2.22
40 CFR 262.40	Recordkeeping requirements	25.2.2.23
40 CFR 262.41	Generator--biennial report	25.2.2.24
40 CFR 262.42	Exception reporting if copy of manifest is not returned to generator within the specified time period	25.2.2.25
40 CFR 262.43	Additional reporting	25.2.2.26
40 CFR Part 263 (HWMR-7, § 401)	**Standards Applicable to Transporters of Hazardous Waste**	**25.2.3**
40 CFR 263.10(a)	Compliance with DOT regulations	25.2.3.1
40 CFR 263.11	EPA identification number	25.2.3.2
40 CFR 263.20 - 263.22	Compliance with the manifest system and recordkeeping	25.2.3.3
40 CFR 263.30	Immediate action after hazardous waste discharges	25.2.3.4
40 CFR 263.31	Discharge cleanup	25.2.3.5
40 CFR Part 265 (HWMR-7, § 601)	**Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities**	**25.2.4**
40 CFR 265.10	Applicability	25.2.4.1
40 CFR 265.11	EPA identification number	25.2.4.2
40 CFR 265.12	Required notices to the off-site source(s)	25.2.4.3
40 CFR 265.13	General waste analysis	25.2.4.4
40 CFR 265.14	Security	25.2.4.5
40 CFR 265.15	General inspection requirements	25.2.4.6
40 CFR 265.16	Personnel training	25.2.4.7
40 CFR 265.17	General requirements for ignitable, reactive, or incompatible wastes	25.2.4.8
40 CFR 265.18	Location standards	25.2.4.9

CITATION	REQUIREMENT	BECR SECTION
40 CFR 265.31	Maintenance and operation of facility	25.2.4.10
40 CFR 265.32	Required equipment	25.2.4.11
40 CFR 265.33	Testing and maintenance of equipment	25.2.4.12
40 CFR 265.34	Access to communications or alarm system	25.2.4.13
40 CFR 265.35	Required aisle space	25.2.4.14
40 CFR 265.37	Arrangements with local authorities	25.2.4.15
40 CFR 265.51	Purpose and implementation of the contingency plan	25.2.4.16
40 CFR 265.52	Content of the contingency plan	25.2.4.17
40 CFR 265.53	Copies of contingency plan	25.2.4.18
40 CFR 265.54	Amendment of contingency plan	25.2.4.19
40 CFR 265.55	Emergency Coordinator	25.2.4.20
40 CFR 265.56	Emergency procedures	25.2.4.21
40 CFR 265.71	Use of manifest system	25.2.4.22
40 CFR 265.72	Manifest discrepancies	25.2.4.23
40 CFR 265.73	Operating record	25.2.4.24
40 CFR 265.74	Availability, retention, and disposition of records	25.2.4.25
40 CFR 265.75	TSDF biennial report	25.2.4.26
40 CFR 265.76	Unmanifested waste report	25.2.4.27
40 CFR 265.77	Additional reports	25.2.4.28
40 CFR 265.90	Applicability of the ground-water monitoring system	25.2.4.29
40 CFR 265.91	Ground-water monitoring system	25.2.4.30
40 CFR 265.92	Sampling and analysis	25.2.4.31
40 CFR 265.93	Preparation, evaluation, and response	25.2.4.32
40 CFR 265.94	Recordkeeping and reporting	25.2.4.33

CITATION	REQUIREMENT	BECR SECTION
40 CFR 265.110	Applicability of the closure/post-closure requirements	25.2.4.34
40 CFR 265.111	Closure performance standard	25.2.4.35
40 CFR 265.112	Closure plan; amendment of plan	25.2.4.36
40 CFR 265.113	Time allowed for closure	25.2.4.37
40 CFR 265.114	Disposal or decontamination of equipment, structures, and soils	25.2.4.38
40 CFR 265.115	Certification of closure	25.2.4.39
40 CFR 265.116	Survey plat	25.2.4.40
40 CFR 265.117	Postclosure care and use of property	25.2.4.41
40 CFR 265.118	Postclosure plan; amendment of plan	25.2.4.42
40 CFR 265.119	Postclosure notices	25.2.4.43
40 CFR 265.120	Certification of completion of post-closure care	25.2.4.44
40 CFR 265.142	Cost estimate for closure	25.2.4.45
40 CFR 265.143	Financial assurance for closure	25.2.4.46
40 CFR 265.144	Cost estimate for postclosure care	25.2.4.47
40 CFR 265.145	Financial assurance for postclosure care	25.2.4.48
40 CFR 265.146	Use of a mechanism for financial assurance of both closure and post-closure care	25.2.4.49
40 CFR 265.147	Liability requirements	25.2.4.50
40 CFR 265.148	Incapacity of owners or operators, guarantors, or financial institutions	25.2.4.51
40 CFR 265.149 [HWMR-7, § 602(A)]	Use of State-required mechanisms	25.2.4.52
40 CFR 265.150 [HWMR-7, § 602(B)]	State assumption of responsibility	25.2.4.53
40 CFR 265.171	Condition of containers	25.2.4.54
40 CFR 265.172	Compatibility of waste with containers	25.2.4.55

CITATION	REQUIREMENT	BECR SECTION
40 CFR 265.173	Management of containers	25.2.4.56
40 CFR 265.174	Inspections	25.2.4.57
40 CFR 265.176	Special requirements for ignitable or reactive waste	25.2.4.58
40 CFR 265.177	Special requirements for incompatible wastes	25.2.4.59
40 CFR 265.190-.445	Tank systems; surface impoundments; waste piles; land treatment; incinerators; thermal treatment; chemical, physical, and biological treatment; underground injection; and drip pads	25.2.4.60
40 CFR 265.1032	Standards (air emission) for process vents	25.2.4.61
40 CFR 265.1052-.1062	Air emission standards for equipment leaks	25.2.4.62
40 CFR Part 268	**Land Disposal Restrictions**	**2.2.2**
40 CFR 268.1	Purpose, scope, and applicability	2.2.2.1
40 CFR 268.6(a)	Submittal of petitions to allow land disposal of a waste prohibited under Subpart C of Part 268	2.2.2.2
40 CFR 268.6(b)	Requirements of demonstration of no-migration in petition	2.2.2.3
40 CFR 268.6(c)	Contents of petition	2.2.2.4
40 CFR 268.6(d)	Submittal of petition to EPA Administrator	2.2.2.5
40 CFR 268.6(e)	Consistency of activities with those described in the petition and notification of EPA of changes in conditions at the unit and/or in the environment	2.2.2.6
40 CFR 268.6(f)	Activities required if hazardous constituents are found to have migrated from the repository	2.2.2.7
40 CFR 268.6(g)	Certification in petition	2.2.2.8

CITATION	REQUIREMENT	BECR SECTION
40 CFR 268.6(h)	Additional information requested by Administrator	2.2.2.9
40 CFR 268.6(k)	Terms of variance	2.2.2.10
40 CFR 268.6(n)	Non-exemption of liquid hazardous wastes containing ≥ 500 ppm PCBs	2.2.2.11
40 CFR 268.7	Waste analysis and recordkeeping	2.2.2.12
40 CFR 268.8	Landfill and surface impoundment disposal restrictions	2.2.2.13
40 CFR 268.9	Special rules regarding wastes that exhibit a characteristic	2.2.2.14
40 CFR 268.10-12	Identification of waste to be evaluated by August 8, 1988; by June 8, 1989; and by May 8, 1990	2.2.2.15
40 CFR 268.30	Waste-specific prohibitions--solvent wastes	2.2.2.16
40 CFR 268.31	Waste-specific prohibitions--dioxin-containing wastes	2.2.2.17
40 CFR 268.32	Waste-specific prohibitions--California listed wastes	2.2.2.18
40 CFR 268.33	Waste prohibitions--first-third wastes	2.2.2.19
40 CFR 268.34	Waste prohibitions--second-third wastes	2.2.2.20
40 CFR 268.35	Waste prohibitions--third-third wastes	2.2.2.21
40 CFR 268.41	Treatment standards expressed as concentrations in waste extract	2.2.2.22
40 CFR 268.42	Treatment standards expressed as specified technologies	2.2.2.23
40 CFR 268.43	Treatment standards expressed as waste concentrations	2.2.2.24
40 CFR 268.44	Variance from a treatment standard	2.2.2.25
40 CFR 268.50	Prohibitions on storage of restricted wastes	2.2.2.26

CITATION	REQUIREMENT	BECR SECTION
40 CFR Part 270 (HWMR-7, § 901)	**EPA Administered Permit Programs: the Hazardous Waste Permit Program**	**25.2.5**
40 CFR 270.1	Purpose and scope of the RCRA permit program regulations	25.2.5.1
40 CFR 270.10	General application requirements	25.2.5.2
40 CFR 270.11	Signatories to permit applications and reports	25.2.5.3
40 CFR 270.13	Contents of Part A of the permit application	25.2.5.4
40 CFR 270.14 (HWMR-7, §§ 901 and 902)	Contents of Part B: general requirements	25.2.5.5
40 CFR 270.15	Specific Part B information requirements for containers	25.2.5.6
40 CFR 270.23	Specific Part B requirements for miscellaneous units	25.2.5.7
40 CFR 270.30	Conditions applicable to all permits	25.2.5.8
40 CFR 270.31	Requirements for recording and reporting of monitoring results	25.2.5.9
40 CFR 270.42 (HWMR-7, §§ 901 and 902)	Permit modification at the request of the permittee	25.2.5.10
40 CFR 270.71	Operation during interim status	25.2.5.11
40 CFR 270.72	Changes during interim status	25.2.5.12
55 FR 47700	**Conditional No-Migration Determination (NMD)**	**2.3**
Condition 1, IV.B.1 and VI(1)	Testing of long-term acceptability of WIPP only	2.3.1
Condition 2, IV.B.2 and VI(2)	Wastes not to exceed 8,500 drums or 1 percent of repository's total capacity	2.3.2
Condition 3, IV.B.3 and VI(3)	Retrieval of waste if noncompliance with 40 CFR 268.6	2.3.3
Condition 4, IV.B.4 and VI(4)	Readily retrievable placement of waste	2.3.4

CITATION	REQUIREMENT	BECR SECTION
Condition 5, IV.B.5 and VI(5)	Installation of carbon adsorption device	2.3.5
Condition 6, IV.B.6 and VI(6)	Implementation of air monitoring plan for VOCs	2.3.6
Condition 7(a), IV.B.7(a) and VI(7)(a)	Waste analysis: flammable mixtures of gases	2.3.7
Condition 7(b), IV.B.7(b) and VI(7)(b)	Waste analysis: comparison of analytical results with estimated compositions	2.3.8
Condition 7(c), IV.B.7(c) and VI(7)(c)	Waste analysis: maintenance of records	2.3.9
Condition 8, IV.B.8 and VI(8)	Annual report	2.3.10
55 FR 47700	**General Conditions for Compliance with the NMD**	**2.3**
General condition (GC) 1, IV.B.1	Correlation between wastes received and those described in the No-Migration Variance Petition	2.3.11
GC 2, VI	Notification of EPA of changes in conditions	2.3.12
GC 3, VI	Suspension of receipt of restricted wastes and notification of EPA in the event of migration of hazardous constituents from the repository	2.3.13
GC 4, VI	Term of petition approved	2.3.14
55 FR 13068	**Additional Requirements for Air Monitoring under the Proposed Variance**	**2.3**
Proposed Variance (PV) 1, IV.K	Monitoring in the exhaust shaft	2.3.15
PV 2, IV.K	Monitoring of bin-scale experiment rooms	2.3.16
PV 3, IV.K	Monitoring of alcoves	2.3.17
PV 4, IV.K.1	Measurement of the leakage rate of sealed alcoves	2.3.18
PV 5, IV.K.1	Weekly collection of air samples	2.3.19

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PV 6, IV.K.1	Weekly monitoring at the exhaust shaft and air intake locations	2.3.20
PV 7, IV.K.1	Monitoring frequency for the bin discharge system	2.3.21
PV 8, IV.K.1	Increased monitoring frequency due to increased variability	2.3.22
PV 9, IV.K.2	Routine quantification of any VOC	2.3.23
PV 10, IV.K.2	Standard operating procedures to identify certain other VOCs	2.3.24
PV 11, IV.K.3	Use of the average response factor for each target analyte	2.3.25
PV 12, IV.K.4	Use of standard operating procedures to ensure the validity of the monitoring data	2.3.26
PV 13, IV.K.4	Recalibration of instruments	2.3.27
PV 14, IV.K.4	Establishment and annual evaluation of the method limit of quantification for each target analyte	2.3.28
PV 15, IV.K.4	Separate determination of the method limit of quantification for the bin, alcove, and exhaust shaft monitoring locations	2.3.29
PV 16, IV.K.4	Collection and analysis of recovery samples	2.3.30
PV 17, IV.K.4	Collection and analysis of duplicate samples	2.3.31
PV 18, IV.K.4	Validation of the completeness of the data	2.3.32
PV 19, IV.K.4	Tracking and evaluation of accuracy, precision, and completeness of the data	2.3.33
PV 20, IV.K.4	Performance of systems audits	2.3.34
PV 21, IV.K.4	Corrective action required for improper conditions or practices	2.3.35

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PV 22, IV.K.4	Establishment of specific quality assurance objectives for data acceptability	2.3.36
PV 23, IV.K.4	Corrective action required	2.3.37
PV 24, IV.K.5	Annual averaging of concentrations of targeted constituents	2.3.38
PV 25, IV.K.5	Submittal of annual data summaries and summaries of data accuracy, precision, and completeness for each monitoring location	2.3.39
PV 26, IV.K.5	Maintenance of documentation on all aspects of QA/QC	2.3.40
SWMR-3	**Solid Waste Management Regulations**	**26.1**
SWMR-3, § 104	Applicability of regulations	26.2.1
SWMR-3, § 106	General requirements	26.2.2
SWMR-3, § 107	Prohibited acts	26.2.3
SWMR-3, § 109	Recordkeeping and annual reports	26.2.4
SWMR-3, § 201, 202, 209, 210	Permit application requirements	26.2.5
SWMR-3, Part IV	Solid waste facility operation requirements	26.2.6
SWMR-3, Part V	Closure and postclosure requirements	26.2.7
SWMR-3, Part VI	Operator certification	26.2.8
SWMR-3, § 706(C)	Storage and containment requirements for infectious waste	26.2.9
SWMR-3, § 706(D)	Operational requirements for infectious waste treatment, storage, and disposal facilities	26.2.10
SWMR-3, § 706(E)	Treatment and disposal of infectious waste	26.2.11
SWMR-3, § 706(F)	Requirements for infectious waste transporters	26.2.12

CITATION	REQUIREMENT	BECR SECTION
SWMR-3, § 711	Manifest requirements (to accompany each load of infectious waste)	26.2.13
Underground Storage Tanks		
USTR	**New Mexico Underground Storage Tank Regulations**	**25.2.6**
USTR Sec. 103	Applicability	25.2.6.1
USTR Sec. 200	Existing tanks	25.2.6.2
USTR Sec. 201	Transfer of ownership	25.2.6.3
USTR Sec. 202	New UST system	25.2.6.4
USTR Sec. 203	Substantially modified UST systems	25.2.6.5
USTR Sec. 204	Notification of spill or release	25.2.6.6
USTR Sec. 205	Emergency repairs and tank replacement	25.2.6.7
USTR Sec. 206	Application forms	25.2.6.8
USTR Sec. 207	Registration certificate	25.2.6.9
USTR Sec. 300	Payment of fee	25.2.6.10
USTR Sec. 301	Amount of fee	25.2.6.11
USTR Sec. 302	Late payment penalties	25.2.6.12
USTR Sec. 400(a)	Performance standards to ensure that new UST systems/tanks are properly designed and constructed	25.2.6.13
USTR Sec. 400(b)	Piping to be properly designed and constructed	25.2.6.14
USTR Sec. 400(c)(1)(i)	Spill prevention equipment	25.2.6.15
USTR Sec. 400(c)(1)(ii)	Overfill prevention equipment	25.2.6.16
USTR Sec. 400(d)	Installation of tanks and piping	25.2.6.17
USTR Sec. 400(e)	Certificate of installation	25.2.6.18
USTR Sec. 401(a)	Upgrading of existing UST systems	25.2.6.19

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USTR Sec. 401(b)	Upgrading requirements for steel tanks	25.2.6.20
USTR Sec. 401(c)	Upgrading requirements for metal piping	25.2.6.21
USTR Sec. 401(d)	Spill and overfill protection equipment	25.2.6.22
USTR Sec. 402 (by reference to 40 CFR 280.22)	Certification of compliance and notification requirements	25.2.6.23
USTR Sec. 500(a)	Spill and overflow control	25.2.6.24
USTR Sec. 501(a)	Corrosion protection	25.2.6.25
USTR Sec. 501(b)	Inspections of cathodic protection systems	25.2.6.26
USTR Sec. 501(c)	Inspections of impressed-current cathodic protection systems	25.2.6.27
USTR Sec. 501(d)	Records of operation of the cathodic protection system	25.2.6.28
USTR Sec. 502	Compatibility	25.2.6.29
USTR Sec. 503(a)	Repairs allowed	25.2.6.30
USTR Sec. 503(b)	Repairs to fiberglass-reinforced plastic tanks	25.2.6.31
USTR Sec. 503(c)	Replacement or repair of pipe sections and fittings	25.2.6.32
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CITATION	REQUIREMENT	BECR SECTION
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USTR Sec. 600(b)	Notification of releases	25.2.6.42
USTR Sec. 600(c)	Schedule for required release detection	25.2.6.43
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USTR Sec. 601(a)	Requirements for tanks of petroleum UST systems	25.2.6.45
USTR Sec. 601(b)	Requirements for piping of petroleum UST systems	25.2.6.46
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
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49 CFR 177.800, 177.816, and 177.825	Training responsibilities and requirements for Class 7 material	16.2.19
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CITATION	REQUIREMENT	BECR SECTION
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40 CFR 122.26(a)	Requirement for a storm water discharge permit	7.2.5
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IV(A)(4)	Notice of Termination	7.3.2
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CITATION	REQUIREMENT	BECR SECTION
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CITATION	REQUIREMENT	BECR SECTION
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DP-831 GR--Spills, Leaks, and Other Unauthorized Discharges	Reporting and remediation of any spills, leaks, and any other unauthorized discharges	30.3.9
DP-831 GR--Retention of Records	Retention of all monitoring information, discharge plan reports, and data used to complete the discharge plan application	30.3.10
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WQCC 82-1, 3-104	Authorization only of effluent(s)/ leachate(s) as specified in discharge plan	30.2.5
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CITATION	REQUIREMENT	BECR SECTION
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WSR 3, § 208(I)	Cross connections	31.2.4
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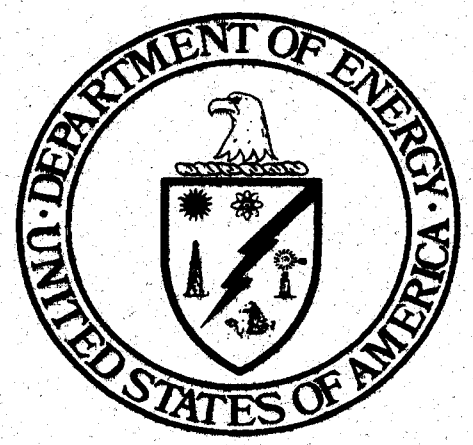
WSR 3, § 404(B)	Public notice requirements pertaining to lead	31.2.12

DOE/CAO-96-2160

Final
No-Migration
Variance Petition



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June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume III of VIII

Appendices BH, BRAGFLO, BWQ, CLI, CLP

APPENDIX BH

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-308
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: Railroad

ELEVATION: Not Recorded
TOTAL DEPTH: 39.9'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/01/79 **Date Completed:** 02/01/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-308	Caliche	0-10.5
	Gatuna	10.5-19.5
	Dewey Lake	19.5-39.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-307**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	Railroad
ELEVATION:	Not Recorded
TOTAL DEPTH:	40'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/01/79 **Date Completed:** 02/01/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-307	Caliche	0-5.6
	Sand	5.6-11.1
	Gatuna	11.1-17.1
	Dewey Lake	17.1-40

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-306**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 38'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/02/79 **Date Completed:** 02/02/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-306	Sand	0-7.3
	Caliche	7.3-18
	Santa Rosa	18-38

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-305
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 41'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/06/79 **Date Completed:** 02/06/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-305	Sand	0-14.5
	Caliche	14.5-19.5
	Sand	19.5-25.5
	Caliche	25.5-33
	Sand	33-41

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-304**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 41.5'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/06/79 **Date Completed:** 02/06/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-304	Sand	0-20.6
	Caliche	20.6-33
	Sand	33-41.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-303**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.1'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/07/79 **Date Completed:** 02/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-303	Sand	0-15.5
	Caliche	15.5-18
	Dewey Lake	18-39.1

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-302**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/07/79 **Date Completed:** 02/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-302	Sand	0-10.4
	Caliche	10.4-23
	Dewey Lake	23-39.0

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-301**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/08/79 **Date Completed:** 02/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-301	Sand	0-1
	Caliche	1-24
	Dewey Lake	24-39.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-54**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499386.52, E666651.92
ELEVATION:	3408.60'
TOTAL DEPTH:	210'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 02/14/79
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/13/79 **Date Completed:** 02/14/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-54	Sand	0-6
	Caliche	6-12
	Gatuna	12-25
	Santa Rosa	25-30
	Dewey Lake	30-210

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-53**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N496651.28, E665463.05
ELEVATION:	3386.65'
TOTAL DEPTH:	30.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/30/79 **Date Completed:** 01/30/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-53	Sand	0-8.5
	Caliche	8.5-15.7
	Gatuna	15.7-23.7
	Dewey Lake	23.7-30.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-52**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N496981.21, E665461.91
ELEVATION:	3385.48'
TOTAL DEPTH:	30.0'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/26/79 **Date Completed:** 01/26/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-52	Sand	0-3.1
	Caliche	3.1-8.5
	Gatuna	8.5-19
	Dewey Lake	19-30

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-51**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498337.48, E667341.75
ELEVATION:	3404.74'
TOTAL DEPTH:	15.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/25/79 **Date Completed:** 01/25/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-51	Sand	0-7.5
	Caliche	7.5-14.5
	Gatuna	14.5-15.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-50**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498487.09, E667236.23
ELEVATION:	3405.65'
TOTAL DEPTH:	23.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/26/79 **Date Completed:** 01/26/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-50	Sand	0-9.5
	Caliche	9.5-15
	Gatuna	15-23.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-49**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498937.22, E667294.71
ELEVATION:	3409.07'
TOTAL DEPTH:	19.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/24/79 **Date Completed:** 01/24/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-49	Sand	0-8.5
	Caliche	8.5-10.5
	Silty Sand	10.5-15
	Gatuna	15-19.2

W

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-48**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498839.26, E667854.93
ELEVATION:	3412.12'
TOTAL DEPTH:	15.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/24/79 **Date Completed:** 01/24/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-48	Sand	0-9
	Caliche	9-15.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-47**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499206.77, E667193.82
ELEVATION:	3409.49'
TOTAL DEPTH:	17.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/25/79 **Date Completed:** 01/25/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-47	Sand	0-8.9
	Caliche	8.9-15
	Gatuna	15-17.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-46**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.54, E666777.36
ELEVATION:	3401.98'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-46	Sand	0-8
	Caliche	8-13
	Gatuna	13-41
	Santa Rosa	41-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-45**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.44, E666747.36
ELEVATION:	3401.51'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/10/79 **Date Completed:** 01/17/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-45	Sand	0-7.5
	Caliche	7.5-15.3
	Gatuna	15.3-31.3
	Dewey Lake	31.3-44.2
	Sandstone	44.2-44.7
	Siltstone	44.7-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-44**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499172.96, E667523.82

ELEVATION: 3411.48'
TOTAL DEPTH: 100'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/08/79 **Date Completed:** 01/08/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-44	Sand	0-16
	Caliche	16-21
	Gatuna	21-38
	Santa Rosa	38-52
	Dewey Lake	52-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-43
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499202.96, E667523.70

ELEVATION: 3410.75'
TOTAL DEPTH: 100'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/06/79 **Date Completed:** 01/06/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-43	Sand	0-12
	Caliche	12-20
	Gatuna	20-43
	Santa Rosa	43-53
	Dewey Lake	53-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-42**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.57, E666873.35
ELEVATION:	3408.99'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-42	Sand	0-6
	Caliche	6-14
	Gatuna	14-42
	Santa Rosa	42-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-41**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.51, E666858.36
ELEVATION:	3407.86'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/05/79 **Date Completed:** 01/05/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-41	Sand	0-6
	Caliche	6-15
	Gatuna	15-42
	Santa Rosa	42-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-40**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499023.04, E670353.77
ELEVATION:	3438.48'
TOTAL DEPTH:	27.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/10/79 **Date Completed:** 01/10/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-40	Sand	0-7.6
	Caliche	7.6-13
	Gatuna	13-19
	Sandstone	19-27.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-39**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499018.31, E669019.04
ELEVATION:	3422.08'
TOTAL DEPTH:	27.6'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-39	Sand	0-7
	Caliche	7-13
	Gatuna	13-27.6

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-38**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499155.65, E669683.42

ELEVATION: 3429.88'
TOTAL DEPTH: 50'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 1/23/79
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/11/79 **Date Completed:** 01/23/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-38	Sand	0-5.5
	Caliche	5.5-14
	Gatuna	14-20.5
	Sandstone	20.5-40.2
	Santa Rosa	40.2-43.7
	Dewey Lake	43.7-50

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-37A**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499260.53, E669370.39
ELEVATION:	3426.68'
TOTAL DEPTH:	22.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-37A	Sand	0-5.5
	Caliche	5.5-13.5
	Gatuna	13.5-22.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-37**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499297.91, E670352.77
ELEVATION:	3438.91'
TOTAL DEPTH:	27.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/09/79 **Date Completed:** 01/09/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-37	Sand	0-5.5
	Caliche	5.5-12.5
	Gatuna	12.5-20
	Siltstone	20-20.3
	Sandstone	20.3-27.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-36**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499293.25, E669018.07
ELEVATION:	3422.03'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/07/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-36	Sand	0-5.9
	Caliche	5.9-13.2
	Gatuna	13.2-25
	Siltstone	25-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-35
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498326.97, E667196.82

ELEVATION: 3402.55'
TOTAL DEPTH: 32'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/05/79 **Date Completed:** 01/05/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-35	Sand	0-7
	Caliche	7-12
	Gatuna	12-23
	Sandstone	23-32

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-34**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.49, E666762.36
ELEVATION:	3401.97'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/09/79 **Date Completed:** 01/09/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-34	Sand	0-9.1
	Caliche	9.1-14.8
	Gatuna	14.8-40
	Siltstone & Claystone	40-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-33**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498874.29, E666470.03
ELEVATION:	3404.05'
TOTAL DEPTH:	30.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/29/78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide curring faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-33	Sand	0-6.7
	Caliche	6.7-15.8
	Gatuna	15.8-19
	Sandstone	19-24
	Intercalated Siltstone & Mudstone	24-29.8
	Sandstone	29.8-30.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-32
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499187.96, E667523.76

ELEVATION: 3410.89'
TOTAL DEPTH: 100'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/07/79 **Date Completed:** 01/07/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-32	Sand	0-12.5
	Caliche	12.5-19.5
	Gatuna	19.5-26.5
	Siltstone & Claystone	26.5-43
	Santa Rosa	43-53
	Dewey Lake	53-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-31**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499206.60, E667143.76
ELEVATION:	3410.27
TOTAL DEPTH:	30.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/29//78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

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STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-31	Sand	0-7.8
	Caliche	7.8-13.4
	Gatuna	13.4-30.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-30**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499185.81, E666933.86
ELEVATION:	3408.75'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/28/78 **Date Completed:** 12/28/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-30	Sand	0-7.5
	Caliche	7.5-11.5
	Gatuna	11.5-17.6
	Sandstone	17.6-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-29**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499397.21, E667253.07
ELEVATION:	3410.87'
TOTAL DEPTH:	28.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/30/78 **Date Completed:** 12/30/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-29	Sand	0-13
	Gatuna	13-28.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-28**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499295.02, E666718.53
ELEVATION:	3408.17'
TOTAL DEPTH:	27'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/04/79 **Date Completed:** 01/04/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-28	Sand	0-6
	Caliche	6-12
	Gatuna	12-21
	Sandstone	21-27

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-27**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498982.08, E665854.70
ELEVATION:	3400.20'
TOTAL DEPTH:	25.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/11/79 **Date Completed:** 01/11/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-27	Sand	0-4
	Caliche	4-11
	Gatuna	11-22
	Sandstone	22-22.5
	Claystone	22.5-23
	Sandstone	23-24
	Intercalated Sandstone	24-25.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-26
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499600.58, E666892.43

ELEVATION: 3410.19'
TOTAL DEPTH: 27.5'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/03/79 **Date Completed:** 01/03/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-26	Sand	0-5
	Caliche	5-11
	Gatuna	11-23
	Siltstone	23-27.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-25
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499414.91, E666693.11

ELEVATION: 3408.19'
TOTAL DEPTH: 901.8'
TYPE OF WELL: Deep Exploratory Drilling
DRILLER: Gil's Drilling Co.

DRILLING RECORD: **Date Started:** 12/01/78 **Date Completed:** 01/18/79

CASING RECORD: Drilling Equipment:
GD-2000 drill.

PLUGGING SCHEDULE:

From: 909'
To: 750.4'
Interval: 158.6'
Material: Salt Grout

From: 750.4'
To: 466'
Interval: 284.4'
Material: Freshwater Grout

From: 466'
To: 20'
Interval: 446'
Material: Sand

From: 20'
To: Surface
Interval: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-25	Sand	0-10
	Caliche	10-14
	Gatuna	14-34.7
	Santa Rosa	34.7-44.8
	Dewey Lake	44.8-533
	Rustler Formation	533-842.9
	Magenta Member	592.7-617
	Culebra Member	704.1-728
	Salado Formation	842.9-901.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-24**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498342.84, E668846.53
ELEVATION:	3417.87'
TOTAL DEPTH:	29.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/07/78 **Date Completed:** 12/07/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-24	Sand	0-5.5
	Caliche	5.5-12
	Gatuna	12-29.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-23
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498341.06, E668346.63

ELEVATION: 3412.07'
TOTAL DEPTH: 40.5'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/06/78 **Date Completed:** 12/06/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-23	Sand	0-6
	Caliche	6-14.3
	Gatuna	14.3-40.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-22**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498339.28, E667846.73
ELEVATION:	3406.85'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/11/78 **Date Completed:** 12/11/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-22	Sand	0-7.5
	Caliche	7.5-13
	Gatuna	13-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-21**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498337.50, E667346.75
ELEVATION:	3404.55'
TOTAL DEPTH:	40.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/17/78 **Date Completed:** 11/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-21	Sand	0-9.5
	Caliche	9.5-20
	Gatuna	20-32.5
	Sandstone	32.5-40.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-20A**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498341.34, E666847.10

ELEVATION: 3403.53'
TOTAL DEPTH: 34.2'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/12/78 **Date Completed:** 12/16/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-20A	Sand	0-13.9
	Caliche	13.9-19
	Gatuna	19-34.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-20
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498335.72, E666846.91

ELEVATION: 3403.53'
TOTAL DEPTH: 14'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/12/78 **Date Completed:** 12/16/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-20	Sand	0-10
	Caliche	10-14

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-19**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498333.94, E666347.03
ELEVATION:	3399.84'
TOTAL DEPTH:	38.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/30/78 **Date Completed:** 11/30/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-19	Sand	0-8.5
	Caliche	8.5-18.5
	Gatuna	18.5-21.1
	Sandstone	21.1-38.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-18**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498842.75, E668844.75
ELEVATION:	3419.32'
TOTAL DEPTH:	33.3'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/15/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/14/78 **Date Completed:** 12/15/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-18	Sand	0-7.1
	Caliche	7.1-15
	Gatuna	15-33.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-17**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498840.97, E668343.86
ELEVATION:	3413.26'
TOTAL DEPTH:	25.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/13/78 **Date Completed:** 12/13/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

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STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-17	Silty Sand	0-5.1
	Caliche	5.1-10.5
	Gatuna	10.5-25.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-16**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498839.19, E667844.94
ELEVATION:	3411.21'
TOTAL DEPTH:	31'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/15/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/14/78 **Date Completed:** 12/15/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-16	Sand	0-7
	Caliche	7-15
	Gatuna	15-31

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-15
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498837.40, E667345.06

ELEVATION: 3408.64'
TOTAL DEPTH: 56.8'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 11/16/78 **Date Completed:** 11/17/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-15	Sand	0-9
	Caliche	9-13
	Silty Sand	13-26
	Gatuna	26-51.5
	Santa Rosa	51.5-55
	Shale	54.5-56.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-14**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498835.60, E666845.14
ELEVATION:	3406.57'
TOTAL DEPTH:	24.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/13/78 **Date Completed:** 12/13/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-14	Sand	0-4.8
	Caliche	4.8-9.9
	Gatuna	9.9-14
	Claystone	14-24.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-13**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498833.82, E666345.25
ELEVATION:	3403.91'
TOTAL DEPTH:	28.3'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/12/78 **Date Completed:** 12/16/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-13	Sand	0-7
	Caliche	7-12.5
	Gatuna	12.5-26
	Claystone	26-28.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-12**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499342.61, E668842.93
ELEVATION:	3421.77'
TOTAL DEPTH:	41.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/01/78 **Date Completed:** 12/01/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-12	Sand	0-6
	Caliche	6-13
	Gatuna	13-20
	Sandstone	20-26
	Claystone	26-27
	Sandstone	27-31.5
	Claystone	31.5-33.5
	Sandstone	33.5-38.5
	Intercalated Sandstone	38.5-41.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-11**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499340.83, E668343.05
ELEVATION:	3414.30'
TOTAL DEPTH:	30'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/15/78 **Date Completed:** 12/15/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-11	Sand	1.2-4.1
	Caliche	4.1-13.5
	Gatuna	13.5-30

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-10**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499339.05, E6678434.11
ELEVATION:	3413'
TOTAL DEPTH:	32'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/19/78 **Date Completed:** 12/19/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-10	Sand	0-10.2
	Caliche	10.2-17
	Gatuna	17-26.5
	Siltstone	26.3-27
	Sandstone	27-32

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-9**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499337.27, E667343.26
ELEVATION:	3410.47'
TOTAL DEPTH:	38.3
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/19/78 **Date Completed:** 12/19/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test corings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-9	Sand	0-8.1
	Caliche	8.1-18
	Gatuna	18-32.1
	Siltstone	32.1-36
	Sandstone	36-38.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-8**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.46, E666843.36
ELEVATION:	3408.55'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/03/79 **Date Completed:** 01/03/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-8	Sand	0-7
	Caliche	7-12
	Gatuna	12-35.7
	Santa Rosa	35.7-40
	Dewey Lake	40-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-7**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499333.68, E666343.48
ELEVATION:	3404.19'
TOTAL DEPTH:	34.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/21/78 **Date Completed:** 11/21/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-7	Sand	0-5.5
	Caliche	5.5-20
	Gatuna	20-25
	Sandstone	25-27.5
	Santa Rosa	27.5-34.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-6**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499842.47, E668841.15
ELEVATION:	3422.01'
TOTAL DEPTH:	26.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-6	Silty Sand	0-3.5
	Caliche	3.5-10.1
	Gatuna	10.1-26.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-5**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499840.69, E668341.29
ELEVATION:	3417.43'
TOTAL DEPTH:	32.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-5	Silty Sand	0-8.2
	Caliche	8.2-17
	Gatuna	17-22.4
	Sandsone	22.4-26.9
	Intercalated Siltstone	26.9-32.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-4A
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499837.97, E667829.91

ELEVATION: 3417.08'
TOTAL DEPTH: 13.6'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/19/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/19/78 **Date Completed:** 12/19/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds of downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-4A	Silty Sand	0-11.5
	Caliche	11.5-13.6

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-4
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499838.91, E667841.39

ELEVATION: 3417.08'
TOTAL DEPTH: 38.8'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/18/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/17/78 **Date Completed:** 12/18/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and wither air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-4	Silty Sand	0-8.5
	Caliche	8.5-19
	Gatuna	19-37
	Claystone	37-38.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-3
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499837.13, E667341.49

ELEVATION: 3415.33'
TOTAL DEPTH: 29'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/18/78 **Date Completed:** 12/18/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed wtih 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-3	Sand	0-7.8
	Caliche	7.8-14
	Gatuna	14-24.2
	Siltstone	24.2-25
	Sandstone	25-28
	Siltstone	28-29

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-2**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499835.35, E666841.60
ELEVATION:	3411.62'
TOTAL DEPTH:	33.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/22/78 **Date Completed:** 11/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D, 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-2	Sand	0-6.5
	Caliche	6.5-15.5
	Gatuna	15.5-23
	Siltstone	23-30.6
	Intercalated Sandstone and Soil	30.6-33.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-1A
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499833.20, E666356.32

ELEVATION: 3412.48'
TOTAL DEPTH: 12.9'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/29/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/29/78 **Date Completed:** 12/29/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D, 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-1A	Sand	0-11.2
	Caliche	11.2-12.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-1**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499833.57, E666341.70
ELEVATION:	3412.48'
TOTAL DEPTH:	58.2'
TYPE OF WELL:	Shallow Exploratory Drilling Converted to Observation Well 12/29/78
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/27/78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	
STRATIGRAPHIC SUMMARY:	Attached

W

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-1	Silty Sand, Sand	0-9.5
	Caliche	9.5-14.5
	Gatuna	14.5-38
	(Santa Rosa) Sandstone	38-58.2

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-207
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit NM-08285

LOCATION: 1480' North and 1330' East of Southwest Corner of Section 19, SW1/4 Section 19 Township 22 South, Range 31 East. NMPM

ELEVATION: 3406'
TOTAL DEPTH: 1613'
TYPE OF WELL: Potash Core Test
DRILLER: Joy Drilling Company

DRILLING RECORD: **Date Started:** 06/16/58 **Date Completed:** 07/03/58
Rotary Drill
6-1/4" Rockbit: 0-811'
3-13/16" Corebit: 811-1613'

CASING RECORD: 4" Casing: 811'
Recovered: 811'

PLUGGING SCHEDULE: All casing was pulled and the following cement plugs were run:
1) 66 sacks of cement mixed with 3% CaCl^2 and brine at bottom of hole.
2) 25 sacks of cement mixed with fresh water bottomed at 560'.

The remainder of the hole was filled with cuttings and soil, a four-foot marker post set, and the location left in good order.

STRATIGRAPHIC SUMMARY: Rustler Formation: 330'
Top of Salt: 811'
Top of USGS 124 Bed: 1519'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-235
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit LC-062188

LOCATION: 2878' from South Line and 789' from West Line of Section 25, NW1/4 Section 25, Township 22 South, Range 30 East. NMPM

ELEVATION: 3336'
TOTAL DEPTH: 1506'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/11/77 **Date Completed:** 11/03/77
Rotary Drill
6-1/4" Rockbit: 0-689'
3-7/8" Corebit: 689-1506'
Encountering an air blow at 860'

CASING RECORD: 4" Casing: 689'
Recovered: 400'

PLUGGING SCHEDULE: 400' of 4" casing was pulled. Pennsylvania Drilling Company then cemented the hole with 110 sacks of neat cement making a continuous plug from T.D. to surface. A four-foot marker post was then set and drill location was left in good order.

STRATIGRAPHIC SUMMARY: Rustler Formation: Unknown
Top of Salt: 670'
Top of USGS 124 Bed: 1390'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-123
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit LC-066112

LOCATION: 2614' North and 277' West of Southeast Corner of Section 34, NE1/4 Section 34, Township 22 South, Range 31 East. NMPM

ELEVATION: 3432'
TOTAL DEPTH: 1880'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 07/19/53 **Date Completed:** 08/07/53
Rotary Drill
6-1/4" Rockbit: 0-934'
Corebit: 934-1880'

CASING RECORD: 4" Casing: 934'
Recovered: 692'

PLUGGING SCHEDULE: Shot casing at 910' and 850'. Pulled 692' leaving 242' in hole. The following cement plugs were run:
1) 73 sacks of cement mixed with 3% CaCl^2 and brine at bottom of hole.
2) 45 sacks of cement mixed with fresh water bottomed at 880'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 670'
Top of Salt: 988'
Top of USGS 124 Bed: 1779'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: **D-160**
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit M-2618

LOCATION: 2464' from South Line and 1117' from West Line of Section 36, SW1/4 Section 36, Township 22 South, Range 30 East. NMPM

ELEVATION: 3305'
TOTAL DEPTH: 1354'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 07/21/54 **Date Completed:** 07/31/54
Rotary Drill
6-1/4" Rockbit: 0-596'
Corebit: 596-1354'
Encountering an air blow at 860' causing seat to leak.

CASING RECORD: 4" Casing: 596'
Recovered: 596'

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 58 sacks of cement mixed with brine and 3% CaCl^2 and brine at bottom of hole.
2) 37 sacks of cement mixed with fresh water bottomed at 445'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 240'
Top of Salt: 543'
Top of USGS 124 Bed: 1301'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-104
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit PPP-058761

LOCATION: 2585' from North Line and 1394' from East Line of Section 24, NE1/4 Section 24, Township 22 South, Range 30 East. NMPM

ELEVATION: 3388'
TOTAL DEPTH: 1597'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 09/25/52 **Date Completed:** 10/07/52
Rotary Drill
6-1/4" Rockbit: 0-759'
Corebit: 759-1597'
Lost Circulation: 730-747'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 62 sacks mixed with brine and 3% CaCl^2 at bottom of hole.
2) 30 sacks mixed with fresh water bottomed at 660'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 520'
Top of Salt: 759'
Top of USGS 124 Bed: 1504'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-120
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit PPP-058761

LOCATION: 1562' South and 1565' East of NW Corner Section 13, NW1/4 Section 13, Township 22 South, Range 30 East. NMPM

ELEVATION: 3338'
TOTAL DEPTH: 1500'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 02/14/53 **Date Completed:** 02/27/53
Rotary Drill
6-1/4" Rockbit: 0-704'
3-13/16" Corebit: 704-1500'

CASING RECORD: 4" Casing: 704'
Recovered: 704'

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 62 sacks of cement mixed with brine and 3% CaCl^2 and brine at bottom of hole.
2) 30 sacks of cement mixed with fresh water bottomed at 590'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 330'
Top of Salt: 684'
Top of USGS 124 Bed: 1407'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-91
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-075014

LOCATION: 200' from South Line and 200' from West Line of Section 10, SW1/4, Township 22 South, Range 31 East. NMPM

ELEVATION: 3460'
TOTAL DEPTH: 1788'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/07/62 **Date Completed:** 04/17/62
Rotary Drill
Rockbit: 0-1070'
Corebit: 1070-1788'

CASING RECORD: 4-1/4" Casing: 1070'
Recovered: 1070'

PLUGGING SCHEDULE:

From: 1788'
To: 1060'
Int: 728'
Material: Cement

From: 1060'
To: 840'
Int: 220'
Material: Cuttings & Brine

From: 840'
To: 800'
Int: 40'
Material: Cement

From: 800'
To: 10'
Int: 790'
Material: Cuttings & Brine

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 630'
Top of Salt: 1070'
Base of USGS 124 Bed: Unknown

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-92
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-094314

LOCATION: 200' from South Line and 200' from East Line of Section 8, SE1/4, Township 22 South, Range 31 East. NMPM

ELEVATION: 3420'
TOTAL DEPTH: 1818'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/21/62 **Date Completed:** 05/03/62
Rockbit: 0-1058'
Corebit: 1058-1818'

CASING RECORD: 4-1/2" Casing: 1058'
Recovered: 1058'

PLUGGING SCHEDULE:
From: 1818'
To: 945'
Int: 873'
Material: Cement

From: 945'
To: 850'
Int: 95'
Material: Cuttings & Brine

From: 850'
To: 810'
Int: 40'
Material: Cement

From: 810'
To: 10'
Int: 800'
Material: Cuttings & Brine

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: Unknown
Top of Salt: 950'
Base of USGS 124 Bed: Unknown

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-70
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit LC-065506

LOCATION: 177' from South Line and 177' from West
Line of Section 7, NE1/4 Section 7,
Township 22 South, Range 31 East. NMPM

ELEVATION: 3388'
TOTAL DEPTH: 1603'
TYPE OF WELL: Potash Core Test
DRILLER: Joy Mfg. Company, Drilling Division

DRILLING RECORD: **Date Started:** 09/26/56 **Date Completed:** 10/09/56
Rotary Drill
6-1/4" Rockbit: 0-902'
Corebit: 902-1603'

CASING RECORD: 4-1/2" Casing: 902'
Recovered: 902'

PLUGGING SCHEDULE: From: 1603'
To: 1370'
Int: 233'
Material: Brine & Salt

From: 1370'
To: 902'
Int: 468'
Material: Cement

From: 902'
To: 10'
Int: 892'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 541'
Top of Salt: 898'
USGS 124 Bed: 1515'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-82
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-057290

LOCATION: 154' from South Line and 37' from West Line of Section 8, Township 22 South, Range 31 East. NMPM

ELEVATION: 3382'
TOTAL DEPTH: 1684'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/21/61 **Date Completed:** 10/03/61
6-1/4" Rockbit: 0-922'
Corebit: 922-1684'

CASING RECORD: 5-1/2" Casing: 922'
Recovered: 922'

PLUGGING SCHEDULE:

From: 1684'
To: 922'
Int: 762'
Material: Cement

From: 922'
To: 710'
Int: 212'
Material: Brine & Salt

From: 710'
To: 510'
Int: 200'
Material: Cement

From: 510'
To: 10'
Int: 500'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 538'
Top of Salt: 910'
USGS 124 Bed: 1593'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-459
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 2500' from North Line and 2000' from East Line of Section 3, NE1/4 Section 3, Township 23 South, Range 31 East. NMPM

ELEVATION: 3385'
TOTAL DEPTH: 1855'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 08/11/76 **Date Completed:** 08/24/76
Rotary Drill
6-1/4" Rockbit: 0-900'
3-7/8" Rockbit: 900-1330'
3-7/8" Corebit: 1330-1855'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: From: 1855'
To: 0'
Int: 1885'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 580'
Top of Salt: 940'
Top of USGS 124 Bed: 1739'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: NFU-1
OPERATOR: Farmers Educational and Cooperative Union of America
PERMIT NO.: Potassium Prospecting Permit NM-065503

LOCATION: 100' from North Line and 100' from West Line of Section 9, NW1/4 Section 9, Township 22 South, Range 31 East. NMPM

ELEVATION: 3422'
TOTAL DEPTH: 1747'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 12/19/50 **Date Completed:** 01/21/51
Rotary Drill
6-1/4" Rockbit: 0-944'

CASING RECORD: 4" Casing: 940'
Recovered: 675'

PLUGGING SCHEDULE: 4 sacks cement at 1640'
7 sacks cement at 955'
7 sacks cement at 840'
8 sacks cement at 740'

Could not pull 4" casing, but broke circulation around it before pumping in 7 sacks at 955'. Shot casing at 900', 700', and 675'. Recovered 675' of 940'. Filled hole with mud and placed 4" pipe marker.

STRATIGRAPHIC SUMMARY: Rustler Formation: 635'
Top of Salt: 935'
Base of USGS 124 Bed: 1641'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-457
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 200' from South Line and 1200' from West Line of Section 27, SW1/4 Section 27 Township 22 South, Range 31 East. NMPM

ELEVATION: 3460'
TOTAL DEPTH: 1885'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 07/08/76 **Date Completed:** 07/22/76
Rotary Drill
6-1/4" Rockbit: 0-940'
3-7/8" Rockbit: 940-1480'
3-7/8" Corebit: 1480-1885'

CASING RECORD: 4" Casing: 0-980'
Recovered: 0-980'

PLUGGING SCHEDULE: From: 1885'
To: 0'
Int: 1885'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 660'
Top of Salt: 980'
Top of USGS 124 Bed: 1777'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-458
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 2500' from North Line and 400' from East Line of Section 4, NE1/4 Section 4, Township 23 South, Range 31 East. NMPM

ELEVATION: 3410'
TOTAL DEPTH: 1750'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 07/23/76 **Date Completed:** 08/09/76
Rotary Drill
6-1/4" Rockbit: 0-960'
3-7/8" Rockbit: 960-1385'
3-7/8" Corebit: 1385-1750'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: From: 1750'
To: 0'
Int: 1750'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 580'
Top of Salt: 970'
Top of USGS 124 Bed: 1623'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-383
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359160

LOCATION: 287' South 52 degrees East from W1/4 Corner of Section 1, SW1/4 Section 1, Township 23 South, Range 30 East. NMPM

ELEVATION: 3272'
TOTAL DEPTH: 1307'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 07/19/65 **Date Completed:** 08/26/65
Rotary Drill
6-1/4" Rockbit: 0-481'
3-7/8" Rockbit: 481-1000'
3-7/8" Corebit: 1000-1307'

CASING RECORD: 4" Casing: 0-481'
Recovered: 0-105'

PLUGGING SCHEDULE:
From: 1307'
To: 481'
Int: 826'
Material: Cement

From: 481'
To: 320'
Int: 161'
Material: Cement

From: 320'
To: 210'
Int: 110'
Material: Mud

From: 210'
To: 150'
Int: 60'
Material: Cement

From: 150'
To: 15'
Int: 135'
Material: Mud

From: 15'
To: 0'
Int: 15'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 160'
Top of Salt: 475'
Top of USGS 124 Bed: 1211'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-456
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 300' from South Line and 2650' from East Line of Section 22, SW1/4 Section 22, Township 22 South, Range 31 East. NMPM

ELEVATION: 3520'
TOTAL DEPTH: 1975'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 06/22/76 **Date Completed:** 07/07/76
Rotary Drill
6-1/4" Rockbit: 0-940'
3-7/8" Rockbit: 940-1580'
3-7/8" Corebit: 1580-1975'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: From: 1975'
To: 0'
Int: 1975'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 790'
Top of Salt: 1080'
Top of USGS 124 Bed: 1853'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

Top of Salt: 840'
Top of USGS 124 Bed: 1581'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-377
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 105' South 48 degrees East from Northwest Corner of Section 22, NW1/4 Section 22, Township 22 South, Range 31 East. NMPM

ELEVATION: 3490'
TOTAL DEPTH: 1876'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Co.

DRILLING RECORD: **Date Started:** 06/26/65 **Date Completed:** 07/16/65
Rotary Drill
6-1/4" Rockbit: 0-996'
3-7/8" Rockbit: 996-1530'

CASING RECORD: 4" Casing: 0-996'
Recovered: 0-996'

PLUGGING SCHEDULE:

From: 1876'
To: 996'
Int: 880'
Material: Cement

From: 996'
To: 925'
Int: 71'
Material: Mud

From: 925'
To: 885'
Int: 40'
Material: Cement

From: 885'
To: 730'
Int: 155'
Material: Mud

From: 730'
To: 700'
Int: 30'
Material: Cement

From: 700'
To: 10'
Int: 690'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 700'
Top of Salt: 1014'
Top of USGS 124 Bed: 1770'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-375
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359161

LOCATION: 144' South 24 degrees East from Northwest Corner of Section 33, NW1/4 Section 33, Township 22 South, Range 31 East. NMPM

ELEVATION: 3390'
TOTAL DEPTH: 1746'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 04/28/65 **Date Completed:** 05/13/65
Rotary Drill
6-1/4" Rockbit: 0-520'
3-7/8" Rockbit: 520-1300'
3-7/8" Corebit: 1300-1746'

CASING RECORD: 4" Casing: 0-817'
Recovered: 0-129'

PLUGGING SCHEDULE:
From: 1746'
To: 817'
Int: 929'
Material: Cement

From: 817'
To: 510'
Int: 307'
Material: Cement

From: 510'
To: 20'
Int: 490'
Material: Mud

From: 20'
To: 0'
Int: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 470'
Top of Salt: 790'
Top of USGS 124 Bed: 1602'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-376
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384583

LOCATION: 400' South 75 degrees East from Northwest Corner of Section 20, NW1/4 Section 20, Township 22 South, Range 31 East. NMPM

ELEVATION: 3410'
TOTAL DEPTH: 1702'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 06/15/65 **Date Completed:** 06/23/65
Rotary Drill
6-1/4" Rockbit: 0-840'
3-7/8" Rockbit: 840-1328'
3-7/8" Corebit: 1328-1702'

CASING RECORD: 4" Casing: 0-840'
Recovered: 0-840'

PLUGGING SCHEDULE:
From: 1702'
To: 800'
Int: 902'
Material: Cement

From: 800'
To: 720'
Int: 80'
Material: Mud

From: 720'
To: 660'
Int: 60'
Material: Cement

From: 660'
To: 540'
Int: 120'
Material: Mud

From: 540'
To: 480'
Int: 60'
Material: Cement

From: 480'
To: 30'
Int: 450'
Material: Mud

From: 30'
To: 0'
Int: 30'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 500'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-374
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359163

LOCATION: 424' North 45 degrees West from S1/4
Corner of Section 30, SW1//4 Section 30,
Township 22 South, Range 31 East. NMPM

ELEVATION: 3340'
TOTAL DEPTH: 1538'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 04/15/65 **Date Completed:** 04/27/65
Rotary Drill
6-1/4" Rockbit: 0-714'
3-7/8" Rockbit: 714-1149'
3-7/8" Corebit: 1149-1538'

CASING RECORD: 4" Casing: 0-714'
Recovered: 0-437'

PLUGGING SCHEDULE: From: 1538'
To: 714'
Int: 824'
Material: Cement

From: 714'
To: 470'
Int: 244'
Material: Cement

From: 470'
To: 20'
Int: 450'
Material: Mud

From: 20'
To: 0'
Int: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 360'
Top of Salt: 690'
Top of USGS 124 Bed: 1399'

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POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-21**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	852' FNL, 150' FEL of Sec. 15, NE1/4 Sec. 15, T 22 S, R 31 E
ELEVATION:	3510'
TOTAL DEPTH:	1915'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 10/15/76 **Date Completed:** 10/26/76
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water between 525-595'.
RUSTLER FORMATION:	734-1043'
TOP OF SALADO:	1043'
MARKER BED 124:	1796-1805'
PLUGGING SCHEDULE:	From: 1915' To: 0' Int: 1915' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-21	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-225
	Permian Rocks	
	Dewey Lake Red Beds	225-734
	Rustler Formation	734-1043
	Magenta Dolomite Member	788-812
	Culebra Dolomite Member	899-924
	Salado Formation	1043-1918
	Upper Member	1043-1526
	McNutt Potash Zone	1526-1887
	Vaca Triste Sandstone Member	1526-1533
	11th Ore Zone	1579-1583
	MB 117	1591-1593
	MB 118	1615-1616
	MB 119	1637-1638
	10th Ore Zone	1647-1653
	MB 120	1659-1660
	9th Ore Zone	1665-1669
	MB 121	1676-1678
	MB 122	1685-1686
	8th Ore Zone	1690-1699
	Union Anhydrite	1707-1714
	7th Ore Zone	1727-1732
	6th Ore Zone	1740-1744
	5th Ore Zone	1748-1757
	MB 123	1781-1789
	MB 124	1796-1805
	4th Ore Zone	1811-1817
	3d Ore Zone	1824-1837
	2d Ore Zone	1841-1845
	1st Ore Zone	1859-1873
	MB 126	1886-1887
	Lower Member	1887-1918
	MB 127	1912-1913

POTASH BOREHOLE DATA BASE

BOREHOLE: P-20
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 794' FSL, 103' FEL of Sec. 14, SE1/4
Sec. 14, T 22 S, R 31 E

ELEVATION: 3552.9'
TOTAL DEPTH: 1995'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/06/76 **Date Completed:** 10/14/76

Remarks: Very weak air flow noted during logging operation on October 14, 1976. Air pocket escaped detection throughout coring operation.

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS:
RUSTLER FORMATION:
TOP OF SALADO:
MARKER BED 124:

PLUGGING SCHEDULE: From: 1995'
To: 0'
Int: 1995'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-20	Holocene Deposits	0-6
	Triassic Rocks	
	Santa Rosa Sandstone	6-261
	Permian Rocks	
	Dewey Lake Red Beds	261-780
	Rustler Formation	780-1103
	Magenta Dolomite Member	839-866
	Culebra Dolomite Member	953-979
	Salado Formation	1103-1996
	Upper Member	1103-1604
	McNutt Potash Zone	1604-1977
	Vaca Triste Sandstone Member	1604-1612
	11th Ore Zone	1658-1662
	MB 117	1671-1673
	MB 118	1696-1697
	MB 119	1720-1721
	10th Ore Zone	1728-1735
	MB 120	1742-1743
	9th Ore Zone	1747-1750
	MB 121	1756-1758
	MB 122	1764-1765
	8th Ore Zone	1771-1779
	Union Anhydrite	1789-1795
	7th Ore Zone	1807-1811
	6th Ore Zone	1821-1823
	5th Ore Zone	1828-1839
	MB 123	1866-1873
	MB 124	1880-1891
	4th Ore Zone	1893-1904
	3d Ore Zone	1911-1924
	2d Ore Zone	1928-1932
	1st Ore Zone	1947-1961
	MB 126	1975-1977
	Lower Member	1977-1996

POTASH BOREHOLE DATA BASE

BOREHOLE: P-19
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 1652' FSL, 2330' FWL of Sec. 23, SW1/4
Sec. 23, T 22 S, R 31 E

ELEVATION: 3546.3'
TOTAL DEPTH: 2000'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/19/76 **Date Completed:** 11/04/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS:
RUSTLER FORMATION:
TOP OF SALADO:
MARKER BED 124:

PLUGGING SCHEDULE: From: 2000'
To: 0'
Int: 2000'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-19	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-232
	Permian Rocks	
	Dewey Lake Red Beds	232-758
	Rustler Formation	758-1117
	Magenta Dolomite Member	814-839
	Culebra Dolomite Member	967-997
	Salado Formation	1117-2002
	Upper Member	1117-1621
	McNutt Potash Zone	1621-2011
	Vaca Triste Sandstone Member	1621-1628
	11th Ore Zone	1677-1681
	MB 117	1688-1690
	MB 118	1711-1713
	MB 119	1735-1737
	10th Ore Zone	1745-1753
	MB 120	1760-1761
	9th Ore Zone	1767-1771
	MB 121	1776-1778
	MB 122	1785-1786
	8th Ore Zone	1792-1801
	Union Anhydrite	1812-1822
	7th Ore Zone	1835-1840
	6th Ore Zone	1850-1854
	5th Ore Zone	1858-1872
	MB 123	1892-1901
	MB 124	1909-1917
	4th Ore Zone	1923-1933
	3d Ore Zone	1944-1955
	2d Ore Zone	1962-1967
	1st Ore Zone	1983-1994

POTASH BOREHOLE DATA BASE

BOREHOLE: P-18
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 138.5' FSL, 732.7' FEL of Sec. 26, SE1/4
Sec. 26, T 22 S, R 31 E

ELEVATION: 3479'
TOTAL DEPTH: 1998'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/19/76 **Date Completed:** 11/05/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: Unknown

WATER HORIZONS: Unknown
RUSTLER FORMATION: 626-1088'
TOP OF SALADO: 1088'
MARKER BED 124: 1880-1889'

PLUGGING SCHEDULE: From: 1998'
To: 1125'
Int: 873'
Material: Cement

From: 1125'
To: 0'
Int: 1125'
Material: Well

Note: Hole plugged from 1998-1125' with cement, and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-18	Holocene Deposits	0-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-87
	Permian Rocks	
	Dewey Lake Red Beds	87-626
	Rustler Formation	626-1088
	Magenta Dolomite Member	704-730
	Culebra Dolomite Member	909-938
	Salado Formation	1088-2000
	Upper Member	1088-1604
	McNutt Potash Zone	1604-1987
	Vaca Triste Sandstone Member	1604-1614
	11th Ore Zone	1658-1662
	MB 117	1670-1672
	MB 118	1692-1694
	MB 119	1716-1718
	10th Ore Zone	1726-1734
	MB 120	1741-1742
	9th Ore Zone	1749-1752
	MB 121	1756-1758
	MB 122	1765-1766
	8th Ore Zone	1772-1783
	Union Anhydrite	1793-1808
	7th Ore Zone	1812-1817
	6th Ore Zone	1828-1830
	5th Ore Zone	1835-1844
	MB 123	1868-1875
	MB 124	1880-1889
	4th Ore Zone	1897-1910
	3d Ore Zone	1919-1933
	2d Ore Zone	1938-1942
	1st Ore Zone	1961-1972
	MB 126	1986-1987

POTASH BOREHOLE DATA BASE

BOREHOLE: P-17
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 1372.2' FSL, 401.9' FWL of Sec. 4, SW1/4
Sec. 4, T 23 S, R 31 E

ELEVATION: 3340'
TOTAL DEPTH: 1660'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/18/76 **Date Completed:** 10/26/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: Unknown

WATER HORIZONS: Hit water at 265' and at 600'.
RUSTLER FORMATION: 382-715'
TOP OF SALADO: 715'
MARKER BED 124: 1527-1535'

PLUGGING SCHEDULE: From: 1660'
To: 731'
Int: 929'
Material: Cement

From: 731'
To: 0'
Int: 731'
Material: Well

Note: Hole plugged from 1660'-731 with cement and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-17	Holocene Deposits	0-14
	Pleistocene Rocks	
	Gatuna Formation	14-46
	Permian Rocks	
	Dewey Lake Red Beds	46-382
	Rustler Formation	382-715
	Magenta Dolomite Member	438-463
	Culebra Dolomite Member	558-583
	Salado Formation	715-1662
	Upper Member	715-1234
	McNutt Potash Zone	1234-1648
	Vaca Triste Sandstone Member	1234-1242
	11th Ore Zone	1294-1299
	MB 117	1306-1308
	MB 118	1330-1334
	MB 119	1358-1359
	10th Ore Zone	1368-1376
	MB 120	1387-1388
	9th Ore Zone	1391-1396
	MB 121	1402-1404
	MB 122	1410-1411
	8th Ore Zone	1418-1428
	Union Anhydrite	1438-1453
	7th Ore Zone	1456-1461
	6th Ore Zone	1471-1474
	5th Ore Zone	1478-1487
	MB 123	1513-1521
	MB 124	1527-1535
	4th Ore Zone	1544-1563
	3d Ore Zone	1573-1587
	2d Ore Zone	1594-1599
	1st Ore Zone	1619-1630
	MB 126	1647-1648

POTASH BOREHOLE DATA BASE

BOREHOLE: P-16
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 951' FSL, 1629' FEL of Sec. 5, SW1/4
Sec. 5, T 23S, R 31E

ELEVATION: 3323'
TOTAL DEPTH: 1585'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/27/76 **Date Completed:** 10/05/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Unknown
RUSTLER FORMATION: 316-646'
TOP OF SALADO: 646'
MARKER BED 124: 1460-1470"

PLUGGING SCHEDULE: From: 1585'
To: 0'
Int: 1585'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-16	Holocene Deposits	0-14
	Pleistocene Rocks	
	Gatuna Formation	14-32
	Permian Rocks	
	Dewey Lake Red Beds	32-316
	Rustler Formation	316-646
	Magenta Dolomite Member	376-401
	Culebra Dolomite Member	500-523
	Salado Formation	646-1587
	Upper Member	646-1174
	McNutt Potash Zone	1174-1585
	Vaca Triste Sandstone Member	1174-1182
	11th Ore Zone	1235-1237
	MB 117	1245-1247
	MB 118	1269-1273
	MB 119	1293-1295
	10th Ore Zone	1307-1313
	MB 120	1323-1324
	9th Ore Zone	1328-1331
	MB 121	1336-1338
	MB 122	1345-1346
	8th Ore Zone	1352-1365
	Union Anhydrite	1373-1390
	7th Ore Zone	1396-1400
	6th Ore Zone	1411-1412
	5th Ore Zone	1417-1425
	MB 123	1450-1456
	MB 124	1460-1470
	4th Ore Zone	1480-1501
	3d Ore Zone	1510-1526
	2d Ore Zone	1533-1536
	1st Ore Zone	1556-1568
	MB 126	1583-1585

POTASH BOREHOLE DATA BASE

BOREHOLE: P-15
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 410.8' FSL, 192.32' FWL of Sec. 21, SW1/4
Sec. 31, T 22 S, R 31 E

ELEVATION: 3309.7'
TOTAL DEPTH: 1465'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/04/76 **Date Completed:** 10/14/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2": Casing Unknown
Recovered: 210' of casing left in hole between 530-740' below land surface.

WATER HORIZONS:
RUSTLER FORMATION:
TOP OF SALADO:
MARKER BED 124:

PLUGGING SCHEDULE:

From: 1465'
To: 620'
Int: 845'
Material: Cement

From: 620'
To: 0'
Int: 620'
Material: Well

Note: Hole plugged from 1465'-620' with cement, and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-15	Holocene Deposits	0-11
	Pleistocene Rocks	
	Gatuna Formation	11-32
	Permian Rocks	
	Dewey Lake Red Beds	32-231
	Rustler Formation	231-542
	Magenta Dolomite Member	294-321
	Culebra Dolomite Member	413-435
	Salado Formation	542-1465
	Upper Member	542-1057
	McNutt Potash Zone	1057-1453
	Vaca Triste Sandstone Member	1057-1065
	11th Ore Zone	1116-1119
	MB 117	1128-1130
	MB 118	1149-1152
	MB 119	1176-1178
	10th Ore Zone	1187-1195
	MB 120	1203-1204
	9th Ore Zone	1208-1212
	MB 121	1216-1218
	MB 122	1225-1226
	8th Ore Zone	1234-1244
	Union Anhydrite	1251-1263
	7th Ore Zone	1271-1275
	6th Ore Zone	1284-1288
	5th Ore Zone	1292-1301
	MB 123	1326-1333
	MB 124	1343-1353
	4th Ore Zone	1361-1376
	3d Ore Zone	1384-1397
	2d Ore Zone	1404-1408
	1st Ore Zone	1426-1436
	MB 126	1452-1453

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-13**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	125' FNL, 116' FWL of Sec. 18, NW1/4 Sec. 18, T 22 S, R 31 E
ELEVATION:	3345'
TOTAL DEPTH:	1576'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/17/76 **Date Completed:** 09/23/76
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Hit water at 630'.
RUSTLER FORMATION:	427-721'
TOP OF SALADO:	721'
MARKER BED 124:	1462-1471'
PLUGGING SCHEDULE:	From: 1576' To: 0' Int: 1576' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-13	Holocene Deposits	0-12
	Pleistocene Rocks	
	Gatuna Formation	12-38
	Permian Rocks	
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-721
	Magenta Dolomite Member	490-514
	Culebra Dolomite Member	604-627
	Salado Formation	721-1573
	Upper Member	721-1201
	McNutt Potash Zone	1201-1547
	Vaca Triste Sandstone Member	1201-1208
	11th Ore Zone	1252-1255
	MB 117	1264-1265
	MB 118	1287-1289
	MB 119	1309-1311
	10th Ore Zone	1317-1323
	MB 120	1330-1331
	9th Ore Zone	1336-1340
	MB 121	1344-1346
	MB 122	1355-1356
	8th Ore Zone	1359-1368
	Union Anhydrite	1377-1382
	7th Ore Zone	1395-1400
	6th Ore Zone	1407-1410
	5th Ore Zone	1413-1423
	MB 123	1447-1453
	MB 124	1462-1471
	4th Ore Zone	1474-1483
	3d Ore Zone	1491-1501
	2d Ore Zone	1506-1510
	1st Ore Zone	1525-1533
	MB 126	1547-1548
	Lower Member	1548-1573
	MB 127	1572-1573

POTASH BOREHOLE DATA BASE

BOREHOLE: P-14
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 307' FSL, 615.8' FWL of Sec. 24, SW1/4
Sec. 24, T 22 S, R 30 E

ELEVATION: 3358'
TOTAL DEPTH: 1545'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/24/76 **Date Completed:** 10/03/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Hit water at 589'.
RUSTLER FORMATION: 387-687'
TOP OF SALADO: 687'
MARKER BED 124: 1410-1419'

PLUGGING SCHEDULE:

From: 1545'
To: 775'
Int: 770'
Material: Cement

From: 775'
To: 0'
Int: 775'
Material: Well

Note: Hole plugged from 1545'-775' with cement and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-14	Holocene Deposits	0-10
	Pleistocene Rocks	
	Gatuna Formation	10-42
	Permian Rocks	
	Dewey Lake Red Beds	42-387
	Rustler Formation	387-687
	Magenta Dolomite Member	453-475
	Culebra Dolomite Member	573-595
	Salado Formation	687-1540
	Upper Member	687-1133
	McNutt Potash Zone	1133-1510
	Vaca Triste Sandstone Member	1133-1141
	11th Ore Zone	1186-1190
	MB 117	1199-1200
	MB 118	1225-1228
	MB 119	1251-1253
	10th Ore Zone	1257-1263
	MB 120	1273-1274
	9th Ore Zone	1277-1282
	MB 121	1287-1289
	MB 122	1297-1298
	8th Ore Zone	1302-1310
	Union Anhydrite	1319-1328
	7th Ore Zone	1342-1345
	6th Ore Zone	1352-1355
	5th Ore Zone	1361-1370
	MB 123	1394-1400
	MB 124	1410-1419
	4th Ore Zone	1423-1435
	3d Ore Zone	1443-1455
	2d Ore Zone	1461-1465
	1st Ore Zone	1482-1492
	MB 126	1509-1510
	Lower Member	1510-1540
	MB 127	1534-1536

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-12	Holocene Deposits	0-8
	Permian Rocks	
	Dewey Lake Red Beds	8-461
	Rustler Formation	461-749
	Magenta Dolomite Member	519-543
	Culebra Dolomite Member	633-656
	Salado Formation	749-1598
	Upper Member	749-1226
	McNutt Potash Zone	1226-1597
	Vaca Triste Sandstone Member	1226-1233
	11th Ore Zone	1280-1284
	MB 117	1290-1292
	MB 118	1314-1317
	MB 119	1338-1340
	10th Ore Zone	1346-1353
	MB 120	1361-1362
	9th Ore Zone	1367-1370
	MB 121	1376-1378
	MB 122	1384-1385
	8th Ore Zone	1390-1398
	Union Anhydrite	1407-1417
	7th Ore Zone	1432-1436
	6th Ore Zone	1442-1445
	5th Ore Zone	1450-1459
	MB 123	1486-1492
	MB 124	1494-1509
	4th Ore Zone	1514-1523
	3d Ore Zone	1533-1546
	2d Ore Zone	1550-1555
	1st Ore Zone	1572-1582
	MB 126	1596-1597

POTASH BOREHOLE DATA BASE

BOREHOLE: P-12
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 167' FNL, 195' FEL of Sec. 24, NE1/4
Sec. 24, T 22 S, R 30 E

ELEVATION: 3376'
TOTAL DEPTH: 1598'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/17/76 **Date Completed:** 10/20/76

Remarks: Lost circulation at 742' and 813' below land.

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Unknown
RUSTLER FORMATION: 461-749'
TOP OF SALADO: 749'
MARKER BED 124: 1494-1509'

PLUGGING SCHEDULE: From: 1598'
To: 0'
Int: 1598'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

POTASH BOREHOLE DATA BASE

BOREHOLE: P-11
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 175' FNL and 177' FWL of Sec. 23, NW1/4
Sec. 23, T 22 S, R 31 E

ELEVATION: 3506'
TOTAL DEPTH: 1940'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/24/76 **Date Completed:** 10/16/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Unknown
RUSTLER FORMATION: 745-1058'
TOP OF SALADO: 1058'
MARKER BED 124: 1824-1833'

PLUGGING SCHEDULE: From: 1940'
To: 0'
Int: 1940'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-11	Holocene Deposits	0-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-224
	Permian Rocks	
	Dewey Lake Red Beds	224-745
	Rustler Formation	745-1058
	Magenta Dolomite Member	798-823
	Culebra Dolomite Member	912-938
	Salado Formation	1058-1942
	Upper Member	1058-1550
	McNutt Potash Zone	1550-1917
	Vaca Triste Sandstone Member	1550-1557
	11th Ore Zone	1604-1608
	MB 117	1616-1618
	MB 118	1640-1642
	MB 119	1664-1666
	10th Ore Zone	1674-1682
	MB 120	1687-1688
	9th Ore Zone	1693-1698
	MB 121	1702-1704
	MB 122	1711-1712
	8th Ore Zone	1717-1724
	Union Anhydrite	1735-1740
	7th Ore Zone	1754-1759
	6th Ore Zone	1767-1770
	5th Ore Zone	1775-1785
	MB 123	1811-1818
	MB 124	1824-1833
	4th Ore Zone	1837-1846
	3d Ore Zone	1853-1866
	2d Ore Zone	1871-1874
	1st Ore Zone	1890-1901
	MB 126	1916-1917
	Lower Member	1917-1942
	MB 127	1940-1941

POTASH BOREHOLE DATA BASE

BOREHOLE: P-10
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 2315' FNL, 339' FWL of Sec. 26, NW1/4
Sec. 26, T 22 S, R 31 E

ELEVATION: 3508'
TOTAL DEPTH: 2009'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/24/76 **Date Completed:** 10/15/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Unknown
RUSTLER FORMATION: 686-1086'
TOP OF SALADO: 1086'
MARKER BED 124: 1880-1888'

PLUGGING SCHEDULE: From: 2009'
To: 0'
Int: 2009'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-10	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-151
	Permian Rocks	
	Dewey Lake Red Beds	151-686
	Rustler Formation	686-1086
	Magenta Dolomite Member	757-781
	Culebra Dolomite Member	931-957
	Salado Formation	1086-2009
	Upper Member	1086-1594
	McNutt Potash Zone	1594-1983
	Vaca Triste Sandstone Member	1594-1603
	11th Ore Zone	1652-1655
	MB 117	1662-1664
	MB 118	1686-1688
	MB 119	1710-1712
	10th Ore Zone	1717-1725
	MB 120	1733-1734
	9th Ore Zone	1740-1744
	MB 121	1751-1753
	MB 122	1759-1760
	8th Ore Zone	1765-1775
	Union Anhydrite	1784-1798
	7th Ore Zone	1807-1811
	6th Ore Zone	1822-1825
	5th Ore Zone	1831-1841
	MB 123	1868-1875
	MB 124	1880-1888
	4th Ore Zone	1892-1905
	3d Ore Zone	1913-1929
	2d Ore Zone	1934-1938
	1st Ore Zone	1961-1969
	MB 126	1982-1983
	Lower Member	1983-2009
	MB 127	2005-2008

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-9**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	1493' FSL, 143' FEL of Sec. 33, SE1/4 Sec. 33, T 22 S, R 31 E
ELEVATION:	3409'
TOTAL DEPTH:	1796'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/16/76 **Date Completed:** 09/25/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water at 220' below land surface, making about 25 gpm.
RUSTLER FORMATION:	562-881'
TOP OF SALADO:	881'
MARKER BED 124:	1686-1695'
PLUGGING SCHEDULE:	From: 1796' To: 0' Int: 1796' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-9	Holocene Deposit	0-11
	Triassic Rocks	
	Santa Rosa Sandstone	11-66
	Permian Rocks	
	Dewey Lake Red Beds	66-562
	Rustler Formation	562-881
	Magenta Dolomite Member	617-644
	Culebra Dolomite Member	734-757
	Salado Formation	881-1796
	Upper Member	881-1401
	McNutt Potash Zone	1401-1796
	Vaca Triste Sandstone Member	1401-1410
	11th Ore Zone	1458-1462
	MB 117	1471-1473
	MB 118	1496-1499
	MB 119	1519-1521
	10th Ore Zone	1530-1538
	MB 120	1546-1547
	9th Ore Zone	1552-1555
	MB 121	1561-1563
	MB 122	1569-1570
	8th Ore Zone	1577-1585
	Union Anhydrite	1597-1608
	7th Ore Zone	1613-1618
	6th Ore Zone	1626-1629
	5th Ore Zone	1634-1643
	MB 123	1668-1676
	MB 124	1686-1695
	4th Ore Zone	1699-1714
	3d Ore Zone	1723-1738
	2d Ore Zone	1744-1748
	1st Ore Zone	1769-1778
	MB 126	1795-1796

POTASH BOREHOLE DATA BASE

BOREHOLE: P-8
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 642' FNL, 96' FWL of Sec. 4, NW1/4
Sec. 4, T 23 S, R 31 E

ELEVATION: 3336'
TOTAL DEPTH: 1660'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/08/76 **Date Completed:** 09/15/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: No water reported by driller.
RUSTLER FORMATION: 391-715'
TOP OF SALADO: 715'
MARKER BED 124: 1537-1545'

PLUGGING SCHEDULE: From: 1660'
To: 0'
Int: 1660'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-8	Holocene Deposits	0-9
	Pleistocene Rocks	
	Gatuna Formation	9-39
	Permian Rocks	
	Dewey Lake Red Beds	39-391
	Rustler Formation	391-715
	Magenta Dolomite Member	450-474
	Culebra Dolomite Member	563-585
	Salado Formation	715-1660
	Upper Member	715-1237
	McNutt Potash Zone	1237-1652
	Vaca Triste Sandstone Member	1237-1245
	11th Ore Zone	1297-1301
	MB 117	1308-1310
	MB 118	1333-1337
	MB 119	1360-1362
	10th Ore Zone	1373-1380
	MB 120	1389-1390
	9th Ore Zone	1395-1399
	MB 121	1405-1407
	MB 122	1413-1414
	8th Ore Zone	1421-1430
	Union Anhydrite	1440-1455
	7th Ore Zone	1461-1465
	6th Ore Zone	1472-1475
	5th Ore Zone	1481-1492
	MB 123	1517-1524
	MB 124	1537-1545
	4th Ore Zone	1554-1567
	3d Ore Zone	1577-1596
	2d Ore Zone	1601-1604
	1st Ore Zone	1624-1633
	MB 126	1661-1662

POTASH BOREHOLE DATA BASE

BOREHOLE: P-7
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 513' FNL, 396' FWL of Sec. 5, NW1/4
Sec. 5, T 23 S, R 31 E

ELEVATION: 3332'
TOTAL DEPTH: 1574'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/04/76 **Date Completed:** 09/21/76

Remarks: Encountered air pocket at 980' below land surface, and lost casing seat. Encountered several air pockets between 980-1264'. Lost mud at 1234'.

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: 210' of casing left in hole between 530-740' below land surface.

WATER HORIZONS: Unknown
RUSTLER FORMATION: 312-630'
TOP OF SALADO: 630'
MARKER BED 124: 1448-1459'

PLUGGING SCHEDULE: From: 1830'
To: 0'
Int: 1830'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-7	Holocene Deposits	0-11
	Pleistocene Rocks	
	Gatuna Formation	11-45
	Permian Rocks	
	Dewey Lake Red Beds	45-312
	Rustler Formation	312-630
	Magenta Dolomite Member	373-398
	Culebra Dolomite Member	496-522
	Salado Formation	630-1574
	Upper Member	630-1155
	McNutt Potash Zone	1155-1566
	Vaca Triste Sandstone Member	1155-1162
	11th Ore Zone	1215-1220
	MB 117	1228-1230
	MB 118	1252-1256
	MB 119	1277-1279
	10th Ore Zone	1291-1296
	MB 120	1307-1308
	9th Ore Zone	1312-1316
	MB 121	1326-1328
	MB 122	1330-1331
	8th Ore Zone	1335-1346
	Union Anhydrite	1358-1372
	7th Ore Zone	1377-1382
	6th Ore Zone	1391-1393
	5th Ore Zone	1398-1407
	MB 123	1433-1441
	MB 124	1448-1459
	4th Ore Zone	1467-1484
	3d Ore Zone	1492-1507
	2d Ore Zone	1513-1518
	1st Ore Zone	1537-1547
	MB 126	1565-1566

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-6**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	2767' FSL, 199' FWL of Sec. 30, NW1/4 Sec. 30, T 22 S, R 31 E
ELEVATION:	3354'
TOTAL DEPTH:	1573'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/03/76 **Date Completed:** 09/16/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	357-659'
TOP OF SALADO:	659'
MARKER BED 124:	1453-1462'
PLUGGING SCHEDULE:	From: 1573' To: 0' Int: 1573' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-6	Holocene Deposits	0-8
	Pleistocene Rocks	
	Gatuna Formation	8-18
	Permian Rocks	
	Dewey Lake Red Beds	18-357
	Rustler Formation	357-659
	Magenta Dolomite Member	417-443
	Culebra Dolomite Member	537-560
	Salado Formation	659-1573
	Upper Member	659-1162
	McNutt Potash Zone	1162-1560
	Vaca Triste Sandstone Member	1162-1170
	11th Ore Zone	1218-1221
	MB 117	1231-1233
	MB 118	1252-1256
	MB 119	1279-1281
	10th Ore Zone	1291-1296
	MB 120	1307-1308
	9th Ore Zone	1313-1317
	MB 121	1324-1326
	MB 122	1332-1333
	8th Ore Zone	1338-1348
	Union Anhydrite	1357-1365
	7th Ore Zone	1378-1382
	6th Ore Zone	1394-1396
	5th Ore Zone	1400-1410
	MB 123	1436-1443
	MB 124	1453-1462
	4th Ore Zone	1468-1481
	3d Ore Zone	1489-1502
	2d Ore Zone	1509-1513
	1st Ore Zone	1533-1543
	MB 126	1559-1560

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-5**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	202' FSL, 165' FEL of Sec. 17, SE1/4 Sec. 17, T 22 S, R 31 E
ELEVATION:	3472'
TOTAL DEPTH:	1830'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/10/76 **Date Completed:** 09/21/76
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 568' of casing left in hole between 435-1003' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	623-947'
TOP OF SALADO:	947'
MARKER BED 124:	1695-1705'
PLUGGING SCHEDULE:	From: 1830' To: 0' Int: 1830' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-5	Holocene deposits	0-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-146
	Permian Rocks	
	Dewey Lake Red Beds	146-623
	Rustler Formation	623-947
	Magenta Dolomite Member	686-711
	Culebra Dolomite Member	804-827
	Salado Formation	947-1830
	Upper Member	947-1429
	McNutt Potash Zone	1429-1785
	Vaca Triste Sandstone Member	1429-1436
	11th Ore Zone	1482-1486
	MB 117	1492-1494
	MB 118	1514-1517
	MB 119	1541-1543
	10th Ore Zone	1550-1556
	MB 120	1560-1561
	9th Ore Zone	1567-1571
	MB 121	1573-1575
	MB 122	1580-1582
	8th Ore Zone	1589-1595
	Union Anhydrite	1604-1611
	7th Ore Zone	1623-1628
	6th Ore Zone	1635-1638
	5th Ore Zone	1643-1659
	MB 123	1680-1687
	MB 124	1695-1705
	4th Ore Zone	1709-1717
	3d Ore Zone	1725-1737
	1st Ore Zone	1742-1746
	MB 126	1784-1785
	Lower Member	1785-1830
	MB 127	1810-1811
	MB 128	1821-1822

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-4**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	146' FSL, 1487' FEL of Sec. 28, SE1/4 Sec. 28, T 22 S, R 31 E
ELEVATION:	3441'
TOTAL DEPTH:	1857'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/28/76 **Date Completed:** 09/04/76
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water at 850'.
RUSTLER FORMATION:	609-930'
TOP OF SALADO:	930'
MARKER BED 124:	1742-1752'
PLUGGING SCHEDULE:	From: 1857' To: 0' Int: 1857' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-4	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-99
	Permian Rocks	
	Dewey Lake Red Beds	99-609
	Rustler Formation	609-930
	Magenta Dolomite Member	662-686
	Culebra Dolomite Member	775-802
	Salado Formation	930-1857
	Upper Member	930-1446
	McNutt Potash Zone	1446-1853
	Vaca Triste Sandstone Member	1446-1452
	11th Ore Zone	1506-1509
	MB 117	1519-1521
	MB 118	1544-1547
	MB 119	1570-1572
	10th Ore Zone	1581-1589
	MB 120	1596-1597
	9th Ore Zone	1603-1607
	MB 121	1610-1612
	MB 122	1620-1621
	8th Ore Zone	1628-1637
	Union Anhydrite	1646-1659
	7th Ore Zone	1667-1671
	6th Ore Zone	1683-1686
	5th Ore Zone	1690-1700
	MB 123	1728-1735
	MB 124	1742-1752
	4th Ore Zone	1756-1768
	3d Ore Zone	1777-1792
	2d Ore Zone	1798-1803
	1st Ore Zone	1824-1835
	MB 126	1852-1853

POTASH BOREHOLE DATA BASE

BOREHOLE: P-3
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 103' FSL, 3122' FEL of Sec. 20, SW1/4
Sec. 20, T 22 S, R 31 E

ELEVATION: 3382'
TOTAL DEPTH: 1676'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 08/26/76 **Date Completed:** 09/07/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: 336' of casing left in hole between 490-826' below land surface.

WATER HORIZONS: Unknown
RUSTLER FORMATION: 468-786'
TOP OF SALADO: 786'
MARKER BED 124: 1571-1579'

PLUGGING SCHEDULE: From: 1676'
To: 0'
Int: 1676'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-3	Holocene Deposits	0-10
	Pleistocene rocks	
	Gatuna Formation	10-41
	Permian Rocks	
	Dewey Lake Red Beds	41-468
	Rustler Formation	468-786
	Magenta Dolomite Member	529-553
	Culebra Dolomite Member	642-665
	Salado Formation	786-1668
	Upper Member	786-1287
	McNutt Potash Zone	1287-1668
	Vaca Triste Sandstone Member	1287-1295
	11th Ore Zone	1346-1349
	MB 117	1357-1358
	MB 118	1375-1378
	MB 119	1405-1407
	10th Ore Zone	1415-1420
	MB 120	1428-1429
	9th Ore Zone	1434-1438
	MB 121	1443-1445
	MB 122	1452-1453
	8th Ore Zone	1458-1467
	Union Anhydrite	1473-1481
	7th Ore Zone	1494-1499
	6th Ore Zone	1509-1511
	5th Ore Zone	1515-1525
	MB 123	1555-1563
	MB 124	1571-1579
	4th Ore Zone	1585-1595
	3d Ore Zone	1599-1617
	2d Ore Zone	1623-1627
	1st Ore Zone	1645-1656
	MB 126	1667-1668

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-2**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	125' FNL, 172' FEL of Sec. 28, NE1/4 Sec. 28, T 22 S, R 31 E
ELEVATION:	3478'
TOTAL DEPTH:	1895'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/25/76 **Date Completed:** 09/02/76
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	690-1008'
TOP OF SALADO:	1008'
MARKER BED 124:	1787-1795'
PLUGGING SCHEDULE:	From: 1895' To: 0' Int: 1895' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-2	Holocene Deposits	0-18
	Pleistocene Rocks	
	Gatuna Formation	18-38
	Triassic Rocks	
	Santa Rosa Sandstone	38-164
	Permian Rocks	
	Dewey Lake Red Beds	164-690
	Rustler Formation	690-1008
	Magenta Dolomite Member	748-773
	Culebra Dolomite Member	857-883
	Salado Formation	1008-1895
	Upper Member	1008-1506
	McNutt Potash Zone	1506-1883
	Vaca Triste Sandstone Member	1506-1512
	11th Ore Zone	1562-1565
	MB 117	1574-1576
	MB 118	1599-1601
	MB 119	1622-1626
	10th Ore Zone	1632-1639
	MB 120	1646-1647
	9th Ore Zone	1652-1656
	MB 121	1662-1663
	MB 122	1670-1671
	8th Ore Zone	1678-1687
	Union Anhydrite	1695-1705
	7th Ore Zone	1712-1719
	6th Ore Zone	1731-1733
	5th Ore Zone	1738-1745
	MB 123	1774-1781
	MB 124	1787-1795
	4th Ore Zone	1799-1809
	3d Ore Zone	1818-1832
	2d Ore Zone	1836-1840
	1st Ore Zone	1859-1870
	MB 126	1882-1883
	Lower Member	1883-1894

POTASH BOREHOLE DATA BASE

BOREHOLE: P-1
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 327' FSL, 551' FWL of Sec. 29, SW 1/4
Sec. 29, T 22 S, R 31 E

ELEVATION: 3345'
TOTAL DEPTH: 1591'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 08/23/76 **Date Completed:** 09/02/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: 203' of casing left in hole between 591-794' below land surface.

WATER HORIZONS: Unknown
RUSTLER FORMATION: 358-677'
TOP OF SALADO: 677'
MARKER BED 124: 1477-1486'

PLUGGING SCHEDULE: From: 1591'
To: 0'
Int: 1591'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-1	Holocene Deposits	0-10
	Pleistocene Rocks	
	Gatuna Formation	10-40
	Permian Rocks	
	Dewey Lake Red Beds	40-358
	Rustler Formation	358-677
	Magenta Dolomite Member	423-448
	Culebra Dolomite Member	538-565
	Salado Formation	677-1591
	Upper Member	677-1191
	McNutt Potash Zone	1191-1583
	Vaca Triste Sandstone Member	1191-1201
	11th Ore Zone	1246-1250
	MB 117	1259-1262
	MB 118	1282-1285
	MB 119	1307-1309
	10th Ore Zone	1319-1324
	MB 120	1334-1335
	9th Ore Zone	1338-1343
	MB 121	1347-1349
	MB 122	1356-1357
	8th Ore Zone	1361-1370
	Union Anhydrite	1381-1393
	7th Ore Zone	1400-1404
	6th Ore Zone	1414-1416
	5th Ore Zone	1419-1432
	MB 123	1462-1469
	MB 124	1477-1486
	4th Ore Zone	1490-1503
	3d Ore Zone	1511-1526
	2d Ore Zone	1533-1538
	1st Ore Zone	1554-1562
	MB 126	1582-1583
	Lower Member	1583-1587

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-18
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1473 (State Engineer's Office)

LOCATION: 964.8' FNL, 445.6' FWL, Sec. 20, T 22 S, R 31 E

ELEVATION: 3414.21' (Top of Casing)
TOTAL DEPTH: 840'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/29/87 **Date Completed:** 11/16/87

CASING RECORD:

Diameter: 10 3/4
Grade: H-40
Wt/Ft: 40.5
From: 0
To: 39

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 673

Note: 6 1/8" inch open hole from 673' to the plugged back depth of 766'.

PLUGGING SCHEDULE: The borehole was plugged back with cement grout to a total depth of 766' on 11/19/87.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-18	Quaternary Deposits	
	Holocene	
	Drill Pad Material & Unconsolidated Sand	0-5
	Pleistocene	
	Mescalero Caliche	5-8
	Upper Triassic	
	Dockum Group	8-20
	Upper Permian	
	Dewey Lake Red Beds	20-506.1
	Rustler Formation	506.1-820.9
	Forty-Niner Member	506.1-571.2
	Magenta Dolomite	571.2-594.2
	Tamarisk Member	594.2-688.6
	Culebra Dolomite Member	688.6-712.8
	Unnamed Lower Member	712.8-820.9
	Salado Formation	820.9-830.5+

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-17
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1477 (State Engineer's Office)

LOCATION: 1465.5' FSL, 994.1' FWL, Sec. 3, T 23 S, R 31 E

ELEVATION: 3385.31' (Top of Casing)
TOTAL DEPTH: 880'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/21/87 **Date Completed:** 11/04/87

CASING RECORD:

Diameter: 10 3/4
Grade: H-40
Wt/Ft: 40.5
From: 0
To: 38

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 692

Note: 6 1/8" inch open hole from 693' to the plugged back depth of 773'.

PLUGGING SCHEDULE: The borehole was plugged back with cement grout to a total depth of 773' on 11/06/87.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-17	Quaternary Deposits	
	Holocene	0-15
	Pleistocene	
	Mescalero Caliche	15-21.5
	Upper Triassic	
	Dockum Group	21.5-55
	Upper Permian	
	Dewey Lake Red Beds	55-509
	Rustler Formation	509-855.7
	Forty-Niner Member	509-564
	Magenta Dolomite Member	564-590.8
	Tamarisk Member	590.8-705.8
	Culebra Dolomite Member	705.8-731.4
	Unnamed Lower Member	731.4-855.7
	Salado Formation	855.7-870.3+

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-15	Surficial Deposits	0-8
	Gatuna Formation	4-42
	Dockum Group	42-168
	Dewey Lake Red Beds	168-692
	Rustler Formation	692-T.D.
	Magenta Dolomite Member	748-773
	Culebra Dolomite Member	861-883
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	900

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-16**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1471 (State Engineer's Office)

LOCATION: 1112.6 FSL, 1241.3 FEL, Sec. 20, T 22 S, R 31 E

ELEVATION: 3406.77' (Top of Casing)
TOTAL DEPTH: 850.9'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/13/87 **Date Completed:** 08/18/87

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft: 40.5
From: 0
To: 36.5

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 469

Note: 6 1/8" inch open hole from 469' to total depth of 850.9'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-14	Surficial Deposits	0-13
	Gatuna Formation	13-40
	Dockum Group	NP
	Dewey Lake Red Beds	40-360
	Rustler Formation	360-T.D.
	Magenta Dolomite Member	424-448
	Culebra Dolomite Member	545-572
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	589

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-15**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1470 (State Engineer's Office)
LOCATION:	88.7' FNL, 174.3' FEL, Sec. 28, T 22 S, R 31 E
ELEVATION:	3481.63' (Top of Casing)
TOTAL DEPTH:	900'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 11/86 **Date Completed:** 11/86
CASING RECORD:	Diameter: 8.625 Grade: Wt/Ft: 28 From: 0 To: 39 Diameter: 5.5 Grade: Wt/Ft: 15.5 From: +1.4 To: 853
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-12	Quaternary Deposits	0-10+
	Dockum Group	10+-70
	Dewey Lake Red Beds	70-622
	Rustler Formation	622-976
	Forty-Niner Member	622-678
	Magenta Dolomite Member	678-703
	Tamarisk Member	703-823
	Culebra Dolomite Member	823-850
	Unnamed Lower Member	850-976
	Salado Formation	976-T.D.
	Unnamed Upper Member	976-T.D.
	Total Depth	1001

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-14
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1469 (State Engineer's Office)

LOCATION: 372.2' FSL, 562.4' FWL, Sec. 29, T 22 S, R 31 E

ELEVATION: 3347.11' (Top of Casing)
TOTAL DEPTH: 589'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/86 **Date Completed:** 10/86

CASING RECORD:

Diameter: 8.625
Grade:
Wt/Ft: 28
From: +1.6
To: 39
Cement:

Diameter: 5.5
Grade:
Wt/Ft: 15.5
From: 0
To: 532
Cement:

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-11b4
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1474 (State Engineer's Office)

LOCATION: 1514.7' FSL, 320.2' FEL, Sec. 33, T 22 S, R 31 E

ELEVATION: 3410.89' (Top of Casing)
TOTAL DEPTH: 765'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 02/23/88 **Date Completed:** 03/17/88

CASING RECORD:

Diameter: 8 5/8
Grade: H-40
Wt/Ft: 28
From: 0
To: 27
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 714
Cement:

Note: 4 3/4 " open hole from 715' to total depth of 765'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-12
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1463 (State Engineer's Office)

LOCATION: 23.1' FNL, 91.9' FEL,
Sec. 15, T 23 S, R 31 E

ELEVATION: 3427.19' (Top of Casing)
TOTAL DEPTH: 1001'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/03/83 **Date Completed:** 10/18/83

CASING RECORD:

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 36
From: 0
To: 37
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: +1.45
To: 820
Cement:

Note: 4 3/4 " open hole from 820' to plugged back depth of 890'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-11b3**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1462 (State Engineer's Office)

LOCATION: 1501.7' FSL, 105.2' FEL, Sec. 33, T 22 S, R 31 E

ELEVATION: 3412.42' (Top of Casing)
TOTAL DEPTH: 788.7' (Below Kelly Bushing)
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 12/01/83 **Date Completed:** 01/84

CASING RECORD:

Diameter: 9 5/8
Grade: H-30
Wt/Ft: 40
From: 0
To: 34
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 55
From: 0
To: 733
Cement:

Note: 4 3/4" open hole from 733' to the total depth of 788.7'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-11b3	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	
	Rustler Formation	
	Magenta Dolomite Member	616-644
	Culebra Dolomite Member	734-759
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	788.7

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-11b2**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1462 (State Engineer's Office)

LOCATION: 1436.3' FSL, 168.7' FEL, Sec. 33, T 22 S, R 31 E

ELEVATION: 3411.64' (Top of Casing)
TOTAL DEPTH: 776'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/83 **Date Completed:** 11/28/83

CASING RECORD:

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 40
From: 0
To: 37
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 733.39
Cement: Cemented

Note: 4 3/4" open hole from 733.39' to the total depth of 776'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-11b2	Magenta Dolomite Member	618-644
	Culebra Dolomite Member	733-757
	Total Depth	776

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-10c**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1282 (State Engineer's Office)

LOCATION: 384.5' FSL, 1981.8 FEL, Sec. 20, T 23 S, R 32 E

ELEVATION: 3687'
TOTAL DEPTH: 1550'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/11/79 **Date Completed:** 08/20/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 20
From: 0
To: 1483
Cement: 627 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-10c	Holocene	
	Unconsolidated Alluvium and Eolian Sand	0-5
	Pleistocene	
	Mescalero Caliche	5-9
	Gatuna Formation	9-90
	Triassic	
	Dockum Group	
	Chinle Formation	90-482
	Santa Rosa Sandstone	482-658
	Permian	
	Dewey Lake Red Beds	658-1204
	Rustler Formation	1204-1501
	Magenta Dolomite Member	1256-1280
	Culebra Dolomite Member	1360-1387
	Salado Formation	1501
	Top of Salt Interval	1501
	Total Depth	1538

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-10a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1280 (State Engineer's Office)

LOCATION: 433.0' FSL, 2068.9' FEL, Sec. 20, T 23 S, R 32 E

ELEVATION: 3688.67' (Top of Casing)
TOTAL DEPTH: 1318'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/21/79 **Date Completed:** 08/26/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 1243
Cement: 519 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-10b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1281 (State Engineer's Office)

LOCATION: 484.5' FSL, 1981.8' FEL, Sec. 20, T 23 S, R 32 E

ELEVATION: 3689.47' (Top of Casing)
TOTAL DEPTH: 1398'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/07/79 **Date Completed:** 10/13/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 1346
Cement: 480 Cu. Ft.

Note: Hole in standby condition for possible future tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-9b	Surficial Deposits	0-5
	Gatuna Formation	5-25
	Dockum Group	NP
	Dewey Lake Red Beds	24-455
	Rustler Formation	455-T.D.
	Magenta Dolomite Member	523-554
	Culebra Dolomite Member	647-677
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	708

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-9c**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1279 (State Engineer's Office)

LOCATION: 2479.06' FNL, 188.02' FWL,
Sec. 4, T 24 S, R 31 E

ELEVATION: 3407.30' (Top of Casing)
TOTAL DEPTH: 816'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/01/79 **Date Completed:** 09/24/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 783
Cement: 320 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-9a	Holocene	
	Surficial Deposits	0-5
	Pleistocene	
	Gatuna Formation	5-25
	Ochoan	
	Dewey Lake Red Beds	25-455
	Rustler Formation	455-T.D.
	Forty-Niner Member	455-523
	Magenta Dolomite Member	523-554
	Tamarisk Member	554-647
	Culebra Dolomite Member	647-677
	Unnamed Part	677-T.D.
	Total Depth	692

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-9b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1278 (State Engineer's Office)

LOCATION: 2391.04' FNL, 238.63' FWL,
Sec. 4, T 24 S, R 31 E

ELEVATION: 3406.86' (Top of Casing)
TOTAL DEPTH: 708'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/14/79 **Date Completed:** 08/28/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 638
Cement: 295 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-8c	Holocene	
	Unconsolidated Alluvium and Eolian Sand	0-4
	Pleistocene Rocks	
	Mescalero Caliche	4-10
	Gatuna Formation	10-153
	Permian	
	Dewey Lake Red Beds	153-399
	Rustler Formation	399-733
	Magenta Dolomite Member	466-488
	Culebra Dolomite Member	588-614
	Salado Formation	733-
	Dissolution Residue	733-774
	MB 103	774-786
	Top of Salt Interval	798
	Total Depth	808

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-9a**
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08.1277 (State Engineer's Office)

LOCATION: 2392.14' FNL, 138.92' FWL,
Sec. 4, T 24 S, R 31 E

ELEVATION: 3406.68' (Top of Casing)
TOTAL DEPTH: 692'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/09/79 **Date Completed:** 08/23/83

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 570
Cement: 266 Cu. Ft.

Diameter: 4.5" O.D.
Grade: J-55
Wt/Ft: 9.5
From: 0
To: 643
Cement:

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-8b	Surficial Deposits	0-10
	Gatuna Formation	10-153
	Dockum Group	NP
	Dewey Lake Red Beds	153-399
	Rustler Formation	399-T.D.
	Magenta Dolomite Member	466-490
	Culebra Dolomite Member	586-613
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	624

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-8c**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1276 (State Engineer's Office)

LOCATION: 2059.36' FNL, 1470.14' FEL,
Sec. 23, T 24 S, R 30 E

ELEVATION: 3432.90' (Top of Casing)
TOTAL DEPTH: 808'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/27/79 **Date Completed:** 08/06/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 108 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 20
From: 0
To: 734
Cement: 314 Cu. Ft.

Note: Hole is standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-8a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1274 (State Engineer's Office)

LOCATION: 1962.61' FNL, 1486.59' FEL,
Sec. 23, T 24 S, R 30 E

ELEVATION: 3432.99' (Top of Casing)
TOTAL DEPTH: 505'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/07/79 **Date Completed:** 09/18/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 108 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 452
Cement: 393

Note: Hole in standby condition for testing

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-8b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1275 (State Engineer's Office)

LOCATION: 1994.76' FNL, 1405.41' FEL,
Sec. 23, T 24 S, R 30 E

ELEVATION: 3433.64' (Top of Casing)
TOTAL DEPTH: 624'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/06/79 **Date Completed:** 08/12/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 108 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 20
From: 0
To: 574
Cement: 378 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-7c
OPERATOR: Sandia National Labs
PERMIT NO.:

LOCATION: 2591.93' FNL, 2467.51' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164.13 (Top of Casing)
TOTAL DEPTH: 420'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/06/79 **Date Completed:** 11/02/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 68 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 356
Cement: 706 Cu. Ft.

Note: Hole in standby condition for testing. Slotted liner installed from 347' to 420'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7c	Holocene	
	Unconsolidated Alluvium and Dune Sand	0-5
	Pleistocene	
	Gatuna Formation	5-57
	Permian	
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-283
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	237-273.5
	Salado Formation	283-420
	Dissolution Residue	283-405
	Top of Salt Interval	405
	Total Depth	420

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-7b2
OPERATOR: Sandia National Labs
PERMIT NO.: ---- (State Engineer's Office)

LOCATION: 2662.16' FNL, 2537.98' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164.40' (Top of Casing)
TOTAL DEPTH: 295'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/27/83 **Date Completed:** 09/02/83

CASING RECORD:

Diameter: 9 7/8
Grade:
Wt/Ft:
From: 0
To: 20
Cement: Casing set in cement

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 230.19
Cement: Cemented in place

PLUGGING SCHEDULE: Hole was back filled with peu gravel from 295' to 268' and left open for testing.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7b2	Surficial Deposits	
	Gatuna Formation	57
	Dockum Group	NP
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-T.D.
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	232-280
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	295

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-7b1**
OPERATOR:	Sandia National Lab
PERMIT NO.:	0.08-1272 (State Engineer's Office)
LOCATION:	2565.80' FNL, 2563.45' FWL, Sec. 14, T 23 S, R 30 E
ELEVATION:	3164.17' (Top of Casing)
TOTAL DEPTH:	286'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/13/79 **Date Completed:** 09/18/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: 54 Cu. Ft. Diameter: 7 Grade: Wt/Ft: 23 From: 0 To: 230 Cement: 270 Cu. Ft. Note: Hole in standby condition for testing.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7b1	Holocene	
	Surficial Deposits	0-5
	Pleistocene	
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-T.D.
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	237-283
	Salado Formation	
	Upper Member	
	Lower Member	
	Castile Formation	
	Total Depth	286

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-6c	Surficial Deposits	0-12
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-721
	Magenta Dolomite Member	490-514
	Culebra Dolomite Member	604-627
	Salado Formation	721-T.D.
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	741

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-7a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08-1271 (State Engineer's Office)

LOCATION: 2495.04' FNL, 2492.35' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164'
TOTAL DEPTH: 154'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/18/79 **Date Completed:** 10/18/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From:0
To: 38
Cement: 81 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 109
Cement: 265 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-6b	Surficial Deposits	0-12
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-T.D.
	Magenta Dolomite Member	492-511
	Culebra Dolomite Member	604-627
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	640

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-6c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1164 (State Engineer's Office)

LOCATION: 281.06' FNL, 374.47' FWL,
Sec. 18, T 22 S, R 31 E

ELEVATION: 3348.52' (Top of Casing)
TOTAL DEPTH: 741'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 06/19/78 **Date Completed:** 06/26/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: +1.29
To: 699
Cement: 335 Cu. Ft.

Note: Bridge plug set at 641'. Perforated from 604' to 631' with 108 holes spaced at 4 holes per foot.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-6a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1162 (State Engineer's Office)

LOCATION: 283.30' FNL, 274.34' FWL,
Sec. 18, T 22 S, R 31 E

ELEVATION: 3347.83' (Top of Casing)
TOTAL DEPTH: 525'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/06/78 **Date Completed:** 07/11/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 475
Cement: 155 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests. 4 1/2" packer set at 594' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder at 608' in the Culebra Dolomite. The hole is dual-completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-6b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1163 (State Engineer's Office)

LOCATION: 196.34' FNL, 332.96' FWL,
Sec 18, T 22 S, R 31 E

ELEVATION: 3348.25' (Top of Casing)
TOTAL DEPTH: 640'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 06/19/78 **Date Completed:** 07/05/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 590
Cement: 210 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-5c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1161 (State Engineer's Office)

LOCATION: 1005.55 FNL, 134.95 FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.04' (Top of Casing)
TOTAL DEPTH: 1076'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/03/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 1024
Cement: 416 Cu. Ft.

Note: Bridge plug set at 935'. Perforated from 895' to 925' with 120 holes spaced at 4 holes per foot. Hole in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-5c	Surficial Deposits	0-8
	Gatuna Formation	NP
	Dockum Group	8-225
	Dewey Lake Red Beds	225-732
	Rustler Formation	732-1041
	Magenta Dolomite Member	788-812
	Culebra Dolomite Member	899-924
	Salado Formation	1041-T.D.
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	1076

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-5b
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08.1160 (State Engineer's Office)

LOCATION: 1008.30' FNL, 236.22' FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.04' (Top of Casing)
TOTAL DEPTH: 925'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/13/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 881
Cement: 336 Cu. Ft.

Note: Hole is in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-5b	Surficial Deposits	0-8
	Gatuna Formation	NP
	Dockum Group	8-225
	Dewey Lake Red Beds	225-732
	Rustler Formation	732-T.D.
	Magenta Dolomite Member	785-805
	Culebra Dolomite Member	897-920
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4c	Surficial Deposits	0-13
	Gatuna Formation	13-29
	Dockum Group	NP
	Dewey Lake Red Beds	29-315
	Rustler Formation	315-626
	Magenta Dolomite Member	377-403
	Culebra Dolomite Member	490-516
	Salado Formation	626-661

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-5a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1159 (State Engineer's Office)

LOCATION: 1091.98 FNL, 185.03 FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.19 (Top of Casing)
TOTAL DEPTH: 824'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/20/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 774
Cement: 192 Cu. Ft.

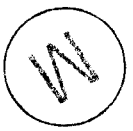
Note: Hole in standby condition for hydro tracer tests. 4 1/2" inflatable packer set at 895' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder set at 905' in the Culebra Dolomite. The hole is dual-completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4b	Surficial Deposits	0-13
	Gatuna Formation	13-29
	Dockum Group	NP
	Dewey Lake Red Beds	29-315
	Rustler Formation	315-T.D.
	Magenta Dolomite Member	377-402
	Culebra Dolomite Member	498-522
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	529



HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-4c**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1152 (State Engineer's Office)

LOCATION: 446.36 FNL, 717.89 FWL,
Sec. 5, T 23 S, R 31 E

ELEVATION: 3334.04' (Top of Casing)
TOTAL DEPTH: 661'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/30/78 **Date Completed:** 05/09/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 33
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 610
Cement: 270 Cu. Ft.

Note: Bridge plug at 530'. Perforated from 494' to 520' with 104 holes spaced at 4 holes per foot. Hole in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4a	Holocene	
	Surficial Deposits	0-13
	Pleistocene	
	Gatuna Formation	13-29
	Ochoan	
	Dewey Lake Red Beds	29-315
	Rustler Formation	315
	Magenta Dolomite Member	375-400
	Total Depth	415

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-4b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1154 (State Engineer's Office)

LOCATION: 498.47' FNL, 632.54' FWL,
Sec. 5, T 23 S, R 31 E

ELEVATION: 3333.35 (Top of Casing)
TOTAL DEPTH: 529'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/30/78 **Date Completed:** 05/15/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 33
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 476
Cement: 269 Cu. Ft.

Note: Hole is in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3d	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	420
	Rustler Formation	
	Forty-Niner Member	508-537
	Forty-Niner Claystone Member	537-547
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-4a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1153 (State Engineer's Office)

LOCATION: 545.89' FNL, 720.00' FWL,
Sec. 5, T 23 S, R 31 E

ELEVATION: 3333.29' (Top of Casing)
TOTAL DEPTH: 415'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/30/78 **Date Completed:** 05/23/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 32
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 364
Cement: 173 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests. 4 1/2" inflatable packer set at 485' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder set at 499' in the Culebra Dolomite. The hole is dual completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b3	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	
	Rustler Formation	
	Magenta Dolomite Member	563-586
	Culebra Dolomite Member	673-696
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3d (H-3b4)**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2067.3' FSL, 164.3' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3390.01' (Top of Casing)
TOTAL DEPTH:	554'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:**
CASING RECORD:	Diameter: 8 5/8 Grade: Wt/Ft: From: 0 To: 39 Cement: Note: 7 7/8" uncased borehole 33-559'.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b2	Surficial Deposits	0-11
	Gatuna Formation	
	Dockum Group	11-65
	Dewey Lake Red Beds	65-565.7
	Rustler Formation	565.7-788.7
	Magenta Dolomite Member	564-590
	Culebra Dolomite Member	676-700
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	725

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3b3**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2022.35' FSL, 217.30' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3388.67' (Top of Casing)
TOTAL DEPTH:	730'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:** 01/30/84
CASING RECORD:	Diameter: 5.5 Grade: J-55 Wt/Ft: 15.5 From: .50 To: 670.5 Cement: Casing cemented in place
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b1	Holocene	
	Surficial Deposits	0-4
	Quaternary	
	Gatuna Formation	4-22
	Permian	
	Dewey Lake Red Beds	22-502
	Rustler Formation	502-821
	Magenta Dolomite Member	559-584
	Culebra Dolomite Member	672-694
	Top of Rustler Salt	Not Given
	Salado Formation	821- T.D.
	Maximum Depth	902

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3b2**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2122.15' FSL, 231.29' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3390.03' (Top of Casing)
TOTAL DEPTH:	725'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:**
CASING RECORD:	Diameter: 5 1/2 O.D. Grade: J-55 Wt/Ft: 15.5 From: 0 To: 672.7 Cement:
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2c	Holocene	
	Surficial Deposits	0-34
	Quaternary	
	Gatuna Formation	0-34
	Permian	
	Dewey Lake Red Beds	34-457
	Rustler Formation	
	Magenta Dolomite Member	515-540
	Culebra Dolomite Member	624-642
	Top of Rustler Salt	642
	Salado Formation	764-795 (T.D.)
	Maximum Depth	795

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-3b1**
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08.991 (State Engineer's Office)

LOCATION: 2085.31' FSL, 138.10' FEL,
Sec. 29, T 22 S, R 31 E

ELEVATION: 3390.64' (Top of Casing)
TOTAL DEPTH: 902'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/25/76 **Date Completed:** 08/12/76

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft: 40.5
From: 0
To: 38
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 891
Cement: 625 Sacks

Note: Perforated from 813 to 837 with 72 holes, 683 to 703 with 3 holes per ft, 675 to 683 with 3 holes per ft, 562 to 590 with 3 holes per ft.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2b2	Holocene	
	Surficial Deposits	0-14
	Quaternary	
	Gatuna Formation	14-38
	Permian	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-660 (T.D.)
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-660 (T.D.)

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-2c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 637.15' FNL, 1708.62' FWL,
Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.41' (Top of Casing)
TOTAL DEPTH: 795'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 01/28/77 **Date Completed:** 02/05/77

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft:
From: 0
To: 33
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 742
Cement: 339 Cu. Ft.

Note: Perforated from 618-655 with 3 holes per foot.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2b1	Holocene	
	Surficial Deposit	0-14
	Pleistocene	
	Gatuna Formation	14-38
	Ochoan	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-661
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-661
	Total Depth	661

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-2b2**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 700.6' FNL, 1690.8' FWL, Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.31' (Top of Casing)
TOTAL DEPTH: 660'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/16/83 **Date Completed:** 05/03/84

CASING RECORD:

Diameter: 9.625 O.D.
Grade: J-55
Wt/Ft: 36
From: 0
To: 20
Cement:

Diameter: 5.5 O.D.
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 620
Cement:

Note: Open 613-650'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2a	Holocene	
	Surficial Deposit	0-14
	Pleistocene	
	Gatuna Formation	14-38
	Ochoan	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-672 (T.D.)
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-672 (T.D.)
	Total Depth	672

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-2b1**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 695.57' FNL, 1660.57' FWL,
Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.46 (Top of Casing)
TOTAL DEPTH: 661'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 02/07/77 **Date Completed:** 02/14/77

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft:
From: 0
To: 33
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 609
Cement: 282 Cu. Ft.

Note: Perforated from 510'-538' with 3 holes per foot.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-1	Holocene	
	Surficial Deposits	0-15
	Pleistocene	
	Gatuna Formation	15-35
	Ochoan	
	Dewey Lake Red Beds	35-502
	Rustler Formation	502-824
	Magenta Dolomite Member	563-589
	Culebra Dolomite Member	676-699
	Top of Salado	824
	Total Depth	856

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-2a**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.990 (State Engineer's Office)
LOCATION:	726.96' FNL, 1697.64', FWL Sec. 29, T 22 S, R 31 E
ELEVATION:	3378.09' (Top of Casing)
TOTAL DEPTH:	672'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 02/14/77 **Date Completed:** 02/21/77
CASING RECORD:	Diameter: 10 3/4 Grade: Wt/Ft: From: 0 To: 33 Cement: 54 Cu. Ft. Diameter: 6 5/8 Grade: J-55 Wt/Ft: 24 From: 0 To: 511 Cement: 260 Cu. Ft.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-34	Quaternary Deposits	0-11
	Triassic Rocks	
	Santa Rosa Sandstone	11-154
	Permian Rocks	
	Dewey Lake Red Beds	154-657
	Rustler Formation	657-973
	Magenta Dolomite Member	716-741
	Culebra Dolomite Member	834-861
	Salado Formation	973-1820+
	Upper Unit	973-1437
	MB 101	1092
	MB 102	1122
	MB 103	1148
	MB 104	1158
	MB 105	1173
	MB 106	1191
	MB 107	1228
	MB 108	1237
	MB 109	1280
	MB 110	1317
	MB 111	1326
	MB 112	1344
	MB 113	1366
	MB 114	1396
	MB 115	1420
	MB 116	1430
	McNutt Potash Unit	1437-1751
	Vaca Triste Sandstone Member	1437-1442
	MB 117	1498
	MB 118	1520
	MB 119	1540
	MB 120	1560
	MB 121	1573
	MB 122	1580
	Union Anhydrite	1599-1607
	MB 123	1676
	MB 124	1690
	MB 125	—
	MB 126	1751
	Lower Unit	1751-1820+
	MB 127	1768
	MB 128	1775
	MB 129	1785

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-1
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.979 (State Engineer's Office)

LOCATION: 623.2' FNL, 1083.1' FWL Sec. 29, T 22 S, R 31 E

ELEVATION: 3399.53' (Top of Casing)
TOTAL DEPTH: 856'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/20/76 **Date Completed:** 06/10/76

CASING RECORD:

Diameter: 10 1/8
Grade:
Wt/Ft: 40.5
From: 0
To: 48
Cement: 51 Cu. Ft.

Diameter: 7
Grade: K-55
Wt/Ft: 26
From: 0
To: 848
Cement: 192 Cu. Ft.

Note: Perforated from 803 to 827 with 72 holes, 703 to 683 with 3 holes per foot, 683 to 675 with 3 holes per foot, 562 to 590 with 3 holes per foot. All depths are measured from Kelly Bushing 8' above ground level except DST's which are measured from ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-33	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-34**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	08.08.1291 (State Engineer's Office) 08.08.1195 (reentry)
LOCATION:	201.78' FSL, 1999.73' FWL Sec. 9, T 22 S, R 31 E
ELEVATION:	3433' (Top of Casing)
TOTAL DEPTH:	1820'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/16/79 **Date Completed:** 09/04/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement:
	Note: Hole filled with brine based mud.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-32	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-33**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	SEO: 04/25/79
LOCATION:	1762.48' FSL, 2426.65' FWL Sec. 13, T 22 S, R 30 E
ELEVATION:	3323.23' (Top of Casing)
TOTAL DEPTH:	840'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/13/79 **Date Completed:** 07/26/79
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 192 Cu. Ft.
	Note: Hole filled with brine based mud. Fluid level at 27 ft.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-31	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-32**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	SEO: 04/25/79; USGS: 10/15/79
LOCATION:	1673.22' FSL, 29.14' FEL Sec. 33, T 22 S, R 29 E
ELEVATION:	3023.26' (Top of Casing)
TOTAL DEPTH:	390'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/07/79 **Date Completed:** 08/23/79
CASING RECORD:	No casing used.
PLUGGING SCHEDULE:	Note: Hole plugged to surface with 500 Cu. Ft. cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-30	Permian Rocks	
	Dewey Lake Red Beds	0-449
	Rustler Formation	449-748
	Magenta Dolomite Member	513-537
	Culebra Dolomite Member	631-653
	Salado Formation	748-912 (T.D.)
	Upper Member	748-912
	Salt Interval	748-912
	MB 101	862
	MB 102	894
	MB 103	In Bed at Total Depth
	Maximum Depth Recorded	908

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-31
OPERATOR: Sandia National Laboratories
PERMIT NO.: Unknown

LOCATION: 422.54' FSL, 1762.24' FWL
Sec. 35, T 20 S, R 30 E

ELEVATION: 3401.43' (Top of Casing)
TOTAL DEPTH: 1981.7'
TYPE OF WELL: Geologic Exploration
DRILLER: Chortes Drilling Company

DRILLING RECORD: **Date Started:** 07/18/80 **Date Completed:** 09/29/80 (Recompletion)

CASING RECORD:

Diameter:
Grade: 6' x 6' CEL
Wt/Ft:
From: 0
To: 5
Cement: Dirt

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 3
To: 37
Cement: 81 Cu. Ft.

Diameter: 7 5/8
Grade: J-55
Wt/Ft: 26.4
From: 2.5
To: 808
Cement: 414 Cu. Ft.

Note: Hole loaded with brine based mud pending further testing and/or plugging.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-29	Holocene Deposits	0-12
	Permian Rocks	
	Rustler Formation	12-143
	Culebra Dolomite Member	12-42
	Salado Formation	143-377 (T.D.)
	Upper Member	143-248
	Dissolution Residue	143-248
	MB 101	175
	MB 102	181
	MB 103	199
	MB 109	228
	McNutt Potash Zone	248-377 (T.D.)
	Dissolution Residue	248-251
	Vaca Triste Sandstone Member	248-251
	Salt Interval	251-377
	MB 117	319
	MB 118	346
	Maximum Depth Recorded	358

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-30**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1177 (State Engineer's Office)

LOCATION: 667.5' FNL, 177.41' FWL
Sec. 33, T 21 S, R 30 E

ELEVATION: 3429.05' (Top of Casing)
TOTAL DEPTH: 913'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/08/78 **Date Completed:** 10/02/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 246
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 912
Cement: 463 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 631-654 with 92 holes spaced at 4 holes per foot. Magenta perforated from 510-540 with 120 holes spaced at 4 holes per foot. Rustler perforated from 731-753 with 88 holes spaced at 4 holes per foot. Top of Pip Packers set at 701.1 and 585.4.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-28	Holocene Deposits	0-12
	Permian Rocks	
	Dewey Lake Red Beds	12-215
	Rustler Formation	215-531
	Magenta Dolomite Member	285-310
	Culebra Dolomite Member	420-446
	Salado Formation	531-801 (T.D)
	Upper Member	531-801
	Dissolution Residue	531-589
	MB 101	567
	MB 103	585
	Salt Interval	589-801
	MB 105	598
	MB 106	612
	MB 107	656
	MB 108	664
	MB 109	694
	MB 111	731
	MB 112	743
	MB 113	769
	MB 114	791
	Maximum Depth Recorded	802

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-29**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1176 (State Engineer's Office)
LOCATION:	406.62' FSL, 1827.54' FEL Sec. 34, T 22 S, R 29 E
ELEVATION:	2978.26' (Top of Casing)
TOTAL DEPTH:	377'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/03/78 **Date Completed:** 10/10/78
CASING RECORD:	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 376 Cement: 135 Cu. Ft. Note: Top joint of 5.5 casing is 14 lb. Culebra perforated from 10-45 with 140 holes spaced at 4 holes per foot. Rustler perforated from 216-250 with 136 holes spaced at 4 holes per foot. Top of Pip Packers set at 203.7.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-27	Quaternary Deposits	
	Holocene Deposits	0-74
	Mescalero Caliche	74-79
	Permian Rocks	
	Dewey Lake Red Beds	79-152
	Rustler Formation	152-421
	Dissolution Residue	152-193
	Magenta Dolomite Member	175-193
	Dissolution Residue	270-281
	Culebra Dolomite Member	292-318
	Dissolution Residue	321-421
	Salado Formation	421-592
	Upper Member	421-592
	Dissolution Residue	421-509
	MB 101	442-447
	MB 102	449-451
	MB 103	456-468
	MB 107-108	481-484
	MB 109	487-494
	Salt Interval	509-592
	MB 113	548-550
	Maximum Depth Recorded	592

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-28**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1175 (State Engineer's Office)

LOCATION: 98.72' FNL, 2400.99' FEL
Sec. 18, T 21 S, R 31 E

ELEVATION: 3349.21' (Top of Casing)
TOTAL DEPTH: 801'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/07/78 **Date Completed:** 08/28/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 21
Cement: Ready Mix

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 223
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 800
Cement: 314 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 420-446 with 104 holes spaced at 4 holes per foot. Magenta perforated from 285-310 with 100 holes spaced at 4 holes per foot. Rustler perforated from 549-589 with 160 holes spaced at 4 holes per foot. Top of Pip Packers set at 526.7 and 365.1.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-26	Holocene Deposits	0-10
	Permian Rocks	
	Rustler Formation	10-309
	Dissolution Residue	34-50
	Magenta Dolomite Member	70-99
	Dissolution Residue	152-174
	Culebra Dolomite Member	186-209
	Dissolution Residue	213-234
	Salado Formation	309-503
	Upper Member	309-503
	Dissolution Residue	309-320
	Salt Interval	320-503
	MB 101	387
	MB 102	423
	MB 103	460
	MB 104	469
	MB 105	481
	MB 106	495
	Maximum Depth Recorded	503

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-27**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1174 (State Engineer's Office)
LOCATION:	89.79' FNL, 1485.03' FWL Sec. 21, T 21 S, R 30 E
ELEVATION:	3178.98' (Top of Casing)
TOTAL DEPTH:	592'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 09/12/78 **Date Completed:** 10/09/78
CASING RECORD:	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 588 Cement: 440 Cu. Ft.
	Note: Culebra perforated from 290-320 with 120 holes spaced at 4 holes per foot. Magenta perforated from 175-195 with 80 holes spaced at 4 holes per foot. Rustler perforated from 425-460 with 135 holes and from 483-513 with 120 holes spaced at 4 holes per foot. Top of Pip Packers set at 399.4 and 267.4.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-25	Pleistocene Deposits	0-17
	Permian Rocks	
	Dewey Lake Red Beds	17-232
	Rustler Formation	232-565
	Dissolution Residue	270-287
	Magenta Dolomite Member	302-328
	Dissolution Residue	415-424
	Culebra Dolomite Member	447-472
	Dissolution Residue	475-512
	Salado Formation	565-655 (T.D.)
	Upper Member	565-600
	Dissolution Residue	565-600
	MB 101	589
	MB 102	599
	Salt Interval	600-655
	MB 103	615
	MB 104	628
	MB 105	640
	Maximum Depth Recorded on Geophysical Logs	651

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-26**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1173 (State Engineer's Office)

LOCATION: 2232.27' FNL, 12.20' FEL
Sec. 29, T 22 S, R 30 E

ELEVATION: 3153.20' (Top of Casing)
TOTAL DEPTH: 503'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/28/78 **Date Completed:** 09/11/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 268
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 502
Cement: 510 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 185-210 with 100 holes spaced at 4 holes per foot. Magenta perforated from 70-100 wih 120 holes spaced at 4 holes per foot, and from 50-70 with 80 holes spaced at 4 holes per foot. Rustler perforated from 288-329 with 164 holes spaced at 4 holes per foot. Top of Pip Packers set at 269 and 139.1.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-22	Quaternary Deposits	
	Holocene Deposits	0-6
	Mescalero Caliche	6-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-81
	Permian	
	Dewey Lake Red Beds	81-574
	Rustler Formation	574-885
	Dissolution Residue	603-614
	Magenta Dolomite Member	630-654
	Dissolution Residue	717-728
	Culebra Dolomite Member	742-764
	Dissolution Residue	767-773
	Salt Interval	777-885
	Salado Formation	885-1450
	Upper Member	883-1363
	MB 101	1000-1003
	MB 102	1036-1037
	MB 103	1049-1063
	MB 104	1071-1072
	MB 105	1086-1087
	MB 106	1102-1103
	MB 107	1142-1143
	MB 108	1150-1151
	MB 109	1172-1196
	MB 111	1242-1243
	MB 112	1259-1261
	MB 113	1285-1286
	MB 114	1307-1308
	MB 115	1342-1344
	MB 116	1353-1355
	McNutt Potash Unit	1363-1450
	Vaca Triste Sandstone Member	1363-1367
	MB 117	1426-1427
	Maximum Depth Recorded	1448

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-25**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1172 (State Engineer's Office)

LOCATION: 1852.77' FSL, 2838.10' FEL
Sec. 15, T 22 S, R 30 E

ELEVATION: 3214.39' (Top of Casing)
TOTAL DEPTH: 650'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 08/28/78 **Date Completed:** 09/12/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 21
Cement:

Diameter: 5 1/2
Grade: K-55
Wt/Ft: 15.5
From: 0
To: 649
Cement: 269 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 445-475 with 120 holes spaced at 4 holes per foot. Magenta perforated from 300-330 with 120 holes spaced at 4 holes per foot. Rustler perforated from 579-608 with 116 holes spaced at 4 holes per foot. Top of Pip Packers set at 572.7 and 365.1.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-21	Quaternary Deposits	
	Holocene Deposits	0-6
	Mescalero Caliche	6-12
	Gatuna Formation	12-39
	Triassic Rocks	
	Santa Rosa Sandstone	39-73
	Permian Rocks	
	Dewey Lake Red Beds	73-560
	Rustler Formation	560-868
	Dissolution Residue	588-601
	Magenta Dolomite Member	618-642
	Dissolution Residue	706-715
	Culebra Dolomite Member	729-753
	Dissolution Residue	755-759
	Salt-bearing Interval	770-868
	Salado Formation	868-1046
	Upper Member	868-1046
	MB 101	986-989
	MB 102	1025-1026
	MB 103	1039
	Maximum Depth Recorded	1046

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-22**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1127 (State Engineer's Office)
LOCATION:	2544.9' FSL, 10.82' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3428.12' (Top of Casing)
TOTAL DEPTH:	1450'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brother Drilling
DRILLING RECORD:	**Date Started:** 05/08/78 **Date Completed:** 05/24/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 20 Cement:
	Note: Hole loaded with mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-19	Quaternary Deposits	
	Holocene Deposits	0-7
	Mescalero Caliche	7-14
	Triassic Rocks	
	Santa Rosa Sandstone	14-96
	Permian Rocks	
	Dewey Lake Red Beds	96-590
	Rustler Formation	590-895
	Dissolution Residue	619-629
	Magenta Dolomite Member	647-672
	Dissolution Residue	730-756
	Culebra Dolomite Member	756-779
	Dissolution Residue	781-795
	Salt-bearing Interval	795-895
	Salado Formation	895-1038.2
	Upper Member	895-1038.2
	MB 101	1010-1012
	Maximum Depth Recorded	1034

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-21
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1126 (State Engineer's Office)

LOCATION: 1450.6' FSL, 11.7' FEL
Sec. 20, T 22 S, R 31 E

ELEVATION: 3418.96' (Top of Casing)
TOTAL DEPTH: 1045'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 05/24/78 **Date Completed:** 05/26/78

CASING RECORD:
Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 20
Cement:

Note: Hole loaded with brine mud pending further testing and/or plugging.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-18	Quaternary Deposits	
	Holocene Deposits	0-5
	Mescalero Caliche	5-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-138
	Permian Rocks	
	Dewey Lake Red Beds	138-613
	Rustler Formation	613-928
	Dissolution Residue	643-655
	Magenta Dolomite Member	672-696
	Dissolution Residue	757-769
	Culebra Dolomite Member	787-808
	Dissolution Residue	812-822
	Salt-bearing Interval	822-928
	Salado Formation	928-1060
	Upper Member	928-1060
	MB 101	1049
	Maximum Depth Recorded	1060

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-19**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1124 (State Engineer's Office)
LOCATION:	2286.5' FNL, 12.7' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3435.14' (Top of Casing)
TOTAL DEPTH:	1038'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 04/06/78 **Date Completed:** 05/08/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 8 Cement:
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-16
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1290 (State Engineer's Office) 0.08.1182 (reentry)

LOCATION: 2356.6' FSL, 138.8' FWL
Sec. 5, T 21 S, R 30 E

ELEVATION: 3383.40' (Top of Casing)
TOTAL DEPTH: 1300'
TYPE OF WELL: Geologic Exploration
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 01/11/80 **Date Completed:** 02/08/80

CASING RECORD:

Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 38
Cement:

Diameter: 4 1/2
Grade: J-55
Wt/Ft: 10.5
From: 0
To: 459
Cement:

Note: Hole filled with brine based mud and temporarily abandoned.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-18**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1123 (State Engineer's Office)
LOCATION:	983.58' FNL, 11.85' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3458.7' (Top of Casing)
TOTAL DEPTH:	1060'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 03/14/78 **Date Completed:** 04/03/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 16 Cement:
	Note: Hole loaded with mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-15**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.13.00 (State Engineer's Office)

LOCATION: 2426' FNL, 1973' FWL
Sec. 18, T 23 S, R 35 E

ELEVATION: 3269.34' (G.L.l)
TOTAL DEPTH: 810'
TYPE OF WELL: Geologic Exploration
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 03/08/78 **Date Completed:** 04/04/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 13
Cement:

Diameter: 6 1/8
Grade: HW
Wt/Ft: 11.3
From: 13
To: 592
Cement:

Diameter: 4
Grade: Core
Wt/Ft:
From: 592
To: 810
Cement:

Diameter: 4 1/2
Grade: HW
Wt/Ft: 11.3
From: 0
To: 555
Cement:

Note: Hole loaded with mud and temporarily capped pending further testing and/or plugging. Hole was relinquished to land owner for use as water well to relieve liability for plugging.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-15	Quaternary Deposits	
	Clay	0-34
	Marl	34-99
	Sand	99-153.3
	Clay	153.3-226
	Sand	226-547.2
	Triassic Rocks	
	Chinle	547.2-790.5
	Santa Rosa Sandstone	790.5-812

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-14
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1458 (State Engineer's Office)

LOCATION: 98.57' FSL, 2112.08' FEL
Sec. 9, T 22 S, R 31 E

ELEVATION: 3429' (G.L.)
TOTAL DEPTH: 1000'
TYPE OF WELL: Geologic Exploration
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 05/02/81 **Date Completed:** 06/08/81

CASING RECORD:
Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 111
Cement:

Note: Hole loaded with brine based mud and temporarily abandoned pending further tests and/or plugging.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-14	Quaternary Rocks	
	Sand (Holocene-eolian)	0-15.4
	Triassic Rocks	
	Santa Rosa Sandstone	15.4-141.0
	Permian Rocks	
	Dewey Lake Red Beds	141.0-638.7
	Rustler Formation	638.7-951
	Magenta Dolomite Member	706.5-730.0
	Culebra Dolomite Member	817.2-836.2
	Salado Formation (Upper Member)	951.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-13	Quaternary Deposits	0-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-66
	Permian Rocks	
	Dewey Lake Red Beds	66-517
	Rustler Formation	517-846
	Dissolution Residue	543-550
	Magenta Dolomite Member	565-583
	Dissolution Residue	679-686
	Culebra Dolomite Member	703-726
	Dissolution Residue	730-735
	Top of Highest Salt in Section	745
	Salado Formation	846-1025
	Upper Member	846-1025
	MB 101	967
	MB 102	1003
	MB 103	1018
	DEEPENED PORTION OF WIPP-13 (Distance below K.B.)	
	Permian Rocks	
	Salado Formation	858.0-2971.6
	Upper Member	858.0-1356.7
	MB 103	1030.0-1042.3
	MB 104	1069.8
	MB 105	1091.0
	MB 106	1111.0
	MB 107	1128.0
	MB 108	1136.1
	MB 109	1161.0-1185.0
	MB 111	1232.8
	MB 112	1250.0
	MB 113	1277.9
	MB 114	1300.9
	MB 115	1338.3
	MB 116	1350.0
	McNutt Member	1356.7-1730.4
	Vaca Triste Sandstone Member	1356.7-1359.0
	MB 117	1426.5
	MB 118	1451.5
	MB 119	1478.2
	MB 120	1497.0
	MB 121	1513.8
	MB 122	1522.0
	Union Anhydrite	1542.0-1550.0
	MB 123	1628.0
	MB 124	1644.7
	MB 126	1730.4
	Lower Member	1730.4-2971.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-13	MB 127	1757.8
	MB 128	1770.0
	MB 129	1794.0
	MB 130	1804.5
	MB 131	1873.6
	MB 132	1902.0
	MB 133	1924.0
	MB 134	1968.9-1980.6
	MB 135	1996.8
	MB 136	2033.0-2048.0
	MB 137	2063.0
	MB 138	2110.2
	MB 139	2168.3
	MB 140	2221.0-2232.9
	MB 141	2294.6
	MB 142	2341.5-2355.0
	MB 143	2409.0-2417.0
	MB 144	2460.4
	Cowden Anhydrite	2493.9-2521.6
	Castile Formation	2971.6-3861.6+ (T.D.)
	Anhydrite III	2971.6-3518.7
	Halite II	3518.7-3638.0
	Anhydrite II	3638.0-3727.5
	Halite I	3727.5-3821.0
	Anhydrite I	3821.0-3861.6+ (T.D.)

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-12	MB 133	1976.0
	MB 134	2015.0-2025.0
	MB 135	2040.0
	MB 136	2071.6-2083.1
	MB 138	2135.1
	MB 139	2184.9
	MB 140	2226.1-2238.1
	MB 141	2290.0-2296.0
	MB 142	2332.0-2344.0
	MB 143	2381.5-2387.6
	MB 144	2413.5-2423.9
	Cowden Anhydrite	2445.5-2471.0
	Castile Formation	2337.5-T.D.
	DEEPENED PORTION OF WIPP-12	
	Castile Formation	2776.0-T.D.
	Anhydrite III Member	2776.0-3053.9
	Halite II Member	3053.9-3281.8
	Anhydrite II Member	3281.8-3391.0
	Halite I Member	3391.0-3901.6
	Anhydrite I Member	3901.6-T.D.

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-13
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.09.1182 (State Engineer's Office)

LOCATION: 2565.68' FSL, 1730.59' FWL
Sec. 17, T 22 S, R 31 E

ELEVATION: 2565.68' (Top of Casing)
TOTAL DEPTH: 3856'
TYPE OF WELL: Geologic Exploration
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/26/78 **Date Completed:** 10/05/79 (Recompletion)

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 35.5
Cement: 108 Cu. Ft.

Diameter: 9 5/8
Grade:
Wt/Ft: 36
From: 0
To: 1023
Cement: 665 Cu. Ft.

Note: Hole loaded with brine based mud pending further test and/or plugging. All depths are measured from Kelly Bushing 12.2 ft. above ground except cores between 570 and 878 ft. and Schlumberger logs which were measured from ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-12
OPERATOR: Westinghouse
PERMIT NO.: Unknown

LOCATION: 149.4' FSL, 80.4' FEL
Sec. 17, T 22 S, R 31 E

ELEVATION: 3472.06 (Top of Casing)
TOTAL DEPTH: 3927.5'
TYPE OF WELL: Geologic Exploration
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 11/17/81 **Date Completed:** 12/07/78

CASING RECORD:

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 32.3
From: 39
To: 1001.8
Cement: 475 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 39
Cement: 475 Cu. Ft.

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 32
From: 39
To: 1013
Cement: 475 Cu. Ft.

Note: Hole loaded with brine based mud pending further tests. All depths are measured from Kelly Bushing 12.2 ft. above ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-12	Quaternary Deposits	
	Sand (Holocene-eolian)	0-16.2
	Mescalero Caliche	16.2-19.2
	Gatuna Formation	19.2-28.8
	Triassic Rocks	
	Santa Rosa Sandstone	28.8-167.0
	Permian Rocks	
	Dewey Lake Red Beds	167.0-640.0
	Rustler Formation	640.0-966.0
	Magenta Dolomite Member	703.9-727.0
	Culebra Dolomite Member	822.0-846.8
	Salado Formation	966.0-2737.5
	Upper Member	966.0-1444.0
	MB 101	1084.5
	MB 102	1116.0
	MB 103	1130.0-1141.0
	MB 104	1150.0
	MB 105	1167.6
	MB 106	1183.5
	MB 107	1223.5
	MB 108	1232.5
	MB 109	1254.0-1278.0
	MB 111	1324.0
	MB 112	1338.0-1342.0
	MB 113	1367.0
	MB 114	1389.0
	MB 115	1424.5
	MB 116	1436.0
	McNutt Member	1444.0-1798.0
	Vaca Triste Sandstone Member	1444.0-1447.0
	MB 117	1507.5
	MB 118	1531.0
	MB 119	1552.0-1556.5
	MB 120	1575.0
	MB 121	1588.0
	MB 122	1596.0
	Union Anhydrite	1617.0-1625.0
	MB 123	1695.0-1700.8
	MB 124	1708.0-1715.4
	MB 126	1798.0
	Lower Member	1798.0-2737.5
	MB 127	1825.0
	MB 128	1834.0
	MB 129	1856.0
	MB 130	1867.0
	MB 131	1928.0
	MB 132	1957.5

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-11
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.994 (State Engineer's Office)

LOCATION: 711.80' FNL, 294.08' FWL
Sec. 9, T 22 S, R 31 E

ELEVATION: 3426.07'
TOTAL DEPTH: 3580'
TYPE OF WELL: Geologic Exploration
DRILLER: Verna Drilling Compa

DRILLING RECORD: **Date Started:** 02/06/78 **Date Completed:** 03/14/78

CASING RECORD:

Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 40
Cement: 81 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 985
Cement: 656 Cu. Ft.

Note: Hole loaded with brine based mud, hole temporarily capped pending further testing and/or plugging, all depths are measured from Kelly Bushing 13 ft. above ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-11	MB 136-T	1978.5
	MB 136-B	1978.5-1986.0
	MB 138-T	1986-2025.0
	MB 138-B	2025-2027
	Anhydrite A	Not Encountered
	Anhydrite B	Not Encountered
	MB 139-T	2061.0
	MB 139-B	2061-2064
	MB 140-T	2064-2092
	MB 140-B	2092-2105

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-2	Quaternary	
	Holocene-Dune Sand	0-8
	Pleistocene-Mescalero Caliche	8-13
	Triassic	
	Santa Rosa Sandstone	13-133.3
	Permian	
	Dewey Lake Red Beds	133.3-639.1
	Rustler Formation	639.1-698.6
	Forty-Niner Member	698.6-722.4
	Magenta Dolomite Member	722.4-823.7
	Tamarisk Member	823.7-846.0
	Culebra Dolomite Member	846.0-960.9
	Unnamed Lower Member	
	Salado Formation	960.9-3082.8
	Upper Member	960.9-1448.7
	MB 101	1080.3-1084.2
	MB 102	1116.6-1117.7
	MB 103	1130.4-1143.5
	MB 104	1154.7-1155.1
	MB 105	1170.8-1171.8
	MB 106	Not Present
	MB 107	1228.0-1228.4
	MB 108	1237.5-1238.1
	MB 109	1260.0-1283.5
	MB 110	Not Present
	MB 111	1330.8-1331.0
	MB 112	1347.0-1349.2
	MB 113	1372.4-1372.9
	MB 114	1394.3-1394.8
	MB 115	1427.7-1430.6
	MB 116	1439.3-1441.4
	McNutt Potash Zone	1448.7-1827.4
	Vaca Triste Sandstone	1448.7-1456.1
	MB 117	1510.0-1511.9
	MB 118	1533.6-1534.7
	MB 119	1556.8-1557.9
	10th Ore Zone	1574.0-1580.0
	MB 120	1581.4-1581.8
	9th Ore Zone	1580-1584(EST.)
	MB 121	1598.5-1599.8
	MB 122	1606.6-1607.5
	8th Ore Zone	1611.1-1619.3
	Union Anhydrite	1630.1-1637.9
	MB 123	1716.5-1721.9
	MB 124	1728.8-1738.4
	4th Ore Zone	1746.0-1748.5
	3rd Ore Zone	1766-1774(EST.)
	2nd Ore Zone	1780-1782.5(EST.)
	MB 125	Not Present
	MB 126	1825.9-1827.4

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-2	Lower Member	1827.4-3082.8
	MB 127	1852.7-1853.8
	MB 128	1864.5-1865.5
	MB 129	1889.9-1891.9
	MB 130	1901.8-1902.0
	MB 131	1971.2-1971.7
	MB 132	1999.7-2001.2
	MB 133	2018.8-2021.7
	MB 134	2069.3-2081.0
	MB 135	2099.8-2100.5
	MB 136	2144.9-2157.3
	MB 137	Not Present
	MB 138	2203.1
	MB 139	2303.3-2306.3
	MB 140	2372.1-2388.0
	MB 141	2450.1-2454.5
	MB 142	2503.6-2517.9
	MB 143	2566.4-2571.6
	MB 144	2603.6-2615.7
	Cowden Anhydrite	2644.5-2669.5
	Castile Formation	3082.8-4071.4
	Anhydrite III	3082.8-3801.1
	Halite II	Not Present
	Anhydrite II	?
	Halite I	3801.1-3809.2
	Anhydrite I	3809.2-4071.4
	Delaware Mountain Group	
	Bell Canyon Formation	4071.4-4325+
	Lamar Limestone Member	4071.4-4103.4
	Ramsey Sand	4103.4-4174.0
	Ford Shale	4174.0-4182.8
	Olds Sand	4182.8-4218.2(?)
	Hays Sand	4218.2(?)-4248+

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-1	MB 138	2264.0
	MB 139	2323.7
	MB 140	2374.5-2389.0
	MB 141	2457.0
	MB 142	2497.0-2512.0
	MB 143	2563.5-2570.5
	MB 144	2606.0-2621.5
	Cowden Anhydrite	2647.8-2677.0
	Castile Formation	2936.5 (T.D.)
	Anhydrite III	2936.5-3374.8
	Halite II	3374.8-3600.0
	Anhydrite II	3600.0-3708.3
	Halite I	3708.3-4032.3
	Anhydrite I	4032.3-(T.D.)

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **DOE-2**
OPERATOR: U.S. Department of Energy
PERMIT NO.: 0.08.1467(State Engineer's Office)

LOCATION: 704.07' FSL, 128.19' FEL
Sec. 8, T 22 S, R 31 E

ELEVATION: 3419.09' (Top of Casing)
TOTAL DEPTH: 4325'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Unkown

DRILLING RECORD: **Date Started:** 09/08/84 **Date Completed:** 09/18/84

CASING RECORD:
Diameter: 9.625
Grade: J-55
Wt/Ft: 36
From: 0
To: 1009
Cement:

Diameter: 13 3/8 O.D.
Grade: H-40
Wt/Ft: 48#
From: 0
To: 39
Cement: Cemented with 81 Cu. Ft.

PLUGGING SCHEDULE:
No plugging data.

STRATIGRAPHIC SUMMARY: Attached

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: DOE-1
OPERATOR: Westinghouse
PERMIT NO.: Unknown

LOCATION: 182.4' FSL, 607.8' FEL
Sec. 28, T 22 S, R 31 E

ELEVATION: 3465.22' (Top of Casing)
TOTAL DEPTH: 4057.3'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Salazar Bros. Drilling Co.

DRILLING RECORD: **Date Started:** 07/14/82 **Date Completed:** 07/28/82

CASING RECORD:
Diameter: 10 3/4 O.D.
Grade:
Wt/Ft:
From: 0
To: 41
Cement: Set and cemented

Diameter: 10 3/4 O.D.
Grade: J-55
Wt/Ft: 40.5
From: 49
To: 1126.2
Cement:

Diameter: 7 7/8
Grade:
Wt/Ft:
From: 1126.2
To: 4057
Cement: Uncased

PLUGGING SCHEDULE:
No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-1	Quaternary	
	Eolian Sand	Not Described
	Gatuna Formation	Not Described
	Triassic	
	Santa Rosa Sandstone	46.0-133.0
	Permian	
	Dewey Lake Red Beds	133.0-667.5
	Rustler Formation	667.5-976.5
	Magenta Dolomite Member	722.0-745.0
	Culebra Dolomite Member	828.6-850.5
	Salado Formation	976.5-2936.5
	Upper Member	976.5-1486.0
	MB 101	1102.0
	MB 102	1138.5
	MB 103	1159.0-1169.0
	MB 105	1199.0
	MB 106	1216.0
	MB 107	1254.0
	MB 108	1263.0
	MB 109	1286.0-1309.5
	MB 111	1361.3
	MB 112	1379.8
	MB 113	1406.9
	MB 114	1429.3
	MB 115	1465.8
	MB 116	1477.6
	McNutt Potash Zone	1486.0-1880.3
	Vaca Triste Sandstone	1486.0-1489.8
	MB 117	1557.2
	MB 118	1582.6
	MB 119	1608.0
	MB 120	1632.0
	MB 121	1646.5
	MB 122	1656.0
	Union Anhydrite	1681.4-1694.0
	MB 123	1762.0-1769.9
	MB 124	1773.0-1783.8
	MB 126	1880.3
	Lower Member	1880.3-2936.5
	MB 127	1907.4
	MB 128	1919.7
	MB 129	1944.3
	MB 130	1956.7
	MB 131	2025.8
	MB 132	2056.6
	MB 133	2076.0
	MB 134	2117.0-2130.0
	MB 135	2149.4
	MB 136	2192.1-2197.1
	MB 137	2209.2

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **D-268**
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unkown

LOCATION: 720.4 FSL, 762.7 FEL, Sec. 35, T 22 S, R 30 E

ELEVATION: 3280.70 (Top of Casing)
TOTAL DEPTH: 1411'
TYPE OF WELL: Old Potash Drillhole
DRILLER: Pennsylvania Drilling Co.

DRILLING RECORD: **Date Started:** 11/15/89 **Date Completed:**

CASING RECORD:
Diameter: 4 1/2
Grade:
Wt/Ft:
From: 0
To: 528'
Cement: Cement in place

PLUGGING SCHEDULE:
From: 1411'
To: 528'
Int:
Material: Concrete Plug

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
D-268	Quaternary	
	Holocene-Eolian Sand	0-15.0
	Mescalero Caliche	
	Triassic	
	Santa Rosa Sandstone	15.0-30.0
	Permian	
	Dewey Lake Red Beds	30.0-187.0
	Rustler Formation	187.0-494.0
	Megenta Dolomite Member	255.0-275.0
	Culebra Dolomite Member	369.0-392.0
	Salado Formation	469.0
	Upper Member	
	MB 101	
	MB 102	
	MB 103	
	MB 104	
	MB 105	
	MB 106	
	MB 107	
	MB 108	
	MB 109	
	MB 111	
	MB 112	
	MB 114	
	MB 116	
	McNutt Potash Zone	
	Vaca Triste Sandstone	
	MB 117	
	MB 118	
	MB 119	
	MB 121	
	MB 122	
	Union Anhydrite	
	MB 123	
	MB 124	
	MB 126	
	Lower Member	
	MB 128	
	MB 129	
	MB 131	
	MB 132	1411.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
BABY-1	Quaternary	15.5
	Triassic	
	Santa Rosa Sandstone	15.5-142.8
	Permian	
	Dewey Lake Red Beds	142.8-362.9
	Rustler Formation	362.9-653.0
	Magenta Dolomite Member	375.0-414.1
	Culebra Dolomite Member	469.0-487.2
	Salado Formation	653.0-2703.5
	Upper Member	781.3
	MB 101	818.0
	MB 102	845.0-851.0
	MB 103	884.2
	MB 105	922.1
	MB 106	946.8
	MB 107	962.1
	MB 108	977.0-993.9
	MB 109	1036.9
	MB 111	1065.8
	MB 112	1097.0
	MB 113	1117.1
	MB 114	1157.1
	MB 115	1169.8
	MB 116	1182.0-1585.1
	McNutt Potash Zone	1251.0
	MB 117	1277.6
	MB 118	1299.9
	MB 119	1328.9
	MB 120	1346.1
	MB 121	1353.2
	MB 122	1381.8-1395.2
	Union Anhydrite	1454.5-1463.1
	MB 123	1470.0-1481.0
	MB 124	1585.1
	MB 126	1585.1-2703.5
	Lower Member	1610.2
	MB 127	1621.8
	MB 128	1650.1
	MB 129	1663.2
	MB 130	1732.9
	MB 131	1763.7
	MB 132	1784.2
	MB 133	1837.7-1848.9
	MB 134	1871.9
	MB 135	1871.9
	MB 136	1905.2-1912.0
	MB 137	1930.5
	MB 138	1990.4
	MB 139	2040.7
	MB 140	2104.0-2110.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
BABY-1	MB 141	2188.8-2196.9
	MB 142	2239.8-2259.0
	MB 143	2314.1-2321.0
	MB 144	2356.0-2370.0
	Cowden Anhydrite	2407.7-2434.7
	Castile Formation	2703.5-4045.0
	Anhydrite III	2703.5-3154.8
	Halite II	3154.8-3373.1
	Anhydrite II	3373.1-3480.0
	Halite I	3480.0-3810.0
	Anhydrite I	3810.0-4045.0
	Bell Canyon Formation	4045.0-T.D.
	Lamar Limestone	4045.0-4086.0
	Ramsey Sandstone	4086.0-4132.0
	Ford Shale	4132.0-4140.0
	Olds Sandstone	4140.0-4171.0
	Hays Sandstone	4171.0-4298.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-10	MB 139	1993.0
	MB 140	2053.0-2062.5
	MB 141	2150.9-2155.4
	MB 142	2220.6-2237.4
	MB 143	2302.6-2313.6
	Castile Formation	2350.0-3842.9
	Anhydrite IV	2350.0-2398.2
	Cowden Anhydrite	2398.2-2424.0
	Anhydrite III	2424.0-3097.2
	Halite II	3097.2-3283.7
	Anhydrite II	3283.7-3377.4
	Halite I	3377.4-3616.4
	Anhydrite I	3616.4-3842.9
	Bell Canyon Formation	3842.9-4430.0 (T.D.)
	Lamar Limestone	3842.9-3870.0
	Ramsey Sandstone	3870.0-3918.0
	Ford Shale	3918.0-3928.0
	Old Sandstone	3928.0-3956.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **BABY-1**
OPERATOR: U.S. Department of Energy
PERMIT NO.:

LOCATION: 1989.5' FNL, 2017.1' FEL
Sec 5, T 23 S, R 31 E

ELEVATION: 3328.38' (Top of Casing)
TOTAL DEPTH: 4298.6'
TYPE OF WELL: Oil and Gas Well (Exploratory)
DRILLER: Michel P. Grace - 1974 and Salazar Bros.- 1983

DRILLING RECORD: **Date Started:** 08/12/83 **Date Completed:** 02/08/75

Deepened to 4298.6'
Date Started: 17/18/83
Date Completed: 08/19/83

CASING RECORD:
13 3/8" O.D. casing set in cement to surface 650'
9 7/8" O.D. 650 - 4159'
7 27/32" O.D. 4159 - 4298.6'

PLUGGING SCHEDULE:
Ran 20 joints of 13 3/8 71# casing set at 650'. Cemented with 275 sacks of Trin. Lt. Wt. and 125 sacks Cl. C. and 300# CaCl and 69# celloflake.

STRATIGRAPHIC SUMMARY: Attached

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: ERDA-10
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 200' FNL, 2327' FEL
Sec. 34, T 23 S, R 30 E

ELEVATION: 3371.2' (Top of Casing)
TOTAL DEPTH: 4418.5'
TYPE OF WELL: Geologic Exploration
DRILLER: Corel Drilling Company

DRILLING RECORD: **Date Started:** 08/18/77 **Date Completed:** 10/14/77

CASING RECORD:
Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 50
Cement: 81 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 805
Cement: 554 Cu. Ft.

Note: Hole plugged to surface.
All depths are measured from Kelly Bushing 13' above ground level.

PLUGGING SCHEDULE:
10/01/77 - Made trip with 7 7/8" bit and conditioned hole. Ran 2 3/8" O.D. tubing in the hole and plugged back hole using Dowell with 10 barrels of water ahead of 48 barrels of mud wash followed by 414 cu. ft. of class "C" cement with 2% calcuim chloride. Displace cement with 12.5 barrels of water. Cement in place at 1300 hours. Pulled tubing and waited on cement.

10/03/77 - Made trip with 7 7/8" bit and tagged cement at 3556', conditioned hole. Made up 7 13/16" core bit and cut core #32 from 3556' to 3595', recovered 10' of cement. Cut core #33 from 3595' to 3623', recovered 20' of cement. Cut core #34 from 3623' to 3630'.

10/04/77 - Completed core #34 from 3630' to 3673', recovered 27' of cement. Ran 2 7/8" O.D. tubing in the hole to 3673'. Cemented plug #2 using Dowell with 10 barrels of water ahead of 84 barrels of mud flush followed by 10 barrels of water ahead of 1040 cu. ft. of 70% class "C" cement and 30% Litepoz. Cement in place at 1140 hours. Pulled tubing to 2300' and curculated hole. Waited on cement. Laid down drill pipe.

10/05/77 - Waited on cement to 0900 hours. Tagged top of plug #2 at 2335' with tubing. Cemented plug #3 with 10 barrels of water, 60 barrels of mud flush and 10 barrels of water, ahead of 1039 cu. ft. of cement slurry. Cement in place at 1420 hours. Pulled tubing to 803' and circulated out mud flush and cement. Waited on cement.

10/06/77 - Tagged top of plug #3 at 827'. Cemented plug #4 to surface with 10 barrels of water, 1000 gallons of mud flush and 10 barrels of water ahead of 417 cu. ft. of cement slurry. Cement in place at 0050 hours. Rigged down government furnished equipment and released rig at 1600 hours.

10/14/77 - Cement had dropped to 11.5' inside the 9 5/8" O.D. casing. Cemented to surface with 6 sacks of cement. Hole plugged

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-10	Quaternary	
	Holocene-Eolian Sand	
	Mescalero Caliche	13.0-17.0
	Triassic	
	Gatuna Formation	17.0-164.0
	Permian	
	Dewey Lake Red Beds	164.0-378.0
	Rustler Formation	378.0-640.0
	Magenta Dolomite Member	378.0-379.0
	Culebra Dolomite Member	489.0-517.0
	Salado Formation	640.0-2350.0
	Upper Member	640.0-1078.0
	MB 101	696.0
	MB 102	743.0
	MB 103	775.0-783.5
	MB 104	794.5
	MB 105	807.0
	MB 106	817.0
	MB 107	829.0
	MB 108	852.5
	MB 109	879.5-904.5
	MB 111	960.0
	MB 112	978.0
	MB 113	1018.0
	MB 114	1035.0
	MB 115	1068.0
	MB 116	1076.0
	McNutt Postash Zone	1087.0-1521.5
	Vaca Triste Sands	1087.0-1092.5
	MB 117	1162.0
	MB 118	1189.0
	MB 119	1225.0
	MB 121	1264.0
	MB 122	1279.5
	Union Anhydrite	1310.0-1330.0
	MB 123	1380.5-1387.0
	MB 124	1399.5-1407.5
	MB 125	1482.5
	MB 126	1521.5
	Lower Member	1521.5-2350.0
	MB 128	1556.0
	MB 129	1590.0
	MB 130	1604.0
	MB 131	1674.5
	MB 132	1704.5
	MB 133	1722.0
	MB 134	1771.5-1781.0
	MB 135	1807.0
	MB 136	1855.0-1864.5
	MB 138	1930.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-9	Kelly Bushing (KB) to Land Surface (LS)	0-12.0
	Holocene Deposits	12.0-22.0
	Pleistocene Rocks	
	Mescalero Caliche	22.0-27.0
	Gatuna Formation	27.0-54.0
	Triassic	
	Santa Rosa Sandstone	54.0-63.0
	Permian	
	Dewey Lake Red Beds	63.0-550.0
	Ruslter Formation	550.0-860.0
	Dissolution Residue	580.0-592.0
	Magenta Dolomite Member	608.0-632.0
	Dissolution Residue	691.0-710.0
	Culebra Dolomite Member	716.0-739.0
	Dissolution Residue	742.0-748.0
	Salado Formation	860.0-2836.0
	Upper Member	860.0-1362.0
	MB 100	939.0
	MB 101	984.0
	MB 102	1026.0
	MB 103	1040.0-1050.0
	MB 104	1061.0
	MB 105	1075.0
	MB 106	1093.0-1094.0
	MB 107	1132.0
	MB 108	1142.0
	MB 109	1165.0-1188.0
	MB 110	NP
	MB 111	1238.0
	MB 112	1256.0-1258.0
	MB 113	1282.0-1284.0
	MB 114	1306.0
	MB 115	1340.0-1344.0
	MB 116	1354.0-1356.0
	McNutt Potash Zone	1362.0-1742.0
	Vaca Triste Sands	1365.0-1367.0
	11th Ore Zone	1420.0-1422.0
	MB 117	1431.0-1433.0
	MB 118	1455.0-1463.0
	MB 119	1482.0
	10th Ore Zone	1487.0-1493.0
	MB 120	1501.0-1502.0
	9th Ore Zone	1507.0-1512.0
	MB 121	1515.0-1517.0
	MB 122	1524.0
	8th Ore Zone	1531.0-1542.0
	Union Anhydrite	1549.0-1557.0
	7th Ore Zone	1572.0-1576.0
	6th Ore Zone	1590.0-1593.0
	5th Ore Zone	1597.0-1603.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-9	MB 123	1630.0-1637.0
	MB 124	1645.0-1653.0
	4th Ore Zone	1659.0-1669.0
	3rd Ore Zone	1676.0-1688.0
	2nd Ore Zone	1696.0-1698.0
	MB 125	NP
	1st Ore Zone	1712.0-1723.0
	MB 126	1742.0
	Lower Member	1742.0-2836.0
	MB 127	1768.0-1770.0
	MB 128	1778.0-1781.0
	MB 129	1803.0-1805.0
	MB 130	1815.0
	MB 131	1884.0
	MB 132	1914.0-1915.0
	MB 133	1933.0-1935.0
	MB 134	1976.0-1989.0
	MB 135	2006.0
	MB 136	2043.0-2058.0
	MB 137	2075.0
	MB 138	2120.0-2121.0
	MB 139	2177.0-2180.0
	MB 140	2241.0-2251.0
	MB 141	2320.0-2330.0
	MB 142	2377.0-2391.0
	MB 143	2450.0-2456.0
	MB 144	2493.0-2506.0
	Cowden Anhydrite	2540.0-2653.0
	Castile Formation	2836.0-2889.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-6	MB 124	1529.4-1537.5
	4th Ore Zone	1541.9-1549.1
		1549.7-1553.0
	3rd Ore Zone	1555.5-1567.2
	2nd Ore Zone	1571.0-1574.3
	MB 125	NP
	1st Ore Zone	1587.0-1603.3
	MB 126	NP
	Lower Member	1612.9-2396.5
	MB 127	1635.0-1635.7
	MB 128	1647.7-1648.5
	MB 129	1670.0-1671.5
	MB 130	NP
	MB 131	1743.0-1743.7
	MB 132	1770.6-1771.4
	MB 133	1785.6-1789.2
	MB 134	1833.2-1843.4
	MB 135	1860.4-1861.5
	MB 136	1900.5-1910.5
	MB 137	NP
	MB 138	1967.5-1967.7
	MB 139	2019.5-2022.4
	MB 140	2060.4-2075.6
	MB 141	2124.5-2126.6
	MB 142	2163.8-2169.5
	MB 143	2212.7-2215.6
	MB 144	2237.0-2237.7
	Cowden Anhydrite	2269.5-2291.0
	Castile Formation	2400.5-2775.0
	Halite II	2400.5-2555.1
	Anhydrite II	2555.1-2732.5 (Fault or Rupture Zone)
	Halite I	2732.5-2775.0
	Cowden Anhydrite	2540.0-2653.0
	Castile Formation	2836.0-2889.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **ERDA-9**
OPERATOR: Sandia National Labs
PERMIT NO.: Unknown

LOCATION: 267.17' FSL, 176.74' FEL
Sec. 20, T 22 S, R 31 E

ELEVATION: 3410.10' (Top of Casing)
TOTAL DEPTH: 2886'
TYPE OF WELL: Geologic Exploration
DRILLER: Sonora Drilling Company

DRILLING RECORD: **Date Started:** 04/28/76 **Date Completed:** 06/26/76

CASING RECORD:
Diameter: 16
Grade:
Wt/Ft:
From: 0
To: 40
Cement: 95 Cu. Ft.

Diameter: 10 3/4
Grade: J-55
Wt/Ft: 40.5
From: 0
To: 1045
Cement: 1159 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 2883
Cement: Mud Pack

Note: Ran Dresser Atlas caliper log. Ran 79 joints (2889.66') of 7" O.D., 23# casing with a Dowell swirl type shoe on bottom and a Dowell orifice fill collar on top of the bottom joint. Set casing at 2882.66' with centralizers at 2868', 2520', and 1030'. Rigged up Dowell and pumped in 140 barrels of Baroid casing pack mud. Cemented annulus with 10 barrels of water, 12 barrels of chemical wash, 12 barrels of oil base slurry ahead of 122 cu. ft. (115 sacks) of Class "H" cement + 3% calcium chloride. Seated plug with 1000 psi, plug holding. Cement in place at 1445 hours.

All depths are measured from Kelly Bushing 11.5' above ground level.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **ERDA-6**
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 2152' FSL, 910' FEL
Sec. 35, T 21 S, R 31 E

ELEVATION: 3540.2' (Top of Casing)
TOTAL DEPTH: 2775'
TYPE OF WELL: Geologic Exploration
DRILLER: Boyles Bros. Drilling Company: 06/11/75 to 08/15/75 - Pan AM E

DRILLING RECORD: **Date Started:** 06/13/75 **Date Completed:** 09/23/75

CASING RECORD:
Diameter: 13 3/8
Grade:
Wt/Ft: 54.5
From: 0
To: 30
Cement: Ready Mix

Diameter: 8 5/8
Grade: K-55
Wt/Ft: 24
From: 0
To: 880
Cement: 575 SX.

Note: Plugged back 2773' to 2560' with 225 cement. Hole filled with brine.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-6	Quaternary	
	Holocene-Eolian Sand	0-9
	Mescalero Caliche	9-17
	Triassic	
	Santa Rosa Sandstone	17-72
	Permian	
	Dewey Lake Red Beds	72-538
	Rustler Formation	538-811
	Dissolution Residue	570-581
	Magenta Dolomite Member	598-623
	Dissolution Residue	696-707
	Culebra Dolomite Member	713-739
	Dissolution Residue	742-762
	Salado Formation	811-2396.5
	Upper Unit	811-1276.6
	MB 100	NR
	MB 101	923.5-929.9
	MB 102	956.8-958.2
	MB 103	970.3-984.3
	MB 104	992.1-992.4
	MB 105	NR
	MB 106	NR
	MB 107	1060.0-1060.9
	MB 108	1069.1-1069.9
	MB 109	1090.9-1113.5
	MB 110	NP
	MB 111	1161.5-1161.8
	MB 112	1178.9-1180.2
	MB 113	NP
	MB 114	1224.9-1226.9
	MB 115	1256.1-1257.2
	MB 116	1268.7-1271.4
	McNutt Potash Zone	1276.6-1612.9
	Vaca Triste Sandstone	1276.6-1287.3
	11th Ore Zone	1324.7-1329.8
	MB 117	1340.7-1342.7
		1346-1349.0
	MB 118	1359.0-1366.2
	MB 119	1378.4-1379.4
	10th Ore Zone	1386.1-1395.5
	MB 120	1401.0-1402.3
	9th Ore Zone	1403.2-1410.3
	MB 121	1413.3-1415.5
	MB 122	1422.3-1424.3
	8th Ore Zone	1424.9-1437.0
	Union Anhydrite	1444.6-1453.8
	7th Ore Zone	1464.0-1468.5
	6th Ore Zone	1479.7-1482.2
	5th Ore Zone	1487.8-1494.9
	MB 123	1517.7-1524.9

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-8	Quaternary: Holocene-Eolian Sand	9.0-29.0
	Mescalero Caliche	29.0-35.0
	Triassic	
	Santa Rosa Sandstone	35.0-177.4
	Permian	
	Dewey Lake Red Beds	177.4-668.0
	Rustler Formation	668.0-990.0
	Magenta Dolomite Mem	727.3-749.5
	Culebra Dolomite Mem	848.3-873.3
	Salado Formation	990.0-2979.6
	Upper Member	990.0-1469.3
	MB 101	1101.0-1116.5
	MB 102	1146.7
	MB 103	1157.7-1173.7
	MB 104	1184.4
	MB 105	1197.6
	MB 106	1215.3
	MB 107	1240.5
	MB 108	1261.3
	MB 109	1286.1-1304.7
	MB 111	1351.9
	MB 112	1370.4
	MB 113	1398.7
	MB 114	1418.2
	MB 115	1451.3
	MB 116	1462.5
	McNutt Potash Zone	1469.3-1826.5
	Vaca Triste Sands	1469.3-1484.1
	MB 117	1535.4
	MB 118	1557.0
	MB 119	1580.5
	MB 120	1603.2
	MB 121	1622.0
	MB 122	1628.6
	Union Anhydrite	1648.0-1657.9
	MB 123	1733.5
	MB 124	1746.8
	MB 126	1826.5
	Lower Member	1826.5-2979.6
	MB 127	1849.5
	MB 128	1861.5
	MB 129	1885.3
	MB 130	1894.7
	MB 131	1959.6
	MB 132	1989.0
	MB 133	2005.5
	MB 134	2047.9-2060.5
	MB 135	2076.0
	MB 136	2114.0-2128.3
	MB 137	2138.5

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-8	MB 138	2187.4
	MB 139	2247.8
	MB 140	2309.1-2316.5
	MB 141	2369.1
	MB 142	2411.8-2419.6
	MB 143	2465.2-2472.7
	MB 144	2498.8-2510.9
	Cowden Anhydrite	2539.5-2561.6
	Castile Formation	2979.6-4315.0
	Anhydrite III	2979.6-3290.0
	Halite II	3290.0-3555.0
	Anhydrite II	3555.0-3695.5
	Halite I	3695.5-4038.0
	Anhydrite I	4038.0-4315.0
	Bell Canyon Formation	4315.0-4918.0 (T.D.)
	Lamar Limestone	4344.5-4374.0
	Ramsey Sand	4374.0-4436.0
	Ford Shale	4436.0-?

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: AEC-7
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1323

LOCATION: 2036.97' FNL, 2033.23' FEL
Sec. 31, T 21 S, R 32 E

ELEVATION: 3657.25' (Top of Casing)
TOTAL DEPTH: 4734'
TYPE OF WELL: Geological Exploration
DRILLER: Verna Drilling Company

DRILLING RECORD: **Date Started:** 03/20/74 **Date Completed:** 04/19/80

CASING RECORD:
Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 40
Cement:

Diameter: 8 5/8
Grade: H-40
Wt/Ft: 28
From: 0
To: 1016
Cement:

PLUGGING SCHEDULE:
No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-7	Quaternary	
	Holocene-Eolian Sand	16.2-20.2
	Mescalero Caliche	20.2-24.2
	Triassic	
	Santa Rosa Sandstone	24.2-133.0
	Permian	
	Dewey Lake Red Beds	133.0-675.0
	Rustler Formation	675.0-1000.6
	Magenta Dolomite Member	733.5-767.0
	Culebra Dolomite Member	872.2-900.5
	Salado Formation	1000.6-3014.7
	Upper Member	1000.6-1505.1
	MB 101	1125.8
	MB 102	1158.5
	MB 103	1171.4-1186.5
	MB 104	1197.0
	MB 105	1211.5
	MB 106	1230.5
	MB 107	1269.0
	MB 108	1278.0
	MB 109	1303.8-1324.5
	MB 111	1378.0
	MB 112	1397.5
	MB 114	1450.5
	MB 116	1498.4
	McNutt Potash Zone	1505.1-1881.0
	Vaca Triste Sandstone	1505.1-1514.1
	MB 117	1578.9
	MB 118	1595.6
	MB 119	1619.8
	MB 121	1661.5
	MB 122	1668.5
	Union Anhydrite	1696.2-1705.0
	MB 123	1774.8-1781.2
	MB 124	1785.5-1795.5
	MB 126	1881.0
	Lower Member	1881.0-3104.7
	MB 128	1918.0
	MB 129	1943.9
	MB 131	2013.5
	MB 132	2039.0
	MB 133	2057.5
	MB 134	2097.0-2109.0
	MB 136	2161.0-2168.0
	MB 139	2267.5
	MB 140	2302.8-2314.2
	MB 141	2364.5
	MB 142	2400.2-2406.5
	MB 143	2453.0-2455.6
	Cowden Anhydrite	2520.0-2539.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-7	Castile Formation	3014.7-4535.3
	Anhydrite III	3014.7-3113.0
	Halite II	3113.0-3310.0
	Anhydrite II	3310.0-3506.9
	Halite II	3506.9-3588.2
	Anhydrite II	3588.2-4055.0
	Halite I	4055.0-4182.3
	Anhydrite I	4182.3-4535.5
	Bell Canyon Formation	4535.5-4731.9 (T.D.)
	Reef Talus	4535.5-4584.7
	Lamar Limestone	4584.7-4633.3
	Ramsey Sandstone	4633.3-4678.5
	Ford Shale	4678.5-4714.9
	Olds Sandstone	4714.9-4731.9

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: AEC-8
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 935' FNL, 1979' FWL
Sec. 11, T 22 S, R 31 E

ELEVATION: 3532' (Top of Casing)
TOTAL DEPTH: 4922'
TYPE OF WELL: Geological Exploration
DRILLER: Sonora Drilling Company

DRILLING RECORD: **Date Started:** 06/28/76 **Date Completed:** 08/05/76

CASING RECORD:
Diameter: 13 3/8
Grade:
Wt/Ft: 54.5
From: 0
To: 42
Cement:

Diameter: 8 5/8
Grade:
Wt/Ft: 28
From: 0
To: 885
Cement: 660 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 4919
Cement: 2481 Cu. Ft.

Note: Completed logging. Ran 7 7/8" bit in the hole and conditioned mud to run casing. Corrected total depth to 4922'. Laid down drill pipe. Ran 123 joints (4933.72') of 5 1/2" O.D., 15.50#, J-55, range 3, ST&C casing in the hole and landed at 4918.77' (4907.22' GL). A Halliburton guide shoe was on bottom with a float shoe at 4859.52' GL. Centralizers were placed at 4905' GL, 4827' GL, 800' GL and 50' GL. 38 joints (1533.25') of casing were sand blasted for better bond from 2374' to 4907' KB.

Completed running casing. Cemented annulus using Halliburton with 1500 sacks (2085 cu ft) of 50-50 Pozmix "C" with 9.7 #/sk of salt and 2% bentonite followed by 300 sacks (396 cu ft) of Class "C" cement. Displaced cement with 117 barrels of water. Casing was reciprocated during displacement. After displacing 90 barrels approximately 2 barrels of cement circulated to the surface, circulation was lost at this point. Bumped plug with 2000 psi and held. Cement in place at 0220 hours. Ran Dresser Atlas temperature log, top of cement at 880'. Ran Sperry-Sun gyroscopic multishot survey in the hole on 25' stations and 100' stations out of the hole.

All depths are measured from Kelly Bushing 11.5' above ground level.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-309	Sand	0-5.6
	Caliche	5.6-14
	Gatuna	14-19.8
	Santa Rosa	19.8-22
	Dewey Lake	22-39.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-309**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: South Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 39.4'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/02/79 **Date Completed:** 02/02/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

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APPENDIX BRAGFLO

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INTRODUCTION

The following text describing the theory and implementation of the BRAGFLO (Brine and Gas Flow) code is taken verbatim from Chapter 4 of the BRAGFLO Users' Manual (Sandia National Laboratories, 1996). The complete text of the Users' Manual is available in the Sandia WIPP Central Files in Albuquerque, as part of a quality assurance (QA) package that documents the use of the code in evaluations of regulatory compliance. The text provided here is unchanged from the QA documentation, except for page numbering and section numbering. Details concerning qualification of the BRAGFLO code can be found in Chapter 7 of the NMVP.

1.0 Description of the Models and Methods

Quantification of gas and brine flow requires use of a two-phase flow code. For performance assessment, the DOE uses the two-phase flow code BRAGFLO to simulate gas and brine flow as well as to incorporate the effects of disposal room consolidation and closure, gas generation, and interbed fracture in response to gas pressure. This section develops the governing equations for BRAGFLO, its initial and boundary conditions, and the submodels incorporated in BRAGFLO that were developed specifically for performance assessment of the WIPP.

1.1 One-Dimensional Fluid Flow in Porous Media

Historically, BRAGFLO was developed as a two phase flow model for petroleum production applications. For this reason, BRAGFLO uses terminology common to the petroleum industry. Further details of the concepts necessary for the finite difference solution of reservoir simulation problems are available in Peaceman (1977), Aziz and Settari (1979), and Thomas (1982).

We consider now the material balance equation governing the flow of a fluid in a one dimensional porous media. Figure 1 shows a one-dimensional reservoir with area-normal-to-flow as a function of x; Area = A(x). The flow streamlines will actually flare in or out due to the variable area. However, we make the assumption that density and velocity are representative of average properties over the area normal to flow. From the reservoir, select an element of volume of incremental length Δx.

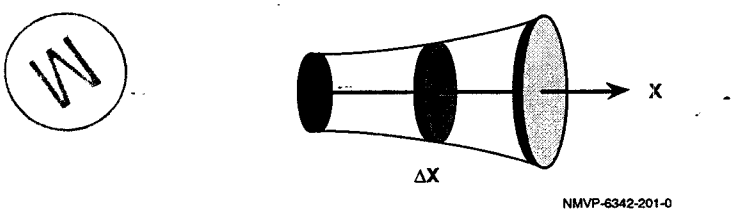


Figure 1. One dimensional reservoir with area-normal-to-flow as a function of x.

Let

Q = volume flow rate [l^3/t]
ρ = fluid density [m/l^3]
q = mass flow rate [m/t]
v = flow velocity [l/t]
ϕ = porosity [pore volume/bulk volume]
A = normal cross-section area [l^2]

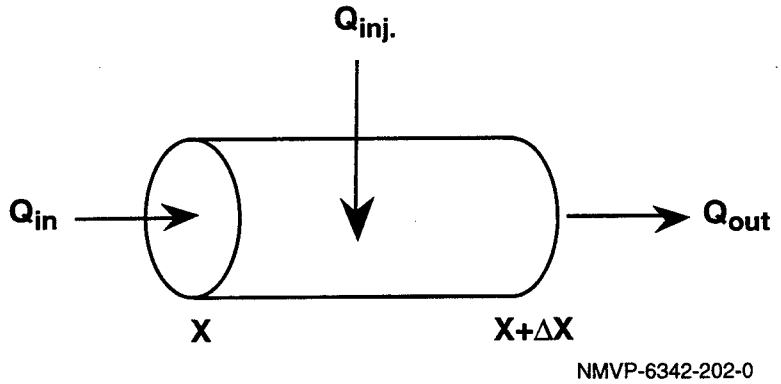


Figure 2. Element of volume of length Δx.

The mass rate and volume rate of flow are related by $q = \rho Q$.

The sign convention on Q_{inj} is

$Q_{inj} > 0$, injection,
$Q_{inj} < 0$, production.

Also, Q_{inj} = volume rate/injected volume, which implies fluid injection is uniformly distributed over control volume $A\Delta x$.

Mass balance requires that

$$q_{in} - q_{out} + q_{inj} A\Delta x = \text{change in fluid mass/time}$$

where

q_{inj} = mass injection rate/unit volume.

Now

$$q_{in} = (vA\rho)_x$$

$$q_{out} = (vA\rho)_{x+\Delta x}$$

and

$$\text{rate of change of fluid mass} = \frac{\partial}{\partial t}(\phi A\Delta x\rho).$$

The mass balance is then

$$(vA\rho)_x - (vA\rho)_{x+\Delta x} + q_{inj} A\Delta x = \frac{\partial}{\partial t}(\phi A \Delta x \rho).$$

Express the area as $A = \alpha(x)$, then dividing by Δx yields

$$\frac{(\alpha v\rho)_x - (\alpha v\rho)_{x+\Delta x}}{\Delta x} + \alpha q_{inj} = \frac{\partial}{\partial t}(\alpha\phi\rho).$$

In the limit as $\Delta x \to 0$, we get the material balance equation for one-dimensional single phase flow

$$-\frac{\partial}{\partial t}(\alpha v\rho) + \alpha q_{inj} = \frac{\partial}{\partial t}(\alpha\phi\rho)$$

1.2 Darcy's Law

For the viscous flow of a fluid through a porous media the flow velocity is related to the fluid potential by Darcy's Law. Henry Darcy (1856) at Dijon, France, developed a mathematical model from empirical data gathered in experiments using the device illustrated in Figure 3.

In Figure 3, Q is volume flow rate [l^3/t] and positive distance is measured from L_2 to L_1. Potential is measured as

$$\Phi = p + \rho g h$$

where depth, h, is measured positive upward from a reference datum and gravity acts downward. For example, a fluid in gravity equilibrium, ϕ = constant, exhibits a pressure increase with decrease in depth.

Darcy observed that

$$Q > 0, \text{ if } \Phi_2 > \Phi_1$$
$$Q < 0, \text{ if } \Phi_2 < \Phi_1$$

$$Q = 0, \text{ if } \Phi_2 = \Phi_1 .$$

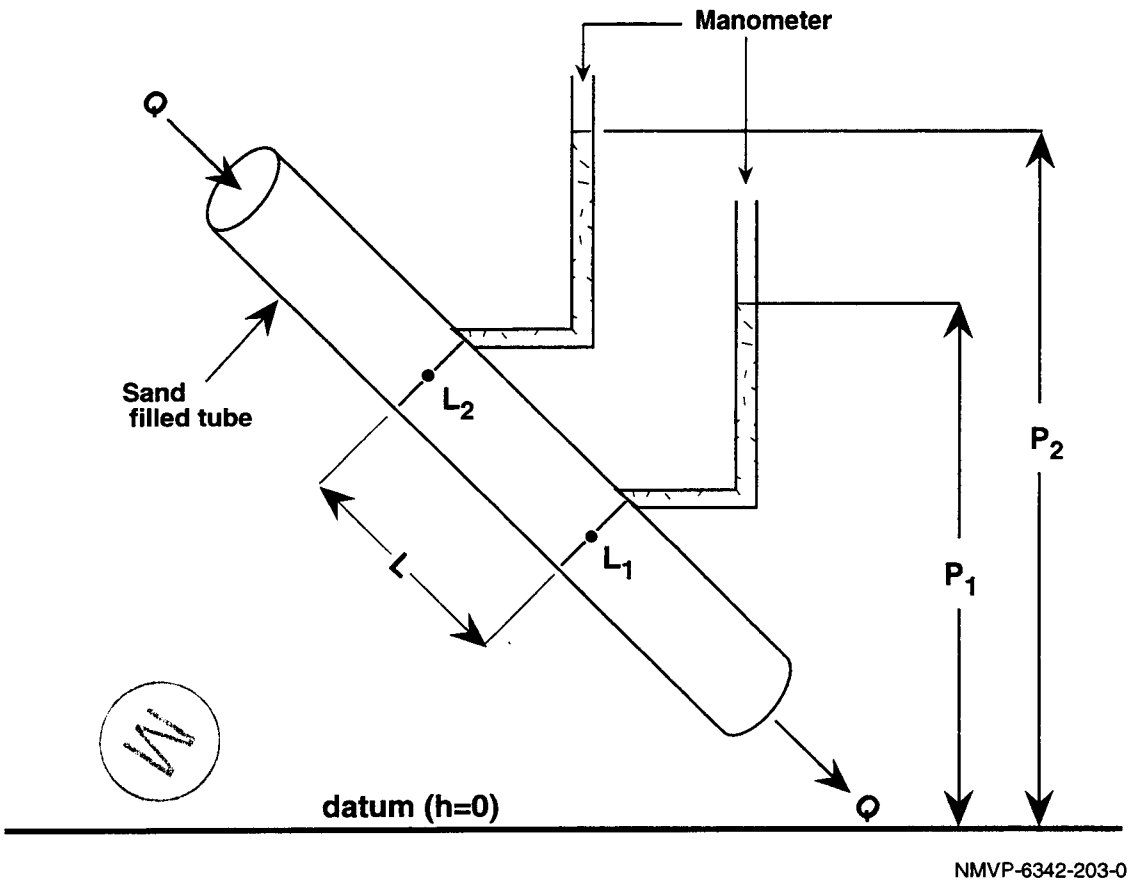


Figure 3. Experiment for illustration of Darcy's Law.

The implication is that flow is in the direction of decreasing potential. Next, Darcy observed that if $\Phi_2 - \Phi_1$ is doubled, Q is doubled. Thus

$$Q \approx \Phi_2 - \Phi_1 \quad (\approx \text{ is read proportional to})$$

Also, if L is doubled, Q is halved. Thus

$$Q \approx \frac{\Phi_2 - \Phi_1}{L}$$

If cross-sectional area is doubled, Q is doubled. Thus

$$Q \approx \frac{A(\Phi_2 - \Phi_1)}{L}$$

If the fluid is changed (different viscosity), then

$$Q \approx \frac{A(\Phi_2 - \Phi_1)}{\mu L}$$

Finally,

$$Q = \frac{kA(\Phi_2 - \Phi_1)}{\mu L}$$

where the constant of proportion, k, is called the absolute permeability of the media. The differential form of Darcy's Law is obtained when $L \to 0$,

$$Q = \frac{-kA}{\mu}\frac{d\Phi}{dx}.$$

The negative sign in Darcy's Law indicates flow is in the direction of decreasing potential. The units used in BRAGFLO are

$Q = m^3/s$
$A = m^2$
$\mu = Pa \cdot s$
$\frac{d\Phi}{dx} = \frac{Pa}{m}$

The units for permeability are

$$k = \left[\frac{m^3}{s}\right][Pa \cdot s]\left[\frac{1}{m^2}\right]\left[\frac{m}{Pa}\right] = m^2.$$

Velocity is given by

$$v = \frac{Q}{A} = -\frac{k}{\mu}\frac{d\Phi}{dx},$$

where v is called the Darcy velocity or superficial flow velocity. The quantity

$$V = \frac{Q}{A\phi} = \frac{v}{\phi} = \frac{\text{bulk volume}}{\text{normal area}} / \text{time}$$

is called the interstitial or average linear velocity, where ϕ is the formation porosity.

The distinction between the Darcy velocity and the interstitial velocity is demonstrated in Figure 4. Assume fluid in the unit bulk volume at the left end of the reservoir is displaced by a piston over unit time into a media with porosity $\phi = 0.20$. The cubic meter of fluid will occupy 5 m^3 of the porous material and the fluid will advance to a position 5 meters from the interface. The velocity of the fluid in the bulk volume is Q/A or the Darcy velocity, while the fluid velocity in the porous material is $Q/A/\phi$ or the interstitial velocity. For example, if a tracer element were introduced into the porous material it would travel at the interstitial velocity. The Darcy velocity is the rate at which the bulk volume is transported.

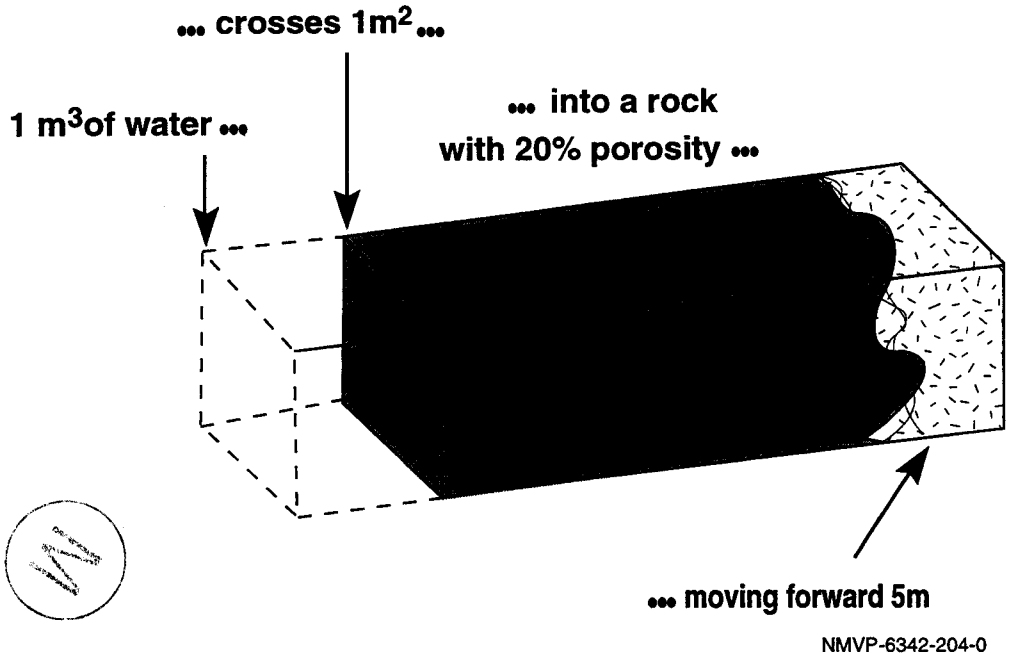


Figure 4. Bulk volume vs. Porous Media Displacement.

1.3 Permeability Tensor, Darcy's Law, and Material Balance in Higher Dimension

The permeability of a geological formation can be direction dependent (anisotropic). For example, a sedimentary formation may consist of uniform sand or lime laminae of high permeability alternating with thin, uniform layers of silty, shaley laminae of low permeability. The large scale permeability characteristics can be approximated as uniformly anisotropic. That is, the layered system is replaced by a homogeneous system having permeabilities k_1 parallel to the plane of the laminae and k_2 normal to this plane. Further, the direction of the laminae may not be parallel or normal to the formation boundary as evident in a cross-bedded structure.

Figure 5 shows two cartesian coordinate systems (ξ,η) and (x,y). Suppose the principal permeabilities are given with respect to (ξ,η) system with k_1 the permeability in the ξ

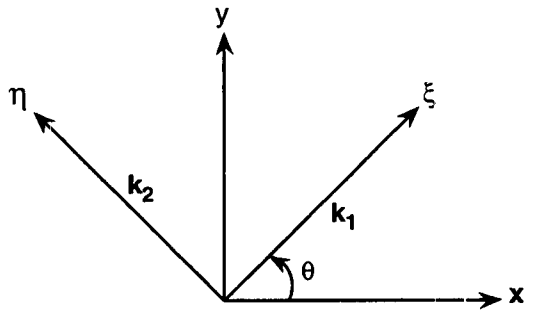


Figure 5. Permeability with anisotropic values k_1 and k_2 in direction ξ and η

direction and k_2 the permeability in the η direction. Further, assume the reservoir geometry is aligned with respect to the (x,y) system, which implies that the fluid flow equations are to be formulated with respect to the x,y axes.

The coordinate transformation from the (ξ,η) system to the (x,y) system is

$$x = \xi \cos\theta - \eta \sin\theta.$$
$$y = \xi \sin\theta + \eta \cos\theta.$$

If $\hat{1}_\xi$ and $\hat{1}_\eta$ represent the unit vectors in the ξ,η directions, respectively, then the Darcy velocity vector is

$$\hat{v} = \frac{k_1}{\mu}\frac{\partial\Phi}{\partial\xi}\hat{1}_\xi - \frac{k_2}{\mu}\frac{\partial\Phi}{\partial\eta}\hat{1}_\eta.$$

The coordinate transformation maps the unit vectors into

$$\hat{1}_\xi \rightarrow \cos\Phi\,\hat{1}_x + \sin\Phi\,\hat{1}_y$$

and

$$\hat{1}_\eta \rightarrow -\sin\Phi\,\hat{1}_x + \cos\Phi\,\hat{1}_y .$$

The chain rule gives

$$\frac{\partial\Phi}{\partial\xi} = \cos\theta\frac{\partial\Phi}{\partial X} + \sin\theta\frac{\partial\Phi}{\partial y}$$

and

$$\frac{\partial \Phi}{\partial \xi} = -\sin\theta \frac{\partial \Phi}{\partial X} + \cos\theta \frac{\partial \Phi}{\partial y}.$$

Then the Darcy velocity is

$$\hat{v} = \frac{-k_1}{\mu}\left(\cos\theta \frac{\partial \Phi}{\partial x} + \sin\Phi \frac{\partial \Phi}{\partial y}\right)\left(\cos\theta\ \hat{1}_x + \sin\theta\ \hat{1}_y\right)$$

$$\frac{-k_2}{\mu}\left(-\sin\theta \frac{\partial \Phi}{\partial x} + \cos\Phi \frac{\partial \Phi}{\partial y}\right)\left(-\sin\theta\ \hat{1}_x + \cos\theta\ \hat{1}_y\right)$$

The vector components of the Darcy velocity are

$$v_x = \frac{-k_1}{\mu}\left(\cos^2\theta \frac{\partial \Phi}{\partial x} + \sin\theta\cos\theta \frac{\partial \Phi}{\partial y}\right)$$

$$\frac{-k_2}{\mu}\left(\sin^2\theta \frac{\partial \Phi}{\partial x} - \sin\theta\cos\theta \frac{\partial \Phi}{\partial y}\right),$$

$$v_y = \frac{-k_1}{\mu}\left(\sin\theta\cos\theta \frac{\partial \Phi}{\partial x} + \sin^2\theta \frac{\partial \Phi}{\partial y}\right)$$

$$\frac{-k_2}{\mu}\left(-\sin\theta\cos\theta \frac{\partial \Phi}{\partial x} + \cos^2\theta \frac{\partial \Phi}{\partial y}\right).$$

The dependence of the Darcy velocity components on pressure gradients in both x and y direction will add significantly to the complexity of the material balance equation in 2-dimensions. A similar analysis with more complexity could be performed in 3-dimensions.

A significant simplification occurs if the directions of the permeability tensor are aligned with the reservoir coordinate axis; that is, $\theta = 0$. If $\theta = 0$, then

$$v_x = \frac{-k_1}{\mu}\frac{\partial \Phi}{\partial x} \quad \text{and} \quad v_y = \frac{-k_2}{\mu}\frac{\partial \Phi}{\partial y}.$$

BRAGFLO makes this assumption. Thus, in three dimensions with anisotropic permeability, the components of the Darcy velocity are

$$v_x = \frac{-k_x}{\mu}\frac{\partial\Phi}{\partial x},\ v_y = \frac{-k_y}{\mu}\frac{\partial\Phi}{\partial y},\ v_z = \frac{-k_z}{\mu}\frac{\partial\Phi}{\partial z}$$

where k_x, k_y, k_z are input permeabilities in the direction of the corresponding coordinate axes. To generalize the flow equation to higher dimension, we replace the flux term with (Peaceman 1977)

$$\nabla\bullet\left(\frac{\alpha\rho[k]}{\mu}\nabla\Phi\right) = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right)\bullet\left(\frac{\alpha\rho k_x}{\mu}\frac{\partial\Phi}{\partial x}\hat{i} + \frac{\alpha\rho k_y}{\mu}\frac{\partial\Phi}{\partial y}\hat{j} + \frac{\alpha\rho k_z}{\mu}\frac{\partial\Phi}{\partial z}\hat{k} + \right)$$

$$= \frac{\partial}{\partial x}\left(\frac{\alpha\rho k_x}{\mu}\frac{\partial\Phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\alpha\rho k_y}{\mu}\frac{\partial\Phi}{\partial y}\right) + \frac{\partial}{\partial z}\left(\frac{\alpha\rho k_z}{\mu}\frac{\partial\Phi}{\partial z}\right)$$

where

[k] = permeability tensor,

α = area normal to flow direction in one dimension (x),

= thickness normal to flow plane in two-dimensions (x,y),

= 1 in three-dimension (x,y,z).

The three-dimensional flow of a single fluid incorporating Darcy's law is

$$\frac{\partial}{\partial x}\left(\frac{\alpha\rho k_x}{\mu}\frac{\partial\Phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\alpha\rho k_y}{\mu}\frac{\partial\Phi}{\partial y}\right) + \frac{\partial}{\partial z}\left(\frac{\alpha\rho k_z}{\mu}\frac{\partial\Phi}{\partial z}\right) + \alpha q_{inj} = \frac{\partial}{\partial t}(\alpha\phi\rho)$$

1.4 Equation of State

From the previous section the three dimensional flow of a single phase fluid is governed by the equation

$$\frac{\partial}{\partial x}\left(\frac{\alpha\rho k_x}{\mu}\frac{\partial\Phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\alpha\rho k_y}{\mu}\frac{\partial\Phi}{\partial y}\right) + \frac{\partial}{\partial z}\left(\frac{\alpha\rho k_z}{\mu}\frac{\partial\Phi}{\partial z}\right) + \alpha q_{inj} = \frac{\partial}{\partial t}(\alpha\phi\rho)$$

This equation has two dependent variables, pressure, p, and density, ρ. Independent variables are space (x, y, and z) and time (t). We must relate ρ and p and hence eliminate one of the dependent variables. This problem is generally treated over three fluid regimes:

- incompressible fluid (ρ = constant)
- slightly compressible fluid (water, oil)
- highly compressible fluid (gas)

The incompressible fluid assumption is not valid for most applications and will not be considered.

Slightly compressible fluid assumes:

$$\frac{d\rho}{dp} = c\rho,$$

where c is fluid compressibility.

For ideal fluid c = constant. Then the differential equation can be solved as

$$\rho = \rho_o \exp\left(c(p - p_o)\right)$$

where ρ_o is density at reference pressure p_o. This is the equation BRAGFLO uses to evaluate brine density.

Recall

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots$$

and if x is close to zero

$$e^x \cong 1 + x.$$

Therefore, if $c(p-p_o)$ is relatively small, then

$$\rho \cong \rho_o\left(1 + c(p - p_o)\right).$$

This linearization is sometimes used as an approximation to the exponential density function.

A highly compressible fluid such as gas requires a real gas equation of state

$$\rho = \rho(p,T)$$

which, for isothermal flow, gives density as a function of pressure. BRAGFLO uses the Redlich-Kwong-Soave equation of state to relate gas density to pressure.

The formation rock behaves as a sightly compressible material which yields an expression for porosity analogous to the expression for brine density. In BRAGFLO the formation porosity is evaluated as

$$\phi = \phi_o \exp\left(c_r(p - p_o)\right)$$

where ϕ_o is the porosity at reference pressure p_o and c_r denotes rock compressibility.

With the equation of state the material balance equation is formulated and solved in terms of a single dependent variable, namely pressure. Note that the partial differential equation (PDE) is nonlinear. Nonlinearity occurs from several sources:

- nonlinear dependence of density on pressure
- product of density and pressure gradient
- product of porosity and density in accumulation term since porosity is pressure dependent due to rock compressibility
- viscosity could be pressure dependent for gases, however, BRAGFLO treats viscosity constant for both water and gas.

For the one-dimensional case of the equation presented at the end of Section 4.3,

$$\frac{\partial}{\partial x}\left(\frac{\alpha \rho k_x}{\mu}\frac{\partial \Phi}{\partial x}\right) + q_{inj} = \frac{\partial}{\partial t}(\alpha \phi \rho)$$

the material balance equation (PDE) requires:

initial conditions:

$$p(x,0) = f(x),\ 0 \le x \le L$$

and

boundary conditions:

$$p(0,t) = g_o(t), \qquad p(L,t) = g_L(t),\ t \ge 0$$

or

$$\frac{\partial p}{\partial x}(0,t) = g_o(t), \qquad \frac{\partial p}{\partial x}(L,t) = g_L(t) \qquad t \ge 0.$$

The first type of boundary condition in which the solution is specified at the boundary is called a Dirchlet boundary condition. The condition in which the pressure gradient is

specified is called a Neumann boundary condition. Generally, most reservoir simulations assume $\frac{\partial p}{\partial x} = 0$ on the boundary (no flow boundary condition). The boundary condition may be of mixed type. BRAGFLO assumes a no flow Neumann type boundary condition at all exterior grid boundaries.

BRAGFLO has the capability of maintaining (Dirichlet condition) pressure and/or saturation at specified grid blocks. This allows the maintenance of initial conditions at far field locations in the upper formations such as the Culebra.

1.5 Finite Difference and Discretization of Material Balance Equation

Recall Taylor's formula with remainder for a function f expanded about x_o

$$f(x) = f(x_o) + f'(x_o)(x - x_o) + \frac{f^{(2)}(x_o)}{2!}(x - x_o)^2$$
$$+ \ldots + \frac{f^{(n)}(x_o)}{n!}(x - x_o)^n + \frac{f^{(n+1)}(\xi)}{(n+1)!}(x - x_o)^{n+1}$$

where ξ is the interval between x and x_o. Thus

$$f(x) = p(x) + R_n(x,x_o)$$

or

$$f(x) - p(x) + R_n(x,x_o).$$

if $f^{(n+1)}$ is continuous on some interval [a,b] containing, x,x_o, then $f^{(n+1)}$ is bounded,

$$|f^{(n+1)}(x)| \le M,$$

and

$$|f(x) - p(x)| \le C|x - x_o|^{n+1}.$$

Therefore, as $x \to x_o$, the error goes to zero like $(x-x_o)^{n+1}$. Consider the following derivative approximations. First order forward difference requires the Taylor formula:

$$f(x) = f(x_o) + f'(x_o)(x - x_o) + R_2(x,x_o)$$

Let $x = x_o + h$, then

$$\left| \frac{f(x_o + h) - f(x_o)}{h} - f'(x_o) \right| = \left| \frac{R_2(x,x_o)}{h} \right| \le \frac{Ch^2}{h} = Ch.$$

The difference approximation

$$f'(x_o) \cong \frac{f(x_o + h) - f(x_o)}{h}$$

is said to be first order in h. This type of approximation is used for the time derivative. Second order central approximation:

$$f(x_o + h) = f(x_o) + f'(x_o)h + \frac{f^{(2)}(x_o)}{2!}h^2 + R_3(x_o, x_o + h)$$

$$f(x_o - h) = f(x_o) - f'(x_o)h + \frac{f^{(2)}(x_o)}{2!}h^2 + R_3(x_o, x_o - h)$$

where subtraction yields

$$f(x_o + h) - f(x_o - h) = 2hf'(x_o) + R_3(x_o, x_o + h) - R_3(x_o, x_o - h).$$

This is rearranged to give:

$$\frac{f(x_o + h) - f(x_o - h)}{2h} - f'(x_o) = \frac{R_3(x_o, x_o + h) - R_3(x_o, x_o - h)}{2h}$$

which produces the estimate

$$\left| \frac{f(x_o + h) - f(x_o - h)}{2h} - f'(x_o) \right| \leq \frac{Ch^3}{h} = Ch^2.$$

Therefore, the difference approximation $\frac{f(x_o + h) - f(x_o - h)}{h}$ is a second order approximation to $f'(x_o)$.

Consider discretization of the one-dimensional material balance equation:

$$\frac{\partial}{\partial x}\left(\frac{\alpha k \rho}{\mu} \frac{\partial p}{\partial x} \right) + \alpha q_{inj} = \frac{\partial}{\partial t}(\alpha \phi \rho),$$

where we assume the gradient of the depth is zero.

Space discretization requires the partition of the interval [0,L] into IM subintervals with length Δx_i, I=1,2,..., IM.

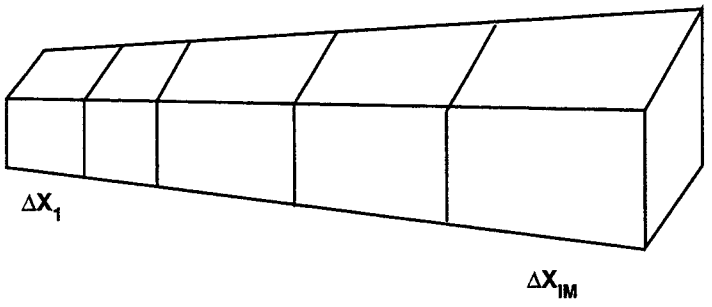


Figure 6. Partition interval [0,L] into IM subintervals.

Consider an arbitrary grid block i and its neighbors i-1, i+1 as shown in Figure 7.

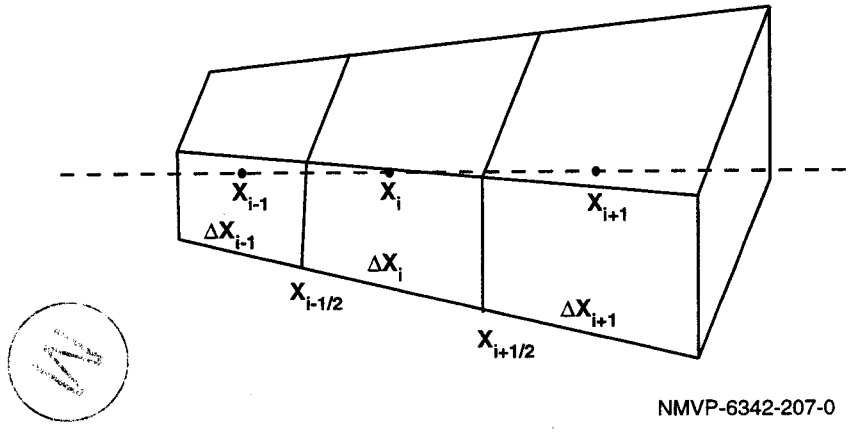


Figure 7. Depiction of arbitrary grid block.

We reference the location of the grid block interfaces as

$x_{i-1/2}$ = location of interface between i-1 and i,

$x_{i+1/2}$ = location of interface between i and i+1.

For example,

$$x_{i-1/2} = x_{i-1} + \Delta x_{i-1/2} .$$

On the ith grid block the partial derivative in the flux term is approximated by the 2nd order correct finite difference

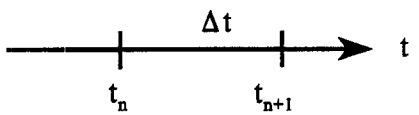
$$\frac{\partial}{\partial x}\left(\frac{\alpha k\rho}{\mu}\frac{\partial p}{\partial x}\right) \cong \frac{\left(\frac{\alpha k\rho}{\mu}\frac{\partial p}{\partial x}\right)_{i+1/2} - \left(\frac{\alpha k\rho}{\mu}\frac{\partial p}{\partial x}\right)_{i-1/2}}{\Delta x_i}.$$

The partials are approximated at the interface by the 2nd order correct finite difference

$$\left(\frac{\alpha k\rho}{\mu}\frac{\partial p}{\partial x}\right)_{i-1/2} = \left(\frac{\alpha k\rho}{\mu}\right)_{i-1/2}\frac{p_i - p_{i-1}}{x_i - x_{i-1}}.$$

A similar expression exists at $i + \frac{1}{2}$. If the gridding is nonuniform then the above approximations are no longer 2nd order correct.

Time discretization is as shown below.



Assume the solution is known at time t_n, and we wish to compute a solution at time t_{n+1} with time step size $\Delta t = t_{n+1} - t_n$. The time discretization of the accumulation term in the ith grid block uses the first order correct finite difference

$$\frac{\partial}{\partial t}(\alpha\phi\rho) \cong \frac{(\alpha\phi\rho)_i^{n+1} - (\alpha\phi\rho)_i^n}{\Delta t},$$

where the superscript references the time index. The fully discretized system of equations can be written as

$$\frac{(\alpha\phi\rho)_i^{n+1} - (\alpha\phi\rho)_i^n}{\Delta t} - \frac{1}{\Delta x_i}\left(\frac{(\alpha k\rho)}{\mu}\right)_{i+1/2}\frac{p_{i+1} - p_i}{x_{i+1} - x_i} + \frac{1}{\Delta x_i}\left(\frac{(\alpha k\rho)}{\mu}\right)_{i-1/2}\frac{p_i - p_{i-1}}{x_i - x_{i-1}} - \alpha_i(q_{inj})_i = 0,$$

$i = 1,2,...,IM.$

In this equation, the time level is not indicated on the pressure and pressure dependent variables in the flux and injection terms.

If all the pressures and pressure dependent variables in the flux and source/sink terms are evaluated at the beginning of the time step, $t\text{-}t_n$, then the formulation is called explicit. If these quantities are evaluated at the end of the time step, $t=t_{n+1}$ the formulation is called implicit.

The numerical solution of the material balance equation starts at initial time with specified initial pressures. The evaluation of the pressure solution in time requires at each time step the solution of a system of nonlinear equations for the grid block pressures. The error introduced by the discretization of the continuum equation is called truncation error. Errors will also be introduced in the nonlinear equation solver since it will not solve the system exactly (see Subsection 4.6, Newton-Raphson Method). Another source of error involves the choice of discretization. A numerical artifact of the solution of evolution equations is that small errors introduced at early time can be either damped with time (stable) or grow with time (unstable). The errors in an unstable solution will usually grow large enough to dominate the solution with numerical noise. The numerical stability of a discretization can sometimes depend on the size of the space discretization (Δx) relative to the time discretization (Δt). In this case, the method is said to be conditionally stable.

In the above formulations (explicit, implicit) we observe that

Formulation Advantages:

Explicit is simplistic computationally.

Implicit is unconditionally stable.

Formulation Disadvantages:

Implicit is complex computationally.

Explicit is conditionally stable.

The stability question dictates that the BRAGFLO formulation be fully implicit. The evaluation of the interblock flux coefficients at $i\pm\frac{1}{2}$ will be discussed in Subsection 4.8, on Two Phase Flow.

1.6 Newton-Raphson Method for Solution of Nonlinear Algebraic Equations

Consider a real valued function of a real variable (scalar case). A root of f is a value x = a such that f(a) = 0. Let x^k be an approximation to the root of f (k^{th} iterate approximation). Expand f(x) in a Taylor series about x_k:

$$f(x) = f(x^k) + f'(x^k)(x - x^k) + \frac{f^{(2)}(x^k)}{2!}(x - x^k)^2 + \ldots = 0.$$

Replace the nonlinear root problem with the linear approximation:

$$f(x^k) + f'(x^k)(x - x^k) = 0$$

with solution $x = x^{k+1}$. Define

$$\delta x^k = x^{k+1} - x^k$$

Then

$$\delta x^k = -\frac{f(x^k)}{f'(x^k)},$$

and

$$x^{k+1} = x^k + \delta x^k.$$

The Newton-Raphson iteration requires an initial guess to the root. In Figure 8 it appears from the geometry that the iteration would proceed to the root of f. If the initial guess was not close to the solution, such as to the right of the maximum in Figure 8, then the iteration may not converge or it could converge to another solution. When solving the system of nonlinear material balance equations over a time step, the solution at the beginning of the time step is used as an initial guess for the Newton-Raphson iteration.

In general consider a system of n nonlinear equations (NLS) in n unknowns:

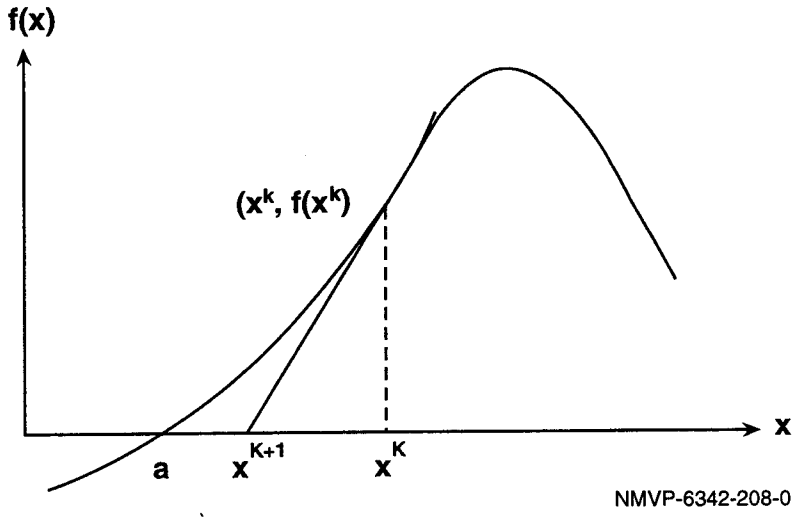


Figure 8. Newton-Raphson method.

$$f_1(x_1,\ldots,x_n) = 0$$

$$f_2(x_1,\ldots,x_n) = 0$$

$$\vdots \qquad \text{(NLS)}$$

$$f_n(x_1,\ldots,x_n) = 0$$

In vector notation, the system is written

$$f(x_1,\ldots,x_n) = \begin{pmatrix} f_1(x_1,\ldots x_n) \\ \vdots \\ f_n(x_1,\ldots x_n) \end{pmatrix} = 0,$$

and further, if $\hat{x} = (x_1,\ldots x_n)$, then, $F(\hat{x}) = 0$ is equivalent to (NLS).

Consider Newton-Raphson for n = 2. Let $\left(x_1^k, x_2^k\right)$ be an approximation to the root of

$$f_1(x_1, x_2) = 0$$

$$f_2(x_1, x_2) = 0.$$

1 The Taylor series through linear terms expanded about $\left(x_1^k, x_2^k\right) = \hat{x}^k$ are

$$f_1(x_1,x_2) = f_1(x_1^k,x_2^k) + \frac{\partial f_1}{\partial x_1}(x_1^k,x_2^k(x_1 - x_1^k) + \frac{\partial f_1}{\partial x_2}(x_1^k,x_2^k)(x_2 - x_2^k)$$

$$f_2(x_1,x_2) = f_2(x_1^k,x_2^k) + \frac{\partial f_2}{\partial x_1}(x_1^k,x_2^k(x_1 - x_1^k) + \frac{\partial f_2}{\partial x_2}(x_1^k,x_2^k)(x_2 - x_2^k).$$

2 Replace the system of nonlinear equations

$$f_1(x_1, x_2) = 0$$

$$f_2(x_1, x_2) = 0$$

3 by the linear system

$$\frac{\partial f_1}{\partial x_1}(\hat{x}^k)\left(x_1^{k+1} - x_1^k\right) + \frac{\partial f_1}{\partial x_2}(\hat{x}^k)\left(x_2^{k+1} - x_2^k\right) = -f_1(\hat{x}^k)$$

$$\frac{\partial f_2}{\partial x_1}(\hat{x}^k)\left(x_1^{k+1} - x_1^k\right) + \frac{\partial f_2}{\partial x_2}(\hat{x}^k)\left(x_2^{k+1} - x_2^k\right) = -f_2(\hat{x}^k)$$

4 Define the change in iterate values

$$\delta x_1 = x_1^{k+1} - x_1^k$$

$$\delta x_2 = x_2^{k+1} - x_2^k.$$

5 Then the above linear system is written

$$\frac{\partial f_1}{\partial x_1}(\hat{x}^k)\delta x_1 + \frac{\partial f_1}{\partial x_2}(\hat{x}^k)\delta x_2 = -f_1(\hat{x}^k)$$

$$\frac{\partial f_2}{\partial x_1}(\hat{x}^k)\delta x_1 + \frac{\partial f_2}{\partial x_2}(\hat{x}^k)\delta x_2 = -f_2(\hat{x}^k)$$

6 The coefficient matrix

$$J(\hat{x}) = \begin{pmatrix} \frac{\partial f_1}{\partial x_1}(\hat{x}) & \frac{\partial f_1}{\partial x_2}(\hat{x}) \\ \frac{\partial f_2}{\partial x_1}(\hat{x}) & \frac{\partial f_2}{\partial x_2}(\hat{x}) \end{pmatrix}$$

is called the Jacobian matrix for the nonlinear system.

Then the $(k+1)^{th}$ iterative step of the Newton-Raphson method is

$$J(\hat{x}^k)\delta\hat{x} = -F(\hat{x}^k)$$

or

$$\delta\hat{x} = -J^{-1}(\hat{x}^k)F(\hat{x}^k)$$

and

$$\hat{x}^{k+1} = \hat{x}^k + \delta\hat{x}.$$

For a system of n equations in n unknowns the Jacobian matrix generalizes to

$$J(\hat{x}) = \begin{pmatrix} \frac{\partial f_1}{\partial x_1}(\hat{x}) \cdots \frac{\partial f_1}{\partial x_n}(\hat{x}) \\ \vdots \\ \frac{\partial f_n}{\partial x_1}(\hat{x}) \cdots \frac{\partial f_n}{\partial x_n}(\hat{x}) \end{pmatrix}$$

or

$$J(\hat{x})_{i,j} = \frac{\partial f_i}{\partial x_j}(\hat{x}).$$

The computation procedure in Newton-Raphson method computes the Jacobian matrix, $J(\hat{x}^k)$, and the function vector, $F(\hat{x}^k)$. The matrix inversion is equivalent to the solution of a system of linear equations which returns the change in iterate values. The iterates are then updated.

When analytical derivatives are not tractable, Newton-Raphson uses difference approximation for partials

$$\frac{\partial f_i}{\partial x_j}(\hat{x}) = \frac{f_i(x_1,...,x_j + \Delta x_j,...,x_n) - f_i(x_1,...,x_n)}{\Delta x_j}.$$

The major computational effort involves the function evaluations. The above numerical approach to the Jacobian requires the evaluation of the function f n^2+n times.

If the Jacobian is evaluated by an analytic derivative then any change in the formulation of properties would require significant code changes. Also, some properties, see Characteristic Curves (Subsection 4.10), use different model descriptions with user input control. In this case it would be difficult to implement the analytic derivative treatment. For these reasons BRAGFLO uses the difference approximation for the Jacobian evaluation.

The modified Newton-Raphson algorithm is

$$J(\hat{x}^1)\delta\hat{x} = -F(\hat{x}^k), k = 1,2,...,$$

that is, the Jacobian is not updated each iteration. In BRAGFLO the user can specify from input directives the iteration frequency for the Jacobian evaluation.

Consider now the solution of the nonlinear flow equation. The ith equation represents material balance in i^{th} grid block. Newton-Raphson iteration requires solution of the linear system

$$\begin{bmatrix} J_{11} & J_{12} \cdots & J_{1IM} \\ J_{21} & J_{22} \cdots & J_{21M} \\ \vdots & & \\ J_{IM1} & J_{IM2} \cdots & J_{IMIM} \end{bmatrix} \begin{bmatrix} \delta p_1 \\ \delta p_2 \\ \vdots \\ \delta p_{IM} \end{bmatrix} = - \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_{IM} \end{bmatrix}.$$

and $p_i^{(k+1)} = p_i^{(k)} + \delta p_i$, where Jacobian and right hand side are evaluated at k^{th} iteration pressures. If the Newton-Raphson iteration converges then

$$\lim_{k \to \infty} p_i^{(k)} = p_i^{n+1}$$

From the flow equations we note the Jacobian matrix has a tridiagonal structure

$$\begin{bmatrix} J_{11} J_{12} o \cdots\cdots\cdots o \\ J_{21} J_{22} J_{23} \\ \ddots \ddots \ddots \\ o \cdots\cdots J_{ii-1} J_{ii} J_{ii+1} \cdots\cdots o \\ \ddots \ddots \ddots \\ o \cdots\cdots J_{IMIM-1} J_{IMIM} \end{bmatrix} \begin{bmatrix} \delta p_1 \\ \delta p_2 \\ \vdots \\ \delta p_i \\ \vdots \\ \delta p_{IM} \end{bmatrix} = - \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_i \\ \vdots \\ F_{IM} \end{bmatrix}$$

For both storage and computational considerations the linear equation solver should take advantage of the banded structure. This is true for all the BRAGFLO solvers.

1.7 Discretization in Two-Dimensions

Consider the two dimensional flow equation

$$\frac{\partial}{\partial x}\left(\frac{\alpha k_x \rho}{\mu}\frac{\partial p}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\alpha k_y \rho}{\mu}\frac{\partial p}{\partial y}\right) + \alpha q_{inj} = \frac{\partial}{\partial t}(\alpha\phi\rho)$$

Discretized equation in 2-dimensions with implicit treatment of the well and flux terms is

$$-\frac{(\alpha\phi\rho)_{i,j}^{n+1} - (\alpha\phi\rho)_{i,j}^{n}}{\Delta t} + \frac{1}{\alpha x_i}\left(\frac{\alpha k_x \rho}{\mu}\right)_{i+1/2,j}^{n+1} \frac{p_{i+1,j}^{n+1} - p_{i,j}^{n+1}}{x_{i+1} - x_i}$$

$$-\frac{1}{\Delta x_i}\left(\frac{\alpha k_x \rho}{\mu}\right)_{i-1/2,j}^{n+1} \frac{p_{i,j}^{n+1} - p_{i-1,j}^{n+1}}{x_i - x_{i-1}} + \frac{1}{\Delta y_j}\left(\frac{\alpha k_y \rho}{\mu}\right)_{i,j+1/2}^{n+1} \frac{p_{i,j+1}^{n+1} - p_{i,j}^{n+1}}{y_{j+1} - y_j}$$

$$-\frac{1}{\Delta y_j}\left(\frac{\alpha k_y \rho}{\mu}\right)_{i,j-1/2}^{n+1} \frac{p_{i,j}^{n+1} - p_{i,j-1}^{n+1}}{y_j - y_{j-1}} + \alpha_{i,j}(q_{inj})_{i,j} = 0.$$

A typical two dimensional grid is shown in Figure 9.

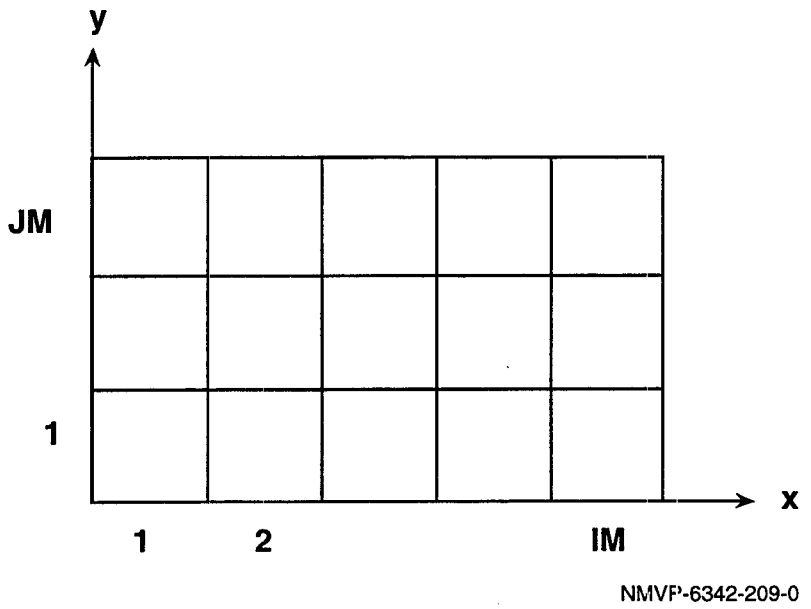


Figure 9. 2-dimensional grid.

A computational molecule or stencil is shown in Figure 10 and the stencil shows the indices of the pressures which appear in the material balance equation for the (i,j) grid block.

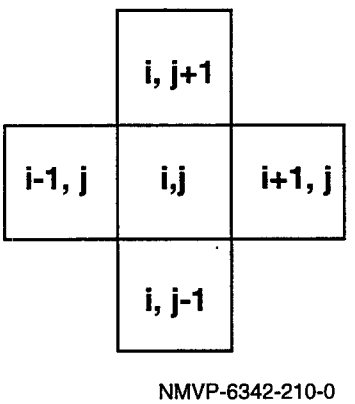


Figure 10. Computational molecule (or stencil).

With IM=5 and JM=3 in Figure 9, the number of equations is NEQ = IM * JM = 5 x 3 = 15. Suppose the equations or grid blocks are sequentially indexed as in Figure 11.

Then the Jacobian matrix has the structure shown in Figure 12 where * entries are the only nonzero values.

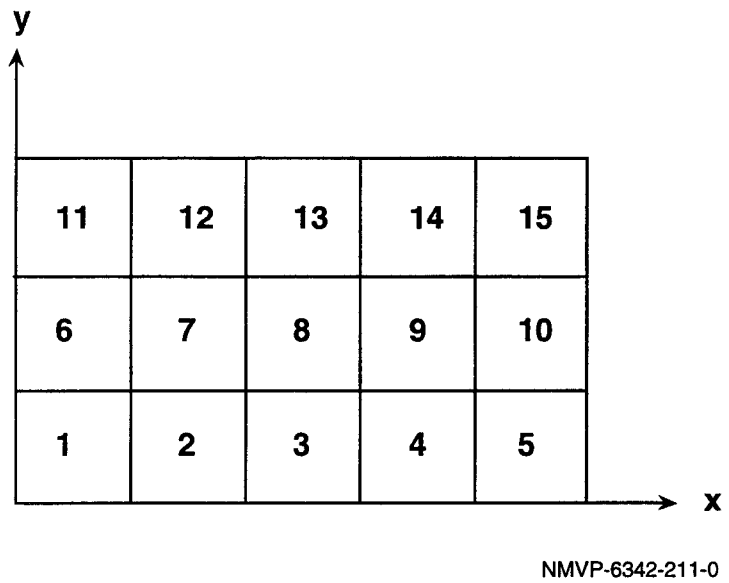


Figure 11. Sequential indexing of equations.

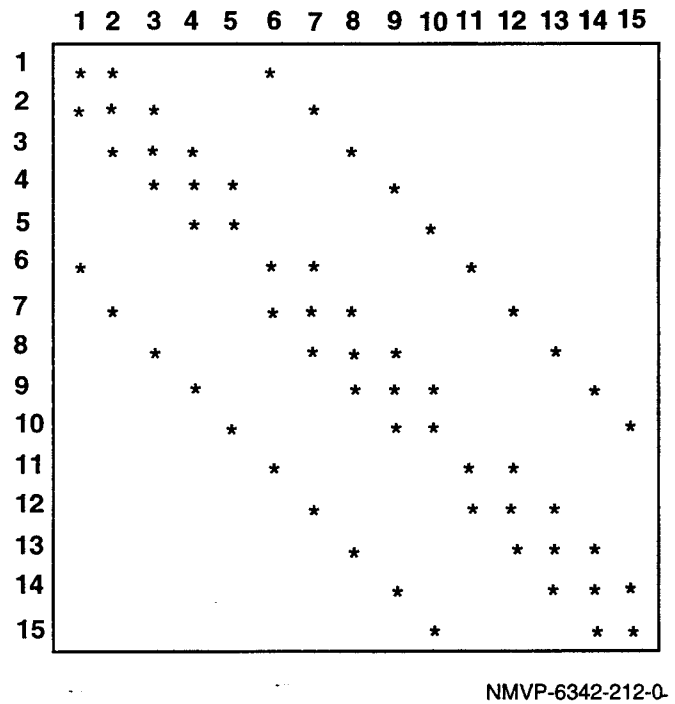


Figure 12. Jacobian matrix.

This is said to have penta-diagonal band structure, with bandwidth = IBW = 2IM + 1 (for the example, IBW=11).

Suppose the grid is indexed as in Figure 13.

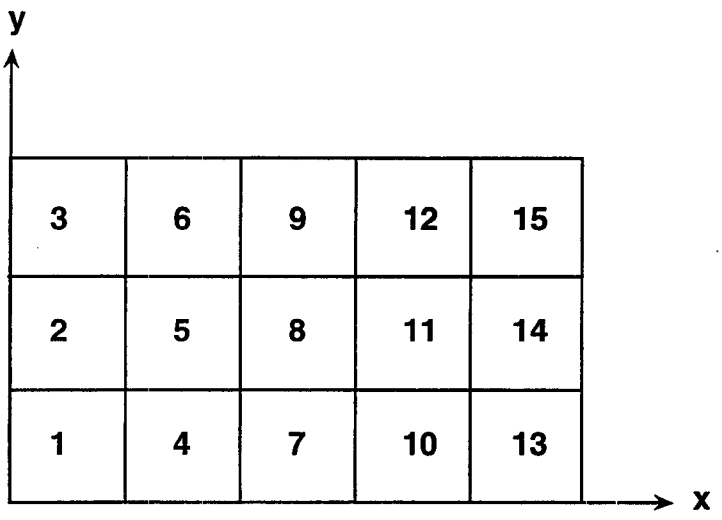


Figure 13. A different sequential indexing.

Then IBW = 2 * JM + 1 (for the example, IBW=7).

Therefore, to minimize the bandwidth, BRAGFLO orders the grid blocks so that sequential indexing proceeds first in the shortest grid direction, then in the longest grid direction. In this case

IBW = 2 * min (IM, JM) + 1.

Storage requirements are as follows:

Full matrix storage = $(IM * JM)^2$ words of memory
Band matrix storage = IM * JM * IBW words of memory

If IM ≤ JM then

$$\frac{\text{Band storage}}{\text{Full matrix storage}} = \frac{(2IM + 1) * IM * JM}{(IM * JM)^2} = \frac{2IM + 1}{IM * JM} \simeq \frac{2}{JM}$$

For various values of JM storage ratios are given by:

JM	Storage ratio
5	0.4 (40%)
10	0.2 (20%)
50	0.04 (4%)
100	0.02 (2%)

To determine the required computational effort assume the major effort is the multiplications/divisions.

Banded structure:

multiplication/division ≅ NEQ * IB * IB where IB is the half bandwidth,

IB = min (IM,JM).

Full matrix:

multiplication/division ≅ 1/3 NEQ^3

A typical performance assessment grid is

IM = 70
JM = 15
NEQ = 15(70) = 1050
IBW = 2(15) + 1 = 31
IB = 15

Computational effort

banded matrix structure = 1050 (15 * 15) = 236,250
full matrix structure = 1/3 $(1050)^3$ ≅ 3.86 E8.

The disparity in storage and computation between a band matrix solver and a full matrix solver is greater in two-dimensions than in one dimension. Of course, when solving 3-dimensional problems this disparity becomes even greater.

Although the equation solver is a major part of the time step calculation, other calculations involve evaluation of pressure dependent functions, coefficient generation, reporting and other overhead. However, the equation solver is a good indication of the computational effort for the time step solution. If the multiplication/division count of NEQ*IB*IB is used as a measure of equation solver speed, then a grid refinement for which the number of grid blocks is doubled in both the x and y direction (2-dimensional) would result in an increase in the number of equations by a factor of 4 and an increase in

the half bandwidth by a factor of 2. Therefore, the computational effort would increase by a factor of 16. This estimate should warn the user that when attempting a grid refinement the computation (and also storage) does not depend linearly on the grid size.

1.8 Two Phase Flow

BRAGFLO assumes a water/gas system.

For miscible flow, the fluids will diffuse within each other and there is not a defined interface between the fluids. Specifically, there is no capillary pressure effect.

Immiscible fluids are not capable of mixing and have interfaces across which pressure discontinuities exist. This interfacial tension effect produces a capillary pressure between phase. In BRAGFLO fluids are assumed to be immiscible.

Phase saturation is the fraction of the pore space occupied by the fluids in a given phase. The notation is

S_w = water saturation
S_g = gas saturation

For example, the volume occupied by water within a bulk volume V with porosity ϕ is $V\phi S_w$.

The saturation constraint for fully saturated media is

$$S_w + S_g = 1.$$

Capillary pressure is defined by

$$p_c = p_g - p_w = p_c(S_w)$$

For a water wetting phase, $p_c \geq 0$.

The ability of a fluid to flow is affected by the presence of another fluid. The relative permeability is the ratio of the effective permeability of a given fluid phase to the permeability at 100% saturation. This is written as

$$k_{rl} = \frac{k_1}{k}$$

where k is the formation or absolute permeability, k_l is the effective permeability of phase l, and k_{rl} is the relative permeability of phase l. We observe that $0 \le k_{rl} \le 1$ and k_{rl} will be dependent on the phase saturation.

Typical relative permeability curves are shown in Figure 14, where S_{wr} is the residual water saturation. For water saturation at or below S_{wr}, water will not flow.

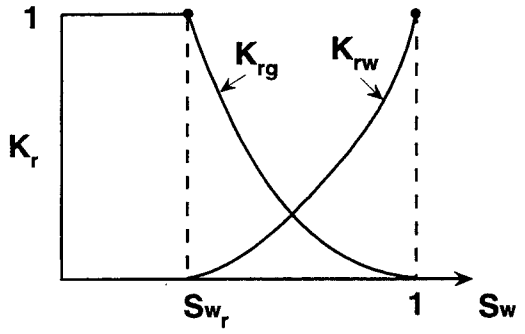


Figure 14. Typical relative permeability curve.

Darcy's Law extended to multiphase flow replaces absolute permeability with an effective permeability

$$\hat{q_1} = - \frac{k k_{rl} \rho}{\mu} \nabla \Phi .$$

The following system of two mass balance equations and two constraint equations is the BRAGFLO description of the two phase flow within a repository site:

Gas Mass Balance:

$$\nabla \cdot \left[\frac{\alpha \rho_g [k] k_{rg}}{\mu_g} \nabla \left(p_g + \rho_g g h \right) \right] + \alpha q_g + \alpha q_{rg} = \alpha \frac{\partial \left(\phi \rho_g S_g \right)}{\partial t}$$

Brine Mass Balance:

$$\nabla \cdot \left[\frac{\alpha \rho_w [k] k_{rw}}{\mu_w} \nabla \left(p_w + \rho_w g h \right) \right] + \alpha q_w + \alpha q_{rw} = \alpha \frac{\partial \left(\phi \rho_w S_w \right)}{\partial t}$$

Saturation Constraint:

$$S_g + S_w = 1$$

Capillary Pressure Constraint:

$$p_c = p_g - p_w.$$

Additional terms include

q_{rg} = rate of gas production (or consumption, if negative) due to chemical reaction.
q_{rw} = rate of water production (or consumption, if negative) due to chemical reaction.

The above system of four equations describes the time and space behavior of the four variables S_g, S_w, p_g, p_w. The finite difference method requires the introduction of a grid in either one, two or three dimensions and then a discretization of the gas and brine mass balance equation with respect to this grid and with respect to time. The resulting system of nonlinear algebraic equations is solved over a time step by the Newton-Raphson method.

The discretization of the gas mass balance equation in two dimensions (x,y) is given by

$$\frac{1}{\Delta x_i}\left\{\frac{1}{x_{i+1}-x_i}\left[\frac{\alpha\rho_g k_x k_{rg}}{\mu_g}\right]^{n+1}_{i+1/2,j}\left(\Phi^{n+1}_{g_{i+1,j}}-\Phi^{n+1}_{g_{i,j}}\right)-\frac{1}{x_i-x_{i-1}}\left[\frac{\alpha\rho_g k_x k_{rg}}{\mu_g}\right]^{n+1}_{i-1/2,j}\left(\Phi^{n+1}_{g_{i,j}}-\Phi^{n+1}_{g_{i-1,j}}\right)\right\}$$

$$+\frac{1}{\Delta y_j}\left\{\frac{1}{y_{j+1}-y_j}\left[\frac{\alpha\rho_g k_y k_{rg}}{\mu_g}\right]^{n+1}_{i,j+1/2}\left(\Phi^{n+1}_{g_{i,j+1}}-\Phi^{n+1}_{g_{i,j}}\right)-\frac{1}{y_j-y_{j-1}}\left[\frac{\alpha\rho_g k_y k_{rg}}{\mu_g}\right]^{n+1}_{i,j-1/2}\left(\Phi^{n+1}_{g_{i,j}}-\Phi^{n+1}_{g_{i,j-1}}\right)\right\}$$

$$+\alpha_{ij}\,q^{n+1}_{g_{ij}}+\alpha_{ij}\,q^{n+1}_{rg_{ij}}-\frac{\left(\alpha\phi\rho_g S_g\right)^{n+1}_{i,j}-\left(\alpha\phi\rho_g S_g\right)^{n}_{i,j}}{\Delta t}=0.$$

A similar equation for the brine mass balance is obtained by replacing the gas subscript with the brine subscript. The superscript n refers to the time level t_n at which the solution is known and the superscript n+1 refers to the time level t_{n+1} at which the solution is to be computed. Note that the flux and rate terms are evaluated at time level n+1. Therefore, the formulation is fully implicit.

For each grid block there are two material balance equations. The saturation constraint is used to eliminate brine saturation and the capillary pressure equation is used to eliminate

the gas pressure. The remaining unknowns for each grid block are gas saturation, S_g, and brine pressure, p_b. Consequently, at each time step it is necessary to solve 2(NX)(NY) equations, where NX, NY are the number of grid blocks in the x,y direction, respectively, for 2(NX)(NY) unknowns.

In order to investigate the Jacobian matrix structure, assume for sake of argument that NY<NX. In this case the grid indexing moves most rapid in the y-direction and then in the x-direction. If the number of grid blocks is denoted NGB, then NGB = NX(NY). In BRAGFLO the equation indexing is first with respect to the gas equation, then the brine equation and outer most indexing with respect to the gird block. For example, the equation ordering is as follows:

equation index	equation
1	gas equation in grid block 1
2	brine equation in gride block 1
3	gas equation in grid block 2
4	brine equation in grid block 2
•	
•	
•	
2NGB-1	gas equation in grid block NGB
2NGB	brine equation in grid block NGB

The unknowns are gas saturation and brine pressure. The unknowns are ordered by gas saturation, then brine pressure and then with respect to grid block. The unknown indexing
is:

unknown index	equation
1	gas saturation in grid block 1
2	brine pressure in grid block 1
3	gas saturation in grid block 2
4	brine pressure in grid block 2
•	
•	
•	
2NGB-1	gas saturation in grid block NGB
2NGB	brine pressure in grid block NGB

Information at the i,j grid block and its neighboring grid blocks will use the compass notation

P corresponds to information with respect to grid block i,j

E corresponds to information with respect to grid block i+1,j
W corresponds to information with respect to grid block i-1,j
N corresponds to information with respect to grid block i,j+1
S corresponds to information with respect to grid block i,j-1.

Assume that the i,j grid block has sequential index ℓ. Then the Jacobian matrix has a 2x2 block penta diagonal structure and the resulting linear system in the Newton-Raphson iteration step can be represented as follows

$$\begin{bmatrix} P_1 & N_1 & & E_1 & & & & \\ S_2 & P_2 & N_2 & & E_2 & & & \\ & \ddots & \ddots & \ddots & & \ddots & & \\ & & \ddots & \ddots & \ddots & & \ddots & \\ & & & \ddots & \ddots & \ddots & & \ddots \\ & W_\ell & & S_\ell & P_\ell & N_\ell & & E_\ell \\ & & \ddots & & \ddots & \ddots & \ddots & \\ & & & \ddots & & \ddots & \ddots & \ddots \\ & & & & \ddots & & \ddots & \ddots \\ & & & & & \ddots & & \ddots \\ & & & W_{NGB} & & S_{NGB} & & P_{NGB} \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \\ \\ \\ \\ \delta_\ell \\ \\ \\ \\ \\ \delta_{NGB} \end{bmatrix} = - \begin{bmatrix} G_1 \\ G_2 \\ \\ \\ \\ G_\ell \\ \\ \\ \\ \\ G_{NGB} \end{bmatrix}$$

The 2x2 block matrices in the Jacobian are defined by

$$P_\ell = \begin{pmatrix} \frac{\partial F_1(i,j)}{\partial S_g(i,j)} & \frac{\partial F_1(i,j)}{\partial p_b(i,j)} \\ \frac{\partial F_2(i,j)}{\partial S_g(i,j)} & \frac{\partial F_2(i,j)}{\partial p_b(i,j)} \end{pmatrix}$$

$$E_\ell = \begin{pmatrix} \frac{\partial F_1(i,j)}{\partial S_g(i+1,j)} & \frac{\partial F_1(i,j)}{\partial p_b(i+1,j)} \\ \frac{\partial F_2(i,j)}{\partial S_g(i+1,j)} & \frac{\partial F_2(i,j)}{\partial p_b(i+1,j)} \end{pmatrix} \quad W_\ell = \begin{pmatrix} \frac{\partial F_1(i,j)}{\partial S_g(i-1,j)} & \frac{\partial F_1(i,j)}{\partial p_b(i-1,j)} \\ \frac{\partial F_2(i,j)}{\partial S_g(i-1,j)} & \frac{\partial F_2(i,j)}{\partial p_b(i-1,j)} \end{pmatrix}$$

$$N_\ell = \begin{pmatrix} \frac{\partial F_1(i,j)}{\partial S_g(i,j+1)} & \frac{\partial F_1(i,j)}{\partial p_b(i,j+1)} \\ \frac{\partial F_2(i,j)}{\partial S_g(i,j+1)} & \frac{\partial F_2(i,j)}{\partial p_b(i,j+1)} \end{pmatrix} \quad S_\ell = \begin{pmatrix} \frac{\partial F_1(i,j)}{\partial S_g(i,j-1)} & \frac{\partial F_1(i,j)}{\partial p_b(i,j-1)} \\ \frac{\partial F_2(i,j)}{\partial S_g(i,j-1)} & \frac{\partial F_2(i,j)}{\partial p_b(i,j-1)} \end{pmatrix}$$

The block vectors in the unknown solution vector are

$$\delta_\ell = \begin{pmatrix} \delta S_g(i,j) \\ \delta p_b(i,j) \end{pmatrix}.$$

The block vectors in the equation vector are

$$G_\ell = \begin{pmatrix} F_1(i,j) \\ F_2(i,j) \end{pmatrix}.$$

In the above, F_1 denotes the left hand side of the gas mass balance equation, and F_2 denotes the left hand side of the brine mass balance equation.

An inspection of the above discretized gas mass balance equation shows that the flux between neighboring grid blocks involves interblock flow terms evaluated at grid block interfaces, such as i+1/2, i-1/2, j+1/2 and j-1/2. It is necessary to discuss how BRAGFLO evaluates these interblock flow terms.

Consider the following term in the brine equation for flow in the x-direction between grid blocks i and i+1:

$$\frac{1}{\Delta x_i\left(x_{i+1} - x_i\right)}\left(\frac{\alpha\rho_w k_x k_{rw}}{\mu_w}\right)_{1+1/2}\left(\Phi_{wi+1} - \Phi_{wi}\right).$$

Since pressure and saturation are determined at grid block centers x_i and x_{i+1}, the question remains as to how to evaluate the interface term at $x_{i+1/2}$.

First, we define the harmonic average, H, of a_1, a_2, as

$$\frac{1}{H} = \frac{1}{2}\left(\frac{1}{a_1} + \frac{1}{a_2}\right)$$

or

$$H = \frac{2a_1a_2}{a_1 + a_2}.$$

Further, the weighted harmonic average of a_1,a_2 is

$$\frac{1}{H} = \frac{w_1}{a_1} + \frac{w_2}{a_2}$$

or

$$H = \frac{a_1a_2}{w_2a_1 + w_1a_2},$$

where the weights satisfy $w_1 + w_2 = 1$. Now introduce the shorthand notation

$$\bar{\tau}_{i+1/2} = \left(\frac{\alpha\rho_w k_x k_{rw}}{\mu_w}\right)_{i+1/2}$$

At the i+1/2 interface, assume the mass flux is continuous

$$\bar{q}_{i+1/2} = q_{\bar{i}+1/2} = q^{+}_{i+1/2}$$

where

$\bar{q}_{i+1/2}$ is average flow between x_i and x_{i+1},

$q_{\bar{i}+1/2}$ is flow to the left of interface,

$q^{+}_{i+1/2}$ is flow to the right of interface.

From Darcy's Law, neglecting gravity potential

$$\bar{q}_{i+1/2} = \tau_{i+1/2} \frac{p_{i+1} - p_i}{x_{i+1} - x_i}$$

or

$$\bar{q}_{i+1/2} = \tau_{i+1/2} \frac{p_{i+1} - p_i}{1/2\left(\Delta x_i + \Delta x_{i+1}\right)}$$

This yields

$$p_{i+1} - p_i = \frac{\bar{q}_{i+1/2} \frac{1}{2} \left(\Delta x_i + \Delta x_{i+1}\right)}{\tau_{i+1/2}}$$

Similarly,

$$q_{\bar{i}+1/2} + \tau_i \frac{\left(p_{i+1/2} - p_i\right)}{\frac{1}{2}\Delta x_i}$$

$$q^{+}_{i+1/2} = \tau_{i+1} \frac{\left(p_{i+1} - p_{i+1/2}\right)}{\frac{1}{2}\Delta x_{i+1}}$$

Pressure drop is then written as

$$p_{i+1} - p_i = p_{i+1} - p_{i+1/2} + \left(p_{i+1/2} - p_i\right).$$

Then

$$\bar{q}_{i+1/2} \frac{\frac{1}{2}\left(\Delta x_i + \Delta x_{i+1}\right)}{\tau_{i+1/2}} = q^{+}_{i+1/2} \frac{\frac{1}{2}\Delta x_{i+1}}{\tau_{i+1}} + q^{-}_{i+1/2} \frac{\frac{1}{2}\Delta x_i}{\tau_i}.$$

Solving for $\tau_{i+1/2}$ yields

$$\tau_{i+1/2} = \frac{\tau_i \tau_{i+1}}{\frac{\Delta x_{i+1}}{\Delta x_i + \Delta x_{i+1}} \tau_i + \frac{\Delta x_i}{\Delta x_i + \Delta x_{i+1}} \tau_{i+1}}.$$

This is the harmonic mean of τ_i, τ_{i+1}, weighted with respect to the distance to the interface.

One further modification is made in the interblock term

$$\tau_{i+1/2} = \left(\frac{\alpha \rho_w k_x k_{rw}}{\mu_w}\right)_{i+1/2} = \left(\frac{\alpha \rho_w k_x}{\mu_w}\right)_{i+1/2} \left(k_{rw}\right)_{i+1/2}.$$

The harmonic averaging is used to evaluate

$$\left(\frac{\alpha \rho_w k_x}{\mu_w}\right)_{i+1/2}$$

However, the interblock relative permeability is evaluated by upstream weighting:

$$(k_{rw})_{i+1/2} = k_{rw_{i+1}}, p_{wi} < p_{w_{i+1}}$$
$$= k_{rw_i}, \text{otherwise} .$$

This treatment of the interblock flow term is justified by the following process typical in performance assessment analysis. Assume gas is generated and is displacing water from the left to the right as in Figure 15. At the gas front, the gas potential is highest in the ith grid block. Therefore, gas wants to flow from i to i+1 grid block. Although the gas is mobile ($k_{rg} > 0$) in the ith block, it is immobile ($k_{rg} = 0$) in the $i+1^{th}$ block. If the relative permeability is included in the interblock harmonic averaging, then $\tau_{i+1/2}$ is zero and no gas is transported. By upstream weighting the gas relative permeability we allow the mobile gas to flow from i to i+1 block.

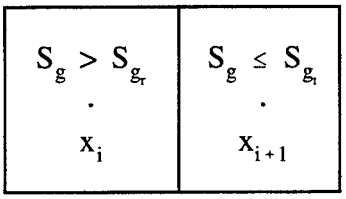


Figure 15. Gas Displacement Front

Another treatment of relative permeability is to split it out of the harmonic average and evaluate it as an arithmetic average of the two adjacent relative permeabilities.

$$(k_{rw})_{i+1/2} = w_i k_{rw_i} + w_{i+1} k_{rw_{i+1}}$$

where the weights sum to 1. The arithmetic average of interblock relative permeability does not correctly treat the following case. Suppose water is displaced from left to right in Figure 16

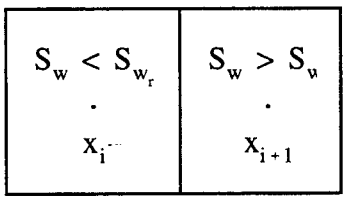


Figure 16. Displacement of Immobile Water

with potential satisfying $\Phi_{w_i} > \Phi_{w_{i+1}}$. The potential tries to move water from i to i+1 block. Since $k_{rw_i} = 0$ and $k_{rw_{i+1}} > 0$, the interblock relative permeability by arithmetic averaging is greater than zero and the immobile water would be transported from the ith block. Upstream weighting would yield interblock relative permeability of zero with no water transported. Thus the upstream weighting prevents immobile fluid from being transported. The upstream weighting of relative permeability is controlled by input parameters.

1.9 Characteristic Curves

Relative permeability and capillary pressure are computed from several different empirical relations (Brooks 1964; van Genuchten 1978; WIPP PA 1992). Choice of the characteristic curves is controlled by input directives.

The van Genuchten-Parker model determines

Capillary Pressure

$$P_c = P_o\left(S_e^{-1/m} - 1\right)^{1-m}$$

where P_o is a constant determined by equating the van Genuchten-Parker capillary pressure with the Brooks-Corey capillary pressure (discussed below) at $S_e = 0.5$.

Relative Permeabilities

$$k_{rw} = S_e^{1/2}\left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2$$

$$k_{rg} = \left(1 - S_e\right)^{1/2}\left(1 - S_e^{1/m}\right)^{2m}$$

where the effective saturation is

$$S_e = \frac{S_w - S_{wr}}{1 - S_{gr} - S_{wr}}$$

In the original van Genuchten-Parker model the residual gas saturation S_{gr} was zero. BRAGFLO has the capability of using a nonzero residual gas saturation in the S_e calculation.

The parameter m is related to the input parameter by

$$m = \frac{\lambda}{1 + \lambda} .$$

Typical characteristic curves using the van Genuchten-Parker model are shown in Figure 17 with parameters

$$\lambda = 0.7 \ (m = 0.41)$$
$$S_{wr} = 0.2.$$

The original Brooks-Corey model determines

Capillary Pressure

$$P_c = P_t / S_e^{1/\lambda}$$

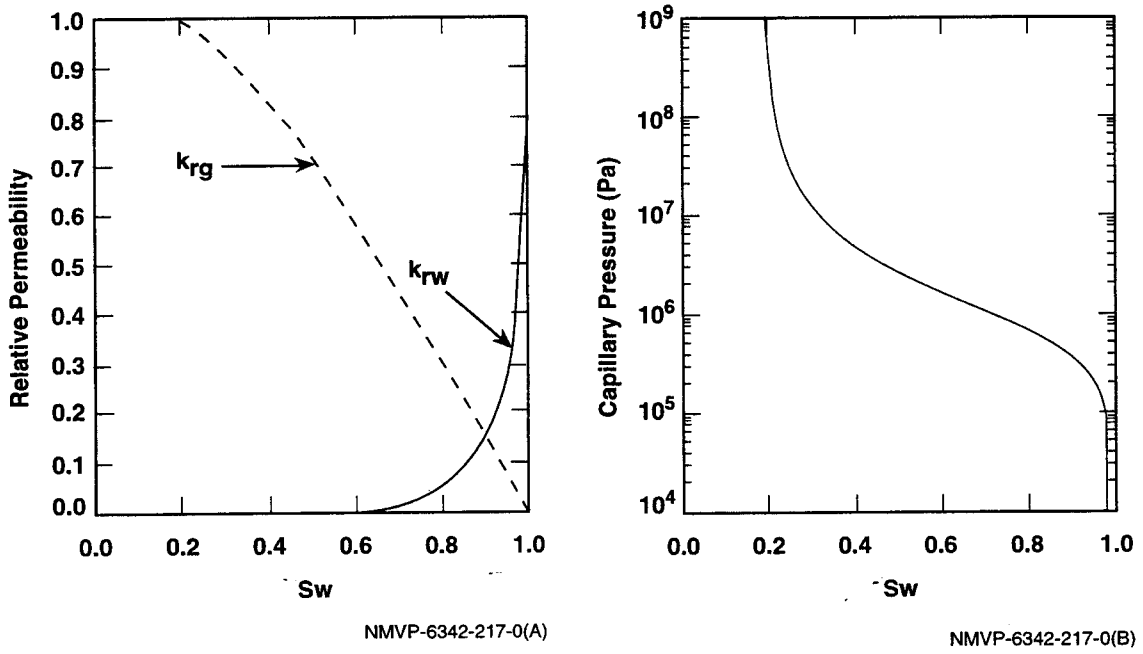


Figure 17. Relative Permeabilities for van Genuchten-Parker Model (left plot) and Capillary Pressure for van Genuchten-Parker Model (right plot)

Relative Permeabilities

$$k_{rw} = S_e^{(2 + 3\lambda)/\lambda}$$
$$k_{rg} = \left(1 - S_e\right)^2 \left(1 - S_e^{(2 + \lambda)/\lambda}\right)$$

where $S_e = (S_w - S_{wr})/(1 - S_{wr})$, P_t is threshold pressure and λ is pore size distribution parameter. Note that if this option is used with $P_t = 0$, then P_c is identically zero.

Typical characteristic curves using the original Brooks-Corey model are shown in Figure 18 with parameters

$$\lambda = 0.7$$
$$S_{wr} = 0.2$$
$$P_t = 1.E6.$$

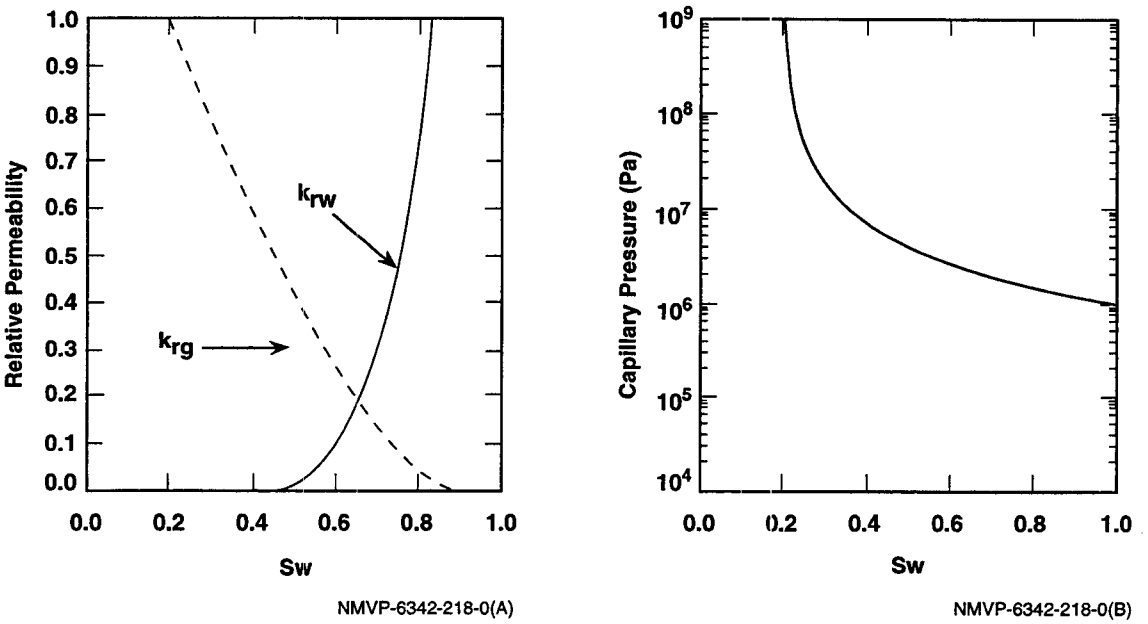


Figure 18. Relative Permeabilities for Original Brooks-Corey Model (left plot) and Capillary Pressure for Original Brooks-Corey Model (right plot)

Two modifications of the Brooks-Corey model are available which differ in the treatment of the effective saturation, S_e.

The first modified Brooks-Corey model computes both phase relative permeabilities using an effective saturation

$$S_e = \frac{S_w - S_{wr}}{1 - S_{gr} - S_{wr}}$$

where S_{gr} is residual gas saturation.

Characteristic curves for this option are shown in Figure 19 with input parameters

$$\begin{aligned} \lambda &= 0.7 \\ S_{wr} &= 0.2 \\ S_{gr} &= 0.2 \\ P_t &= 1.E6. \end{aligned}$$

Note that for $S_w \geq 1 - S_{gr}$, gas is immobile and water has 100% mobility. Also, note that the capillary pressure curve assumes the threshold capillary pressure at $S_w = 1 - S_{gr}$.

The second modified Brooks-Corey model uses residual gas saturation to calculate effective saturation only for the gas phase. This treatment results in the characteristic curves shown in Figure 20.

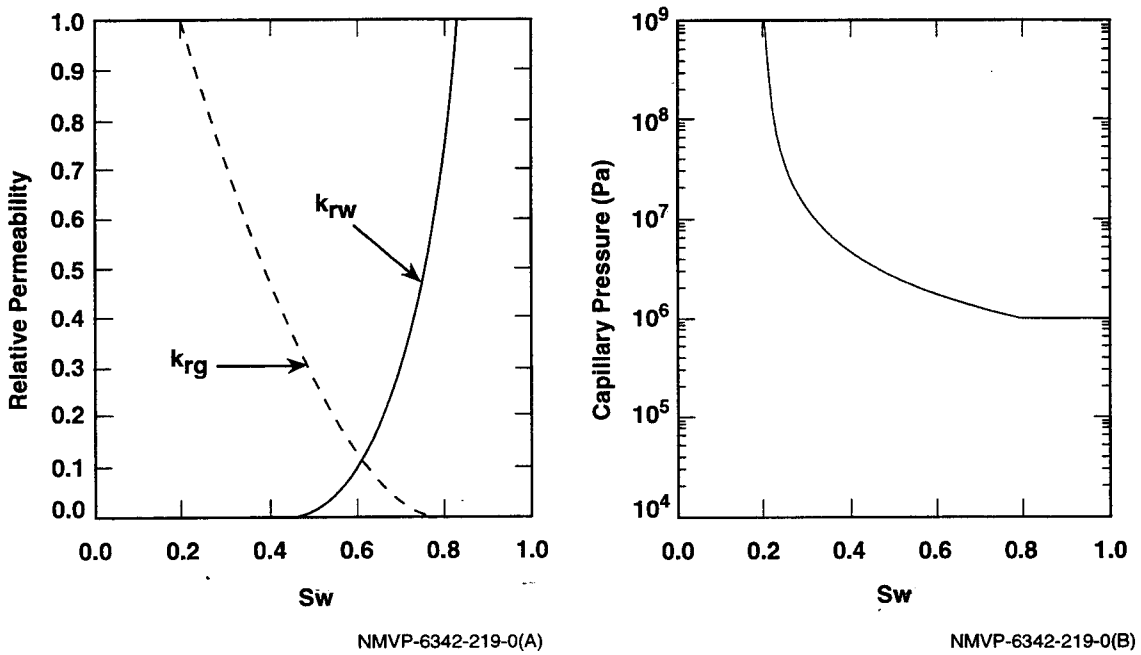


Figure 19. Relative Permeabilities for Modified Brooks-Corey Model (left plot) and Capillary Pressure for Modified Brooks-Corey Model (right plot)

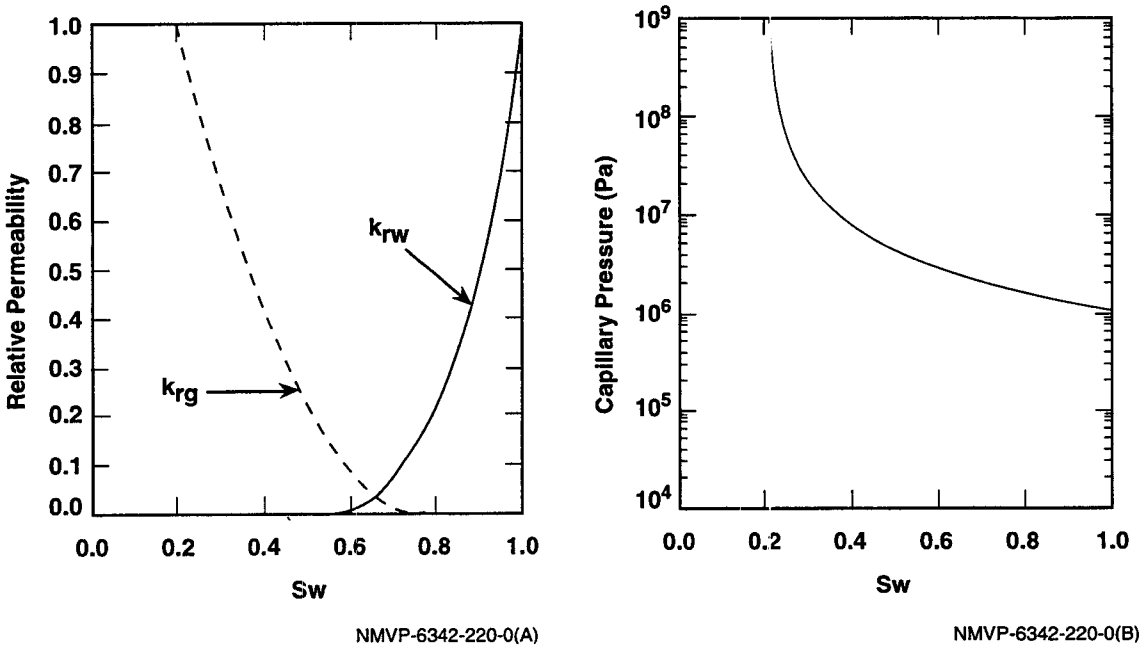


Figure 20. Relative Permeabilities for Second Modified Brooks-Corey Model (left plot) and Capillary Pressure for Second Modified Brooks-Corey Model (right plot)

Finally, a linear model is available with relative permeability and capillary pressure shown in Figure 21. The only input parameters honored are $S_{wr} = 0.2$ and $P_c = P_t$.

For both the van Genuchten-Parker and the Brooks-Corey model, the capillary pressure function is unbounded from the right ($S_w = S_{wr}^+$). An option is available which truncates the capillary pressure function at the PCMAX value. The capillary pressure curve with this option and PCMAX = 1.E8 is shown in Figure 22 (left plot) for the van Genuchten-Parker model and in Figure 22 (right plot) for the original Brooks-Corey model.

The dependence of the characteristic curves for both van Genuchten-Parker and Brooks-Corey on the pore size distribution parameter λ is shown in Figure 23 and Figure 24.

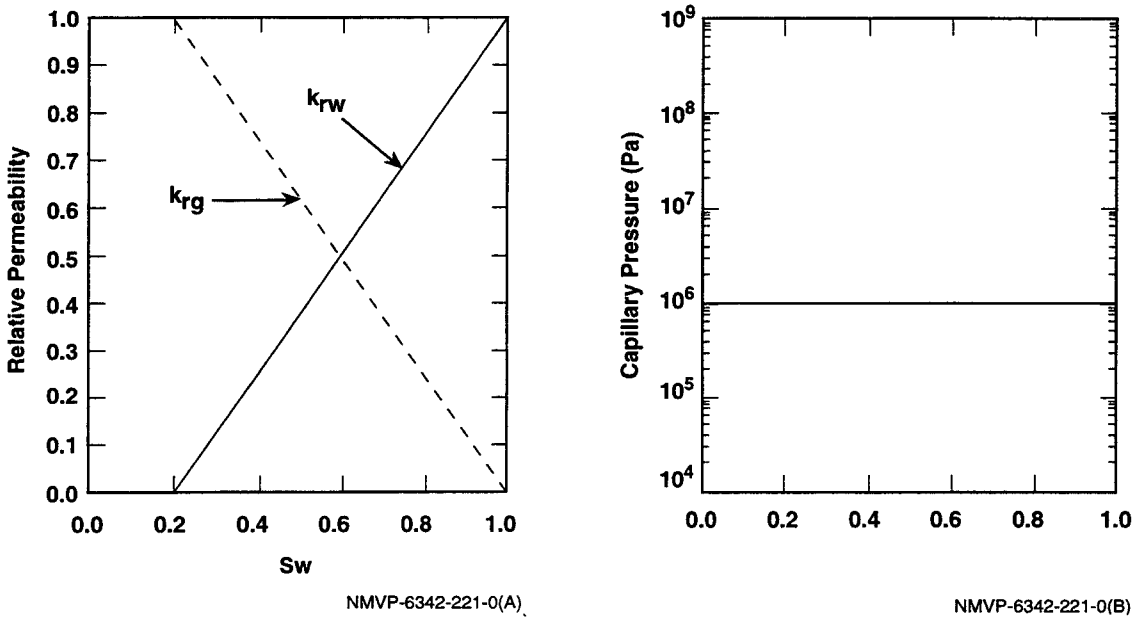


Figure 21. Relative Permeabilities for Linear Model (left plot) and Capillary Pressure for Linear Model (right plot)

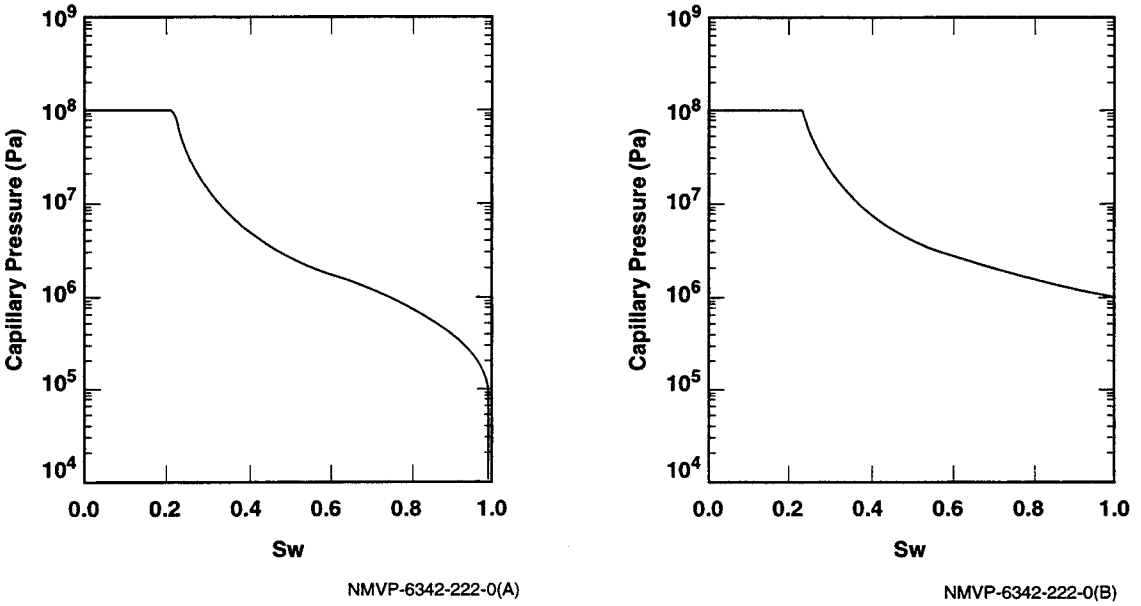


Figure 22. Capillary Pressure for van Genuchten-Parker Model PCmax=1.0E+08 (left plot) and Capillary Pressure for Original Brooks-Corey Model PCmax=1.0E+08(right plot)

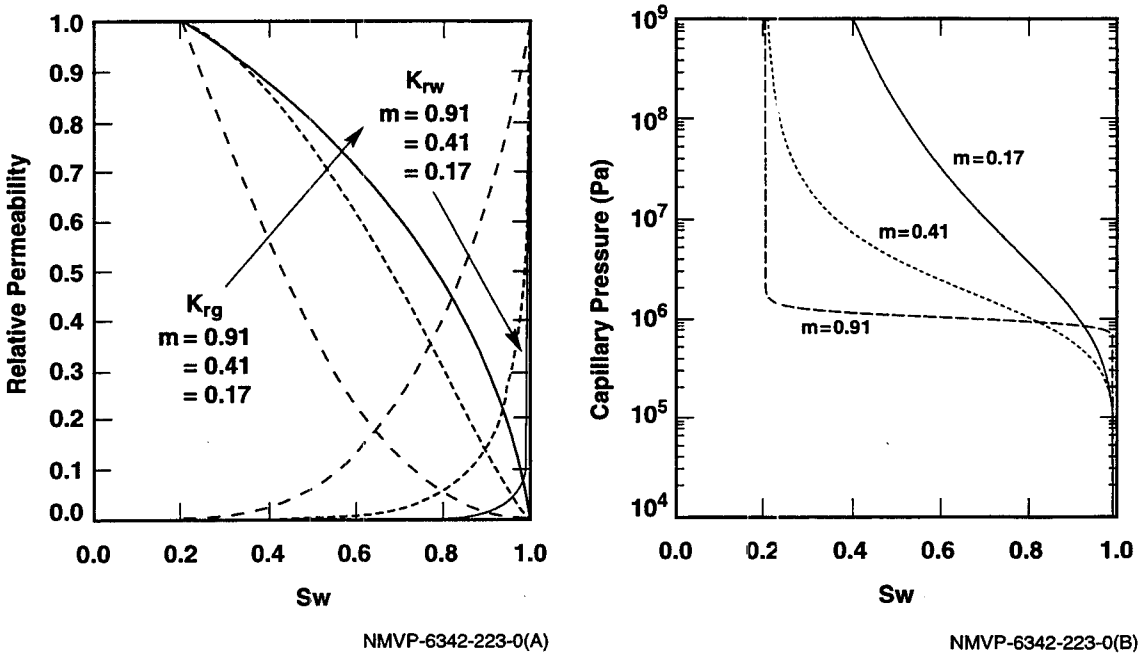


Figure 23. Relative Permeabilities for van Genuchten-Parker Model, effect of parameter m (left plot) and Capillary Pressure for van Genuchten-Parker Model, effect of parameter m (right plot)

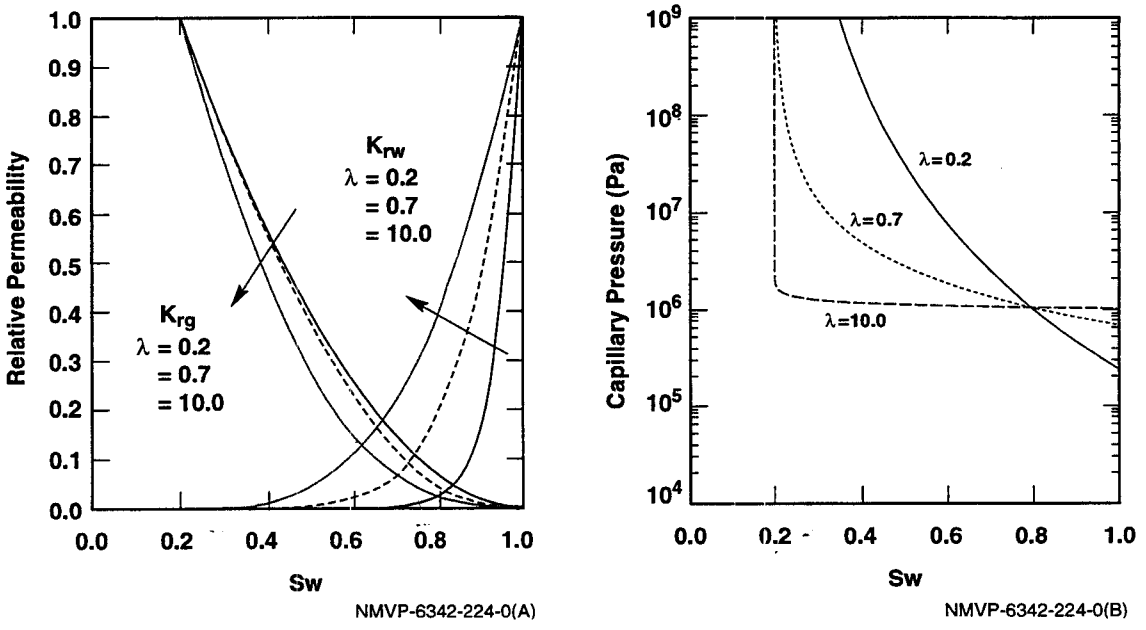


Figure 24. Relative Permeabilities for Brooks-Corey Model effect of pore size distribution parameter (left plot) and Capillary Pressure for Brooks-Corey Model effect of pore size distribution parameter (right plot)

1.10 Pressure-Induced Fracture Treatment

Most fluid flow models for porous media, such as BRAGFLO, allow for coupling to the mechanical system (rock matrix) through the introduction of rock compressibility, which is defined as the relative rate of change of porosity with respect to pressure

$$C = \frac{1}{\phi}\frac{d\phi}{dp}$$

where

C = rock compressibility,
ϕ = porosity,
p = pore pressure.

For constant compressibility, porosity can be expressed as a function of pressure

$$\phi = \phi_o \exp\left(C(p - p_o)\right)$$

where

ϕ_o = porosity at reference pressure p_o.

The fracture treatment in BRAGFLO (Key 1994) allows for pressure induced alterations to the porosity by introducing a pressure-dependent porosity. Figure 25 shows the piecewise linear rock compressibility function. Below an initiating pressure, p_i, compressibility is a constant intact value, C_i. For pressures above p_i, the compressibility increases linearly to a fully altered compressibility, C_a, at the fully altered pressure, p_a. For pressures above p_a no further alteration occurs, which implies that $C = 0$.

The porosity can now be computed from the compressibility definition giving for $p \le p_i$

$$\phi = \phi_o \exp\left(C_i(p - p_o)\right) \qquad (A)$$

for $p_i < p \le p_a$

$$\phi = \phi_o \exp\left\{C_i(p - p_o) + \frac{(C_a - C_i)}{(p_a - p_i)}\frac{(p - p_i)^2}{2}\right\} \qquad (B)$$

for $p \ge p_a$

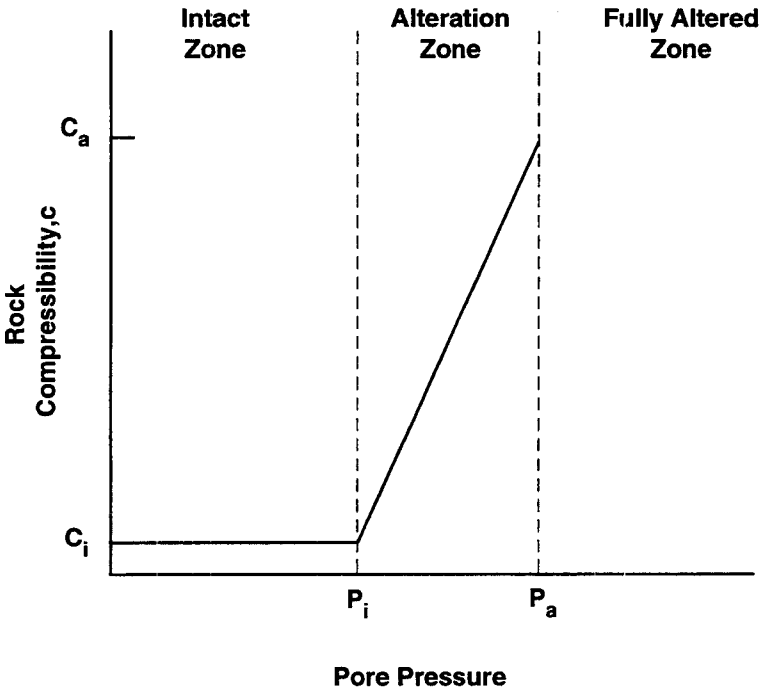


Figure 25. Pressure dependent compressibility.

$$\phi = \phi_a. \qquad (C)$$

BRAGFLO input requires the pressures p_i and p_a and the porosity at the fully altered conditions, ϕ_a. From this information, the fully altered compressibility, C_a, is determined from equation (B) as

$$C_a = C_i\left[1 - 2\frac{(p_a - p_o)}{p_a - p_i}\right] + \frac{2}{(p_a - p_i)}\ln\left(\frac{\phi_a}{\phi_o}\right).$$

The BRAGFLO fracture treatment further allows for change in the fracture material permeability. The often used parallel plate analogy for flow in fractured rock suggests the form

$$\frac{k}{k_i} = \left[\frac{\phi}{\phi_i}\right]^n$$

where

k	=	permeability of altered material,
k_i	=	permeability of intact material,
ϕ	=	porosity of altered material,
ϕ_i	=	porosity of intact material,
n	=	an empirical parameter.

The altered permeability model requires as input n. Also, the anisotropic nature of permeability is specified for the fracture materials.

A geometric realization of the pressure-dependent porosity and permeability within a fracture material is shown in Figure 26.

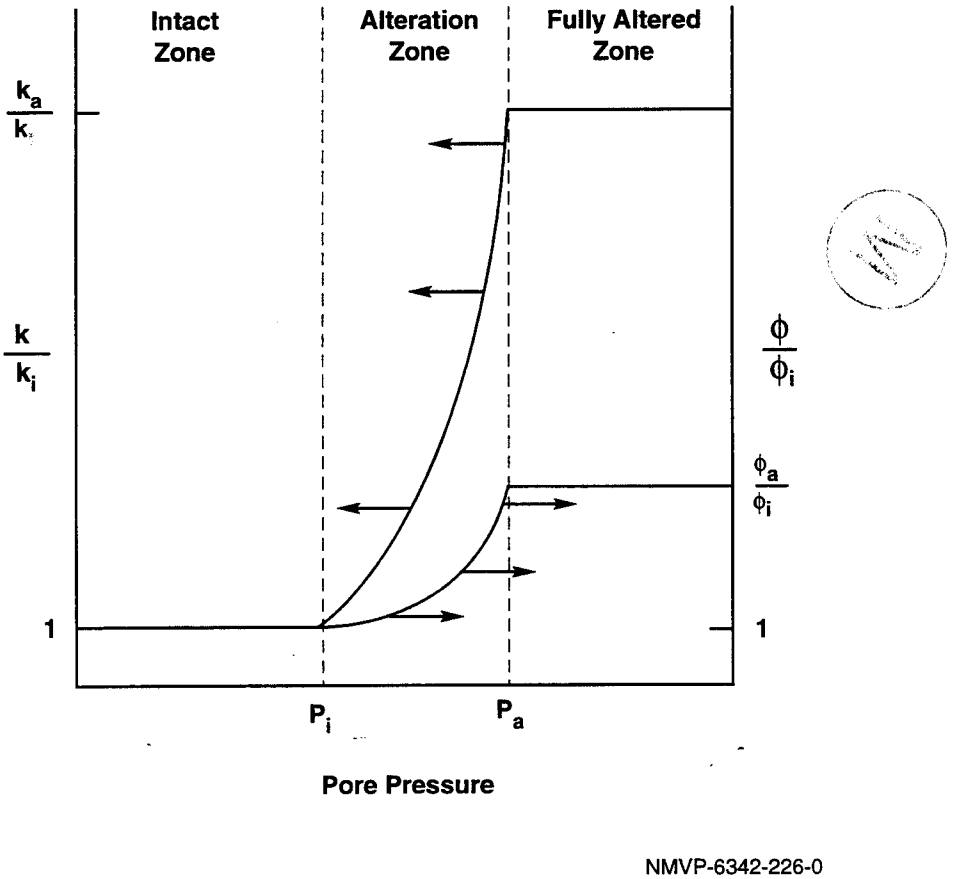


Figure 26. Pressure dependent porosity and permeability.

In a system where gas is displacing water, the fracture treatment can influence the gas migration distance. At elevated pressure, the increased porosity will produce more storage with corresponding shorter gas migration distance, while the increase in permeability will enhance the fluid mobility with resulting longer gas migration. The net effect will depend on the relative magnitudes of the storage and permeability effects.

1.11 Creep Closure

The excavation of the WIPP will result in the plastic deformation of the salt material (creep) and resultant closure (creep closure) of excavated areas. The principal effect of this closure for performance assessment is its effect on repository pressure due to the reduction in void volume accompanying creep closure. Accordingly, creep closure is represented in BRAGFLO by changing the porosity of the waste disposal area in a manner consistent with expectations developed from detailed modeling studies. Detailed modeling studies used the code SANCHO (Butcher et al. 1995), and more recently, SANTOS (Butcher et al. 1995), to develop time- and pressure-dependent predictions of waste disposal area void volume. Pressure variation was consistent with variation in the gas generation rates possible in the waste disposal areas. The results were used to develop a look-up table of porosity as a function of time and waste disposal area pressure that is used in BRAGFLO to vary waste disposal area porosity. Essential features of the look-up table (porosity surface) are shown in Figure 27.

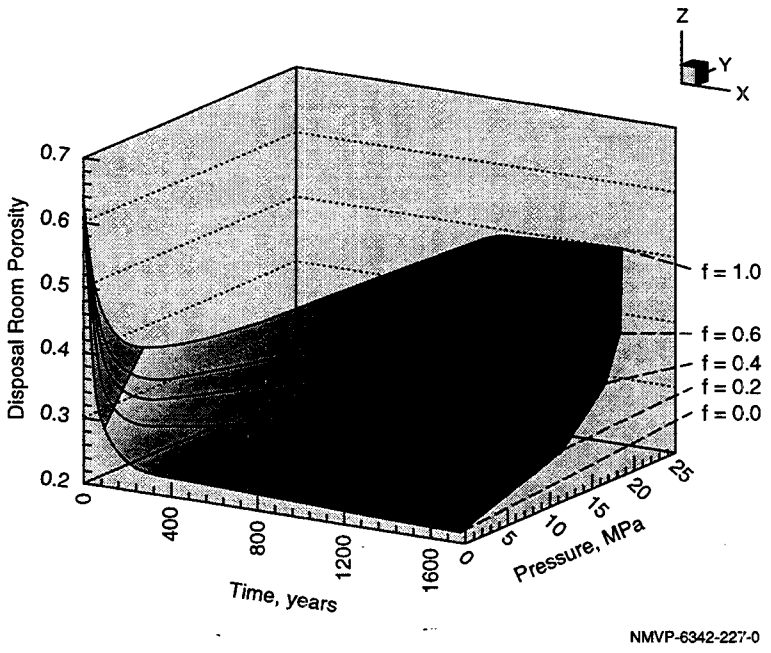


Figure 27. Pressure driven porosity function generated from SANCHO structural mechanics code.

The surface is generated by a family of five f factors which is representative of the level of gas generation. The value of f = 1.0 corresponds to 2 moles of gas per drum per year for 550 years, 1 mole per drum per year from 550 to 1050 years, and zero gas generation after 1050 years. For each f-factor the above rates are scaled by f. BRAGFLO uses a volumetric average pressure over the waste and time to interpolate the surface in Figure 11-1 for the average waste porosity.

1.12 Klinkenberg Effect

For gases in a tight porous material at low pressures the boundary condition of zero gas velocity at the solid surface is not satisfied (Klinkenberg 1941; Corey 1990; WIPP PA 1992). This phenomenon has been called gas slippage and results in a larger gas velocity. This slipping of the gas flow contributes to an apparent pressure-dependent increase in permeability, which was originally observed by Klinkenberg. A correction to the formation permeability to the gas phase is related to pressure by

$$k_g = k_w\left(1 + b k_w^{-a}/p\right)$$

where

k_g = formation permeability to gas [m^2],
k_w = formation permeability to water [m^2],
a,b = formation dependent constants,
p = pressure [Pa].

The constants a,b are input. The recommended values found in the BRAGFLO user's manual are from a tight gas/sand correlation. Figure 28 shows the gas phase permeability as a function of pressure for a family of k_w with a = 0.33 and b = 0.98.

1.13 Gas Generation Model

Within BRAGFLO there are chemical reactions with the effect of consuming brine and generating gas. One reaction represents the corrosion of the waste containers. A second reaction models the microbial consumption of cellulose material.

Two possible anoxic reactions are used to describe the corrosion when waste drums are exposed to brine:

$$Fe + 2H_2O \rightarrow H_2 + Fe(OH)_2 \quad (1)$$

$$3Fe + 4H_2O \rightarrow 4H_2 + Fe_3O_4 \quad (2)$$

If the equations are normalized to unit mole of iron, then equation (2) is written

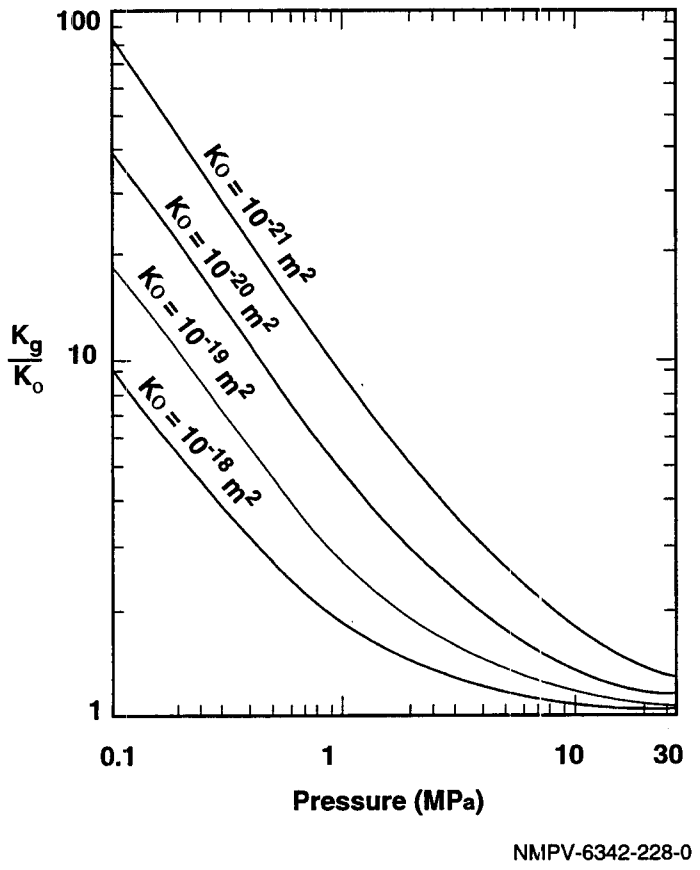


Figure 28. Increase in gas phase permeability due to Klinkenberg effect.

$$Fe + 4/3\ H_2O \rightarrow 4/3\ H_2 + 1/3\ Fe_3O_4. \quad (3)$$

In the performance assessment of the WIPP site, a weighted average of the above two reactions is assumed

$$xFe + 2x\ H_2O + (1\text{-}x)\ Fe + (1\text{-}x)\ 4/3\ H_2O \rightarrow xH_2 + (1\text{-}x)\ 4/3\ H_2 + Inerts$$

where weighting factor x satisfies $0 \le x \le 1$. This is written for a unit mole of iron as

$$Fe + (2x + 4)/3\ H_2O \rightarrow (4\text{-}x)/3\ H_2 + Inerts.$$

From input (line 9.8), the corrosion stoichiometry is described by

$$S(1,2)\ H_2O + S(1,3)\ Fe \rightarrow S(1,1)\ H_2 + Inerts.$$

The PA calculations sample x from a uniform distribution on the interval [0,1] and compute stoichiometric coefficients

$S(1,1) = (4-x)/3$ [mole H_2]
$S(1,2) = (2x+4)/3$ [mole H_2O]
$S(1,3) = 1.0$ [mole Fe]

In order to account for the material balance of brine and gas, the rate of reaction must be specified. BRAGFLO assumes all reaction rates are zero order (constant). However, BRAGFLO recognizes a different reaction rate if the steel is in contact with liquid brine (inundated condition) or if the steel reacts with brine in the gas phase (humid condition). The input directives describing the two reaction rates are

RK(1) = brine inundated corrosion reaction rate [mol Fe/m^3/s],
HF(1) = factor multiplying RK(1) to get humid corrosion reaction rate.

We introduce the notation

K_{CI} = RK(1), inundated reaction rate,
K_{CH} = HF(1) * RK(1), humid reaction rate.

The portion of steel in contact with brine is assumed to react at the inundated rate, while the portion of steel in contact with gas reacts at the humid rate as long as some liquid phase brine is present to be in equilibrium with the brine in the gas phase. The fraction of steel in contact with brine in a grid block is assumed equal to the volume fraction of brine in the pore space, S_w. Similarly, the fraction of steel in contact with gas is equal to the volume fraction of gas, S_g. Thus the effective corrosion reaction rate becomes

$$K_C = K_{CI} S_w + K_{CH} S_g.$$

The rate of H2 production by corrosion per unit volume of panel is

$$q_{CH_2} = K_C X_{CH_2} M_{H_2}$$

where

X_{CH_2} = corrosion stoichiometry factor, S(1,1),
M_{H_2} = molecular weight of H_2 [kg/mol].

The rate of brine consumption by corrosion per unit volume of panel is

$$q_{CH_2O} = K_C X_{CH_2O} M_{H_2O}$$

where

X_{CH_2O} = corrosion stoichiometry factor, S(1,2),
M_{H_2O} = molecular weight of H_2O [kg/mol].

In BRAGFLO the biodegradation reaction assumes microbial consumption of cellulose (CH_2O) with hydrogen gas as a product

$$CH_2O + \text{microbes} \rightarrow X\ H_2 + \text{unknowns},$$

where

X = stoichiometry coefficient, [mol H_2/mol CH_2O]

BRAGFLO PA samples on X as uniform distribution on the interval [0, 5/3]. The stoichiometry coefficients for the biodegradation reaction are read on input as

S(2,1) = moles H_2,
S(2,2) = moles H_2O = 0.0
S(2,3) = moles CH_2O = 1.0.

Reaction rates for biodegradation are analogous to the corrosion reaction rates; that is, rates are specified for both inundated and humid conditions. The input directives describing the two reaction rates are

RK(2) = brine inundated biodegradation rate [mol $CH_2O/m^3/s$]
HF(2) = factor multiplying RK(2) to get humid biodegradation rate.

and are used to determine the overall biodegradation rate in the same way RK(1) and HF(1) are used to determine the overall corrosion rate.

1.14 Linear Equation Solver

Each iteration step in the Newton-Raphson method requires the solution of a system of linear equations. Linear equation solvers fall into two general categories: direct or elimination type solvers and iterative solvers. Algorithms for direct solvers involve a finite number of arithmetic steps to produce the solution. Solution error in a direct solver occurs from roundoff error in the arithmetic operations which is a result of the finite word length representation of any number on a computer. BRAGFLO is written with double precision word length which produces floating point number representation of 64 bit or

approximately 15 significant digits on a single word length machine such as the DEC ALPHA. BRAGFLO has available two direct solvers, LU-decomposition and the LINPACK solver which also uses an LU-decomposition.

For large scale problems accumulation of roundoff error in a direct solver can swamp the true solution. Also storage and computation time may become prohibitive for direct solvers. Iterative solvers are generally advantageous over direct solvers when the problem size becomes large. There are many iterative solvers found in the numerical literature. BRAGFLO includes a successive over relaxation (SOR) solver. Iterative solvers have the disadvantage that the solution depends on the convergence of an iterative procedure. For this reason direct solvers are more simplistic in concept and application.

For performance assessment work the original LU-decomposition method has been used exclusively and is strongly recommended. It has been found from experience that the iterative solvers are not robust enough to successfully solve many of the performance assessment problems.

A description of the LU-decomposition algorithm will be presented. The method will be demonstrated with a small (4x4 matrix) example. The objective is to write the coefficient matrix (Jacobian matrix) as a product of two matrices,

$$\mathbf{LU} = \mathbf{A}$$

where **L** is lower triangular (has non-zero elements only on the diagonal and below) and **U** is upper triangular (has non-zero elements only on the diagonal and above). It is further possible to require the diagonals of **L** to be equal to one. If $\mathbf{A} = (a_{ij})$, $\mathbf{L} = (\alpha_{ij})$ and $\mathbf{U} = (\beta_{ij})$, then for the case of a 4x4 matrix the decomposition would look like

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{21} & 1 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 1 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 1 \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} \\ 0 & \beta_{22} & \beta_{23} & \beta_{24} \\ 0 & 0 & \beta_{33} & \beta_{34} \\ 0 & 0 & 0 & \beta_{44} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}$$

For example, it can be checked by matrix multiplication that the following is an LU-decomposition of the given 4x4 matrix:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -2 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 3 & 3 & 3 \\ 0 & 0 & -2 & -2 \\ 0 & 0 & 0 & 4 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ -2 & 1 & 1 & 1 \\ 0 & 3 & 1 & 1 \\ 1 & 4 & 2 & 6 \end{bmatrix}$$

If the LU-decomposition of the matrix A is known then the solution of the system of equations
Ax = b can be written as

$$\mathbf{Ax = (LU)x = L(Ux) = b}$$

The solution is obtained by solving for the vector y such that

$$\mathbf{Ly = b}$$

and then solving

$$\mathbf{Ux = y}$$

The advantage of decomposing one linear set of equations into two successive sets of equations is that the solution of a triangular set of equations is an easy substitution calculation. Recall for the Modified Newton-Raphson method the Jacobian matrix is not updated every iteration while the right-hand side of the system of equations is recalculated each iteration. Once the LU-decomposition of the Jacobian matrix is obtained, the Newton-Raphson iteration step is accomplished by solving the system **Ly = b** with updated right-hand side vector **b** by applying the forward substitution algorithm

$$y_1 = \frac{b_1}{\alpha_{11}}$$

$$y_i = \frac{1}{\alpha_{ii}}\left[b_i - \sum_{j=1}^{i-1} \alpha_{ij}y_j\right] \quad i = 2,3,...,N$$

and then solving the system **Ux = y** with the back substitution algorithm

$$x_N = \frac{y_N}{\beta_{NN}}$$

$$x_i = \frac{1}{\beta_{ii}}\left[y_i - \sum_{j=i+1}^{N} \beta_{ij}x_j\right] \quad i = N-1,\ N-2,...,1$$

Given the coefficient matrix **A**, how are the decomposition matrices **L** and **U** computed? The (i,j)th entry in matrix **A** will be the inner product of the ith row of **L** with the jth column of **U**. If the triangular structure of **L** and **U** are considered, then the resulting product is described by the two cases,

$$\sum_{k=1}^{i} \alpha_{ik}\beta_{kj} = a_{ij} \quad i = 1,...,j \tag{A1}$$

$$\sum_{k=1}^{j} \alpha_{ik}\beta_{kj} = a_{ij} \quad i = j+1,...,N \tag{B1}$$

Crout's algorithm (Maron 1982) solves the equations for the α's and β's by arranging the equations in a certain order. The algorithm is sequential over columns from 1 to N. For the jth column the β_{1j} to β_{jj} are computed from equation (A1) by

$$\beta_{ij} = a_{ij} = \sum_{k=1}^{i-1} \alpha_{ik}\beta_{kj} \quad \text{for } i = 1,...,j \tag{A2}$$

followed by the solution of α_{j+1j} to α_{Nj} from equation (B1) by

$$\alpha_{ij} = \frac{1}{\beta_{jj}}\left(a_{ij} - \sum_{k=1}^{j-1} \alpha_{ik}\beta_{kj}\right) \quad \text{for } i = j+1,...,N. \tag{B2}$$

The example will demonstrate that the α's and β's that occur on the right-hand side of equations (A2) and (B2) are already determined by the time they are needed.

Within BRAGFLO the LU-decomposition is done within the band structure of the Jacobian matrix. This is crucial for efficient computation. Therefore, the above algorithms must be modified to work only within the bandwidth of the Jacobian matrix. Further, only the band structure is stored in the BRAGFLO treatment. This allows considerable saving in the storage requirement. Finally, BRAGFLO implements a partial pivoting (row interchanges) which reduces the roundoff errors in the arithmetic and is essential for the numerical stability of Crout's method.

Now consider the example with

$$A = \begin{bmatrix} 1 & 1 & 1 & 1 \\ -2 & 1 & 1 & 1 \\ 0 & 3 & 1 & 1 \\ 1 & 4 & 2 & 6 \end{bmatrix}$$

Starting with the first column we solve for $\beta_{11} = 1$ from equation (A2) where the sum is taken to mean zero. Equation (B2) is then used to solve sequentially for $\alpha_{21} = -2$, $\alpha_{31} = 0$, and $\alpha_{41} = 1$. We now proceed to the second column and from equation (A2) compute sequentially $\beta_{12} = 1$, $\beta_{22} = 3$. Now from equation (B2) we compute $\alpha_{32} = 1$ and $\alpha_{42} = 1$. This procedure is continued for the 3rd and 4th columns with the resulting L and U given by the example stated earlier in this Subsection.

Now suppose the solution of the system $\mathbf{Ax} = \mathbf{b}$ is required given right-hand side vector $\mathbf{b} = (4, 1, 5, 13)^T$. We first solve the system $\mathbf{Ly} = \mathbf{b}$ by the forward substitution algorithm. The system is

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -2 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} 4 \\ 1 \\ 5 \\ 13 \end{bmatrix}$$

Forward substitution from the first equation to the fourth equation yields $\mathbf{y} = (4, 9, -4, 4)^T$. We then solve the system $\mathbf{Ux} = \mathbf{y}$. The system is

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 3 & 3 & 3 \\ 0 & 0 & -2 & -2 \\ 0 & 0 & 0 & 4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} 4 \\ 9 \\ -4 \\ 4 \end{bmatrix}$$

Back substitution from the fourth equation to the first equation yields $\mathbf{x} = (1, 1, 1, 1)^T$.

1.15 Model Geometry

The mesh used in the BRAGFLO simulations attempts to incorporate radial flow phenomena at large distances from the repository and to include the full accessible volume available for multiphase flow. Time and cost constraints currently preclude a full three-dimensional representation of the repository and surrounding strata, so a two-dimensional approximation to the actual geometry is made, as described in WIPP PA Department (1992, Volume 5).

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APPENDIX BWQ

BACKGROUND WATER QUALITY

APPENDIX D17

BACKGROUND WATER QUALITY CHARACTERIZATION REPORT FOR THE WASTE ISOLATION PILOT PLANT

(From the WIPP RCRA Part B Permit Application, Rev. 6)

BACKGROUND WATER QUALITY CHARACTERIZATION REPORT FOR THE WASTE ISOLATION PILOT PLANT (WIPP)

DOE-WIPP 92-013

June 1992

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List of Abbreviations/Acronyms

Bendix	Bendix Field Engineering Services
BSEP	Brine Sampling and Evaluation Program
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft^2/day	square feet per day
gpm	gallons per minute
ITAS	IT Analytical Services
m^2/s	square meters per second
MCL	maximum contaminant level
MDL	method detection limit
µg/ℓ	micrograms per liter
mg/ℓ	milligrams per liter
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant level
SNL	Sandia National Laboratories
TDS	total dissolved solids
TOC	total organic carbon
TOX	total organic halogen
TRU	transuranic
UNC	United Nuclear Corporation
VOC	volatile organic compound
WAESD	Westinghouse Advanced Energy Systems Division
WIPP	Waste Isolation Pilot Plant
WQSP	Water Quality Sampling Program

1.0 Introduction

This report presents water-quality data collected during the preoperational period at the Waste Isolation Pilot Plant (WIPP). The Water Quality Sampling Program (WQSP) has collected groundwater quality data from numerous wells in the vicinity of the WIPP for more than six years to establish the background for the area prior to waste receipt at the WIPP. This report has been prepared to establish the background for numerous water quality parameters including general chemistry, trace metals, and volatile and semi-volatile organic compounds.

1.1 Waste Isolation Pilot Plant

The WIPP, located in southeastern New Mexico, is a research and development facility with the mission to demonstrate the safe and environmentally-sound disposal of radioactive and mixed wastes resulting from defense activities and research programs of the United States government (Figure 1-1). The facility was authorized by the U.S. Department of Energy (DOE) National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (Public Law 96-164).

The WIPP is designed to receive, handle, and emplace defense-generated transuranic (TRU) waste. This waste, generated at other DOE facilities, will be shipped to the WIPP. Waste will be stored 2150 feet underground at the WIPP in the bedded salt deposits of the Salado Formation.

1.2 Water Quality Sampling Program

The WQSP has been responsible for the collection of groundwater samples from wells drilled and completed specifically for WIPP studies, as well as from privately owned water-supply wells located in the WIPP area. The program has been operational since January 1985. Groundwater quality data developed by the WQSP was used to establish the WIPP water quality background characterization.

1.3 Report Organization

Chapter 2.0 discusses the WQSP; monitoring well locations are presented, along with well construction and groundwater sampling procedures. The list of WQSP analytes is also presented in Chapter 2.0. Chapter 3.0 presents the geologic and hydrologic setting of the WIPP Site. Chapter 4.0 provides the methodology used to evaluate the WQSP data; this includes the methods employed to evaluate trends and outliers. Statistical procedures, as well

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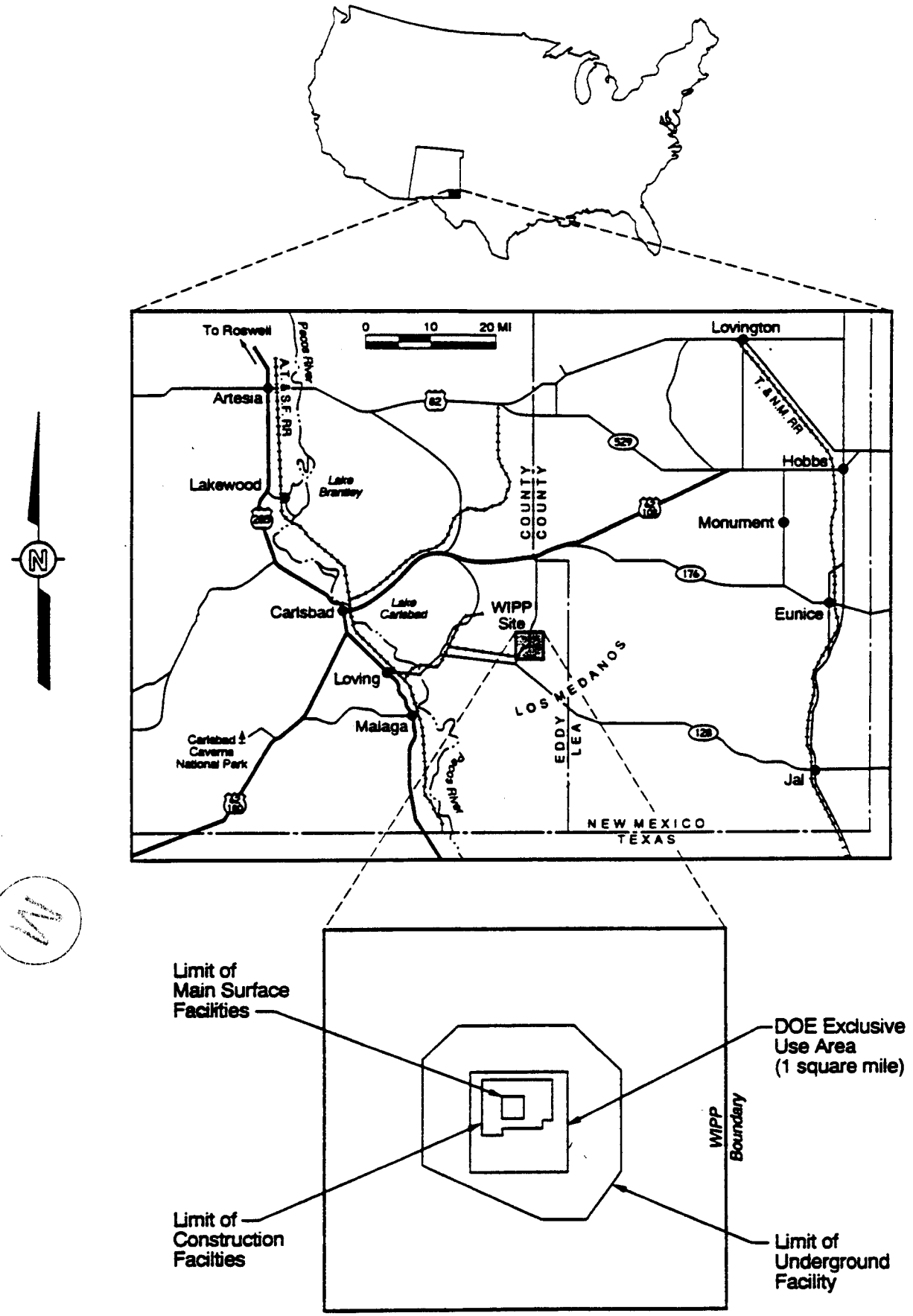

FIGURE 1-1 LOCATION OF WIPP SITE

as, factors that influence data usability are also discussed in Chapter 4.0. Chapter 5.0 presents the results of the WQSP background evaluation, including tabulated background groundwater chemistry data for 28 monitoring wells. Chapter 6.0 is a comparison of WQSP groundwater chemistry to appropriate water quality standards. Finally, Chapter 7.0 provides a summary of findings and conclusions. A compilation of WQSP outlier data and a tabulation of all WQSP data used in this report are included as appendices.

2.0 Water Quality Sampling Program

The WQSP was initiated in January 1985. The objectives of the program have been to collect representative and reproducible groundwater samples from water-bearing zones in the area of the WIPP Site. A program plan initially developed by Colton and Morse (1985) defined the basic structure and operational activities for the program. The monitoring plan was revised in 1987, and the "Waste Isolation Pilot Plant Water Quality Sampling Manual," *WP 7-2*, Revision 1 (Westinghouse, 1987) became the governing document for the program in 1988. This document was subsequently revised (Westinghouse, 1991a). This manual describes the specific monitoring techniques used, lists the specific WQSP monitoring wells to be sampled, and identifies the types of analyses required for the program. Specific procedures detailing sample collection techniques and methods for field analyses have also been prepared and were followed during all groundwater sampling activities. These procedures can be found in the "Waste Isolation Pilot Plant Groundwater Monitoring Program Plan and Procedures Manual," *WP 02-1* (Westinghouse, 1991b).

2.1 Programs Supported by the Water Quality Sampling Program

The water-quality analytical data generated by the WQSP have directly supported five major programs at the WIPP. These programs include site characterization, performance assessment (compliance with 40 CFR 191), the Radiological Baseline Program, Operational Environmental Monitoring Program, and the Ecological Monitoring Program. Additionally, the Environmental Evaluation Group has been provided with water samples from each sampling site for independent analysis. The WIPP WQSP was not designed as a Resource Conservation and Recovery Act (RCRA) groundwater monitoring program in accordance with 40 CFR 264 or 265. A brief description of each of the supported programs is given below to illustrate the role of the WQSP at WIPP.

Site Characterization. The geologic and hydrogeologic characteristics of the WIPP area have been studied by Sandia National Laboratories (SNL) for several years. One of the main goals of these studies has been to better understand the flow of groundwater within water-bearing units of the Rustler Formation. The WQSP provided samples to SNL for use in evaluating the flow regimes in the Culebra and Magenta Dolomite Members of the Rustler Formation. These rock units are considered to be the most feasible pathways for radionuclide transport in hypothetical repository breach scenarios. Data from the WQSP were used in

evaluating present groundwater flow directions and the hydrologic evolution of the Rustler Formation in the northern Delaware Basin.

Performance Assessment. The WIPP is required to comply with the U.S. Environmental Protection Agency's (EPA) Environmental Standards for the management and disposal of spent nuclear fuel, high level, and TRU wastes (40 CFR 191). The WQSP supported this effort by providing water chemistry data for use in predictive modeling of the potential solubility and transport of radionuclides and mixed waste components along potential flow pathways.

Radiological Baseline Program. The Radiological Baseline Program was established in 1985 to measure key radiological parameters in a variety of environmental media in and around the WIPP Site during the preoperational period. The WQSP provided groundwater samples to the Westinghouse Advanced Energy Systems Division (WAESD) for the analysis of a suite of radionuclides as part of the Radiological Baseline Program. The results from these analyses were published yearly in the WIPP Annual Site Environmental Report, Reith et al. (1986), Banz et al. (1987), Flynn et al. (1988, 1989). In 1989, the Radiological Baseline Program was superceded by the Operational Environmental Monitoring Program, which continues the monitoring of groundwater for both radiological and nonradiological parameters.

Ecological Monitoring Program. The Ecological Monitoring Program was established in 1984 to monitor the nonradiological impacts of WIPP construction activities on the surrounding ecosystem. The WQSP provided water-quality data on key environmental parameters for groundwater near the WIPP. Samples were routinely analyzed for general-chemical parameters, metals, and EPA-listed hazardous organic substances. In 1989, the Ecological Monitoring Program was superceded by the Operational Environmental Monitoring Program.

2.2 Water Quality Monitoring Locations

The WQSP has sampled 28 separate WIPP monitoring wells since the program began in 1985. Of these 28 wells, 24 were identified for repeated sampling to establish the preoperational baseline at the WIPP. The additional wells have been sampled occasionally upon the request of various WIPP programs. At the time of completion of this report, 24 wells had been sampled a minimum of three separate times. Eleven of the wells have

been sampled three times, six wells sampled four times, and seven wells sampled five times. Table 2-1 lists the WIPP monitoring wells sampled by the WQSP, the formation in which each well is located, and the number of times each well has been sampled. In addition to the WIPP monitoring wells, the WQSP has sampled 11 privately owned wells in the general vicinity of the WIPP. Ten of these wells provide water for livestock; 1 well provides water for human consumption. The same information for these wells is also presented in Table 2-1. The WIPP monitoring wells and the private wells were selected for sampling because of their areal coverage of the WIPP Site (Figure 2-1). The type of well completion and well-production flow rates were also considered. Together, these factors increase the likelihood of obtaining representative water samples from the formations of interest.

Groundwater quality data from the WQSP have been published in annual data reports and in the "Annual Site Environmental Monitoring Report for Calendar Year 1989 and 1990." The data from previous samplings can be found in several publications including: Uhland and Randall (1986), Uhland et al. (1987), Randall et al. (1988), Lyon (1989), and the "Annual Site Environmental Monitoring Reports for Calendar Years 1989 and 1990" (DOE, 1990a, and DOE, 1991).

WIPP monitoring wells are completed in two main water-bearing units at the site, the Culebra and Magenta Dolomite Members of the Rustler Formation. Of the 24 wells sampled as part of the baseline program, 20 of these wells produce water from the Culebra Dolomite and 4 from the Magenta Dolomite.

The privately owned wells are completed in three main water-bearing units. The water-bearing units include the Permian Dewey Lake Redbeds, the Permian Culebra Dolomite, and the Triassic Dockum Group, Undivided. Of the 11 privately owned wells sampled, 4 are completed in the Culebra Dolomite, 5 are completed in the Dewey Lake Redbeds, and 2 in the Dockum Group.

2.3 Monitoring Well Construction

Many of the WIPP monitoring wells were drilled and completed prior to 1980. As the WIPP Project advanced, additional monitoring wells were completed in the vicinity of the site. Drilling of WIPP monitoring wells began in 1976 and continued into 1988. Table 2-2 details the dates of drilling and completion of all WIPP monitoring wells included in the WQSP. Detailed information on monitoring well drilling and completion can be found in Winstanley and Carrasco (1986).

Table 2-1

Wells Sampled by the Water Quality Sampling Program

Well	Formation	Samples
DOE-1	Culebra	3
DOE-2	Culebra	3
DOE-2	Bell Canyon	1
H-02a	Culebra	3
H-02c	Culebra	1
H-03b1	Magenta	5
H-03b3	Culebra	5
H-04b	Culebra	5
H-04c	Magenta	5
H-05b	Culebra	5
H-05c	Magenta	5
H-06b	Culebra	5
H-06c	Magenta	5
H-07b1	Culebra	5
H-08b	Culebra	3
H-09b	Culebra	4
H-11b3	Culebra	5
H-12	Culebra	3
H-14	Culebra	3
H-15	Culebra	3
H-17	Culebra	1
H-18	Culebra	3
P-14	Culebra	3
P-17	Culebra	3
WIPP-13	Culebra	1
WIPP-19	Culebra	5
WIPP-25	Culebra	4
WIPP-26	Culebra	3
WIPP-29	Culebra	2
Private Wells Sampled		
Barn Well	Dewey Lake	4
Clifton Well	Dockum	2
Comanche Well	Dockum	2
Engle Well	Culebra	3
Fairview Well	Dewey Lake	2
Mobley Well	Culebra	2
Poker Trap	Culebra	2
Ranch Well	Dewey Lake	5
Twin Wells - Pasture Well	Dewey Lake	4
Unger Well	Dewey Lake	2
USGS-1	Culebra	2

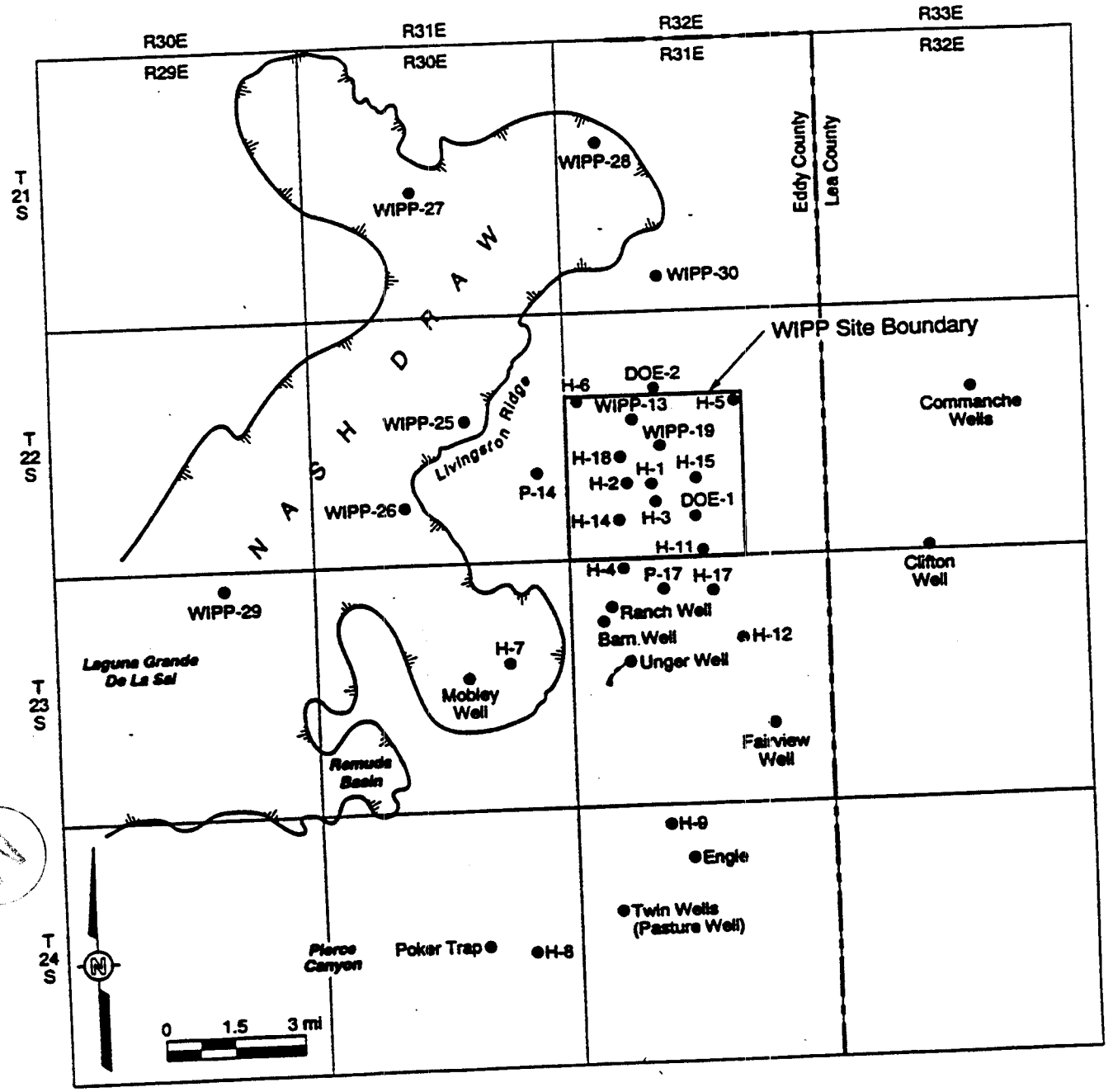

FIGURE 2-1 LOCATION OF WELLS SAMPLED AS PART OF THE WATER QUALITY SAMPLING PROGRAM

Table 2-2
Monitor Well Drilling and Completion Dates

Well	Formation	Completion Type	Date Completed
DOE-1*	Culebra	Perforated	07/82
DOE-2*	Culebra	Perforated	09/84
H-02a	Culebra	Screened	02/77
H-02c	Culebra	Perforated	02/77
H-03b1	Magenta	Perforated	08/76
H-03b3*	Culebra	Open Hole	01/84
H-04b	Culebra	Open Hole	05/78
H-04c	Magenta	Perforated	05/78
H-05b	Culebra	Open Hole	06/78
H-05c	Magenta	Perforated	06/78
H-06b*	Culebra	Open Hole	07/78
H-06c	Magenta	Perforated	06/78
H-07b1*	Culebra	Open Hole	09/79
H-08b	Culebra	Open Hole	08/79
H-09b	Culebra	Open Hole	08/79
H-11b3*	Culebra	Open Hole	01/84
H-12	Culebra	Open Hole	10/83
H-14	Culebra	Open Hole	10/86
H-15	Culebra	Open Hole	11/86
H-17	Culebra	Open Hole	11/87
H-18*	Culebra	Open Hole	11/87
P-14	Culebra	Perforated	10/76
P-17	Culebra	Perforated	10/76
WIPP-13*	Culebra	Perforated	08/78
WIPP-19	Culebra	Perforated	05/78
WIPP-25*	Culebra	Perforated	09/78
WIPP-26	Culebra	Perforated	09/78
WIPP-29*	Culebra	Perforated	10/78

*Sampled using an electric submersible pump.
Source: Winstanley and Carrasco (1986), Beauheim (1987), and Lyon (1989).

In general, all WIPP monitoring wells were drilled as part of the geologic site characterization and resource evaluation programs. Most WIPP monitoring wells were drilled and completed using oil field techniques. Monitoring wells at the site have been completed, generally, in two styles. One type of installation includes drilling the well to some depth below the base of the Culebra Dolomite and then casing the well to the bottom of the hole. The interval of the Culebra or the Magenta Dolomite is then perforated to allow access to the formation for testing or sampling purposes. The second type of completion consists of drilling the hole to a depth just above the top of the Culebra Dolomite, installing well casing to the bottom of the drilled hole, and then coring or drilling through the Culebra Dolomite interval, leaving the interval open to the well. The two types of well completion are shown in Figure 2-2.

These types of well completions presented problems in collecting undisturbed and representative samples from the water-bearing units. The open-hole completions have, in some cases, resulted in sediments below the Culebra Dolomite being exposed in the sampling interval. In some cases, these sediments are rich in halite or other evaporite minerals, causing the water chemistry in the well bore and in the water-bearing unit surrounding the well to be altered. Often, during drilling and completion of monitoring wells, fluids containing fresh water, saturated brines, or other drilling fluids have been introduced into the holes. In some cases, these fluids were left standing in the well bore for extended periods of time resulting in contamination of the surrounding formation (Crawley, 1988).

Well drilling and completion techniques such as those described above are usually not used for installation of monitoring wells employed in RCRA or other groundwater sampling programs, due to the likelihood of aquifer contamination. These practices required that the WQSP utilize extensive groundwater pumping in order to obtain uncontaminated water samples.

Standard oil-field steel well casing was used during completion of the WIPP monitoring wells. This type of casing is easily corroded by the brackish to brine water found in the WIPP area. Based on serial sampling results, it appears that the products of well-casing corrosion migrate from the well bore into the formation, resulting in a halo or plume of groundwater with altered chemistry surrounding the monitoring wells. Obtaining a representative sample has required that the monitoring wells be pumped for long periods of time to remove the contamination.

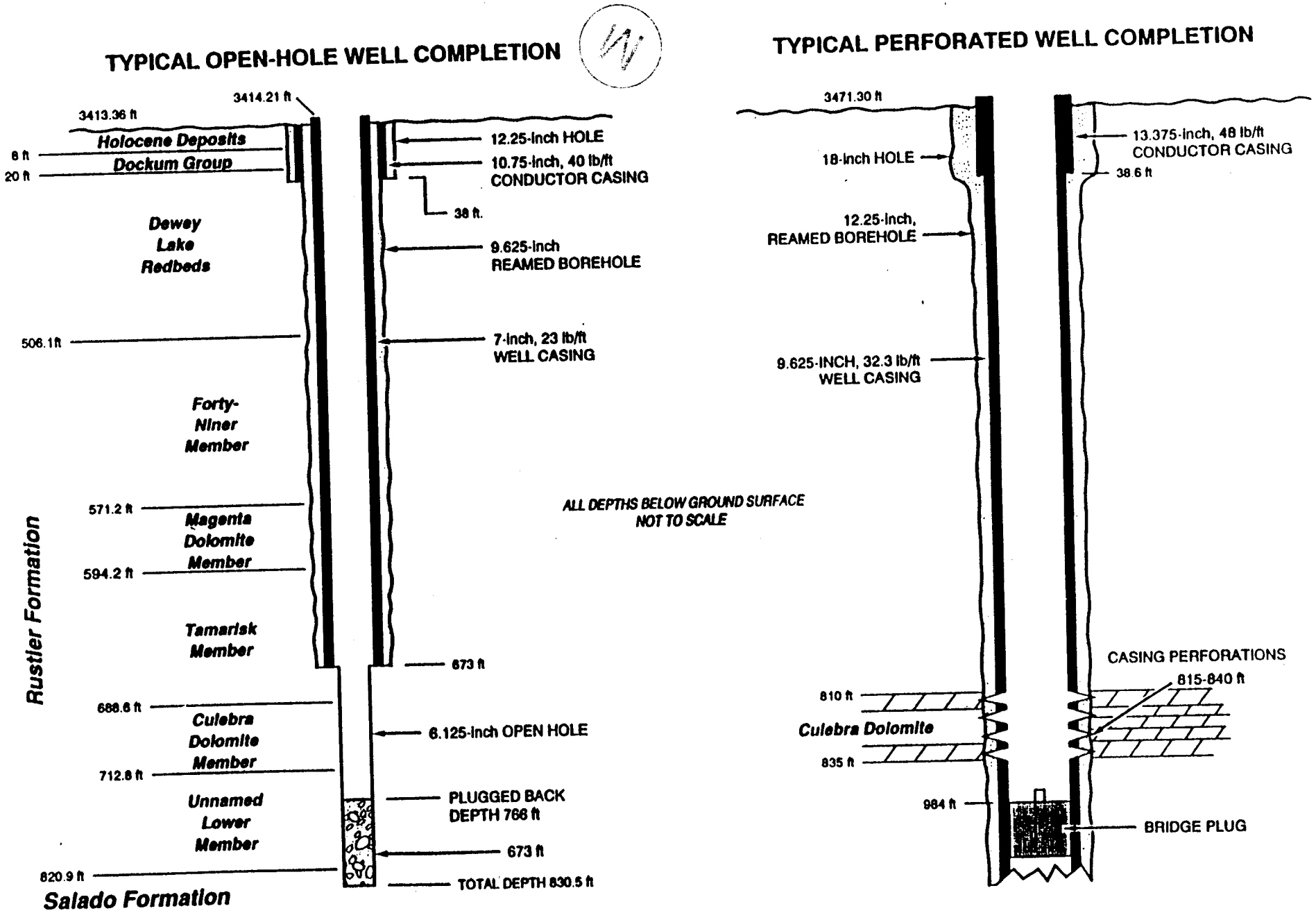

FIGURE 2-2 SCHEMA[illegible] OF THE TWO TYPICAL TYPES OF WIPP [illegible]NITOR WELL CONSTRUCTION

The difficulty in obtaining representative groundwater samples, due to the design of the wells used by the WQSP, necessitated use of a serial sampling technique. Serial sampling and the associated equipment are discussed below.

2.4 Sampling Program Description

The WQSP has employed two types of sampling procedures at WIPP: serial sampling and final sampling.

2.4.1 Serial Sampling

Serial sampling is the collection of sequential samples for the purpose of determining when the water chemistry stabilizes or reaches steady state. Ideally, when the water chemistry stabilizes, it is assumed that the chemistry is representative of the native formation fluid, and a final sample is collected. However, in reality, serial sampling leads to the collection of water samples with reproducible chemistries which may or may not be representative of undisturbed groundwater. The water samples may still be impacted by well construction practices and effects from the installation of downhole pumping and sampling equipment. The WQSP generally monitored serial sampling parameters on a daily frequency in a mobile field laboratory that was located at the well site during pumping operations.

The field analytical parameters found to be the most useful in identifying a steady-state condition of the water chemistry include chloride, divalent cations (hardness), and alkalinity, which are analyzed by classic wet chemistry bench methods (titrations). Total and ferrous iron have also been found to be useful indicators and are analyzed using spectrophotometric methods. Other serial sampling parameters analyzed in the field include measurement of pH, Eh, temperature, specific conductance, and specific gravity. The field serial sampling parameters and the frequency at which they are analyzed are as follows:

Field Parameter	Approximate Frequency
Temperature	Daily
pH	Daily
Eh	Daily
Iron (total and ferrous)	Daily
Divalent Cations	Daily
Chloride	Daily
Alkalinity	Daily
Specific Conductance	First and Final Serial Sample
Specific Gravity	First and Final Serial Sample

The three field parameters temperature, Eh, and pH were generally determined using an inline technique that employed a self-contained flow cell. The flow cell was used to isolate the sample from the atmosphere and to maintain sample pressure. The iron, divalent cations, chloride, alkalinity, specific conductance, and specific gravity samples were collected from a nylon sample line running from the pumping equipment at atmospheric pressure. Additional detail on the serial sampling technique is given in the "WIPP Water Quality Sampling Manual," *WP 07-2* (Westinghouse, 1991a).

Serial sampling data will not be presented in the WQSP baseline report. However, all of the serial sampling data collected prior to January 1989 are presented in the Annual Water Quality Data Reports: Uhland and Randall (1986), Uhland et al. (1987), Randall et al. (1988), and Lyon (1989).

2.4.2 Collection of Final Samples

Final groundwater samples were collected once evidence from serial sampling indicated that the pumped groundwater had reached a chemical steady state. Final samples were forwarded to a contract analytical laboratory for analysis of a long list of parameters (Section 2.6). Final samples were collected in the appropriate type of container for the specific analysis to be performed. For each parameter analyzed, a sufficient volume of sample was collected to satisfy the volume requirements of the analytical laboratory. This included an additional volume of sample water necessary for maintaining quality control standards. All final samples were treated, handled, and preserved as required for the specific type of analysis to be performed. Details on the sample preservation methods and sample volumes required for individual types of analyses are given in the "WIPP Water Quality Sampling Manual," *WP 07-2* (Westinghouse, 1991a).

2.5 Groundwater Pumping and Sampling Equipment

The water-bearing units at the WIPP are highly variable in their ability to yield water to monitoring wells. The Culebra Dolomite, which is the most transmissive hydrologic unit in the WIPP area, exhibits transmissivities that range many orders of magnitude across the site area (Section 3.2) and has been the primary focus of the WQSP. The Magenta Dolomite, which has a lower transmissivity, yields very small quantities of water to wells. Because the water-yielding characteristics of the hydrologic units at the WIPP are variable, different types of pumping equipment were required during the WQSP.

The groundwater pumping and sampling systems at each site were designed to provide continuous and adequate production of water so that a repeatable sample could be obtained. The wells listed in Table 2-1 vary in flow rate, production interval depth, and pumping lift. These factors affected the duration of pumping and the equipment required at each well.

2.5.1 High- and Medium-Flow Rate Wells

The groundwater pumping and sampling system for high- and medium-flow rate wells (greater than 1 gallon per minute [gpm]) generally utilized a submersible pump, downhole packer, a main water discharge line, and a separate sample collection line. Submersible pumps generally produced much more water than was required for sampling. The surplus water was stored in portable oil field storage tanks for off-site disposal by oil field service companies. The high-flow wells are restricted to the Culebra Dolomite and include H-03b3, H-06b, H-07b1, H-11b3, H-18, DOE-1, DOE-2, WIPP-13, WIPP-25, and WIPP-29 (Table 2-2).

The submersible pump was set in the production zone and was then isolated from the stagnant water in the well casing above or below (or both) using a packer, straddle packer, and/or bridge plug combination. The general procedure was to install the pump, packer, and sampling assembly in the well and then inflate the packer(s). A general diagram of the submersible pump and sampling assembly is shown in Figure 2-3.

During pumping, the pressure above and below the packer were continuously monitored using pressure transducers and dataloggers. The pressure below the packer was monitored to determine the fluid level in the well during pumping in order to prevent dewatering of the well or adverse effects on the surrounding formation. The pressure above the packer was measured to monitor packer performance. The pressure above the packer remained constant if the packer was properly seated and did not leak.

2.5.2 Low-Flow Rate Wells

The low-flow rate wells produced less than 1 gpm. These wells are completed in both the Culebra and the Magenta Dolomites (Table 2-2). The low-volume wells required the use of a gas-driven piston pump capable of varying the flow rate from 0.1 to 1.0 gpm. The gas-driven pump was constructed of inert, noncontaminating materials and was operated using an air compressor. Figure 2-4 shows a schematic of the gas-driven piston pump sampling assembly.

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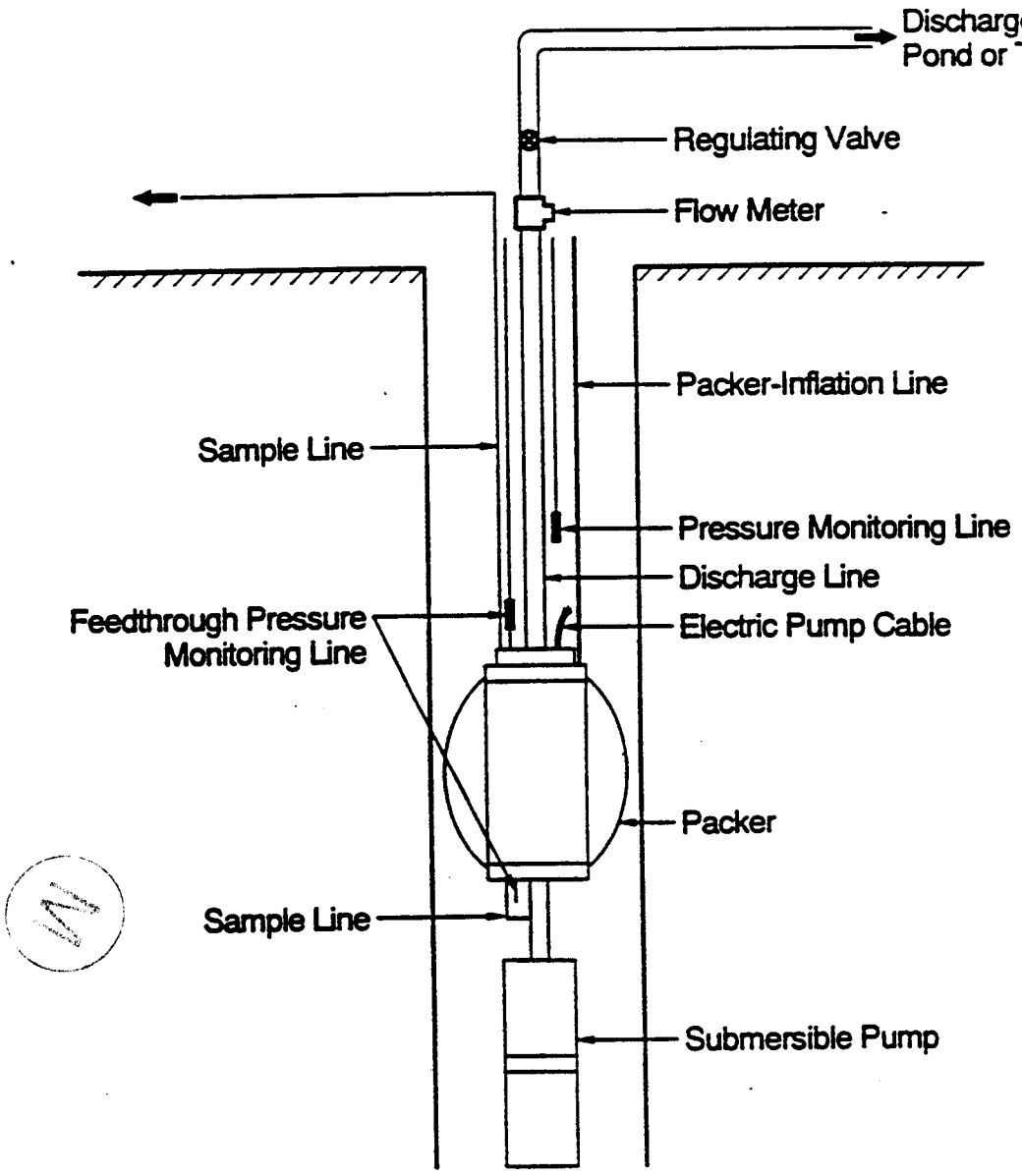
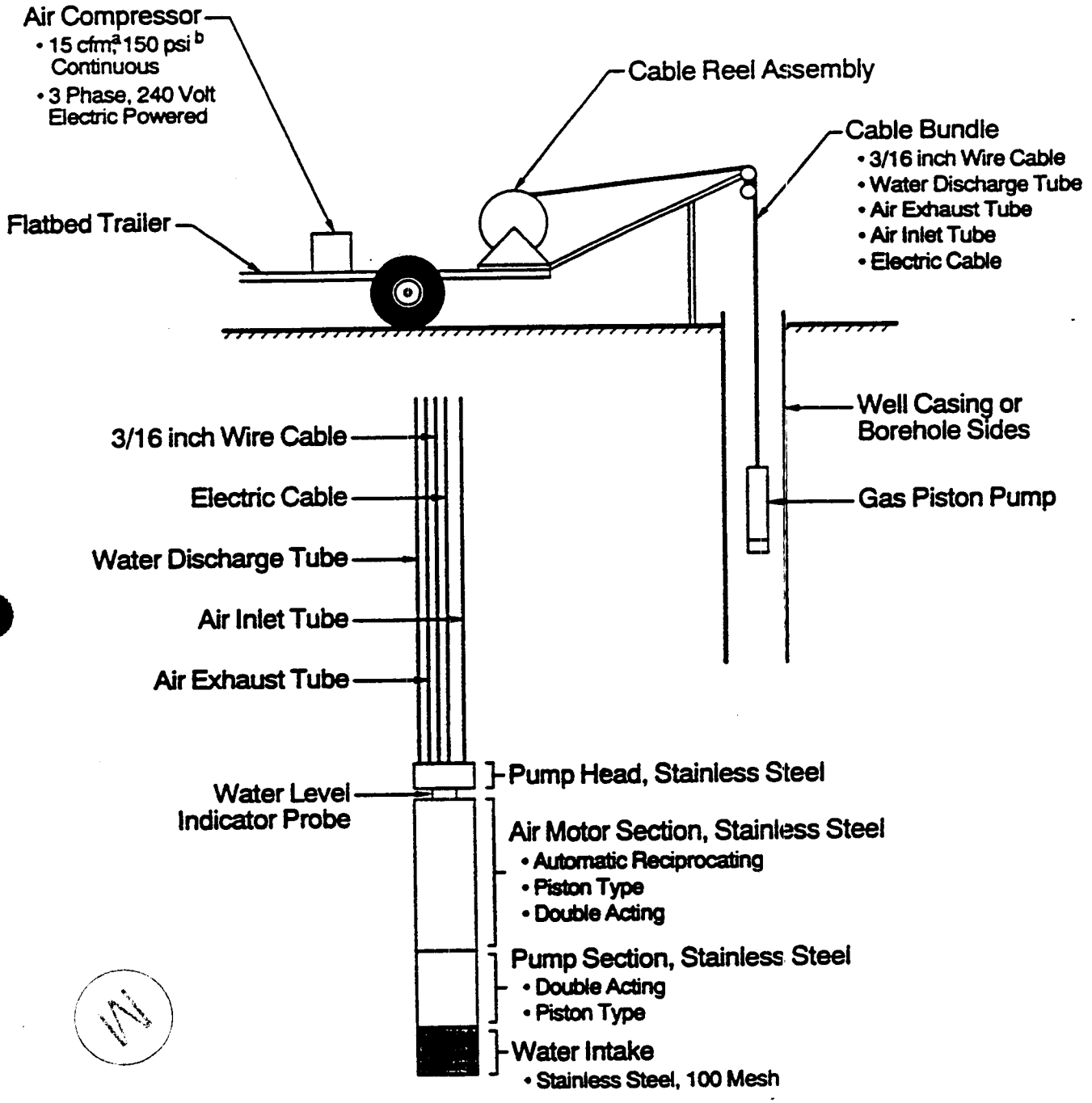


Source: Westinghouse, 1987

FIGURE 2-3 DOWNHOLE PUMP, PACKER, AND SAMPLING SYSTEM



Source: Westinghouse, 1987

a Cubic feet per minute
b Pounds per square inch

FIGURE 2-4 SCHEMATIC OF GAS-DRIVEN PISTON PUMP (Bennett Model 1800) WITH EXPLODED VIEW OF CABLE BUNDLE

The pump intake was set at a predetermined depth near or in the production interval. The low-volume wells were purged, as needed, prior to installation of the low-volume sampling system. The pumping rate and pump intake were routinely adjusted to maintain the water level in the well above the pump intake.

For the low-flow rate wells, the total amount of water produced from the pump was directed through the portable field laboratory for sample collection and operation of the constant temperature bath. An inflatable packer was generally used to isolate the production interval from overlying stagnant water in the well bore. When a packer was used, pressures above and below the packer were continuously monitored to determine the water level in the well and the performance of the packer, as discussed in Section 2.5.1. Note that the packer assembly is not shown in Figure 2-4. Excess water not used for sampling was routed from the field laboratory and disposed of in either a lined pit or storage tank.

2.6 Water Quality Analytical Parameters

Groundwater samples collected as final samples were shipped to contract laboratories for analysis at the conclusion of the serial sampling episode. The laboratories responsible for sample analyses included IT Analytical Services (ITAS), which analyzed the largest list of parameters; Bendix Field Engineering Services (Bendix); United Nuclear Corporation (UNC); and WAESD for radionuclides. Bendix was purchased by UNC during the second sampling round, and these two organizations actually represent the same laboratory. The complete analytical suite consists of six separate parameter groups. These include:

- General chemistry
- Metals
- Hazardous organic compounds
- Dissolved gases
- Redox couples
- Radionuclides.

Radionuclide analyses are performed in support of the Radiological Baseline Program and Operational Environmental Monitoring Program at the WIPP and are not reported as part of the WQSP. Radionuclides, dissolved gases, and redox couples are not considered in this baseline report. Radionuclide analyses are reported in WIPP Annual Site Environmental Reports: Reith et al. (1986), Banz et al. (1987), Flynn et al. (1988, 1989), DOE (1990a), and DOE (1991). Dissolved gases and redox couple data are presented in the WIPP Annual Water Quality Data Reports: Uhland and Randall (1986), Uhland et al. (1987), Randall et al.

(1988), and Lyon (1989). Redox couple data are also presented in Seigel et al. (1991). Table 2-3 lists the analytical parameters analyzed by the contract laboratories for the majority of the samples collected by the WQSP. Table 2-4 details the specific hazardous organic parameters included in the "Organics" category of Table 2-3. However, analysis of all the parameters listed in Tables 2-3 and 2-4 were not performed continuously for all sampling rounds.

Initially, the list of metals analysis for many Round 1 and several Round 2 samples did not include the trace metals antimony, cadmium, lithium, silver, or thallium. In addition, the major cations calcium, magnesium, potassium, and sodium were not included in the initial metals parameter list. The complete list of metals as shown in Table 2-3 was not adopted until late 1986, when these parameters were added to the list.

For the first eight wells sampled during Round 1 of the WQSP, the major cations and anions were analyzed by Bendix for SNL. Beginning with Well H-12, major cations and anions were analyzed by both Bendix and ITAS for a short period of time. For the first eight wells sampled, the baseline data set includes only the preliminary data from the Bendix analyses. For all subsequent samples, the data set for the major cations and anions is from analyses by ITAS.

During the early part of the 1989 sampling year, the analyses by UNC for redox couples and dissolved gases were dropped from the analytical schedule. Therefore, only three rounds of analyses for these parameters are available for most wells. In addition, analyses for the hazardous organic parameters were omitted from the program beginning in the middle of the 1990 sampling year. However, all wells included in the background data collection program have at least three rounds of organic analyses.

2.7 Problems with Laboratory Analyses

As reported in Randall et al. (1988), evaluation of laboratory analytical results have shown that reported concentrations of trace metals exhibit a high degree of uncertainty. In a groundwater sample collected in a given sampling round, several trace metals would be reported at concentrations that exceed the expected values for these metals in natural waters (Hem, 1985). However, in samples from the same well collected during previous or subsequent rounds, concentrations of the same trace metals would be below the detection limit, suggesting that the reported high concentrations were not accurate.

Table 2-3

Contracted Analytical Laboratories
Water Quality Analyses

International Technology Analytical Services		Sandia National Laboratories	United Nuclear Corporation	Environmental Evaluation Group	Westinghouse Advanced Energy Systems Division
General Chemistry Alkalinity Bromide Chloride Cyanide Fluoride Iodide Nitrate pH Phenolics Phosphate, Total Filterable Residue Nonfilterable Residue Specific Conductance Sulfate Total Organic Carbon Total Organic Halogen Organic Compounds Volatile Hazardous Substance List Semi-volatile Hazardous Substance List PCB	Metals Aluminum Antimony Arsenic Barium Beryllium Boron Cadmium Calcium Cesium Chromium Cobalt Copper Iron Lead Lithium Magnesium Mercury Molybdenum Nickel Potassium Selenium Silica Silver Sodium Strontium Thallium Titanium Vanadium Zinc	Isotopes Radiocarbon Major Ions Trace Elements	Dissolved Gases Argon Oxygen Nitrogen Carbon Monoxide Carbon Dioxide Methane Ethane C-3 C-4 C-5 C-6 Sum of CO_2 Total Gas Redox Couples Ammonia Nitrate Total Iron Ferrous Iron Arsenic III Total Arsenic Selenium IV Total Selenium Iodide Iodate	General Chemistry Radionuclides	Radionuclides Co-60 Cs-137 H-3 K-40 Np-237 Pu-238 Pu-239/Pu-240 Pu-241 Pu-242 Ra-226 Ra-228 Sr-90/Yt-90 Th-228 Th-230 Th-232 U-233 U-234 U-235 U-238

Source: Lyon, 1989

Table 2-4
List of Organic Analytical Parameters

Volatile Hazardous Substances Parameter	Semivolatile Hazardous Substances Parameter	
Acetone	Acenaphthene	2,6-Dinitrotoluene
Benzene	Acenaphthylene	Di-N-octyl phthalate
2-Butanone	Anthracene	Fluoranthene
Bromoform	Benzo(A)anthracene	Fluorene
Carbon disulfide	Benzo(A)pyrene	Hexachlorobenzene
Carbon tetrachloride	3,4-Benzofluoranthene	Hexachlorobutadiene
Chlorobenzene	Benzo(G,H,I)perylene	Hexachlorocyclopentadiene
Chlorodibromomethane	Benzoic acid	Hexachloroethane
Chloromethane	Benzo(K)fluoranthene	Indeno(1,2,3-CD)pyrene
2-Chloroethylvinyl ether	Benzyl alcohol	Isophorone
Chloroform	Bis(2-chloroethoxy)methane	2-Methylnaphthalene
cis-1,3-Dichloropropene	Bis(2-chloroethyl)ether	2-Methylphenol
Dichlorobromomethane	Bis(2-chloroisopropyl)ether	4-Methylphenol
1,1-Dichloroethane	Bis(2-ethylhexyl)phthalate	Naphthalene
1,2-Dichloroethane	4-Bromophenyl phenyl ether	2-Nitroaniline
1,1-Dichloroethylene	Butyl benzyl phthalate	3-Nitroaniline
1,2-Dichloropropane	4-Chloroaniline	4-Nitroaniline
Ethylbenzene	2-Chloronaphthalene	Nitrobenzene
2-Hexanone	2-Chlorophenol	2-Nitrophenol
Methyl bromide	4-Chlorophenyl phenyl ether	4-Nitrophenol
Methyl chloride	Chrysene	N-Nitrosodi-N-propylamine
4-Methyl-2-pentanone	Dibenzo(A,H)anthracene	N-Nitrosodiphenylamine
Methylene chloride	Dibenzofuran	P-Chloro-M-cresol
Styrene	1,2-Dichlorobenzene	Pentachlorophenol
1,1,2,2-Tetrachloroethane	1,3-Dichlorobenzene	Phenanthrene
Tetrachloroethylene	1,4-Dichlorobenzene	Phenol
Toluene	3,3-Dichlorobenzidine	Pyrene
trans-1,2-Dichloroethylene	2,4-Dichlorophenol	1,2,4-Trichlorobenzene
trans-1,3-Dichloropropene	Diethyl phthalate	2,4,5-Trichlorophenol
1,1,1-Trichloroethane	2,4-Dimethylphenol	2,4,6-Trichlorophenol
1,1,2-Trichloroethane	4,6-Dinitro-o-cresol	Polychlorinated biphenyls
Trichloroethylene	2,4-Dinitrophenol	
Vinyl Acetate	Dimethylphthalate	
Vinyl Chloride	Di-n-butyl phthalate	
Total Xylenes	2,4-Dinitrotoluene	

Source: Lyon, 1989

The high concentrations of dissolved solids in many of the WQSP wells at the WIPP Site, coupled with the relatively low concentration of trace elements, appear to have resulted in analytical error due to enhancements or interferences. In many cases reported trace element concentrations are probably much higher than actual concentrations.

Detection limits for trace elements were affected by the high total dissolved solids (TDS) load of many samples due to the need for multiple dilutions of samples prior to analysis. Equipment limitations have required that many samples be diluted up to 1000 to 1, raising the lower limit of detection for trace elements into the milligram-per-liter (mg/ℓ) range. Unfortunately, the high detection limits and erroneous concentrations reported for trace metals are not useful in establishing a baseline for these parameters.

As reported in Lyon (1989), an alternative method for analysis of trace metals was attempted by the WQSP and the ITAS laboratory. This method adapted an ion-exchange technique that separates and concentrates transition-metal elements from alkali and alkaline-earth elements in seawater (Kingston et al., 1978). Fifteen trace metals from the WQSP parameter list were selected for study. Preliminary testing and method development began in the spring of 1988 using water from Well H-05b as the test matrix. After the preliminary testing was completed, samples from three wells (H-05b [round three], H-08b [round three], and WIPP-19 [round three]) were analyzed for the 15 trace metals using the separation technique. These three wells were selected to test the separation technique on the range of groundwater types found in the Culebra Dolomite across the WIPP area. The detailed procedure for conducting this trace-metal analysis is described in Appendix A.

In general, the ITAS results for hazardous organic compounds have shown no detectable concentrations in the majority of samples analyzed. As described in Randall et al. (1988), some organic compounds were occasionally reported for a few wells. The compounds were chiefly acetone, methylene chloride, and phthalate compounds. In the majority of cases, the compounds were not detected in either previous or subsequent samples, suggesting that the reported detection was due to contamination. Acetone, methylene chloride, and phthalates are common laboratory contaminants due to their abundance in the typical laboratory environment. The detections of hazardous organic compounds are discussed in Chapter 5.0.

3.0 Geologic and Hydrologic Setting of the WIPP Site

The geology and hydrology of the WIPP area have been extensively characterized since 1975. Site characterization and performance assessment studies have developed a large data base of hydrogeologic information for the WIPP Site region of the Delaware Basin in southeastern New Mexico. A general overview of site geology and hydrology as well as the major guiding factors used to characterize the background water quality are presented below.

3.1 Local Geology

The WIPP Site is located in the northern portion of the Delaware Basin of southeastern New Mexico (Figure 1-1). The Delaware Basin is the westernmost basin of the sedimentary basins collectively known as the Permian Basin.

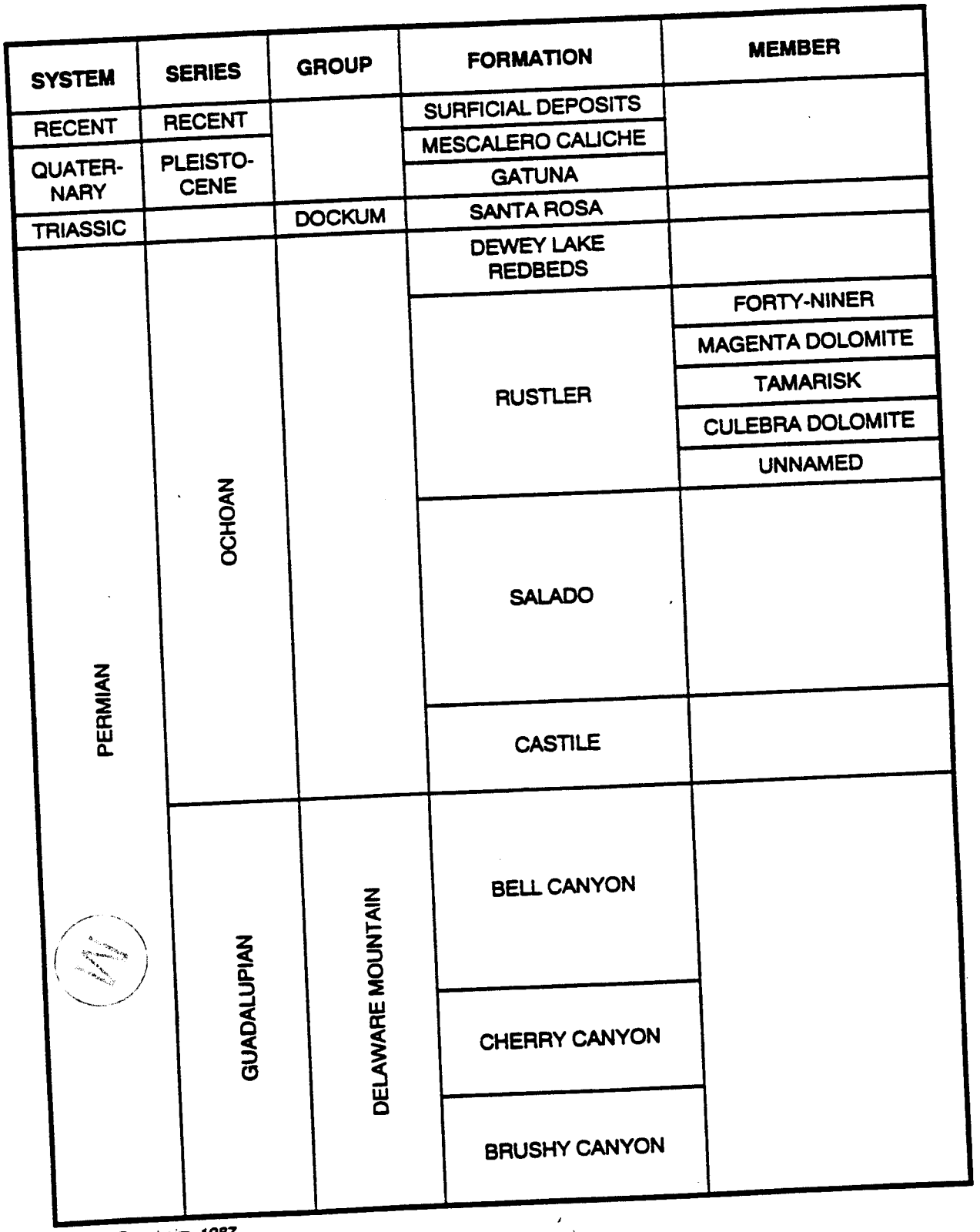
The northern Delaware Basin is surrounded by the Capitan Reef complex of Permian Age, which is the only major source of potable groundwater in the Delaware Basin. Within the basin, and in the WIPP vicinity, a thick sequence of Permian sedimentary rocks were deposited. These rock units are shown in the stratigraphic column presented in Figure 3-1. These eight rock units are important to the hydrogeology at the WIPP. A generalized geologic cross section is shown in Figure 3-2.

3.1.1 Delaware Mountain Group

The Delaware Mountain Group is part of the Guadalupian Series deposited during the Permian Period and consists of fine-grained clastic rocks with occasional limestones and shale beds (Mercer, 1983). The group is divided in ascending order into the Brushy Canyon, Cherry Canyon, and the Bell Canyon Formations. The Delaware Mountain Group is overlain by the Ochoan Series of Permian Age. The Bell Canyon Formation is the first water-bearing formation beneath the Ochoan evaporite sequence in which the WIPP is located. The WQSP sampled water from the Bell Canyon Formation one time, at Well DOE-2. The results of this sampling are not considered in the WQSP baseline report.

3.1.2 Ochoan Series

The Ochoan Series generally consists of evaporites with increasing quantities of siltstones and mudstones in the younger rocks. The Ochoan Series is represented in ascending order by the Castile, Salado, the Rustler Formations, and the Dewey Lake Redbeds. Each of these units is discussed below.



Source: Beauheim, 1987

FIGURE 3-1 GENERALIZED STRATIGRAPHIC COLUMN OF THE DELAWARE MOUNTAIN GROUP AND YOUNGER SEDIMENTARY ROCKS AT AND NEAR THE WIPP SITE

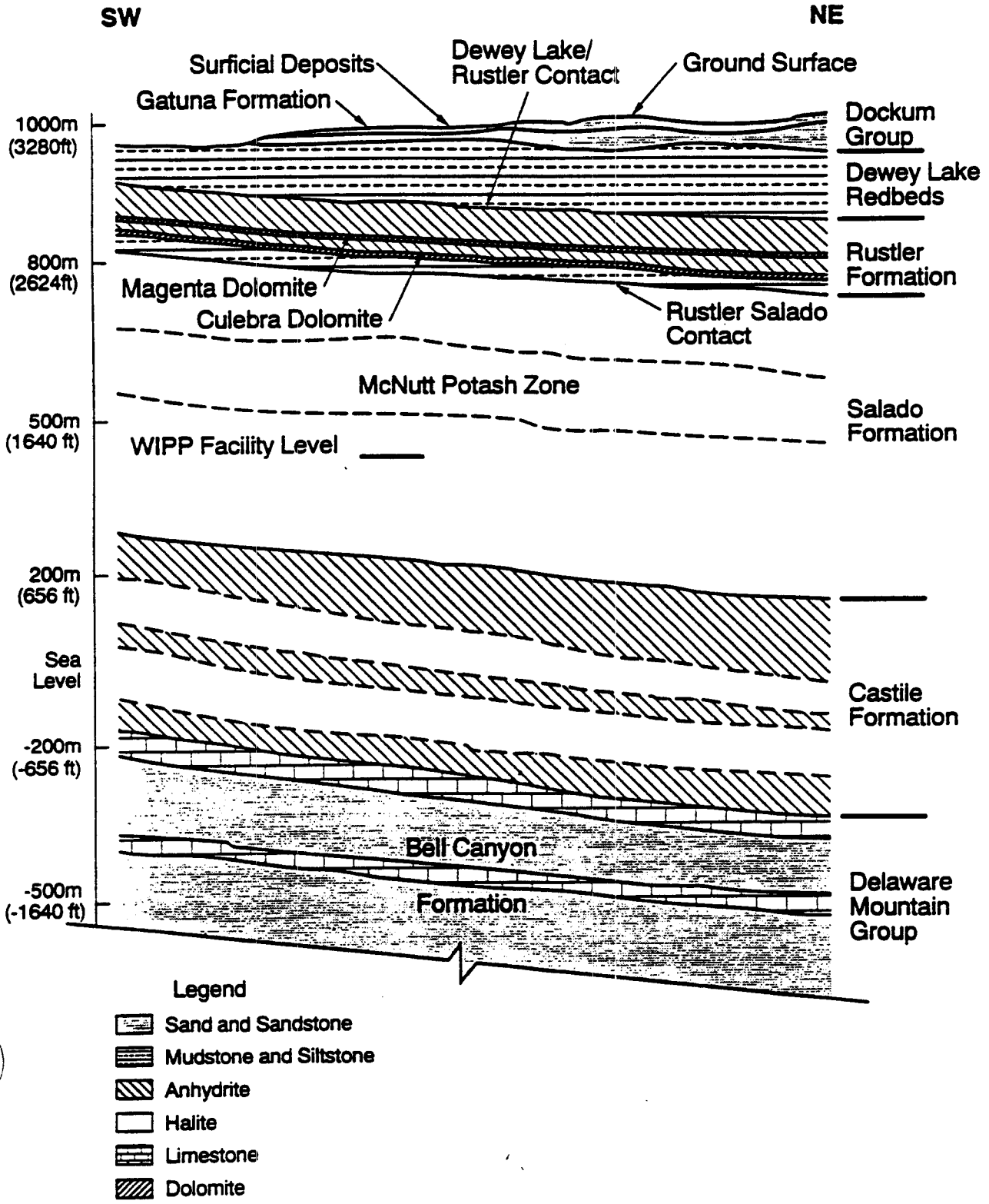


FIGURE 3-2 GENERALIZED STRATIGRAPHIC CROSS SECTION

Castile Formation. The Castile Formation consists mainly of anhydrite, calcite-banded anhydrite, and halite with some limestone and sandstone (Mercer, 1983). The Castile Formation is considered a hydrologic barrier and regional aquiclude between the overlying Salado Formation and the underlying and water-bearing Bell Canyon Formation. The WQSP has not attempted to collect water samples from the Castile Formation, and thus, this formation is not considered in the water-quality baseline.

Salado Formation. The Salado Formation is the host unit for the WIPP facility repository. The formation is approximately 2,000 feet thick in the vicinity of the WIPP. The Salado Formation is an evaporite unit consisting predominantly of halite with minor amounts of anhydrite, polyhalite, and other potash or potassium-bearing minerals. Due to a slight eastward tilting of the Delaware Basin, the Salado Formation has been exposed and erosionally removed from the west and south sides of the basin, leaving a horseshoe-shaped rim of brecciated insoluble material. The Salado Formation does not contain circulating groundwater and is considered a major regional confining unit in the Delaware Basin. Small brine seeps have been observed in the WIPP underground and have been characterized by the WIPP Brine Sampling and Evaluation Program (BSEP). The WQSP has not sampled Salado Formation brines, and the water chemistry of the Salado is not considered in this baseline report. Results from BSEP sampling and analyses can be found in the annual BSEP reports (Deal and Case, 1987; Deal et al., 1987; Deal et al., 1989; Deal et al., 1991; Deal et al., 1992).

Rustler Formation. The Rustler Formation is the youngest of the Ochoan evaporite-bearing formations in the Delaware Basin and directly overlies the Salado Formation. The Rustler Formation is significant to the WIPP because it contains the most significant water-bearing zones in the WIPP area (Figures 3-1 and 3-2). The Rustler Formation in the WIPP area consists of a variable lithologic mixture of interbedded sulfates, carbonates, clastics, and halite. The Rustler was divided by Vine (1963) into five main subdivisions: (1) at the base, an unnamed unit of clayey siltstone and very fine-grained sandstone with thin interbeds of anhydrite and halite in its upper part; (2) the Culebra Dolomite Member, a unit of thin-bedded, finely crystalline dolomite; (3) the Tamarisk Member, chiefly anhydrite; (4) the Magenta Dolomite Member, a unit of thinly cross-laminated, fine-grained dolomite; and (5) the Forty-Niner Member, anhydrite with a single thin interbed of siltstone. The two dolomite members are hydrologically important to the WIPP area and also serve as distinctive subsurface marker beds across the Delaware Basin (Adams, 1944).

The Culebra and Magenta Dolomite Members are the principal water-bearing units at the WIPP and have been studied extensively during site characterization and performance assessment investigations. The WQSP has focused primarily on sampling the Culebra Dolomite. The WQSP baseline at WIPP is generally limited to the Culebra and Magenta Dolomite Members of the Rustler Formation.

Dewey Lake Redbeds. The Dewey Lake Redbeds are the uppermost of the four Ochoan formations and represents the close of the Paleozoic Era in the Delaware Basin. The Dewey Lake Redbeds are important to WIPP hydrogeology because they act as a barrier to downward infiltration of groundwater into the evaporite section overlying the WIPP facility repository. The Dewey Lake conformably overlies the Rustler Formation and unconformably underlies the Triassic Dockum Group and younger sediments. The Dewey Lake Redbeds consists almost entirely of mudstone, claystone, siltstone, and interbedded sandstone. Much of the Dewey Lake Redbeds is characterized by gypsum-filled fractures that are the result of unloading (Holt and Powers, 1988) and indicate that for the general WIPP area no fresh groundwater has moved through the Dewey Lake Redbeds since they were formed. However, to the south of the WIPP there is an area where local recharge may be occurring and the upper part of the formation is saturated. The WQSP has sampled groundwater from the Dewey Lake Redbeds through the private well sampling effort. Some of these data are included in this report.

3.1.3 Post-Permian Deposits

In the WIPP area, the only Triassic unit present is the Santa Rosa Sandstone, part of the Dockum Group. The Santa Rosa Sandstone is present to the east of the WIPP, having been removed by erosion west of the site. It consists of sandstone and conglomerate with interbeds of siltstone and mudstone. The WQSP has collected samples from private wells believed to be completed in the Santa Rosa Sandstone; however, the data are insufficient to establish background water quality.

Tertiary and Quaternary deposits in the WIPP facility area include the Ogallala Formation of Miocene age; the Gatuna Formation of Pleistocene age; and sands, playa deposits, caliche, and alluvium of Holocene age. These deposits cover most of the region and lie unconformably on older rocks. In the WIPP area, these Tertiary and Quaternary deposits are not water-bearing, and no attempt has been made to collect groundwater-quality samples from them.

3.2 Groundwater Hydrology

At the WIPP, the Culebra and Magenta Dolomite Members of the Rustler Formation are the most significant water-bearing units. Sampling and analysis of groundwater by the WQSP have focused on these two rock units, and the water-quality background will generally be established only for the Culebra and Magenta Dolomite Members. The WQSP has also sampled a few wells completed in the Dewey Lake Redbeds, and the results from wells that have been sampled three or more times will be reported. Therefore, the following discussion of site groundwater hydrology is limited to the Rustler Formation, with a brief summary for the Dewey Lake Redbeds.

The groundwater hydrology at the WIPP has been characterized in great detail and has been reported in several publications. The reader is referred to the following publications: (1) "Geological Characterization Report for the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico" (Powers et al., 1978); (2) "Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico" (Mercer, 1983); (3) "Summary of Site-Characterization Studies Conducted from 1983 Through 1987 at the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico" (Lappin, 1988); (4) "Final Safety Analysis Report, Waste Isolation Pilot Plant" (DOE, 1990b); (5) "Waste Isolation Pilot Plant No-Migration Variance Petition" (DOE, 1990c); and (6) "Conceptual Hydrogeologic Model of the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant Site, Southeastern New Mexico" (Holt et al., 1992).

3.2.1 Dewey Lake Redbeds

The Dewey Lake Redbeds comprise the youngest rocks in the Ochoan sequence at the WIPP Site and mark an abrupt change in the depositional environment (Figure 3-1). In general, the Dewey Lake Redbeds consist almost entirely of mudstone, claystone, siltstone, and some lenticular interbeds of fine-grained sandstone. Nearly all of the siltstone and mudstone are veined with selenite gypsum as seen in core. Because of its characteristically minimal permeability, it does not contain significant quantities of groundwater (Mercer, 1983).

Holt and Powers (1990) report that the upper portion of the Dewey Lake Redbeds are cemented with carbonate. Based on observations made in the WIPP air intake shaft, the researchers report that this carbonate-cemented upper portion is moist. Holt and Powers also report that an abrupt change in cement type, from carbonate to a much harder, unidentified material, occurs in the section of Dewey Lake Redbeds studied in the shaft. Below the

change in cement type, fractures were filled with gypsum, and the formation was no longer moist.

Drilling during hydrogeologic evaluation did not reveal a continuous zone of saturation within the Dewey Lake Redbeds; however, localized permeable zones were detected. Detailed data collected during drilling of test holes with air identified minor zones of saturation, particularly in several of the thin lenticular sands in the upper part of the Dewey Lake Redbeds at test holes H-01, H-02, and H-03 (Mercer and Orr, 1979). Geologic data from the wells at the WIPP Site indicate that the sands pinch out laterally. Where water is present, it probably is perched or semiperched and its occurrence is localized, depending to a great extent on locally favorable conditions for recharge.

Four intervals of the Dewey Lake Redbeds were tested in foundation boreholes at the WIPP facility. Although saturated conditions were not detected, ten of these boreholes were completed as observation wells. Water levels were measured monthly over an 18-month period to determine if a transient zone of saturation might develop. Water levels measured in these wells were always below the level of the deepest perforations, indicating that any water encountered was from well completion.

In the immediate WIPP area, the Dewey Lake Redbeds are not saturated and do not yield water to wells. However, to the south of the WIPP Site several private wells completed in the Dewey Lake Redbeds supply water for domestic and livestock use. These wells include two wells at the Mills Ranch (Ranch Well and Barn Well), Fairview Windmill, Unger Windmill, and Twin Wells-Pasture Well. The two wells at the Mills Ranch may be completed in one of the lenticular sands. Geologic data indicate that the wells are completed in the upper part of the Dewey Lake Redbeds (Mercer, 1983). These wells have either saline water or small yields. In the vicinity of these two wells is an extensive area of thick, active sand dunes, which could be an area of recharge for the upper Dewey Lake Redbeds in this area.

Recharge of sand units in the Dewey Lake Redbeds is probably an unusual and localized phenomenon dependent on local geological conditions, such as those at the Mills Ranch. Recharge may also occur by downward percolation of water through fractures or along bedding planes in mudstone and siltstone. Discharge towards deeper zones through existing fractures or through dissolution of gypsum veinlets is minor. Generally, in the WIPP Site

area the Dewey Lake Redbeds act as an unsaturated confining layer over the Rustler Formation (Mercer, 1983).

The WQSP collected groundwater samples from the Dewey Lake Redbeds using the private wells discussed above. The private wells that are completed in the Dewey Lake Redbeds and have been sampled three or more times (see Table 2-1) include Barn Well, Ranch Well, and Twin Wells-Pasture Well. The results from these three wells are included in the water-quality background characterization for the WIPP.

3.2.2 Rustler Formation

The Rustler Formation contains the most transmissive water-bearing units in the WIPP area. The Culebra Dolomite Member of the Rustler Formation is the first continuous water-bearing zone above the Salado Formation (waste repository horizon) and is the most transmissive hydrologic unit in the WIPP area (Figure 3-2). Water in the Culebra Dolomite is usually present in fractures and is confined by the overlying gypsum or anhydrite and underlying clay and anhydrite beds of the other Rustler members. The Magenta Dolomite Member, also a confined water-bearing unit in the WIPP area, is a distinctive clastic carbonate bed with thin interbeds of anhydrite. The Magenta Dolomite is the uppermost water-producing zone in the Rustler Formation (Figure 3-2). Where the Magenta Dolomite is saturated, water usually occurs in the thin silt beds or silty dolomite but also has been found along bedding planes and in fractures.

Water chemistry and hydrogeologic characteristics of the Culebra and Magenta Dolomites are highly variable across the site area. Results of site characterization studies have shown that water-quality variability in the Culebra Dolomite may be a function of the local variability in hydrogeologic conditions. The groundwater hydrology and water-quality characteristics of the Culebra and Magenta Dolomite Members of the Rustler Formation are discussed in detail below.

3.2.2.1 Culebra Dolomite Member of the Rustler Formation

Hydraulic properties of the Culebra Dolomite vary considerably from place to place across the site (LaVenue et al., 1988). In general, transmissivity appears to be a function of the size and number of fractures and openings. The transmissivity of the Culebra Dolomite across the WIPP region varies by six orders of magnitude (Figure 3-3). The higher transmissivity values have been measured in Nash Draw, a highly fractured area caused by dissolution of Rustler and Salado Formation evaporites. The highest value of transmissivity reported for the

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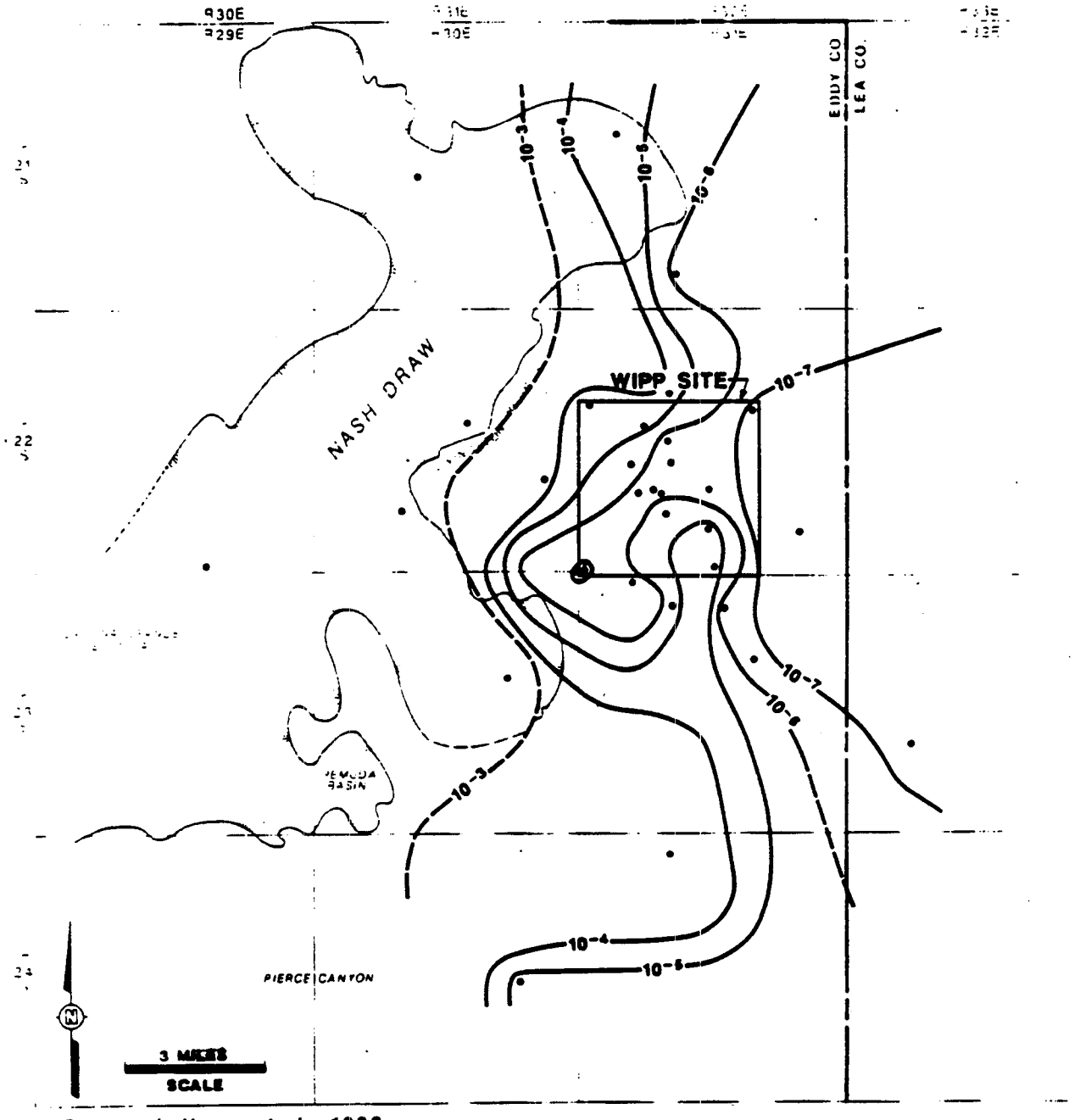

Source: LaVenue et al., 1988

EXPLANATION

• WELLS TESTED

—10-5— TRANSMISSIVITY CONTOUR
SQUARE METERS PER SECOND

FIGURE 3-3 CALCULATED CULEBRA DOLOMITE TRANSMISSIVITIES

Culebra is 1.25 x 10^3 square feet per day (ft^2/day) or 1.34 x 10^{-3} square meters per second (m^2/s) at Well WIPP-26 within Nash Draw. The transmissivity of the Culebra Dolomite generally decreases from west to east across the site area (Figure 3-3). The lowest transmissivity reported is $\leq$ 0.004 ft^2/day (2.15 x 10^{-9} m^2/s) at Well P-18 east of the WIPP Site. As shown in the contour map in Figure 3-3, Culebra Dolomite transmissivities are relatively high in a wide region south of the WIPP Site and east of Nash Draw. A narrow linear zone of high transmissivity extends north into the WIPP area from the southern high transmissivity region. A zone of higher transmissivity occurs north of, but does not penetrate, the WIPP Site area.

Groundwater flow in the Culebra Dolomite exhibits considerable variability in both direction and gradient across the WIPP Site area. This variability may be the result of lateral variation in Culebra Dolomite permeability and differences in fracture orientation as discussed by Mercer (1983). Culebra Dolomite water levels in the WIPP Site vicinity have been impacted by continuous drainage into one or more of the WIPP shafts since construction of the original exploratory shaft and by large-scale pumping during numerous aquifer tests and WQSP sampling. LaVenue et al. (1988) reviewed Culebra Dolomite water-level data, borehole-fluid density data, and WIPP-related hydraulic stresses and derived estimates of the undisturbed freshwater equivalent heads at 31 wells (Figure 3-4). The contours on Figure 3-4 show that the estimated flow direction in the Culebra Dolomite prior to WIPP-related effects was generally to the south and southwest. Flow directions presented by Crawley (1988) and Lappin (1988) also indicate a general southerly flow direction across the WIPP Site area (Figure 3-4). The flow directions shown by the arrows on Figure 3-4 were developed considering the variability of formation- fluid density and the local geologic structure of the Culebra Dolomite. Davies (1989) and Crawley (1988) suggest that flow directions south of the WIPP Site may have a larger easterly, down-dip component than is predicted considering only freshwater heads.

Figure 3-5 shows the recent (post-WIPP-related stresses) potentiometric surface of the Culebra Dolomite based on the results of the Pressure-Density Survey Program (Crawley, 1988). Figure 3-5 indicates that there is considerable variability in gradient and flow direction within the WIPP Site area. The hydraulic gradient in the immediate WIPP Site vicinity is approximately 20 feet per mile, while the gradient south and southwest of the site is much flatter. The gradient between Wells H-07b and H-09b is less than 5 feet per mile, while the gradient between Wells H-07b and H-08b is less than 1 foot per mile (Crawley, 1988). The broad area south of the WIPP, where the gradient appears to be extremely flat, may represent

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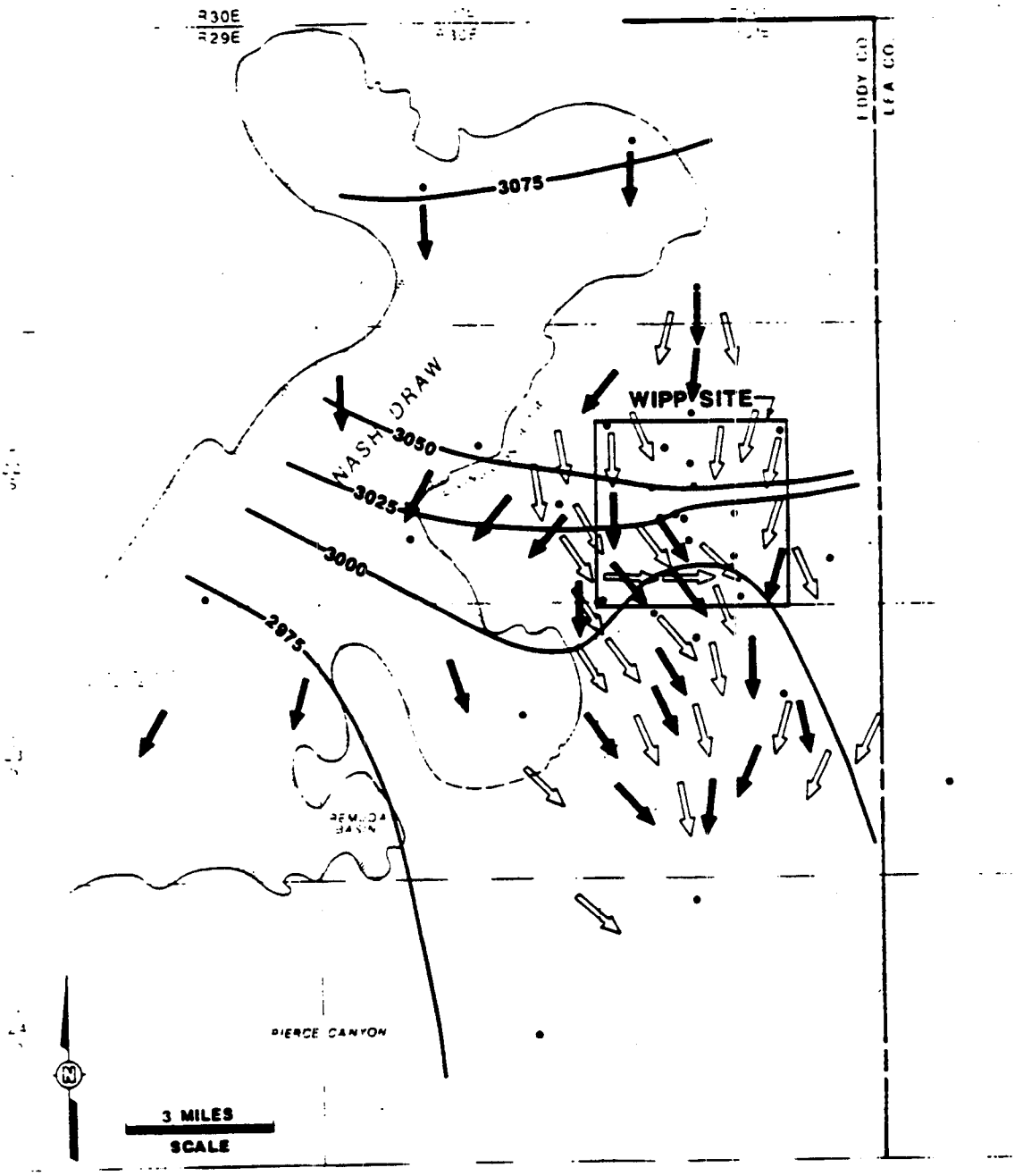


Source: Holt et al., 1992

EXPLANATION

—3000— FRESHWATER-HEAD ELEVATION CONTOUR, CONTOUR INTERVAL = 25 FEET FROM LA VENUE, ET AL., 1988

• WELLS TESTED

GENERAL DIRECTION OF GROUNDWATER FLOW
⇨ FROM CRAWLEY, 1988
➡ FROM LAPPIN, 1988

FIGURE 3-4 ESTIMATED CULEBRA DOLOMITE FRESHWATER HEADS AND FLOW DIRECTIONS

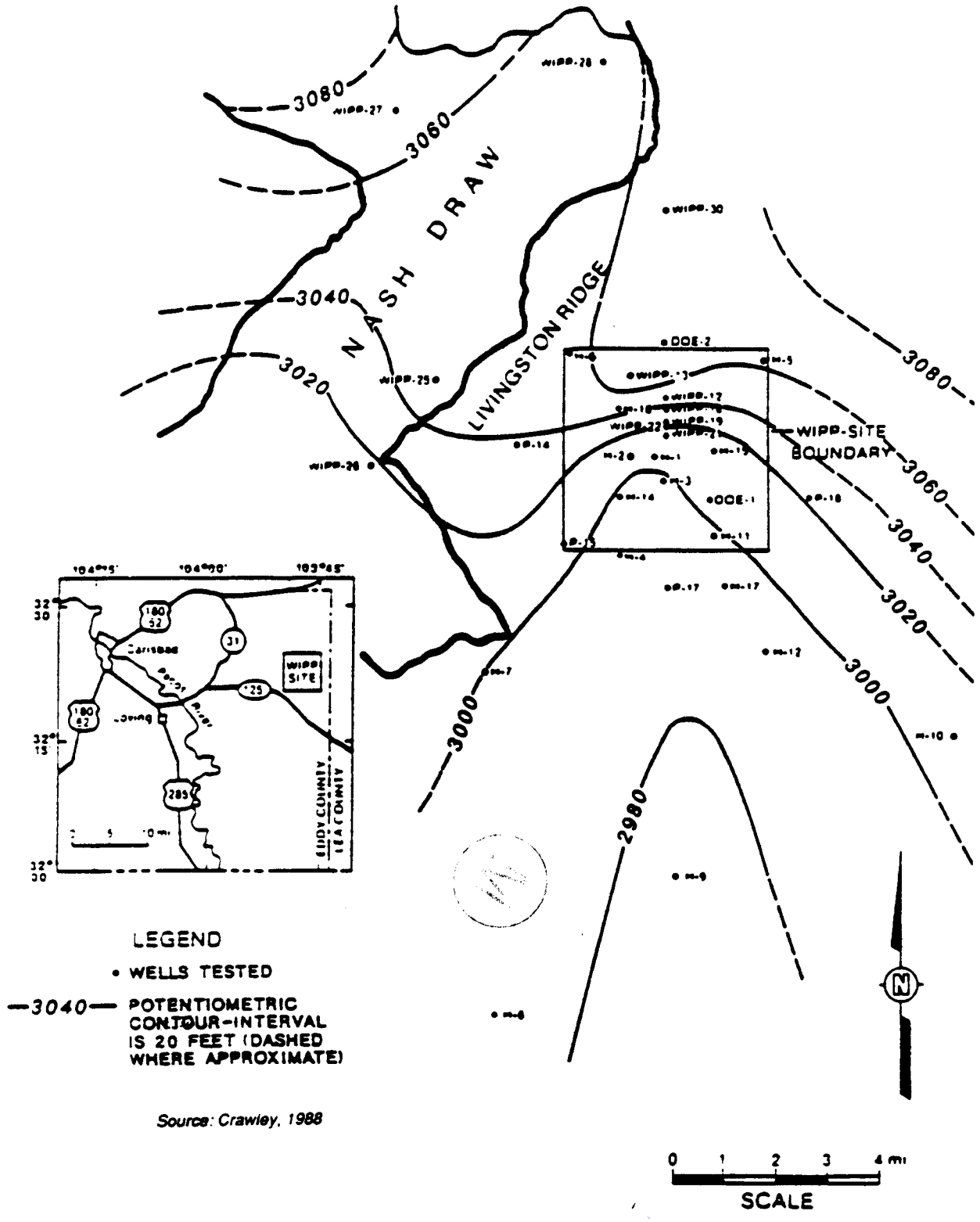


FIGURE 3-5 CULEBRA DOLOMITE FRESHWATER HEAD POTENTIOMETRIC SURFACE

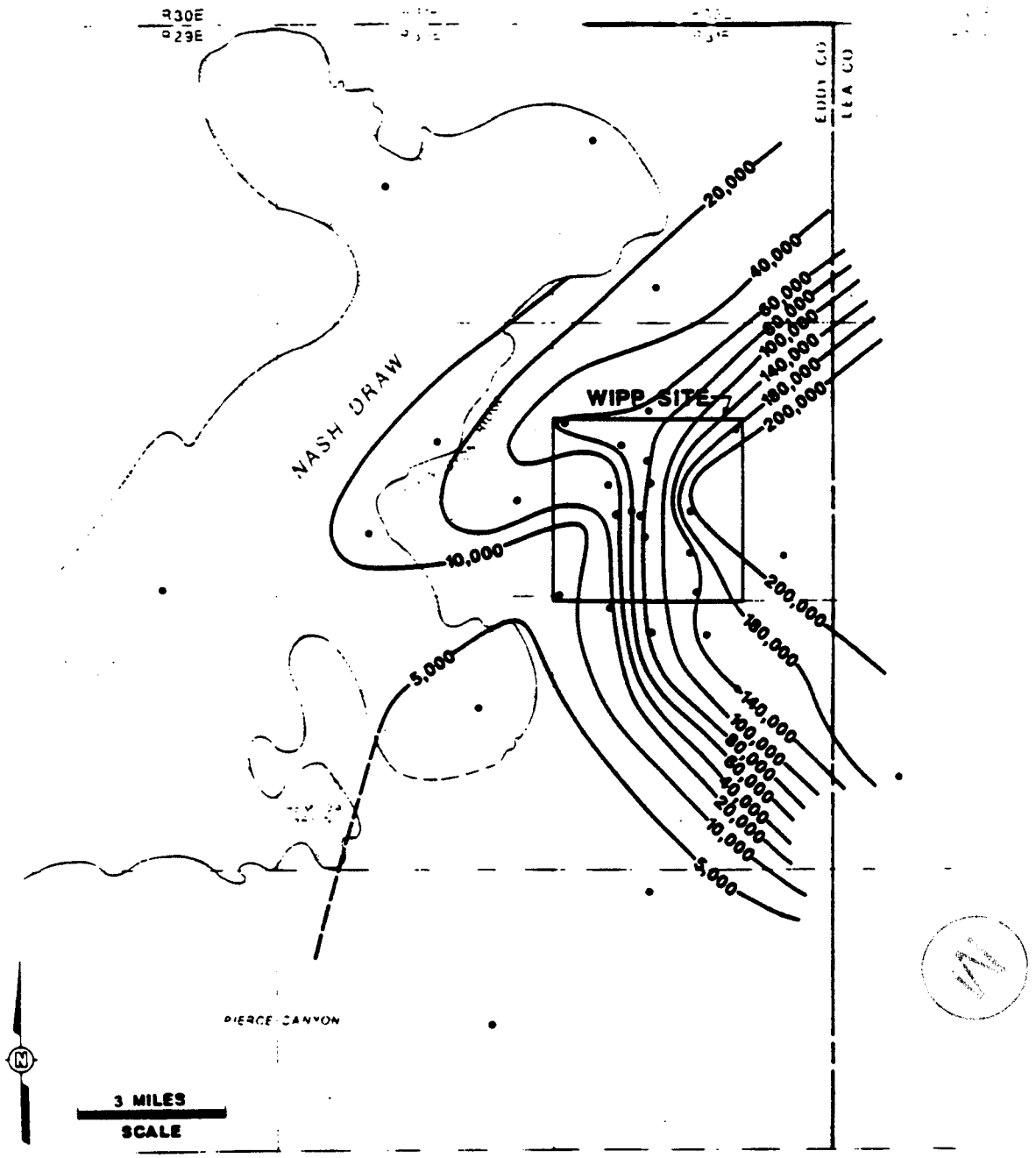
the transition from an area of fractured dolomite to that of a fractured and disrupted unit created by the extensive dissolution in Nash Draw area.

Culebra Groundwater Chemistry. The groundwater chemistry of the Culebra Dolomite across the WIPP Site area is extremely variable. The TDS within the Culebra Dolomite ranges from less than 5,000 mg/ℓ southwest of the WIPP to greater than 200,000 mg/ℓ east of the site (Figure 3-6) (Crawley, 1988; Holt et al., 1992; Siegel et al., 1991). Culebra Dolomite water chemistry also varies from a slightly brackish calcium sulfate type southwest of the site to a predominantly sodium chloride water east of the WIPP.

The great variability in water quality in the WIPP vicinity can be characterized on the basis of TDS, major element concentrations, and major element ratios. The water quality of the Culebra Dolomite has been divided into "type areas" based on these chemical characteristics. Siegel et al. (1991) and Holt et al. (1992) show four coinciding type areas of Culebra Dolomite water quality (Figure 3-7). These types of areas are similar to those described by Ramey (1985) and are briefly summarized below.

The easternmost type area (Type Area 1) is characterized by a highly saline sodium-chloride brine with TDS greater than 100,000 mg/ℓ and high concentrations of magnesium, calcium, and potassium. Type Area 2, located southwest of the WIPP Site, contains water which is relatively fresh with calcium and sulfate as the dominant solute species. Type Area 3 is an intermediate zone of variable composition dominated by sodium chloride, with TDS increasing to the east. This type area may represent a mixing zone between the sodium-chloride brine of Type Area 1 and the fresher calcium-sulfate water of Type Area 2 (Holt et al., 1992). In all Culebra Dolomite hydrochemical type areas, groundwater is at or near saturation with respect to gypsum ($CaSO_4 \cdot 2H_2O$). The distinction between Type Areas 1, 2, and 3 is primarily due to the amount of sodium and chloride in the groundwater. Located in the western half of Nash Draw, anomalously high salinities and potassium contents characterize the groundwater of Type Area 4 (Siegel et al., 1991; Holt et al., 1992). The water in Type Area 4 appears to be contaminated by effluent from potash mining operations in the area (Siegel et al., 1991; Holt et al., 1992).

The division of the Culebra Dolomite in the WIPP area into hydrochemical type areas shows that there are distinct populations of water chemistry. Area-wide background values for the water-chemistry parameters cannot be established due to their highly variable nature.



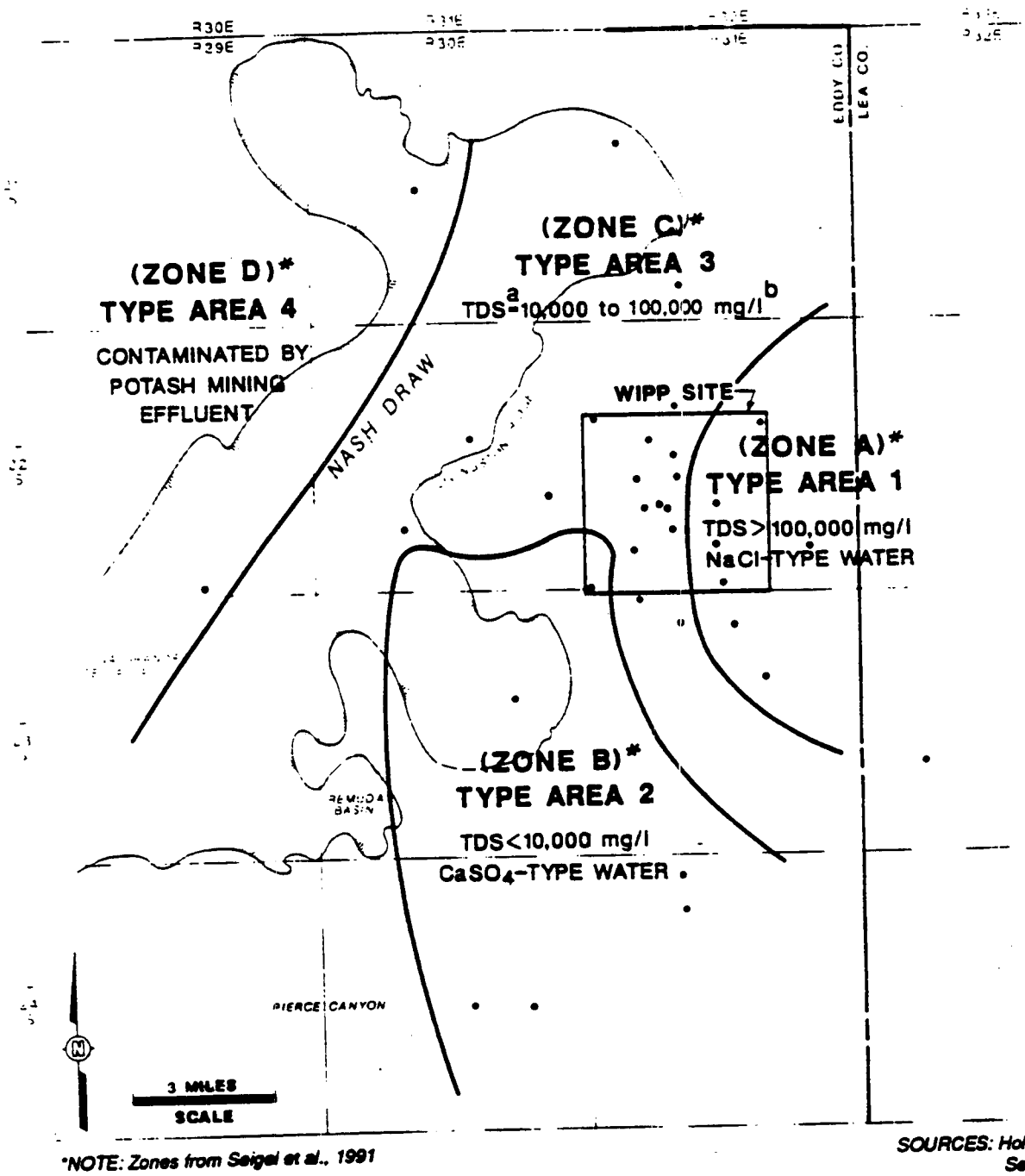
Source: Holt et al., 1992

EXPLANATION

• WELLS TESTED

—10,000— EQUAL CONCENTRATION CONTOUR LINE, MILLIGRAMS PER LITER

FIGURE 3-6 DISTRIBUTION OF TOTAL DISSOLVED SOLIDS (TDS) IN THE CULEBRA DOLOMITE GROUNDWATER



*NOTE: Zones from Seigel et al., 1991

SOURCES: Holt et al., 1992
Seigel et al., 1991

EXPLANATION

a TOTAL DISSOLVED SOLIDS

b MILLIGRAMS PER LITER

• WELLS TESTED

FIGURE 3-7 CULEBRA DOLOMITE HYDROCHEMICAL TYPE AREAS

Concentrations of the major cations and anions often differ by more than an order of magnitude in wells separated by less than 2 miles (such as between H-02 and H-15) in the immediate WIPP area. Considering this great variability, the background must be established on an individual well-by-well basis and not characterized on an area-wide relationship. The background mean concentration or range of concentrations for given analytical parameters must be defined at each well in order to be useful for future comparisons in determining changes in local water quality.

Ramey (1985) was first to note that modern groundwater flow directions within the Culebra Dolomite do not appear consistent with the modern solute distribution. When compared with groundwater flow directions, the distribution of TDS within the Culebra Dolomite generally decreases down gradient in the direction of flow which is an unusual relationship. As summarized in Lappin (1988) and Holt et al. (1992), isotopic evidence (Lambert and Harvey, 1987), as well as modern Culebra Dolomite transmissivity and head distribution, preclude modern vertical recharge to the Culebra Dolomite . Modern vertical recharge cannot account for the modern flow/salinity distribution relationship. One possible mechanism that may account for the modern relationship between flow direction and solute distribution involves paleo fluid flow to the northeast during past periods of higher recharge followed by a reversal in flow direction to that seen today (Lambert and Harvey, 1987; Holt et al., 1992). This relationship is consistent with the interpretation of Lambert and Harvey (1987) that suggests a transient, rather than steady state, hydrologic setting, and no present active recharge to the Culebra Dolomite in the immediate WIPP area.

Mercer (1983) noted an increase in TDS in the Culebra Dolomite from west to east and defined a line to the east, where the sum of the potassium plus magnesium concentrations exceed 100 milliequivalents per liter. Mercer indicates that this line approximates the dividing line between regions of higher transmissivity to the west and lower transmissivity to the east, possibly indicating a stagnant flow system east of the site.

Chapman (1988) indicates that there is a clear linear correlation between TDS and chloride, and the almost one-to-one molar correlation between sodium and chloride is strong evidence that the salinity increase is due to halite dissolution. Chapman also proposes that the increase in magnesium and potassium concentrations eastward across the site is the result of dissolution of other evaporite minerals associated with the halite and that there is no obvious reason to relate the high potassium and magnesium concentrations to low aquifer transmissivity and long residence times as described by Mercer (1983).

Holt et al. (1992) present the argument that there is a clear correlation between Culebra Dolomite transmissivity and water chemistry. The presence of high-TDS groundwater with high concentrations of magnesium and potassium in the eastern WIPP area may reflect the record of a past flow system where the Culebra Dolomite received recharge from the west or southwest with groundwater flow to the east, which supports the nonsteady state hypothesis of Lambert and Harvey (1987). The present very low transmissivity found in the Culebra Dolomite in the eastern section of the project area may have restricted the redistribution of solute back toward the southwestern part of the project area.

The magnesium/calcium molar ratio (Holt et al., 1992) increases from southwest to northeast from 0.3 at Well H-09 and the Poker Trap Windmill to 3.1 at Well H-15. The high magnesium concentrations to the east may be the result of long-term dissolution of evaporite minerals with little, if any, input of fresh water. This fluid may result from very long residence times in a stagnant flow system as suggested by Mercer (1983) and Holt et al. (1992). The existence of low TDS water with a fundamentally distinct chemical composition and relatively high transmissivity in the southwestern region may indicate that this area acts as a separate and active flow system within the Culebra Dolomite. These data suggest that the southwestern area may have a limited hydrologic connection to the Culebra Dolomite in the eastern and northeastern sections of the project area.

Chapman (1988) notes that as groundwater moves from north to south, TDS decreases by an order of magnitude and the overall water chemistry changes from sodium-chloride-dominant to calcium-sulfate-dominant. Chapman proposes that the only plausible mechanism for this change is the input of a large quantity of low TDS water, or recharge. The possibility of recharge in the southern area is enhanced by the presence of solution and fill features such as gypsum caves in the Forty-Niner Member of the Rustler Formation near the Gnome Site. Chapman (1988) indicates that these features could act as conduits, supplying fresh water to deeper Rustler Formation units.

The observations of many investigators support the concept that the Culebra Dolomite may have experienced changes in groundwater flow directions and that it has received recharge at different periods of time in the past and may be receiving recharge locally in the western and southwestern parts of the WIPP area today. All of these conditions have influenced the water chemistry of the Culebra Dolomite as seen today.

3.2.2.2 *Magenta Dolomite Member of the Rustler Formation*

The Magenta Dolomite Member of the Rustler Formation is the uppermost of two regionally persistent dolomite units within the Rustler Formation (Figure 3-2). The Magenta Dolomite is typically a fine-grained, gypsiferous, arenaceous dolomite (Holt and Powers, 1988).

The Magenta Dolomite was tested hydrologically at 16 locations in the vicinity of the WIPP Site (Mercer, 1983; Beauheim, 1986, 1987). The measured transmissivity values from these tests are shown on Figure 3-8. Most of these values are less than or equal to 0.1 ft^2/day (1.1 x 10^{-7} m^2/s). Higher values of transmissivity have been measured at some wells including H-06a and H-09a (0.3 and 1.0 ft^2/day [3.2 x 10^{-7} and 1.0 x 10^{-6} m^2/s], respectively). The transmissivity of the Magenta Dolomite has been enhanced in Nash Draw, where dissolution of the Salado and Rustler Formations has produced significant fracturing of the unit. The two highest transmissivities measured in the Magenta Dolomite, 375 ft^2/day (4.0 x 10^{-4} m^2/s) and 53 ft^2/day (5.7 x 10^{-5} m^2/s), were found in Nash Draw at Wells WIPP-25 and WIPP-27, respectively.

Water levels have been measured in the Magenta Dolomite since 1979. Figure 3-9 shows the elevations of these water levels along with equivalent freshwater-head elevations calculated using borehole-fluid density data presented in Mercer et al. (1981), Dennehy and Mercer (1982), Mercer (1983), Lambert and Robinson (1984), and Richey (1986, 1987). The contours on Figure 3-9 indicate a general westerly flow across the WIPP Site area toward Nash Draw, where groundwater probably flows through fractures and drains into lower units. In the northeast end of Nash Draw, the water flow is generally to the southwest, probably moving down through fractures into lower units in the central part of the draw.

The potentiometric surface map in Figure 3-9 suggests some variability in permeability across the WIPP Site area. The hydrologic gradient across the site varies from 16 to 20 feet per mile on the eastern side, steepening to about 32 feet per mile along the western side near Nash Draw. This steepening may reflect drainage of groundwater from the Magenta Dolomite into lower units through fractures associated with dissolution or may only reflect a decrease in permeability.

If modern recharge to the Magenta Dolomite is occurring, it probably takes place outside of the WIPP area, in areas such as Bear Grass Draw or possibly Clayton Basin (Holt et al., 1992, and Hunter, 1985). The potentiometric contour map seems to indicate that recharge may be occurring to the east of the WIPP Site. However, it is believed that the apparent

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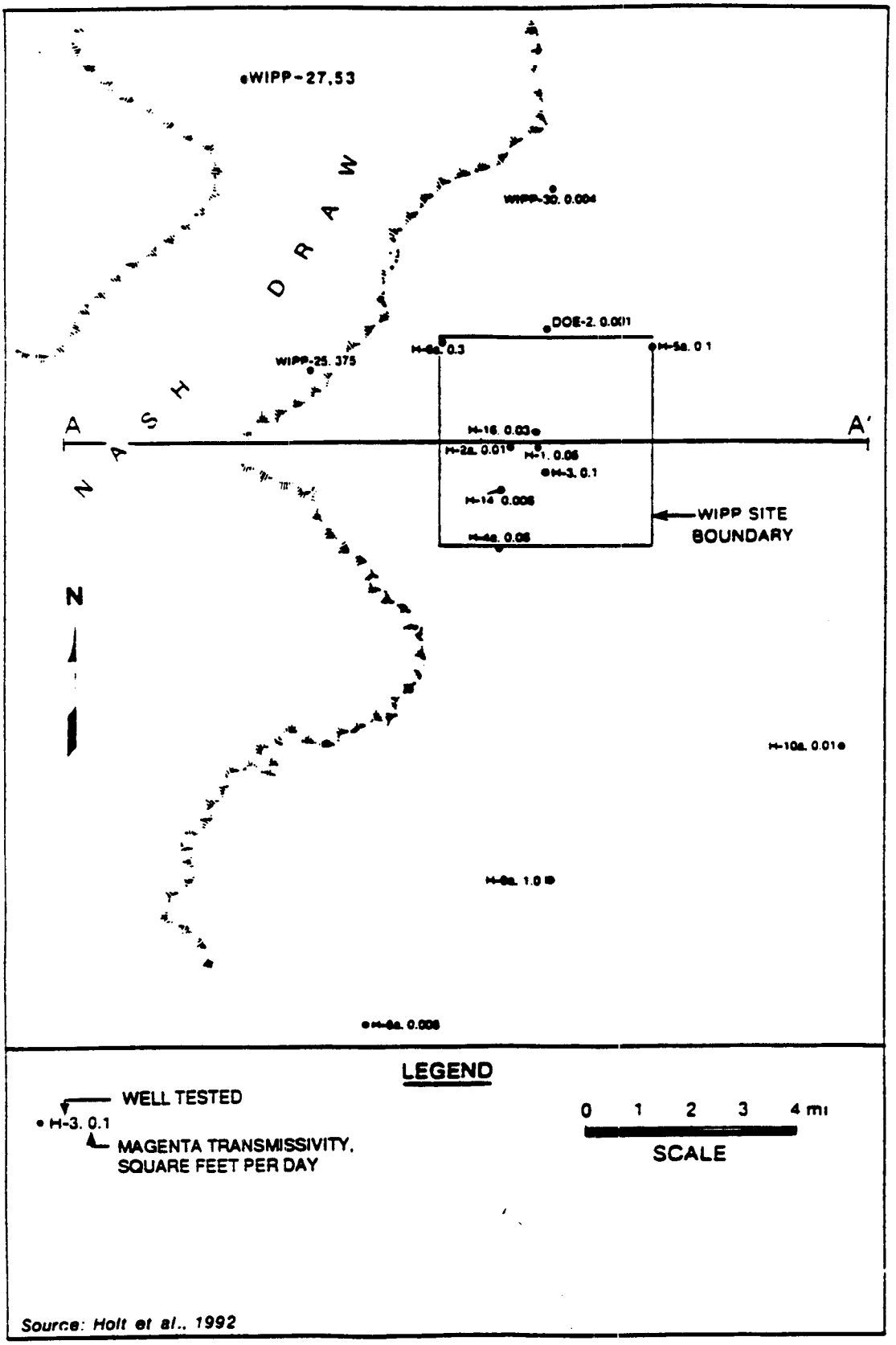

FIGURE 3-8 MAGENTA DOLOMITE TRANSMISSIVITY

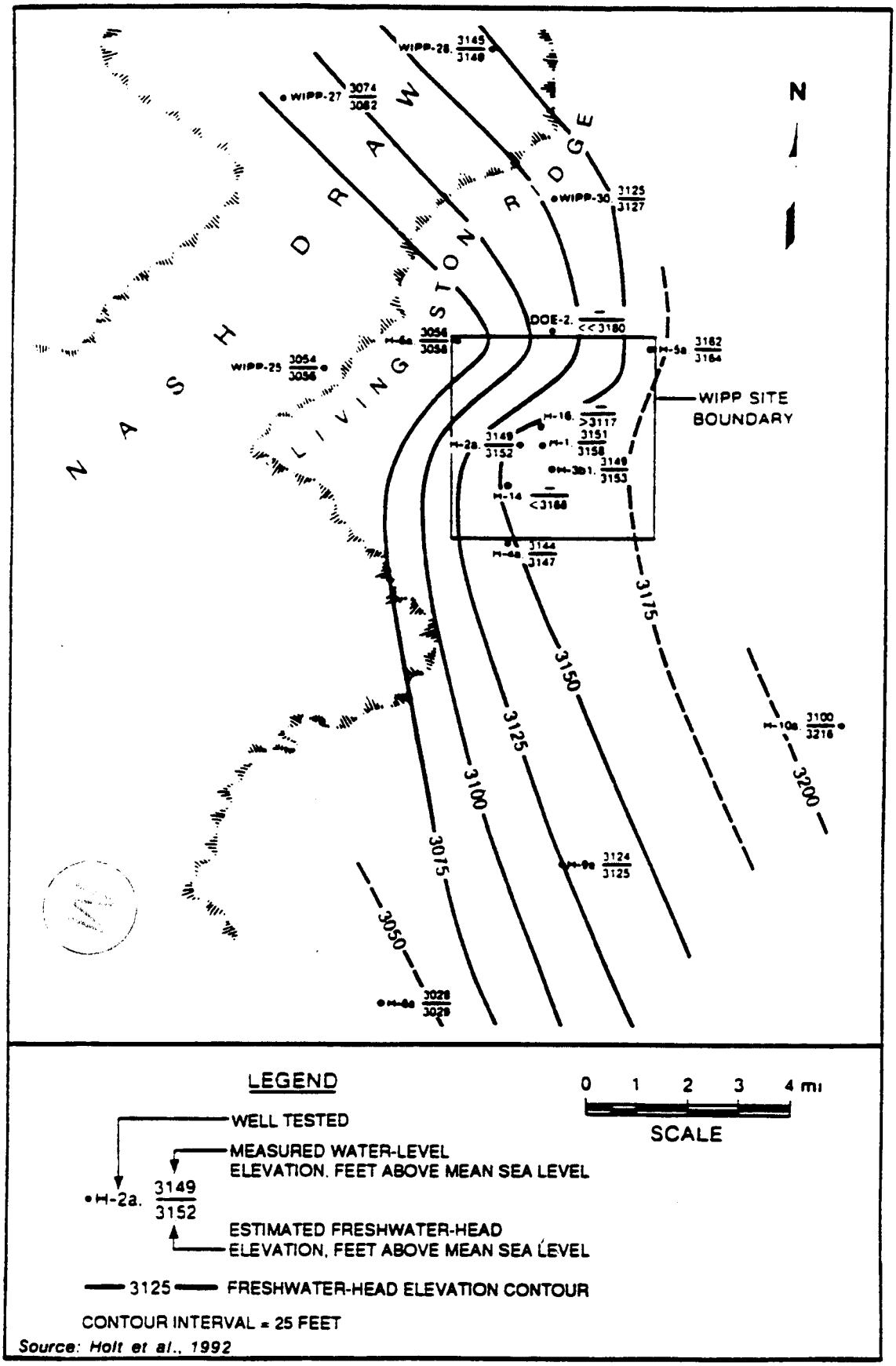

FIGURE 3-9 MEASURED WATER LEVEL AND ESTIMATED FRESHWATER HEAD ELEVATION, MAGENTA DOLOMITE MEMBER

recharge is either from the effect of corrections made for variable water quality (density corrections) or the locally steep gradients that result from decreased permeability to the east.

The TDS in Magenta Dolomite groundwater range in concentration from 5,460 mg/ℓ in Well H-09a to 270,000 mg/ℓ in Well H-10a (see Figure 3-9 for the location of Well H-10a). The water is considered saline to briny. The Magenta Dolomite has not been sampled with the same density as the Culebra Dolomite, due to the fewer number of wells completed in the Magenta Dolomite and the fact that much more emphasis was placed on characterizing the Culebra Dolomite in past investigations. The WQSP has routinely sampled only four wells completed in this unit. Groundwater-quality data were collected from Wells H-03b1, H-04c, H-05c, and H-06c.

In general, the chemistry of Magenta Dolomite water is variable. Groundwater types range from a predominantly sodium-chloride type at Well H-04c to a calcium-magnesium-sodium-sulfate type at Well H-06c. Water-quality data do not indicate a clear trend or definitive groupings of water chemistry in the Magenta Dolomite. Groundwater at Well H-04c appears to be anomalously high in TDS concentration (23,500 mg/ℓ) and sodium (7,100 mg/ℓ). The TDS concentration for the other three wells sampled by the WQSP are in the range of 4,800 to 8,100 mg/ℓ and sodium concentrations from 650 to 1,500 mg/ℓ. The water chemistry at Well H-04c may indicate a general overall increase in TDS concentrations to the south and southwest, away from the WIPP Site, and a potential change to a predominantly sodium-chloride type water in that area.

In the WIPP area, the general water quality of the Magenta Dolomite is better than that of the Culebra Dolomite. However, water from the Magenta Dolomite is not used anywhere in the vicinity of the WIPP.

4.0 Background Groundwater Quality - Methodology

The main objective in characterizing background water-quality for the area around a waste management facility is to develop a tool that can be used to assess future changes in water quality as related to activities conducted at that facility. The characterization of the WIPP water-quality represents a best estimate of the naturally occurring background water chemistry in the area of the WIPP. The background water chemistry will be used as the standard to which future analyses will be compared to determine if changes in water quality have occurred.

As discussed in Section 3.2.2, the water quality of the Culebra and Magenta Dolomite Members of the Rustler Formation is highly variable between individual wells across the WIPP Site area; therefore, background water-quality values could not be defined for the WIPP area as a whole. The variable nature of water quality required that background concentration values for the individual chemical parameters be defined at each individual well.

WIPP water-quality data for each well included in the background characterization program were evaluated for general data quality, accuracy, precision, and repeatability to develop a useful and reliable data set. The data were then evaluated for apparent trends, such as general increases or decreases in parameter concentration with time. Finally, the data were tested for outliers, and where possible, background mean concentrations, concentration ranges, and confidence intervals were established. These concentrations and ranges represent the background values for the chemical parameters evaluated at the individual well sites. The results of this evaluation are presented in Chapter 5.0.

The following sections describe in more detail the methodology employed to determine background groundwater quality.

4.1 Preliminary Data Evaluation

For the purpose of establishing background water quality, analytical parameters were divided into the following groups:

- ***Major Cation and Anions*** - The major cations and anions include calcium, sodium, magnesium, potassium, chloride, sulfate, and bicarbonate. Together these are the bulk (greater than 99 percent) of the dissolved constituents in WIPP area groundwaters. The concentrations of these parameters were generally well above the method detection limit (MDL). A background concentration range

was established for each of these parameters at each well using standard statistical methods.

- ***Minor Cations, Anions, and Indicator Parameters*** - These include, for example, trace metals, phosphorus, and total organic carbon (TOC). In general, concentrations of these parameters were very close to or below the MDL. A background concentration range based on statistical methods could not be established for these parameters, as discussed in Section 4.5. However, a background range, based on detections and MDLs, was established for the minor constituents at each well.

- ***Organic Compounds*** - These parameters include selected volatile and semi-volatile organic compounds (VOCs and Semi-VOCs, respectively), pesticides, and polychlorinated biphenyls (PCBs). Very few of these compounds were detected in WQSP groundwater samples. Because of the extremely small number of detections, each detection is listed in the appropriate table for each well in Chapter 5.0.

4.2 Evaluation of Trends

An important objective of groundwater-quality monitoring is to detect changes or trends in parameter concentrations over time. In a hydrologic system such as the Rustler Formation at the WIPP, which presently exhibits great areal variability in water chemistry and appears to be in a transient state, natural water-quality changes may occur over long periods of time. Large-scale pumping of groundwater during testing and sampling activities may act to enhance water-quality changes by promoting migration of water with different chemistries toward pumping centers. In addition, water quality at a particular well may change with pumping due to the removal of contaminants introduced during well construction.

If trends in chemical parameter concentrations exist, representative background values may be difficult to establish. Future parameter concentrations at individual well sites may differ from the estimated background concentrations due to natural changes, which could make evaluation of the impact from the WIPP facility difficult.

Water-quality data for separate parameters from individual wells were plotted on concentration versus time graphs as described by Gilbert (1987). The graphs were visually examined for apparent temporal trends in concentration over time. In general, temporal trends in groundwater chemistry for most parameters at most wells were not observed (or were relatively weak). Apparent trends were further evaluated using the Mann-Kendall Nonparametric Test for Trends (Gilbert, 1987). In all cases, the test results indicated that the

probability of an actual trend was very low, at least based on the small data set available for analysis. Long-term temporal trends may exist but could not be identified with the small number of data points available for evaluation (3 to 5) and the variability of the data.

The main conclusion from the trend evaluation is that no significant temporal trends can be identified from the available data. Based on this conclusion, the statistical methods selected for data analysis are appropriate. Statistically-determined background concentration mean values and associated confidence intervals can be determined and are probably not influenced by trending data. Detail on potential trends at individual wells is provided in Chapter 5.0 and summarized in Chapter 7.0.

4.3 Evaluation of Outliers

Prior to the statistical analysis and the construction of confidence intervals, the WQSP data were evaluated to identify potential outliers. Outliers are values that do not fall within an expected range or whose deviation from a mean is greater than expected (Kennedy and Neville, 1986). The procedure employed to identify outliers included the following:

- Potential outliers were visually identified on the concentration versus time plots.
- Each of these potential outliers was tested using the Q Test (Fritz and Schenk, 1966). The Q Test is applicable when the number of observations is small. The test was conducted at a confidence level of 90 percent, indicating that a questionable value may be rejected with 90 percent confidence that it is significantly different from the other results in the sample. The Q Test involves dividing the difference between the value of the potential outlier and the nearest neighboring value by the range to obtain a quotient, Q. The range includes the potential outlier. If the calculated Q is greater than a rejection quotient, $Q_{0.90}$, the questionable value is labeled as an outlier.
- An additional test was performed on the values labeled as outliers by the Q Test to ensure that the outliers were not due to a routine and acceptable level of analytical error. It was assumed that an acceptable relative accuracy for WQSP data was $\pm$ 20 percent. For each Q Test outlier and its nearest neighbor, the $\pm$ 20 percent interval was calculated. If the intervals overlapped, the difference between the two values was ascribed to acceptable analytical error, and the questionable value was considered to be valid. Conversely, if the intervals did not overlap, the questionable value was considered to be a true outlier.

Concentration values determined to be outliers by the above procedure were removed from the data set used to construct background confidence intervals for the major cations and

anions. Outliers identified by this procedure were also removed from the minor constituent data sets before preparing background concentration ranges. Appendix B presents a list of all of the outliers that were removed from the WQSP data set prior to the background determination. These outliers amount to approximately two percent of the WQSP cations, anions, and indicator analytes data.

4.4 Statistical Methods

Background concentration ranges, represented by 95 percent confidence intervals, were established for major cations and anions. The major cations and anions are listed in Section 4.1. Confidence intervals were constructed for each parameter at each well using the Student's t distribution following standard methodology presented in Khazanie (1986). The t distribution was selected because the number of samples available from each well was small, i.e., 3 to 5. The construction of confidence intervals based on the t distribution assumes that the data are normally distributed. As discussed in Section 4.2, temporal trends in groundwater chemistry were not generally observed (or were relatively weak). The lack of temporal trends indicated that the use of the Student's t distribution was appropriate. This, combined with the observation that concentrations of major constituents were generally well above detection limits, indicates that the assumption of normality is warranted.

The 95 percent confidence level was selected because the 99 percent level produced unrealistically wide background concentration ranges when only three samples were available. The 90 percent confidence level was not selected because it produced very narrow ranges when five samples were available. The 95 percent confidence level implies that there is 0.95 probability that a "true" mean background concentration is within the computed concentration range represented by the 95 percent confidence interval.

Table 4-1 lists the number of observations used to construct confidence intervals for the major cations and anions. It is apparent from Table 4-1 that the number of observations at a given well varies. This variation was due to changes in the analytical program from one sampling round to the next and was also due to the removal of outliers. Table 4-1 explains why confidence intervals were not computed for some major cations and anions at certain wells. Confidence interval construction for a specific parameter at a given well requires the following:

Table 4-1
Number of Observations Used to Construct Confidence Intervals

Well	Boron	Calcium	Iron	Lithium	Magnesium	Manganese	Potassium	Sodium	Strontium
Barn Well	3	3	4[a]	3	3	4[a]	3[a]	3	3
DOE-1	2[b]	3	3	1[c]	3	3	3	3	3
DOE-2	3	3	2[b]	1[c]	3	3	3	3	3
Engle Well	3	3	3	2[c]	3	3	3	3	3
H-02a	3	3	3	2[c]	3	3	3	3	3
H-03b1	5	5	5[a]	2[b]	5	5[a]	5	4[d]	5
H-03b3	5	5	5	3	5	5	5	5	5
H-04b	5	4[d]	5	4	5	5	5	5	5
H-04c	5	4[d]	5	5	5	5	5	4[d]	5
H-05b	5	5	5	3	5	5	5	5	5
H-05c	5	5	5	5	5	5[a]	5	5	5
H-06b	5	5	5	3	5	5	5	5	5
H-06c	5	5	5	5	5	5[a]	5	4[d]	5
H-07b1	5	5	4[a]	4	5	5	4[d]	5	5
H-08b	3	3	3	2[c]	3	3[a]	3	3	3
H-09b	3[d]	4	4[a]	3	4	4	4	4	4
H-11b3	4[d]	5	5[a]	2[b]	5	5	5	5	5
H-12	3	3	3	2[c]	3	3	3	3	3
H-14	3	3	3	3	3	3	3	3	3
H-15	3	3	2[b]	3	3	3[a]	3	3	3
H-18	3	3	3	3	3	3	3	3	3
P-14	3	3	3	2[c]	3	3	3	3	3
P-17	3	3	3	2[c]	3	3	3	3	3
Ranch Well	4	3[d]	5[a]	2[b]	4	5[a]	4	4	4
Twin Wells	3	3	4[a]	2[c]	3	4[a]	3[a]	3	3
WIPP-19	5	5	4[a]	4[d]	5	5	5	5	5
WIPP-25	4	4	4	3	4	4	4	4	4
WIPP-26	3	3	3[a]	2[c]	3	3[a]	3	3	3

Refer to footnotes at the end of this table.

Table 4-1 *(Continued)*
Number of Observations Used to Construct Confidence Intervals

Well	Alkalinity	Bromide	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
Barn Well	3	3[a]	4	4	4	4	4
DOE-1	2[b]	3	3	3	3	3	3
DOE-2	2[b]	3	3	3	3	3	3
Engle Well	2[b]	3[a]	3	3	3	3	3
H-02a	3	3	3	2[b]	3	3	3
H-03b1	4	4[a]	5	5	5	5	5
H-03b3	4	5	5	5	5	5	5
H-04b	4	5	5	5	5	5	5
H-04c	5	5	5	5	4[d]	5	5
H-05b	5	5	5	5	4[d]	5	5
H-05c	5	5	4[d]	5	5	5	5
H-06b	5	5	5	5	5	5	5
H-06c	5	5[a]	5	5	5	5	5
H-07b1	5	5[a]	4[d]	5	5	5	5
H-08b	3	3[a]	3	2[b]	3	3	3
H-09b	4	4	4	4	4	4	4
H-11b3	4	5	5	5	5	5	5
H-12	3	3	3	3	3	3	3
H-14	3	3	3	3	3	3	3
H-15	3	3	3	3	3	3	3
H-18	3	3	3	3	3	3	3
P-14	3	3	3	3	3	3	3
P-17	3	3	3	3	2[b]	3	3
Ranch Well	4	4	5	5	5	5	5
Twin Wells	3	3	4	4	4	3[d]	4
WIPP-19	5	5	5	5	5	5	5
WIPP-25	4	4	4	4	4	4	4
WIPP-26	3	3	3	3	3	3	3

Refer to footnotes at the end of this table.

Table 4-1 *(Continued)*
Number of Observations Used to Construct Confidence Intervals

FOOTNOTES:

[a]Confidence interval not constructed because greater than 50 percent of observations were below the method detection limit.
[b]Outlier removed, confidence interval not constructed because only two observations remain.
[c]Confidence interval not constructed because there are less than three observations.
[d]Outlier removed, confidence interval was constructed.
[e]Outlier removed, confidence interval not constructed because greater than 50 percent of remaining observations were below the method detection limit.

- At least three observations.
- At least 50 percent of the observations must be greater than the MDL.

The t statistic varies inversely as a function of the number of observations. This means that confidence interval widths are related to the number of observations, as well as, the sample standard deviation. Thus, at a given well, the relative variability in width of confidence intervals is due to both the sample standard deviation and the number of observations used to construct the confidence intervals.

4.5 Factors Influencing Data Usability

As described in Section 2.7, the TDS content (filterable residue) of groundwater samples from many WQSP wells was relatively high. High TDS samples required dilution prior to analysis, and the dilution factors apparently varied during the WQSP. The variable dilution factors resulted in MDLs that were not consistent from sampling round to round. Variable MDLs affected the use of the minor constituent data in establishing background concentrations. For example, the MDLs for many of the trace metal analyses were relatively high (often from 1.0 to 10 mg/ℓ), preventing quantification of trace metal concentrations. Large dilutions and the resulting high MDLs, in effect, reduced the sensitivity of the analysis of samples for minor constituents. The numerous nondetections at high MDLs made establishing background concentrations difficult for many trace metals.

Large sample dilution probably magnified spurious, near-MDL detections. For example, if the MDL for chromium is 0.010 mg/ℓ, detections of 0.011 and 0.012 mg/ℓ are typically observed. However, if samples are diluted 100 to 1, the MDL becomes 1.0 mg/ℓ, and the same low-level detections become 1.1 and 1.2 mg/ℓ, respectively. In this manner, spurious detections can appear to be very significant. Considering the reasons discussed above, confidence intervals were not calculated for minor cations, anions, and indicator analytes.

5.0 Background Groundwater Quality - Results

This chapter presents the results of the analysis of WIPP WQSP background groundwater chemistry. For each well, background groundwater chemistry is listed in a summary table and major cation and anion concentrations are plotted as a function of time. Also, temporal trends in groundwater chemistry are discussed. The results presented below do not include outliers. The procedure used to identify outliers is given in Section 4.3, and the resulting outliers are tabulated in Appendix B. Appendix C contains the WIPP WQSP groundwater quality data set used to produce this report. Chapter 5.0 is divided into sections that correspond to individual wells.

5.1 Barn Well

Samples of groundwater from the Dewey Lake Redbeds were collected at the Barn Well. The Barn Well was sampled four times; the first groundwater sample was collected in November 1987, and the most recent was collected in June 1990. Samples collected in April 1988 were analyzed for an abbreviated suite of metal and general chemical parameters. Volatile organic compounds, semi-VOCs, and total PCBs were analytes in the November 1987 sampling event. Pesticides and a limited suite of VOCs were analytes in the April 1988 sampling. Consequently, groundwater from the Barn Well was tested only once for most hazardous organic compounds.

Background concentrations for constituents in Barn Well groundwater are listed in Table 5-1. Table 5-1 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-1 are the concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from the Barn Well.

Sodium is the dominant cation in Barn Well groundwater, followed by calcium and magnesium; bicarbonate and sulfate are the dominant anions (Table 5-1). Groundwater collected from Barn Well is classified as fresh, because the TDS concentration is less than 1000 mg/ℓ (Freeze and Cherry, 1979).

Figure 5-1 shows the temporal variation in the concentration of six major constituents of Barn Well groundwater. Though concentrations fluctuate, no temporal trends are observed in these or any other constituents of Barn Well groundwater.

Table 5-1
Background Groundwater Chemistry
Barn Well

Major Constituents[a]	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.36	0.03	0.28 - 0.44
Calcium	66	8	47 - 85
Iron	NC[b]	NC	<0.1[c]
Lithium	0.05	0.01	0.03 - 0.06
Magnesium	34	3	26 - 41
Manganese	NC	NC	<0.015[c]
Potassium	NC	NC	<5[c]
Sodium	108	14	74 - 142
Strontium	0.9	0.1	0.6 - 1.2
General Chemistry			
Alkalinity (as HCO_3^-)	277	6	262 - 291
Bromide	NC	NC	<2[c]
Chloride	41	5	32 - 49
Fluoride	2.6	0.1	2.5 - 2.7
pH (s.u.)[d]	7.27	0.57	6.37 - 8.17
Sulfate	206	25	167 - 246
Total Dissolved Solids	668	39	606 - 729

See footnotes at end of table.

Table 5-1 *(Continued)*
Background Groundwater Chemistry
Barn Well

Minor Constituents[a]	Concentration Range
<u>Metals</u>	
Aluminum	<2
Antimony	<0.06
Arsenic	<0.05
Barium	<0.2
Beryllium	<0.005
Cadmium	<0.005
Cesium	<0.2
Chromium	≤0.02
Cobalt	<0.05
Copper	≤0.03
Lead	<0.05
Mercury	<0.0002
Molybdenum	<0.02
Nickel	<0.04
Selenium	<0.05
Silica	24 - 54
Silver	<0.01
Thallium	<0.05
Titanium	<0.03
Vanadium	0.06
Zinc	≤0.03
<u>General Chemistry</u>	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	7.1 - 9.6
Phenolics	<0.008
Phosphate (as P)	≤0.04
Total Organic Carbon	≤4
Total Organic Halogen	≤0.15

See footnotes at end of table.

Table 5-1 *(Continued)*
Background Groundwater Chemistry
Barn Well

Hazardous Organic Constituents

None Detected

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.

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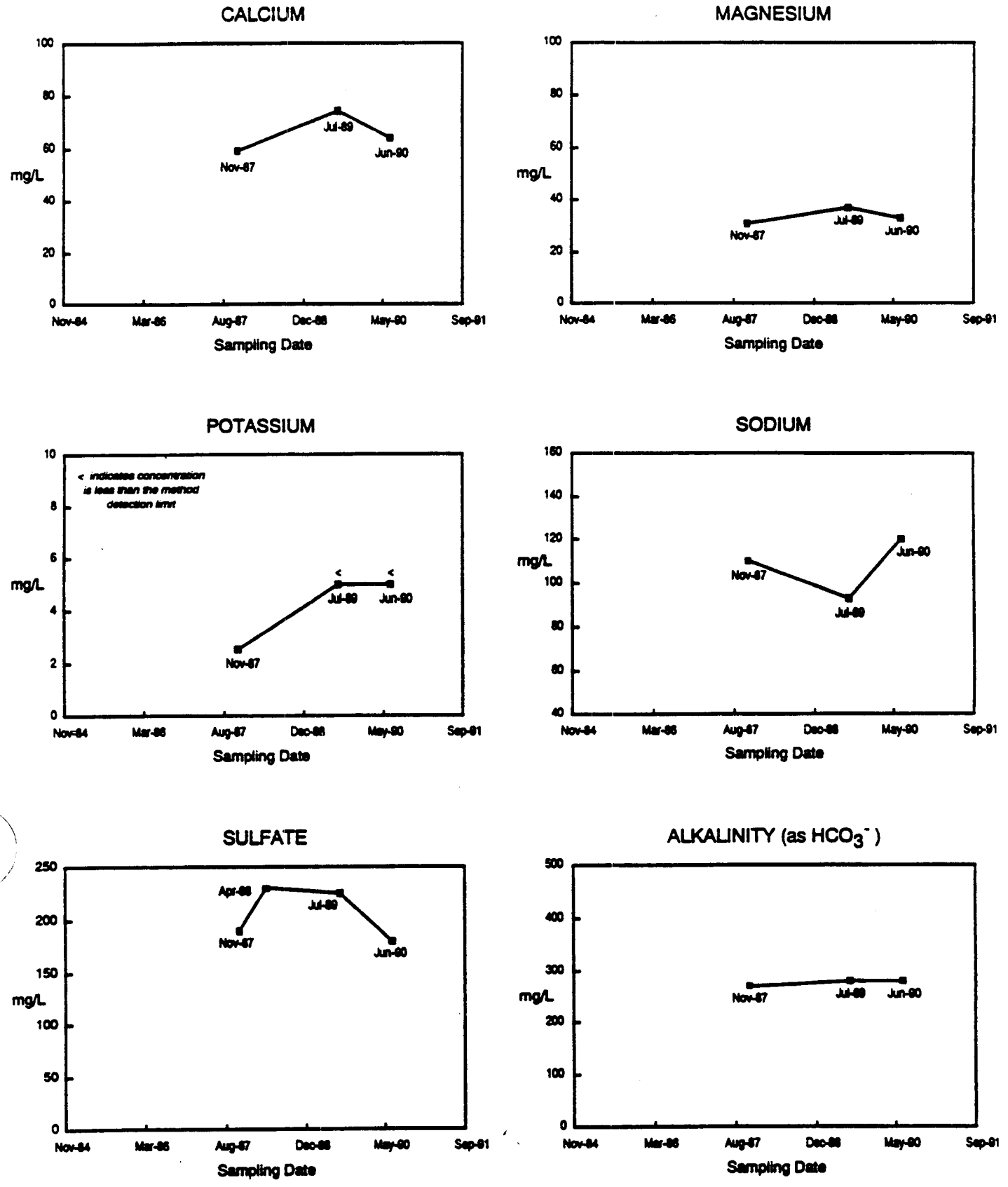


FIGURE 5-1 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF BARN WELL GROUNDWATER

5.2 Well DOE-1

Groundwater samples from the Culebra Dolomite were collected at Well DOE-1. Well DOE-1 was sampled three times; the first sampling occurred in April 1985, and the most recent sampling took place in July 1987. Groundwater collected during each sampling event was analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. Samples collected during the July 1986 and July 1987 rounds were also analyzed for total PCBs. Analytical results for major constituents from the April 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for constituents in groundwater from Well DOE-1 are listed in Table 5-2. Table 5-2 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-2 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well DOE-1.

Sodium is the dominant cation in groundwater at Well DOE-1, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-2). Groundwater in Well DOE-1 is classified as brine (Freeze and Cherry, 1979), because TDS exceed 100,000 mg/ℓ. Well DOE-1 lies within hydrochemical Type Area 1 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 1 contains TDS greater than 100,000 mg/ℓ, and sodium and chloride are the dominant dissolved constituents. Several trace metals were detected in groundwater samples from Well DOE-1. Cesium, chromium, cobalt, copper, lead, and titanium were repeatedly detected at concentrations generally less than 1 mg/ℓ (Table 5-2). However, as discussed in Section 4.5, the validity of trace constituent data is uncertain, due to the problems associated with the analysis of high-TDS solutions.

Several hazardous organic constituents were detected in samples of groundwater from Well DOE-1 (Table 5-2). The majority of the detections occurred in the April 1985 sample, and the only compound repeatedly detected was acetone (Table 5-2). According to an EPA risk assessment guidance document (EPA, 1989), all of the organic compounds detected, with the exception of n-nitroso-di-methylamine, could be attributed to laboratory contamination.

Figure 5-2 shows the temporal variation in the concentration of the six major constituents of Well DOE-1 groundwater. The calcium concentration appears to decrease with time, while

Table 5-2
Background Groundwater Chemistry
Well DOE-1

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	NC[b]	NC	34 - 35[c]
Calcium	1,567	153	1,187 - 1,946
Iron	1.1	0.4	0.2 - 2.1
Lithium	NC	NC	3.2[c]
Magnesium	1,533	116	1,247 - 1,820
Manganese	0.27	0.10	0.02 - 0.53
Potassium	1,000	100	752 - 1,248
Sodium	46,000	0	46,000
Strontium	18.1	13.5	0 - 51.5
General Chemistry			
Alkalinity (as HCO_3^-)	NC	NC	44 - 57[c]
Bromide	61	3	55 - 68
Chloride	77,333	3 512	68,609 - 86,058
Fluoride	1.0	0.1	0.6 - 1.3
pH (s.u.)[d]	6.84	0.32	6.06 - 7.62
Sulfate	6,883	454	5,756 - 8,010
Total Dissolved Solids	131,667	2,887	124,495 - 138,838

See footnotes at end of table.

Table 5-2 *(Continued)*
Background Groundwater Chemistry
Well DOE-1

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	≤1.4
Antimony	1.3
Arsenic	<0.5
Barium	≤0.07
Beryllium	≤0.24
Cadmium	0.07
Cesium	0.4 - 0.48
Chromium	0.38 - 0.4
Cobalt	0.1 - 0.30
Copper	0.1 - 0.18
Lead	0.6 - 1.3
Mercury	≤0.0008
Molybdenum	<0.05
Nickel	<0.3
Selenium	<0.5
Silica	11 - 21
Silver	0.1
Thallium	<0.5
Titanium	≤0.69
Vanadium	0.2
Zinc	<0.1
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	≤0.1
Phenolics	0.012
Phosphate (as P)	≤0.01
Total Organic Carbon	≤1
Total Organic Halogen	0.84 - 9.7

See footnotes at end of table.

Table 5-2 *(Continued)*
Background Groundwater Chemistry
Well DOE-1

Hazardous Organic Constituents[e]

	Sample Date	Concentration
2-Butanone[f]	25-Apr-85	97
Acetone[f]	25-Apr-85	29
Acetone[f]	28-Jul-87	44
Bis(2-ethylhexyl)phthalate[f]	28-Jul-87	33
Butyl Benzyl Phthalate[f]	25-Apr-85	1.9
Di-n-butyl Phthalate[f]	25-Apr-85	2.6
Methylene Chloride[f]	03-Jul-86	10
N-nitroso-di-methylamine	25-Apr-85	2.4
Toluene[f]	25-Apr-85	2.1

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

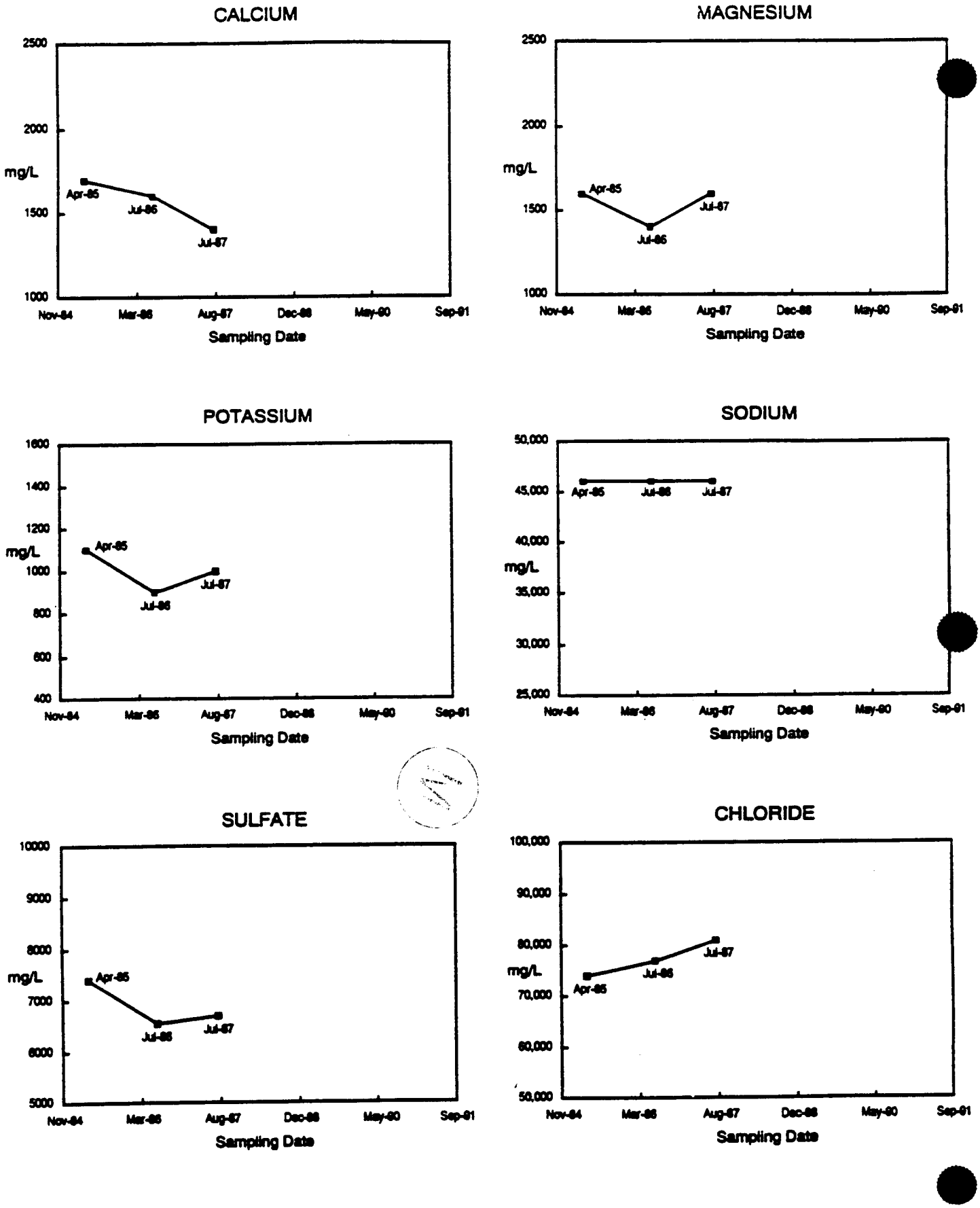


FIGURE 5-2 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL DOE-1 GROUNDWATER

chloride and strontium (not shown on Figure 5-2) concentrations appear to increase. Based on charge balance considerations, the calcium and chloride concentration trends do not appear to be real. Thus, it is likely that the observed trends are due to sampling and analytical variability, rather than actual changes in Well DOE-1 groundwater chemistry.

5.3 Well DOE-2

Groundwater samples from both the Culebra Dolomite and the Bell Canyon Formation were collected at Well DOE-2. The following discussion pertains only to samples collected from the Culebra Dolomite. Well DOE-2 was sampled three times; the first sampling occurred in March 1985, and the most recent sampling took place in May 1988. Groundwater samples were analyzed for metals and general chemical parameters; however, only August 1986 and May 1988 samples were analyzed for VOCs, semi-VOCs, and total PCBs. Analytical results for major constituents from the March 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for constituents in groundwater from Well DOE-2 are presented in Table 5-3. Table 5-3 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-3 are the concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from Well DOE-2.

Sodium is the dominant cation in groundwater at Well DOE-2, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-3). Groundwater collected from Well DOE-2 is classified as saline, because the TDS are approximately 50,000 mg/ℓ (Freeze and Cherry, 1979). Well DOE-2 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ. The MDLs for trace metals in Well DOE-2 groundwater were relatively high, due to the requirement that high-TDS samples must be diluted prior to analysis.

Figure 5-3 shows the temporal variation in the concentration of the six major dissolved constituents of Well DOE-2. Calcium and chloride concentrations and pH (not shown on Figure 5-3) appear to have decreased during the WQSP, while the potassium concentration appears to have increased. Based on charge balance considerations, the large decrease in chloride concentration is not likely. Although the calcium concentration also appears to have decreased, the change is not great enough to counter the decrease in the chloride

Table 5-3
Background Groundwater Chemistry
Well DOE-2

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	18	6	4 - 31
Calcium	1,867	153	1,487 - 2,246
Iron	NC[b]	NC	0.35 - 0.4[c]
Lithium	NC	NC	0.51[c]
Magnesium	1,052	84	844 - 1,260
Manganese	0.49	0.12	0.20 - 0.77
Potassium	430	27	364 - 496
Sodium	17,500	500	16,258 - 18,742
Strontium	28	6	13 - 43
General Chemistry			
Alkalinity (as HCO_3^-)	NC	NC	130 - 160[c]
Bromide	41	6	21 - 61
Chloride	32,233	2,909	25,006 - 39,461
Fluoride	1.3	0.1	1.0 - 1.6
pH (s.u.)[d]	6.74	0.31	5.98 - 7.51
Sulfate	4,067	404	3,063 - 5,071
Total Dissolved Solids	56,500	2,179	51,086 - 61,915

See footnotes at end of table.

Table 5-3 *(Continued)*
Background Groundwater Chemistry
Well DOE-2

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	<10
Antimony	0.6
Arsenic	<0.05
Barium	<0.5
Beryllium	<0.5
Cadmium	<0.05
Cesium	0.03 - 1.7
Chromium	<1
Cobalt	<1
Copper	<1
Lead	<5
Mercury	≤0.0017
Molybdenum	0.03 - 0.09
Nickel	<3
Selenium	<0.5
Silica	6.5 - 24
Silver	<0.1
Thallium	<0.05
Titanium	<3
Vanadium	0.1
Zinc	<1
General Chemistry	
Cyanide	≤0.02
Iodide	<2
Nitrate (as N)	<0.1
Phenolics	≤0.01
Phosphate (as P)	≤0.01
Total Organic Carbon	≤5
Total Organic Halogen	0.61 - 2

See footnotes at end of table.

Table 5-3 *(Continued)*
Background Groundwater Chemistry
Well DOE-2

Hazardous Organic Constituents

None Detected

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.

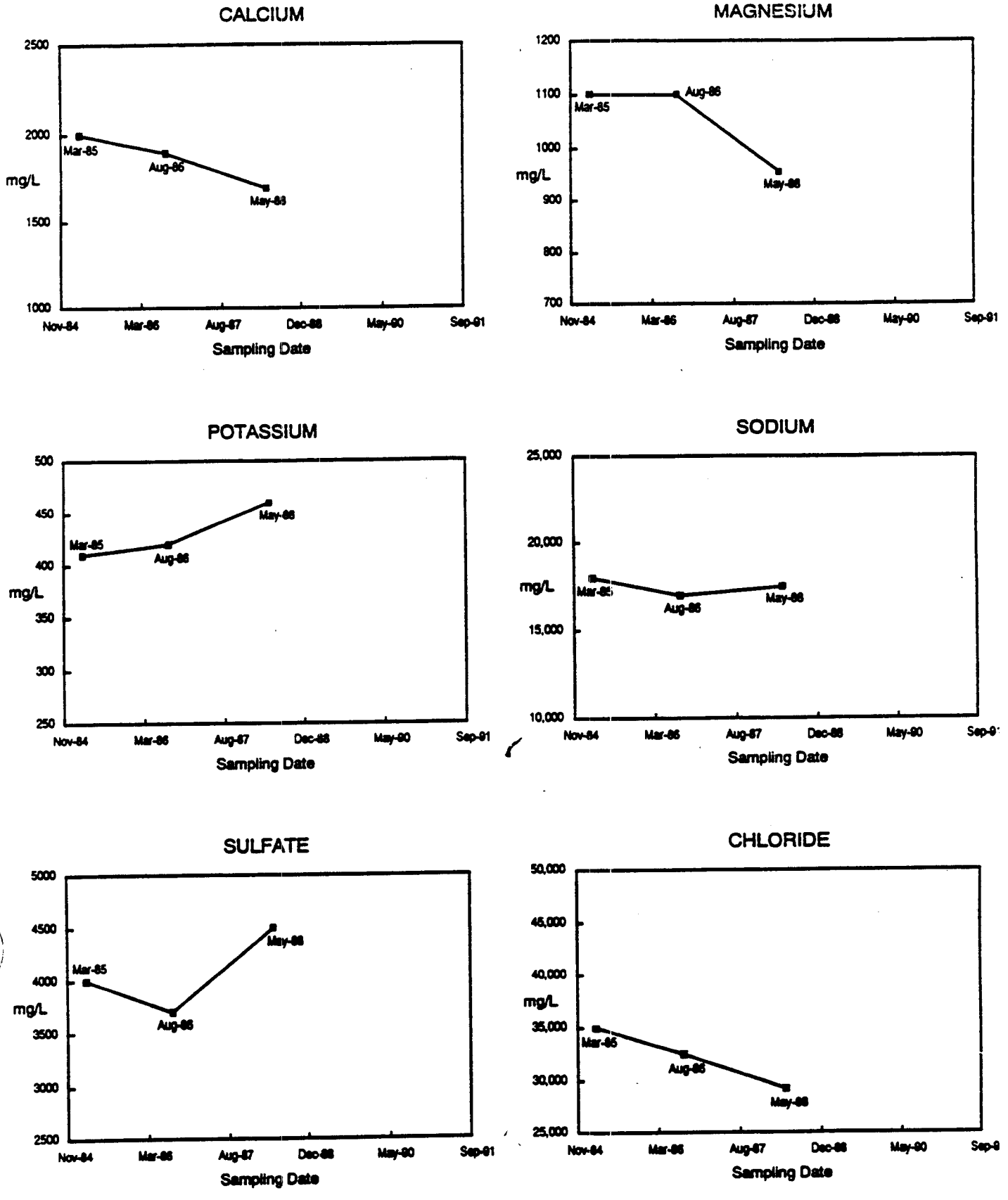


FIGURE 5-3 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL DOE-2 GROUNDWATER

shown in Figure 5-3. Seigel et al. (1991) report that the alkalinity concentration observed at Well DOE-2 increased from the March 1985 to the August 1986 sampling event. They attribute this increase to acidification of the well in 1985.

5.4 Engle Well

Samples of groundwater from the Culebra Dolomite were collected from the Engle Well. The Engle Well was sampled three times-March 1985, December 1987, and January 1990. During all three rounds, samples were analyzed for metals and general chemical parameters. Groundwater samples collected in March 1985 and January 1990 were analyzed for VOCs and semi-VOCs. An abbreviated suite of VOCs were analytes in the December 1987 sampling event. Pesticides were analytes in the December 1987 and January 1990 sampling events. Analytical results for major constituents from the March 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for constituents in Engle Well groundwater are listed in Table 5-4. Table 5-4 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-4 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from the Engle Well.

Calcium is the dominant cation in Engle Well groundwater, followed by sodium and magnesium; sulfate is the dominant anion, followed by chloride and bicarbonate (Table 5-4). Engle Well groundwater is classified as brackish, because the TDS are approximately 3,500 mg/ℓ (Freeze and Cherry, 1979). Engle Well lies within hydrochemical Type Area 2 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 2 contains TDS less than 10,000 mg/ℓ, and calcium and sulfate are the dominant dissolved constituents.

Several detections of hazardous organic constituents were observed in samples of Engle Well groundwater (Table 5-4). None of the compounds were repeatedly detected, and according to an EPA risk assessment guidance document (EPA, 1989), acetone and diethyl phthalate are common laboratory contaminants.

Figure 5-4 shows the temporal variation in the concentration of the six major constituents of Engle Well groundwater. While concentrations fluctuate, no temporal trends are observed in these or any other dissolved constituents of Engle Well groundwater. Both sodium and

Table 5-4
Background Groundwater Chemistry
Engle Well

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	1.49	0.87	0 - 3.64
Calcium	590	20	540 - 640
Iron	1.31	1.99	0 - 6.25
Lithium	NC[b]	NC	0.16 - 0.2[c]
Magnesium	153	6	139 - 168
Manganese	0.055	0.058	0 - 0.200
Potassium	8	2	2 - 13
Sodium	285	130	0 - 609
Strontium	7.8	0.7	6.1 - 9.4
General Chemistry			
Alkalinity (as HCO_3^-)	NC	NC	74 - 110[c]
Bromide	NC	NC	<2[c]
Chloride	290	140	0 - 638
Fluoride	2.5	0.5	1.4 - 3.7
pH (s.u.)[d]	6.65	0.41	5.64 - 7.65
Sulfate	1,983	29	1,912 - 2,055
Total Dissolved Solids	3,685	282	2,984 - 4,386

See footnotes at end of table.

Table 5-4 *(Continued)*
Background Groundwater Chemistry
Engle Well

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	≤0.2
Antimony	0.11 - 0.17
Arsenic	<0.005
Barium	<0.05
Beryllium	<0.005
Cadmium	0.012 - 0.013
Cesium	<0.2
Chromium	≤0.08
Cobalt	0.02
Copper	<0.1
Lead	≤0.14
Mercury	<0.0002
Molybdenum	0.032 - 0.08
Nickel	≤0.04
Selenium	<0.2
Silica	12 - 25
Silver	≤0.03
Thallium	<0.5
Titanium	≤0.22
Vanadium	0.04
Zinc	0.2 - 2.2
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	≤0.5
Phenolics	0.006
Phosphate (as P)	≤0.16
Total Organic Carbon	≤3
Total Organic Halogen	<0.1

See footnotes at end of table.

Table 5-4 *(Continued)*
Background Groundwater Chemistry
Engle Well

Hazardous Organic Constituents[e]

	Sample Date	Concentration
2-Nitroaniline	31-Jan-90	50
Acetone[f]	04-Mar-85	31
Diethyl Phthalate[f]	04-Mar-85	3.9
N-nitroso-di-phenylamine	04-Mar-85	5.9

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

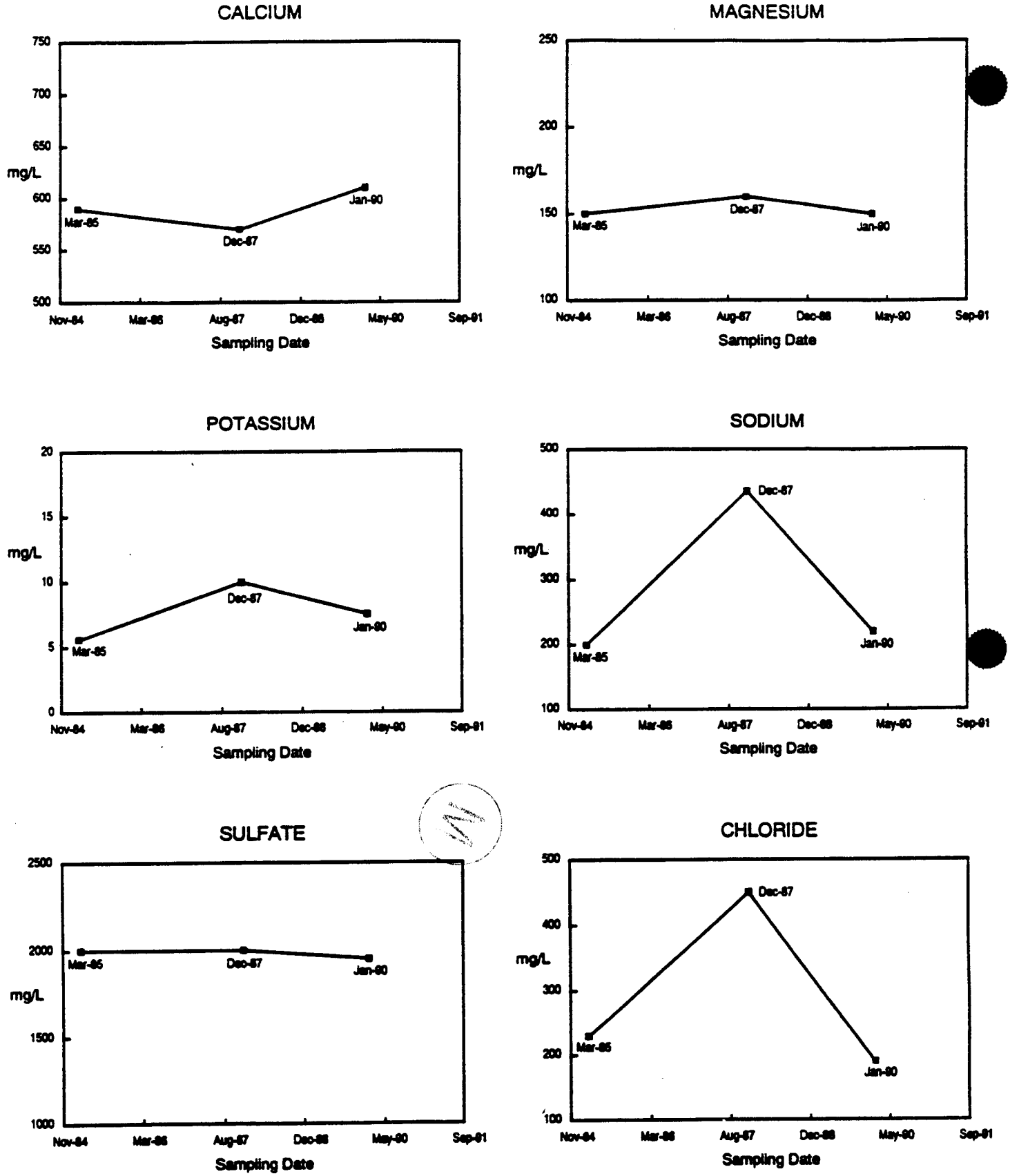


FIGURE 5-4 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF ENGLE WELL GROUNDWATER

chloride concentrations were elevated in December 1987, relative to other sampling rounds (Figure 5-4).

5.5 Well H-02a

Groundwater samples from the Culebra Dolomite were collected at Well H-02a. Well H-02a was sampled three times; the first groundwater sample was collected in April 1986, and the most recent was collected in January 1989. During all three rounds, samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. A sample collected in August 1987 was analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well H-02a are presented in Table 5-5. Table 5-5 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-5 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-02a.

Sodium is the dominant cation in groundwater from Well H-02a, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-5). Well H-02a groundwater is classified as borderline brackish to saline, because the TDS are approximately 11,000 mg/ℓ (Freeze and Cherry, 1979). Well H-02a lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Several trace metals were detected in Well H-02a groundwater at concentrations below 1 mg/ℓ (Table 5-5). However, with the exception of molybdenum, the detections are one-time occurrences, not repeated in other sampling rounds.

Several detections of hazardous organic compounds were observed in samples of groundwater from Well H-02a (Table 5-5). All of the detections could be due to laboratory contamination, according to a tabulation of common laboratory contaminants listed in an EPA risk assessment guidance document (EPA, 1989). Only acetone was detected during more than one sampling round (Table 5-5). The poor agreement between the acetone concentration detected in the January 1989 sample and its laboratory duplicate, i.e., 27 versus 1200 micrograms per liter (µg/ℓ) (Table 5-5), combined with the detection of acetone in a sample blank, questions the validity of the acetone detection. Similarly, methylene chloride was detected in the January 1989 sample blank.

Table 5-5
Background Groundwater Chemistry
Well H-02a

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	10	1	9 - 12
Calcium	715	51	589 - 841
Iron	0.75	0.45	0 - 1.9
Lithium	NC[b]	NC	0.26 - 0.72[c]
Magnesium	167	6	152 - 181
Manganese	0.06	0.03	0 - 0.13
Potassium	103	7	86 - 119
Sodium	2,533	1,102	0 - 5,270
Strontium	8.4	1.5	4.7 - 12
General Chemistry			
Alkalinity (as HCO_3^-)	56	2	52 - 60
Bromide	2	1	0 - 5
Chloride	4,567	874	2,396 - 6,737
Fluoride	NC	NC	2.1 - 2.2[c]
pH (s.u.)[d]	7.71	0.13	7.38 - 8.04
Sulfate	2,933	351	2,061 - 3,806
Total Dissolved Solids	11,650	1,626	7,612 - 15,689

See footnotes at end of table.

Table 5-5 *(Continued)*
Background Groundwater Chemistry
Well H-02a

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	<1
Antimony	<0.5
Arsenic	≤0.014
Barium	<0.05
Beryllium	<0.05
Cadmium	≤0.08
Cesium	≤0.1
Chromium	≤0.4
Cobalt	<0.1
Copper	<0.11
Lead	≤0.5
Mercury	<0.0002
Molybdenum	≤0.07
Nickel	<0.3
Selenium	<0.05
Silica	6.1 - 14
Silver	≤0.2
Thallium	<0.5
Titanium	<0.3
Vanadium	≤0.1
Zinc	<0.1
General Chemistry	
Cyanide	<0.04
Iodide	1 - 9
Nitrate (as N)	≤0.3
Phenolics	≤0.097
Phosphate (as P)	≤0.03
Total Organic Carbon	5 - 7
Total Organic Halogen	≤0.14

See footnotes at end of table.

Table 5-5 *(Continued)*
Background Groundwater Chemistry
Well H-02a

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Acetone[f]	12-Aug-87	1400
Acetone[f]	19-Jan-89	27 (1200)[g]
Bis(2-ethylhexyl)phthalate[f]	19-Jan-89	20
Methylene Chloride[f]	19-Jan-89	16 (45)[g]

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.
[g] Duplicate analysis in parentheses.

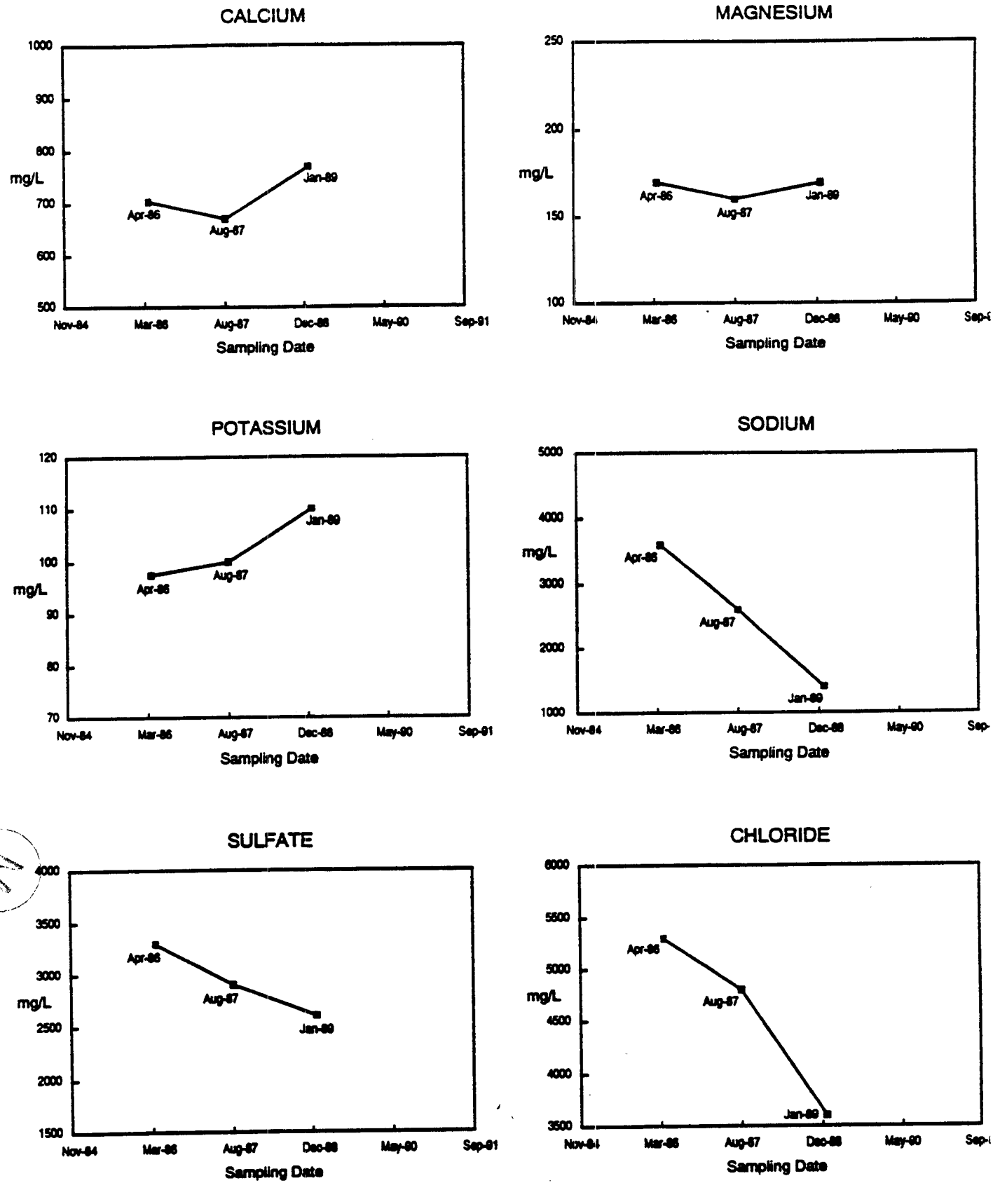


FIGURE 5-5 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-02a GROUNDWATER

Figure 5-5 shows the temporal variation in the concentration of the six major constituents of Well H-02a groundwater. Sodium, chloride, and sulfate concentrations appear to have decreased with time, while the potassium concentration may have increased. Based on charge balance considerations, the observed concentration decreases are possible, with the loss of sodium cations being countered by the decrease in chloride and sulfate anions. The potassium concentration trend is relatively minor and may be due to sampling and analytical variability. Siegel et al. (1991) reported that sodium and chloride concentrations are changing with time at Well H-02a. They questioned the representativeness of all samples from the well.

5.6 Well H-03b1

Groundwater samples from the Magenta Dolomite were collected at Well H-03b1. Well H-03b1 was sampled five times; the first sampling occurred in July 1985, and the most recent sampling took place in August 1990. Groundwater collected during each sampling event was analyzed for metals and general chemical parameters. Samples were analyzed for VOCs and semi-VOCs during four of the five sampling rounds; the August 1990 samples were not analyzed for hazardous organic constituents. Total PCB analyses were performed on samples collected in September 1986 and September 1987; and individual PCBs (e.g., Aroclor 1242) were analytes in the March 1989 sampling event. Analytical results for major constituents from the July 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for dissolved constituents in groundwater from Well H-03b1 are listed in Table 5-6. Table 5-6 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-6 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-03b1.

Sodium is the dominant cation in groundwater at Well H-03b1, followed by calcium, magnesium, and potassium. Chloride is the dominant anion, followed by sulfate and bicarbonate (Table 5-6). Groundwater in Well H-03b1 is classified as brackish, because the TDS are approximately 8,500 mg/ℓ (Freeze and Cherry, 1979).

Several hazardous organic constituents were detected in samples of groundwater from Well H-03b1 (Table 5-6). Only toluene was detected during more than one sampling round. With the exception of benzo(a)pyrene and n-nitroso-di-phenylamine, the organic compounds

Table 5-6
Background Groundwater Chemistry
Well H-03b1

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	3.6	0.5	3.0 - 4.2
Calcium	1,005	62	928 - 1,082
Iron	NC[b]	NC	≤0.3[c]
Lithium	NC	NC	0.3 - 0.33[c]
Magnesium	296	22	269 - 323
Manganese	NC	NC	<0.05[c]
Potassium	34	2	31 - 37
Sodium	1,525	126	1,325 - 1,725
Strontium	16	2	14 - 18
General Chemistry			
Alkalinity (as HCO_3^-)	43	8	30 - 56
Bromide	6	0	6
Chloride	3,360	108	3,225 - 3,495
Fluoride	1.9	0.2	1.7 - 2.2
pH (s.u.)[d]	6.97	0.41	6.45 - 7.48
Sulfate	2,130	234	1,840 - 2,420
Total Dissolved Solids	8,690	513	8,053 - 9,327

See footnotes at end of table.

Table 5-6 *(Continued)*
Background Groundwater Chemistry
Well H-03b1

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<1
Antimony	<0.5
Arsenic	<0.05
Barium	<0.2
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.2
Chromium	≤0.2
Cobalt	<0.1
Copper	<0.1
Lead	<0.5
Mercury	<0.0004
Molybdenum	<0.1
Nickel	<0.3
Selenium	≤0.09
Silica	4.5 - 12
Silver	<0.1
Thallium	<1
Titanium	≤0.3
Vanadium	<0.1
Zinc	<0.1
General Chemistry	
Cyanide	<0.02
Iodide	≤2
Nitrate (as N)	<0.1
Phenolics	≤0.053
Phosphate (as P)	≤0.03
Total Organic Carbon	≤4
Total Organic Halogen	≤0.85

See footnotes at end of table.

Table 5-6 *(Continued)*
Background Groundwater Chemistry
Well H-03b1

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Benzo(a)pyrene	01-Jul-85	6.5
Bis(2-ethylhexyl)phthalate[f]	16-Mar-89	11
Methylene Chloride[f]	16-Sep-86	14
N-nitroso-di-phenylamine	16-Sep-86	24
Toluene[f]	01-Jul-85	2
Toluene[f]	16-Sep-86	32

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

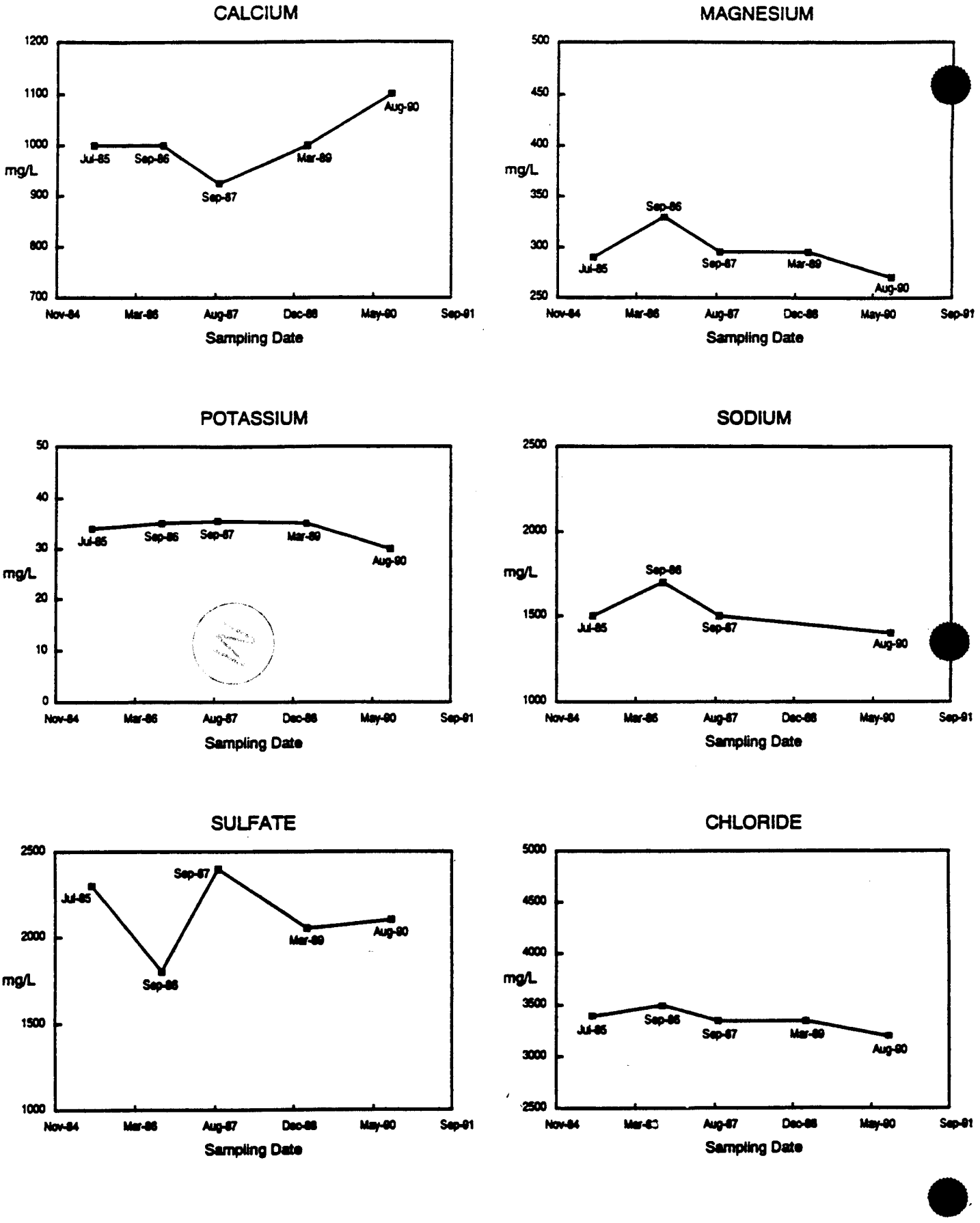


FIGURE 5-6 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-03b1 GROUNDWATER

detected in Well H-03b1 samples are common laboratory contaminants, according to an EPA risk assessment guidance document (EPA, 1989).

Figure 5-6 shows the temporal variation in the concentration of the six major constituents of Well H-03b1 groundwater. Chloride concentrations exhibit a weak decrease with time; however, the concentration change is no greater than the analytical uncertainty. Though concentrations fluctuate, no temporal trends are observed in the constituents shown in Figure 5-6 or any other dissolved constituent of Well H-03b1 groundwater.

5.7 Well H-03b3

Groundwater samples from the Culebra Dolomite were collected from Well H-03b3. The sampling history of this well is very similar to that of Well H-03b1. Well H-03b3 was sampled five times; the first sample was collected in February 1985, and the most recent was collected in August 1990. Groundwater collected during each sampling event was analyzed for metals and general chemical parameters. Samples were analyzed for VOCs and semi-VOCs during four of the five sampling rounds; the August 1990 samples were not analyzed for hazardous organic constituents. Total PCB analyses were performed on samples collected in May 1986 and August 1987; and individual PCBs (e.g., Aroclor 1242) were analytes in the March 1989 sampling event. Analytical results for major constituents from the February 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for constituents in groundwater from Well H-03b3 are presented in Table 5-7. Table 5-7 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-7 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-03b3.

Sodium is the dominant cation in groundwater from Well H-03b3, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-7). Well H-03b3 groundwater is classified as saline, because the TDS concentration is approximately 54,000 mg/ℓ (Freeze and Cherry, 1979). Well H-03b3 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Low concentrations, i.e., less than 1 mg/ℓ, of several trace metals were detected in samples from Well H-03b3 (Table 5-7).

Table 5-7
Background Groundwater Chemistry
Well H-03b3

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	25	5	19 - 32
Calcium	1,360	134	1,193 - 1,527
Iron	0.30	0.13	0.14 - 0.47
Lithium	0.48	0.14	0.15 - 0.82
Magnesium	768	46	710 - 826
Manganese	0.13	0.04	0.08 - 0.18
Potassium	453	65	372 - 534
Sodium	17,020	709	16,140 - 17,900
Strontium	25	4	21 - 30
General Chemistry			
Alkalinity (as HCO_3)	50	3	46 - 54
Bromide	24	14	7 - 41
Chloride	28,790	1,649	26,742 - 30,838
Fluoride	1.5	0.1	1.5 - 1.6
pH (s.u.)[b]	7.26	0.33	6.85 - 7.66
Sulfate	4,680	115	4537 - 4823
Total Dissolved Solids	54,150	822	53,130 - 55,170

See footnotes at end of table.

Table 5-7 *(Continued)*
Background Groundwater Chemistry
Well H-03b3

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	≤0.8
Arsenic	<0.1
Barium	≤0.06
Beryllium	≤0.15
Cadmium	≤0.07
Cesium	<0.2
Chromium	0.007 - 0.4
Cobalt	<0.5
Copper	≤0.26
Lead	≤0.5
Mercury	≤0.001
Molybdenum	≤0.2
Nickel	≤0.44
Selenium	<0.5
Silica	4.5 - 13
Silver	≤0.1
Thallium	<10
Titanium	≤0.8
Vanadium	<0.5
Zinc	≤0.2
General Chemistry	
Cyanide	≤0.11
Iodide	<2
Nitrate (as N)	<0.2
Phenolics	≤0.033
Phosphate (as P)	≤0.06
Total Organic Carbon	≤2
Total Organic Halogen	0.14 - 0.42

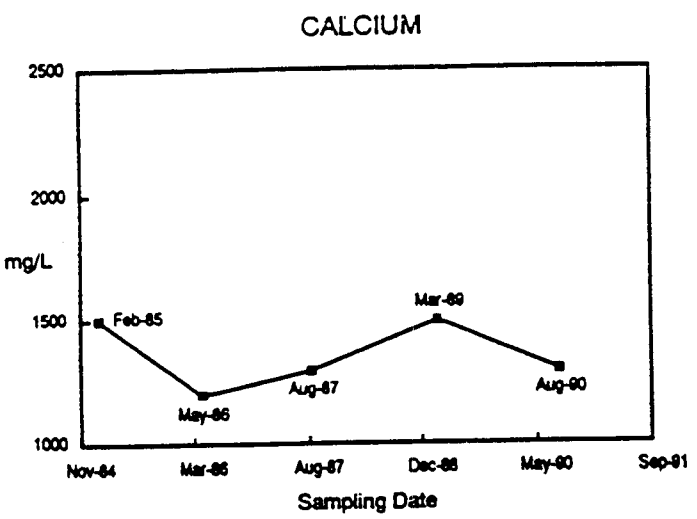
See footnotes at end of table.

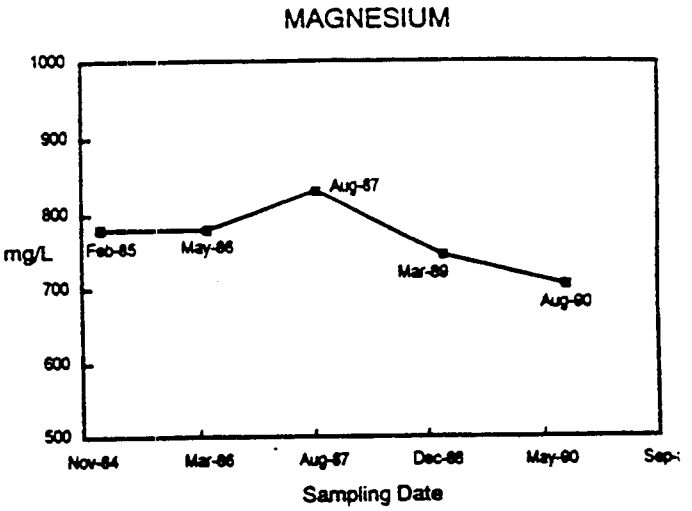
Table 5-7 *(Continued)*
Background Groundwater Chemistry
Well H-03b3

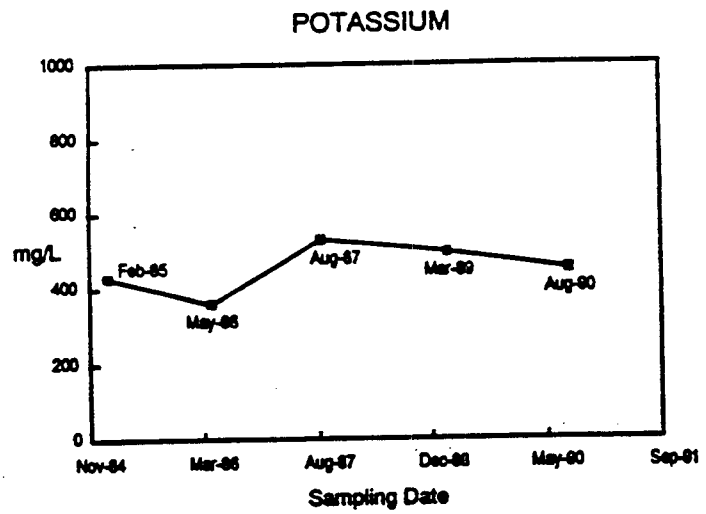
Hazardous Organic Constituents[c]

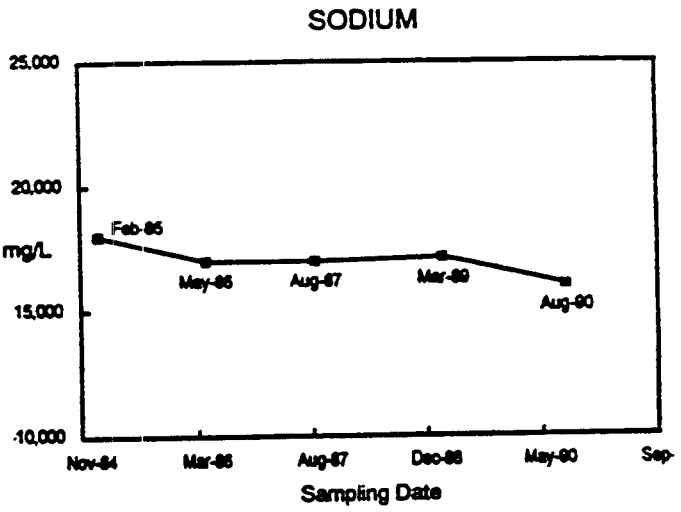
	Sample Date	Concentration
Acetone[d]	05-May-86	11
Benzoic Acid	04-Feb-85	17
Bis(2-ethylhexyl)phthalate[d]	04-Feb-85	20
N-nitroso-di-phenylamine	04-Feb-85	6.5
Pentachlorophenol	04-Feb-85	5.6

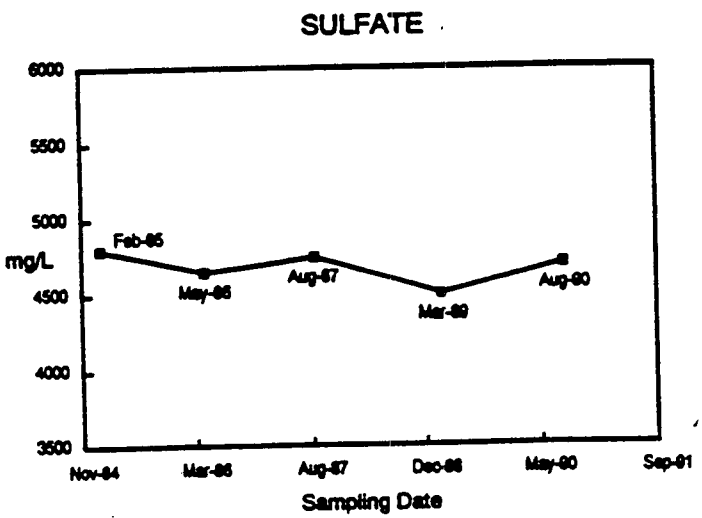
[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.
[c] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[d] Suspected laboratory contaminant.











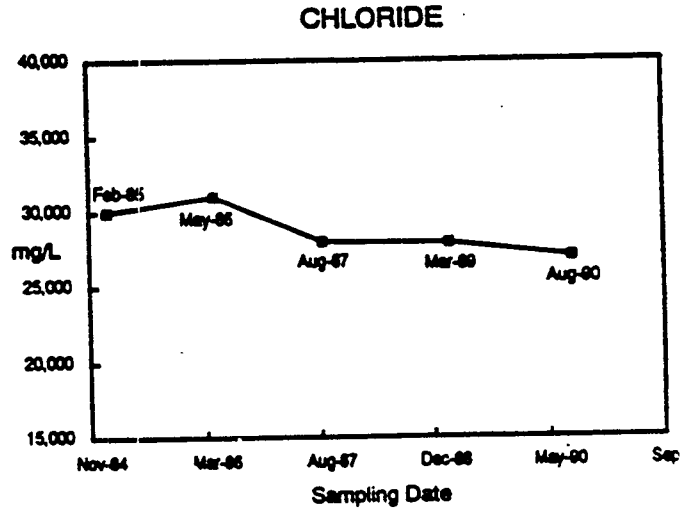


FIGURE 5-7 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-03b3 GROUNDWATER

However, only chromium, copper, molybdenum, and zinc were repeatedly detected above respective MDLs.

Several detections of hazardous organic compounds were observed in samples of groundwater from Well H-03b3 (Table 5-7). Four of the five detections occurred in the February 1985 sample. The detection of acetone and bis(2-ethylhexyl)phthalate could be due to laboratory contamination, based on a tabulation of common laboratory contaminants listed in an EPA risk assessment guidance document (EPA, 1989).

Figure 5-7 shows the temporal variation in the concentration of the six major constituents of Well H-03b3 groundwater. Magnesium, chloride, and sulfate concentrations appear to have decreased during the WQSP (Figure 5-7). However, the trends are relatively weak; the concentration decreases are of the same magnitude as the analytical uncertainty. Also, a corresponding weak decrease in the TDS is not observed. Thus, the composition of groundwater at Well H-03b3 has probably remained relatively constant throughout the WQSP.

5.8 Well H-04b

Groundwater samples from the Culebra Dolomite were collected at Well H-04b. Well H-04b was sampled five times; the first sampling occurred in July 1985, and the most recent sampling took place in September 1990. Groundwater collected during each sampling event was analyzed for metals and general chemical parameters. Samples were analyzed for VOCs and semi-VOCs during four of the five sampling rounds; the September 1990 samples were not analyzed for hazardous organic constituents. Total PCB analyses were performed on samples collected in November 1986 and September 1987; and individual PCBs (e.g., Aroclor 1242) were analytes in the April 1989 sampling event. Analytical results for major constituents from the July 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for constituents in Well H-04b groundwater are presented in Table 5-8. Table 5-8 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-8 are the concentration ranges of minor constituents and a list of the hazardous organic constituents that were detected in groundwater samples from Well H-04b.

Sodium is the dominant cation in groundwater from Well H-04b, followed by calcium, magnesium, and potassium. Chloride is the dominant anion, followed by sulfate (Table 5-8).

Table 5-8
Background Groundwater Chemistry
Well H-04b

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	18	3	14 - 21
Calcium	673	43	604 - 741
Iron	0.48	0.06	0.40 - 0.55
Lithium	0.42	0.10	0.25 - 0.58
Magnesium	426	33	385 - 468
Manganese	0.13	0.03	0.09 - 0.17
Potassium	220	33	179 - 261
Sodium	5,940	254	5,625 - 6,255
Strontium	14	1	13 - 16
General Chemistry			
Alkalinity (as HCO_3^-)	61	7	51 - 72
Bromide	57	21	31 - 83
Chloride	7,033	4,980	1,968 - 12,099
Fluoride	1.9	0.2	1.7 - 2.2
pH (s.u.)[b]	7.06	0.61	6.30 - 7.82
Sulfate	5,480	832	4,447 - 6,513
Total Dissolved Solids	20,030	2,433	17,010 - 23,050

See footnotes at end of table.

Table 5-8 *(Continued)*
Background Groundwater Chemistry
Well H-04b

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	<0.6
Arsenic	<0.1
Barium	<0.1
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.2
Chromium	≤0.3
Cobalt	<0.5
Copper	<0.25
Lead	<0.5
Mercury	≤0.0017
Molybdenum	≤0.2
Nickel	<0.4
Selenium	<0.05
Silica	5.6 - 14
Silver	<0.1
Thallium	<0.5
Titanium	≤0.5
Vanadium	<0.5
Zinc	≤0.4
General Chemistry	
Cyanide	<0.02
Iodide	≤2
Nitrate (as N)	<0.1
Phenolics	≤0.026
Phosphate (as P)	≤0.03
Total Organic Carbon	3 - 5
Total Organic Halogen	0.06 - 0.64

See footnotes at end of table.

Table 5-8 *(Continued)*
Background Groundwater Chemistry
Well H-04b

Hazardous Organic Constituents[c]

	Sample Date	Concentration
Benzo(a)pyrene	20-Jul-85	6.5

[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.
[c] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.

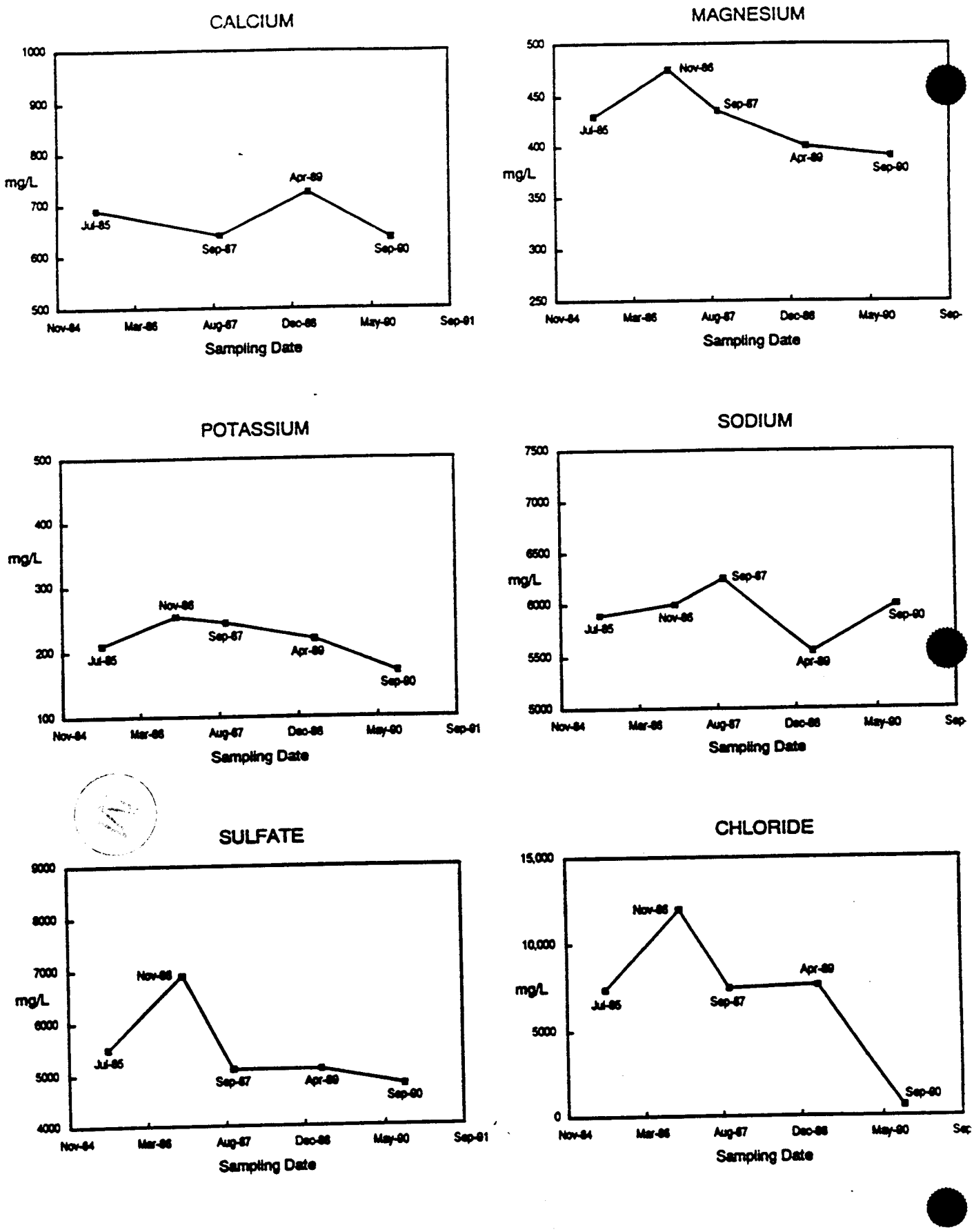


FIGURE 5-8 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-04b GROUNDWATER

Well H-04b groundwater is classified as saline, because the TDS are approximately 20,000 mg/ℓ (Freeze and Cherry, 1979). Well H-04b lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Several trace metals were repeatedly detected in groundwater samples from Well H-04b. Cesium, chromium, mercury, molybdenum, titanium, and zinc were detected in concentrations below 1 mg/ℓ (Table 5-8).

Benzo(a)pyrene was detected during the July 1985 sampling of Well H-04b. This one-time detection was the only occurrence of a hazardous organic compound in groundwater from the well.

Figure 5-8 shows the temporal variation in the concentration of the six major constituents of Well H-04b groundwater. Concentrations fluctuate, however, no temporal trends are observed in the constituents shown in Figure 5-8 or any other constituent of Well H-04b groundwater. The chloride concentration was highly variable; this may reflect sampling or analytical problems.

5.9 Well H-04c

Groundwater samples from the Magenta Dolomite were collected at Well H-04c. Well H-04c was sampled five times; the first sampling occurred in November 1986, and the most recent sampling took place in October 1990. Groundwater collected during each sampling event was analyzed for metals and general chemical parameters. Samples were analyzed for PCBs, VOCs, and semi-VOCs during four of the five sampling rounds; the October 1990 samples were not analyzed for hazardous organic constituents. Total PCB analyses were performed on samples collected during the first three rounds; and individual PCBs (e.g., Aroclor 1242) were analytes in the April 1989 sampling event.

Background concentrations for constituents in groundwater from Well H-04c are listed in Table 5-9. Table 5-9 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-9 are the concentration ranges of minor constituents and a list of the hazardous organic constituents that were detected in groundwater samples from Well H-04c.

Sodium is the dominant cation in groundwater from Well H-04c, followed by calcium, magnesium, and potassium. Chloride is the dominant anion, followed closely by sulfate

Table 5-9
Background Groundwater Chemistry
Well H-04c

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	11.8	0.5	11.2 - 12.4
Calcium	646	36	588 - 704
Iron	0.6	0.4	0.1 - 1.1
Lithium	0.41	0.02	0.39 - 0.43
Magnesium	445	40	396 - 494
Manganese	0.20	0.16	0.00 - 0.39
Potassium	102	23	73 - 130
Sodium	7,250	178	6,967 - 7,533
Strontium	13	1	11 - 14
General Chemistry			
Alkalinity (as HCO_3^-)	71	17	50 - 93
Bromide	7	1	6 - 8
Chloride	8,890	1,276	7,306 - 10,474
Fluoride	2.6	0.2	2.3 - 2.8
pH (s.u.)[b]	7.68	0.22	7.34 - 8.03
Sulfate	7,330	860	6,262 - 8,398
Total Dissolved Solids	23,690	830	22,660 - 24,720

See footnotes at end of table.

Table 5-9 *(Continued)*
Background Groundwater Chemistry
Well H-04c

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	<2
Antimony	≤0.6
Arsenic	<0.1
Barium	<0.2
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.1
Chromium	≤0.2
Cobalt	<0.5
Copper	≤0.3
Lead	<0.5
Mercury	≤0.0008
Molybdenum	<0.2
Nickel	<0.4
Selenium	<0.05
Silica	3.9 - 12
Silver	≤0.1
Thallium	<5
Titanium	≤0.5
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.02
Iodide	≤4
Nitrate (as N)	<0.1
Phenolics	≤0.038
Phosphate (as P)	≤0.06
Total Organic Carbon	≤3
Total Organic Halogen	≤0.53

See footnotes at end of table.

Table 5-9 *(Continued)*
Background Groundwater Chemistry
Well H-04c

Hazardous Organic Constituents[c]

	Sample Date	Concentration
1,3-Dichlorobenzene	19-Jul-88	15
Bis(2-ethylhexyl)phthalate[d]	19-Jul-88	110

[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.
[c] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[d] Suspected laboratory contaminant.

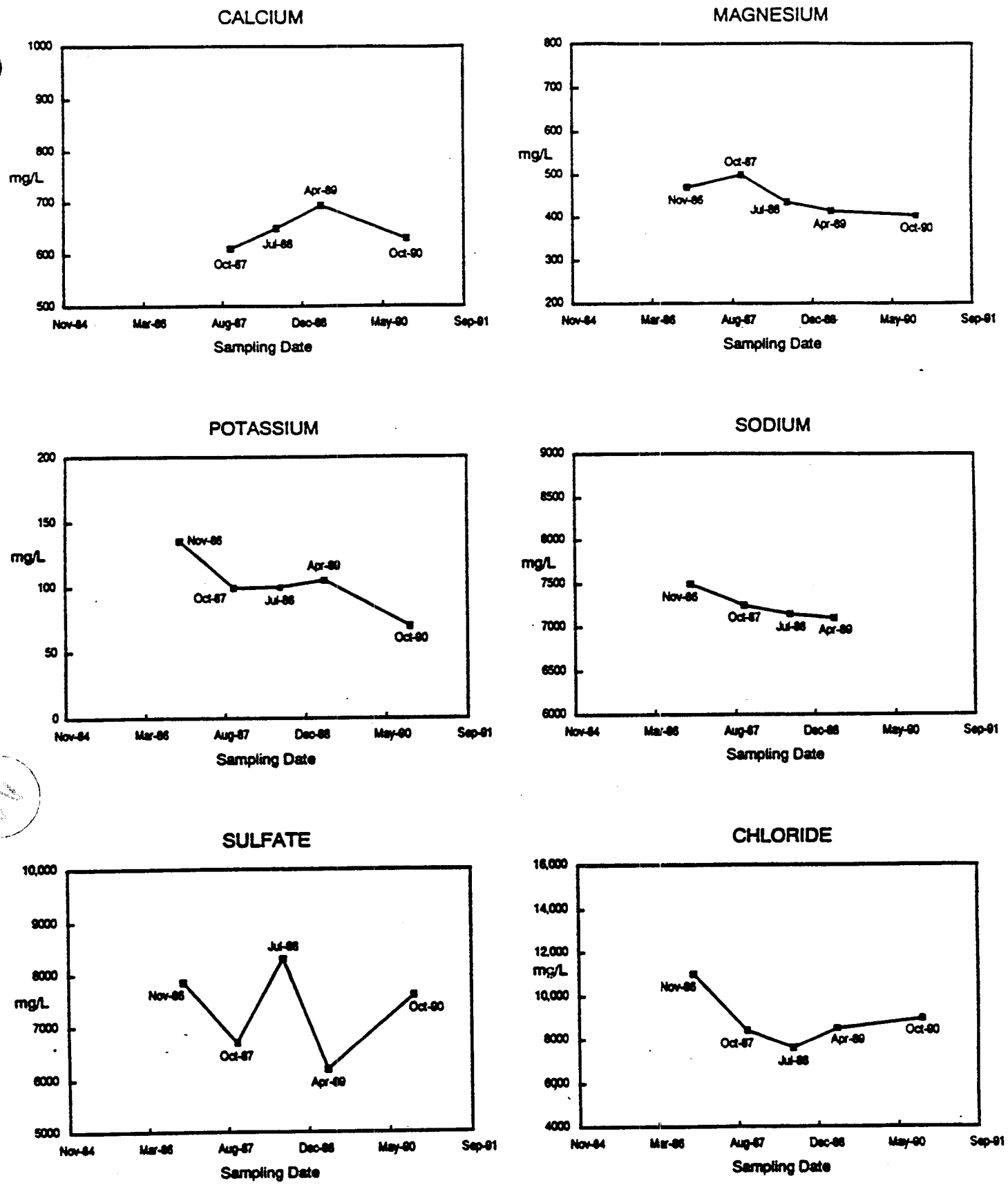


FIGURE 5-9 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-04c GROUNDWATER

(Table 5-9). Well H-04c groundwater is classified as saline, because TDS are approximately 23,500 mg/ℓ (Freeze and Cherry, 1979). Cesium, chromium, copper, mercury, and titanium were detected in Well H-04c groundwater during more than one sampling round. However, concentrations were considerably less than 1 mg/ℓ (Table 5-9).

Bis(2-ethylhexyl)phthalate and 1,3-dichlorobenzene were detected during the July 1988 sampling of groundwater at Well H-04c (Table 5-9). These are the only detections of hazardous organic compounds in samples from Well H-04c. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant, according to an EPA risk assessment guidance document (EPA, 1989).

Figure 5-9 shows the temporal variation in the concentration of the six major constituents of groundwater from Well H-04c. The general downward trend in magnesium, potassium, and sodium concentrations is not supported by a corresponding decrease in TDS. Total dissolved solids actually increased during the WQSP (not shown in Figure 5-9). The concentration of chloride and several other constituents not shown in Figure 5-9 decreased significantly from the first (November 1986) to the second (October 1987) sampling round. This may be indicative of a "cleaning-up" effect, i.e., the first round sample may have been contaminated by drilling activities.

5.10 Well H-05b

Groundwater samples from the Culebra Dolomite were collected at Well H-05b. Well H-05b was sampled five times; the first sampling occurred in August 1985, and the most recent sampling took place in May 1990. Groundwater collected during each sampling event was analyzed for metals and general chemical parameters. Samples were analyzed for VOCs during four of the five sampling rounds; the August 1989 samples were not analyzed for VOCs. Samples were analyzed for semi-VOCs during three of the five sampling rounds; August 1989 and May 1990 samples were not analyzed for semi-VOCs. Total PCB analyses were performed on samples collected in May 1986 and February 1988.

Background concentrations for constituents in groundwater from Well H-05b are presented in Table 5-10. Table 5-10 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-10 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-05b.

Table 5-10
Background Groundwater Chemistry
Well H-05b

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	31	3	28 - 35
Calcium	1,540	270	1,205 - 1,875
Iron	2.5	0.6	1.8 - 3.2
Lithium	0.9	0.1	0.6 - 1.3
Magnesium	1,840	204	1,586 - 2,094
Manganese	0.32	0.13	0.16 - 0.48
Potassium	1,188	140	1,014 - 1,362
Sodium	50,240	4,603	44,526 - 55,955
Strontium	27	7	18 - 36
General Chemistry			
Alkalinity (as HCO_3^-)	43	3	39 - 47
Bromide	61	30	24 - 99
Chloride	87,960	3,121	84,085 - 91,835
Fluoride	1.0	0.2	0.7 - 1.2
pH (s.u.)[b]	7.00	0.07	6.88 - 7.11
Sulfate	6,780	698	5,914 - 7,646
Total Dissolved Solids	153,300	8,693	142,508 - 164,093

See footnotes at end of table.

Table 5-10 *(Continued)*
Background Groundwater Chemistry
Well H-05b

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	<2
Antimony	0.6 - 0.77
Arsenic	<0.1
Barium	<0.5
Beryllium	<0.05
Cadmium	≤0.11
Cesium	<1.1
Chromium	≤0.3
Cobalt	≤3.0
Copper	<1
Lead	≤1
Mercury	≤0.0005
Molybdenum	0.03 - 0.3
Nickel	<3
Selenium	≤7.3
Silica	<21
Silver	≤0.1
Thallium	<0.1
Titanium	≤0.1
Vanadium	<0.5
Zinc	0.03 - 2.5
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	≤0.4
Phenolics	≤0.051
Phosphate (as P)	<0.19
Total Organic Carbon	≤4
Total Organic Halogen	≤7.6

See footnotes at end of table.

Table 5-10 *(Continued)*
Background Groundwater Chemistry
Well H-05b

Hazardous Organic Constituents[c]

	Sample Date	Concentration
Methylene Chloride[d]	02-May-90	6

[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.
[c] All concentrations in microgram per liter, only detected hazardous organic compounds are listed.
[d] Suspected laboratory contaminant.

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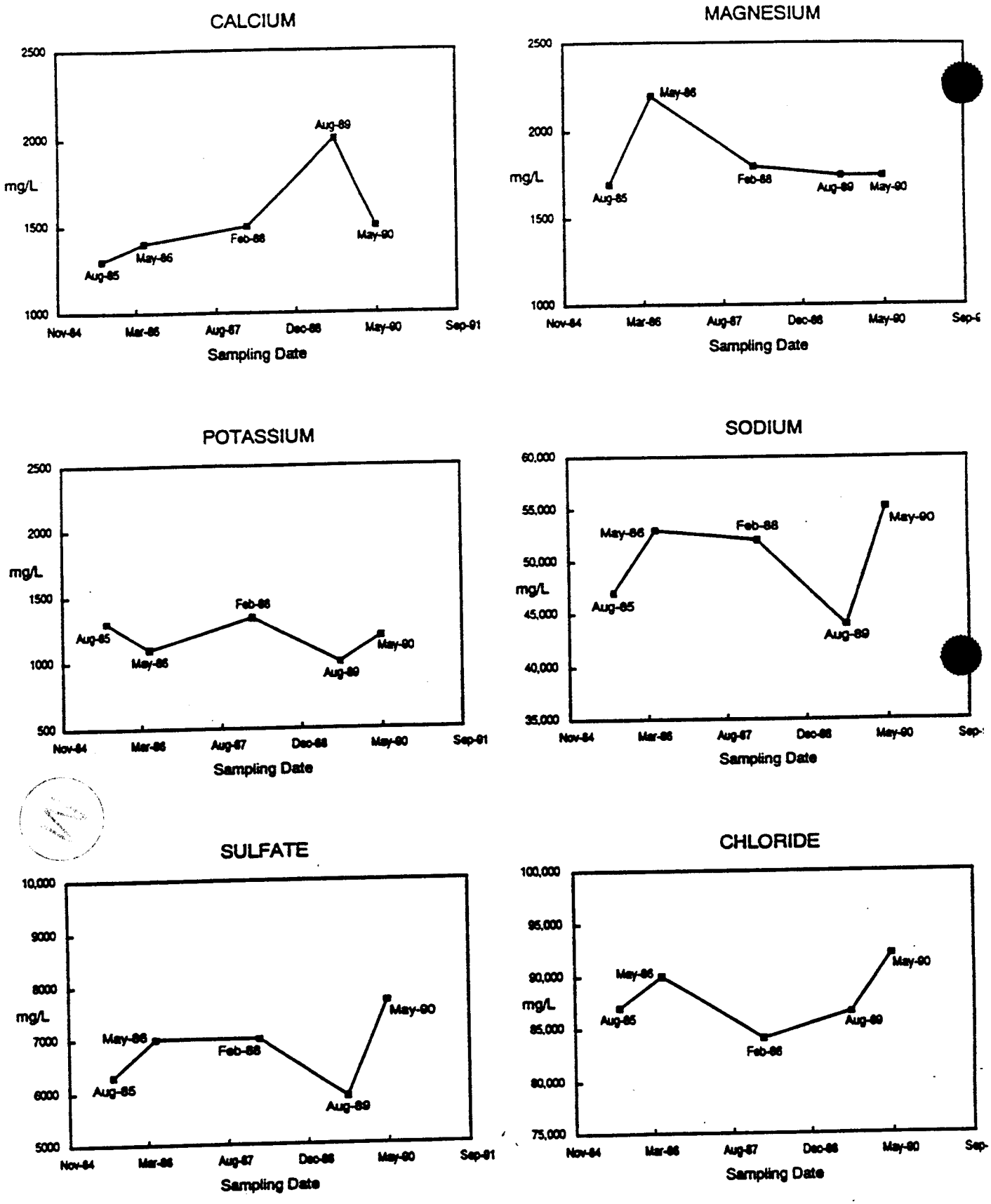

FIGURE 5-10 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-05b GROUNDWATER

Sodium is the dominant cation in groundwater at Well H-05b, followed by magnesium, calcium, and potassium; chloride is the dominant anion in groundwater, followed by sulfate (Table 5-10). Groundwater at Well H-05b is classified as brine, because the TDS exceed 100,000 mg/ℓ (Freeze and Cherry, 1979). Well H-05b lies within hydrochemical Type Area 1 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 1 is a sodium chloride brine. Antimony, molybdenum, silver, and zinc were repeatedly detected in groundwater samples from Well H-05b. Several other trace metals were detected at concentrations that exceed 1 mg/ℓ (e.g., selenium) (Table 5-10), although these detections were usually one-time occurrences. As discussed in Section 4.5, relatively-high MDLs and trace metal concentrations are probably due to sample dilution prior to analysis. Thus, for brines, the analytical uncertainty associated with trace metal data is relatively large.

Methylene chloride was detected at 6 µg/ℓ in a May 1990 groundwater sample. This is the only detection of a hazardous organic compound in samples from Well H-05b. Methylene chloride is a common laboratory contaminant (EPA, 1989), and 10 µg/ℓ was also detected in the trip blank.

Figure 5-10 shows the temporal variation in the concentration of the six major constituents of Well H-05b groundwater. Though concentrations fluctuate, no temporal trends are observed in these or any other constituents. Much of the fluctuation may be due to difficulties related to the analysis of high-TDS samples.

5.11 Well H-05c

Samples of groundwater from the Magenta Dolomite were collected at Well H-05c. This well was sampled five times; the first sample was collected in October 1986, and the most recent was collected in May 1990. Groundwater collected during each round was analyzed for metals and general chemical parameters. Samples collected during the first three rounds were analyzed for VOCs, semi-VOCs, and total PCBs.

Background concentrations for constituents in groundwater from Well H-05c are presented in Table 5-11. Table 5-11 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-11 are the concentration range of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-05c.

Table 5-11
Background Groundwater Chemistry
Well H-05c

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	11	1	10 - 12
Calcium	621	100	496 - 746
Iron	0.7	0.4	0.2 - 1.2
Lithium	0.21	0.01	0.19 - 0.22
Magnesium	186	9	175 - 197
Manganese	NC[b]	NC	<0.15[c]
Potassium	40	7	32 - 48
Sodium	1,304	203	1,052 - 1,556
Strontium	10	1	9 - 11
General Chemistry			
Alkalinity (as HCO_3^-)	56	8	46 - 66
Bromide	2	1	1 - 4
Chloride	949	65	846 - 1,052
Fluoride	2.8	0.2	2.5 - 3.1
pH (s.u.)[d]	7.68	0.41	7.17 - 8.19
Sulfate	3,520	476	2,929 - 4,112
Total Dissolved Solids	7,050	158	6,854 - 7,246

See footnotes at end of table.

Table 5-11 *(Continued)*
Background Groundwater Chemistry
Well H-05c

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	<1
Arsenic	<0.1
Barium	<0.05
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.2
Chromium	≤0.2
Cobalt	<0.5
Copper	<0.25
Lead	≤0.6
Mercury	≤0.0005
Molybdenum	<0.2
Nickel	<0.4
Selenium	<0.05
Silica	4.7 - 12
Silver	≤0.2
Thallium	<1
Titanium	≤0.4
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	<0.1
Phenolics	≤0.016
Phosphate (as P)	≤0.04
Total Organic Carbon	≤3
Total Organic Halogen	<0.06

See footnotes at end of table.

Table 5-11 *(Continued)*
Background Groundwater Chemistry
Well H-05c

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Bis(2-ethylhexyl)phthalate[f]	03-Mar-88	10

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

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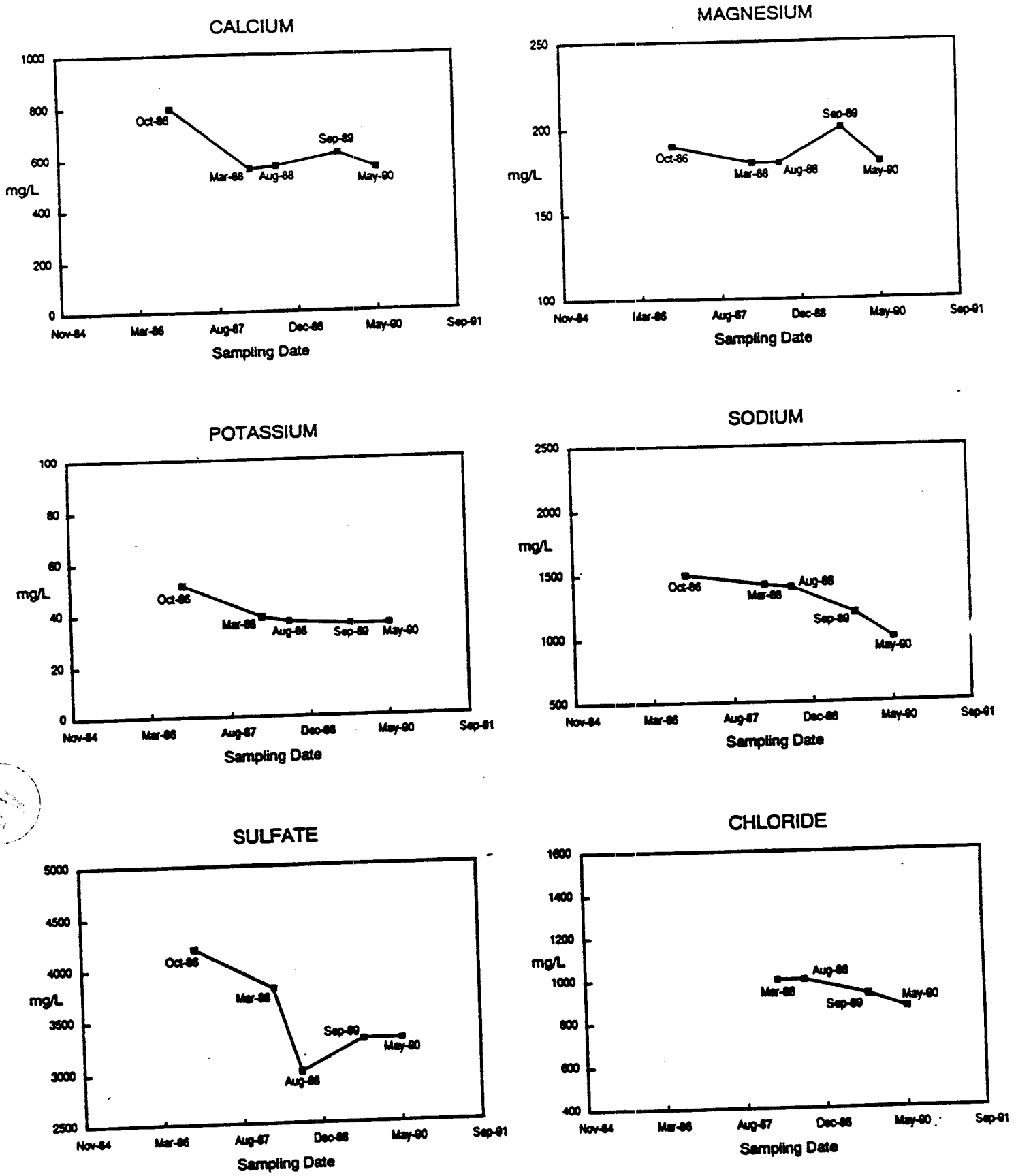


FIGURE 5-11 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-05c GROUNDWATER

Sodium is the dominant cation in Well H-05c groundwater, followed by calcium, magnesium, and potassium; sulfate is the dominant anion, followed by chloride and bicarbonate (Table 5-11). Well H-05c groundwater is classified as brackish, because TDS are approximately 7,000 mg/ℓ. Several trace metals were detected at concentrations less than 1 mg/ℓ in groundwater from Well H-05c (Table 5-11).

Bis(2-ethylhexyl)phthalate was detected during the March 1988 sampling of Well H-05c. This is the only detection of a hazardous organic compound in samples from the well. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant, according to an EPA risk assessment guidance document (EPA, 1989).

Figure 5-11 shows the temporal variation in the concentration of the six major constituents of Well H-05c groundwater. In general, concentrations appear to decrease with time; however, a corresponding decrease in TDS (not shown in Figure 5-11) is not observed. Based on charge-balance considerations, the decrease in the sodium concentration could be balanced by the corresponding decrease in chloride and sulfate concentrations.

The concentration of calcium, sulfate, and to a lesser extent potassium and sodium decreased significantly from the first (October 1986) to the second (March 1988) sampling round. The pattern is also observed in some constituents that are not shown in Figure 5-11 (e.g., alkalinity). This trend may be due to a "cleaning-up" effect, i.e., the first round sample may have been contaminated by drilling activities to a greater extent than subsequent samples.

5.12 Well H-06b

Groundwater samples from the Culebra Dolomite were collected from Well H-06b. Well H-06b was sampled five times; the first groundwater sample was collected in September 1985, and the most recent was collected in February 1990. During all five rounds, samples were analyzed for metals and general chemical parameters. Samples were analyzed for VOCs during all but the July 1989 sampling round, and samples were analyzed for semi-VOCs during only the first three rounds, i.e., September 1985, July 1986, and November 1987. Total PCB analyses were performed on samples collected during July 1986 and November 1987.

Background concentrations for constituents in groundwater from Well H-06b are presented in Table 5-12. Table 5-12 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-12 are the

Table 5-12
Background Groundwater Chemistry
Well H-06b

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	9.2	1.2	7.7 - 10.7
Calcium	1,920	175	1,702 - 2,138
Iron	0.4	0.1	0.2 - 0.6
Lithium	0.5	0.1	0.3 - 0.7
Magnesium	938	118	791 - 1,085
Manganese	0.22	0.05	0.15 - 0.28
Potassium	443	91	330 - 556
Sodium	15,970	1,402	14,230 - 17,710
Strontium	29	4	24 - 34
General Chemistry			
Alkalinity (as HCO_3^-)	96	4	91 - 101
Bromide	37	20	12 - 62
Chloride	31,640	2274	28,816 - 34,464
Fluoride	1.4	0.1	1.2 - 1.5
pH (s.u.)[b]	6.77	0.48	6.18 - 7.37
Sulfate	3,310	175	3,093 - 3,527
Total Dissolved Solids	60,700	3117	56,831 - 64,569

See footnotes at end of table.

Table 5-12 (*Continued*)
Background Groundwater Chemistry
Well H-06b

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	≤0.8
Arsenic	<0.5
Barium	<0.1
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.3
Chromium	0.22 - 0.45
Cobalt	≤0.94
Copper	<0.25
Lead	≤0.83
Mercury	≤0.0012
Molybdenum	≤0.5
Nickel	≤0.56
Selenium	≤1.3
Silica	8.3 - 25
Silver	≤0.1
Thallium	<10
Titanium	≤0.6
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.04
Iodide	<2
Nitrate (as N)	≤0.2
Phenolics	0.004 - 0.016
Phosphate (as P)	≤0.02
Total Organic Carbon	≤7
Total Organic Halogen	0.16 - 3

See footnotes at end of table.

Table 5-12 *(Continued)*
Background Groundwater Chemistry
Well H-06b

Hazardous Organic Constituents

None Detected

[a] All concentrations in mg/L, except where noted.
[b] s.u. = standard pH units.

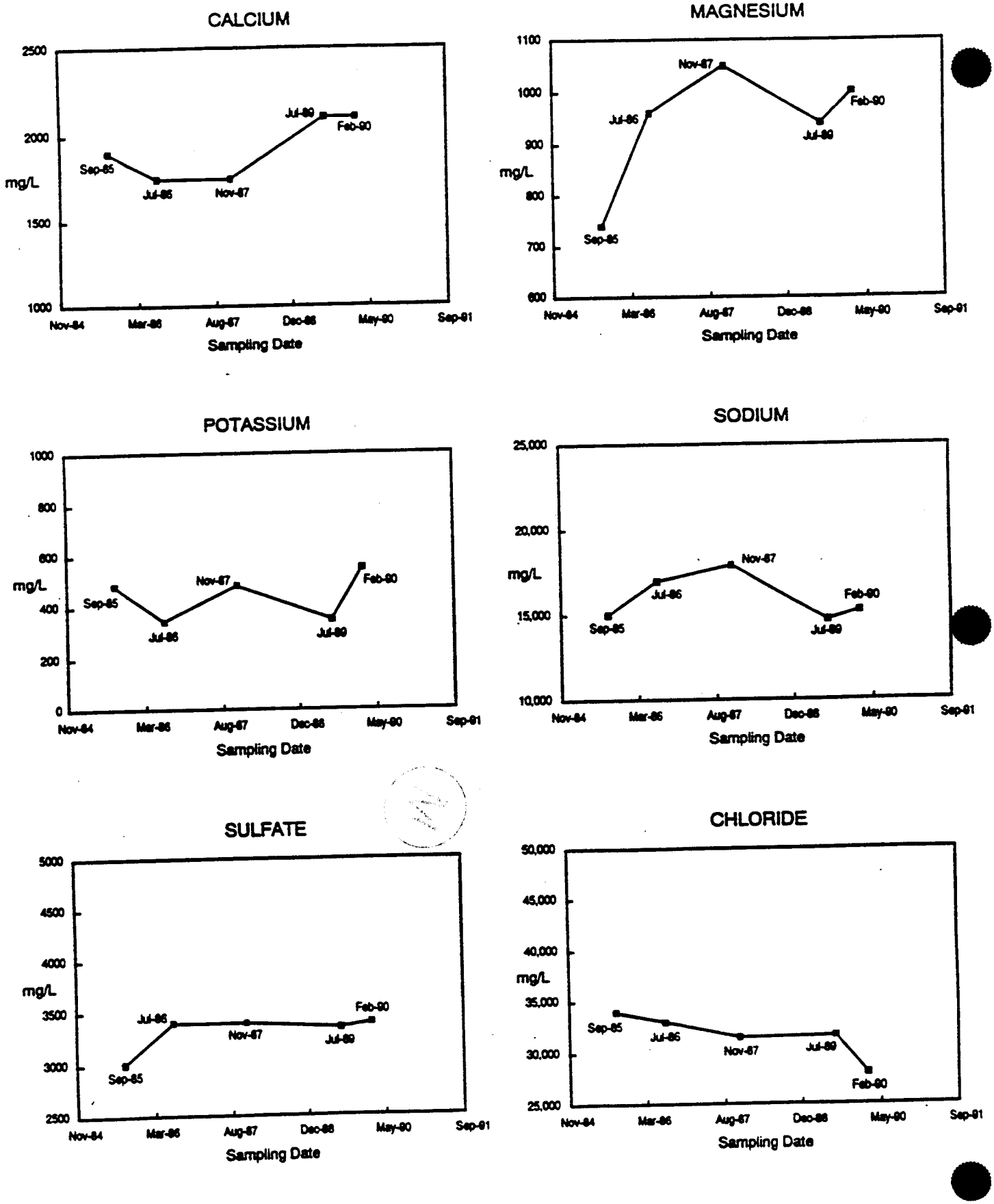


FIGURE 5-12 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-06b GROUNDWATER

concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from Well H-06b.

Sodium is the dominant cation in groundwater at Well H-06b, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-12). Groundwater at Well H-06b is classified as saline, because the TDS are approximately 61,000 mg/ℓ (Freeze and Cherry, 1979). Well H-06b lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Several trace metals were detected at concentrations below 1 mg/ℓ (Table 5-12). Only chromium and molybdenum were repeatedly detected in groundwater samples from Well H-06b.

Figure 5-12 shows the temporal variation in the concentration of the six major dissolved constituents of Well H-06b groundwater. Although concentrations fluctuate, no temporal trends are observed in these or any other dissolved constituent of groundwater from Well H-06b.

5.13 Well H-06c

Groundwater samples from the Magenta Dolomite were collected from Well H-06c. Well H-06c was sampled five times; the first groundwater sample was collected in October 1986, and the most recent was collected in March 1990. Samples were analyzed for metals and general chemistry during all five rounds. Samples were analyzed for VOCs in four rounds; samples collected in August 1989 were not analyzed for VOCs. Also, groundwater samples were analyzed for total PCBs and semi-VOCs during the first three rounds, i.e., October 1986, November 1987, and July 1988.

Background concentrations for constituents in groundwater from Well H-06c are presented in Table 5-13. Table 5-13 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-13 are the concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from Well H-06c.

Sodium and calcium are the dominant cations in groundwater at Well H-06c, followed by magnesium; sulfate is the dominant anion, followed by chloride and bicarbonate (Table 5-13). Well H-06c groundwater is classified as brackish, because the TDS are approximately 5,000 mg/ℓ (Freeze and Cherry, 1979). Trace metal concentrations are below MDLs with the exception of one-time detections of cesium and mercury (Table 5-13).

Table 5-13
Background Groundwater Chemistry
Well H-06c

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	2.3	0.1	2.2 - 2.5
Calcium	567	45	512 - 623
Iron	0.4	0.1	0.2 - 0.5
Lithium	0.21	0.01	0.20 - 0.23
Magnesium	166	9	155 - 177
Manganese	NC[b]	NC	<0.15[c]
Potassium	18	7	10 - 26
Sodium	614	34	560 - 668
Strontium	9.0	1.2	7.5 - 10.4
General Chemistry			
Alkalinity (as HCO_3^-)	52	1	51 - 53
Bromide	NC	NC	<2[c]
Chloride	418	60	381 - 455
Fluoride	1.9	0.1	1.8 - 2.1
pH (s.u.)[d]	6.92	0.54	6.25 - 7.60
Sulfate	2,494	90	2,382 - 2,606
Total Dissolved Solids	4,760	89	4,649 - 4,871

See footnotes at end of table.

Table 5-13 *(Continued)*
Background Groundwater Chemistry
Well H-06c

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	<0.6
Arsenic	<0.01
Barium	<0.05
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.3
Chromium	<0.1
Cobalt	<0.5
Copper	<0.30
Lead	<0.5
Mercury	≤0.0005
Molybdenum	<0.2
Nickel	<0.4
Selenium	<0.5
Silica	5.1 - 13
Silver	<0.1
Thallium	<0.5
Titanium	<0.3
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.06
Iodide	<2
Nitrate (as N)	<0.1
Phenolics	≤0.014
Phosphate (as P)	≤0.02
Total Organic Carbon	≤1
Total Organic Halogen	≤0.06

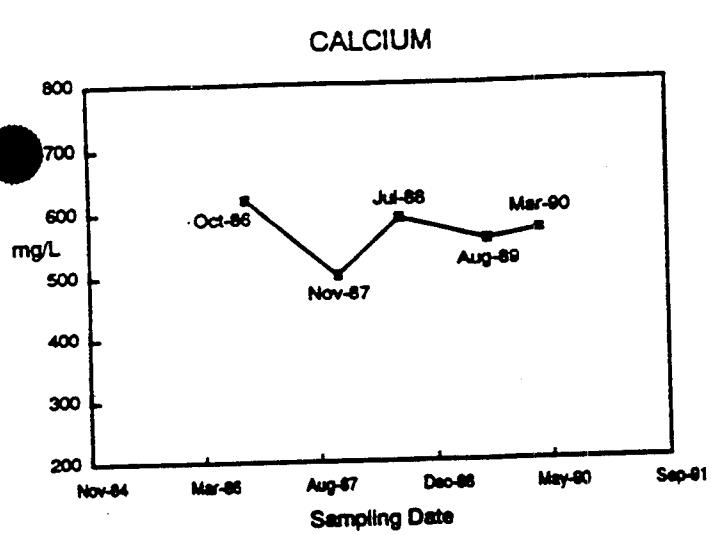
See footnotes at end of table.

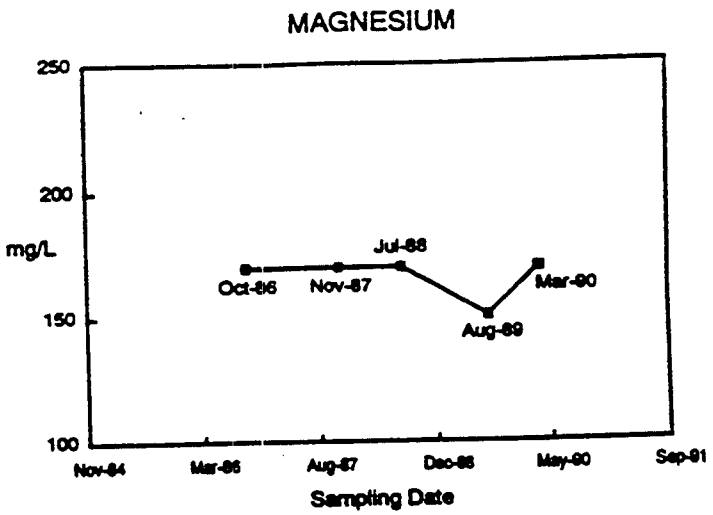
Table 5-13 *(Continued)*
Background Groundwater Chemistry
Well H-06c

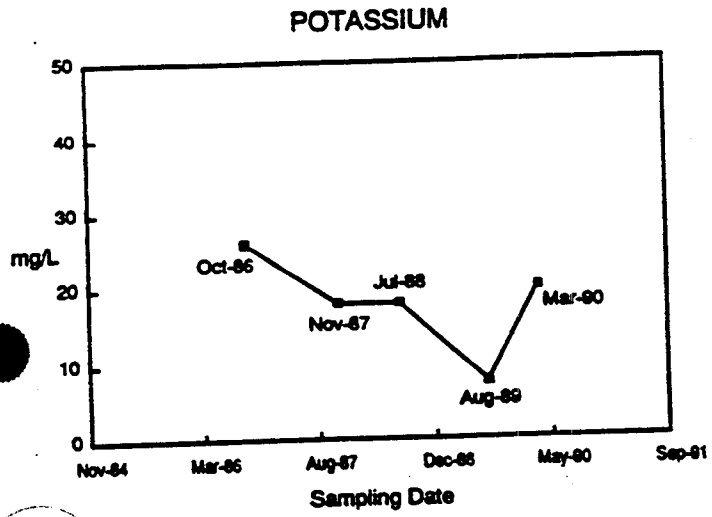
Hazardous Organic Constituents

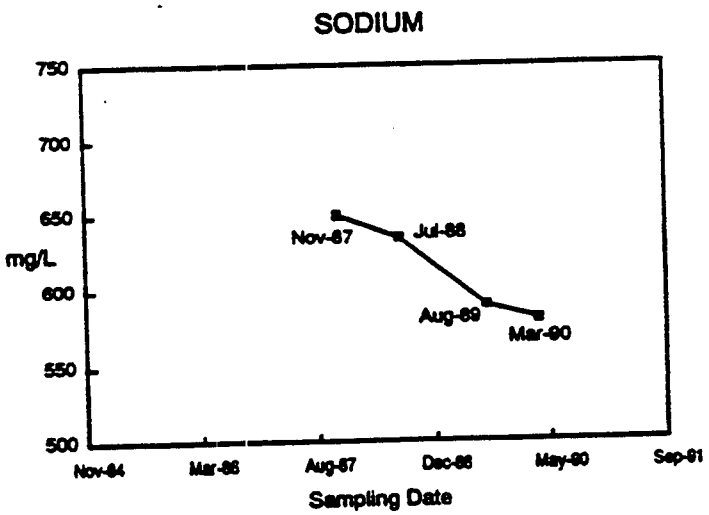
None Detected

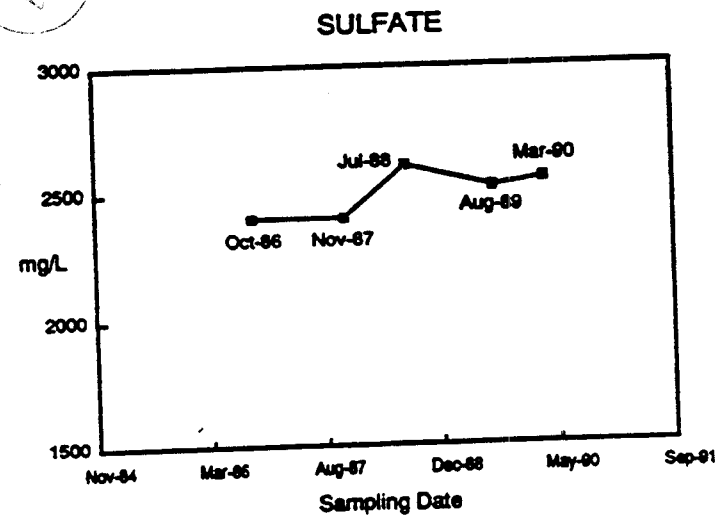
[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.











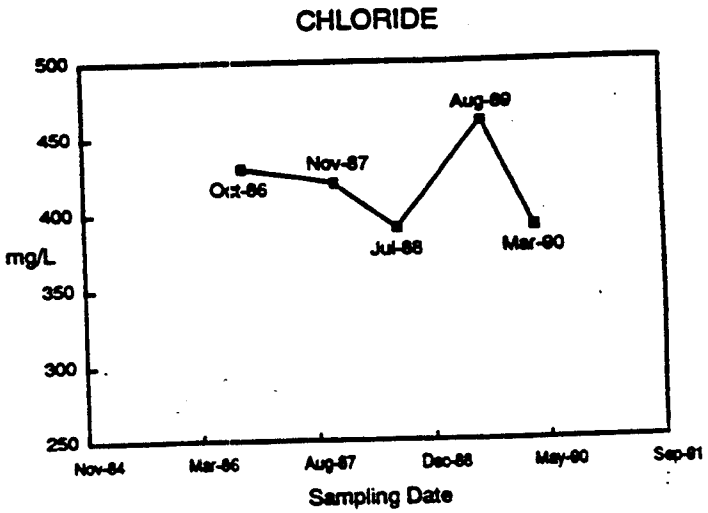


FIGURE 5-13 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-06c GROUNDWATER

Figure 5-13 shows the temporal variation in the concentration of the six major constituents of Well H-06c groundwater. Sodium concentrations appear to have decreased slightly with time; however, the total concentration change is within sampling and analytical variability. In general, concentrations of dissolved constituents in Well H-06c groundwater fluctuate but do not exhibit any significant temporal trends.

5.14 Well H-07b1

Groundwater samples from the Culebra Dolomite were collected at Well H-07b1. Well H-07b1 was sampled five times; the first sampling occurred in March 1986, and the most recent took place in November 1990. During all five rounds, groundwater samples were analyzed for metals and general chemical parameters. Samples collected during the first three rounds were also analyzed for VOCs and semi-VOCs, and samples collected during February 1987 and April 1988 were also analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well H-07b1 are presented in Table 5-14. Table 5-14 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-14 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-07b1.

Calcium is the dominant cation in Well H-07b1 groundwater, followed by sodium and magnesium; sulfate is the dominant anion, followed by chloride and bicarbonate (Table 5-14). Well H-07b1 groundwater is classified as brackish, because the TDS are approximately 3,500 mg/ℓ. Well H-07b1 lies within hydrochemical Type Area 2 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. The TDS of Type Area 2 groundwater is less than 10,000 mg/ℓ, and calcium and sulfate are the dominant dissolved constituents. Chromium is the only trace metal detected in groundwater samples from Well H-07b1 (Table 5-14).

Methylene chloride was detected during the March 1986 sampling of Well H-07b1. This is the only detection of a hazardous organic compound in samples from the well. Methylene chloride is a common laboratory contaminant, according to an EPA risk assessment guidance document (EPA, 1989).

Table 5-14
Background Groundwater Chemistry
Well H-07b1

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.8	0.1	0.7 - 0.9
Calcium	604	54	538 - 671
Iron	NC[b]	NC	≤0.3[c]
Lithium	0.10	0.03	0.05 - 0.15
Magnesium	132	6	125 - 139
Manganese	0.06	0.02	0.03 - 0.08
Potassium	8	1	7 - 9
Sodium	178	47	120 - 236
Strontium	7.9	1.2	6.4 - 9.4
General Chemistry			
Alkalinity (as HCO_3^-)	116	16	97 - 136
Bromide	NC	NC	≤3[c]
Chloride	283	25	243 - 322
Fluoride	1.4	0.1	1.3 - 1.6
pH (s.u.)[d]	7.19	0.24	6.90 - 7.49
Sulfate	1,960	261	1,636 - 2,284
Total Dissolved Solids	3,450	100	3,326 - 3,574

See footnotes at end of table.

Table 5-14 *(Continued)*
Background Groundwater Chemistry
Well H-07b1

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	<0.6
Arsenic	<0.01
Barium	<0.05
Beryllium	<0.05
Cadmium	<0.05
Cesium	<0.2
Chromium	≤0.3
Cobalt	<0.5
Copper	<0.25
Lead	<0.5
Mercury	<0.002
Molybdenum	<0.2
Nickel	<0.4
Selenium	<0.05
Silica	20 - 46
Silver	<0.1
Thallium	<0.5
Titanium	<0.3
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	0.7 - 0.9
Phenolics	<0.05
Phosphate (as P)	≤0.08
Total Organic Carbon	<1
Total Organic Halogen	≤0.21

See footnotes at end of table.

Table 5-14 *(Continued)*
Background Groundwater Chemistry
Well H-07b1

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Methylene Chloride[f]	27-Mar-86	11

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

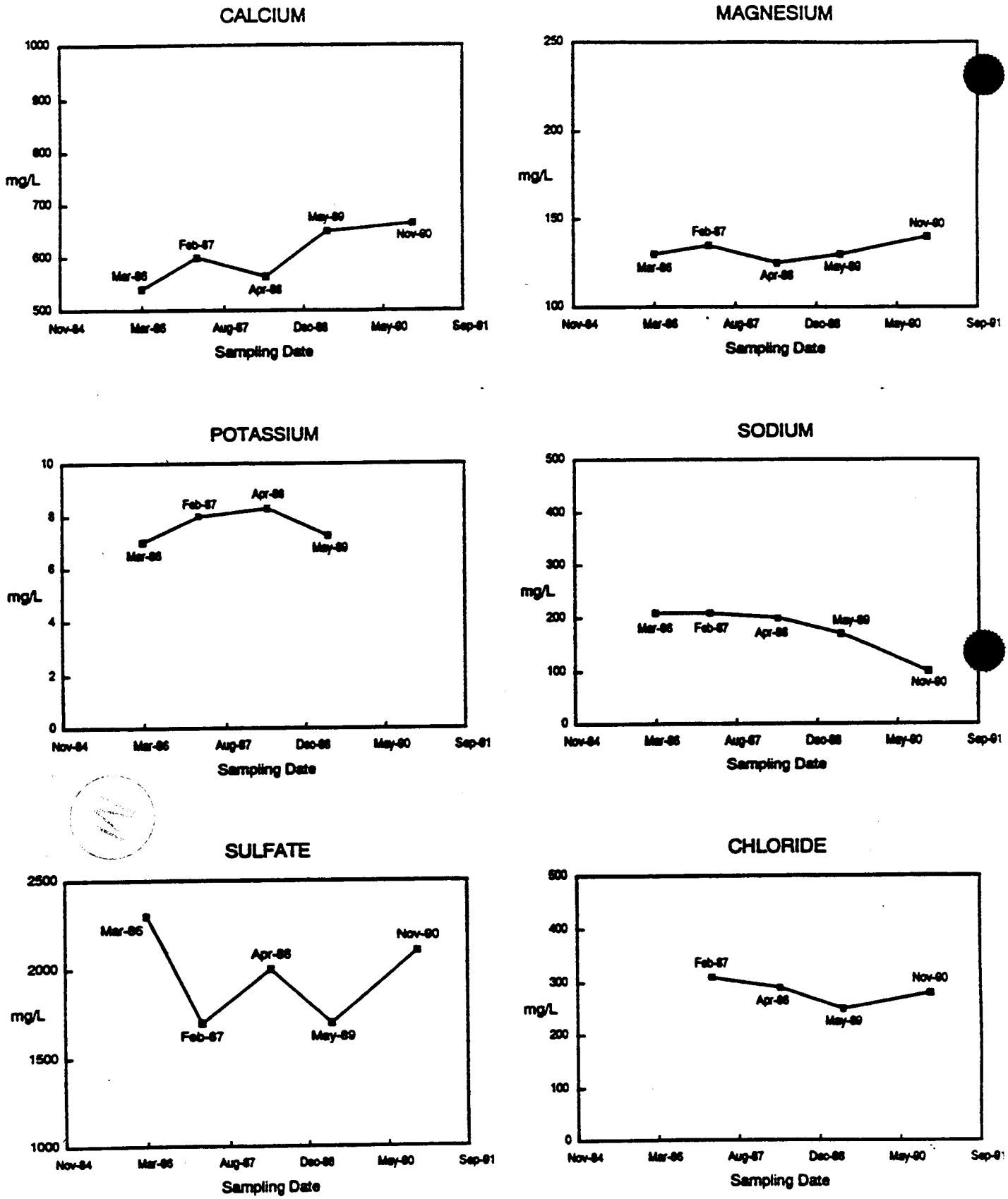


FIGURE 5-14 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-07b1 GROUNDWATER

Figure 5-14 shows the temporal variation in the concentration of the six major constituents of Well H-07b1 groundwater. The calcium concentration appears to have increased; while, sodium and bicarbonate (not shown in Figure 5-14) concentrations appear to have decreased. Based on charge balance considerations, the decrease in sodium could be offset by the increase in calcium concentration.

5.15 Well H-08b

Groundwater samples from the Culebra Dolomite were collected from Well H-08b. Well H-08b was sampled three times; the first sample was collected in January 1986, and the most recent was collected in June 1988. During all three rounds, samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. Samples collected during the first two rounds (i.e., January 1986 and February 1987) were also analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well H-08b are presented in Table 5-15. Table 5-15 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-15 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-08b.

Calcium is the dominant cation in groundwater from Well H-08b, followed by magnesium and sodium; sulfate is the dominant anion, followed by bicarbonate and chloride (Table 5-15). Well H-08b groundwater is classified as brackish, because the TDS concentration is approximately 3,000 mg/ℓ (Freeze and Cherry, 1979). Well H-08b lies within hydrochemical Type Area 2 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. The TDS of Type Area 2 groundwater is less than 10,000 mg/ℓ, and calcium and sulfate are the dominant dissolved constituents. Several trace metals are detected in groundwater samples from Well H-08b; however, detections are sporadic, and concentrations are well below 1 mg/ℓ (Table 5-15).

Bis(2-ethylhexyl)phthalate and 1,2-dichloroethane were detected in the January 1986 groundwater sample from Well H-08b (Table 5-15). The detection of bis(2-ethylhexyl)phthalate could be due to laboratory contamination, as the compound has been identified by the EPA as a common laboratory contaminant (EPA, 1989).

Figure 5-15 shows the temporal variation in the concentration of the six major constituents of Well H-08b groundwater. Calcium and sulfate concentrations appear to have increased with

Table 5-15
Background Groundwater Chemistry
Well H-08b

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.4	0.3	0 - 1.1
Calcium	568	33	486 - 651
Iron	0.05	0	0.05
Lithium	NC[b]	NC	0.12[c]
Magnesium	165	5	153 - 177
Manganese	NC	NC	<0.1[c]
Potassium	4.1	0.4	3.1 - 5.0
Sodium	54	2	48 - 59
Strontium	5.8	1.6	1.8 - 9.9
General Chemistry			
Alkalinity (as HCO_3^-)	95	2	91 - 99
Bromide	NC	NC	<2[c]
Chloride	34	2	30 - 38
Fluoride	NC	NC	2.4 - 2.5[c]
pH (s.u.)[d]	7.50	0.38	6.56 - 8.44
Sulfate	1,750	132	1,421 - 2,079
Total Dissolved Solids	3,050	132	2,721 - 3,379

See footnotes at end of table.

Table 5-15 *(Continued)*
Background Groundwater Chemistry
Well H-08b

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<1
Antimony	<0.5
Arsenic	<0.02
Barium	<0.1
Beryllium	<0.05
Cadmium	<0.05
Cesium	<0.24
Chromium	<0.1
Cobalt	<0.1
Copper	≤0.11
Lead	<0.5
Mercury	≤0.0002
Molybdenum	≤0.02
Nickel	<0.3
Selenium	<0.5
Silica	11 - 27
Silver	<0.1
Thallium	<0.05
Titanium	<0.3
Vanadium	0.04
Zinc	≤0.24
General Chemistry	
Cyanide	≤0.1
Iodide	<2
Nitrate (as N)	0.9 - 1.4
Phenolics	≤0.051
Phosphate (as P)	≤0.02
Total Organic Carbon	<1
Total Organic Halogen	<0.05

See footnotes at end of table.

Table 5-15 *(Continued)*
Background Groundwater Chemistry
Well H-08b

Hazardous Organic Constituents[e]

	Sample Date	Concentration
1,2-Dichloroethane	22-Jan-86	2.5
Bis(2-ethylhexyl)phthalate[f]	22-Jan-86	1.1

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

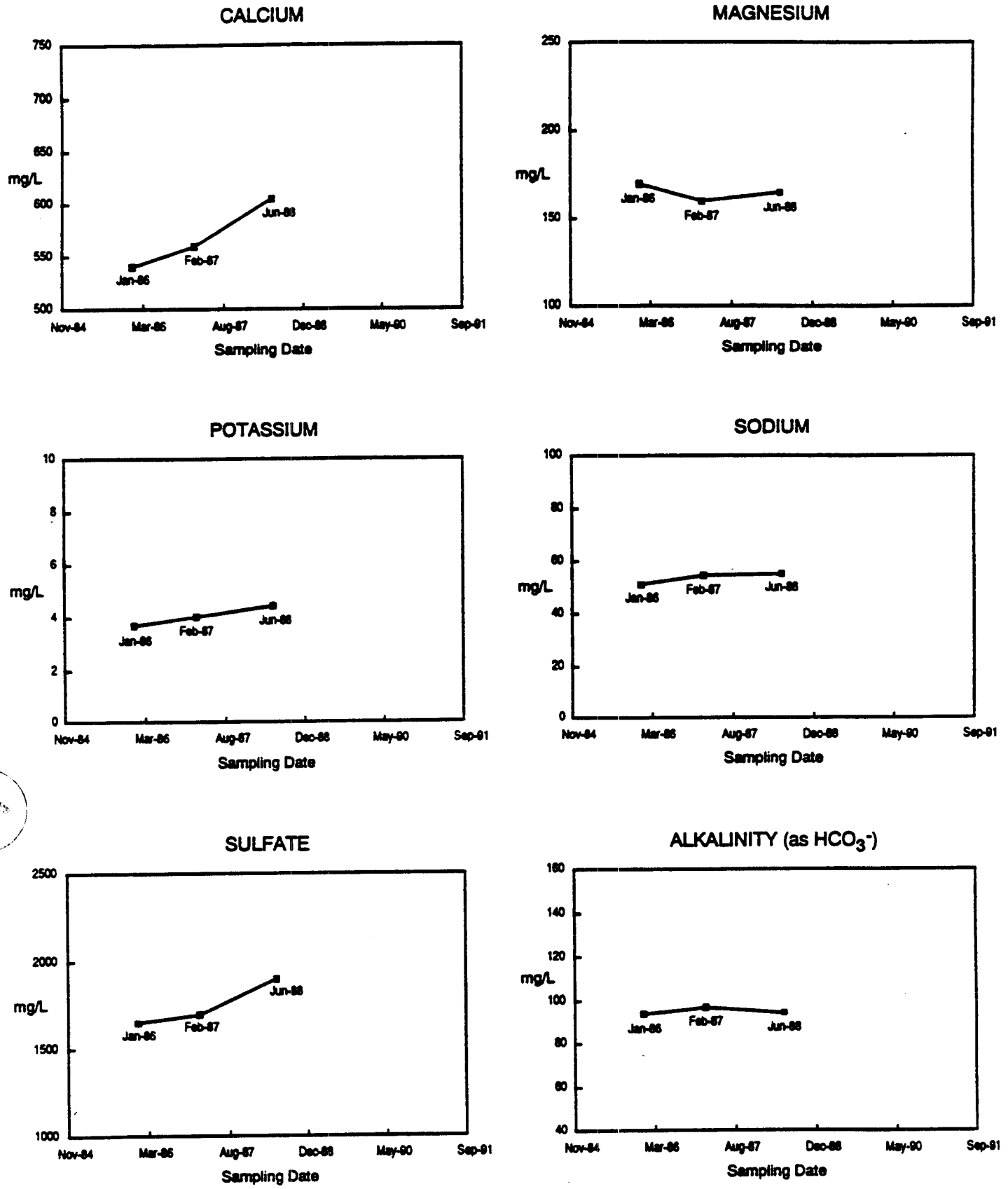


FIGURE 5-15 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-08b GROUNDWATER

time. This could be due to the dissolution of gypsum, if the groundwater at Well H-08b is not saturated with respect to the mineral. However, the observed increase in sulfate is greater than would be expected from the congruent dissolution of gypsum. Also, TDS (not shown in Figure 5-15) appear to be decreasing with time at Well H-08b. Thus, the observed concentration trends are not conclusive; more data would be required to further evaluate trends at Well H-08b.

5.16 Well H-09b

Groundwater samples from the Culebra Dolomite were collected at Well H-09b. Well H-09b was sampled four times; the first sample was collected in November 1985, and the most recent was collected in January 1990. During all four rounds, groundwater samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. Samples collected during the January 1987 and June 1988 rounds were analyzed for total PCBs, and the January 1990 sample was analyzed for individual PCBs (e.g., Aroclor 1016).

Background concentrations for constituents in groundwater from Well H-09b are presented in Table 5-16. Table 5-16 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-16 are the concentration range of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-09b.

Calcium is the dominant cation in Well H-09b groundwater, followed by magnesium and sodium; sulfate is the dominant anion, followed by chloride and bicarbonate (Table 5-16). Well H-09b groundwater is classified as brackish, because the TDS are approximately 3,250 mg/ℓ (Freeze and Cherry, 1979). Well H-09b lies within hydrochemical Type Area 2 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. The TDS of Type Area 2 groundwater is less than 10,000 mg/ℓ, and calcium and sulfate are the dominant dissolved constituents. Trace concentrations of cesium, cobalt, and mercury were detected in groundwater from Well H-09b (Table 5-16). Detected concentrations were well below 1 mg/ℓ, and detections were sporadic (i.e., not detected consistently from one round to the next). Molybdenum was consistently detected in Well H-09b groundwater (Table 5-16).

The compounds 1,3-dichlorobenzene and 2-butanone (metyl ethyl ketone) were detected in groundwater samples from Well H-09b (Table 5-16). The 1,3-dichlorobenzene was detected at 20 µg/ℓ in a groundwater sample and was also detected at 13 µg/ℓ in a method blank. The detection of 2-butanone could be due to laboratory contamination, as this compound was

Table 5-16
Background Groundwater Chemistry
Well H-09b

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.7	0.1	0.5 - 0.9
Calcium	613	37	554 - 672
Iron	NC[b]	NC	≤0.11[c]
Lithium	0.19	0.02	0.15 - 0.23
Magnesium	141	9	128 - 155
Manganese	0.06	0.05	0 - 0.13
Potassium	7.7	0.6	6.8 - 8.6
Sodium	129	27	96 - 163
Strontium	7.3	0.5	6.5 - 8.1
General Chemistry			
Alkalinity (as HCO_3^-)	120	0	120
Bromide	0.9	0.3	0.5 - 1.3
Chloride	183	17	155 - 210
Fluoride	3.1	0.4	2.5 - 3.7
pH (s.u.)[d]	7.40	0.26	6.99 - 7.81
Sulfate	1,650	168	1,382 - 1,918
Total Dissolved Solids	3,250	100	3,091 - 3,409

See footnotes at end of table.

Table 5-16 *(Continued)*
Background Groundwater Chemistry
Well H-09b

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<1
Antimony	<0.5
Arsenic	<0.01
Barium	<0.2
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.2
Chromium	<0.1
Cobalt	≤0.12
Copper	<0.1
Lead	<0.5
Mercury	≤0.0041
Molybdenum	0.01 - 0.05
Nickel	<0.3
Selenium	<0.5
Silica	12 - 30
Silver	<0.1
Thallium	<0.5
Titanium	<0.3
Vanadium	<0.05
Zinc	<0.1
General Chemistry	
Cyanide	≤0.24
Iodide	<2
Nitrate (as N)	0.11 - 0.5
Phenolics	<0.05
Phosphate (as P)	≤0.03
Total Organic Carbon	≤3
Total Organic Halogen	≤0.22

See footnotes at end of table.

Table 5-16 *(Continued)*
Background Groundwater Chemistry
Well H-09b

Hazardous Organic Constituents[e]

	Sample Date	Concentration
1,3-Dichlorobenzene	19-Jan-90	20
2-Butanone[f]	14-Nov-85	46

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

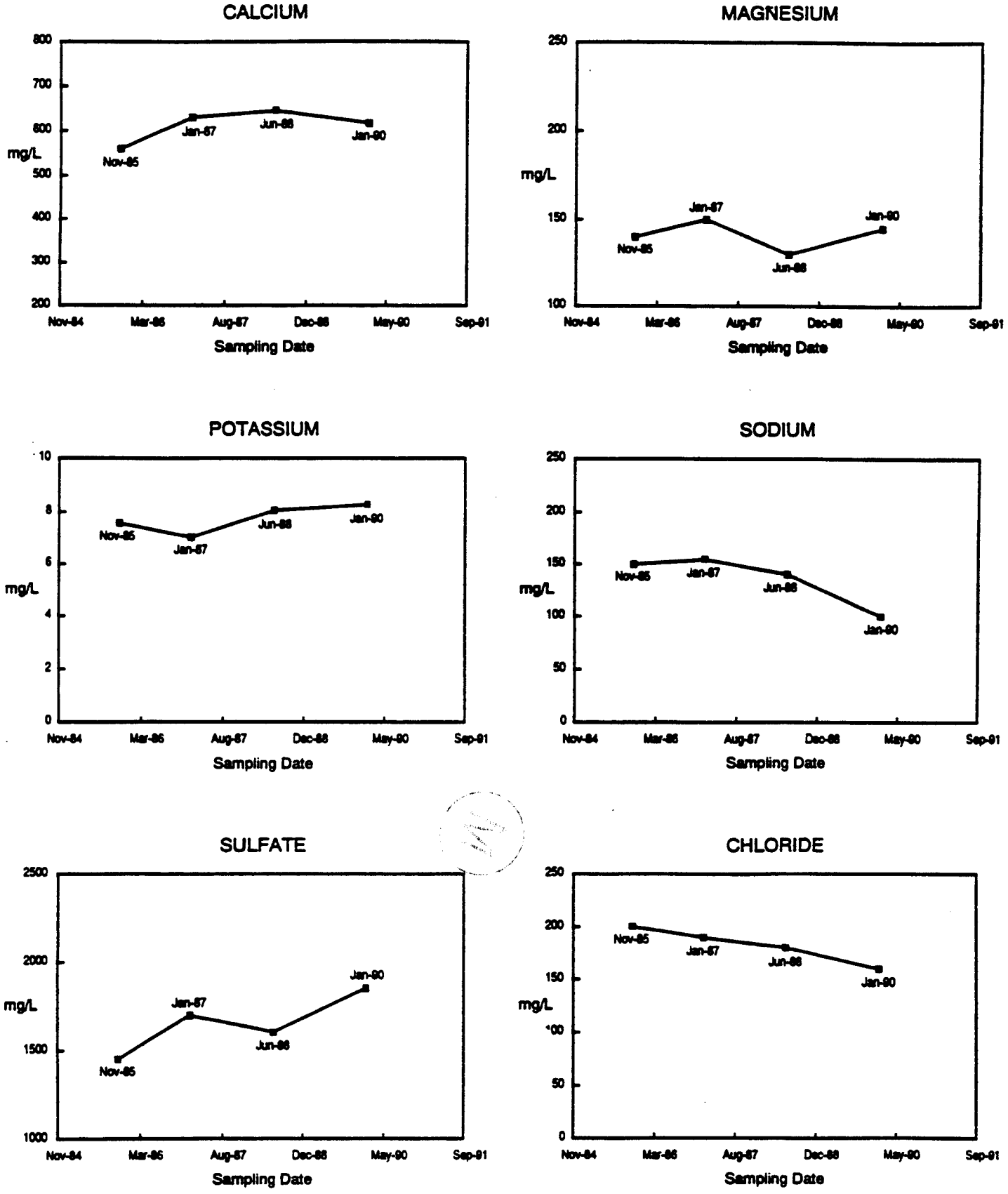


FIGURE 5-16 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-09b GROUNDWATER

identified as a common laboratory contaminant in an EPA risk assessment guidance document (EPA, 1989).

Figure 5-16 shows the temporal variation in the concentration of the six major constituents of Well H-09b groundwater. Sodium and chloride concentrations appear to have decreased slightly with time, while the sulfate concentration appears to have increased. Based on charge balance considerations, an actual increase in sulfate is not likely. Also, TDS (not shown in Figure 5-16) have remained relatively constant throughout the sampling of Well H-09b.

5.17 Well H-11b3

Groundwater samples from the Culebra Dolomite were collected from Well H-11b3. Well H-11b3 was sampled five times; the first sample was collected in June 1985, and the most recent was taken in October 1990. Samples from all five rounds were analyzed for metals and general chemical parameters. Groundwater samples from the first three rounds were also analyzed for VOCs and semi-VOCs. Samples collected during the June 1986 and September 1987 rounds were analyzed for total PCBs. Analytical results for major constituents from the June 1985 sampling event were provided by Bendix (Uhland and Randall, 1986). All other results were provided by ITAS.

Background concentrations for constituents in groundwater from Well H-11b3 are presented in Table 5-17. Table 5-17 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-17 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-11b3.

Sodium is the dominant cation in Well H-11b3 groundwater, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate. Groundwater at well H-11b3 is classified as brine, because the TDS are greater than 100,000 mg/ℓ (Freeze and Cherry, 1979). Well H-11b3 lies within hydrochemical Type Area 1 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 1 contains TDS in excess of 100,000 mg/ℓ, and sodium and chloride are the dominant dissolved constituents. Several trace metals were detected in groundwater samples from Well H-11b3. Cadmium, cesium, chromium, copper, lead, molybdenum, silver, and titanium were repeatedly detected at Well H-11b3. Concentrations of these metals were all less than 1 mg/ℓ (Table-5-17). The MDLs for most of the trace metals were relatively high because of sample dilution during analysis.

Table 5-17
Background Groundwater Chemistry
Well H-11b3

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	30	1	29 - 31
Calcium	1,492	132	1,329 - 1,655
Iron	NC[b]	NC	<1[c]
Lithium	NC	NC	0.5 - 0.6[c]
Magnesium	1,155	94	1,038 - 1,272
Manganese	0.26	0.07	0.17 - 0.35
Potassium	822	136	654 - 990
Sodium	39,300	3,328	35,169 - 43,432
Strontium	23	6	15 - 30
General Chemistry			
Alkalinity (as HCO_3^-)	51	5	44 - 58
Bromide	54	29	18 - 90
Chloride	64,780	6,216	57,063 - 72,497
Fluoride	1.1	0.1	1.0 - 1.2
pH (s.u.)[d]	7.08	0.11	6.95 - 7.22
Sulfate	6,620	626	5,843 - 7,397
Total Dissolved Solids	118,400	3,782	113,705 - 123,095

See footnotes at end of table.

Table 5-17 *(Continued)*
Background Groundwater Chemistry
Well H-11b3

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	≤0.9
Arsenic	≤0.15
Barium	<0.1
Beryllium	<0.05
Cadmium	0.06 - 0.09
Cesium	≤0.55
Chromium	0.32 - 0.4
Cobalt	<0.5
Copper	≤0.26
Lead	≤0.6
Mercury	<0.0004
Molybdenum	0.032 - 0.3
Nickel	<0.4
Selenium	<0.5
Silica	4.1 - 15
Silver	0.1 - 0.2
Thallium	<10
Titanium	≤0.69
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	≤0.15
Iodide	<2
Nitrate (as N)	<0.3
Phenolics	≤0.02
Phosphate (as P)	≤0.04
Total Organic Carbon	≤3
Total Organic Halogen	≤1.5

See footnotes at end of table.

Table 5-17 *(Continued)*
Background Groundwater Chemistry
Well H-11b3

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Acetone[f]	15-Sep-87	16
Bis(2-ethylhexyl)phthalate[f]	04-Jun-86	97
Bis(2-ethylhexyl)phthalate[f]	15-Sep-87	12
Methylene Chloride[f]	15-Sep-87	8

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

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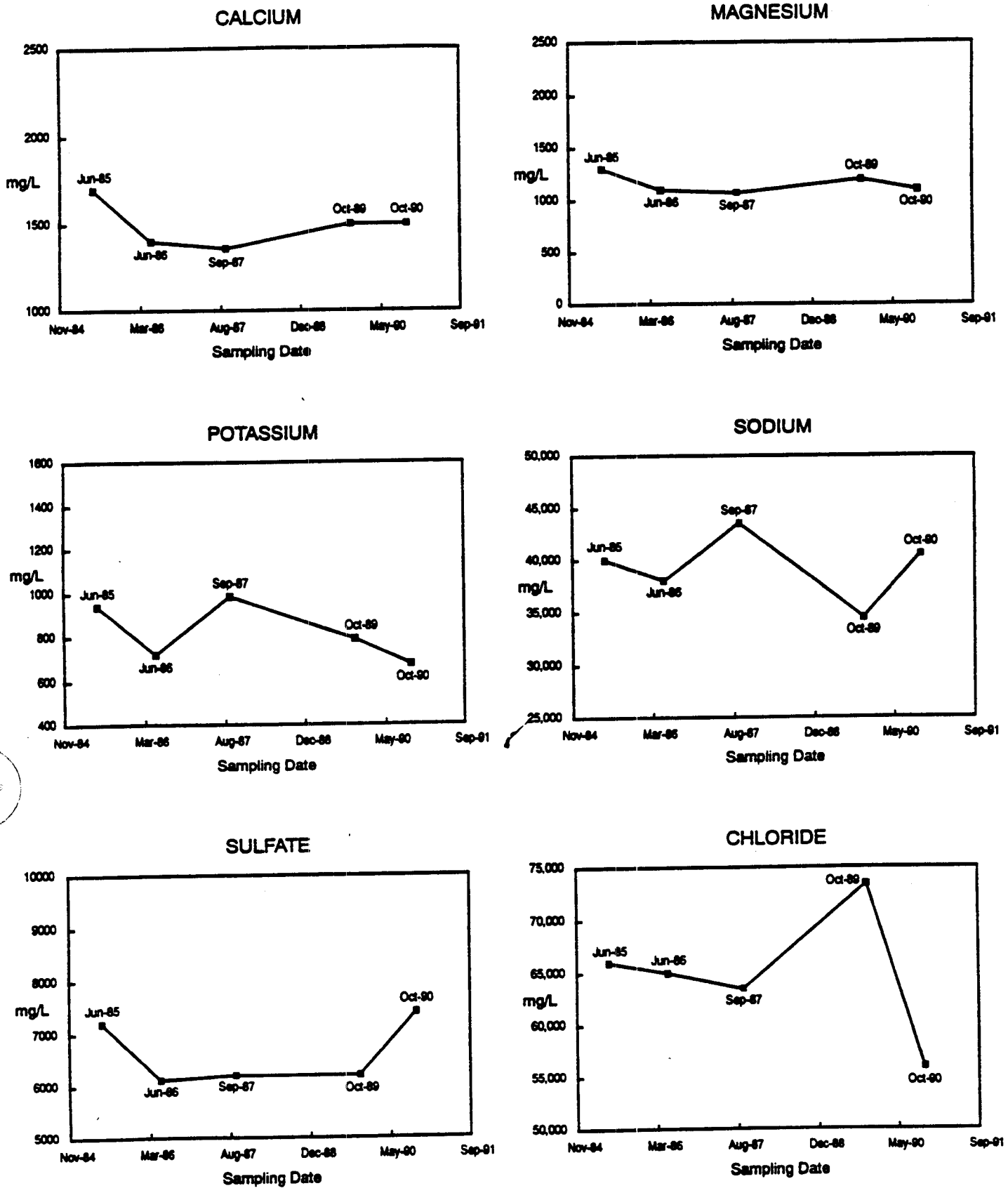

FIGURE 5-17 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-11b3 GROUNDWATER

Several detections of hazardous organic compounds were observed in samples of groundwater from Well H-11b3 (Table 5-17). All of the detections could be due to laboratory contamination, according to a list of common laboratory contaminants presented in an EPA risk assessment guidance document (EPA, 1989). Bis(2-ethyhexyl)phthalate was detected twice (Table 5-17); the other compounds were detected only once. Acetone was detected at 16 µg/ℓ in the September 1987 sampling. However, 19 µg/ℓ of acetone was also detected in a trip blank during the same sampling round.

Figure 5-17 shows the temporal variation in the concentration of the six major constituents of Well H-11b3 groundwater. While concentrations fluctuate, no temporal trends are observed in these constituents. The TDS of Well H-11b3 groundwater (not shown on Figure 5-17) appear to have decreased with time; however, this decrease is not supported by the major constituents shown in Figure 5-17.

5.18 Well H-12

Samples of groundwater from the Culebra Dolomite were collected at Well H-12. Well H-12 was sampled three times; the first sample was collected in August 1985, and the most recent was collected in December 1988. Groundwater samples collected during all three rounds were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. Samples collected during the January 1987 and December 1988 rounds were also analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well H-12 are presented in Table 5-18. Table 5-18 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-18 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-12.

Sodium is the dominant cation in groundwater from Well H-12, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate. Groundwater at Well H-12 is classified as brine, because the TDS are greater than 100,000 mg/ℓ (Freeze and Cherry, 1979). Well H-12 lies within hydrochemical Type Area 1 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 1 is a sodium-chloride brine. Several trace metals were repeatedly detected in groundwater samples from Well H-12. The MDLs for most of the trace metals were relatively high because of

Table 5-18
Background Groundwater Chemistry
Well H-12

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	38	3	31 - 46
Calcium	1,700	150	1,327 - 2,073
Iron	1.7	1.0	0 - 4.2
Lithium	NC[b]	NC	0.73 - 11[c]
Magnesium	1,700	300	955 - 2,445
Manganese	0.28	0.32	0 - 1.1
Potassium	1,480	131	1,154 - 1,806
Sodium	46,750	4,116	36,526 - 56,974
Strontium	30	11	4 - 57
General Chemistry			
Alkalinity (as HCO_3^-)	56	9	33 - 79
Bromide	103	37	12 - 194
Chloride	78,967	896	76,740 - 81,193
Fluoride	1.13	0.03	1.06 - 1.21
pH (s.u.)[d]	7.06	0.24	6.45 - 7.66
Sulfate	7,200	1,179	4,271 - 10,129
Total Dissolved Solids	136,500	8,322	115,826 - 157,174

See footnotes at end of table.

Table 5-18 *(Continued)*
Background Groundwater Chemistry
Well H-12

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<1
Antimony	1 - 2
Arsenic	≤0.17
Barium	<0.05
Beryllium	<0.05
Cadmium	0.05 - 0.15
Cesium	<10
Chromium	≤0.8
Cobalt	≤0.2
Copper	≤0.45
Lead	≤1.2
Mercury	≤0.001
Molybdenum	0.32 - 0.35
Nickel	≤0.84
Selenium	≤0.6
Silica	2.7 - 45
Silver	≤0.2
Thallium	<2.5
Titanium	<0.3
Vanadium	0.3
Zinc	0.3
General Chemistry	
Cyanide	<0.04
Iodide	<2
Nitrate (as N)	≤0.9
Phenolics	≤0.011
Phosphate (as P)	≤0.09
Total Organic Carbon	≤15
Total Organic Halogen	0.18 - 1.4

See footnotes at end of table.

Table 5-18 *(Continued)*
Background Groundwater Chemistry
Well H-12

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Bis(2-Ethylhexyl)phthalate[f]	16-Jan-87	38
Bis(2-Ethylhexyl)phthalate[f]	14-Dec-88	16
Methylene Chloride[f]	14-Dec-88	5.6 (5.3)[g]

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.
[g] Duplicate analysis in parentheses.

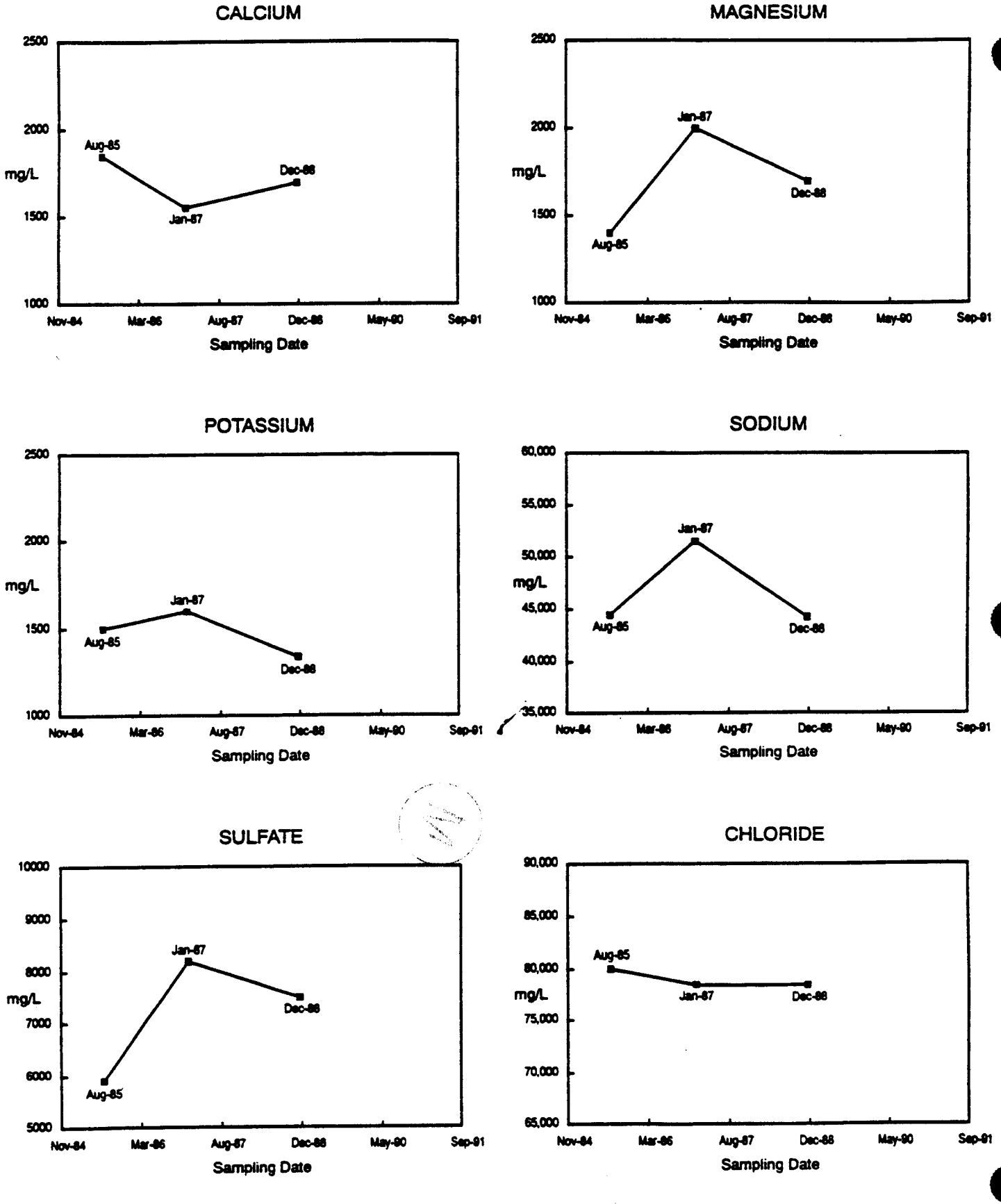

FIGURE 5-18 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-12 GROUNDWATER

sample dilution during analysis. Some of the relatively high concentrations (e.g., lead at 1.2 mg/ℓ) could be due to problems associated with the analysis of high-TDS solutions.

Bis(2-ethylhexyl)phthalate and methylene chloride were detected in groundwater samples from Well H-12 (Table 5-18). The phthalate compound was detected twice, in successive rounds. The presence of both compounds could be due to laboratory contamination, as the compounds have been identified by the EPA as common laboratory contaminants (EPA, 1989).

Figure 5-18 shows the temporal variation in the concentration of the six major constituents of groundwater from Well H-12. Though concentrations fluctuate, no temporal trends are observed in these or any other constituent of Well H-12 groundwater. The TDS (not shown on Figure 5-18) appear to have decreased by approximately 15,000 mg/ℓ from the first to the last sampling round. However, this decrease is not supported by concentration decreases in the major dissolved constituents.

5.19 Well H-14

Groundwater samples from the Culebra Dolomite were collected from Well H-14. Well H-14 was sampled three times; the first sampling occurred in May 1987, and the most recent took place in April 1989. During all three rounds, groundwater samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. In addition, samples collected during the first two rounds were analyzed for total PCBs, and a sample collected during the most recent round was analyzed for individual PCB compounds.

Background concentrations for constituents in groundwater from Well H-14 are presented in Table 5-19. Table 5-19 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-19 are the concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from Well H-14.

Sodium is the dominant cation in groundwater at Well H-14, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-19). Groundwater at Well H-14 is classified as saline (Freeze and Cherry, 1979), because the TDS are approximately 17,000 mg/ℓ. Well H-14 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Several trace metals were detected in groundwater samples from

Table 5-19
Background Groundwater Chemistry
Well H-14

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	11	0	11
Calcium	1,817	126	1,504 - 2,129
Iron	0.4	0.2	0.1 - 0.8
Lithium	0.47	0.04	0.39 - 0.56
Magnesium	532	33	451 - 613
Manganese	0.08	0.05	0 - 0.21
Potassium	245	5	233 - 257
Sodium	3,467	289	2,750 - 4,184
Strontium	32	1	30 - 35
General Chemistry			
Alkalinity (as HCO_3^-)	39	2	35 - 43
Bromide	13	2	9 - 18
Chloride	8,367	569	6,954 - 9,779
Fluoride	1.4	0.5	0.1 - 2.6
pH (s.u.)[b]	7.20	0.52	5.89 - 8.50
Sulfate	1,750	218	1,209 - 2,291
Total Dissolved Solids	16,967	1,168	14,066 - 19,867

See footnotes at end of table.

Table 5-19 *(Continued)*
Background Groundwater Chemistry
Well H-14

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	≤1
Antimony	0.5 - 0.6
Arsenic	<0.05
Barium	<0.05
Beryllium	<0.05
Cadmium	≤0.06
Cesium	<0.6
Chromium	0.2 - 0.4
Cobalt	<0.1
Copper	≤0.1
Lead	≤0.5
Mercury	≤0.0004
Molybdenum	0.06 - 0.2
Nickel	<0.3
Selenium	<0.05
Silica	5.5 - 14
Silver	≤0.1
Thallium	<5
Titanium	≤0.5
Vanadium	0.1 - 0.2
Zinc	<0.1
General Chemistry	
Cyanide	<0.04
Iodide	<2
Nitrate (as N)	≤0.4
Phenolics	0.068 - 0.14
Phosphate (as P)	≤0.05
Total Organic Carbon	≤2
Total Organic Halogen	0.08 - 1.1

See footnotes at end of table.

Table 5-19 *(Continued)*
Background Groundwater Chemistry
Well H-14

Hazardous Organic Constituents

None Detected

[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.

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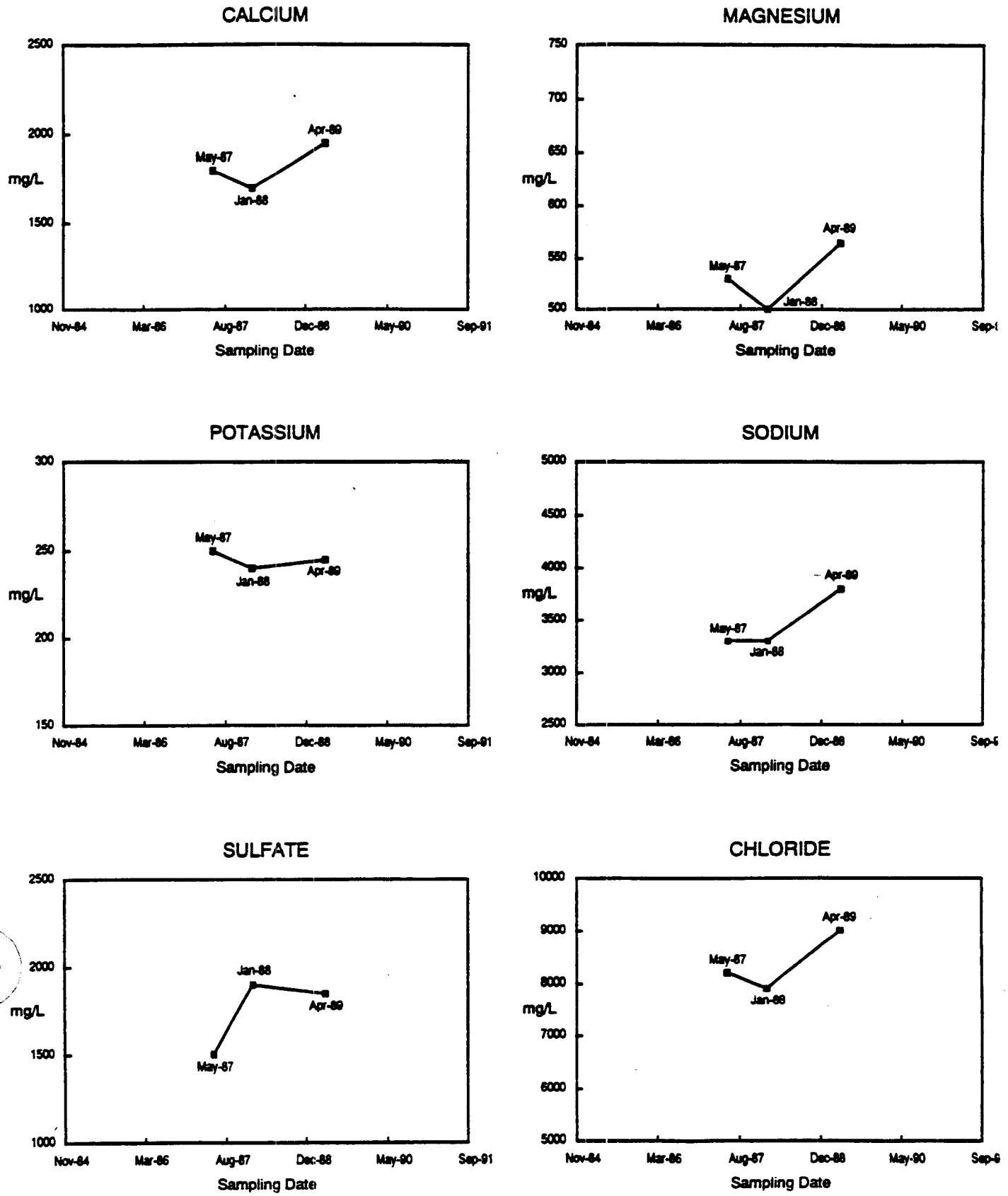

FIGURE 5-19 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-14 GROUNDWATER

Well H-14. Antimony, chromium, copper, molybdenum, titanium, and vanadium were repeatedly detected. Concentrations were below 1 mg/ℓ (Table 5-19).

Figure 5-19 shows the temporal variation in the concentration of the six major constituents of groundwater at Well H-14. Although concentrations vary, no trends are observed in these constituents. The TDS of groundwater at Well H-14 (not shown in Figure 5-19) appear to have decreased with time throughout the WQSP; however, this trend is not supported by a decrease in the concentration of the major constituents.

5.20 Well H-15

Groundwater samples from the Culebra Dolomite were collected from Well H-15. Well H-15 was sampled three times; the first sampling occurred in May 1987, and the most recent took place in November 1988. During all three rounds, groundwater samples were analyzed for VOCs, semi-VOCs, total PCBs, metals, and general chemical parameters.

Background concentrations for constituents in groundwater from Well H-15 are presented in Table 5-20. Table 5-20 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-20 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-15.

Sodium is the dominant cation in Well H-15 groundwater, followed by magnesium, potassium, and calcium; chloride is the dominant anion, followed by sulfate (Table 5-20). Groundwater at Well H-15 is a brine (Freeze and Cherry, 1979), as the TDS concentration greatly exceeds 100,000 mg/ℓ. Well H-15 lies within hydrochemical Type Area 1 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 1 is a sodium-chloride brine. The MDLs for trace metals are relatively-high, due to dilution prior to the analysis of the high-TDS samples from Well H-15. Also, several trace metals were detected at relatively-high concentrations, i.e., chromium and lead (Table 5-20). The validity of the trace metal data in uncertain, due to sample dilution and the problems associated with the analysis of high-TDS solutions.

Bis(2-ethylhexyl)phthalate was detected in Well H-15 groundwater samples from all three rounds (Table 5-20). This compound may have been present due to laboratory contamination; bis(2-ethylhexyl)phthalate is listed as a common laboratory contaminant in an EPA risk assessment guidance document (EPA, 1989). However, the repeated detection of the

Table 5-20
Background Groundwater Chemistry
Well H-15

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	47	3	40 - 55
Calcium	1,667	306	908 - 2,426
Iron	NC[b]	NC	3[c]
Lithium	0.8	0.1	0.6 - 1.1
Magnesium	2,533	208	2,016 - 3,051
Manganese	NC	NC	≤0.6[c]
Potassium	1,817	29	1,745 - 1,888
Sodium	77,967	6,550	61,694 - 94,239
Strontium	31	1	29 - 32
General Chemistry			
Alkalinity (as HCO_3^-)	35	3	28 - 43
Bromide	99	2	94 - 103
Chloride	136,333	3,215	128,347 - 144,319
Fluoride	0.7	0.1	0.5 - 0.8
pH (s.u.)[d]	6.66	0.13	6.34 - 6.97
Sulfate	6,467	961	4,080 - 8,854
Total Dissolved Solids	235,333	8,387	214,498 - 256,168

See footnotes at end of table.

Table 5-20 *(Continued)*
Background Groundwater Chemistry
Well H-15

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<10
Antimony	≤7
Arsenic	<1
Barium	<0.5
Beryllium	<0.5
Cadmium	≤0.7
Cesium	<1
Chromium	≤3
Cobalt	≤1
Copper	≤2
Lead	≤7
Mercury	<0.002
Molybdenum	0.2 - 0.52
Nickel	<3
Selenium	<5
Silica	<21
Silver	≤1
Thallium	<5
Titanium	<3
Vanadium	≤1
Zinc	≤1
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	≤0.5
Phenolics	≤0.039
Phosphate (as P)	≤0.01
Total Organic Carbon	≤2
Total Organic Halogen	1.2 - 7.4

See footnotes at end of table.

Table 5-20 *(Continued)*
Background Groundwater Chemistry
Well H-15

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Bis(2-ethylhexyl)phthalate[f]	11-May-87	64
Bis(2-ethylhexyl)phthalate[f]	13-Jan-88	22
Bis(2-ethylhexyl)phthalate[f]	07-Nov-88	44

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95 % confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

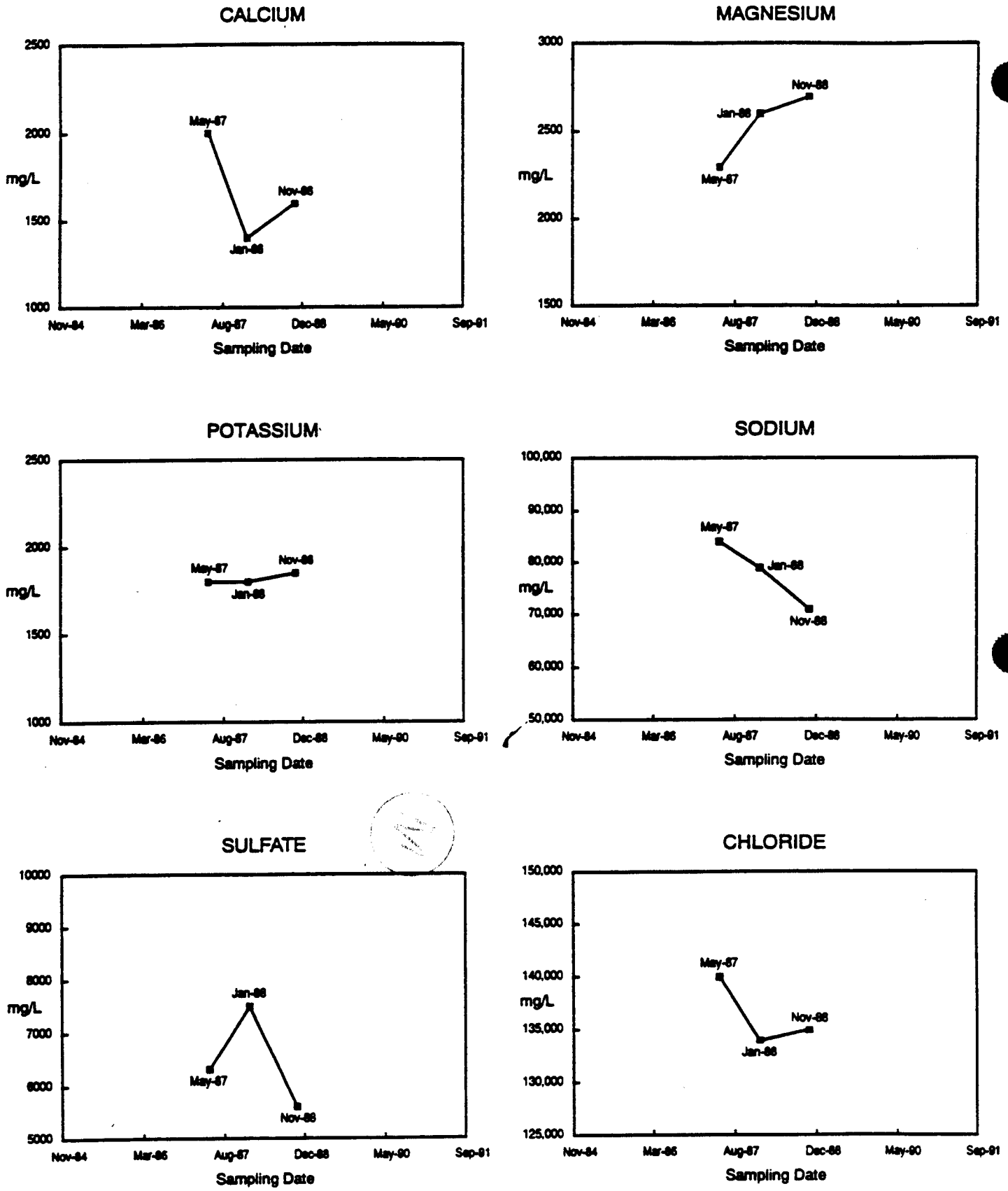

FIGURE 5-20 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-15 GROUNDWATER

compound could indicate actual contamination or the introduction of the compound during the sampling procedure.

Figure 5-20 shows the temporal variation in the concentration of the six major constituents of Well H-15 groundwater. The sodium concentration appears to have decreased, while the magnesium concentration and TDS (not shown on Figure 5-20) appear to have increased. Based on charge balance considerations, the sodium decrease could not be entirely offset by the magnesium increase. Also, the TDS increase is not supported by an increase in the concentration of the major constituents. Thus, it is likely that the observed trends in Well H-15 groundwater chemistry are not significant.

5.21 Well H-18

Groundwater samples from the Culebra Dolomite were collected from Well H-18. Well H-18 was sampled three times, in November 1987, April 1988, and April 1990. During all three rounds, samples were analyzed for VOCs, metals, and general chemical parameters. The November 1987 and April 1988 samples were also analyzed for semi-VOCs and total PCBs.

Background concentrations for constituents in groundwater from Well H-18 are presented in Table 5-21. Table 5-21 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-21 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well H-18.

Sodium is the dominant cation in Well H-18 groundwater, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-21). The groundwater at Well H-18 is classified as saline (Freeze and Cherry, 1979), because TDS are approximately 27,600 mg/ℓ. Well H-18 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Cesium, chromium, and titanium were detected in samples from well H-18 at concentrations of less than 1 mg/ℓ (Table 5-21). Only cesium was repeatedly detected.

The occurrence of 5.5 µg/ℓ of methylene chloride in the April 1988 sample is the only detection of a hazardous organic compound observed in Well H-18 groundwater (Table 5-21). This probably is due to laboratory contamination, since 5.7 µg/ℓ of methylene chloride was

Table 5-21
Background Groundwater Chemistry
Well H-18

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	16	1	14 - 18
Calcium	1,093	110	820 - 1,367
Iron	0.4	0.2	0 - 0.7
Lithium	0.24	0.08	0.04 - 0.44
Magnesium	503	21	452 - 555
Manganese	0.18	0.03	0.09 - 0.26
Potassium	238	13	207 - 270
Sodium	7,617	664	5,967 - 9,266
Strontium	15	1	14 - 17
General Chemistry			
Alkalinity (as HCO_3^-)	53	3	46 - 61
Bromide	15	2	11 - 19
Chloride	12,500	500	11,258 - 13,742
Fluoride	1.7	0.2	1.4 - 2.1
pH (s.u.)[b]	6.92	0.83	4.87 - 8.98
Sulfate	4,233	839	2,150 - 6,317
Total Dissolved Solids	27,633	3,508	18,919 - 36,347

See footnotes at end of table.

Table 5-21 *(Continued)*
Background Groundwater Chemistry
Well H-18

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	<0.6
Arsenic	<0.5
Barium	<0.05
Beryllium	<0.05
Cadmium	<0.05
Cesium	≤0.8
Chromium	≤0.2
Cobalt	<0.5
Copper	<0.25
Lead	<0.5
Mercury	<0.0002
Molybdenum	<2
Nickel	<0.4
Selenium	<0.5
Silica	5.1 - 13
Silver	<0.1
Thallium	<5
Titanium	≤0.6
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	<0.2
Phenolics	≤0.12
Phosphate (as P)	≤0.03
Total Organic Carbon	≤5
Total Organic Halogen	≤0.42

See footnotes at end of table.

Table 5-21 *(Continued)*
Background Groundwater Chemistry
Well H-18

Hazardous Organic Constituents[c]

	Sample Date	Concentration
Methylene Chloride[d]	07-Apr-88	5.5

[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.
[c] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[d] Suspected laboratory contaminant.

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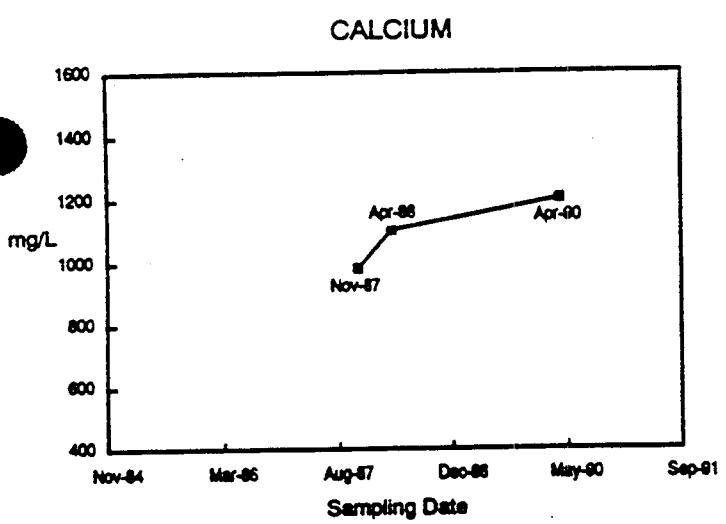
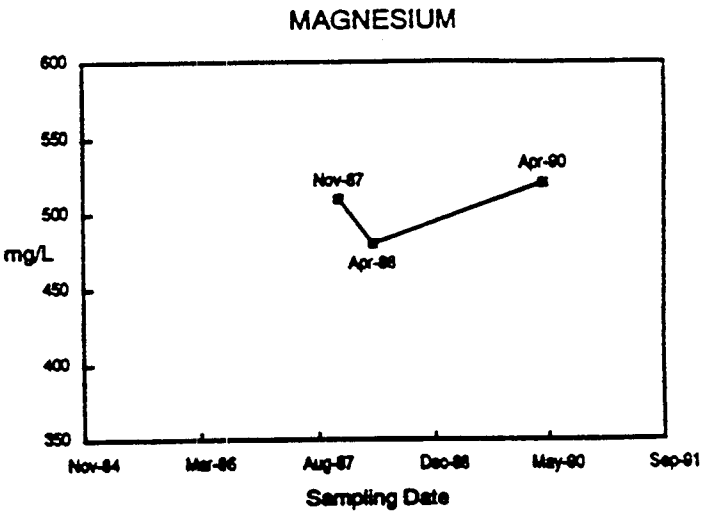
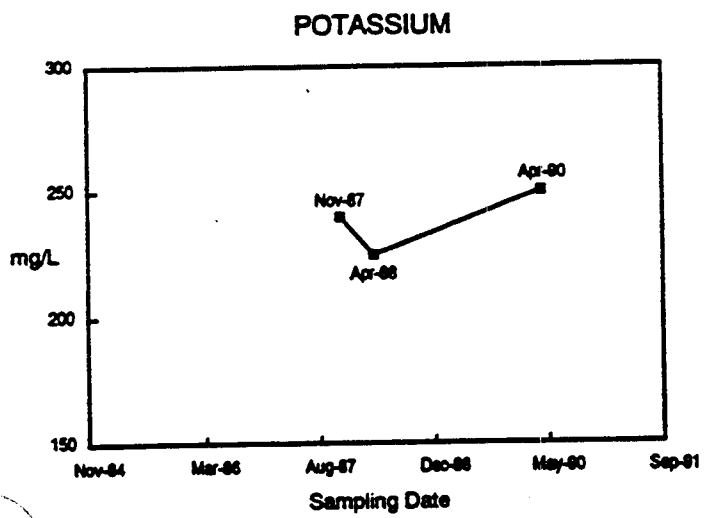
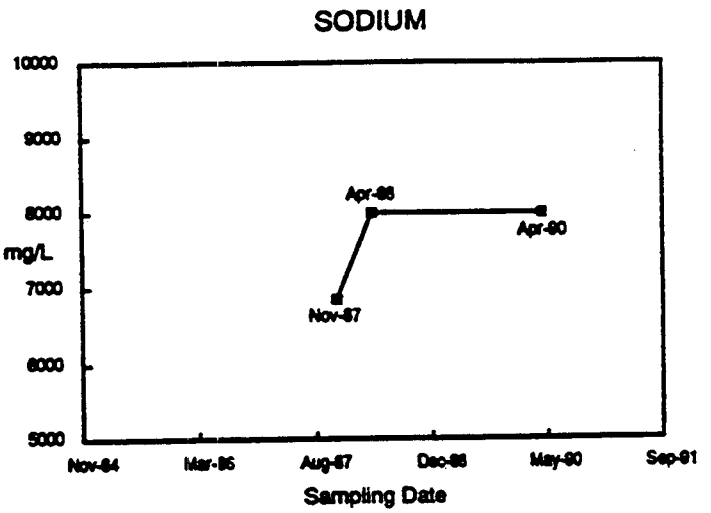
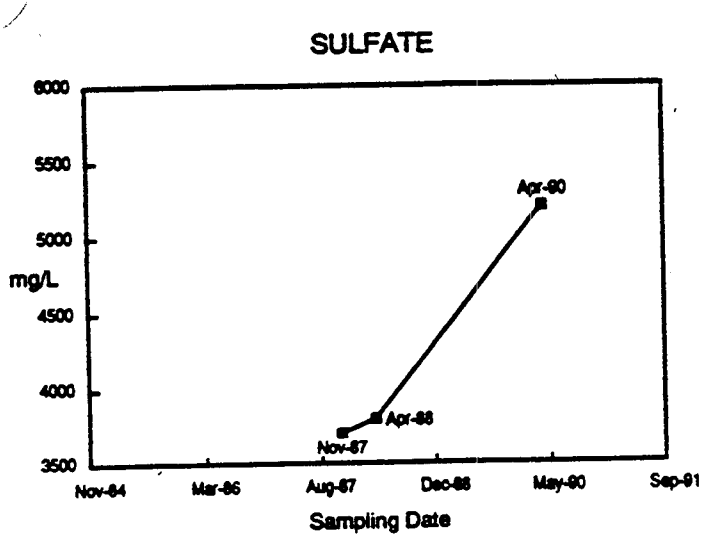










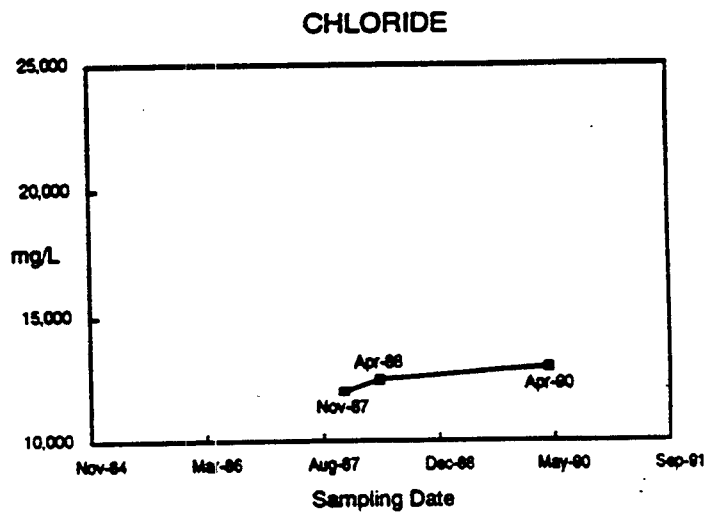


FIGURE 5-21 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL H-18 GROUNDWATER

also detected in a sample blank. The compound is considered a common laboratory contaminant by the EPA (EPA, 1989).

Figure 5-21 shows the temporal variation in the concentration of the six major constituents of Well H-18 groundwater. Calcium, chloride, sulfate and TDS (not show in Figure 5-21) concentrations appear to have increased with time at Well H-18. However, the TDS increase of approximately 7,000 mg/ℓ is much greater than would be expected, based on the increase in calcium, chloride, and sulfate. Also, the addition of positive charge due to the increase in calcium is not enough to balance the negative charge addition due to the increase in chloride and sulfate. Thus, although the data indicate that the Well H-18 groundwater chemistry is changing, the poor correlation between TDS and major-constituent concentrations and the lack of charge balance indicate that the trend is uncertain. Results from additional sampling are required for further trend evaluation.

5.22 Well P-14

Groundwater samples from the Culebra Dolomite were collected from Well P-14. Well P-14 was sampled three times; the first sample was collected in February 1986, and the most recent was collected in March 1988. During all three rounds, groundwater samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. Samples from the two most recent rounds (June 1987 and March 1988) were also analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well P-14 are presented in Table 5-22. Table 5-22 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-22 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well P-14.

Sodium is the dominant cation in Well P-14 groundwater, followed by calcium and magnesium; chloride is the dominant anion, followed by sulfate (Table 5-22). Well P-14 groundwater is classified as saline (Freeze and Cherry, 1979), because TDS are approximately 28,000 mg/ℓ. Well P-14 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. The TDS concentration of groundwater in Type Area 3 ranges from 10,000 to 100,000 mg/ℓ. This groundwater may be a mixture of Type Area 1 and 2 groundwater. Several trace metals were detected in groundwater samples from Well P-14; concentrations were generally below 1 mg/ℓ (Table 5-22). Chromium, copper, lead, molybdenum, titanium, and zinc were detected during more than one sampling round.

Table 5-22
Background Groundwater Chemistry
Well P-14

Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.7	0.1	0.5 - 0.9
Calcium	3,600	265	2,943 - 4,257
Iron	1.82	0.21	1.30 - 2.33
Lithium	NC[b]	NC	0.51 - 2.7[c]
Magnesium	845	75	660 - 1,031
Manganese	0.28	0.04	0.17 - 0.38
Potassium	48	3	41 - 54
Sodium	4,150	427	3,089 - 5,211
Strontium	50	4	39 - 61
General Chemistry			
Alkalinity (as HCO_3^-)	100	0	100
Bromide	19	4	8 - 30
Chloride	14,433	513	13,159 - 15,708
Fluoride	1.3	0.1	1.0 - 1.6
pH (s.u.)[d]	6.83	0.16	6.43 - 7.23
Sulfate	1,533	116	1,247 - 1,820
Total Dissolved Solids	28,033	1,762	23,657 - 32,410

See footnotes at end of table.

Table 5-22 *(Continued)*
Background Groundwater Chemistry
Well P-14

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<1
Antimony	≤0.89
Arsenic	<0.1
Barium	<0.1
Beryllium	<0.05
Cadmium	≤0.062
Cesium	<0.02
Chromium	≤0.41
Cobalt	≤0.63
Copper	≤0.12
Lead	≤0.67
Mercury	<0.0002
Molybdenum	0.05 - 0.12
Nickel	≤0.31
Selenium	<0.5
Silica	14 - 33
Silver	≤0.26
Thallium	<5
Titanium	≤0.68
Vanadium	≤0.24
Zinc	≤2
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	0.03 - 0.6
Phenolics	≤0.019
Phosphate (as P)	≤0.02
Total Organic Carbon	2
Total Organic Halogen	0.33 - 2

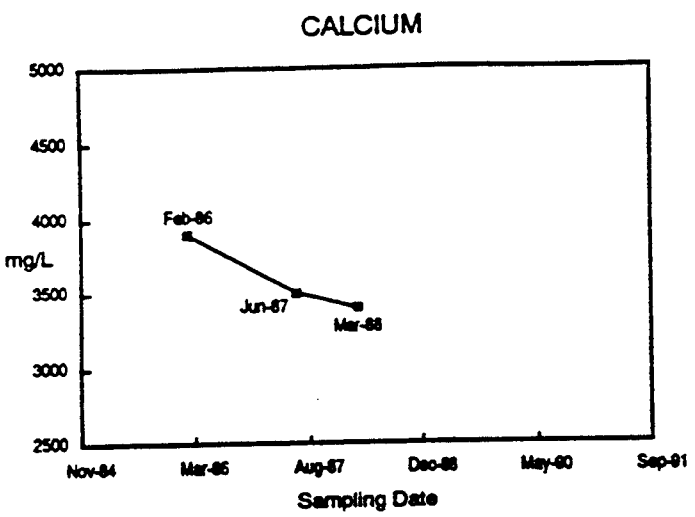
See footnotes at end of table.

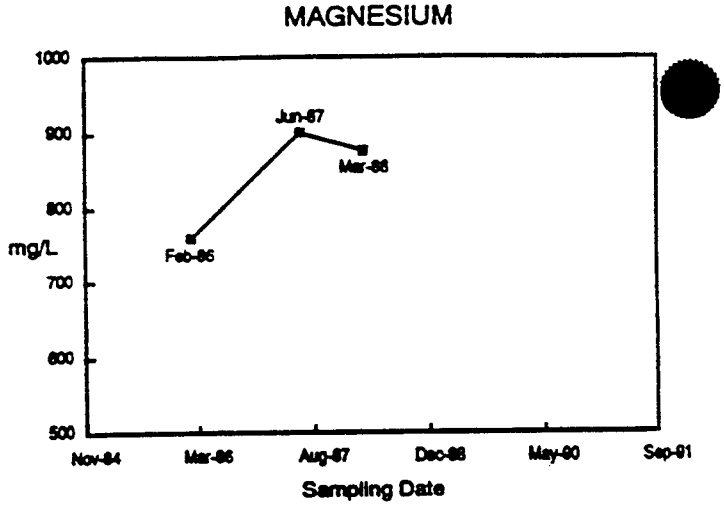
Table 5-22 *(Continued)*
Background Groundwater Chemistry
Well P-14

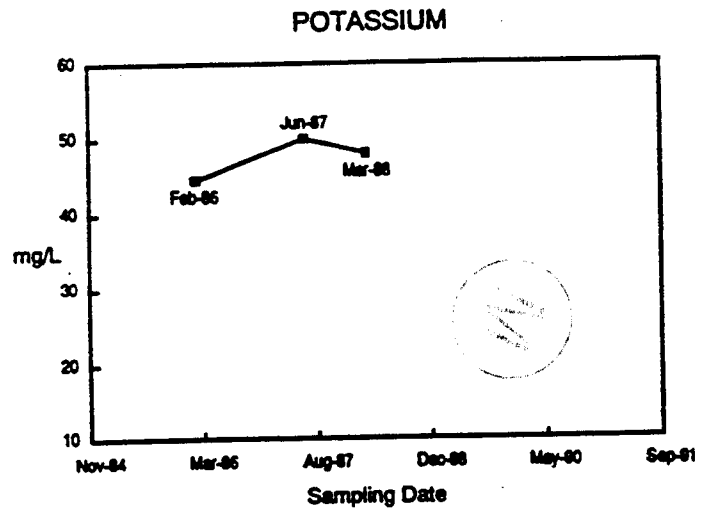
Hazardous Organic Constituents[e]

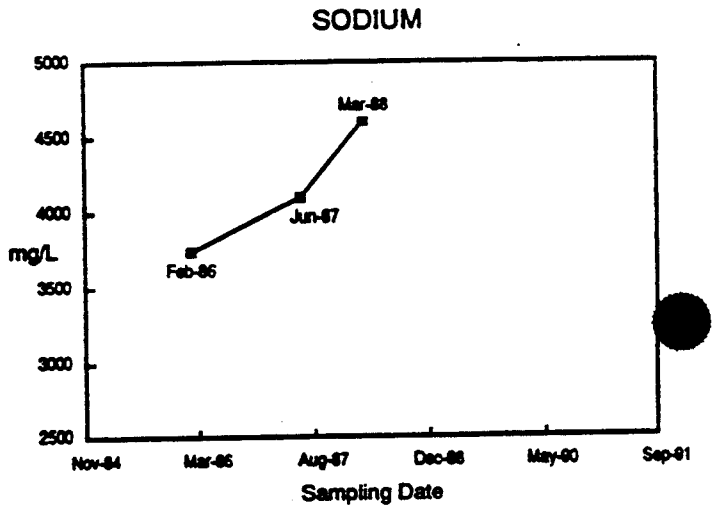
	Sample Date	Concentration
2-Butanone[f]	27-Feb-86	10
Acetone[f]	18-Jun-87	27

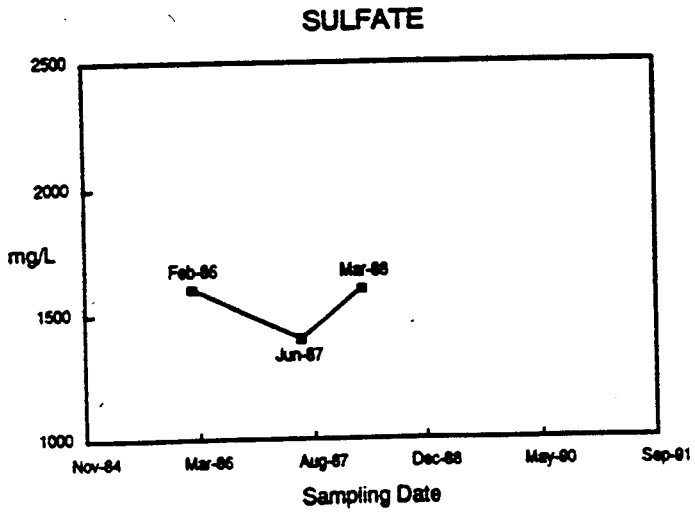
[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.











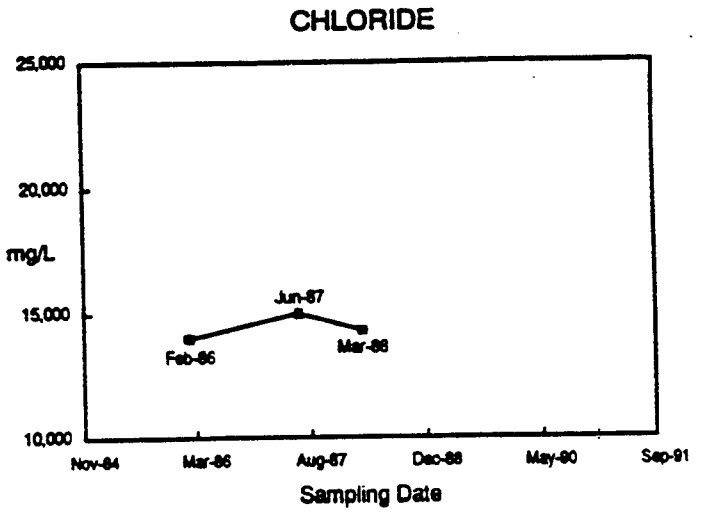


FIGURE 5-22 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL P-14 GROUNDWATER

Acetone and 2-butanone (methyl ethyl ketone) were detected in groundwater samples from Well P-14 (Table 5-22). Both of these compounds have been identified in an EPA risk assessment guidance document (EPA, 1989) as common laboratory contaminants. Acetone was detected at 27 µg/ℓ in the June 1987 sample and was also detected in the sample blank at 46 µg/ℓ.

Figure 5-22 shows the temporal variation in the concentration of the six major constituents of Well P-14 groundwater. The calcium concentration appears to have decreased; while, the sodium concentration appears to have increased. Based on charge-balance considerations, these changes are possible. Additional rounds of data could confirm the potential trends in Well P-14 groundwater.

5.23 Well P-17

Groundwater samples from the Culebra Dolomite were collected from Well P-17. Well P-17 was sampled three times: March 1986, December 1986, and October 1987. During all three rounds, samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. During the two most recent rounds, samples were also analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well P-17 are presented in Table 5-23. Table 5-23 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-23 are the concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from Well P-17.

Sodium is the dominant cation in groundwater at Well P-17, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate. Well P-17 groundwater is classified as saline (Freeze and Cherry, 1979), because the TDS are approximately 87,000 mg/ℓ. Well P-17 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. The TDS concentration of groundwater in Type Area 3 ranges from 10,000 to 100,000 mg/ℓ. Several trace metals were detected in groundwater samples from Well P-17 (Table 5-23), and most of these are repeatedly detected. As discussed above, the quantification of trace metals in high-TDS samples is somewhat uncertain due to analytical limitations.

Table 5-23
Background Groundwater Chemistry
Well P-17

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	35	2	29 - 40
Calcium	1,883	448	770 - 2,997
Iron	3.3	0.5	2.0 - 4.6
Lithium	NC[b]	NC	0.66 - 0.9[c]
Magnesium	1,650	132	1,321 - 1,979
Manganese	1.0	0.2	0.5 - 1.5
Potassium	972	207	457 - 1,487
Sodium	28,667	577	27,232 - 30,101
Strontium	33	5	22 - 45
General Chemistry			
Alkalinity (as HCO_3^-)	54	1	52 - 55
Bromide	84	45	47 - 121
Chloride	52,667	6,658	36,125 - 69,208
Fluoride	1.2	0.2	0.9 - 1.6
pH (s.u.)[d]	NC	NC	7.01 - 7.02[c]
Sulfate	6,367	851	4,254 - 8,480
Total Dissolved Solids	87,333	3,055	79,744 - 94,923

See footnotes at end of table.

Table 5-23 *(Continued)*
Background Groundwater Chemistry
Well P-17

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	≤2
Antimony	1.4 - 1.5
Arsenic	≤0.31
Barium	0.06 - 0.11
Beryllium	<0.05
Cadmium	0.1 - 0.12
Cesium	≤0.6
Chromium	0.39 - 0.6
Cobalt	0.12 - 0.2
Copper	0.13 - 0.5
Lead	1.1
Mercury	<0.0002
Molybdenum	≤0.21
Nickel	<0.3
Selenium	<0.05
Silica	13
Silver	0.2 - 0.3
Thallium	<0.05
Titanium	0.4 - 1
Vanadium	0.3
Zinc	<0.1
General Chemistry	
Cyanide	<0.04
Iodide	≤7.3
Nitrate (as N)	≤0.3
Phenolics	≤0.005
Phosphate (as P)	≤0.02
Total Organic Carbon	≤2
Total Organic Halogen	0.23 - 2.5

See footnotes at end of table.

Table 5-23 *(Continued)*
Background Groundwater Chemistry
Well P-17

Hazardous Organic Constituents

None Detected

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.

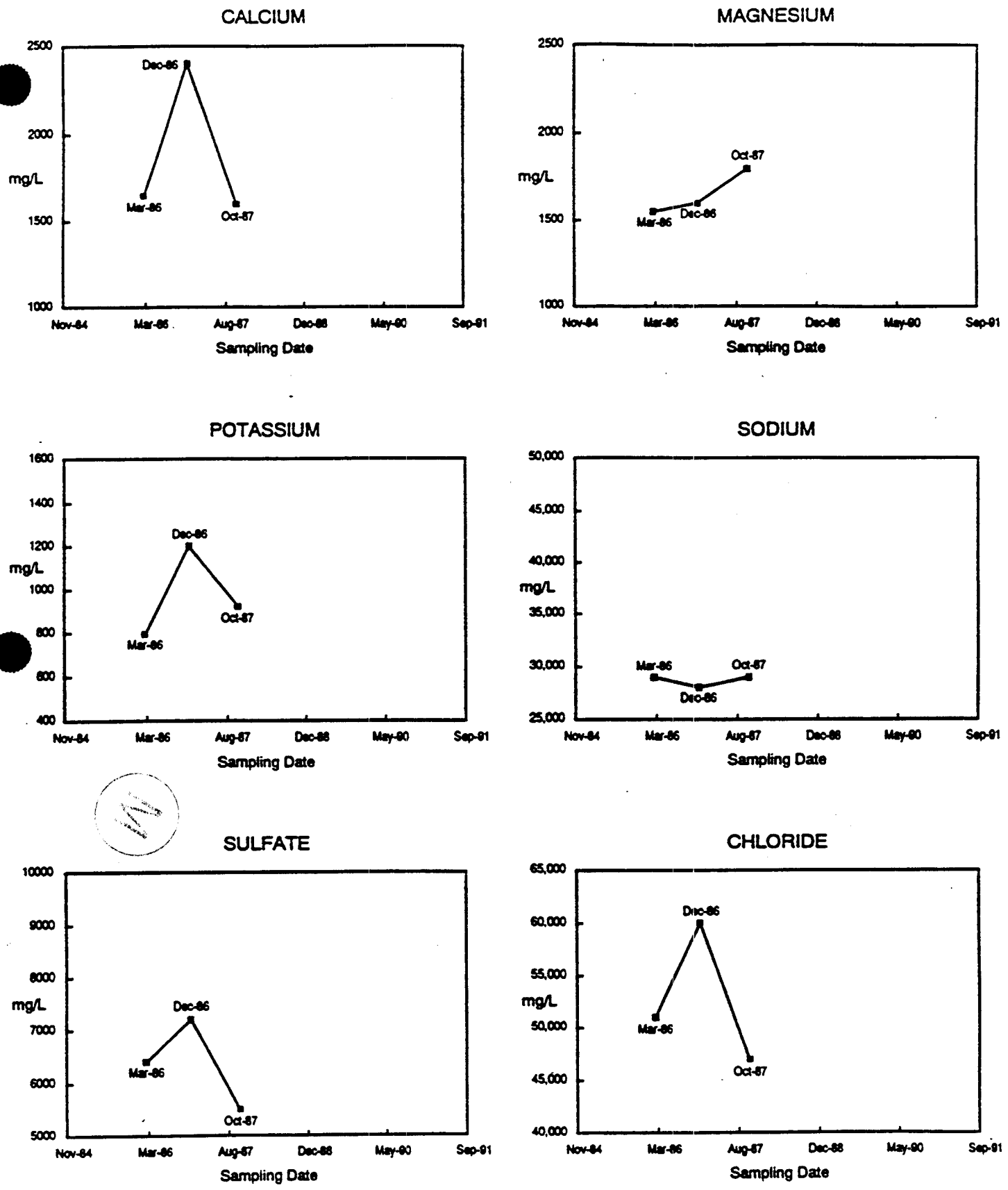


FIGURE 5-23 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL P-17 GROUNDWATER

Figure 5-23 shows the temporal variation in the concentration of the six major constituents of Well P-17 groundwater. The magnesium concentration appears to have increased with time. However, this increase is not supported by a similar increase in TDS or by charge-balance considerations. Data from the December 1986 sampling event is suspect, based on similar trends in calcium, potassium, sulfate, chloride and other constituents that are not shown in Figure 5-23. Concentrations from this sampling round appear to be too high, relative to those observed in other rounds. Although a longer observation period is required, it appears that the groundwater chemistry at Well P-17 is not changing with time.

5.24 Ranch Well

Groundwater samples from the Dewey Lake Redbeds were collected at the Ranch Well. The Ranch Well was sampled five times; the first sample was collected in June 1986, and the most recent was collected in June 1990. During all five rounds, samples were analyzed for metals and general chemical parameters. The list of metal and general chemical parameter analytes changed from round to round. For example, calcium and magnesium were analytes in four of the five rounds, and cyanide was an analyte in only three rounds. Samples collected during the first three rounds were analyzed for VOCs; samples collected during the June 1986 round were analyzed for a more extensive list of VOCs, relative to subsequent rounds. Semi-VOCs and total PCBs were analytes only in the June 1986 sampling event. Also, several pesticides were analytes in the December 1987 and April 1988 rounds.

Background concentrations for constituents in Ranch Well groundwater are presented in Table 5-24. Table 5-24 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-24 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from the Ranch Well.

Calcium is the dominant cation in Ranch Well groundwater, followed by sodium and magnesium; sulfate is the dominant anion, followed by chloride and bicarbonate (Table 5-24). Ranch Well groundwater is classified as brackish (Freeze and Cherry, 1979), because the TDS are approximately 3,000 mg/ℓ. Several trace metals were detected in groundwater from the Ranch Well at concentrations that were below 1 mg/ℓ (Table 5-24). All the detected trace metals listed in Table 5-24, with the exception of mercury, were detected during more than one sampling round. The nitrate concentration of Ranch Well groundwater is relatively high, possibly due to contamination by livestock grazing in the vicinity of the well.

Table 5-24
Background Groundwater Chemistry
Ranch Well

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.23	0.07	0.12 - 0.33
Calcium	340	23	283 - 397
Iron	NC[b]	NC	<0.1[c]
Lithium	NC	NC	<0.1[c]
Magnesium	188	33	135 - 240
Manganese	NC	NC	<0.015[c]
Potassium	3.4	1.2	1.5 - 5.4
Sodium	193	49	115 - 270
Strontium	4.1	1.1	2.3 - 5.9
General Chemistry			
Alkalinity (as HCO_3^-)	235	13	215 - 256
Bromide	2	1	0 - 3
Chloride	394	61	318 - 470
Fluoride	1.1	0.3	0.7 - 1.5
pH (s.u.)[d]	7.16	0.33	6.75 - 7.58
Sulfate	999	241	700 - 1,299
Total Dissolved Solids	3,060	195	2,818 - 3,302

See footnotes at end of table.

Table 5-24 *(Continued)*
Background Groundwater Chemistry
Ranch Well

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	0.1 - 0.16
Arsenic	<0.01
Barium	<0.2
Beryllium	<0.005
Cadmium	≤0.01
Cesium	<0.2
Chromium	≤0.07
Cobalt	<0.05
Copper	<0.025
Lead	≤0.08
Mercury	≤0.0008
Molybdenum	≤0.04
Nickel	<0.04
Selenium	≤0.079
Silica	20 - 49
Silver	≤0.02
Thallium	<1
Titanium	≤0.27
Vanadium	0.05 - 0.07
Zinc	0.02 - 0.16
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	110 - 120
Phenolics	≤0.022
Phosphate (as P)	≤0.05
Total Organic Carbon	3 - 4
Total Organic Halogen	≤0.4

See footnotes at end of table.

Table 5-24 *(Continued)*
Background Groundwater Chemistry
Ranch Well

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Chloroform	20-Dec-87	1.5
Di-n-butyl Phthalate[f]	18-Jun-86	11
Diethyl Phthalate[f]	18-Jun-86	24

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.

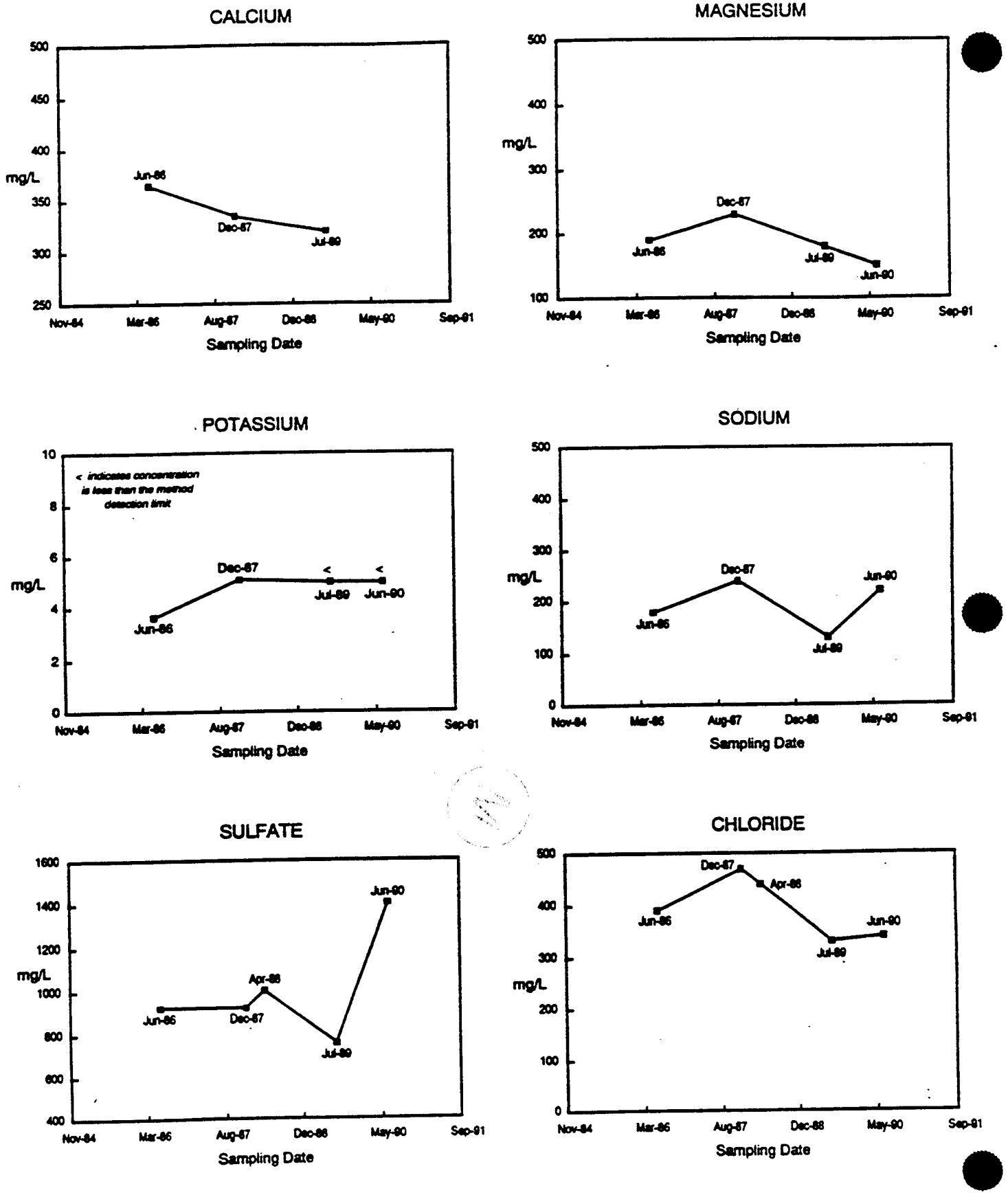


FIGURE 5-24 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF RANCH WELL GROUNDWATER

Chloroform, di-n-butyl phthalate, and diethyl phthalate were detected in Ranch Well groundwater. Chloroform was not detected in the other two rounds in which it was an analyte. Repeated detection of the phthalates could not be confirmed, as they were analytes in only one sampling round. Di-n-butyl and diethyl phthalate are listed as common laboratory contaminants in an EPA risk assessment guidance document (EPA, 1989).

Figure 5-24 shows the temporal variation in the concentration of the six major constituents of Ranch Well groundwater. Calcium concentrations appear to have decreased slightly; however, the concentration change is within the expected range of analytical variability. Overall, though concentrations fluctuate, no significant temporal trends are observed in chemistry of groundwater at the Ranch Well.

5.25 Twin Wells - Pasture Well

Groundwater samples from the Dewey Lake Redbeds were collected at the Twin Wells - Pasture Well (Pasture Well). The Pasture Well was sampled four times; the first sample was collected in January 1986, and the most recent was collected in May 1990. During all four rounds, samples were analyzed for metals and general chemical parameters. The list of metal and general chemical parameter analytes changed from round to round. For example, calcium and magnesium were analytes in three of the four rounds. Samples collected during the first two rounds were analyzed for VOCs; samples collected during the January 1986 round were analyzed for a more extensive list of VOCs, relative to the subsequent round. Semi-VOCs were analytes only in the June 1986 sampling event, and several pesticides were analytes in the August 1988 round.

Background concentrations for constituents in groundwater from the Pasture Well are presented in Table 5-25. Table 5-25 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-25 are the concentration ranges of minor constituents. Hazardous organic constituents were not detected in groundwater samples from the Pasture Well.

Calcium is the dominant cation in Pasture Well groundwater, followed by magnesium and sodium; bicarbonate is the dominant anion, followed by sulfate and chloride (Table 5-25). Groundwater from the Pasture Well is classified as fresh water, because the TDS are less than

Table 5-25
Background Groundwater Chemistry
Twin Wells - Pasture Well

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.15	0.02	0.11 - 0.19
Calcium	79	2	74 - 84
Iron	NC[b]	NC	≤0.34[c]
Lithium	NC	NC	<0.1[c]
Magnesium	24	0.3	23 - 25
Manganese	NC	NC	<0.05[c]
Potassium	NC	NC	<5[c]
Sodium	19	9	0 - 42
Strontium	0.9	0.2	0.3 - 1.5
General Chemistry			
Alkalinity (as HCO_3^-)	220	5	208 - 232
Bromide	4	4	0 - 13
Chloride	40	5	32 - 48
Fluoride	0.65	0.06	0.56 - 0.74
pH (s.u.)[d]	7.61	0.27	7.18 - 8.05
Sulfate	55	5	44 - 66
Total Dissolved Solids	401	9	388 - 415

See footnotes at end of table.

Table 5-25 *(Continued)*
Background Groundwater Chemistry
Twin Wells - Pasture Well

Minor Constituents[a]	Concentration Range
Metals	
Aluminum	<0.2
Antimony	<0.06
Arsenic	<0.01
Barium	<0.2
Beryllium	<0.005
Cadmium	<0.005
Cesium	<0.2
Chromium	≤0.03
Cobalt	≤0.05
Copper	≤0.048
Lead	<0.05
Mercury	≤0.0004
Molybdenum	≤0.03
Nickel	<0.04
Selenium	<0.1
Silica	18 - 43
Silver	≤0.01
Thallium	<0.1
Titanium	<0.1
Vanadium	<0.05
Zinc	≤0.52
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	6.2 - 9.2
Phenolics	≤0.02
Phosphate (as P)	≤0.02
Total Organic Carbon	≤4
Total Organic Halogen	≤0.05

See footnotes at end of table.

Table 5-25 *(Continued)*
Background Groundwater Chemistry
Twin Wells - Pasture Well

Hazardous Organic Constituents

None Detected

[a] All concentrations in milligram per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.

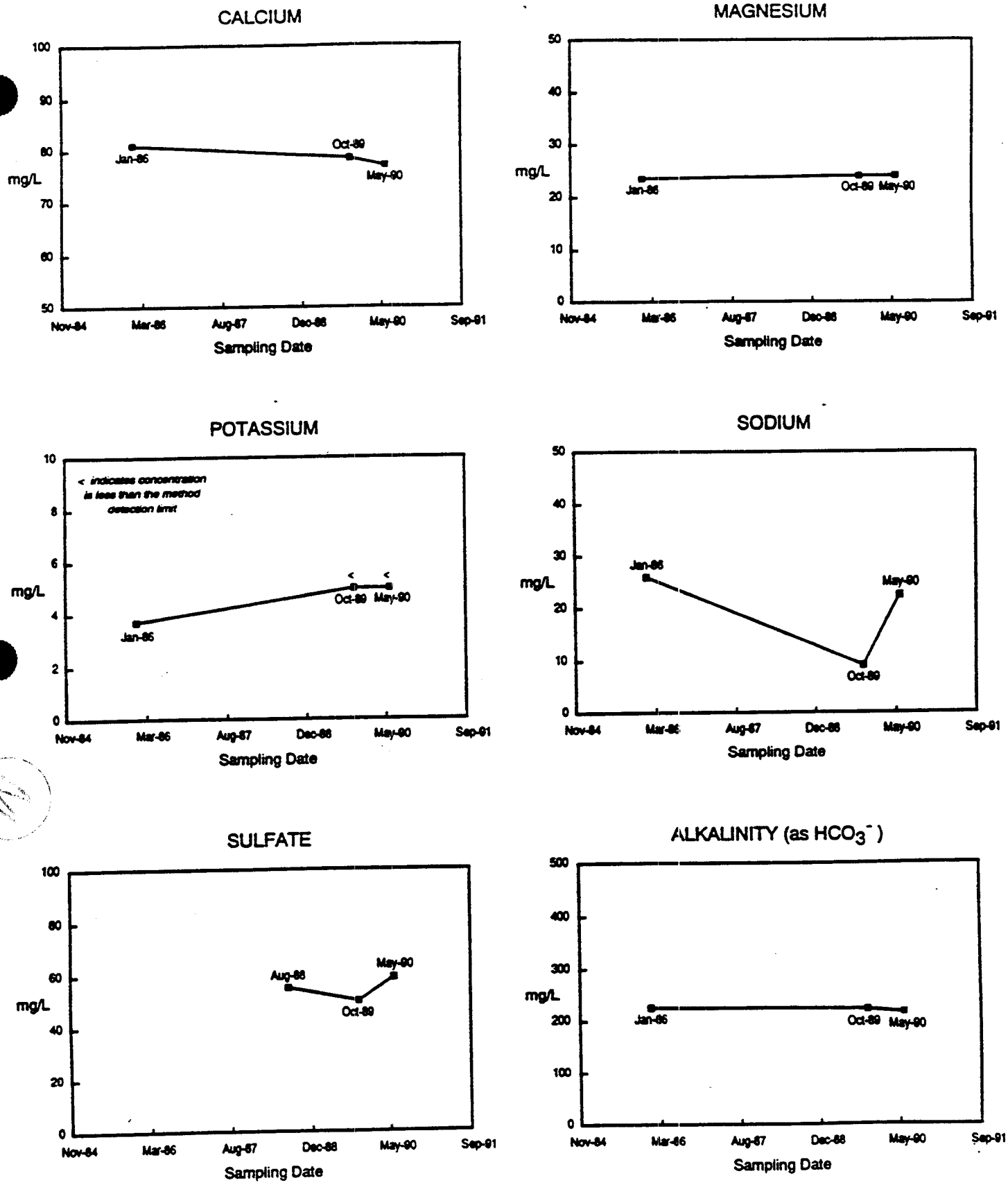


FIGURE 5-25 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF TWIN WELLS-PASTURE WELL GROUNDWATER

1,000 mg/ℓ (Freeze and Cherry, 1979). Several trace metals were detected in groundwater from the Pasture Well, at concentrations below 1 mg/ℓ (Table 5-25). Chromium, mercury, and zinc were detected during more than one sampling round.

Figure 5-25 shows the temporal variation in the concentration of six major constituents of Pasture Well groundwater. No temporal trends are observed in these constituents. The chloride concentration (not shown in Figure 5-25) appears to have decreased; however, charge-balance considerations and the TDS concentration do not support the apparent decrease of chloride in Pasture Well groundwater.

5.26 Well WIPP-19

Groundwater samples from the Culebra Dolomite were collected at Well WIPP-19. Well WIPP-19 was sampled five times; the first sample was collected in July 1987, and the most recent was collected in June 1990. Groundwater collected during each sampling event was analyzed for metals and general chemical parameters. During the first three rounds, i.e., July 1987, February 1988, and August 1988, samples were also analyzed for VOCs, semi-VOCs, and total PCBs.

Background concentrations for constituents in groundwater from Well WIPP-19 are presented in Table 5-26. Table 5-26 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-26 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well WIPP-19.

Sodium is the dominant cation in Well WIPP-19 groundwater, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate (Table 5-26). Groundwater at Well WIPP-19 is classified as saline (Freeze and Cherry, 1979), because the TDS concentration is approximately 86,000 mg/ℓ. Well WIPP-19 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Chromium, vanadium, and zinc were detected in Well WIPP-19 groundwater (Table 5-26). The MDLs of most trace metals were relatively high, due to the required dilution prior to the analysis of high-TDS samples.

Table 5-26
Background Groundwater Chemistry
Well WIPP-19

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	31	3	27 - 34
Calcium	1,680	192	1,441 - 1,919
Iron	NC[b]	NC	≤2[c]
Lithium	0.7	0.2	0.3 - 1.1
Magnesium	1,600	515	961 - 2,239
Manganese	2.3	1.3	0.7 - 4.0
Potassium	739	140	565 - 913
Sodium	28,310	3,503	23,962 - 32,658
Strontium	32	9	21 - 42
General Chemistry			
Alkalinity (as HCO_3^-)	60	8	51 - 70
Bromide	74	42	22 - 126
Chloride	43,860	8,586	33,201 - 54,520
Fluoride	1.0	0.1	0.8 - 1.1
pH (s.u.)[d]	7.04	0.23	6.75 - 7.33
Sulfate	5,430	268	5,097 - 5,763
Total Dissolved Solids	85,770	14,001	68,389 - 103,151

See footnotes at end of table.

Table 5-26 *(Continued)*
Background Groundwater Chemistry
Well WIPP-19

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<20
Antimony	<6
Arsenic	<0.5
Barium	<0.5
Beryllium	<0.5
Cadmium	<0.5
Cesium	<0.5
Chromium	≤2
Cobalt	<1
Copper	<2.5
Lead	<5
Mercury	<0.002
Molybdenum	<0.2
Nickel	<4
Selenium	<0.5
Silica	≤4.4
Silver	<1
Thallium	<10
Titanium	<3
Vanadium	≤1
Zinc	≤2
General Chemistry	
Cyanide	<0.04
Iodide	<2
Nitrate (as N)	≤0.12
Phenolics	≤0.019
Phosphate (as P)	≤0.03
Total Organic Carbon	2 - 7
Total Organic Halogen	0.57 - 3.2

See footnotes at end of table.

Table 5-26 *(Continued)*
Background Groundwater Chemistry
Well WIPP-19

Hazardous Organic Constituents[e]

	Sample Date	Concentration
Acetone[f]	14-Jul-87	71
Acetone[f]	12-Feb-88	18
Acetone[f]	29-Aug-88	45 (33)[g]

[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.
[g] Duplicate analysis in parentheses.

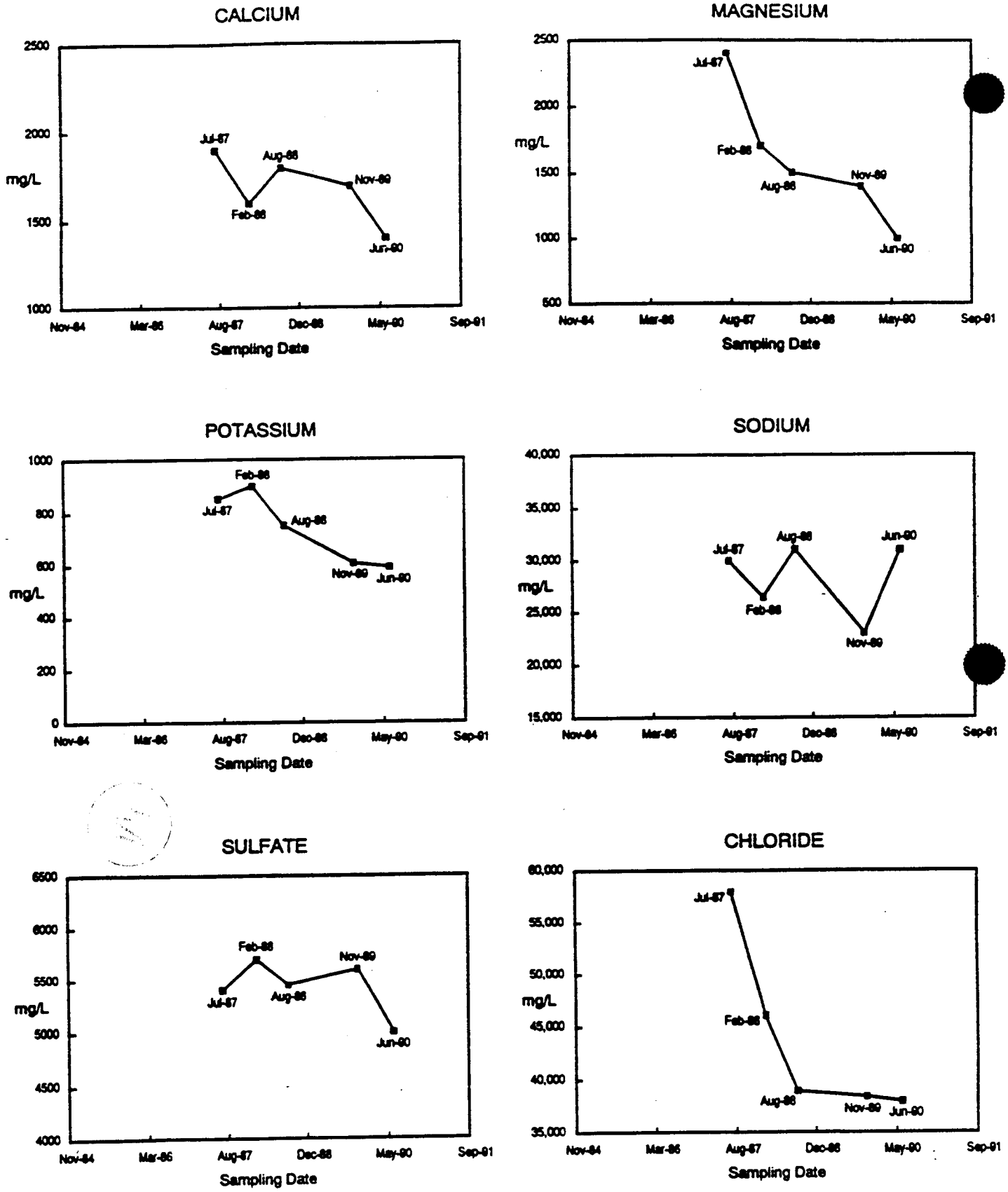


FIGURE 5-26 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL WIPP-19 GROUNDWATER

Acetone was detected in all three rounds in which it was an analyte (Table 5-26). Although acetone is a very common laboratory contaminant (EPA, 1989), its repeated presence may indicate contamination.

Figure 5-26 shows the temporal variation in the concentration of the six major constituents of well WIPP-19 groundwater. The concentration of magnesium and chloride and to a lesser extent calcium and potassium appears to have trended downward. Based on the concentration versus time plots for chloride, TDS (not shown in Figure 5-26), and several minor constituents, it appears that data collected during the first and possibly second sampling rounds are not representative of the groundwater chemistry at well WIPP-19. This could be due to incomplete well development or some other perturbation of the groundwater system in the vicinity of well WIPP-19.

5.27 Well WIPP-25

Groundwater samples from the Culebra Dolomite were collected from Well WIPP-25. Well WIPP-25 was sampled four times; the first sample was collected in February 1986, and the most recent was collected in June 1989. During all four rounds, samples were analyzed for metals and general chemical parameters. Samples from the first three rounds were also analyzed for VOCs and semi-VOCs. Groundwater samples collected in the April 1987 and March 1988 rounds were analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well WIPP-25 are presented in Table 5-27. Table 5-27 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-27 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well WIPP-25.

Sodium is the dominant cation in groundwater from Well WIPP-25, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate and bicarbonate (Table 5-27). Well WIPP-25 groundwater is classified as saline (Freeze and Cherry, 1979), because the TDS are approximately 14,300 mg/ℓ. Well WIPP-25 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Arsenic, silver, and titanium were detected in groundwater from Well WIPP-25 (Table 5-27). Only titanium was detected in

Table 5-27
Background Groundwater Chemistry
Well WIPP-25

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	1.7	0.1	1.5 - 1.9
Calcium	1,163	95	1,012 - 1,313
Iron	0.6	0.4	0.0 - 1.2
Lithium	0.24	0.02	0.21 - 0.28
Magnesium	339	9	325 - 352
Manganese	0.11	0.02	0.07 - 0.14
Potassium	134	26	93 - 175
Sodium	3,463	229	3,099 - 3,826
Strontium	10	10	0 - 26
General Chemistry			
Alkalinity (as HCO_3^-)	118	13	98 - 138
Bromide	4.4	0.7	3.3 - 5.6
Chloride	6,425	150	6,186 - 6,664
Fluoride	1.5	0.1	1.4 - 1.6
pH (s.u.)[b]	7.27	0.31	6.78 - 7.77
Sulfate	2,325	272	1,892 - 2,758
Total Dissolved Solids	14,325	395	13,697 - 14,953

See footnotes at end of table.

Table 5-27 *(Continued)*
Background Groundwater Chemistry
Well WIPP-25

Minor Constituents[a]

	Concentration Range
Metals	
Aluminum	<2
Antimony	<0.5
Arsenic	≤0.27
Barium	<0.05
Beryllium	<0.05
Cadmium	<0.05
Cesium	<0.1
Chromium	<0.3
Cobalt	<0.3
Copper	<0.25
Lead	<0.5
Mercury	<0.0002
Molybdenum	<0.2
Nickel	<0.4
Selenium	<0.5
Silica	13 - 32
Silver	≤0.1
Thallium	<10
Titanium	≤0.8
Vanadium	<0.5
Zinc	<0.2
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	1.8 - 3.6
Phenolics	≤0.013
Phosphate (as P)	≤0.03
Total Organic Carbon	≤4
Total Organic Halogen	≤0.38

See footnotes at end of table.

Table 5-27 *(Continued)*
Background Groundwater Chemistry
Well WIPP-25

Hazardous Organic Constituents[c]

	Sample Date	Concentration
Acetone[d]	12-Feb-86	21
Bis(2-ethylhexyl)phthalate[d]	12-Feb-86	280
Di-n-butyl Phthalate[d]	12-Feb-86	3.5
Di-n-octyl Phthalate[d]	12-Feb-86	33

[a] All concentrations in milligrams per liter, except where noted.
[b] s.u. = standard pH units.
[c] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[d] Suspected laboratory contaminant.

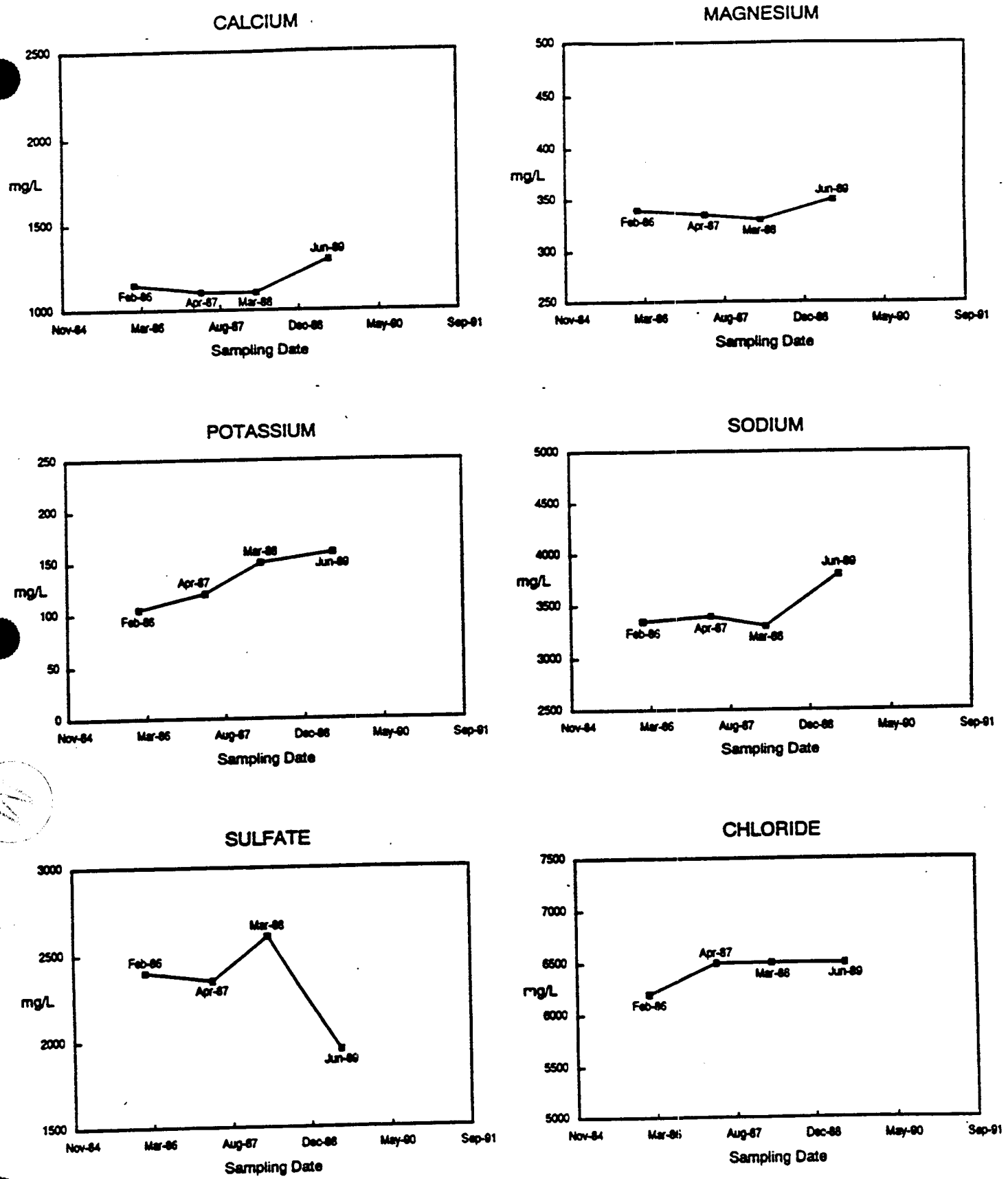


FIGURE 5-27 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL WIPP-25 GROUNDWATER

more than one sampling round. Although the TDS concentration is not extremely high, the MDLs for many of the trace metals are relatively-high (Table 5-27).

Several hazardous organic compounds were detected in the February 1986 groundwater sample from Well WIPP-25 (Table 5-27). The detections may be due to laboratory contamination; an EPA risk assessment guidance document reports that acetone and phthalates are common laboratory contaminants (EPA, 1989). The observation that all detections occurred during one sampling round further supports the contention that the detections are related to laboratory contamination. The organic compounds were not detected in samples from subsequent rounds.

Figure 5-27 shows the temporal variation in the concentration of the six major constituents of Well WIPP-25 groundwater. The concentration of potassium appears to have increased somewhat during the WQSP (Figure 5-27). This increase is not supported by charge-balance considerations or a corresponding increase in TDS. Siegel et al. (1991) report that between August 1980 and February 1986 the concentration of calcium and chloride, and to a lesser extent sodium and magnesium, increased significantly. Also, alkalinity decreased during the same period. Siegel et al. claimed that the concentration changes were not understood at the time. The changes reported by Siegel et al. were not observed during the WQSP (Figure 5-27).

5.28 Well WIPP-26

Groundwater samples from the Culebra Dolomite were collected from Well WIPP-26. Well WIPP-26 was sampled three times: November 1985, April 1987, and April 1988. During all three rounds, samples were analyzed for VOCs, semi-VOCs, metals, and general chemical parameters. In addition, samples collected in the April 1987 and April 1988 rounds were analyzed for total PCBs.

Background concentrations for constituents in groundwater from Well WIPP-26 are presented in Table 5-28. Table 5-28 gives the mean concentration, standard deviation, and 95 percent confidence interval for major groundwater constituents. Also shown in Table 5-28 are the concentration ranges of minor constituents and a list of hazardous organic constituents that were detected in groundwater samples from Well WIPP-26.

Sodium is the dominant cation in groundwater from Well WIPP-26, followed by calcium, magnesium, and potassium; chloride is the dominant anion, followed by sulfate and

Table 5-28
Background Groundwater Chemistry
Well WIPP-26

Major Constituents[a]

	Mean	Std. Dev.	95 % Confidence Interval
Metals			
Boron	0.9	0.8	0 - 2.8
Calcium	1,350	391	380 - 2,320
Iron	NC[b]	NC	<0.1[c]
Lithium	NC	NC	0.25 - 0.27
Magnesium	345	26	281 - 410
Manganese	NC	NC	≤0.09[c]
Potassium	250	87	33 - 467
Sodium	3,217	822	1,174 - 5,259
Strontium	18	1	16 - 20
General Chemistry			
Alkalinity (as HCO_3^-)	117	12	88 - 145
Bromide	7	6	0 - 19
Chloride	6,050	3,161	0 - 13,903
Fluoride	1.5	0.2	1.1 - 1.9
pH (s.u.)[d]	7.12	0.23	6.54 - 7.69
Sulfate	2,083	275	1,399 - 2,768
Total Dissolved Solids	14,617	2,931	7,335 - 21,898

See footnotes at end of table.

Table 5-28 *(Continued)*
Background Groundwater Chemistry
Well WIPP-26

Minor Constituents[a]

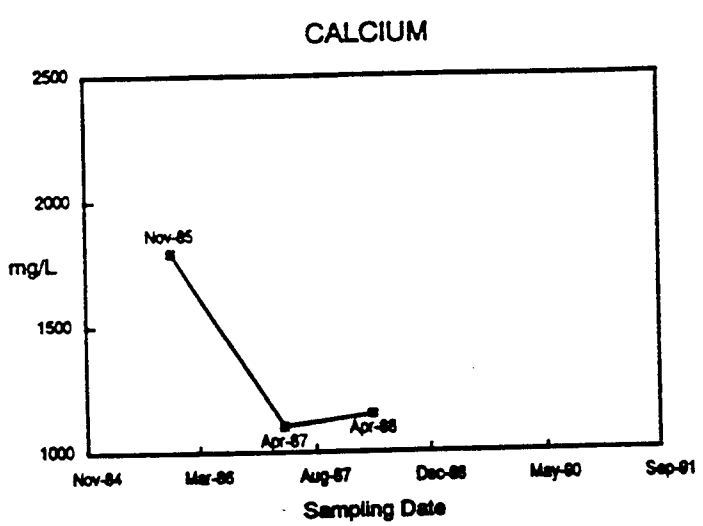
	Concentration Range
Metals	
Aluminum	<1
Antimony	<0.5
Arsenic	<0.5
Barium	<0.1
Beryllium	<0.05
Cadmium	<0.05
Cesium	<0.1
Chromium	≤0.35
Cobalt	≤0.44
Copper	<0.1
Lead	<0.5
Mercury	<0.0002
Molybdenum	<0.01
Nickel	≤0.35
Selenium	<0.1
Silica	15 - 36
Silver	<0.1
Thallium	<0.5
Titanium	≤0.3
Vanadium	<0.1
Zinc	<0.1
General Chemistry	
Cyanide	<0.02
Iodide	<2
Nitrate (as N)	3.6 - 5.7
Phenolics	≤0.012
Phosphate (as P)	0.01 - 0.08
Total Organic Carbon	≤2
Total Organic Halogen	≤0.07

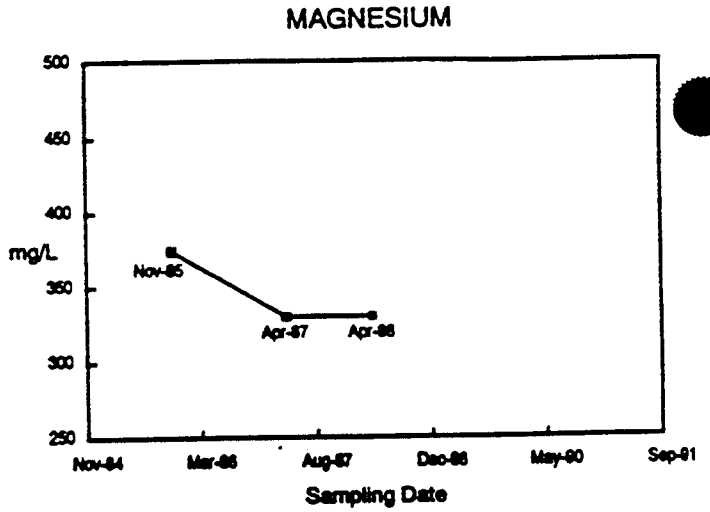
See footnotes at end of table.

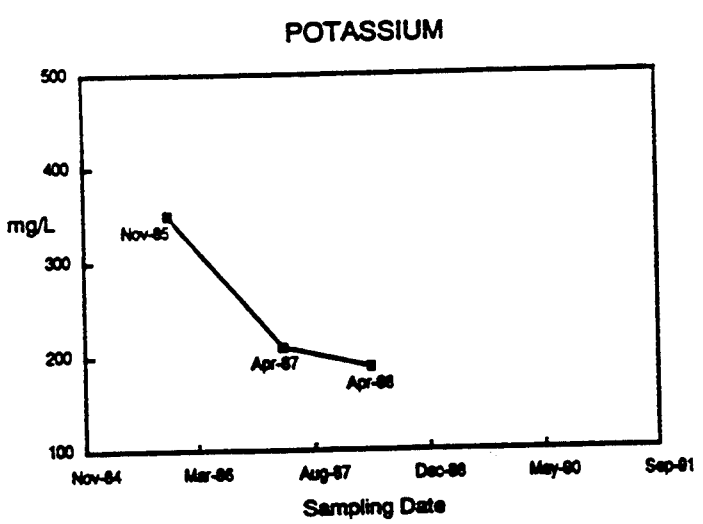
Table 5-28 *(Continued)*
Background Groundwater Chemistry
Well WIPP-26

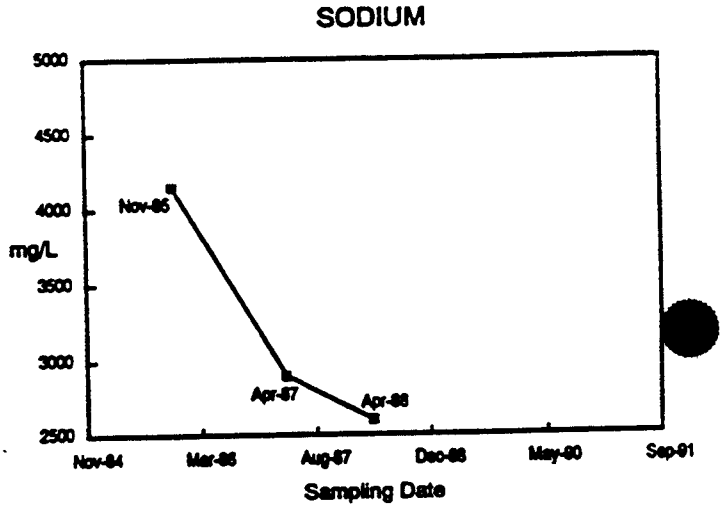
Hazardous Organic Constituents[e]	Sample Date	Concentration
2-Butanone[f]	25-Nov-85	55
Bis(2-ethylhexyl)phthalate[f]	01-Apr-87	260
Bis(2-ethylhexyl)phthalate[f]	14-Apr-88	14
Di-n-octyl Phthalate[f]	01-Apr-87	21
Methylene Chloride[f]	25-Nov-85	11

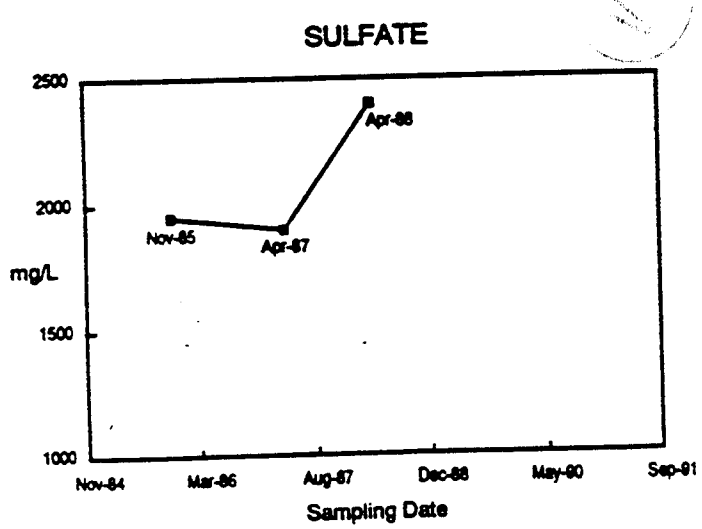
[a] All concentrations in milligrams per liter, except where noted.
[b] NC = not calculated.
[c] The 95% confidence interval was not calculated. The observed concentration range is reported.
[d] s.u. = standard pH units.
[e] All concentrations in micrograms per liter, only detected hazardous organic compounds are listed.
[f] Suspected laboratory contaminant.











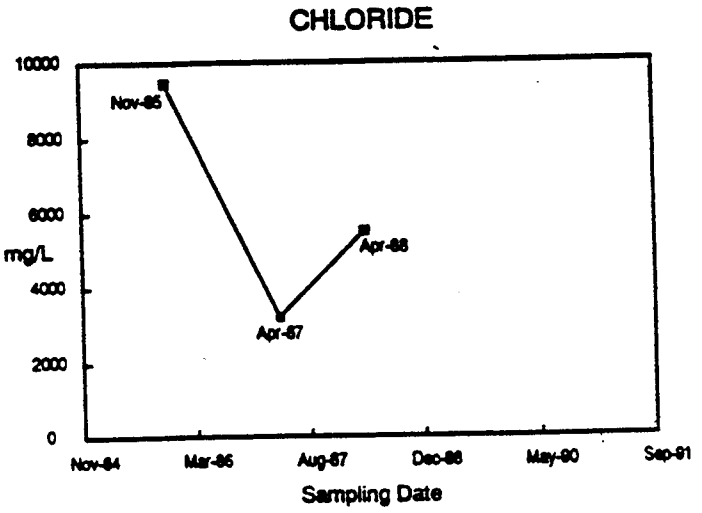


FIGURE 5-28 CONCENTRATION VERSUS TIME PLOTS FOR MAJOR CONSTITUENTS OF WELL WIPP-26 GROUNDWATER

bicarbonate (Table 5-28). Well WIPP-26 groundwater is classified as saline (Freeze and Cherry, 1979), because the TDS are approximately 14,600 mg/ℓ. Well WIPP-26 lies within hydrochemical Type Area 3 of the Culebra Dolomite (Holt et al., 1992), as shown in Figure 3-7. Groundwater in Type Area 3 contains TDS ranging from 10,000 to 100,000 mg/ℓ and may be a mixture of Type Area 1 and 2 groundwater. Chromium, cobalt, nickel, and titanium were detected in groundwater samples from Well WIPP-26 (Table 5-28). Only titanium was detected during more than one sampling round.

Several hazardous organic compounds were detected in groundwater samples from Well WIPP-26. Only bis(2-ethylhexyl)phthalate was detected in more than one round (Table 5-28). All of the compounds detected at Well WIPP-26 could be due to laboratory contamination, according to a listing of common laboratory contaminants reported in an EPA risk assessment guidance document (EPA, 1989).

Figure 5-28 shows the temporal variation in the concentration of the six major constituents of Well WIPP-26 groundwater. Except for magnesium and potassium, the November 1985 concentration of the major constituents appears to be too high, relative to subsequent rounds (Figure 5-28). Siegel et al. (1991) observed that between August 1980 and November 1985, the concentrations of sodium, potassium, chloride, calcium, and magnesium increased significantly and that alkalinity decreased slightly. Siegel et al. also noted the decrease in the concentrations of major constituents from the November 1985 WQSP round to the next round (April 1987). The researchers reported that concentrations in the April 1987 WQSP round were similar to those observed in August 1980. The temporary concentration increases may be due to a "cleaning-up" effect that occurred when Well WIPP-26 was sampled for the first time under the WQSP.

6.0 Comparison to Established Standards

An aquifer as defined by EPA is "a geological formation, a group of formations or part of a formation capable of yielding a significant amount of groundwater to wells or springs." (40 CFR 260.10) By this definition the Culebra and Magenta Members of the Rustler Formation located in the vicinity of the WIPP Site can be considered aquifers, irrespective of water quality. However, water quality, for all practical purposes, dictates the usefulness of any particular aquifer. In the case of the Rustler Formation at the WIPP, water quality is generally extremely poor. This is a result of the natural physical and chemical state of the groundwater. Because of its natural condition, water from the members of the Rustler Formation in the immediate vicinity of the WIPP is not suitable for domestic, livestock, or agricultural purposes. However, groundwater in the Culebra in Type Area 2 southwest of the WIPP is of much better quality (less than 10,000 mg/ℓ TDS). This area is removed from the WIPP by several miles and may have only limited hydrologic connection to the Culebra at the site (Section 3.2.2.1). Magenta water quality in some areas around WIPP is less than 10,000 m/gℓ TDS; however, the yield of water to wells is extremely small, thus limiting its potential usefulness.

6.1 Suitability

One basic measure of water quality is the TDS concentration, which is the total amount of solids (in mg/ℓ) that remain when a water sample is evaporated to dryness. Waters that are considered fresh range in concentration from 0 to 1000 mg/ℓ TDS. Waters that are considered brackish range from 1,000 to 10,000 mg/ℓ TDS. Saline waters range from 10,000 to 100,000 mg/ℓ TDS, and brines have TDS greater than 100,000 mg/ℓ. Sea water has a concentration of 35,000 mg/ℓ TDS (Stumm and Morgan, 1981). The TDS of water from the Culebra and Magenta Dolomites in the WIPP area range from less than 10,000 to over 280,000 mg/ℓ and for practical purposes is considered a brine in much of the area.

As a general measure for comparison, the EPA has developed a three-part classification system for groundwaters of the United States (EPA, 1984) based upon suitability of groundwater for domestic and agricultural uses. These classes are as follows:

- ***Class I: Special Groundwaters*** are those that are highly vulnerable to contamination because of the hydrological characteristics of the areas under which they occur and that are also either an irreplaceable source of drinking water or ecologically vital in that they provide the baseflow for a particularly sensitive ecological system.

- ***Class II: Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses*** are all other groundwaters except Class III.

- ***Class III: Groundwaters Not Considered Potential Sources of Drinking Water and of Limited Beneficial Use*** because the salinity (TDS) is greater than 10,000 mg/ℓ or the groundwater is otherwise contaminated beyond levels that can be removed using methods reasonably employed in public water-supply treatment.

As previously discussed, Magenta and Culebra Dolomite groundwaters in most of the WIPP area range from less than 10,000 to over 280,000 mg/ℓ TDS and therefore are considered Class III groundwaters by the EPA. Based on TDS alone, these waters would not be considered for water-supply development using reasonable methods for treatment. However, as discussed previously, the groundwater from the Culebra in Type Area 2, southwest of the WIPP, is less than 10,000 mg/ℓ TDS and would be considered Class II groundwaters. Because of the rapid changes in Culebra transmissivity, Type Area 2 may have limited hydrologic connection to the WIPP site area. The Magenta in some areas around the WIPP also exhibits TDS concentrations less than 10,000 mg/ℓ and would be considered Class II groundwater. The transmissivity is very low in these areas of fresher Magenta water, thus greatly decreasing its useability, and the Magenta is not considered as a water supply.

Water to be used by livestock is subject to quality limitations that are similar to those that restrict the quality of drinking water for human consumption. Most animals, however, can tolerate water that is considerably higher in TDS than that which is considered satisfactory for humans. Range cattle in the Western United States may get accustomed to highly mineralized water. Hem (1985) reports that cattle will consume water that contains nearly 10,000 mg/ℓ TDS. An upper limit of dissolved solids for cattle is 10,100 mg/ℓ. The upper limit for an adult sheep is 12,900 mg/ℓ. However, for best growth and development, livestock water supplies should have TDS concentrations that are considerably below the upper limit (Hem, 1985).

Other criteria, besides TDS, have been established to determine the suitability of water for consideration as a public water-supply. Drinking water standards have been established by the EPA in order to determine the maximum contaminant levels (MCLs) for materials that may be found in drinking water (40 CFR 143). Primary MCLs have been promulgated for substances that may pose a health risk. For substances such as iron, chloride, sulfate, and

TDS, which can affect the aesthetic quality of water, secondary maximum contaminant levels (SMCLs) have been established. These chemicals are not hazardous to health but may be objectionable due to their effects on water taste, color, and odor.

6.2 Comparability

This section presents the comparison of WQSP background groundwater chemistry data to standards. The selection of wells used in the comparison and the selection of the appropriate water-quality standards are discussed.

6.2.1 Selection of Monitor Wells for Comparison to Standards

The WIPP Site covers an area of 16 square miles. Within this area, the overall water quality of the Culebra and Magenta Dolomites is highly variable, but is typical and representative for the general WIPP area. Groundwater-quality data from monitoring wells located within the 16-square-mile site boundary were selected for comparison with the water-quality standards described below.

The wells located within this area represent both upgradient and downgradient monitoring locations with respect to the WIPP surface operating facilities, which would meet the monitoring requirements of RCRA (40 CFR 264.90 through 100). However, as stated previously, these wells do not meet RCRA monitoring well requirements.

The wells selected for comparison to standards are DOE-1, H-02a, H-03b1, H-03b3, H-04b, H-04c, H-05b, H-05c, H-06b, H-06c, H-11b3, H-14, H-15, H-18, and WIPP-19. This group of wells reflects the variable water quality, with TDS ranging from approximately 10,000 mg/ℓ to 200,000 mg/ℓ, and includes wells completed in both the Culebra and Magenta Dolomites.

6.2.2 Selection of Appropriate Water-Quality Standards

WIPP is a RCRA facility that is currently undergoing a permit application process in order to receive and emplace TRU mixed waste. Consequently, the parameters described in 40 CFR 265 Appendix III, Interim Primary Drinking Water Standards (MCLs), were compared to WQSP data to aid in determining overall water quality in the vicinity of the WIPP Site. In addition, drinking water standards (SMCLs) found in the National Secondary Safe Drinking Water Act (SDWA)(40 CFR 143) were also used to quantify some parameters that were collected/analyzed for and are not listed in Appendix III of 40 CFR 265. Since analysis for pesticides were not performed for the wells of interest, only the inorganic compounds in the

EPA Interim Primary Drinking Water Standards (40 CFR 265 Appendix III) were compared to the WQSP groundwater chemistry. Additionally, since the background data show that Culebra and Magenta Dolomite waters do not contain halogenated hydrocarbons, the organic parameters of the SDWA were not compared with standard values. However, TDS, chloride, sulfate, iron, manganese, copper, and zinc were compared to the secondary drinking water standards (40 CFR 143). A comparison of the 40 CFR 143 and 40 CFR 265 parameters with collected groundwater quality data indicates that the aquifers are presently naturally polluted and should not be used for domestic or agricultural purposes in the foreseeable future.

6.2.3 Comparison to Water-Quality Standards - Results

This section compares the results of the analysis of WIPP WQSP background groundwater chemistry data with the EPA standards described above. For each well, pertinent background groundwater-chemistry data are listed in a summary table along with the relevant water-quality standards. The EPA standards are compared to both a maximum concentration value and a maximum quantitative value. The maximum concentration value can be an actual detection or an MDL, whichever is larger. The maximum quantitative value is the largest value of a given parameter for which an actual measurement was obtained. When quantitative values are not available for a given parameter, the MDL for that particular analysis is listed as the maximum concentration. In many or most wells, concentrations of inorganic chemicals exceed the primary and secondary water quality standards (40 CFR 265 Appendix III and 40 CFR 143, respectively). The following is a summary of the water quality for the selected wells at the WIPP Site.

Well DOE-1. Table 6-1 shows that a number of metal concentrations in the Culebra exceed the interim primary drinking water standards (MCLs) at Well DOE-1. These are cadmium, chromium, lead, selenium, and silver. In addition, secondary standard constituents such as TDS, chloride, sulfate, iron, and manganese exceed SMCLs. Total dissolved solids are over two orders of magnitude greater than the secondary drinking water standard.

Well H-02a. Table 6-2 shows that Culebra groundwater from Well H-02a contains a number of metals with concentrations exceeding MCLs. These include cadmium, chromium, lead, and silver. The selenium MDL exceeds the standard. Parameters such as TDS, chloride, sulfate, iron, and manganese also exceed SMCLs. Total dissolved solids are an order of magnitude greater than the standard.

Well H-03b1. Table 6-3 shows that a number of metal concentrations in Magenta Dolomite groundwater exceed MCLs at Well H-03b1. These are chromium, lead, and selenium. Cadmium and silver concentrations at this well are greater than the standard at the detection limit. Although it is an MDL, the maximum arsenic concentration is equal to the standard. Secondary standard constituents such as TDS, chloride, and sulfate also exceed SMCLs. Maximum iron concentrations are the same as secondary standards in Well H-03b1. The TDS of groundwater at Well H-03b1 are over an order of magnitude greater than the secondary standard.

Well H-03b3. Table 6-4 shows that Culebra Dolomite groundwater from Well H-03b3 contains a number of metals with concentrations exceeding MCLs. These metals are cadmium, chromium, lead, selenium, and silver. Although an MDL, the maximum arsenic concentration also exceeds the standard (Table 6-4). Parameters such as TDS, chloride, sulfate, iron, and manganese also exceed the SMCLs. Total dissolved solids are two orders of magnitude greater than the secondary standard.

Well H-04b. Table 6-5 shows that some of the metal concentrations in Culebra Dolomite groundwater from Well H-04b exceed MCLs. These are chromium, lead, and selenium. The value for mercury is just below the MCL, while cadmium and silver concentrations are greater than the standard at their detection limits. Secondary standard constituents such as TDS, chloride, sulfate, iron, and manganese also exceed SMCLs. Total dissolved solids are over an order of magnitude greater than the secondary standard.

Well H-04c. Table 6-6 shows that Magenta Dolomite groundwater from Well H-04c contains a few constituents that exceed MCLs. These include chromium, fluoride, selenium, and silver. Arsenic, cadmium, and lead concentrations are greater than the standard at their detection limits. Parameters such as TDS, chloride, sulfate, iron, and manganese also exceed SMCLs. Total dissolved solids are over an order of magnitude greater than the secondary standard.

Well H-05b. Table 6-7 shows that the concentration of a number of metals in Culebra Dolomite groundwater from Well H-05b exceeds MCLs. These metals are cadmium, chromium, lead, selenium, and silver. Although an MDL, the maximum arsenic concentration exceeds the primary standard (Table 6-7). Parameters such as TDS, chloride, sulfate, iron,

and manganese also exceed SMCLs in this well. The TDS concentration is over two orders of magnitude greater than the secondary standard.

Well H-05c. Table 6-8 shows that Magenta Dolomite groundwater from Well H-05c contains a number of constituents that exceed MCLs. The constituents are chromium, fluoride, lead, and silver. Arsenic, cadmium, and selenium concentrations are also greater than the standards at their detection limits. Secondary standard constituents such as TDS, chloride, sulfate, and iron exceed SMCLs. The manganese concentration exceeded the standard at the detection limit.

Well H-06b. Table 6-9 presents Culebra Dolomite groundwater from Well H-06b as compared to standards. A number of metals exceed MCLs. These metals are chromium, lead, selenium, and silver. Arsenic and cadmium concentrations are also greater than the standards at their detection limits. The TDS, chloride, sulfate, iron, and manganese concentrations exceed SMCLs at this well. Total dissolved solids in groundwater from Well H-06b are two orders of magnitude greater than the secondary drinking water standard.

Well H-06c. Table 6-10 shows that Magenta Dolomite groundwater from Well H-06c contains several metals with concentrations that are potentially in excess of the MCLs. Concentrations of cadmium, chromium, lead, selenium, and silver are greater than the interim drinking water standards at their detection limits. Secondary standard constituents such as TDS, chloride, sulfate, and iron also exceed SMCLs at this well. The manganese concentration exceeds the secondary drinking water standard at the detection limit. The TDS of groundwater from Well H-06c are almost an order of magnitude greater than the secondary standard.

Well H-11b3. Table 6-11 shows that Culebra Dolomite groundwater from Well H-11b3 contains several metals at concentrations that exceed MCLs. These metals are arsenic, cadmium, chromium, lead, and silver. Concentrations of selenium are also greater than interim primary drinking water standards at the detection limit. The parameters TDS, chloride, sulfate, iron, and manganese exceed SMCLs. The TDS of groundwater at this well are two orders of magnitude greater than the standard.

Well H-14. Table 6-12 shows that Culebra Dolomite groundwater from Well H-14 contains a number of metals with concentrations exceeding MCLs. These metals are cadmium,

chromium, lead, and silver. Concentrations of arsenic and selenium are equal to or greater than standards at the detection limit. The parameters TDS, chloride, sulfate, iron, and manganese also exceed SMCLs. Total dissolved solids are over an order of magnitude larger than the secondary standard.

Well H-15. Table 6-13 shows a number of metal concentrations from Culebra Dolomite groundwater at Well H-15 that exceed MCLs. These metals are cadmium, chromium, lead, and silver. Concentrations of arsenic and selenium are also greater than standards at the detection limit. Mercury concentrations are equal to the standard at the detection limit. Concentrations of TDS, chloride, sulfate, iron, manganese, and copper all exceed SMCLs. Total dissolved solids and chloride concentrations in this groundwater are over two orders of magnitude larger than secondary standards.

Well H-18. Table 6-14 shows Culebra Dolomite groundwater from Well H-18 as compared to standards. Only chromium concentrations exceed MCLs. However, concentrations of arsenic, cadmium, lead, selenium, and silver are greater than the standard at their detection limits. The secondary standard constituents TDS, chloride, sulfate, iron, and manganese exceed SMCLs. Total dissolved solids in this groundwater are over an order of magnitude larger than the secondary standard.

Well WIPP-19. Table 6-15 shows that the concentration of chromium and lead in Culebra Dolomite groundwater exceeds the MCLs for these metals at Well WIPP-19. Concentrations of arsenic, cadmium, selenium, and silver are greater than the standard at their detection limits. Also, the concentration of mercury is equal to the standard at its detection limit. The secondary standard constituents TDS, chloride, sulfate, iron, and manganese exceed SMCLs. Total dissolved solids and chloride are over two orders of magnitude larger than secondary standards.

Table 6-1
Comparison to Established Standards
Well DOE-1

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCL[b]		
Arsenic	0.05	<0.5	0.034
Barium	1.0	0.07	0.07
Cadmium	0.01	0.07	0.07
Chromium	0.05	0.4	0.4
Fluoride	2.4	1.05	1.05
Lead	0.05	1.3	1.3
Mercury	0.002	0.0008	0.0008
Nitrate (as N)	10	0.1	0.1
Selenium	0.01	<0.5	0.183
Silver	0.05	0.1	0.1
	SMCLs[c]		
TDS[d]	500	135,000	135,000
Chloride	250	81,000	81,000
Sulfate	250	7,400	7,400
Iron	0.3	1.4	1.4
Manganese	0.05	0.39	0.39
Copper	1.0	0.18	0.18
Zinc	5.0	<0.1	0.075

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-2
Comparison to Established Standards
Well H-02a

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.014	0.014
Barium	1.0	<0.05	NA
Cadmium	0.01	0.08	0.08
Chromium	0.05	0.4	0.4
Fluoride	2.4	2.2	2.2
Lead	0.05	0.5	0.5
Mercury	0.002	<0.0002	NA
Nitrate (as N)	10	0.3	0.3
Selenium	0.01	<0.05	NA
Silver	0.05	0.2	0.2
	SMCLs[c]		
TDS[d]	500	13,500	13,500
Chloride	250	5,300	5,300
Sulfate	250	3,300	3,300
Iron	0.3	1.2	1.2
Manganese	0.05	0.075	0.075
Copper	1.0	<0.105	NA
Zinc	5.0	<0.1	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-3
Comparison to Established Standards
Well H-03b1

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.05	0.02
Barium	1.0	<0.2	NA
Cadmium	0.01	<0.05	NA
Chromium	0.05	0.2	0.2
Fluoride	2.4	2.2	2.2
Lead	0.05	<0.5	0.14
Mercury	0.002	<0.0004	0.0003
Nitrate (as N)	10	<0.1	NA
Selenium	0.01	0.09	0.09
Silver	0.05	<0.1	0.03
	SMCLs[c]		
TDS[d]	500	9,300	9,300
Chloride	250	3,500	3,500
Sulfate	250	2,400	2,400
Iron	0.3	0.3	0.3
Manganese	0.05	<0.05	0.045
Copper	1.0	<0.1	0.03
Zinc	5.0	<0.1	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-4

Comparison to Established Standards
Well H-03b3

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.1	0.039
Barium	1.0	0.06	0.06
Cadmium	0.01	0.07	0.07
Chromium	0.05	0.4	0.4
Fluoride	2.4	1.6	1.6
Lead	0.05	0.5	0.5
Mercury	0.002	0.001	0.001
Nitrate (as N)	10	<0.2	0.1
Selenium	0.01	<0.5	0.0825
Silver	0.05	0.1	0.1
	SMCLs[c]		
TDS[d]	500	55,000	55,000
Chloride	250	31,000	31,000
Sulfate	250	4,800	4,800
Iron	0.3	<1.0	0.38
Manganese	0.05	0.18	0.18
Copper	1.0	0.26	0.26
Zinc	5.0	0.2	0.2

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-5
Comparison to Established Standards
Well H-04b

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.1	0.04
Barium	1.0	<0.1	NA
Cadmium	0.01	<0.05	NA
Chromium	0.05	0.3	0.3
Fluoride	2.4	2.15	2.15
Lead	0.05	<0.5	0.1
Mercury	0.002	0.0017	0.0017
Nitrate (as N)	10	<0.1	NA
Selenium	0.01	<0.05	0.03
Silver	0.05	<0.1	NA
	SMCLs[c]		
TDS[d]	500	22,500	22,500
Chloride	250	12,000	12,000
Sulfate	250	6,900	6,900
Iron	0.3	<1.0	0.55
Manganese	0.05	<0.175	0.175
Copper	1.0	<0.25	0.2
Zinc	5.0	0.4	0.4

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-6
Comparison to Established Standards
Well H-04c

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.1	NA
Barium	1.0	<0.2	0.06
Cadmium	0.01	<0.05	NA
Chromium	0.05	0.2	0.2
Fluoride	2.4	2.8	2.8
Lead	0.05	<0.5	NA
Mercury	0.002	0.0008	0.0008
Nitrate (as N)	10	<0.1	NA
Selenium	0.01	<0.05	0.04
Silver	0.05	0.1	0.1
	SMCLs[c]		
TDS[d]	500	24,600	24,600
Chloride	250	11,000	11,000
Sulfate	250	7,850	7,850
Iron	0.3	1.1	1.1
Manganese	0.05	0.46	0.46
Copper	1.0	0.3	0.3
Zinc	5.0	<0.2	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-7

Comparison to Established Standards
Well H-05b

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.1	0.042
Barium	1.0	<0.5	NA
Cadmium	0.01	0.11	0.11
Chromium	0.05	0.3	0.3
Fluoride	2.4	1.3	1.3
Lead	0.05	1.0	1.0
Mercury	0.002	0.0005	0.0005
Nitrate (as N)	10	0.4	0.4
Selenium	0.01	7.3	7.3
Silver	0.05	0.1	0.1
	SMCLs[c]		
TDS[d]	500	166,500	166,500
Chloride	250	92,100	92,100
Sulfate	250	7,700	7,700
Iron	0.3	3.2	3.2
Manganese	0.05	0.52	0.52
Copper	1.0	<1.0	0.255
Zinc	5.0	2.5	2.5

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-8
Comparison to Established Standards
Well H-05c

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.1	NA
Barium	1.0	<0.05	NA
Cadmium	0.01	<0.05	NA
Chromium	0.05	0.2	0.2
Fluoride	2.4	3.1	3.1
Lead	0.05	0.6	0.6
Mercury	0.002	0.0005	0.0005
Nitrate (as N)	10	<0.1	0.02
Selenium	0.01	<0.05	NA
Silver	0.05	0.2	0.2
	SMCLs[c]		
TDS[d]	500	7,200	7,200
Chloride	250	1,000	1,000
Sulfate	250	4,200	4,200
Iron	0.3	1.3	1.3
Manganese	0.05	<0.15	NA
Copper	1.0	<0.25	0.2
Zinc	5.0	<0.2	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-9
Comparison to Established Standards
Well H-06b

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.5	NA
Barium	1.0	<0.1	0.06
Cadmium	0.01	<0.05	NA
Chromium	0.05	0.45	0.45
Fluoride	2.4	1.55	1.55
Lead	0.05	0.83	0.83
Mercury	0.002	0.0012	0.0012
Nitrate (as N)	10	0.2	0.2
Selenium	0.01	1.3	1.3
Silver	0.05	0.1	0.1
	SMCLs[c]		
TDS[d]	500	66,000	66,000
Chloride	250	34,000	34,000
Sulfate	250	3,400	3,400
Iron	0.3	<1	0.55
Manganese	0.05	0.28	0.28
Copper	1.0	<0.25	0.125
Zinc	5.0	<0.2	0.1

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-10
Comparison to Established Standards
Well H-06c

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.01	NA
Barium	1.0	<0.05	NA
Cadmium	0.01	<0.05	NA
Chromium	0.05	<0.1	NA
Fluoride	2.4	1.9	1.9
Lead	0.05	<0.5	NA
Mercury	0.002	0.0005	0.0005
Nitrate (as N)	10	<0.1	NA
Selenium	0.01	<0.5	NA
Silver	0.05	<0.1	NA
	SMCLs[c]		
TDS[d]	500	4,800	4,800
Chloride	250	460	460
Sulfate	250	2,600	2,600
Iron	0.3	<1.0	0.4
Manganese	0.05	<0.15	NA
Copper	1.0	<0.3	NA
Zinc	5.0	<0.2	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-11
Comparison to Established Standards
Well H-11b3

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	0.15	0.15
Barium	1.0	<0.1	0.05
Cadmium	0.01	0.09	0.09
Chromium	0.05	0.4	0.4
Fluoride	2.4	1.2	1.2
Lead	0.05	0.6	0.6
Mercury	0.002	<0.0004	NA
Nitrate (as N)	10	<0.3	NA
Selenium	0.01	<0.5	NA
Silver	0.05	0.2	0.2
	SMCLs[c]		
TDS[d]	500	122,000	122,000
Chloride	250	73,400	73,400
Sulfate	250	7,400	7,400
Iron	0.3	<1.0	0.66
Manganese	0.05	0.39	0.39
Copper	1.0	0.26	0.26
Zinc	5.0	<0.2	0.14

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-12
Comparison to Established Standards
Well H-14

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.05	NA
Barium	1.0	<0.05	NA
Cadmium	0.01	0.06	0.06
Chromium	0.05	0.4	0.4
Fluoride	2.4	1.7	1.7
Lead	0.05	0.5	0.5
Mercury	0.002	0.0004	0.0004
Nitrate (as N)	10	0.4	0.4
Selenium	0.01	<0.05	NA
Silver	0.05	0.1	0.1
	SMCLs[c]		
TDS[d]	500	18,000	18,000
Chloride	250	9,000	9,000
Sulfate	250	1,900	1,900
Iron	0.3	0.6	0.6
Manganese	0.05	0.125	0.125
Copper	1.0	0.1	0.1
Zinc	5.0	<0.1	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-13

Comparison to Established Standards
Well H-15

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<1	NA
Barium	1.0	<0.5	NA
Cadmium	0.01	0.7	0.7
Chromium	0.05	3.0	3.0
Fluoride	2.4	0.7	0.7
Lead	0.05	7.0	7.0
Mercury	0.002	<0.002	NA
Nitrate (as N)	10	0.5	0.5
Selenium	0.01	<5.0	NA
Silver	0.05	1.0	1.0
	SMCLs[c]		
TDS[d]	500	245,000	245,000
Chloride	250	140,000	140,000
Sulfate	250	7,500	7,500
Iron	0.3	3.0	3.0
Manganese	0.05	0.6	0.6
Copper	1.0	2.0	2.0
Zinc	5.0	1.0	1.0

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-14
Comparison to Established Standards
Well H-18

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.5	NA
Barium	1.0	<0.05	NA
Cadmium	0.01	<0.05	NA
Chromium	0.05	0.2	0.2
Fluoride	2.4	1.9	1.9
Lead	0.05	<0.5	NA
Mercury	0.002	<0.0002	NA
Nitrate (as N)	10	<0.2	NA
Selenium	0.01	<0.5	NA
Silver	0.05	<0.1	NA
	SMCLs[c]		
TDS[d]	500	31,000	31,000
Chloride	250	13,000	13,000
Sulfate	250	5,200	5,200
Iron	0.3	<1	0.35
Manganese	0.05	0.205	0.205
Copper	1.0	<0.25	0.15
Zinc	5.0	<0.2	NA

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

Table 6-15

Comparison to Established Standards
Well WIPP-19

Parameter	Standard (mg/ℓ)[a]	Maximum Concentration (mg/ℓ)	Maximum Quantitative Value (mg/ℓ)
	Inorganic MCLs[b]		
Arsenic	0.05	<0.5	NA
Barium	1.0	<0.5	NA
Cadmium	0.01	<0.5	NA
Chromium	0.05	2	2
Fluoride	2.4	1.1	1.1
Lead	0.05	<5	1.25
Mercury	0.002	<0.002	0.0003
Nitrate (as N)	10	0.12	0.12
Selenium	0.01	<0.5	NA
Silver	0.05	<1	NA
	SMCLs[c]		
TDS[d]	500	110,000	110,000
Chloride	250	58,000	58,000
Sulfate	250	5,700	5,700
Iron	0.3	2.0	2.0
Manganese	0.05	4.2	4.2
Copper	1.0	<2.5	0.0615
Zinc	5.0	2	2

[a]Milligrams per liter.
[b]Maximum contaminant level.
[c]Secondary maximum contaminant level.
[d]Total dissolved solids.

7.0 Summary and Conclusions

This report contains tabulated background concentrations for groundwater-quality parameters from 28 wells that are located in the vicinity of the WIPP Site. Also presented in this report is a comparison of background groundwater chemistry to appropriate water-quality standards for 15 separate wells located in the immediate WIPP vicinity.

From 1985 to 1990, the WQSP has collected groundwater samples from water-bearing zones in the area of the WIPP Site. The WQSP has sampled 28 WIPP monitoring wells and 11 privately owned wells. Groundwater was sampled during the WQSP from the Bell Canyon Formation, the Culebra and Magenta Dolomite Members of the Rustler Formation, the Dewey Lake Redbeds, and the Dockum Group. The WQSP focused primarily on the characterization of Culebra Dolomite groundwater, since the Culebra Dolomite is the first continuous water-bearing zone above the waste repository horizon and is the most transmissive hydrologic unit in the WIPP area.

Because Culebra and Magenta Dolomite groundwater chemistries are extremely variable across the WIPP Site, area wide background values for groundwater constituents could not be established. Instead, background groundwater quality was defined for each individual well. A minimum of three separate rounds of data from a well was required to establish the background groundwater quality at that well.

Preliminary analysis categorized WQSP data into three groups based on the frequency of detection and the proximity of detections to MDLs. The three groups are as follows:

- ***Major Cations and Anions*** - Constituents that collectively make up greater than 99 percent of the dissolved solids. These constituents are generally detected at concentrations that are well above the MDL.

- ***Minor Cations, Anions, and Indicator Parameters*** - Constituents with concentrations that are generally less than 10 mg/ℓ in groundwater. A substantial amount of the data are below the MDL, and detected concentrations are generally close to the MDL.

- ***Organic Compounds*** - Include VOCs, semi-VOCs, pesticides, and PCBs. Very few detections of these compounds are observed in WQSP data.

Given the three data groups defined above, background concentrations were determined and reported in the following manner:

- A 95 percent confidence interval based on the Student's t distribution was computed for every major constituent from each well. Thus, the expected background concentration range for a major constituent at a given well is represented by a 95 percent confidence interval.

- Confidence intervals for minor constituents could not be calculated; thus, the background concentration range for a minor constituent at a given well is represented by the observed concentration range for that parameter at that well.

- Because of the relatively small number, all observed detections of hazardous organic compounds were tabulated.

Prior to the determination of background concentration values, the WQSP data were evaluated for trends. Trend analysis was necessary to determine if any concentrations were changing with time due to natural (or non-WIPP related) causes. The procedure used to determine background water quality is dependent on, or somewhat controlled by, the nature of the concentration/time relationship. In general, temporal trends in concentrations were not found in the WQSP data, and the procedure used to establish background water quality reflected this finding. The results of the trend analysis are summarized below in the specific findings of this study.

The WQSP data were also evaluated for outliers. Potential outliers were evaluated using the Q Test, a standard statistical method for small data sets. If a value was determined to be an outlier by the Q Test, an additional test was performed to ensure that the value was not labeled as an outlier due to routine analytical uncertainty. Approximately 2 percent of the values were removed from the major and minor constituent data set prior to the establishment of background concentrations.

The WQSP was developed as a site characterization sampling program; it has not served as a regulatory-guided sampling program for RCRA. Consequently, well construction was not typical of that generally used for environmental monitoring programs. Most WIPP monitoring wells were drilled and completed using oil field techniques. This factor, combined with complexities associated with the analysis of high-TDS samples, leads to a high degree of uncertainty in the reported concentration of many minor constituents (e.g., trace metals). The MDL of many trace metal analyses was often relatively high, preventing the

quantification of trace metal concentrations. Also, dilution of high-TDS samples has probably magnified spurious, near-MDL detections of minor groundwater constituents, resulting in false-positive values that appear to be quite significant.

The WIPP is a RCRA facility and will require a permit in order to receive and emplace TRU mixed waste. As a consequence, WQSP data were compared to the EPA interim primary drinking water standards that are listed in 40 CFR 265 Appendix III. In addition, several constituents of WQSP groundwater were compared to National Secondary Safe Drinking Water Act standards. Comparison to secondary standards was not driven by regulatory requirements, but rather it was done to document the general unsuitability of groundwater in the vicinity of the WIPP for domestic and agricultural use.

The following are the specific findings and conclusions of this study:

- Some constituents at several wells, including H-02a, H-05c, H-07b1, H-08b, and H-15, show apparent temporal concentration trends. However, in almost every case, the trend is within the range of expected analytical uncertainty, or the trend is not supported by charge-balance considerations or by similar trends in other constituents, such as TDS.

- Wells H-04c, H-05c, WIPP-19, and WIPP-26 exhibit concentrations of several parameters that decrease significantly from the first to the second sampling round. This may indicate that the first sample is not representative, possibly due to incomplete well development.

- Background groundwater quality was successfully defined for 28 wells. Background concentrations for major and minor cations, anions, and indicator parameters were established for Culebra Dolomite, Magenta Dolomite, and Dewey Lake Redbed groundwater. Although the background concentrations of minor constituents are uncertain, this report documents the "expected" values for these constituents, if similar analytical techniques are used in future sampling efforts.

- Hazardous organic compounds are not present in groundwater in the vicinity of the WIPP Site. Detections of these compounds are very infrequent, and the majority of detected compounds are typical laboratory contaminants as defined by the EPA. Some of the occurrences may also be related to well installation or sampling practices.

- Comparison of WQSP data with EPA interim primary drinking water standards (40 CFR 265 Appendix III) shows that cadmium, chromium, lead, selenium, and

silver concentrations typically exceed MCLs. Again, the quality of trace metal data are uncertain.

- Comparison of WQSP data with secondary drinking water standards (40 CFR 143) shows that TDS, chloride, and sulfate concentrations in groundwater greatly exceed SMCLs. Results indicate that the natural composition of groundwater from the Culebra and Magenta Dolomites makes the groundwater unsuitable for domestic or agricultural use in most areas of the WIPP Site.

- The repeated detection of trace metals such as chromium and molybdenum may be related to the corrosion of well casing that is exposed to high-TDS, high-chloride groundwater.

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APPENDIX A

SEPARATION OF TRACE ELEMENTS FROM WIPP GROUNDWATERS

Appendix A presents a compilation of the results of the IT Analytical Services (ITAS) laboratory analytical methods development program for improving trace-metal analysis accuracy and detection limits. As an alternative method of analysis for some of the trace metals, the ITAS laboratory adapted an ion-exchange technique used for separating and concentrating transition metals from alkali and alkaline-earth elements in sea water (Kingston et al., 1978) for use with some of the Waste Isolation Pilot Plant (WIPP) samples.

The methods development program involved performing cation exchange experiments, using different extraction techniques, on water samples from Well H-05b. Water from this well was selected as the test matrix for method development because it is representative of the more saline water found in the Culebra Dolomite in the WIPP vicinity.

The experiment consisted of preparing the cation-exchange resin, spiking the sample with known concentrations of the metals of interest, passing the sample through the resin column to load the metals onto the resin, and separating them from the sample matrix. The metals were then stripped off the resin using various concentrations of acid solutions, where they were analyzed at increased relative concentrations in a "cleaner" solution. Spike recoveries were calculated to determine the success of the separation and analysis procedure. The testing procedure was modified, as required, to develop the most effective separation technique for the matrix type represented by the WIPP groundwater. Spike recoveries were generally excellent for the 15 trace metals in the Well H-05b groundwater matrix.

Groundwater samples from three wells, H-05b (Round three), H-08b (Round three), and WIPP-19 (Round three) had the 15 trace metals analyzed using the cation exchange technique (Lyon, 1989). Generally, this technique reduced the lower limit of detection for 14 of the 15 trace metals by one or more orders of magnitude. These three wells were selected because they represent a cross section of the types of water quality from WQSP wells found in the WIPP vicinity.

The data from this experimental analysis were reported for the three wells listed above in the annual data report by Lyon (1989). Details of the ion-exchange experimental work were reported in periodic progress reports and data reports from the ITAS laboratory to the WQSP office at the WIPP. These progress and data reports, along with a copy of the report describing the actual technique (Kingston et al., 1978) are included in this appendix. Table A-1, preceding the progress reports included in this appendix, presents the final analytical results for trace-metal concentrations as concluded from this investigation.

Table A-1
Final Results of the WQSP Experimental Trace Metal Analysis

Parameter	WIPP-19	H-05b	H-08b
Concentration (mg/ℓ)[a]			
Antimony	1.08	0.77	<0.20
Arsenic	<0.020	<0.024	<0.020
Cadmium	<0.0030	<0.004	<0.0030
Cesium	<0.24	<0.28	<0.24
Chromium	0.006	0.016	0.005
Cobalt	<0.007	<0.010	<0.007
Copper	0.013	<0.010	0.11
Lead	<0.030	<0.040	<0.030
Lithium	0.73	0.75	0.12
Molybdenum	0.024	0.030	0.008
Nickel	<0.020	<0.10	0.030
Selenium	<0.040	<0.024	<0.040
Silver	<0.020	0.090	<0.020
Titanium	<0.007	<0.010	<0.007
Zinc	0.051	0.030	0.24

[a] milligrams per liter
Source: Lyon, 1989

CHELEX 100 SEPARATION #1
PROGRESS REPORT

COPY

PROJECT: DOE-WIPP

Project Summary:

The ITAS Pittsburgh Laoratory has been requested by ITES-Albuquerque to investigate techniques to achieve enrichment and isolation of cations monitored in the DOE-WIPP site's water quality program. The project goal is to establish an accurate baseline for the metalic species monitored. Ion exchange technology has been utilized by many investigators for the enrichment and isolation of various metalic ions in matrices characterized by high levels of inorganic salts. This first progress report is a summary of initial investigations using an ion exchange technique on characteristic WIPP type sample (Sample H05B). The technique used was taken from "Separation of the Eight Transition Elements from Alkali and Alkaline Earth Elements in Estuarine and Seawater with Chelating Resin and Their Determination by Graphit Furnace Atomic Absorption Spectrometry," H. M. Kingston, I. L. Barnes, T. J. Brady, and T. C. Rains, Analytical Chemistry, Vol. 50, No. 14, December, 1987.

Procedure Summary:

Chelex 100[(1)] resin was added to the column (3.2 grams). The resin bed was washed with subsequent portions of 2.5M HNO_3 and deionized water. The column was then rinsed with ammonium hydroxide until a basic eluant was achieved. After two additional deionized water rinses had been completed, the column was ready for ion exchange.

Once the column had been prepared as described above, 70 grams or approximately 70 milliliters of spiked sample (H05-B) was added to the column. The flow rate through the column was adjusted to approximately one milliliter per minute and the effluent was collected (anion fraction). The

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(1) Chelex 100 is a registered trademark of BIO-RAD Laboratories.

column was then eluted with 40 milliliters of ammonium acetate. This fraction was collected (alkaline and alkali fraction). Two subsequent elutions of 7 milliliters and 5 milliliters of 2.5M nitric acid were collected and labeled transition metals #1 and #2, respectively.

A method blank was processed as stated above. Analytical results of the analyses are listed in the the enclosed table.

Results and Discussion:

The transition elements, as expected, were recovered with the greatest success; however, almost all of the elements studied showed some recovery.

The inflated recoveries for lithium, titanium, and antimony may be due to positive interferences contained in the concentrated anion fraction. Also, concentration values found in the original sample were not subtracted out prior to the percent recovery calculation.

Results and Discussion:

In the next round of experiments, the samples will be diluted prior to the column loading to ensure instantaneous equalibrium on the exchange column. Concentrations of acid solutions will be varied so that cation groupings may be better isolated (or not). The next progress report should be completed by June 17, 1988.

PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #1

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Ni	Cu	Ag	Pb	As	Sb	Se
Anion Fraction	460%	9%	340%	57%	11%	0%	0%	0%	0%	41%	260%	0%
& Alkali Fraction	32%	0%	69%	0%	ISS(1)	0%	0%	0%	0%	6.4%	59%	0%
Transition Metals #1	4%	0%	69%	13%	96%	74%	125%	0%	66%	0%	0%	0%
Transition Metals #2	3%	0%	5%	2%	4%	8%	15%	0%	0%	ISS	0%	0%

Method Blank (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Ni	Cu	Ag	Pb	As	Sb	Se
Anion Fraction	<0.01	<0.01	<0.03	<0.01	0.01	<0.03	<0.01	<0.01	<0.05	<0.005	<0.05	<0.005
Alkaline & Alkali Fraction	<0.006	<0.006	<0.02	<0.006	ISS	<0.02	<0.006	<0.006	<0.03	<0.003	<0.03	<0.003
Transition Metals #1 Fraction	<0.003	<0.003	<0.009	<0.003	<0.003	<0.009	<0.003	<0.003	<0.015	<0.0015	<0.015	<0.0015
Transition Metals #2	<0.002	0.002	<0.006	<0.002	0.002	<0.006	<0.002	<0.002	<0.010	<0.001	<0.010	<0.001
Detection Limit	0.006	0.006	0.009	0.003	0.003	0.009	0.003	0.003	0.015	0.015	0.015	0.0015

(1) ISS = Insufficient sample to perform the required analyusis.

CHELEX 100 SEPARATION #2
PROGRESS REPORT

PROJECT: DOE-WIPP

Procedure Summary; Separation #2A

Chelex 100[1] resin was added to the column (3.2 grams). The resin bed was washed with subsequent portions of 2.5M HNO_3 and deionized water. The column was then rinsed with ammonium hydroxide until a basic eluant was achieved. After two additional deionized water rinses had been completed, the column was ready for ion exchange.

A 50 milliliter aliquot of sample HOS-B was spiked and diluted to 200 milliliters (pH = 2.4). This solution was added to the column. The flow rate through the column was adjusted to approximately one milliliter per minute and the effluent was collected (anion fraction). The column was then eluted with 40 milliliters of 0.5M ammonium acetate. This fraction was collected (alkaline and alkali fraction). Finally, an elution of 20 milliliters of 5.0M nitric acid was collected and labeled transition metals.

Procedure Summary; Separation #2B

The separation was performed as described in separation #2A with one exception, the pH of the diluted sample aliquot was adjusted to 5.5 prior to column loading.

Procedural Changes from Separation #1

Several procedural changes were made during separations #2A and #2B. The amount of spiking solution added to the sample was increased from 10 micrograms to 20 micrograms. Also, cadmium, cobalt, and zinc were added to the elements to be examined.

The sample was diluted by a factor of four in an effort to facilitate instantaneous equilibrium on the exchange column.

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[1]Chelex 100 is a registered trademark of BIO-RAD Laboratories.

The concentration of the nitric acid eluant was raised from 2.5M to 5.0M and one 20 milliliter wash was used rather than two smaller ones.

Analytical results of the analyses are listed in the enclosed tables.

Results and Discussion

The effect of sample pH adjustment was clearly observed and has proven to be a noteworthy consideration. Results for separation #2B showed fraction separations which were clearer and, in general, produced better spike recoveries than those of separation #2A where no pH adjustment was made. Furthermore, analytes which exhibited no spike recovery previously are now beginning to show some recovery, i.e., Ag and As.

Again, inflated recoveries for lithium, titanium, antimony, and zinc may be due to positive interferences contained in the concentrated anion fraction. Also, concentration values found in the original sample were not subtracted prior to the percent recovery calculation.

Results and Discussion

In the next round of experiments, three column pretreatments will be performed.

Separation #3A will duplicate separation #2B with the exception that no spike will be added. The information obtained will be used to subtract the analyte concentrations inherent to sample H08-B from the percent recovery calculations for separation #2B.

Separation #3B will duplicate separation #2B, except that the pH will be adjusted to 6.5 prior to column loading. This adjustment may facilitate the recovery of elements such as arsenic and silver.

Separation #3C will duplicate separation #2B, however, the sample volume will be decreased in a further effort to achieve equilibrium on the exchange column.

Both separations #3B and #3C will contain 40 micrograms of spiking solution rather than 20 micrograms as in separation #2A and #2B.

TABLE 1

SEPARATION #2B (Column A pH = 2.4)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #1

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	320	160	240	140	30	100	110	0	3.4	360	98	180	30	340	0
Alkaline & Alkali Fraction	12	5.7	0	0	0	0	0	0	0	25	3	0	1.3	0	0
Transition Metals #1	6.7	2.2	47	27	120	0	0	113	0	27	0	0	0	0	0

Observed Concentration (Units mg/l)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.32	0.16	0.24	0.14	0.03	0.10	0.11	0	0.34	0.36	0.098	0.18	0.032	0.34	0
Alkaline & Alkali Fraction	0.06	0.03	0	0	0	0	0	0	0	0.13	0.016	0	0.007	0	0
Transition Metals #1 Fraction	0.03	0.01	0.21	0.12	0.54	0	0	0.51	0	0.12	0	0	0	0	0

TABLE 2

SEPARATION #2B (Column B pH = 5.5)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #1

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	300	150	210	30	60	30	40	30	50	0	18	170	13	390	0
Alkaline & Alkali Fraction	15	12	27	5.8	9.6	5.8	7.7	15	5.8	13	2.7	29	10	46	5.4
Transition Metals #1	6.7	4.4	87	93	122	96	98	91	0	420	118	98	56	0	13

Observed Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.30	0.15	0.21	0.03	0.06	0.03	0.04	0.03	0.05	0	0.018	0.17	0.013	0.39	0
Alkaline & Alkali Fraction	0.08	0.06	0.14	0.03	0.05	0.03	0.04	0.08	0.03	0.07	0.014	0.15	0.052	0.24	0.028
Transition Metals #1 Fraction	0.03	0.02	0.39	0.42	0.55	0.43	0.44	0.41	0	1.88	0.533	0.44	0.25	0	0.06

CHELEX 100 SEPARATION #3
PROGRESS REPORT

PROJECT: DOE-WIPP

Procedure Summary; Separation #3A

A slurry of Chelex 100[1] (3.2 gms) was added to the column and allowed to slowly drain forming the resin bed. It was washed with five 15 ml portions of 2.5 M nitric acid and then rinsed with two 5 ml portions of deionized water. The bed was subsequently activated with two 5 ml portions of 2.0 M ammonium hydroxide. This washing was continued until the eluant was basic. The bed was rinsed again with deionized water.

A 50.0 g aliquot of sample H05B was diluted to approximately 200 mls. The pH was then adjusted to 5.5 and the final volume was adjusted to 200 mls. The diluted sample was added to the column and the flow rate was adjusted to approximately 1.0 ml per minute. The effluent was collected and called the anion fraction. The column was then eluted with 40 mls of 0.5M ammonium acetate. This fraction was called the cation fraction (alkaline and alkali fraction). Next the column was eluted with two 10 ml portions of 5.0M nitric acid and called the transition metal fraction.

Procedure Summary; Separation #3B

The separation performed was the same as that described in #3A with a few exceptions. The 50.0g sample (H05B) was spiked with 20 mls of a 2 ppm solution containing the ions being studied. The final pH adjustment was to 6.5.

Procedure Summary; Separation #3C

The separation procedure was the same as #3A with the exception that only 20.0g of sample (H05B) was used and it was spiked with 20 mls of the 2 ppm solution.

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[1] Chelex 100 is a registered trademark of BIO-RAD Laboratories.

Procedural Changes from Separation #2

There were two procedural changes from the one followed in Separation #2. The first was that the pH of the spiked aliquot was adjusted to 6.5 in separation #3B. The second was that the amount of HO5B used was lowered to 20.0g in separation #3C. This second change was made to ensure that the column was not being overloaded.

Analytical results are listed in the enclosed tables.

Results and Discussion

In comparing the results from Separation #2B with that of Separations #3B and #3C (both without sample subtraction, #3A) it can be seen that there is a much clearer separation overall and less positive interferences for elements such as Li, Cs, Ti. The positive background interferencs observed in Seperations #1 and #2 were apparently due to an absorbance signal which was very near the instrument's detection limits, where noise is a more significant factor. The amount of analyte contained in the spiking solution was increased in an effort to minimize this difficulty. This increase in concentration has effected a more stable analytical signal.

The subtraction of the analyte concentration inherent to the sample HO5B (#3A) eliminated many of the positive interferences found with such elements as Li, Sb, and Zn. It has also appeared to eliminate recoveries previously reported in the anionic fraction for elements such as Li, Ti, Cr, Mo, and Sb. With clearer elemental separations, estimates can now be made as to which fraction the element might be expected to be found in.

Separation #3B was the duplicate of #3C with the exception that the pH was adjusted to 6.5 to potentially improve the separation and recovery of elements such as As and Ag. As can be seen in the accompanying tables, this was not a benificial experiment. In fact, Separation #3C appears to have less positive interferences and percent recoveries that are closer to 100 percent overall than #3B.

Several of the parameters that have not achieved an acceptable percent recovery were reanalyzed by Method of Standard Addition, and the results are shown in Tables 4A-4C. In some instances the results improved but, at this point, there is not enough evidence to prove that this method will improve the results overall. The method will be used again in the next round of experiments to determine its usefulness to our end goal.

Future Experiments

In the next round of experiments, four column pretreatments will be performed. In each case, the pH will be lowered to 5.0. This is the lowest of the pH range given by Kingston et.al.[2] Below the pH of 4.5, the ability of the resin to separate the transition metals is drastically lowered; therefore, this is expected to be the last pH adjustment.

Separation #4A will duplicate #3A.

Separation #4B-D will all be spiked with 40 µg of the analytes. Separations #4B and C will be prepared in duplicate to show analytical precision, as the separations preceding them did not prove how well reproducibility may be achieved. Separation 4D will be saved for possible further experiments, such as Hydride Generation and Hexachromium analysis for troublesome analytes.

[2] H. M. Kingston, I.L. Barnes, T. J. Brady, and T.C. Rains, Analytical Chemistry, Vol. 50, No. 14, December 1978.

TABLE I

SEPARATION #3A (Column A; pH = 5.5)
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.18	0	0.27	0.06	0.06	0.017	0	0.01	0.02	0	0.012	0.08	0	0.21	0
Alkaline & Alkali Fraction	0.01	0	0	0	0.03	0	0	0	0	0	0	0	0	0.05	0
Transition Metals #1 Fraction	0.01	0	0.09	0	0.08	0	0	0.01	0	2.3	0	0	0	0	0

TABLE 2A

SEPARATION #3B (Column B; pH = 6.5)
WITHOUT SAMPLE SUBTRACTION (#3A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #3B Percent Recovery

SAMPLE IDENTIFICATION	Li	Cs	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	153	147	17	16	26	0	0	0	0	0	0	0	68	210	0
Alkaline & Alkali Fraction	1	0	0	0	35	0	0	0	0	0	0	0	1.7	0	0
Transition Metals #1 Fraction	0.5	0	76	18	78	104	106	106	0	250	105	100	6.6	3.2	0.3

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.29	0.28	0.033	0.03	0.05	0	0	0	0	0	0	0	0.13	0.397	0
Alkaline & Alkali Fraction	0.01	0	0	0	0.35	0	0	0	0	0	0	0	0.017	0	0
Transition Metals #1 Fraction	0.01	0	1.3	0.30	1.33	1.77	1.8	1.8	0	1.28	1.79	1.7	0.112	0.055	0.005

TABLE 2B

SEPARATION #3B (Column B; pH = 6.5)
WITH SAMPLE CONCENTRATION SUBTRACTION (#3A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #3B (Percent Recovery)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	58	147	0	0	0	0	0	0	0	0	0	0	68	100	0
Alkaline & Alkali Fraction	0	0	0	0	32	0	0	0	0	0	0	0	1.7	0	0
Transition Metals #1 Fraction	0	0	72	18	74	104	106	100	0	116	105	100	6.6	3.2	0.3

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.11	0.26	-0.24	-0.03	-0.01	-0.17	0	-0.01	-0.02	0	-0.012	-0.08	0.13	0.19	0
Alkaline & Alkali Fraction	0	0	0	0	0.32	0	0	0	0	0	0	0	0.017	-0.05	0
Transition Metals #1 Fraction	0	0	1.21	0.30	1.25	1.77	1.8	1.7	0	1.98	1.79	1.7	0.112	0.055	0.005

TABLE 3A

SEPARATION #3C (Column C; pH = 5.5)
WITHOUT SAMPLE SUBTRACTION (#3A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #3C Percent Recovery

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	120	110	40	26	15	0	0	0	6.5	0	0	0	60	150	0
Alkaline & Alkali Fraction	1	0	0	0	29	0	0	0	0	0	0	0	2.9	0	0
Transition Metals #1 Fraction	0.5	0	96	28	82	101	101	104	0	160	102	96	18	3.4	2

Raw Concentration (Units mg/l)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.24	0.22	0.080	0.051	0.03	0	0	0	0.013	0	0	0	0.12	0.298	0
Alkaline & Alkali Fraction	0.01	0	0	0	0.28	0	0	0	0	0	0	0	0.028	0	0
Transition Metals #1 Fraction	0.01	0	1.63	0.473	1.39	1.71	1.71	1.76	0	2.72	1.73	1.63	0.13	0.058	0.029

TABLE 3B

SEPARATION #3C (Column C; pH = 5.5)
WITH SAMPLE CONCENTRATION SUBTRACTED (#3A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #3C (Percent Recovery)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	30	110	0	0	7.5	0	0	0	6	0	0	0	60	45	0
Alkaline & Alkali Fraction	0	0	0	0	26	0	0	0	0	0	0	0	2.9	0	0
Transition Metals #1 Fraction	0	0	91	28	77	101	101	103	0	25	102	96	18	3.4	2

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Anion Fraction	0.06	0.22	-0.19	-0.01	0.03	-0.017	0	0	0.011	0	-0.012	-0.03	0.12	0.09	0
Alkaline & Alkali Fraction	0	0	0	0	0.25	0	0	0	0	0	0	0	0.028	-0.05	0
Transition Metals #1 Fraction	0	0	1.54	0.473	1.31	1.71	1.71	1.75	0	0.42	1.73	1.63	0.31	0.058	0.029

TABLE 4A

SEPARATION #3A (Column A; pH = 5.5)
ANALYSIS BY METHOD OF STANDARD ADDITION
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cr	Ag	As	Se
Anion Fraction	0.290	0	0.010	0	0
Alkaline & Alkali Fraction	0.06	0	0	0	0
Transition Metals #1 Fraction	IS(1)	IS	IS	IS	IS

(1) Insufficient sample to reanalyze this fraction.

TABLE 4B

SEPARATION #3B (Column B; pH = 6.5)
ANALYSIS BY METHOD OF STANDARD ADDITION
WITH SAMPLE SUBTRACTION (#3A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #3B (Percent Recovery)

SAMPLE IDENTIFICATION	Li	Cr	Ag	As	Se
Anion Fraction	157	34	45	46	IS(1)
Alkaline & Alkali Fraction	0	0	0	1.7	0
Transition Metals #1 FRACTION	--	--	--	--	--

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cr	Ag	As	Se
Anion Fraction	0.23	0.063	0.085	0.087	(2)
Alkaline & Alkali Fraction	0	0	0	0.017	0
Transition Metals #1 Fraction	IS	IS	IS	IS	IS

(1) Insufficient sample to reanalyzed the fraction.

(2) Unable to achieve correlation coefficient ≥ 0.995.

TABLE 4C

SEPARATION #3C (Column C; pH = 5.5)
ANALYSIS BY METHOD OF STANDARD ADDITION
WITH SAMPLE SUBTRACTION (#3A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)

Chelex 100 Separation #3C (Percent Recovery)

SAMPLE IDENTIFICATION	Li	Cr	Ag	As	Se
Anion Fraction	35	14	0	77	85
Alkaline & Alkali Fraction	0	0	0	2.4	0
Transition Metals #1 Fraction	--	--	--	--	--

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cr	Ag	As	Se
Anion Fraction	0.07	0.028	0	0.154	0.17
Alkaline & Alkali Fraction	0	0	0	0.024	0
Transition Metals #1 Fraction	IS(1)	IS	IS	IS	IS

CHELEX 100 SEPARATION #4
PROGRESS REPORT

PROJECT: DOE-WIPP

Procedure Summary; Separation #4A

The slurry of Chelex 100[1] resin (3.2g) was added to the column and allowed to slowly drain. The resin bed was washed with five 15 ml portions of 2.5 M nitric acid and then rinsed with two 5 ml portions of deionized water. The bed was subsequently activated with two 5 ml portions of 2.0 M ammonium hydroixde. This washing was continued until the eluant was basic. The column bed was rinsed again with deionized water.

A 50.0 g aliquot of sample H05B was diluted to approximately 200 ml and the pH was adjusted to 5.0. The sample was then brought up to a final volumn of 200 mls and it was added to the column. The column flow rate was adjusted to approximately one milliliter per minute and the effluent was collected and called the anion fraction. The column was then eluted with a total of 40 mls of 1.0 M ammonium acetate. This fraction was called the cation fraction (alkaline and alkali fraction). Next, the column was eluted with three 10 ml aliquots of 5.0 M nitric acid (Transition Metal #1 fraction). The final elution was with two 10 ml washes of 2.0 M sulfuric acid and was called the Transition Metal #2 fraction.

Procedure Summary; Separation #4B

The separation was performed as that described in #4A, with a few exceptions. Before the pH adjustment and the final volume adjustment, the 50.0 g sample was spiked with 20 ml of a 2 ppm solution containing the ions being studied. The final pH was 5.0. The amount of 2.0 M sulfuric acid was 30 mls, instead of 20 mls.

[1] Chelex 100 is a registered trademark of BIO-RAD Laboratories.

Procedure Summary; Separation #4C, #4D

These separations followed the same procedure as that in #4B, except that only 20 mls of the 2.0 M sulfuric acid was used and a new cadmium cobalt and zinc spike was used.

Procedural Changes from Separation #3

The one significant change is that of the pH to 5.0. There was still one unspiked separation (#4A), while three identically spiked separations were eluted to show reproducibility. The third of these three (#4D) was not analyzed at this time.

Analytical results are listed in the enclosed tables.

Results and Discussion

In comparing the results from the separations in #3 with those in #4, it appears that the changes made in separation #4 were successful with few exceptions. The 2.0 M sulfuric acid extraction (Transition Metal #2 fraction) was a suggestion made by BIO-RAD Laboratories to release the elements off the column where there were recovery problems (Ag, Cr, As, etc.). This part of the experiment failed, as there was no recovery of any element found in this fraction.

The first success of this separation procedure was that the change in pH had no adverse effect on the analytes that had shown good recoveries in the past. The second favorable aspect of this extraction was the improvements in the Li, Ti, Mo, and As percent recoveries. The third and most important advancement was with the elements, Ag, Cr, and Se. There now is a small but consistant recovery of silver and within five percent of absolute for chromium and selenium; therefore, the pH of 5.0 is the best range to look for these elements.

When looking at Tables 3A and 3B (Separation #4C) it must be noted that a small amount of the Transition Metal #1 fraction was accidently added to the alkaline/alkali fraction. This was confirmed at the time of extraction by the pH of the elutant. After analysis, it was also confirmed by the percent recoveries being split between these two fractions and, when added together,

achieve near 100 percent recovery. This accident in the extraction procedure does give some more valuable information. It shows, through the percent recoveries in the alkaline/alkali fraction, the order in which the elements come off the column. Zinc is obviously the first off the column, while chromium is held by the column until the end of the extraction. Due to the above mentioned problem, Separations #4B and #4C did not prove method reproducibility.

Following the analytical results tables is a summary containing the analytes pH preference, fraction it will be contained in, the most beneficial procedure for analysis, and the expected detection limit.

Future Experiments

Samples H08B and WIPP-19 will be extracted and analyzed according to the recommendations made in Table 4. The laboratory has not proven the reproducibility of this method during past experiments. This research deviation will be accounted for during the separations of H08B and WIPP-19, where one or more replicates will be prepared and analyzed. Data collected in this study will be presented in the next report. The results will be completed as soon as possible.

TABLE 1

EXTRACTION RESULTS AND EXPECTED RECOVERY VALUES
FOR MATRIX SPIKES

Separation 4A: 50.04g of H05B, pH = 4.9, diluted to 200 ml

FRACTION	AMOUNT RECOVERED (g)
Anionic	213.56
Alkaline/Alkali	58.77
Transition Metal #1	32.24
Transition Metal #2	21.55

Separation 4B: 49.96g of H05B, plus 20 ml of 2 ppm spike, pH = 4.95, to 200 ml

FRACTION	AMOUNT RECOVERED (g)	THEORETICAL VALUE OF MATRIX SPIKE
Anionic	199.74	0.20
Alkaline/Alkali	36.85	1.09
Transition Metal #1	34.77	1.15
Transition Metal #2	29.44	1.36

TABLE 1
(Continued)

Separation 4C: 50.02g of H05B, plus 20 ml of 2 ppm spike, pH = 4.90, to 200 ml

FRACTION	AMOUNT RECOVERED (g)	THEORETICAL VALUE OF MATRIX SPIKE
Anionic	209.50	0.19
Alkaline/Alkali	39.87	1.00
Transition Metal #1	35.66	1.12
Transition Metal #2	17.47	2.29

Separation 4D: 50.04g of H05B, plus 20 ml of 2 ppm spike, pH 5.0, to 200 ml

FRACTION	AMOUNT RECOVERED (g)	THEORETICAL VALUE OF MATRIX SPIKE
Anionic	199.98	0.20
Alkaline/Alkali	37.70	1.06
Transition Metal #1	32.57	1.22
Transition Metal #2	19.68	2.03

TABLE 2A

SEPARATION #4A (Column A; pH = 5.0)
FOR ANALYTES OF SPECIAL INTEREST (H05B)
ICP EMISSION ANALYSIS

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	Sb
Anion Fraction	0	0.32	--(1)	0	0	0	0	0	0	0	0.164
Alkaline & Alkali Fraction	0	0	0.02	0	0	0.05	0	1.87	0	0	0
Transition Metals #1 Fraction	0	0	0.04	0	0	0	0	0.04	0	0	0
Transition Metals #2 Fraction	0	0	0	0	0	0	0	0	0	0	0

(1)Not reported for the indicated parameter because of a laboratory accident.

TABLE 2B

SEPARATION #4A (Column A; pH = 5.0)
FOR ANALYTES OF SPECIAL INTEREST (H05B)
GRAPHITE FURNACE OR FLAME ATOMIC ABSORPTION ANALYSIS

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Cr[1]	Ag[1]	As[1]	Sb	Se[1]
Anion Fraction	0.16	0	0,	0.020	0	0.042	0
Alkaline & Alkali Fraction	0.02	0	0	0	0	0.008	IS[2]
Transition Metals #1 Fraction	0	0	0.022	0	0	0	0
Transition Metals #2 Fraction	0	0	0	0	0	0	0

[1] The element was analyzed by Method of Standard Addition.

[2] IS = Insufficient sample to analyze this fraction.

TABLE 3A

SEPARATION #4B (Column B; pH = 5.0)
WITH SAMPLE SUBTRACTION (#4A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)
ICP EMISSION ANALYSIS

Chelex 100 Separation #4B (Percent Recovery)

SAMPLE IDENTIFICATION	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	Sb
Anion Fraction	0	18	--(1)	0.2	0	0	12	0	34	0	90
Alkaline & Alkali Fraction	0	0	0	0	0	0	0	0	0	0	0
Transition Metals #1 Fraction	103	82	102	102	104	104	0	96	63	92	0
Transition Metals #2 Fraction	0	0	0	0	0	0	0	0	0	0	0

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	Sb
Anion Fraction	0	0.035	--	0.012	0	0	0.025	0	0.069	0	0.179
Alkaline & Alkali Fraction	0	0	0	0	0	0	0	0	0	0	0
Transition Metals #1 Fraction	1.18	0.941	1.17	1.17	1.20	1.2	0	1.1[illegible]	0.72	1.06	0
Transition Metals #2 Fraction	0	0	0	0	0	0	0	0	0	0	0

(1) Not reported for the indicated parameter because of a laboratory accident.

TABLE 3B

SEPARATION #4B (Column B; pH = 5.0)
WITH SAMPLE SUBTRACTION (4A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)
GRAPHITE FURNACE OR FLAME ATOMIC ABSORPTION ANALYSIS

Chelex 100 Separation #4B (Percent Recovery)

SAMPLE IDENTIFICATION	Li	Cs	Cr	Ag	As	Sb	Se
Anion Fraction	80	140	15	3.0	73	154	99
Alkaline & Alkali Fraction	0	0	1.7	0	1.2	0.2	0.9
Transition Metals #1 Fraction	0	0	98	0	6.3	1.1	1.0
Transition Metals #2 Fraction	0	0	0	0	0	0	0

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Cr(1)	Ag(1)	As(1)	Sb	Se(1)
Anion Fraction	0.16	0.28	0.030	0.006	0.142	0.308	0.197
Alkaline & Alkali Fraction	0	0	0.019	0	0.13	0.002	0.010
Transition Metals #1 Fraction	0	0	1.13	0	0.073	0.013	0.012
Transition Metals #2 Fraction	0	0	0	0	0	0	0

(1) The element was analyzed by Method of Standard Addition.

TABLE 4A

SEPARATION #4C (Column C; pH = 5.0)
WITH SAMPLE SUBTRACTION (#4A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)
ICP EMISSION ANALYSIS

Chelex 100 Separation #4C (Percent Recovery)

SAMPLE IDENTIFICATION	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	Sb
Anion Fraction	0	18	--(1)	8.4	0	0	17	0	0	35	107
Alkaline & Alkali(2) Fraction	12	0	23	36	29	20	0	94	36	20	0
Transition Metals(2) #1 Fraction	63	82	71	57	63	71	0	0	61	54	0
Transition Metals #2 Fraction	0	0	0	0	0	0	0	0	0	0	0

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Ti	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	Sb
Anion Fraction	0	0.035	--	0.016	0	0	0.032	0	0	0.067	0.203
Alkaline & Alkali(2) Fraction	0.12	0	0.23	0.358	0.29	0.2	0	0.938	0.357	0.20	0
Transition Metals(2) #1 Fraction	0.71	0.99	0.79	0.63	0.70	0.8	0	0	0.68	0.60	0
Transition Metals # 2 Fraction	0	0	0	0	0	0	0	0	0	0	0

(1) Not reported for the indicated parameter because of a laboratory accident.
(2) At the time of separation, a small amount of alkaline and alkali fraction was contaminated by the transition metal #1 fraction.

TABLE 4B

SEPARATION #4C (Column C; pH = 5.0)
WITH SAMPLE SUBTRACTION (#4A)
PERCENT RECOVERY
FOR ANALYTES OF SPECIAL INTEREST (H05B)
GRAPHITE FURNACE OR FLAME ATOMIC ABSORPTION ANALYSIS

Chelex 100 Separation #3A (Percent Recovery)

SAMPLE IDENTIFICATION	Li	Cs	Cr	Ag	As	Sb	Se
Anion Fraction	79	111	4.2	5.8	65	136	95
Alkaline & Alkali[1] Fraction	0	0	3.6	0	6.0	0.9	0
Transition Metals[1] #1 Fraction	0	0	101	0	18	0.9	0
Transition Metals #2 Fraction	0	0	0	0	0	0	--[2]

Raw Concentration (Units mg/ℓ)

SAMPLE IDENTIFICATION	Li	Cs	Cr[3]	Ag[3]	As[3]	Sb	Se[3]
Anion Fraction	0.15	0.21	0.008	0.011	0.123	0.258	0.181
Alkaline & Alkali[1] Fraction	0	0	0.036	0	0.060	0.009	0
Transition Metals[1] #1 Fraction	0	0	1.126	0	0.204	0.011	0
Transition Metals #2 Fraction	0	0	0	0	0	0	--[2]

[1] At the time of separation, a small amount of the alkaline and alkali fraction was contaminated by the Transition Metal #1.

[2] Unable to achieve correlation coefficient ≥ 0.995.

[3] The element was analyzed by Method of Standard Edition.

TABLE 5

SUMMARY OF RECOMMENDED PROCEDURES
FOR ANALYTES OF SPECIAL INTEREST (HO5B)

	Li	Cs	Tl	Cr	Mo	Co	Ni	Cu	Ag	Zn	Cd	Pb	As	Sb	Se
Recommended pH for Elution	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fraction Element is found	A	A	TM	TM	TM	TM	TM	TM	A	TM	TM	TM	A	A	A
Method of Analysis	FLAA	FLAA	ICP	GFAA/ MSA	ICP	ICP	ICP	ICP	GFAA/ MSA	ICP	ICP	ICP	GFAA/ MSA	ICP	GFAA/ MSA
Detection Limit (mg/t)	0.01	0.06	0.006	0.006	0.006	0.006	0.02	0.006	0.01	0.006	0.003	0.03	0.005	0.05	0.005

A = Anionic Fraction (with sample subtraction)
TM = Transition Metal Fraction (with sample subtraction)
GFAA = Graphite Furnace Atomic Absorption
ICP = Inductively Coupled Plasma
MSA = Method of Standard Addition
FLAA = Flame Atomic Absorption

INTERNATIONAL TECHNOLOGY CORPORATION

Memorandum

To: M. Lyon

Date: January 6, 1989

From: D. L. Waldschmidt

Subject: **Chelex 100 Separation**

IT Analytical Services (ITAS) is submitting a report for the above study.

Results are presented in the enclosed tables. Elements were analyzed according to the methods specified in Report #4, Table #5.

Should you have any questions or require additional information, please contact me at the Pittsburgh Laboratory.

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SEPARATION 5A
METAL ANALYSIS SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001

PARAMETER	UNITS	SAMPLE IDENTIFICATION WIPP 19 Anionic Fraction	Alkaline Alkali. Fraction	Transition Metal Fraction
Antimony	mg/L	1.08	0.12	ND0.03
Arsenic	mg/L	ND0.020	ND0.004	ND0.003
Cadmium	mg/L	0.068	ND0.004	ND0.003
Cesium	mg/L	ND0.24	ND0.05	ND0.04
Chromium	mg/L	ND0.020	ND0.004	0.006
Cobalt	mg/L	0.100	ND0.009	ND0.007
Copper	mg/L	0.11	ND0.009	0.013
Lead	mg/L	0.55	ND0.04	ND0.03
Lithium	mg/L	0.73	0.009	ND0.007
Molybdenum	mg/L	0.24	0.028	0.024
Nickel	mg/L	0.18	ND0.03	ND0.02
Selenium	mg/L	ND0.040	ND0.044	ND0.007
Silver	mg/L	ND0.020	ND0.004	ND0.003
Titanium	mg/L	0.060	ND0.009	ND0.007
Zinc	mg/L	ND0.040	ND0.009	0.051

mg/L = milligrams per liter or parts per million.

ND denotes that the compound is not detected at or above the indicated detection limit.

SEPARATION 5B
METAL ANALYSIS SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001

PARAMETER	UNITS	SAMPLE IDENTIFICATION WIPP 19 Anionic Fraction	Alkaline Alkali Fraction	Transition Metal Fraction
Antimony	mg/L	1.10	0.10	ND0.04
Arsenic	mg/L	ND0.020	ND0.004	ND0.004
Cadmium	mg/L	0.068	ND0.008	ND0.004
Cesium	mg/L	ND0.24	ND0.05	ND0.05
Chromium	mg/L	ND0.020	ND0.004	0.006
Cobalt	mg/L	0.096	ND0.008	ND0.008
Copper	mg/L	0.068	ND0.008	0.110
Lead	mg/L	0.53	ND0.04	ND0.04
Lithium	mg/L	0.68	0.015	ND0.008
Molybdenum	mg/L	0.24	0.024	0.029
Nickel	mg/L	0.16	ND0.02	ND0.03
Selenium	mg/L	ND0.040	ND0.039	ND0.008
Silver	mg/L	ND0.020	ND0.004	ND0.004
Titanium	mg/L	0.056	ND0.008	ND0.008
Zinc	mg/L	ND0.04	ND0.008	0.147

mg/L = milligrams per liter or parts per million.

ND denotes that the compound is not detected at or above the indicated detection limit.

SEPARATION 5C
SPIKE PERCENT RECOVERY SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001
Based on 1st Run

SAMPLE IDENTIFICATION

PARAMETER	Anionic Fraction	WIPP-19 Alkaline Alkali Fraction	Transition Metal Fraction	
		Percent Recovery		
Antimony	66%	2.2%	16%	84.2
Arsenic	58%	5.2%	52%	115.2
Cadmium	0.2%	0%	100%	100.2
Cesium	185%	0%	5.0%	190
Chromium	0%	0%	129%	129
Cobalt	0%	0%	100%	100
Copper	31%	0%	106%	137
Lead	0%	0%	92%	92
Lithium	84%	1.9%	0%	85.9
Molybdenum	0%	0%	102%	102
Nickel	0%	0%	98%	98
Selenium	90%	8%	11%	109
Silver	134%	5.0%	3.8%	142.8
Titanium	0%	0%	94%	94
Zinc	0%	0%	96%	96

SEPARATION 6A
METAL ANALYSIS SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001

PARAMETER	UNITS	SAMPLE IDENTIFICATION Method Blank Anionic Fraction	Alkaline Alkali Fraction	Transition Metal Fraction
Antimony	mg/L	ND0.20	ND0.04	ND0.04
Arsenic	mg/L	ND0.020	ND0.004	ND0.004
Cadmium	mg/L	ND0.020	ND0.004	ND0.004
Cesium	mg/L	ND0.24	ND0.05	ND0.04
Chromium	mg/L	ND0.020	ND0.004	ND0.004
Cobalt	mg/L	ND0.040	ND0.008	ND0.007
Copper	mg/L	ND0.040	ND0.008	ND0.007
Lead	mg/L	ND0.020	ND0.040	ND0.040
Lithium	mg/L	ND0.040	ND0.008	ND0.007
Molybdenum	mg/L	ND0.040	ND0.008	ND0.007
Nickel	mg/L	ND0.12	ND0.02	ND0.02
Selenium	mg/L	ND0.040	ND0.008	ND0.007
Silver	mg/L	ND0.020	ND0.004	ND0.004
Titanium	mg/L	ND0.040	ND0.008	ND0.007
Zinc	mg/L	ND0.04	ND0.008	ND0.007

mg/L = milligrams per liter or parts per million.

ND denotes that the compound is not detected at or above the indicated detection limit.

SEPARATION 6B
METAL ANALYSIS SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001

PARAMETER	UNITS	SAMPLE IDENTIFICATION H08B Anionic Fraction	H08B Alkaline Alkali Fraction	H08B Transition Metal Fraction
Antimony	mg/L	ND0.2	0.04	ND0.03
Arsenic	mg/L	ND0.020	ND0.018	ND0.003
Cadmium	mg/L	ND0.020	ND0.004	ND0.003
Cesium	mg/L	ND0.24	ND0.04	ND0.04
Chromium	mg/L	ND0.020	ND0.004	0.005
Cobalt	mg/L	ND0.04	ND0.007	ND0.007
Copper	mg/L	ND0.04	ND0.007	0.11
Lead	mg/L	ND0.20	ND0.04	ND0.03
Lithium	mg/L	0.12	0.011	ND0.007
Molybdenum	mg/L	ND0.04	0.01	0.008
Nickel	mg/L	ND0.12	ND0.02	0.03
Selenium	mg/L	ND0.04	ND0.007	ND0.007
Silver	mg/L	ND0.020	ND0.004	(ND0.003)
Titanium	mg/L	ND0.04	ND0.007	ND0.007
Zinc	mg/L	ND0.04	0.008	0.24

mg/L = milligrams per liter or parts per million.

ND denotes that the compound is not detected at or above the indicated detection limit.

SEPARATION 6C
SPIKE PERCENT RECOVERY SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001

SAMPLE IDENTIFICATION

PARAMETER	Anionic Fraction	HO8B Alkaline Alkali Fraction	Transition Metal Fraction	
		Percent Recovery		
Antimony	108%	3.8%	7.1%	118.9
Arsenic	69%	0%	6.8%	75.8
Cadmium	0%	0%	92%	92
Cesium	125%	0%	0%	125
Chromium	0%	0.8%	109%	109.8
Cobalt	0%	0%	95%	95
Copper	0%	0%	90%	90
Lead	0%	0%	79%	79
Lithium	100%	25%	0%	125
Molybdenum	0%	0.8%	95%	95.8
Nickel	0%	0%	85%	85
Selenium	91%	0%	10%	101
Silver	0.9%	6.2%	66%	73.1
Titanium	0%	0%	89%	89
Zinc	0%	0.3%	74%	74.3

SEPARATION 6D
SPIKE PERCENT RECOVERY SUMMARY
FOR DOE-WIPP
PROJECT NO. 301001

PARAMETER	SAMPLE IDENTIFICATION: Anionic Fraction	H08B Alkaline Alkali Fraction	Transition Metal Fraction	
	Percent Recovery			
Antimony	101%	3.8%	5.0%	109.8
Arsenic	98%	0%	35%	133
Cadmium	0%	0%	89%	89
Cesium	118%	0%	0%	118
Chromium	0%	8.8%	96%	104.8
Cobalt	0%	0%	91%	91
Copper	0%	0%	91%	91
Lead	0%	0%	80%	80
Lithium	102%	2.5%	0%	104.5
Molybdenum	0%	0.4%	96%	96.4
Nickel	0%	0%	86%	86
Selenium	84%	0%	10%	94
Silver	5%	7.5%	90%	1025
Titanium	0%	0%	84%	84
Zinc	0%	1.5%	69%	70.5

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Separation of Eight Transition Elements from Alkali and Alkaline Earth Elements in Estuarine and Seawater with Chelating Resin and Their Determination by Graphite Furnace Atomic Absorption Spectrometry

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A method is described for determining Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn in seawater using Chelex 100 resin and graphite furnace atomic absorption spectrometry. The pH of the seawater is adjusted to 5.0 to 5.5 and then passed through a Chelex 100 resin column. Alkali and alkaline earth metals are eluted from the resin with ammonium acetate and then the trace elements are eluted with two 5-mL aliquots of 2.5 M HNO_3. The difficulties previously encountered with resin swelling and contracting have been overcome. By careful selection of the instrumental conditions, it is possible to determine subnanogram levels of these trace elements by graphite furnace atomic absorption spectrometry. The proposed method has been shown to separate quantitatively the elements desired from the alkali and alkaline earth metals and has been applied in the analysis of trace elements in estuarine water from the Chesapeake Bay and seawater from the Gulf of Alaska.

The literature of marine water analysis reflects the considerable difficulty in establishing an accurate and precise method of analysis for trace metals. A seawater matrix defies a simplified approach. For example, specific sampling techniques, container contamination, suspended particulate matter, and analytical techniques have to be considered. It is beyond the scope of this paper to discuss all of these parameters; however, the solving of the analytical problem is of little value unless a representative sample can be obtained, free of contamination and properly stored until analysis.

In recent years, methods have been developed to determine trace elements in seawater by X-ray fluorescence (*1*), neutron activation (*2*, *3*), spectrophotometry (*4*), anodic stripping voltammetry (*5*), and atomic absorption spectrometry (*6–8*). However, each of these analytical techniques requires a preliminary separation. Fabricand et al. (*9*) reported the direct determination of Cu, Fe, Mn, Ni, and Zn in seawater by atomic absorption spectrometry (AAS) using an air–acetylene flame, but other workers have reported difficulties using their technique because of light scattering and burner clogging.

Except for neutron activation analysis and anodic stripping voltammetry, no analytical techniques are currently available for the direct determination of trace elements in seawater at concentrations below 5 $\mu g\ L^{-1}$. Usually it is necessary to preconcentrate the trace elements from a large volume and separate the transition elements from the alkali and alkaline earth elements. In such sample preparations, the efficiency of concentration, completeness of separation, and total analytical blank become critical to the final instrumental method (*10*).

Preconcentration techniques which have been used are coprecipitation (*11*), chelation and extraction (*12*), and chelating ion-exchange resin (*10*, *13*). Most of these isolation methods require large volumes of chemicals which can lead to high blanks unless the reagents have been carefully purified.

Of the presently used preconcentration techniques, Chelex 100 chelating resin has been shown to be efficient and yields low analytical blanks (*14*). Applications of Chelex 100 resin for trace metal preconcentration from seawater have been reviewed by Riley and Skirrow (*10*). Chelex 100 is a strong chelator and removes metal ions from most known naturally occuring chelators in seawater (*14–16*). The resin will not, however, remove metals held in organic and inorganic colloids which can be present even after ultrafiltration. Precautions

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Table I. Instrumental Parameters

		P & E 603		HGA-2100			
element	wavelength, nm	SBW, nm	scale expansion	drying, T-sec[c]	charring T-sec	atomization T-sec	gas
Cd	228.8	0.7	1	100-30	200-20	2100-7	Ar[a]
Co	240.7	0.2	2	100-30	500-30	2700-7	Ar[a]
Cu	324.7	0.7	1	100-40	700-30	2500-6	Ar[a]
Fe	248.3	0.2	2	100-30	600-30	2700-7	Ar[a]
Mn	279.5	0.7	2	100-30	300-30	2700-7	Ar[a]
Ni	232.0	0.7	5	100-30	1000-30	2700-6	Ar[a]
Pb	283.3	0.7	3	100-40	400-30	2200-7	Ar[b]
Zn	213.9	0.7	0.5	100-30	500-20	2000-7	Ar[b]

[a] Interrupt mode. [b] Normal mode. [c] Note: T = temperature.

must be taken to destroy such colloids prior to collection of the ions by the resin. Florence and Batley have destroyed interfering organic colloids by the addition of 0.16 M nitric acid and heat and also by using ultraviolet irradiation of the sample prior to collection by the resin (*15*, *16*). While excellent recovery and low analytical blanks are achieved, a relatively high concentration of Na, K, Ca, and Mg are retained with the trace metals. The concentration of these interfering alkali and alkaline earth salts in the final sample are in milligram quantities, as compared to the microgram and submicrogram quantities of concentrated trace metals. The alkali and alkaline earth ions occupy the resin sites not occupied by the transition metals and are co-eluted with the metals when using acids (*13*).

The complete separation of the alkali and alkaline earth metals from the trace metals in seawater has not been previously accomplished using Chelex 100, which has restricted its use. While the salts remaining after preconcentration do not interfere with instrumental techniques such as flame atomic absorption (*10*) or polarography (*15–17*), they do inhibit instrumental techniques which are more susceptible to matrix interelement effects such as flameless atomic absorption (*18*), neutron activation analysis (*19*), optical emission spectrometry using inductively coupled plasma or electrode plasma (dc arc) (*20*), and spark source mass spectrometry (21).

With the development of the graphite furnace for AAS, it is now possible to determine 10^{-9} to 10^{-12} g of many of the trace elements in seawater. However, the high salt content (35 g/kg) in marine water makes it difficult to effectively volatilize the matrix without loss of analyte. The major component in seawater is sodium chloride which has a relatively high volatilization temperature. Also, the trace metals in seawater are present as chlorides, which have a lower volatilization temperature. Therefore, it is difficult to volatilize the sodium chloride during the ashing step without losses of the analyte. Calcium and magnesium chloride are also present in seawater in large quantities and a temperature greater than 2000 °C is required to volatilize these elements. Thus, even if the sodium chloride is removed during the ashing step using matrix modification (*22*), residual calcium and magnesium chlorides remain to interfere with the analyte during atomization.

The research presented here describes a technique for the separation and preconcentration of Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn from Na, K, Ca, and Mg in seawater using a Chelex 100 resin column and the subsequent determination of these trace elements by graphite furnace atomic absorption spectrometry (GFAAS).

EXPERIMENTAL

Reagents. High purity water, nitric and glacial acetic acids were prepared using subboiling distillation at the National Bureau of Standards (NBS) (*23*). All reagents used in the separation process were prepared and stored in clean FEP Teflon bottles unless otherwise stated.

Ammonium hydroxide was prepared by bubbling filtered ammonia gas through high purity water until room temperature saturation was achieved.

A 1.0 M ammonium acetate solution was prepared by mixing 60 g of purified glacial acetic acid and 67 g of saturated NH_4OH and diluting to 1 L in a polypropylene volumetric flask. The acidity was adjusted to pH 5.0 by dropwise addition of HNO_3 and/or NH_4OH. All reagent and sample preparations were done in a class 100 clean air laboratory (*24*).

Chelex 100 chelating resin, 200–400 mesh size, was purchased from Bio-Rad Laboratories.

The radioactive tracers ^{59}Fe, ^{54}Mn, and ^{65}Zn in 0.5 N HCl were purified reagents obtained from the Chemical and Radioisotope Division of ICN. The ^{57}Co, and the short lived isotopes, ^{64}Cu and ^{65}Ni, were made by the Neutron Activation Analysis Group at NBS from "five-9's" pure metals and dissolved in nitric acid. The ^{109}Cd and ^{210}Pb were obtained by the Activation Analysis Group from other sources and analyzed using pulse height analysis for radiochemical purity before use.

All standard stock solutions for AAS were prepared from high purity metals or salts in subboiling distilled NBS acids as described by Dean and Rains (*25*). Working solutions were prepared as needed.

Counting Apparatus. The γ-ray counting of the elemental tracers was done utilizing a 7.6 cm × 7.6 cm NaI(Tl) crystal and associated electronics.

Seawater. The seawater was obtained during high tide at the Virginia Institute of Marine Science (VIMS), Gloucester Point, Va., on the Chesapeake Bay. The sample was collected with a submersible pump and plastic tubing permanently submerged approximately 100 m offshore from the Institute. The seawater was pumped directly into a conventional polyethylene drum which had been cleaned first with hydrochloric and then with nitric acid and purified water prior to use (*26*). After filtration through a 0.45-μm millipore filter using an all polypropylene filter apparatus, the seawater was collected in a polyethylene carboy and acidified (to 0.6 M in HNO_3) with high purity HNO_3 to prevent bacterial growth, to stabilize the trace element concentrations (*27*, *28*), and to strip any trace elements bound by colloidal particles (*15*, *16*).

AAS Apparatus. The instrumental system used in this study consists of a Perkin-Elmer Model 603 atomic absorption spectrometer with HGA-2100 graphite furnace (GFAAS). The 25-μL aliquot of sample was introduced into the furnace with the AS-1 autosampler. The instrumental parameters are given in Table I.

Column Separation Apparatus. The Isolab QS-Q polypropylene column with porous polyethylene resin support was used for 100-mL and 1-L sample volumes. Although the same column was used for both sample volumes, the amount of resin and reservoir systems were entirely different. For the 100-mL sample, the QS-S 25-mL conventional polyethylene extension funnel was attached to the column to act as a reservoir for the sample.

For a 1-L sample the reservoir was a 1-L Teflon (FEP) bottle inverted and modified with a machined Teflon (TFE) closure insert containing a microbore venting tube and outlet tube. The outlet was connected to a valve (TFE) by 1.59-mm ($^1/_{16}$ in.) i.d. Teflon (FEP) tubing connector and linked to the reservoir with a specially machined mount (TFE) which sealed the column into the closed system. The mount contained a vent (sealed with nylon

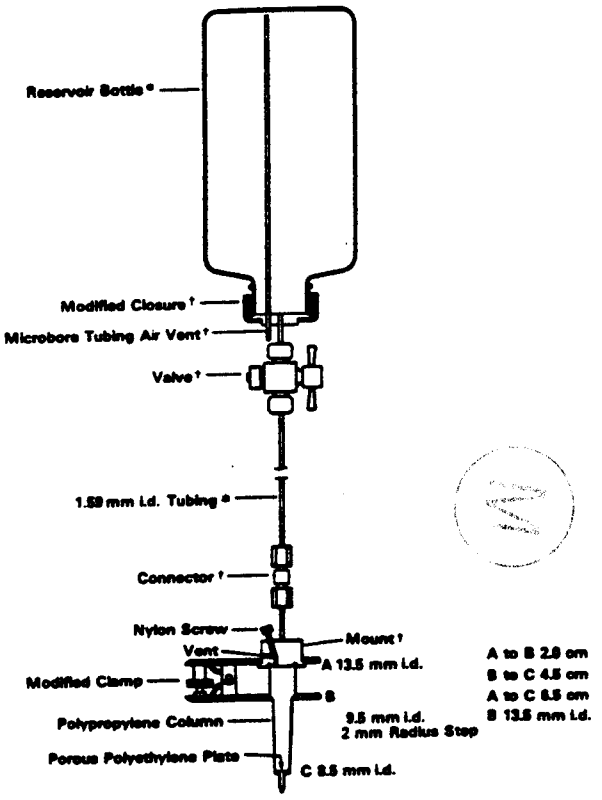

Figure 1. Apparatus used for holding and delivering large volumes of seawater at a controlled rate to Chelex 100 resin. The apparatus (excluding the column and clamp) was fabricated from Teflon FEP (*) or Teflon TFE (†) which has desirable nonwetting and noncontaminating properties

screw, allowing the removal of air from the system) as well as an inlet and was tightly clamped to the column using the lip on the column at point B (See Figure 1). The clamp (a modified glass joint clamp) and mount provided a seal which allowed the reservoir to be raised above the column to obtain enough pressure to control the flow rate using the pressure of the raised reservoir and the valve (Figure 1).

Column Preparation and Purification Procedure. The column preparation procedure consisted of precleaning the columns in 1:4 HCl and then in 1:4 HNO_3 for one week in each bath and then rinsing the columns with water after each acid wash. The column was loaded with a slurry of Chelex 100 resin, 200–400 mesh size (sodium form). For 100-mL seawater samples, 3.2 to 3.4 mL of resin was used which covered the lower barrel of the column from point B to point C in Figure 1. For 1-L samples, 5.8 to 5.9 mL of resin was used which filled the column from point A to point C in Figure 1. The resin was washed with 15 to 20 mL of 2.5 M HNO_3 (for the small and large resin volumes, respectively), in 5-mL portions to elute any trace metal contamination present in the resin. Then two 5-mL volumes of water were used to rinse the resin of excess acid. To transform the resin to the NH_4^+ form, 10 to 15 mL of 2.0 M NH_4OH was added in 5-mL volumes. After checking the pH of the effluent to ensure basicity, the column was then rinsed with 10 to 15 mL of water to remove the excess NH_4OH.

Column Preconcentration and Separation Procedure. For the 100-mL seawater sample, 101.8 ± 0.2 g was weighed directly into a clean 250-mL Teflon (FEP) beaker and the pH adjusted to 5.0 to 5.5 with the dropwise addition of NH_4OH. If a spike (natural or radiochemical) was to be added, it was added prior to the adjustment of the pH to equilibrate the ions in the acid media; the solution was allowed to equilibrate for a minimum of 1 h after the addition of any spike. Then 0.5 mL of 8 M ammonium acetate was added to aid in buffering the system. Any necessary agitation of the solution was done with a Teflon stirring rod. A small amount of the seawater was added to the reservoir and column to allow the resin to undergo its natural shrinkage as it changes ionic form and pH. This shrinkage results in a resin volume of approximately one half of its original volume. After the completion of this transformation was observed (2 to 3 min), the remaining seawater was added to the reservoir as needed to keep it filled; the flow rate was approximately 0.8 mL/min. To selectively elute Na, K, Ca, and Mg, and replace them with NH_4^+, 40 mL of 1.0 M ammonium acetate was added to the column in 10-mL aliquots. At the completion of the ammonium acetate addition, 10 mL of water was added to remove residual ammonium acetate. The transition metals were then eluted using 7 mL of 2.5 M HNO_3 and collected into clean preweighed 10-mL conventional polyethylene bottles. The bottles were capped with clean polyethylene lined caps and reweighed to determine the weight of the effluent accurately.

The procedure for the 1-L samples was the same as the 100-mL samples with minor alterations due to the apparatus (see above). The sample (1018.0 ± 0.5 g) was weighed into a 1-L Teflon (FEP) bottle and the pH adjusted in the same manner as previously described. The bottle became the reservoir and was fitted with a modified closure (see Figure 1). The bottle was inverted and the air purged from the system by means of the vent on the column mount. The flow rate was adjusted using the valve and the height of the reservoir. The flow rate was kept to less than 0.2 mL/min until the shrinkage of the resin was complete. Then the flow rate was increased to 1.0 mL/min and left overnight to flow through the column. After passing the sample through the column, the valve and tubing were removed at the connector above the column mount and replaced with a smaller reservoir containing 70 mL of 1.0 M ammonium acetate. The flow rate was adjusted to 0.5 mL/min until the reagent was exhausted. The resin was then washed with 10 mL of water. The transition metals were eluted with two 5-mL portions of 2.5 M HNO_3 into preweighed polyethylene bottles as previously described.

RESULTS AND DISCUSSION

Effect of Direct Injection of Seawater into Electrothermal Device. From the detection limits published in the literature for GFAAS, it could be assumed that several of the heavy metals in seawater could be determined by direct injection of the sample into the electrothermal device. However, in reality this has not been proved to be true unless the samples are taken from heavily polluted areas. A sample from the Chesapeake Bay was analyzed for Cd, Co, Cu, Mn, Ni, Pb, and Zn by direct injection into the graphite furnace by AAS. Only lead and nickel produced absorption signals of any analytical value. The other elements could not be detected. This is due in part to the highly depressing effect of the matrix on the analyte signal which can vary by a factor of 2 to 10 depending upon the analyte. Also, when the sample is evaporated, a small amount of solution may be trapped in the salt crystal lattice which could result in losses due to splattering during the atomization cycle.

The absorbances obtained for lead and nickel were very erratic due to the smoke produced during atomization. Ediger et al. (22) used matrix modification with ammonium nitrate to assist in the removal of sodium chloride; however, the method of standard addition was necessary to correct for interferences. In applying their method of matrix modification to the Chesapeake Bay sample, Cd, Co, Cu, Fe, Mn, and Zn were still not detected.

Separation of Calcium and Magnesium from Analytes on Chelex 100. To effect a separation of calcium and magnesium from the trace elements on the Chelex 100 resin column, it is necessary to choose a separating agent that can be purified to produce a low analytical blank. Also, the separating agent should not produce any adverse effects on the analytes in the GFAAS analysis. The ammonium ion reacts similarly to the alkali elements, and ammonium nitrate or acetate can be produced from high purity reagents.

While both ammonium nitrate and ammonium acetate remove sodium and potassium at identical rates, ammonium nitrate produced tailing of the calcium and magnesium which

Table II. Concentration of Alkali and Alkaline Earth Metals in Seawater before and after Separation on Chelex 100 Resin Column

	μg/mL			
sample	Na	K	Ca	Mg
original	6200	267	283	742
	after separation[a]			
wash[b]				
H_2O	320	10	350	63.
NH_4NO_3	0.3	0.7	83	1.3
NH_4COOCH_3	1.0	2.0	0.25	<0.05

[a] 100 mL of seawater preconcentrate into 7 mL of 2.5 M HNO_3. [b] Column washed with 50 mL of a given eluent.

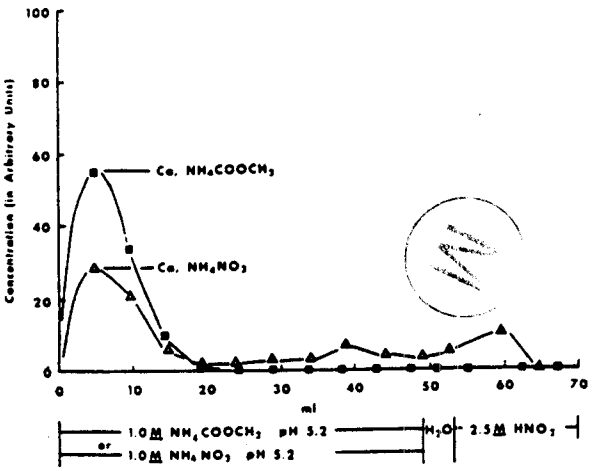

Figure 2. Comparison of ammonium acetate vs. ammonium nitrate for the separation of calcium from a Chelex 100 resin column which has previously chelated 100 mL of seawater

left appreciable quantities of these alkaline earths in the final HNO_3 effluent (Figure 2) (Table II). However, ammonium acetate eluted calcium and magnesium from the column with tailing of only 1 to 2 bed volumes (Figure 2). Manganese, which has the smallest selectivity coefficient of the transition metals of interest, was not eluted at pH 5.0 by ammonium acetate or ammonium nitrate. A relatively high concentration of ammonium acetate in the 2.5 M HNO_3 effluent produced a suppression of several of the analytes by GFAAS; however, the problem was alleviated by washing with 5 to 10 mL of water prior to the stripping of the column with the 2.5 M HNO_3 (Figure 2).

There is a contribution to the removal of calcium and magnesium from the resin by the acetate anion which does not appear with the nitrate ion. Sodium and potassium are replaced by the ammonium ion, but this cation is only partially responsible for the complete separation of chelated calcium and magnesium using ammonium acetate.

Effect of pH on the Separation. A study of the pH of the separating agent (1 M ammonium acetate) showed that a minimum pH of 5.0 was required to retain the transition metal ions on the Chelex 100 resin while removing the alkali and alkaline earth ions. Below pH 5.0, it was found that the transition metals were eluted by the 1 M ammonium acetate. From pH 5.0 to 5.5, the transition metals Cd, Co, Cn, Fe, Mn, Ni, Pb, and Zn were retained by the resin while the Na, K, Ca, and Mg were quantitately eluted (see Figure 3).

The chelating efficiency of Chelex 100 increases for the transition metals from pH 4 to 5 and reaches an optimum at

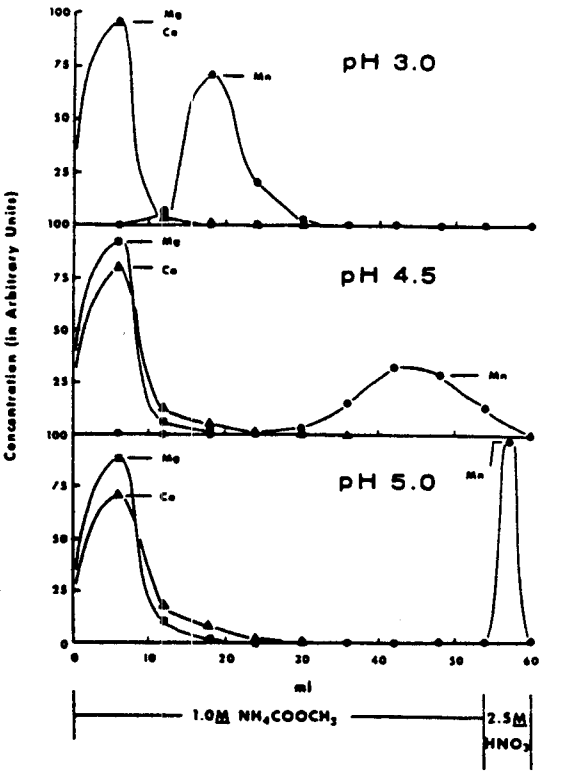

Figure 3. Comparison of ammonium acetate elution of Ca, Mg, and Mn in the pH range of 3.0 to 5.0. The graph depicts percent of the total column content of an element eluted with volume

approximately pH 5.0. For most of the transition elements, this optimum efficiency remains for an increase of several pH units. However, the chelating efficiency of Chelex 100 for Co and Cu has been shown to decrease above pH 6.0 (*29–32*).

The chelation efficiency of Chelex 100 for Ca and Mg has been reported to be similar to those of the transition metals increasing with pH to a maximum at pH 5 in low ionic strength solutions (*30, 33*). However, in high ionic strength solutions of sodium chloride, there exists a minimum in the chelation of Chelex 100 for both Ca and Mg from pH 5.0 to 5.8. Above pH 5.8 the chelating efficiency for Ca and Mg increases sharply (*33*).

From our experimental results and the literature, a working range of pH 5.0 to 5.5 was established for both the preconcentration of the transition elements from the seawater and the elution of the alkali and alkaline earth elements from the resin using the ammonium acetate.

Separation Parameters for Both 100-mL and 1-L Seawater Samples. The separation parameters, as described in the Procedure section, are represented graphically for a 100-mL sea water sample in Figure 4, and for a 1-L sample in Figure 5. The difference between the two systems is approximately double the amount of resin for the 1-L sample. The larger amount of resin was found to be necessary for quantitative retention of this larger volume, but is still rather small considering a 10-fold increase in the total ionic content of the larger sample. An increased volume of ammonium acetate was required for the removal of the greater quantity of salts occupying more residual sites. Also, a larger volume of water is required to wash the residual ammonium acetate from the column prior to transition metal elution with nitric acid. The elimination of ammonium acetate was found to be necessary to prevent both buffering of the acid wash and a suppression of the GFAAS signal caused by the acetate in the subsequent analysis. The acid fraction did not undergo tailing

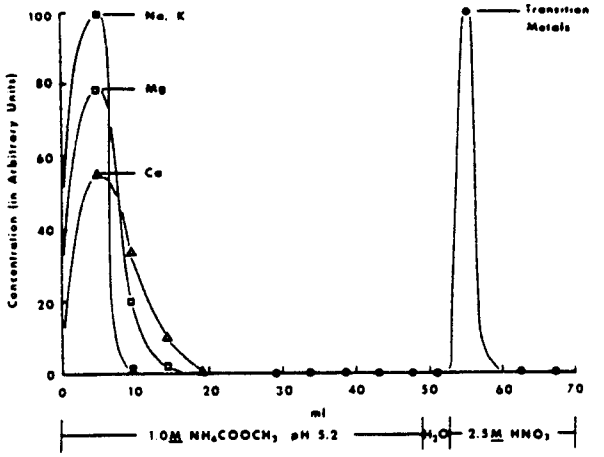

Figure 4. Represents the separation obtained using 1.0 M ammonium acetate at pH 5.0 to 5.5 for the transition metals from Na, K, Ca, and Mg chelated in a column of Chelex 100 from a 100-mL seawater sample

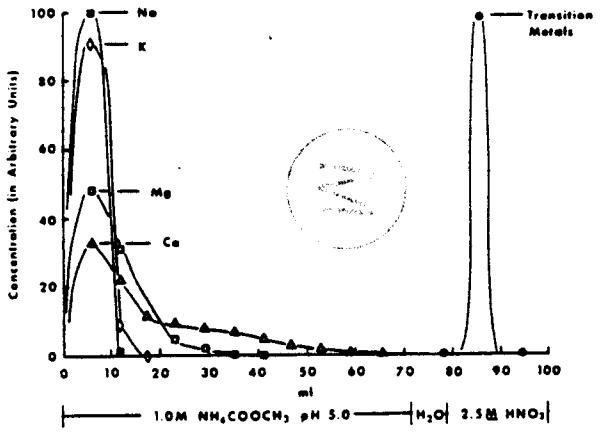

Figure 5. Represents the separation obtained using 1.0 M ammonium acetate at pH 5.0 to 5.5 for the transition metals from Na, K, Ca, and Mg chelated on a column of Chelex 100 from a 1-L seawater sample

from the transition metals as seen by atomic absorption or by radio tracer studies. The Chelex 100 resin in the presence of 2.5 M HNO_3 does not chelate the transition metals and they are eluted simultaneously into a single small volume of acid.

Chelex 100 resin is a dynamic resin, and in the ammonium form at a pH of 7 to 14, the resin shrinks to approximately $^1/_2$ of its original volume when subjected to the seawater sample at pH 5.0 to 5.5. The particle size and subsequent flow rate were also reduced and the use of the column apparatus for 1-L samples became necessary to increase the pressure of the sample to obtain a realistic flow rate for both the sample and ammonium acetate. The flow rate of 1 mL/min was attained by adjusting the Teflon valve and reservoir height simultaneously to control the pressure. The residual volume which would retain any sample in the entire apparatus was estimated at less than 0.10 mL. The use of all Teflon components in contact with the sample affords the nonwetting characteristics and noncontaminating nature of this fluorocarbon which can be scrupulously cleaned in acid (*26*). Another important benefit of this apparatus is that during the preconcentration onto the Chelex 100, the sample and column are protected from contamination from the environment; the only entrance into the system is a microbore tube which can be fitted with a filter to exclude particulate contamination. These characteristics make the column apparatus very attractive for field or shipboard use to prevent contamination.

Radiochemical Study. Radiochemical tracers were used to gain specific information about the behavior of each ion during preconcentration and separation using the Chelex 100. The tracers were added to the seawater as one radioisotope per sample prior to the pH adjustment. The column procedure was identical in all respects to the preparation of the analytical samples previously described. However, all effluent from the column was collected, including the seawater. The seawater, ammonium acetate buffer, acid effluent, and column resin were collected in polyethylene bottles. The 1-L samples were collected in 250-mL bottles and the 100-mL samples were collected in 125-mL bottles. Distilled water was added to the bottles prior to measurement to make all liquid levels the same to give constant counting geometry.

The samples were counted for 10-min periods for γ radiation only (Table III). The counting statistics for each element were optimized by energy discrimination. The concentration of tracers used gave from 10^6–10^7 counts in a 10-min period while background was kept to 10^2–10^3 counts during the same period. The statistical error was obtained using the following equation (*34*, *35*):

$$Q_c = 100 \times \frac{k}{N_s - N_b}\sqrt{N_s + N_b}$$

where Q_c = percent experimental error corrected for background, k = number of standard deviations, N = cpm = counts per minute or period unit time, s = sample including background, and b = background.

This technique enabled the use of ^{64}Cu and ^{65}Ni short-lived isotopes as well as ^{59}Fe and ^{54}Mn intermediately-lived isotopes since counting of all fractions could be completed in 40 min. The error caused by the decay of these isotopes over the course of the experiment was eliminated; nickel which has a half life of only 2.6 h, decayed beyond usefulness over the 1-day period of the 1-L experiment.

The counting technique was checked for total recovery using ^{65}Zn. The tracer was added to 250 mL of the seawater sample and counted prior to manipulation. This volume was then added to 750 mL of seawater and treated as a 1-L ^{65}Zn spiked seawater sample. The final acid volume was then counted at the end of the separation as previously described. The total quantity obtained agreed for both the acid fraction and total recovery, 99.99 ± 0.12 and 100.1 ± 0.12, respectively. Thus, the counting of all effluent fractions and the column itself allows the specific identification of all losses, as well as the total recovery of the element of interest in the acid fraction.

The ammonium acetate separation did not remove a detectable amount of any trace metal with the possible exception of Fe which could have been in the residual volume from the seawater effluent. Thus, the separation does not affect the maximum efficiency of the concentration alone, and the Na, K, Ca, and Mg can be eliminated with the same efficiency as the traditional concentration alone.

The majority of any minute losses Pb 1.4%, Co 0.3%, and Fe 6.3% is due to incomplete removal of the transition metal ions from the seawater. The chelation efficiency of both ^{60}Co and ^{59}Fe was studied by Callahan et al. (*32*). They found that the two oxidation states of cobalt and iron reacted similarly and that 100% retention of cobalt and iron could only be achieved by reduction of Co(III) to Co(II) and Fe(III) to Fe(II) using sodium dithionite ($Na_2S_2O_4$) at pH 5.0 to 5.3. In natural seawater the approximate concentration of Co(II) was found to be 96% of the total cobalt. They obtained 96 to 99% retention for cobalt and 95% for iron without any attempt to reduce the trivalent ions, which is in agreement with our findings.

The radiochemical tracer experiments for Cd, Cu, Fe, Ni, and Zn were repeated several times and all values fell within the calculated error limits with the exception of those for iron.

Table III. Recovery and Characterization of Selected Transition Elements in Seawater Using Chelex 100

	sample, 100 mL[a]				sample, 1 L[a]			
	loss, %			recovery, %	loss, %			recovery, %
element	seawater effluent	1.0 M NH_4COOCH_3, effluent	column and resin	2.5 M HNO_3, effluent	seawater effluent	1.0 M NH_4COOCH_3, effluent	column and resin	2.5 M HNO_3, effluent
^{106}Cd	<0.06	<0.06	<0.06	99.99 ± 0.071	<0.02	<0.06	<0.012	99.99 ± 0.063
^{65}Zn	0.039 ± 0.007	<0.02	<0.02	99.96 ± 0.097	<0.01	<0.03	<0.04	99.99 ± 0.12
^{54}Mn	<0.048	<0.02	<0.006	99.99 ± 0.11	...	...	...	...
^{63}Ni	0.09 ± 0.005	<0.004	<0.004	99.91 ± 0.083	...	...	...	...
^{64}Cu	0.03 ± 0.001	<0.002	<0.02	99.97 ± 0.030	0.17 ± 0.006	<0.007	0.01 ± 0.003	99.82 ± 0.069
^{210}Pb	1.4 ± 0.10	<0.01	0.2 ± 0.13	98.4 ± 0.48	2.15 ± 0.14	<0.06	0.12 ± 0.08	97.7 ± 0.39
^{60}Co	0.3 ± 0.04	<0.03	0.17 ± 0.03	99.5 ± 0.3	1.7 ± 0.05	0.03 ± 0.01	0.9 ± 0.02	97.3 ± 0.2
$^{59}Fe^b$	6.3 ± 1.9	0.41 ± 0.01	0.21 ± 0.01	93.1 ± 2.2	6.2 ± 1.9	0.90 ± 0.3	0.31 ± 0.01	92.6 ± 2.2

[a] The uncertenty is based on 1 σ values calculated as described in the text. [b] The uncertainty was increased to show additional uncertainty found in replicate experiments.

Table IV. Trace Elements in Chesapeake Bay

element	concentration, ng/mL[a] blank	seawater
Cd	<0.01	0.05 ± 0.01
Co	<0.1	<0.1
Cu	<0.1	2.0 ± 0.1
Fe	0.2 ± 0.1	2.1 ± 0.5
Mn	<0.1	2.0 ± 0.1
Ni	<0.1	1.2 ± 0.1
Pb	<0.1	0.3 ± 0.2
Zn	<0.05	4.8 ± 0.3

[a] Replicate analysis of four samples.

Iron exhibited a 2% variation around the average value (Table III). This could be due to altered ratios of Fe(II) and Fe(III) between samples tested.

GFAAS Determination of Trace Elements in Seawater from the Chesapeake Bay. The reliability of the proposed separation and preconcentration method was tested by making replicate analyses on a sample of seawater. These samples were processed as described in the Separation and Preconcentration Procedure. Then the 8–10 mL of 2.5 N HNO_3 effluent collected was analyzed for the trace elements by GFAAS. The instrumental conditions for drying, charring, and atomizing (Table I) for each analyte were optimized to obtain the maximum sensitivity and precision with the minimum of interferences. The samples (25 μL) were introduced into the graphite furnace with the AS-1 which improved the precision of the analysis with the minimum amount of contamination. It was necessary to preclean each sample cup from the AS-1 with 20% HNO_3 to remove trace contaminants. Pyrolytic and nonpyrolytic coated graphite tubes were used in this study. The life of the pyrolytic coated tube was extended by a factor of three over the nonpyrolytic coated tube in the presence of 2.5 M HNO_3. Background correction with the deuterium arc lamp was used for each analyte.

For each analysis the hollow cathode lamp was turned on and allowed to stabilize (15 to 60 min). Working standard solutions of each analyte were prepared in 2.5 M HNO_3, and then a three to five point calibration curve was established using the optimum instrumental conditions. After the calibration curve was established, the unknowns were determined using a sample bracketing technique. As a check for chemical interferences, each sample was tested by the single standard addition method (*36*) and no chemical interferences were encountered. The results are given in Table IV. Cobalt was not detected using a 100-mL sample. To obtain an analytical value for cobalt in the Chesapeake Bay Water, a 1-L sample would be required to be separated and preconcentrated. Some difficulty was encounted in the GFAAS determination of iron. Iron is known to form carbides in the graphite furnace which produce erratic results. Also, a high reagent blank was obtained (see Table IV) whereas the reagent blanks for the other elements were below our detection limits. The lead values are close to the detection limit using a 100-mL sample. With a 0.5- to 1-L sample, the precision of the lead analysis could be improved.

Recovery of Trace Elements Added to Chesapeake Bay Seawater. Since there are no samples of seawater with accurate analytical values for the trace elements under study, the accuracy of the GFAAS technique was checked by adding 0.5 to 2.0 ng/mL of the trace elements to six samples of seawater and processed as previously described. Recoveries of 90 to 117% were obtained (Table V). The high recovery value for zinc was due to the low concentration added to the samples. Since zinc is so sensitive by GFAAS, a 1- to 10-fold dilution of the 2.5 M HNO_3 effluent had to be made. Since

Table V. Recovery of Trace Elements Added to Samples of Seawater by GFAAS

element	concentration, ng/mL[a] present	added	found	av. recovery, %
Cd	0.05	0.5	0.54 ± 0.02	98
Co	<0.1	1.0	1.07 ± 0.02	107
Cu	2.0	1.0	2.9 ± 0.07	97
Fe	2.1	2.0	3.7 ± 0.4	90
Mn	2.4	2.0	4.2 ± 0.04	95
Ni	1.2	2.0	3.2 ± 0.1	100
Pb	0.3	1.0	1.4 ± 0.07	108
Zn	4.8	0.5	6.2 ± 0.09	117

[a] Replicate analysis of six samples.

a dilution was required for GFAAS, the original spikes added to the seawater were too low to obtain accurate recoveries. The recoveries of the other trace elements are consistent with the known reproducibility of the GFAAS at these concentration levels.

Application of the Technique to Alaskan Seawater Samples. In addition to the one homogeneous Chesapeake Bay water sample, other seawater samples were also analyzed for Cd, Mn, Ni, and Pb. These samples were obtained from the Gulf of Alaska and ranged in depth from surface to 1500 m. These samples were treated in the same manner and no alteration in the separation technique was necessary. The trace metal concentrations from Alaskan seawater were found to be generally lower in concentration over those of the Chesapeake Bay. The values for Pb and Mn were found to be consistently 1 to 2 orders of magnitude below those reported here for these same elemental concentrations in the Chesapeake Bay.

CONCLUSION

The application of Chelex 100 resin and GFAAS used in this investigation has been shown to provide a new way of determining Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn in seawater. Chelex 100 resin is known to be an efficient means of separating many of the trace elements from the alkali metals; however, by using an ammonium acetate wash, calcium and magnesium are also removed. Calcium and magnesium severely suppress many analytes in GFAAS and, with their removal, the detection limits of many trace elements by GFAAS can be extended to subnanogram per milliliter. In our radiotracer study, the recovery of Cd, Cu, Mn, Ni, and Zn was greater than 99.9% while the recovery of Co, Pb, and Fe was 99.5, 98.4, and 93.1%, respectively. The precision of the technique was limited by the GFAAS measurements which varied with the element and concentration present. Not only has the proposed technique been applied to seawater from the Chesapeake Bay but the method was applied to the determination of Cd, Mn, Ni, and Pb at the ng/mL level in seawater from the Gulf of Alaska.

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APPENDIX B
WATER QUALITY SAMPLING PROGRAM
DATA OUTLIERS

Appendix B contains a tabulation of the data that were determined to be outliers to the WQSP data set. The procedure used to evaluate the data and determine outliers is presented in Section 4.3. The outliers listed in Appendix B were excluded from the data set used to establish Waste Isolation Pilot Plant WQSP background groundwater chemistry (Chapter 5.0). Likewise, the outliers contained in Appendix B were not used in the comparison to standards presented in Chapter 6.0.

Table B-1
Water Quality Sampling Program
Data Outliers

Well	Parameter	Sample Date	Outlier[a] (mg/ℓ)	Remarks
DOE-1	Boron	04/25/85	7.2	Sampling/analytical error[b]
DOE-1	Cesium	04/25/85	8.6	Dilution/decimal point error[c]
DOE-1	Chromium	04/25/85	<0.001	Sampling/analytical error
DOE-1	Molybdenum	07/03/86	0.27	Sampling/analytical error
DOE-1	Nickel	04/25/85	1.9	Dilution/decimal point error
DOE-1	Nitrate	07/28/87	3.4	Sampling/analytical error
DOE-1	Phenolics	04/25/85	<0.002	Sampling/analytical error
DOE-2	Iron	08/27/86	1.4	Sampling/analytical error
DOE-2	Molybdenum	05/19/88	10.0	Dilution/decimal point error
Engle Well	Cobalt	03/04/85	<0.001	Sampling/analytical error
H-02a	Fluoride	04/21/86	14	Dilution/decimal point error
H-03b1	Bromide	07/01/85	23	Sampling/analytical error
H-03b1	Lithium	09/02/87	3.6	Dilution/decimal point error
H-03b1	Sodium	03/16/89	14,500	Dilution/decimal point error
H-03b3	Barium	08/15/90	<2	High detection limit[d]
H-03b3	Cesium	02/04/85	1.6	Dilution/decimal point error
H-03b3	TOX[e]	08/24/87	1.6	Sampling/analytical error
H-04b	Barium	09/11/90	<2	High detection limit
H-04b	Calcium	11/13/86	1,100	Sampling/analytical error
H-04b	Cesium	04/06/89	<10	High detection limit
H-04b	Selenium	09/25/87	<0.5	High detection limit
H-04b	Thallium	04/06/89	<4	High detection limit
H-04c	Calcium	11/04/86	1,100	Sampling/analytical error
H-04c	Cesium	04/21/89	<10	High detection limit
H-04c	pH	10/05/87	6.44 (s.u.)[f]	Sampling/analytical error

See footnotes at end of table.

Table B-1 *(Continued)*

Water Quality Sampling Program
Data Outliers

Well	Parameter	Sample Date	Outlier[a] (mg/ℓ)	Remarks
H-04c	Selenium	07/19/88	<0.5	High detection limit
H-04c	Sodium	10/02/90	3,600	Sampling/analytical error
H-05b	Aluminum	05/21/86	<10	High detection limit
H-05b	Arsenic	08/27/85	6.7	Dilution/decimal point error
H-05b	Barium	08/23/89	<2	High detection limit
H-05b	Barium	05/02/90	<2	High detection limit
H-05b	Beryllium	05/21/86	<0.5	High detection limit
H-05b	Chromium	05/21/86	<3.0	High detection limit
H-05b	Lead	05/21/86	<5	High detection limit
H-05b	Nitrate	08/27/85	0.4	Sampling/analytical error
H-05b	pH	05/02/90	8.33 (s.u.)[f]	Sampling/analytical error
H-05b	Phenolics	05/02/90	0.160	Sampling/analytical error
H-05b	Thallium	05/02/90	<10	High detection limit
H-05b	TOC[g]	05/02/90	9	Sampling/analytical error
H-05c	Barium	09/14/89	<2	High detection limit
H-05c	Barium	05/16/90	<2	High detection limit
H-05c	Chloride	10/24/86	1,600	Sampling/analytical error
H-05c	Selenium	03/03/88	<0.5	High detection limit
H-06b	Arsenic	09/15/85	78	Dilution/decimal point error
H-06b	Barium	07/24/89	<2	High detection limit
H-06b	Barium	02/12/90	<2	High detection limit
H-06b	Cesium	09/15/85	<1	High detection limit
H-06b	Phenolics	02/12/90	0.55	Sampling/analytical error
H-06c	Barium	08/04/89	<2	High detection limit

See footnotes at end of table.

Table B-1 *(Continued)*
Water Quality Sampling Program
Data Outliers

Well	Parameter	Sample Date	Outlier[a] (mg/ℓ)	Remarks
H-06c	Barium	03/15/90	<2	High detection limit
H-06c	Nitrate	08/04/89	7.3	Sampling/analytical error
H-06c	Sodium	10/01/86	1,050	Sampling/analytical error
H-07b1	Arsenic	02/25/87	<0.05	High detection limit
H-07b1	Barium	11/09/90	<2	High detection limit
H-07b1	Chloride	03/27/86	700	Sampling/analytical error
H-07b1	Iron	11/09/90	<1	High detection limit
H-07b1	Molybdenum	04/25/88	<1	High detection limit
H-07b1	Potassium	11/09/90	<50	High detection limit
H-07b1	Selenium	05/19/89	<0.5	High detection limit
H-07b1	TOC	11/09/90	8	Sampling/analytical error
H-08b	Cesium	01/22/86	<1	High detection limit
H-08b	Fluoride	06/08/88	0.2	Dilution/decimal point error
H-08b	Phenolics	06/08/88	0.165	Sampling/analytical error
H-08b	TOC	01/22/86	14	Sampling/analytical error
H-09b	Boron	11/14/85	<0.1	Sampling/analytical error
H-09b	Thallium	01/19/90	<10	High detection limit
H-11b3	Barium	10/25/89	<2	High detection limit
H-11b3	Barium	10/17/90	<2	High detection limit
H-11b3	Boron	06/04/85	13	Sampling/analytical error
H-11b3	Chromium	06/04/85	<0.001	Sampling/analytical error
H-11b3	Lithium	09/15/87	9.5	Dilution/decimal point error
H-11b3	Nickel	06/04/85	1.1	Dilution/decimal point error
H-11b3	Selenium	09/15/87	<5	High detection limit

See footnotes at end of table.

Table B-1 *(Continued)*
Water Quality Sampling Program
Data Outliers

Well	Parameter	Sample Date	Outlier[a] (mg/ℓ)	Remarks
H-11b3	Silica	06/04/86	150	Dilution/decimal point error
H-11b3	TOX	09/15/87	13	Sampling/analytical error
H-12	Arsenic	08/09/85	18	Dilution/decimal point error
H-12	Barium	08/09/85	1.2	Dilution/decimal point error
H-12	Cobalt	08/09/85	2.4	Dilution/decimal point error
H-12	Molybdenum	08/09/85	15	Dilution/decimal point error
H-12	Phenolics	12/14/88	<0.56	Sampling/analytical error
H-12	Zinc	08/09/85	2.2	Dilution/decimal point error
H-15	Iron	05/11/87	<1.0	Sampling/analytical error
H-15	Mercury	11/07/88	<0.4	High detection limit
H-18	Barium	04/10/90	<2	High detection limit
P-14	Cesium	06/18/87	<1	High detection limit
P-17	Nickel	03/17/86	1.1	Dilution/decimal point error
P-17	pH	10/21/87	6.28 (s.u.)	Sampling/analytical error
P-17	Selenium	03/17/86	<1	High detection limit
P-17	Silica	03/17/86	<0.2	Sampling/analytical error
Ranch Well	Calcium	06/20/90	550	Sampling/analytical error
Ranch Well	Lithium	07/27/89	12	Sampling/analytical error
Ranch Well	Nitrate	07/20/90	71	Sampling/analytical error
Twin Wells-Pasture Well	Sulfate	01/30/86	270	Sampling/analytical error
WIPP-19	Barium	11/03/89	<20	High detection limit
WIPP-19	Barium	06/13/90	<2	High detection limit
WIPP-19	Cobalt	11/03/89	<5	High detection limit
WIPP-19	Iodide	11/03/89	18	Dilution/decimal point error

See footnotes at end of table.

Table B-1 *(Continued)*

Water Quality Sampling Program
Data Outliers

Well	Parameter	Sample Date	Outlier[a] (mg/ℓ)	Remarks
WIPP-19	Iron	11/03/89	<10	High detection limit
WIPP-19	Lithium	07/14/87	3.4	Sampling/analytical error
WIPP-19	Molybdenum	11/03/89	<2	High detection limit
WIPP-19	Nitrate	07/14/87	0.9	Sampling/analytical error
WIPP-19	Phenolics	08/29/88	0.097	Sampling/analytical error
WIPP-19	Silica	07/14/87	21	Mixed reporting as SiO_2 and Si[h]
WIPP-19	Vanadium	11/03/89	<5	High detection limit
WIPP-25	Barium	06/27/89	<2	High detection limit
WIPP-25	Molybdenum	03/28/88	<1.0	High detection limit
WIPP-25	Phenolics	03/28/88	0.106	Sampling/analytical error
WIPP-26	Molybdenum	04/14/88	<2	High detection limit

[a] All outlier concentrations in milligrams per liter (mg/ℓ), except where noted.
[b] The value is an outlier due to an undetermined sampling or analytical error.
[c] It is suspected that the value is different by an order of magnitude from the actual value, i.e., the decimal point was incorrectly placed. This could have occurred if the wrong dilution factor was applied in converting the value recorded by the analytical instrument to the reported value.
[d] The method detection limit is high relative to that of other rounds. This is probably due to the dilution of the sample prior to analysis.
[e] TOX = total organic halogen.
[f] s.u. = standard pH units.
[g] TOC = total organic carbon.
[h] It is suspected that the format for reporting silica data was inconsistent. It appears that some of the values were converted to equivalent silica (SiO_2) prior to reporting; while, other values were not converted and probably reflect the silicon concentration, Si, rather than SiO_2. However, the data are always reported as "silica."

Appendix C contains the WIPP WQSP analytical data set used to establish the background groundwater quality. All analyses were performed by IT Analytical Services, with the exception of the major constituent chemistry for 1985 samples from 7 monitoring wells. These data were provided by Bendix.

Table C-1

Analytical Results Analyzed by Bendix Field Engineering Services[a]

Parameter	Units	Well DOE-1 04/25/85[b]	Well DOE-2 03/12/85	Engle Well 03/04/85	Well H-03b1 07/01/85	Well H-03b3 02/04/85	Well H-04b 07/24/85	Well H-11b3 06/04/85
calcium	mg/ℓ	1,700	2,000	590	1,000	1,500	690	1,700
chloride	mg/ℓ	74,000	35,000	230	3,400	30,000	7,400	66,000
magnesium	mg/ℓ	1,600	1,100	150	290	780	430	1,300
potassium	mg/ℓ	1,100	410	5.6	34	430	210	940
sodium	mg/ℓ	46,000	18,000	200	1,500	18,000	5,900	40,000
sulfate	mg/ℓ	7,400	4,000	2,000	2,300	4,800	5,500	7,200

[a] Preliminary analytical results analyzed by Bendix Field Engineering Services for Sandia National Laboratories.
[b] Sample date.

Source: Uhland and Randall, 1986

WATER QUALITY SAMPLING
DATA BASE OF
CHEMICAL ANALYSIS

WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
** AIS															
AIS	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	ALKALINITY (HCO3)		98.0000			100.0000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	ALUMINUM	<	10.0000	<		10.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	ANTIMONY	<	5.0000	<		5.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	ARSENIC	<	0.0500	<		0.0500			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	BARIUM	<	0.5000	<		0.5000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	BERYLLIUM	<	0.5000	<		0.0500			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	BORON		30.0000			30.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	BROMIDE		22.0000			23.0000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	CADMIUM	<	0.5000	<		0.5000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	CALCIUM		1000.0000			1000.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	CESIUM		0.0600			0.0800			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	CHLORIDE		20500.0000		NA	0.0000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	CHROMIUM		2.0000			2.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	COBALT	<	1.0000	<		1.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	COPPER		1.0000			1.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	FLUORIDE		1.4000			1.4000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	IODIDE	<	2.0000	<		2.0000			mg/l		10/28/88	0	IT	GC
AIS	CULEBRA	IRON	<	1.0000	<		1.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	LEAD	<	5.0000	<		5.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	LITHIUM		0.5000			0.5000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	MAGNESIUM		510.0000			520.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	MANGANESE	<	0.5000	<		0.5000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	MERCURY	<	0.0002	<		0.0002			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	MOLYBDENUM		0.1500			0.1500			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	NICKEL	<	3.0000	<		3.0000			mg/l		10/28/88	0	IT	ME
AIS	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l	NO3-N	10/28/88	0	IT	GC

WATER QUALITY SAMPLING
DATA BASE OF
CHEMICAL ANALYSIS

WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
AIS	CULEBRA	PHENOLICS		0.0240		NA	0.0000			mg/l	10/28/88	0	IT	GC
AIS	CULEBRA	PHOSPHATE		0.0100			0.0100			mg/l T-PO4-P	10/28/88	0	IT	GC
AIS	CULEBRA	POTASSIUM		400.0000			420.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	RESIDUE, FILTERABLE @ 180 C		43100.0000			42200.0000			mg/l	10/28/88	0	IT	GC
AIS	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		110.0000			120.0000			mg/l	10/28/88	0	IT	GC
AIS	CULEBRA	SELENIUM	<	0.5000		<	0.5000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	SILICA		3.7000			3.7000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	SILVER	<	1.0000		<	1.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	SODIUM		12600.0000			12400.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	SPECIFIC CONDUCTANCE		61400.0000			60500.0000			umhos/cm@25C	10/28/88	0	IT	GC
AIS	CULEBRA	STRONTIUM		12.0000			12.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	SULFATE		5900.0000			5400.0000			mg/l	10/28/88	0	IT	GC
AIS	CULEBRA	THALLIUM	<	0.5000		NA	0.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	TITANIUM	<	1.0000		<	1.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	TOTAL ORGANIC CARBON		3.0000			3.0000			mg/l	10/28/88	0	IT	GC
AIS	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500			0.0700			mg/l	10/28/88	0	IT	GC
AIS	CULEBRA	VANADIUM	<	1.0000		<	1.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	ZINC	<	1.0000		<	1.0000			mg/l	10/28/88	0	IT	ME
AIS	CULEBRA	pH		7.9400			7.9500				10/28/88	0	IT	GC
** BARN WELL														
BARN WELL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV

APPENDIX C

WASTE ISOLATION PILOT PLANT
WATER QUALITY SAMPLING PROGRAM DATA

WATER QUALITY SAMPLING
DATA BASE OF
CHEMICAL ANALYSIS

WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	04/20/88	2	IT	HP
BARN WELL	DEWEY LAKE	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	04/20/88	2	IT	HP
BARN WELL	DEWEY LAKE	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	ACETONE	<	10.0000		NA	0.0000		T 24	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	ALKALINITY (CO3)		0.0000			0.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	ALKALINITY (HCO3)		270.0000			270.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	ALKALINITY (HCO3)		280.0000			280.0000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	ALKALINITY (HCO3)		280.0000		NA	0.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	ALUMINUM	<	0.2000		<	0.2000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	ALUMINUM	<	2.0000		<	2.0000			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	ANTIMONY		0.0500		<	0.0500	< 0.05	< 0.05	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	ANTIMONY	<	0.0600		<	0.0600			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	ANTIMONY	<	0.0600		<	0.0600			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	ARSENIC		0.0060		NA	0.0000	< 0.005	< 0.005	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	ARSENIC	<	0.0100		NA	0.0000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	ARSENIC	<	0.0100		NA	0.0000			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	BARIUM		0.0280			0.0280	< 0.005	< 0.005	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	BARIUM		0.0320			0.0320	< 0.005	< 0.005	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	BARIUM	<	0.2000		<	0.2000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	BARIUM	<	0.2000		<	0.2000			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	BORON		0.3900			0.4000	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	BORON		0.3300			0.3300			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	BORON		0.3600			0.3600			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	BROMIDE	<	2.0000		NA	0.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	BROMIDE	<	2.0000		<	2.0000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	BROMIDE	<	2.0000		<	2.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	CALCIUM		59.0000			59.0000			mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	CALCIUM		74.0000			74.0000			mg/l	07/27/89	3	IT	MC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	CALCIUM		64.0000			64.0000			mg/l	06/21/90	4	IT	MC
BARN WELL	DEWEY LAKE	CALCIUM HARDNESS (CaCO3)		150.0000		NA	0.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	CESIUM		0.1000			0.1000	0.02	0.02	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	CESIUM	<	0.1000		NA	0.0000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	CESIUM	<	0.2000		<	0.2000			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	CHLORIDE		35.0000		NA	0.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	CHLORIDE		39.0000		NA	0.0000			mg/l	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	CHLORIDE		48.0000			47.0000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	CHLORIDE		41.0000		NA	0.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	CHROMIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	CHROMIUM		0.0200			0.0200	0.02	0.01	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	CHROMIUM		0.0100			0.0100			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	CHROMIUM	<	0.0100		<	0.0100			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	CHRYSENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	COBALT	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	COBALT	<	0.0500		<	0.0500			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	COBALT	<	0.0500		<	0.0500			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	COLOR	<	1.0000		NA	0.0000			CU	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	COPPER		0.0100			0.0100	0.02	0.01	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	COPPER	<	0.0250		<	0.0250			mg/l	07/27/89	3	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	COPPER	<	0.0250		<	0.0250			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	CYANIDE	<	0.0100		<	0.0200			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	CYANIDE	<	0.0100		NA	0.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	ENDRIN	<	0.0200		NA	0.0000			ug/l	04/20/88	2	IT	HP
BARN WELL	DEWEY LAKE	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	FLUORENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	FLUORIDE		2.7000		NA	0.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	FLUORIDE		2.6000			2.6000			mg/l	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	FLUORIDE		2.5000			2.5000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	FLUORIDE		2.6000		NA	0.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	IODIDE	<	2.0000		NA	0.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	IODIDE	<	2.0000		<	2.0000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	IODIDE	<	2.0000		<	2.0000			mg/l	06/21/90	4	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	IRON		0.0100			0.0100	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	IRON	<	0.0100	<		0.0100	< 0.01	< 0.01	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	IRON	<	0.1000	<		0.1000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	IRON	<	0.1000	<		0.1000			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	ISOPHORONE	<	10.0000	NA		0.0000			ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	LANGELIER SATURATION INDEX		0.2500	NA		0.0000				06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	LEAD	<	0.0500	<		0.0500	< 0.05	< 0.05	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	LEAD	<	0.0500	<		0.0500	< 0.05	< 0.05	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	LEAD	<	0.0500	<		0.0500			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	LEAD	<	0.0500	<		0.0500			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	LINDANE	<	0.0400	NA		0.0000			ug/l	04/20/88	2	IT	HP
BARN WELL	DEWEY LAKE	LITHIUM		0.0500			0.0500	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	LITHIUM		0.0500			0.0500			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	LITHIUM		0.0400			0.0400			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	LSI CORROSIVITY		0.0200	NA		0.0000				04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	MAGNESIUM		31.0000			31.0000			mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	MAGNESIUM		37.0000			37.0000			mg/l	07/27/89	3	IT	MC
BARN WELL	DEWEY LAKE	MAGNESIUM		33.0000			33.0000			mg/l	06/21/90	4	IT	MC
BARN WELL	DEWEY LAKE	MANGANESE	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	MANGANESE	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	MANGANESE	<	0.0150	<		0.0150			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	MANGANESE	<	0.0150	<		0.0150			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	MBAS		0.0300	NA		0.0000			mg/l	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	MERCURY	<	0.0002	<		0.0002			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	MERCURY	<	0.0002	<		0.0002			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	METHOXYCHLOR	<	0.0010	NA		0.0000			mg/l	04/20/88	2	IT	HP
BARN WELL	DEWEY LAKE	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l	11/04/87	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	MOLYBDENUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l		11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	MOLYBDENUM	<	0.0200		<	0.0200			mg/l		07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	MOLYBDENUM	<	0.0200		<	0.0200			mg/l		06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	NICKEL	<	0.0300		<	0.0300	< 0.03	< 0.03	mg/l		11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	NICKEL	<	0.0400		<	0.0400			mg/l		07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	NICKEL	<	0.0400		<	0.0400			mg/l		06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	NITRATE		8.5000		NA	0.0000			mg/l	NO3-N	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	NITRATE		7.2000			6.9000			mg/l	NO3-N	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	NITRATE		9.6000		NA	0.0000			mg/l		07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	NITRATE		8.9000		NA	0.0000			mg/l		06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	ODOR		1.0000		NA	0.0000			T.O.N.		04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	PCB	<	1.0000		NA	0.0000			ug/l		11/04/87	1	IT	PC
BARN WELL	DEWEY LAKE	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	PHENOL	<	10.0000		NA	0.0000			ug/l		11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	PHENOLICS	<	0.0050		<	0.0100			mg/l		07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	PHENOLICS	<	0.0050		NA	0.0000			mg/l		06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	PHOSPHORUS		0.0400		NA	0.0000			mg/l		07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	POTASSIUM		2.6000			2.5000			mg/l		11/04/87	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	POTASSIUM	<	5.0000	<	5.0000				mg/l	07/27/89	3	IT	MC
BARN WELL	DEWEY LAKE	POTASSIUM	<	5.0000	<	5.0000				mg/l	06/21/90	4	IT	MC
BARN WELL	DEWEY LAKE	PYRENE	<	10.0000	NA	0.0000				ug/l	11/04/87	1	IT	SV
BARN WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		670.0000	NA	0.0000				mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		720.0000	NA	0.0000				mg/l	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		630.0000	NA	0.0000				mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		650.0000		650.0000				mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000	NA	0.0000				mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C		29.0000	NA	29.0000				mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000	<	4.0000				mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	SELENIUM	<	0.0500	<	0.0500	< 0.005	< 0.005		mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	SELENIUM		0.0320	NA	0.0000	< 0.005	< 0.005		mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	SELENIUM	<	0.0500	NA	0.0000				mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	SELENIUM	<	0.0500	NA	0.0000				mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	SILICA		54.0000		54.0000	< 0.2	< 0.2		mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	SILICA		24.0000		24.0000				mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	SILICA		25.0000	NA	0.0000				mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	SILVER	<	0.0100	<	0.0100	< 0.01	< 0.01		mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	SILVER	<	0.0100	<	0.0100	< 0.01	< 0.01		mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	SILVER	<	0.0100	<	0.0100				mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	SILVER	<	0.0100	<	0.0100				mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	SODIUM		110.0000		110.0000				mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	SODIUM		93.0000		93.0000				mg/l	07/27/89	3	IT	MC
BARN WELL	DEWEY LAKE	SODIUM		120.0000		120.0000				mg/l	06/21/90	4	IT	MC
BARN WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		1000.0000	NA	0.0000				umhos/cm@25C	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		1092.0000		1095.0000				uMhos/cm@25C	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		1048.0000		1049.0000				uMhos/cm@25C	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	STRONTIUM		0.7900		0.7900	< 0.01	< 0.01		mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	STRONTIUM		1.0000	NA	0.0000				mg/l	07/27/89	3	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	STRONTIUM		0.9400			0.9400			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	STYRENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	SULFATE		190.0000	NA		0.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	SULFATE		230.0000	NA		0.0000			mg/l	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	SULFATE		210.0000			240.0000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	SULFATE		180.0000	NA		0.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	TETRACHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	THALLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	THALLIUM	<	0.0100	NA		0.0000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	THALLIUM	<	0.0100	NA		0.0000			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	TITANIUM	<	0.0300	<		0.0300	< 0.03	< 0.03	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	TITANIUM	<	0.0100	NA		0.0000			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	TITANIUM	<	0.0100	<		0.0100			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	TOLUENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	TOTAL ORGANIC CARBON		4.0000			4.0000			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	TOTAL ORGANIC CARBON	<	1.0000	<		1.0000			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN		0.1800			0.1200			mg/l	06/21/90	4	IT	GC
BARN WELL	DEWEY LAKE	TOXAPHENE	<	0.0005	NA		0.0000			mg/l	04/20/88	2	IT	HP
BARN WELL	DEWEY LAKE	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	TRICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	TURBIDITY		1.0000	NA		0.0000			NTU	04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	VANADIUM		0.0600			0.0600	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	VANADIUM		0.0600			0.0600			mg/l	07/27/89	3	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
BARN WELL	DEWEY LAKE	VANADIUM		0.0600			0.0600			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	04/20/88	2	IT	V
BARN WELL	DEWEY LAKE	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	1	IT	V
BARN WELL	DEWEY LAKE	ZINC		0.0300			0.0300	< 0.01	< 0.01	mg/l	11/04/87	1	IT	ME
BARN WELL	DEWEY LAKE	ZINC		0.0300			0.0300	< 0.01	< 0.01	mg/l	04/20/88	2	IT	ME
BARN WELL	DEWEY LAKE	ZINC		0.0200			0.0200			mg/l	07/27/89	3	IT	MT
BARN WELL	DEWEY LAKE	ZINC	<	0.0200		<	0.0200			mg/l	06/21/90	4	IT	MT
BARN WELL	DEWEY LAKE	pH		6.5000		NA	0.0000				11/04/87	1	IT	GC
BARN WELL	DEWEY LAKE	pH		7.6900			7.7200				04/20/88	2	IT	GC
BARN WELL	DEWEY LAKE	pH		7.1200			7.2700				07/27/89	3	IT	GC
BARN WELL	DEWEY LAKE	pH		7.6900			7.6800				06/21/90	4	IT	GC
** CLIFTON WELL														
CLIFTON WELL	DOCKUM	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
CLIFTON WELL	DOCKUM	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	06/29/88	2	IT	HP
CLIFTON WELL	DOCKUM	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2,4-D	<	0.0050		NA	0.0000			mg/l	06/29/88	2	IT	HP
CLIFTON WELL	DOCKUM	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
CLIFTON WELL	DOCKUM	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	ACETONE		11.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	ALKALINITY (HCO3)		240.0000		NA	0.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	ANTIMONY		0.0600		<	0.0500	< 0.05	< 0.05	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	BARIUM		0.0120			0.0120	< 0.005	< 0.005	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	BARIUM		0.0130			0.0140	< 0.005	< 0.005	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	BORON		0.6200			0.6300	0.04	0.04	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	BROMIDE	<	2.0000		NA	0.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
CLIFTON WELL	DOCKUM	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	CALCIUM		35.0000			35.0000			mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	CESIUM		0.0100			0.0100	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	CHLORIDE		45.0000		NA	0.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	CHLORIDE		50.0000		NA	0.0000			mg/l	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	CHROMIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	CHROMIUM	<	0.0100			0.0100	0.01	0.01	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	COBALT	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	COLOR	<	1.0000		NA	0.0000			CU	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V

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CLIFTON WELL	DOCKUM	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	ENDRIN	<	0.0200		NA	0.0000			ug/l	06/29/88	2	IT	HP
CLIFTON WELL	DOCKUM	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	FLUORENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	FLUORIDE		1.9000		NA	0.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	FLUORIDE		1.5000		NA	0.0000			mg/l	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	IODIDE	<	2.0000		<	2.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	IRON		0.0500			0.0400	0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	IRON	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	LEAD	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	LEAD	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	LINDANE	<	0.0400		NA	0.0000			ug/l	06/29/88	2	IT	HP
CLIFTON WELL	DOCKUM	LITHIUM		0.0800			0.0800	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	LSI CORROSIVITY		0.6000		NA	0.0000				06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	MAGNESIUM		34.0000			34.0000			mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	MANGANESE	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	MANGANESE	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	MBAS		0.0700			0.0700			mg/l	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	MERCURY	<	0.0002		<	0.0002	0.0002	< 0.0002	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	06/29/88	2	IT	ME

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CLIFTON WELL	DOCKUM	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		06/29/88	2	IT	HP
CLIFTON WELL	DOCKUM	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l		10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	MOLYBDENUM	<	0.0100	<	0.0100	< 0.01		< 0.01	mg/l		10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	NICKEL	<	0.0300	<	0.0300	< 0.03		< 0.03	mg/l		10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	NITRATE		1.9000		NA	0.0000			mg/l	NO3-N	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	NITRATE		8.4000		NA	0.0000			mg/l	NO3-N	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	ODOR	<	1.0000		NA	0.0000			T.O.N.		06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	PCB	<	1.0000		NA	0.0000			ug/l		10/28/87	1	IT	PC
CLIFTON WELL	DOCKUM	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	PHENOL	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	PHOSPHATE		0.0100		NA	0.0000			mg/l	T-PO4-P	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	POTASSIUM		3.9000			4.0000			mg/l		10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	PYRENE	<	10.0000		NA	0.0000			ug/l		10/28/87	1	IT	SV
CLIFTON WELL	DOCKUM	RESIDUE, FILTERABLE @ 180 C		790.0000		NA	0.0000			mg/l		10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	RESIDUE, FILTERABLE @ 180 C		780.0000		NA	0.0000			mg/l		06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		NA	0.0000			mg/l		10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	SELENIUM		0.0800			0.0800	< 0.005	< 0.005	mg/l		10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	SELENIUM		0.0650			0.0700	< 0.005	< 0.005	mg/l		06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	SILICA		16.0000			16.0000	1.4	1.4	mg/l		10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	SILVER	<	0.0100	<	0.0100	< 0.01		< 0.01	mg/l		10/28/87	1	IT	ME

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CLIFTON WELL	DOCKUM	SILVER	<	0.0100	<		0.0100	< 0.01	< 0.01	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	SODIUM		190.0000			190.0000			mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	SPECIFIC CONDUCTANCE		1370.0000			1360.0000			umhos/cm@25C	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	STRONTIUM		1.1000			1.1000	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	SULFATE		330.0000		NA	0.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	SULFATE		310.0000		NA	0.0000			mg/l	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	THALLIUM	<	5.0000	<		5.0000	< 0.005	< 0.005	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	TITANIUM	<	0.0300	<		0.0300	< 0.03	< 0.03	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	TOTAL ORGANIC CARBON		1.0000			2.0000			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	06/29/88	2	IT	HP
CLIFTON WELL	DOCKUM	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	TURBIDITY	<	0.9000		NA	0.0000			NTU	06/29/88	2	IT	GC
CLIFTON WELL	DOCKUM	VANADIUM		0.0400			0.0400	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	06/29/88	2	IT	V
CLIFTON WELL	DOCKUM	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/28/87	1	IT	V
CLIFTON WELL	DOCKUM	ZINC		0.1100			0.1100	< 0.01	< 0.01	mg/l	10/28/87	1	IT	ME
CLIFTON WELL	DOCKUM	ZINC		0.2200			0.2200	< 0.01	< 0.01	mg/l	06/29/88	2	IT	ME
CLIFTON WELL	DOCKUM	pH		6.7200			6.8400				10/28/87	1	IT	GC
CLIFTON WELL	DOCKUM	pH		7.6100			7.6500				06/29/88	2	IT	GC

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** COMANCHE WELL														
COMANCHE WELL	DOCKUM	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	06/28/88	2	IT	HP
COMANCHE WELL	DOCKUM	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,4-D	<	0.0050		NA	0.0000			mg/l	06/28/88	2	IT	HP
COMANCHE WELL	DOCKUM	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
COMANCHE WELL	DOCKUM	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	ALKALINITY (HCO3)		230.0000		NA	0.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	ANTIMONY	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	BARIUM		0.0560			0.0560	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	BARIUM		0.0580			0.0580	< 0.005	< 0.005	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V

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COMANCHE WELL	DOCKUM	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	BORON		0.4400			0.4400	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	BROMIDE	<	2.0000		NA	0.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	CALCIUM		31.0000			31.0000			mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	CESIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	CHLORIDE		15.0000			15.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	CHLORIDE		27.0000		NA	0.0000			mg/l	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V

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COMANCHE WELL	DOCKUM	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	CHROMIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	CHROMIUM	<	0.0100		<	0.0100	< 0.01	0.01	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	COBALT	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	COLOR	<	1.0000		<	1.0000			CU	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	ENDRIN	<	0.0200		NA	0.0000			ug/l	06/28/88	2	IT	HP
COMANCHE WELL	DOCKUM	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	FLUORENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	FLUORIDE		2.1000		NA	0.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	FLUORIDE		2.3000			2.2000			mg/l	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV

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COMANCHE WELL	DOCKUM	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	IODIDE	<	2.0000		NA	0.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	IRON		0.0300			0.0300	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	IRON		0.0200			0.0200	< 0.01	< 0.01	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	LEAD	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	LEAD	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	LINDANE	<	0.0400		NA	0.0000			ug/l	06/28/88	2	IT	HP
COMANCHE WELL	DOCKUM	LITHIUM		0.0500			0.0500	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	LSI CORROSIVITY		0.3600		NA	0.0000				06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	MAGNESIUM		22.0000			22.0000			mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	MANGANESE		0.0060			0.0060	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	MANGANESE	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	MBAS		0.0700		NA	0.0000			mg/l	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l	06/28/88	2	IT	HP
COMANCHE WELL	DOCKUM	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	MOLYBDENUM		0.0300			0.0300	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	NICKEL	<	0.0300		<	0.0300	< 0.03	< 0.03	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	NITRATE		2.2000		NA	0.0000			mg/l NO3-N	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	NITRATE		5.8000		NA	0.0000			mg/l NO3-N	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	NITROBENZENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	ODOR	<	1.0000		NA	0.0000			T.O.N.	06/28/88	2	IT	GC

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COMANCHE WELL	DOCKUM	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	PCB	<	1.0000		NA	0.0000			ug/l	10/26/87	1	IT	PC
COMANCHE WELL	DOCKUM	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	PHENOL	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	PHOSPHATE	<	0.0100		NA	0.0000			mg/l T-PO4-P	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	POTASSIUM		5.1000			5.0000			mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	PYRENE	<	10.0000		NA	0.0000			ug/l	10/26/87	1	IT	SV
COMANCHE WELL	DOCKUM	RESIDUE, FILTERABLE @ 180 C		340.0000			350.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	RESIDUE, FILTERABLE @ 180 C		340.0000			330.0000			mg/l	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		NA	0.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	SELENIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	SILICA		28.0000			28.0000	< 0.2	< 0.2	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	SILVER	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	SILVER	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	SODIUM		45.0000			45.0000			mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	SPECIFIC CONDUCTANCE		561.0000			565.0000			umhos/cm@25C	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	STRONTIUM		0.7400			0.7400	< 0.01	< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	SULFATE		40.0000			41.0000			mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	SULFATE		66.0000			63.0000			mg/l	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	THALLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	TITANIUM	<	0.0300		<	0.0300	< 0.03	< 0.03	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	10/26/87	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
COMANCHE WELL	DOCKUM	TOTAL ORGANIC HALOGEN	<	0.0500	<	0.0500				mg/l	10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	TOXAPHENE	<	0.0005	NA	0.0000				mg/l	06/28/88	2	IT	HP
COMANCHE WELL	DOCKUM	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	TRICHLOROETHYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	TRICHLOROETHYLENE	<	1.0000	NA	0.0000			T < 1.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	TURBIDITY	<	0.9000	<	0.9000				NTU	06/28/88	2	IT	GC
COMANCHE WELL	DOCKUM	VANADIUM		0.0300		0.0300	< 0.01		< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	VINYL ACETATE	<	10.0000	NA	0.0000			T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	VINYL CHLORIDE	<	10.0000	NA	0.0000			T < 10	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	VINYL CHLORIDE	<	2.0000	NA	0.0000			T < 2.0	ug/l	06/28/88	2	IT	V
COMANCHE WELL	DOCKUM	XYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	10/26/87	1	IT	V
COMANCHE WELL	DOCKUM	ZINC		0.1200		0.1200	< 0.01		< 0.01	mg/l	10/26/87	1	IT	ME
COMANCHE WELL	DOCKUM	ZINC		0.4400		0.4500	< 0.01		< 0.01	mg/l	06/28/88	2	IT	ME
COMANCHE WELL	DOCKUM	pH		7.4500		7.4800					10/26/87	1	IT	GC
COMANCHE WELL	DOCKUM	pH		7.2600	NA	0.0000					06/28/88	2	IT	GC
** DOE-1														
DOE-1	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	<	5.0000				ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA	0.0000				ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	<	5.0000				ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA	0.0000				ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	<	5.0000				ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA	0.0000				ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,1-DICHLOROETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	<	5.0000				ug/l	07/03/86	2	IT	V

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DOE-1	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	1.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	1.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV

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DOE-1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2-BUTANONE		97.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	2-BUTANONE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV

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DOE-1	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	2-HEXANONE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV

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DOE-1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10		ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	ACETONE		29.0000		NA	0.0000	T < 10		ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	ACETONE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	ACETONE		44.0000		NA	0.0000			ug/l	07/28/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-1	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	ALKALINITY (HCO3)		57.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	ALKALINITY (HCO3)		44.0000		NA	0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	ALUMINUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	ALUMINUM		1.4000		NA	0.0000	< 0.1	< 0.1	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	ANTIMONY		1.4000			1.1000	< 0.05	< 0.05	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	ARSENIC		0.0060			0.0160	< 0.001	< 0.001	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	ARSENIC		0.0340			0.0340	< 0.001	< 0.001	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	ARSENIC	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	BARIUM		0.0700			0.0700	< 0.01	< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	BARIUM		0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	BENZENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-1	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BERYLLIUM		0.2700			0.2000	0.001	< 0.001	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	4.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		33.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV

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DOE-1	CULEBRA	BORON		7.5000			6.9000	< 0.10	< 0.10	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	BORON		35.0000		NA	0.0000	0.03	0.03	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	BORON		34.0000			34.0000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	BROMIDE		63.0000			65.0000			mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	BROMIDE		59.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	BROMIDE		61.0000		NA	0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	BROMOFORM	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	BUTYL BENZYL PHTHALATE		1.9000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	CADMIUM		0.0700			0.0700	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	CALCIUM		1600.0000		NA	0.0000			mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	CALCIUM		1400.0000			1400.0000			mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	CARBON DISULFIDE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	CESIUM		10.0000			7.2000	0.19	0.30	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	CESIUM		0.4000		NA	0.0000	0.2	0.1	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	CESIUM		0.4600			0.4900	< 0.05	< 0.05	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	CHLORIDE		77000.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	CHLORIDE		81000.0000		NA	0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V

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DOE-1	CULEBRA	CHLOROETHANE	<	10.0000	<	10.0000				ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000				ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	CHLOROFORM	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	CHLOROFORM	<	5.0000	<	5.0000				ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	CHLOROFORM	<	5.0000	NA	0.0000				ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	CHROMIUM	<	0.0010	<	0.0010	< 0.001		< 0.001	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	CHROMIUM		0.3800	NA	0.0000	< 0.01		< 0.01	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	CHROMIUM		0.4000		0.4000	< 0.01		< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	CHRYSENE	<	1.0000	NA	0.0000				ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	<	5.0000				ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000				ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	COBALT		0.4100		0.1800	< 0.01		< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	COBALT		0.1300	NA	0.0000	< 0.01		< 0.01	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	COBALT		0.1000		0.1000	< 0.01		< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	COPPER		0.1800		0.1800	< 0.01		< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	COPPER		0.1600	NA	0.0000	< 0.01		< 0.01	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	COPPER		0.1000		0.1000	< 0.01		< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	CYANIDE	<	0.0200	NA	0.0000				mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	CYANIDE	<	0.0200	NA	0.0000				mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	CYANIDE	<	0.0200	NA	0.0000				mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	DI-N-BUTYL PHTHALATE		2.6000	NA	0.0000				ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000	NA	0.0000				ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000	NA	0.0000				ug/l	04/25/85	1	IT	SV

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DOE-1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	DICHLORODIFLUOROMETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	ETHYLBENZENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	Eh		554.0000		NA	0.0000			mV	04/25/85	1	IT	GC
DOE-1	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	FLUORIDE		1.0000		NA	0.0000			mg/l	04/25/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-1	CULEBRA	FLUORIDE		1.0000			1.1000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	FLUORIDE		0.8000		NA	0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	IODIDE	<	1.0000		<	1.0000			mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	IODIDE		1.2000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	IRON		1.3000			1.3000	< 0.01	0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	IRON		1.4000		NA	0.0000	< 0.01	< 0.01	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	IRON		0.7000			0.7000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	LEAD		0.1800			2.4000	< 0.10	< 0.10	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	LEAD		0.6600		NA	0.0000	< 0.05	< 0.05	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	LEAD		0.6000			0.6000	< 0.05	< 0.05	mg/l	07/28/87	3	IT	ME

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DOE-1	CULEBRA	LITHIUM		3.2000			3.1000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	MAGNESIUM		1400.0000		NA	0.0000			mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	MAGNESIUM		1600.0000		NA	0.0000			mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	MANGANESE		0.3500			0.4300	< 0.01	0.02	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	MANGANESE		0.2300		NA	0.0000	< 0.005	< 0.005	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	MANGANESE		0.2000			0.2000	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	MERCURY	<	0.0002			0.0008	< 0.0002	< 0.0002	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	MERCURY		0.0008		NA	0.0000	< 0.0002	< 0.0002	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	METHYL BROMIDE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	METHYL CHLORIDE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	METHYLENE CHLORIDE		10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	MOLYBDENUM		0.0510			0.0440	< 0.001	< 0.001	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	MOLYBDENUM		0.2700		NA	0.0000	0.01	< 0.01	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	MOLYBDENUM	<	0.0500		<	0.0500	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	N-NITROSO-DI-METHYLAMINE		2.4000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV

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DOE-1	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		07/28/87	3	IT	SV
DOE-1	CULEBRA	NICKEL		1.9000			1.9000	< 0.01	< 0.01	mg/l		04/25/85	1	IT	ME
DOE-1	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		07/03/86	2	IT	ME
DOE-1	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		07/28/87	3	IT	ME
DOE-1	CULEBRA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	04/25/85	1	IT	GC
DOE-1	CULEBRA	NITRATE		0.1000			0.1000			mg/l	NO3-N	07/03/86	2	IT	GC
DOE-1	CULEBRA	NITRATE		3.4000		NA	0.0000			mg/l	NO3-N	07/28/87	3	IT	GC
DOE-1	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		04/25/85	1	IT	SV
DOE-1	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/03/86	2	IT	SV
DOE-1	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/28/87	3	IT	SV
DOE-1	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		04/25/85	1	IT	SV
DOE-1	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		07/03/86	2	IT	SV
DOE-1	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		07/28/87	3	IT	SV
DOE-1	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		07/03/86	2	IT	PC
DOE-1	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		07/28/87	3	IT	PC
DOE-1	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		04/25/85	1	IT	SV
DOE-1	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/03/86	2	IT	SV
DOE-1	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/28/87	3	IT	SV
DOE-1	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		04/25/85	1	IT	SV
DOE-1	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/03/86	2	IT	SV
DOE-1	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/28/87	3	IT	SV
DOE-1	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		04/25/85	1	IT	SV
DOE-1	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/03/86	2	IT	SV
DOE-1	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/28/87	3	IT	SV
DOE-1	CULEBRA	PHENOLICS	<	0.0020		NA	0.0000			mg/l		04/25/85	1	IT	GC
DOE-1	CULEBRA	PHENOLICS		0.0120		NA	0.0000			mg/l		07/03/86	2	IT	GC
DOE-1	CULEBRA	PHENOLICS		0.0120		NA	0.0000			mg/l		07/28/87	3	IT	GC
DOE-1	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	04/25/85	1	IT	GC
DOE-1	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	07/03/86	2	IT	GC

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DOE-1	CULEBRA	PHOSPHATE		0.0100		NA	0.0000			mg/l T-PO4-P	07/28/87	3	IT	GC
DOE-1	CULEBRA	POTASSIUM		900.0000		NA	0.0000			mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	POTASSIUM		1000.0000		NA	0.0000			mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l	04/25/85	1	IT	SV
DOE-1	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	07/03/86	2	IT	SV
DOE-1	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	SV
DOE-1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		130000.0000		NA	0.0000			mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		130000.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		130000.0000			140000.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		290.0000		NA	0.0000			mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		58.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		460.0000			440.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	SELENIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	SELENIUM		0.2300			0.1360	< 0.001	0.001	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	SILICA		11.0000			10.0000	0.30	< 0.21	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	SILICA		21.0000		NA	0.0000	0.42	0.41	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	SILICA		12.0000			12.0000	< 0.2	< 0.2	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	SODIUM		46000.0000		NA	0.0000			mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	SODIUM		46000.0000		NA	0.0000			mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	SPECIFIC CONDUCTANCE		146000.0000		NA	0.0000			umhos/cm@25C	04/25/85	1	IT	GC
DOE-1	CULEBRA	SPECIFIC CONDUCTANCE		128000.0000		NA	0.0000			umhos/cm@25C	07/03/86	2	IT	GC
DOE-1	CULEBRA	SPECIFIC CONDUCTANCE		222000.0000			232000.0000			umhos/cm@25C	07/28/87	3	IT	GC
DOE-1	CULEBRA	STRONTIUM		5.8000			5.9000	< 0.01	< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	STRONTIUM		16.0000		NA	0.0000	0.03	0.03	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	STRONTIUM		33.0000			32.0000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	STYRENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	STYRENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V

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DOE-1	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	SULFATE		6700.0000			6400.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	SULFATE		6700.0000		NA	0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	TIN		0.7000			0.7000	< 0.04	< 0.04	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	TITANIUM	<	0.0100			0.0300	< 0.01	< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	TITANIUM		0.6900		NA	0.0000	< 0.03	< 0.03	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	TITANIUM		0.5000			0.5000	< 0.03	< 0.03	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	TOLUENE		2.1000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	TOLUENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	TOTAL ORGANIC HALOGEN		0.8400		NA	0.0000			mg/l	04/25/85	1	IT	GC
DOE-1	CULEBRA	TOTAL ORGANIC HALOGEN		2.3000		NA	0.0000			mg/l	07/03/86	2	IT	GC
DOE-1	CULEBRA	TOTAL ORGANIC HALOGEN		9.7000		NA	0.0000			mg/l	07/28/87	3	IT	GC
DOE-1	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	TRICHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-1	CULEBRA	VANADIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	VINYL ACETATE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	VINYL CHLORIDE	<	10.0000		<	10.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	XYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/25/85	1	IT	V
DOE-1	CULEBRA	XYLENE	<	5.0000		<	5.0000			ug/l	07/03/86	2	IT	V
DOE-1	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	07/28/87	3	IT	V
DOE-1	CULEBRA	ZINC		0.0800			0.0700	< 0.01	< 0.01	mg/l	04/25/85	1	IT	ME
DOE-1	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	07/03/86	2	IT	ME
DOE-1	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/28/87	3	IT	ME
DOE-1	CULEBRA	pH		6.9400		NA	0.0000				04/25/85	1	IT	GC
DOE-1	CULEBRA	pH		7.0900		NA	0.0000				07/03/86	2	IT	GC
DOE-1	CULEBRA	pH		6.4700			6.5000				07/28/87	3	IT	GC
** DOE-2														
DOE-2	BELL CANYON	ALUMINUM	<	0.2000			0.2600	< 0.10	< 0.10	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	BARIUM		0.3200		NA	0.0000	< 0.1	< 0.1	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	BERYLLIUM		0.0120		NA	0.0000	< 0.001	< 0.001	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	BORON		61.0000		NA	0.0000	< 0.1	< 0.1	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	BROMIDE		89.0000			100.0000			mg/l	07/23/85	1	IT	GC
DOE-2	BELL CANYON	CESIUM		3.4000			3.2000	< 0.10	< 0.10	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	CHROMIUM	<	0.0020		<	0.0020	< 0.001	< 0.001	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	COBALT		0.6200		NA	0.0000	< 0.001	< 0.001	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	COPPER		0.3200			0.3000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	FLUORIDE		0.4000			0.4000			mg/l	07/23/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-2	BELL CANYON	IODIDE		7.9000		NA	0.0000			mg/l	07/23/85	1	IT	GC
DOE-2	BELL CANYON	IRON		9.0000			9.2000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	LEAD		0.1400		NA	0.0000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	MANGANESE		2.5000			2.5000	0.01	0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	MERCURY	<	0.0004		<	0.0004	0.0002	< 0.0002	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	MOLYBDENUM		0.1300			0.1500	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	NICKEL		1.8000			1.8000	< 0.01	0.02	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	NITRATE		0.7000			0.8000			mg/l NO3-N	07/23/85	1	IT	GC
DOE-2	BELL CANYON	PHOSPHATE		0.5100		NA	0.0000			mg/l T-PO4-P	07/23/85	1	IT	GC
DOE-2	BELL CANYON	RESIDUE, FILTERABLE @ 180 C		160000.0000		NA	0.0000			mg/l	07/23/85	1	IT	GC
DOE-2	BELL CANYON	RESIDUE, NONFILTERABLE @ 105 C		460.0000		NA	0.0000			mg/l	07/23/85	1	IT	GC
DOE-2	BELL CANYON	SELENIUM		3.6000		NA	0.0000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	SILICA		14.0000		NA	0.0000	< 0.1	< 0.1	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	SPECIFIC CONDUCTANCE		132000.0000		NA	0.0000			umhos/cm@25C	07/23/85	1	IT	GC
DOE-2	BELL CANYON	STRONTIUM		300.0000			300.0000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	TITANIUM	<	0.0200		NA	0.0000	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	ZINC		0.1400			0.1500	< 0.01	< 0.01	mg/l	07/23/85	1	IT	ME
DOE-2	BELL CANYON	pH		6.7200		NA	0.0000				07/23/85	1	IT	GC
DOE-2	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV

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DOE-2	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-2	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V

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DOE-2	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	4-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	ALKALINITY (HCO3)		160.0000			160.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	ALKALINITY (HCO3)		130.0000			130.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	ALUMINUM		0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	ALUMINUM	<	10.0000		NA	0.0000	< 0.1	< 0.1	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	ANTIMONY		0.6000			0.6000	< 0.05	< 0.05	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	ARSENIC		0.0240			0.0260	< 0.001	< 0.001	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	BARIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	BARIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	05/19/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-2	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BERYLLIUM		0.1400			0.1800	< 0.001	< 0.001	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	BERYLLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	BORON		24.0000		NA	0.0000	< 0.10	0.47	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	BORON		14.0000		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	BORON		15.0000			15.0000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	BROMIDE		50.0000		NA	0.0000			mg/l	03/12/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-2	CULEBRA	BROMIDE		36.0000		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	BROMIDE		36.0000		NA	0.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	CALCIUM		1900.0000		NA	0.0000			mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	CALCIUM		1700.0000			1700.0000			mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	CESIUM		1.7000			1.7000	< 0.01	< 0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	CESIUM		0.3000		NA	0.0000	< 0.1	0.1	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	CESIUM		0.0300			0.0300	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	CHLORIDE		33000.0000			32000.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	CHLORIDE		29200.0000		NA	0.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	CHROMIUM		0.0070			0.0080	< 0.001	< 0.001	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	CHROMIUM	<	1.0000		NA	0.0000	< 0.01	0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	CHROMIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV

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DOE-2	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000			ug/l	08/27/86	2 IT	V
DOE-2	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	05/19/88	3 IT	V
DOE-2	CULEBRA	COBALT		0.1600	NA		0.0000	< 0.001	< 0.001	mg/l	03/12/85	1 IT	ME
DOE-2	CULEBRA	COBALT	<	1.0000	NA		0.0000	< 0.01	< 0.01	mg/l	08/27/86	2 IT	ME
DOE-2	CULEBRA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	05/19/88	3 IT	ME
DOE-2	CULEBRA	COPPER		0.1000	NA		0.0000	0.01	0.01	mg/l	03/12/85	1 IT	ME
DOE-2	CULEBRA	COPPER	<	1.0000	NA		0.0000	0.01	0.01	mg/l	08/27/86	2 IT	ME
DOE-2	CULEBRA	COPPER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	05/19/88	3 IT	ME
DOE-2	CULEBRA	CYANIDE		0.0200	NA		0.0000			mg/l	03/12/85	1 IT	GC
DOE-2	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	08/27/86	2 IT	GC
DOE-2	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	05/19/88	3 IT	GC
DOE-2	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/27/86	2 IT	SV
DOE-2	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/19/88	3 IT	SV
DOE-2	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/27/86	2 IT	SV
DOE-2	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/19/88	3 IT	SV
DOE-2	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	08/27/86	2 IT	SV
DOE-2	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	05/19/88	3 IT	SV
DOE-2	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	08/27/86	2 IT	SV
DOE-2	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	05/19/88	3 IT	SV
DOE-2	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000			ug/l	08/27/86	2 IT	V
DOE-2	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	05/19/88	3 IT	V
DOE-2	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000			ug/l	08/27/86	2 IT	V
DOE-2	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	05/19/88	3 IT	V
DOE-2	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/27/86	2 IT	SV
DOE-2	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/19/88	3 IT	SV
DOE-2	CULEBRA	DIMETHYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/19/88	3 IT	SV
DOE-2	CULEBRA	ETHYLBENZENE	<	5.0000	NA		0.0000			ug/l	08/27/86	2 IT	V
DOE-2	CULEBRA	ETHYLBENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	05/19/88	3 IT	V
DOE-2	CULEBRA	Eh		459.0000	NA		0.0000			mV	03/12/85	1 IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-2	CULEBRA	Eh		380.0000		NA	0.0000			mV	08/27/86	2	IT	GC
DOE-2	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	FLUORIDE		1.2000		NA	0.0000			mg/l	03/12/85	1	IT	GC
DOE-2	CULEBRA	FLUORIDE		1.2000			1.2000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	FLUORIDE		1.4000		NA	0.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	03/12/85	1	IT	GC
DOE-2	CULEBRA	IODIDE		1.0000		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	IRON		0.3500		NA	0.0000	< 0.01	< 0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	IRON		1.4000		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	IRON		0.4000			0.4000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	LEAD	<	0.1000		<	0.1000	< 0.10	< 0.10	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	LEAD	<	5.0000		NA	0.0000	< 0.05	< 0.05	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	05/19/88	3	IT	ME

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DOE-2	CULEBRA	LITHIUM		0.5000			0.5200	0.01	0.01	mg/l		05/19/88	3	IT	ME
DOE-2	CULEBRA	MAGNESIUM		1100.0000		NA	0.0000			mg/l		08/27/86	2	IT	ME
DOE-2	CULEBRA	MAGNESIUM		950.0000			960.0000			mg/l		05/19/88	3	IT	ME
DOE-2	CULEBRA	MANGANESE		0.3700		NA	0.0000	< 0.01	< 0.01	mg/l		03/12/85	1	IT	ME
DOE-2	CULEBRA	MANGANESE		0.6000		NA	0.0000	< 0.005	< 0.005	mg/l		08/27/86	2	IT	ME
DOE-2	CULEBRA	MANGANESE		0.4900			0.4900	< 0.005	< 0.005	mg/l		05/19/88	3	IT	ME
DOE-2	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l		03/12/85	1	IT	ME
DOE-2	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l		08/27/86	2	IT	ME
DOE-2	CULEBRA	MERCURY		0.0015			0.0018	0.0014	0.0009	mg/l		05/19/88	3	IT	ME
DOE-2	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l		08/27/86	2	IT	V
DOE-2	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l		05/19/88	3	IT	V
DOE-2	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l		08/27/86	2	IT	V
DOE-2	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		05/19/88	3	IT	V
DOE-2	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l		08/27/86	2	IT	V
DOE-2	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l		05/19/88	3	IT	V
DOE-2	CULEBRA	MOLYBDENUM		0.0300		NA	0.0000	< 0.001	< 0.001	mg/l		03/12/85	1	IT	ME
DOE-2	CULEBRA	MOLYBDENUM		0.0900		NA	0.0000	< 0.01	< 0.01	mg/l		08/27/86	2	IT	ME
DOE-2	CULEBRA	MOLYBDENUM		10.0000			10.0000	< 0.01	< 0.01	mg/l		05/19/88	3	IT	ME
DOE-2	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		08/27/86	2	IT	SV
DOE-2	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		05/19/88	3	IT	SV
DOE-2	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		08/27/86	2	IT	SV
DOE-2	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		05/19/88	3	IT	SV
DOE-2	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		08/27/86	2	IT	SV
DOE-2	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		05/19/88	3	IT	SV
DOE-2	CULEBRA	NICKEL		0.5000		NA	0.0000	< 0.01	0.01	mg/l		03/12/85	1	IT	ME
DOE-2	CULEBRA	NICKEL	<	3.0000		NA	0.0000	< 0.03	< 0.03	mg/l		08/27/86	2	IT	ME
DOE-2	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		05/19/88	3	IT	ME
DOE-2	CULEBRA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	03/12/85	1	IT	GC
DOE-2	CULEBRA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	08/27/86	2	IT	GC

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DOE-2	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l NO3-N	05/19/88	3	IT	GC
DOE-2	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l	08/27/86	2	IT	PC
DOE-2	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l	05/19/88	3	IT	PC
DOE-2	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	PHENOLICS		0.0090		NA	0.0000			mg/l	03/12/85	1	IT	GC
DOE-2	CULEBRA	PHENOLICS		0.0100		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	PHOSPHATE		0.0100		NA	0.0000			mg/l T-PO4-P	03/12/85	1	IT	GC
DOE-2	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l T-PO4-P	08/27/86	2	IT	GC
DOE-2	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l T-PO4-P	05/19/88	3	IT	GC
DOE-2	CULEBRA	POTASSIUM		420.0000		NA	0.0000			mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	POTASSIUM		460.0000			460.0000			mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	SV
DOE-2	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	05/19/88	3	IT	SV
DOE-2	CULEBRA	RESIDUE, FILTERABLE @ 180 C		58000.0000		NA	0.0000			mg/l	03/12/85	1	IT	GC
DOE-2	CULEBRA	RESIDUE, FILTERABLE @ 180 C		54000.0000		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	RESIDUE, FILTERABLE @ 180 C		57500.0000			57500.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		130.0000		NA	0.0000			mg/l	03/12/85	1	IT	GC
DOE-2	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		60.0000		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		120.0000			130.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	SELENIUM		0.0480		NA	0.0000	< 0.001	< 0.001	mg/l	03/12/85	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
DOE-2	CULEBRA	SELENIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	SILICA		11.0000			11.0000	6.7	5.2	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	SILICA		24.0000		NA	0.0000	< 0.2	< 0.2	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	SILICA		6.4000			6.5000			mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	SODIUM		17000.0000		NA	0.0000			mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	SODIUM		17600.0000			17400.0000			mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	SPECIFIC CONDUCTANCE		78900.0000		NA	0.0000			umhos/cm@25C	03/12/85	1	IT	GC
DOE-2	CULEBRA	SPECIFIC CONDUCTANCE		71200.0000		NA	0.0000			umhos/cm@25C	08/27/86	2	IT	GC
DOE-2	CULEBRA	SPECIFIC CONDUCTANCE		76500.0000			76200.0000			umhos/cm@25C	05/19/88	3	IT	GC
DOE-2	CULEBRA	STRONTIUM		28.0000			28.0000	0.01	0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	STRONTIUM		22.0000		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	STRONTIUM		34.0000			34.0000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	SULFATE		3700.0000		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	SULFATE		4500.0000		NA	0.0000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	TITANIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	TITANIUM	<	3.0000		NA	0.0000	< 0.03	< 0.03	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	TITANIUM		0.4000			0.5000	< 0.03	< 0.03	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	TOTAL ORGANIC CARBON		1.0000		NA	0.0000			mg/l	03/12/85	1	IT	GC
DOE-2	CULEBRA	TOTAL ORGANIC CARBON		5.0000		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	TOTAL ORGANIC CARBON		1.0000		<	1.0000			mg/l	05/19/88	3	IT	GC

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DOE-2	CULEBRA	TOTAL ORGANIC HALOGEN		0.6100		NA	0.0000			mg/l	08/27/86	2	IT	GC
DOE-2	CULEBRA	TOTAL ORGANIC HALOGEN		2.1000			1.9000			mg/l	05/19/88	3	IT	GC
DOE-2	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	VANADIUM		0.1000			0.1000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	08/27/86	2	IT	V
DOE-2	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	05/19/88	3	IT	V
DOE-2	CULEBRA	ZINC		0.0400		NA	0.0000	< 0.01	< 0.01	mg/l	03/12/85	1	IT	ME
DOE-2	CULEBRA	ZINC	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/86	2	IT	ME
DOE-2	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/88	3	IT	ME
DOE-2	CULEBRA	pH		7.0800		NA	0.0000				03/12/85	1	IT	GC
DOE-2	CULEBRA	pH		6.6500			6.6800				08/27/86	2	IT	GC
DOE-2	CULEBRA	pH		6.4700			6.4900				05/19/88	3	IT	GC
** ENGLE														
ENGLE	CULEBRA	2-NITROANILINE		50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
** ENGLE WELL														
ENGLE WELL	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V

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ENGLE WELL	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	1,1-DICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	NA		0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	1,2-DICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,2-DICHLOROETHANE	<	1.0000	NA		0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000	NA		0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000	NA		0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005	NA		0.0000			mg/l	12/08/87	2	IT	HP
ENGLE WELL	CULEBRA	2,4,5-TP (SILVEX)	<	1.7000	NA		0.0000		M< 1.7	ug/l	01/31/90	3	IT	H
ENGLE WELL	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV

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ENGLE WELL	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,4-D	<	0.0050		NA	0.0000			mg/l	12/08/87	2	IT	HP
ENGLE WELL	CULEBRA	2,4-D	<	12.0000		NA	0.0000		M< 12	ug/l	01/31/90	3	IT	H
ENGLE WELL	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV

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ENGLE WELL	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		M< 20	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	ACETONE		31.0000		NA	0.0000			ug/l	03/04/85	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
ENGLE WELL	CULEBRA	ACETONE	<	10.0000	NA		0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	ACROLEIN	<	10.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	ACRYLONITRILE	<	10.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	ALKALINITY (CO3)	NA	0.0000	NA		0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	ALKALINITY (CO3)		0.0000	NA		0.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	ALKALINITY (CO3)		0.0000	NA		0.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	ALKALINITY (HCO3)	NA	0.0000	NA		0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	ALKALINITY (HCO3)		74.0000	NA		0.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	ALKALINITY (HCO3)		110.0000			110.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	ALUMINUM	<	0.0100	NA		0.0000	< 0.01	< 0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	ALUMINUM	<	0.1000	<		0.1000	< 0.1	< 0.1	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	ALUMINUM		0.2000			0.2000	< 0.1	< 0.1	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	ANILINE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	ANTHRACENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	ANTHRACENE	<	10.0000	NA		0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	ANTIMONY		0.1600			0.1700	< 0.05	< 0.05	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	ANTIMONY		0.1200			0.1000	< .05	< .05	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	ARSENIC	<	0.0010	NA		0.0000	< 0.001	< 0.001	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	ARSENIC	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	ARSENIC	<	0.0020	NA		0.0000	< .002	< .002	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	BARIUM	<	0.0100	NA		0.0000	< 0.01	< 0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	BARIUM		0.0110			0.0120	< 0.005	< 0.005	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	BARIUM	<	0.0500	<		0.0500	< .005	< .005	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	BENZENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	BENZENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	BENZENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	BENZIDINE	<	4.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000	NA		0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000		M< 10	ug/l	01/31/90	3	IT	SV

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ENGLE WELL	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BERYLLIUM		0.0010		NA	0.0000	0.001	< 0.001	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	BERYLLIUM	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	BERYLLIUM	<	0.0050	<		0.0050	< .005	< .005	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	4.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BORON		0.7700		NA	0.0000	0.87	< 0.1	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	BORON		2.5000			2.4000	< 0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	BORON		1.2000			1.3000	< 0.02	< 0.02	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	BROMIDE		1.2000		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	BROMIDE	<	2.0000	<		2.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	BROMIDE	<	2.0000	<		2.0000			mg/l	01/31/90	3	IT	GC

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ENGLE WELL	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	CADMIUM		0.0120			0.0140	< 0.005	< 0.005	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	CADMIUM		0.0130			0.0110	< .005	< .005	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	CALCIUM		590.0000			550.0000			mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	CALCIUM		610.0000			610.0000	< 0.1	< 0.1	mg/l	01/31/90	3	IT	MC
ENGLE WELL	CULEBRA	CALCIUM HARDNESS		1500.0000			1500.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	CARBON DISULFIDE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	CESIUM		0.0700		NA	0.0000	0.09	< 0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	CESIUM		0.0300			0.0300	0.02	0.02	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	CESIUM	<	0.2000		<	0.2000	< 0.2	< 0.2	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	CHLORIDE		450.0000		NA	0.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	CHLORIDE		190.0000		NA	0.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	CHROMIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	CHROMIUM		0.0700			0.0800	0.01	0.01	mg/l	12/08/87	2	IT	ME

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ENGLE WELL	CULEBRA	CHROMIUM		0.0600			0.0600	< .02	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	COBALT	<	0.0010		NA	0.0000	< 0.001	< 0.001	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	COBALT		0.0200			0.0200	< 0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	COBALT		0.0200			0.0200	< .01	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	COLOR		60.0000		NA	0.0000			CU	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	COPPER	<	0.0100		NA	0.0000	< 0.01	0.12	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	COPPER		0.0200			0.0200	0.03	0.03	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	COPPER	<	0.1000		<	0.1000	< .01	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	DICHLORODIFLUOROMETHANE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V

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ENGLE WELL	CULEBRA	DIETHYL PHTHALATE		3.9000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l	12/08/87	2	IT	HP
ENGLE WELL	CULEBRA	ENDRIN	<	0.1000		NA	0.0000		M< .10	ug/l	01/31/90	3	IT	P
ENGLE WELL	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	Eh		429.0000		NA	0.0000			mV	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	FLUORENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	FLUORIDE		2.8000		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	FLUORIDE		2.0000		NA	0.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	FLUORIDE		2.8000		NA	0.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	FREON-113	<	50.0000		NA	0.0000	T< 50	M< 50	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	12/08/87	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
ENGLE WELL	CULEBRA	IODIDE	<	2.0000	<	2.0000				mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	IRON		0.3200	NA	0.0000		0.02	0.03	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	IRON		3.6000		3.6000	<	0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	IRON	<	0.0300	<	0.0300	<	.03	< .03	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	ISOPHORONE	<	4.0000	NA	0.0000				ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	ISOPHORONE	<	10.0000	NA	0.0000			M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	LEAD	<	0.1000	NA	0.0000	<	0.10	< 0.10	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	LEAD		0.1200		0.1500	<	0.05	< 0.05	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	LEAD		0.0900		0.0800	<	.05	< .05	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	LINDANE	<	0.0400	NA	0.0000				ug/l	12/08/87	2	IT	HP
ENGLE WELL	CULEBRA	LINDANE	<	0.0500	NA	0.0000			M< .05	ug/l	01/31/90	3	IT	P
ENGLE WELL	CULEBRA	LITHIUM		0.2000		0.2000	<	0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	LITHIUM		0.1600		0.1600	<	.01	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	LSI CORROSIVITY		-1.4800	NA	0.0000					12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	MAGNESIUM		160.0000		160.0000				mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	MAGNESIUM		150.0000		150.0000	<	0.1	< 0.1	mg/l	01/31/90	3	IT	MC
ENGLE WELL	CULEBRA	MANGANESE	<	0.0100		0.0200		0.02	< 0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	MANGANESE		0.1200		0.1200	<	0.005	< 0.005	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	MANGANESE		0.0390		0.0360	<	.005	< .005	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	MBAS		1.2000		1.3000				mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	MERCURY	<	0.0002	NA	0.0000	<	0.0002	< 0.0002	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	MERCURY	<	0.0002	<	0.0002	<	0.0002	< 0.0002	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	MERCURY	<	0.0002	<	0.0002	<	.0002	< .0002	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	METHOXYCHLOR	<	0.0010	NA	0.0000				mg/l	12/08/87	2	IT	HP
ENGLE WELL	CULEBRA	METHOXYCHLOR	<	0.5000	NA	0.0000			M< .50	ug/l	01/31/90	3	IT	P
ENGLE WELL	CULEBRA	METHYL BROMIDE	<	10.0000	NA	0.0000				ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	METHYL BROMIDE	<	10.0000	NA	0.0000	T<	10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	METHYL CHLORIDE	<	10.0000	NA	0.0000				ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	METHYL CHLORIDE	<	10.0000	NA	0.0000	T<	10	M< 10	ug/l	01/31/90	3	IT	V

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ENGLE WELL	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T 6	M 6	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	MOLYBDENUM		0.0320		NA	0.0000	0.036	0.002	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	MOLYBDENUM		0.0800			0.0700	< 0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	MOLYBDENUM		0.0500			0.0500	< .02	< .02	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	N-NITROSO-DI-PHENYLAMINE		5.9000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	NICKEL		0.0400		NA	0.0000	0.07	< 0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	NICKEL	<	0.0300			0.0300	< 0.03	< 0.03	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	NICKEL		0.0300		<	0.0300	< .03	< .03	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	NITRATE		0.5000		NA	0.0000			mg/l NO3-N	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	NITRATE	<	0.1000		NA	0.0000			mg/l NO3-N	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	NITRATE		0.1100			0.1200			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	ODOR		4.0000		NA	0.0000			T.O.N.	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000		M< 50	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000		M< 10	ug/l	01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	SV

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ENGLE WELL	CULEBRA	PHENOL	<	10.0000		NA	0.0000		M< 10	ug/l		01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	PHENOLICS		0.0060		NA	0.0000			mg/l		03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	PHENOLICS		0.0060			0.0000			mg/l		01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	PHOSPHATE		0.1700			0.1400			mg/l	T-PO4-P	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	POTASSIUM		10.0000			10.0000			mg/l		12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	POTASSIUM		7.6000			7.5000	< 0.1	< 0.1	mg/l		01/31/90	3	IT	MC
ENGLE WELL	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		03/04/85	1	IT	SV
ENGLE WELL	CULEBRA	PYRENE	<	10.0000		NA	0.0000		M< 10	ug/l		01/31/90	3	IT	SV
ENGLE WELL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3450.0000			3460.0000			mg/l		03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		4000.0000		NA	0.0000			mg/l		12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3600.0000			3600.0000			mg/l		01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		11.0000		NA	0.0000			mg/l		03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		9.0000			8.0000			mg/l		12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l		01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	SELENIUM		0.1000		NA	0.0000	0.011	< 0.001	mg/l		03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	SELENIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l		12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	SELENIUM	<	0.2000		NA	0.0000	< .002	< .002	mg/l		01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	SILICA		25.0000		NA	0.0000	25	37	mg/l		03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	SILICA		17.0000			16.0000	< 0.2	< 0.2	mg/l		12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	SILICA		12.0000			12.0000			mg/l		01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	SILVER		0.0200			0.0300	< 0.01	< 0.01	mg/l		12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	SILVER		0.0200			0.0200	< .01	< .01	mg/l		01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	SODIUM		440.0000			430.0000			mg/l		12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	SODIUM		220.0000			220.0000	< 0.1	< 0.1	mg/l		01/31/90	3	IT	MC
ENGLE WELL	CULEBRA	SPECIFIC CONDUCTANCE		3700.0000		NA	0.0000			umhos/cm@25C		03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	SPECIFIC CONDUCTANCE		4820.0000			4880.0000			umhos/cm@25C		12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	SPECIFIC CONDUCTANCE		4060.0000			4060.0000			uMhos/cm@25C		01/31/90	3	IT	GC

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ENGLE WELL	CULEBRA	STRONTIUM		7.0000		NA	0.0000	8.2	0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	STRONTIUM		8.3000			8.3000	< 0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	STRONTIUM		7.9000			8.0000	< .01	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	SULFATE		2000.0000		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	SULFATE		2000.0000		NA	0.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	SULFATE		1900.0000			2000.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	THALLIUM	<	0.0100		NA	0.0000	< .001	< .001	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	TITANIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	TITANIUM		0.2000			0.2400	< 0.03	< 0.03	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	TITANIUM	<	0.0100		<	0.0100	< .01	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	TOTAL HARDNESS		2200.0000		NA	0.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	TOTAL ORGANIC CARBON		3.0000			3.0000			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.1000		NA	0.0000			mg/l	03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	01/31/90	3	IT	GC
ENGLE WELL	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	12/08/87	2	IT	HP
ENGLE WELL	CULEBRA	TOXAPHENE	<	1.0000		NA	0.0000		M< 1.0	ug/l	01/31/90	3	IT	P
ENGLE WELL	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V

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ENGLE WELL	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	TURBIDITY		60.0000			65.0000			NTU	12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	VANADIUM		0.0400			0.0400	< 0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	VANADIUM		0.0400			0.0400	< .01	< .01	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	12/08/87	2	IT	V
ENGLE WELL	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	03/04/85	1	IT	V
ENGLE WELL	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	01/31/90	3	IT	V
ENGLE WELL	CULEBRA	ZINC		0.2000			0.2000	0.19	0.02	mg/l	03/04/85	1	IT	ME
ENGLE WELL	CULEBRA	ZINC		0.3700			0.3700	< 0.01	< 0.01	mg/l	12/08/87	2	IT	ME
ENGLE WELL	CULEBRA	ZINC		2.2000			2.2000	< .02	< .02	mg/l	01/31/90	3	IT	MT
ENGLE WELL	CULEBRA	pH		6.5000		NA	0.0000				03/04/85	1	IT	GC
ENGLE WELL	CULEBRA	pH		6.2800			6.4000				12/08/87	2	IT	GC
ENGLE WELL	CULEBRA	pH		7.1000			7.1100				01/31/90	3	IT	GC
** FAIRVIEW WINDMILL														
FAIRVIEW WINDMILL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V

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FAIRVIEW WINDMILL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	11/16/87	1	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	07/06/88	2	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	11/16/87	1	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	07/06/88	2	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	BARIUM		0.0110			0.0110	< 0.005	< 0.005	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	BARIUM		0.0280			0.0290	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	CADMIUM		0.0070			0.0100	< 0.005	< 0.005	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	CADMIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	CHLORIDE		140.0000		NA	0.0000			mg/l	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	CHLORIDE		140.0000		NA	0.0000			mg/l	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	CHROMIUM		0.0500			0.0600	< 0.01	< 0.01	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	CHROMIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	COLOR		200.0000		NA	0.0000			CU	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	COLOR	<	1.0000		NA	0.0000			CU	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	COPPER		0.0100			0.0200	< 0.01	< 0.01	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	COPPER		0.1100			0.1200	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V

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FAIRVIEW WINDMILL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	ENDRIN	<	0.0200		NA	0.0000			ug/l	11/16/87	1	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	ENDRIN	<	0.0200		NA	0.0000			ug/l	07/06/88	2	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	FLUORIDE		2.0000		NA	0.0000			mg/l	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	FLUORIDE		2.1000		NA	0.0000			mg/l	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	IRON		6.7000			6.8000	< 0.01	< 0.01	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	IRON		0.0800			0.0800	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	LEAD		0.0700			0.0900	< 0.05	< 0.05	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	LEAD	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	LINDANE	<	0.0400		NA	0.0000			ug/l	11/16/87	1	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	LINDANE	<	0.0400		NA	0.0000			ug/l	07/06/88	2	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	LSI CORROSIVITY		-0.3400		NA	0.0000				11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	LSI CORROSIVITY		-0.0800		NA	0.0000			--	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	MANGANESE		0.1500			0.1500	< 0.005	< 0.005	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	MANGANESE		0.0520			0.0600	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	MBAS	<	0.0250		<	0.0250			mg/l	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	MBAS		0.0320		NA	0.0000			mg/l	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	MERCURY		0.0024		NA	0.0000	< 0.0002	< 0.0002	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l	11/16/87	1	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l	07/06/88	2	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	NITRATE		0.3000		NA	0.0000			mg/l NO3-N	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	NITRATE		1.4000		NA	0.0000			mg/l NO3-N	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	ODOR		20.0000		NA	0.0000			T.O.N	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	ODOR		1.0000		NA	0.0000			T.O.N.	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3400.0000		NA	0.0000			mg/l	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3300.0000		NA	0.0000			mg/l	07/06/88	2	IT	GC

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FAIRVIEW WINDMILL	DEWEY LAKE	SELENIUM		0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	SELENIUM		0.0110		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	SILVER	<	0.0100			0.0100	< 0.01	< 0.01	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	SILVER	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	SULFATE		1600.0000		NA	0.0000			mg/l	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	SULFATE		1900.0000		NA	0.0000			mg/l	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	11/16/87	1	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	07/06/88	2	IT	HP
FAIRVIEW WINDMILL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	TURBIDITY		120.0000			120.0000			NTU	11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	TURBIDITY		1.0000		NA	0.0000			NTU	07/06/88	2	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	11/16/87	1	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	07/06/88	2	IT	V
FAIRVIEW WINDMILL	DEWEY LAKE	ZINC		0.0200			0.0200	< 0.01	< 0.01	mg/l	11/16/87	1	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	ZINC		0.0200			0.0100	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
FAIRVIEW WINDMILL	DEWEY LAKE	pH		7.1700		NA	0.0000				11/16/87	1	IT	GC
FAIRVIEW WINDMILL	DEWEY LAKE	pH		7.1000			7.1300			--	07/06/88	2	IT	GC
** H-02a														
H-02a	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V

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H-02a	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV

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H-02a	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2-BUTANONE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	2-BUTANONE	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-02a	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2-HEXANONE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	2-HEXANONE	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV

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H-02a	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	ACETONE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	ACETONE		1400.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	ACETONE		27.0000			1200.0000	1200	17	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC

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H-02a	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	ALKALINITY (HCO3)		56.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	ALKALINITY (HCO3)		54.0000			54.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	ALKALINITY (HCO3)		57.0000			57.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	ARSENIC	<	0.0100		<	0.0100	< 0.001	< 0.001	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	ARSENIC		0.0150			0.0130	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	BENZENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	BENZENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV

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H-02a	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		20.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	BORON		10.0000			10.0000	< 0.01	< 0.01	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	BORON		10.0000			10.0000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME

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H-02a	CULEBRA	BORON		11.0000			11.0000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	BROMIDE	<	1.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	BROMIDE	<	2.0000		NA	0.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	BROMIDE		3.0000			3.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	BROMOFORM	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	BROMOFORM	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	CADMIUM		0.0800			0.0800	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	CALCIUM		700.0000			710.0000			mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	CALCIUM		670.0000		NA	0.0000			mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	CALCIUM		770.0000			770.0000			mg/l	01/19/89	3	IT	MC
H-02a	CULEBRA	CARBON DISULFIDE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	CARBON DISULFIDE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	CESIUM		0.1000			0.1000	0.03	0.03	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	CHLORIDE		5300.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	CHLORIDE		4800.0000		NA	0.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	CHLORIDE		3600.0000			3600.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	CHLOROBENZENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-02a	CULEBRA	CHLOROBENZENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	CHLOROETHANE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	CHLOROETHANE	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	CHLOROFORM	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	CHLOROFORM	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	CHROMIUM	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	CHROMIUM		0.4000			0.4000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	COPPER	<	0.1000			0.1100	< 0.01	< 0.01	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	COPPER	<	0.1000			0.1000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	CYANIDE	<	0.0400		NA	0.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV

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H-02a	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	ETHYLBENZENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	ETHYLBENZENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	Eh		388.0000		NA	0.0000			mV	04/21/86	1	IT	GC
H-02a	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV

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H-02a	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	FLUORIDE		14.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	FLUORIDE		2.1000		NA	0.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	FLUORIDE		2.2000			2.2000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	IODIDE		1.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	IODIDE		8.0000			7.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	IODIDE		9.0000			8.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	IRON		0.7400			0.7800	< 0.01	< 0.01	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	IRON		0.3000			0.3000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	IRON		1.2000			1.2000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/21/86	1	IT	ME

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H-02a	CULEBRA	LEAD	<	0.5000	<		0.5000	< 0.05	< 0.05	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	LEAD		0.5000			0.5000	< 0.05	< 0.05	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	LITHIUM		0.7200			0.7200	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	LITHIUM		0.2600			0.2500	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	MAGNESIUM		170.0000			170.0000			mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	MAGNESIUM		160.0000		NA	0.0000			mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	MAGNESIUM		170.0000			170.0000			mg/l	01/19/89	3	IT	MC
H-02a	CULEBRA	MANGANESE		0.0700			0.0800	< 0.005	< 0.005	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	MANGANESE		0.0700			0.0700	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	MANGANESE	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	MERCURY		0.0002	<		0.0002	0.0002	< 0.0002	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	METHYL BROMIDE	<	10.0000	<		10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	METHYL BROMIDE	<	10.0000	<		10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	METHYL CHLORIDE	<	10.0000	<		10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	METHYL CHLORIDE	<	10.0000	<		10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	METHYLENE CHLORIDE	<	10.0000	<		10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	METHYLENE CHLORIDE		16.0000			45.0000	< 5	30	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	MOLYBDENUM		0.0400			0.0300	< 0.01	0.02	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	MOLYBDENUM		0.0600			0.0700	0.03	0.03	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	MOLYBDENUM	<	0.0500	<		0.0500	< 0.05	< 0.05	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV

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H-02a	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		04/21/86	1	IT	SV
H-02a	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		04/21/86	1	IT	ME
H-02a	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		08/12/87	2	IT	ME
H-02a	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		01/19/89	3	IT	MT
H-02a	CULEBRA	NITRATE		0.3000		NA	0.0000			mg/l	NO3-N	04/21/86	1	IT	GC
H-02a	CULEBRA	NITRATE	<	0.2000		NA	0.0000			mg/l	NO3-N	08/12/87	2	IT	GC
H-02a	CULEBRA	NITRATE	<	0.0200		<	0.0200			mg/l		01/19/89	3	IT	GC
H-02a	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/21/86	1	IT	SV
H-02a	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/21/86	1	IT	SV
H-02a	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		08/12/87	2	IT	PC
H-02a	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		04/21/86	1	IT	SV
H-02a	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		04/21/86	1	IT	SV
H-02a	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		04/21/86	1	IT	SV
H-02a	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		08/12/87	2	IT	SV
H-02a	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		01/19/89	3	IT	SV
H-02a	CULEBRA	PHENOLICS		0.0290			0.0260			mg/l		04/21/86	1	IT	GC
H-02a	CULEBRA	PHENOLICS		0.0970		NA	0.0000			mg/l		08/12/87	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-02a	CULEBRA	PHENOLICS	<	0.0100		NA	0.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l T-PO4-P	04/21/86	1	IT	GC
H-02a	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l T-PO4-P	08/12/87	2	IT	GC
H-02a	CULEBRA	PHOSPHORUS		0.0200			0.0400			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	POTASSIUM		97.0000			98.0000			mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	POTASSIUM		100.0000		NA	0.0000			mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	POTASSIUM		110.0000			110.0000			mg/l	01/19/89	3	IT	MC
H-02a	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/86	1	IT	SV
H-02a	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	SV
H-02a	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	01/19/89	3	IT	SV
H-02a	CULEBRA	RESIDUE, FILTERABLE @ 180 C		13000.0000			14000.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	RESIDUE, FILTERABLE @ 180 C		11000.0000			11000.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	RESIDUE, FILTERABLE @ 180 C		10500.0000			10400.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		60.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		53.0000			51.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		8.0000			9.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	SELENIUM	<	0.0100		<	0.0100	< 0.001	< 0.001	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	SILICA		13.0000			13.0000	< 0.2	< 0.2	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	SILICA		13.0000			14.0000	< 0.2	< 0.2	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	SILICA		6.0000			6.2000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	SILVER		0.2000			0.2000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	SODIUM		3600.0000			3600.0000			mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	SODIUM		2600.0000		NA	0.0000			mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	SODIUM		1400.0000			1400.0000			mg/l	01/19/89	3	IT	MC
H-02a	CULEBRA	SPECIFIC CONDUCTANCE		18500.0000			18500.0000			umhos/cm@25C	04/21/86	1	IT	GC
H-02a	CULEBRA	SPECIFIC CONDUCTANCE		15800.0000			15700.0000			umhos/cm@25C	08/12/87	2	IT	GC

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H-02a	CULEBRA	SPECIFIC CONDUCTANCE		15800.0000			15800.0000			uMhos/cm@25C	01/19/89	3	IT	GC
H-02a	CULEBRA	STRONTIUM		6.8000			6.9000	0.01	0.01	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	STRONTIUM		9.8000			9.8000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	STRONTIUM		8.6000			8.6000	0.01	0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	STYRENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	STYRENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	SULFATE		3300.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	SULFATE		2900.0000		NA	0.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	SULFATE		2600.0000			2600.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	TIN	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	TITANIUM	<	0.3000		<	0.3000	< 0.3	< 0.3	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	TOLUENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	TOLUENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	TOTAL ORGANIC CARBON		7.0000		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	TOTAL ORGANIC CARBON		5.0000			5.0000			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	TOTAL ORGANIC CARBON		5.0000			6.0000			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	TOTAL ORGANIC HALOGEN		0.1400		NA	0.0000			mg/l	04/21/86	1	IT	GC
H-02a	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	08/12/87	2	IT	GC
H-02a	CULEBRA	TOTAL ORGANIC HALOGEN		0.0700			0.0900			mg/l	01/19/89	3	IT	GC
H-02a	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V

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H-02a	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	TRICHLOROETHYLENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	TRICHLOROETHYLENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	VANADIUM		0.1000			0.1000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	VINYL ACETATE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	VINYL ACETATE	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	VINYL CHLORIDE	<	10.0000		<	10.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	VINYL CHLORIDE	<	10.0000		<	10.0000	< 10	< 10	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	XYLENE	<	5.0000		<	5.0000			ug/l	04/21/86	1	IT	V
H-02a	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	08/12/87	2	IT	V
H-02a	CULEBRA	XYLENE	<	5.0000		<	5.0000	< 5	< 5	ug/l	01/19/89	3	IT	V
H-02a	CULEBRA	ZINC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/21/86	1	IT	ME
H-02a	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/12/87	2	IT	ME
H-02a	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/19/89	3	IT	MT
H-02a	CULEBRA	pH		7.8300		NA	0.0000				04/21/86	1	IT	GC
H-02a	CULEBRA	pH		7.4400			7.7400				08/12/87	2	IT	GC
H-02a	CULEBRA	pH		7.7300			7.7400				01/19/89	3	IT	GC
** H-02c														
H-02c	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V

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H-02c	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	<	100.0000	< 5		< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	<	100.0000	< 5		< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	<	100.0000	< 5		< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	<	100.0000	< 5		< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000	<	100.0000	< 5		< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	1,3-DICHLOROBENZENE		11.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	1,4-DICHLOROBENZENE		23.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000	NA	0.0000			< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,4-DINITROPHENOL	<	50.0000	NA	0.0000			< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,4-DINITROTOLUENE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2,6-DINITROTOLUENE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2-BUTANONE	<	10.0000	<	200.0000	20		< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2-CHLOROPHENOL	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2-HEXANONE	<	10.0000	<	200.0000	< 10		< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2-METHYLPHENOL	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2-NITROANILINE	<	50.0000	NA	0.0000			< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	2-NITROPHENOL	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000	NA	0.0000			< 20	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	3-NITROANILINE	<	50.0000	NA	0.0000			< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000	NA	0.0000			< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	4-CHLOROANILINE	<	10.0000	NA	0.0000			< 10	ug/l	12/13/89	1	IT	SV

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H-02c	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		<	200.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000		< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000		< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	ACETONE		2800.0000			2100.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	ALKALINITY (HCO3)		56.0000		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	ALKALINITY (HCO3)		60.0000			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	ALUMINUM	<	0.2000		<	0.2000	< 0.2	< 0.2	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< .2	< .2	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	ANTIMONY		0.0900			0.0800	< 0.06	< 0.06	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	ANTIMONY	<	0.6000		<	0.6000	< .06	< .06	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	AROCLOR 1016	<	0.5000		NA	0.0000		< 0.5	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	AROCLOR 1221	<	0.5000		NA	0.0000		< 0.5	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	AROCLOR 1232	<	0.5000		NA	0.0000		< 0.5	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	AROCLOR 1242	<	0.5000		NA	0.0000		< 0.5	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	AROCLOR 1248	<	0.5000		NA	0.0000		< 0.5	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	AROCLOR 1254	<	1.0000		NA	0.0000		< 1.0	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	AROCLOR 1260	<	1.0000		NA	0.0000		< 1.0	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	ARSENIC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	ARSENIC	<	0.0100		NA	0.0000	< .01	< .01	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	BARIUM	<	0.2000		<	0.2000	< 0.2	< 0.2	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	BARIUM	<	2.0000		<	2.0000	< .2	< .2	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	BENZENE	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-02c	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000		< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	BORON		10.0000			9.7000	< 0.02	< 0.02	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	BORON		11.0000			11.0000	< .02	< .02	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	BROMIDE		6.0000			6.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	BROMIDE		12.0000			12.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	BROMOFORM	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	CADMIUM		0.0110			0.0120	< 0.005	< 0.005	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	CALCIUM		720.0000			710.0000			mg/l	12/13/89	1	IT	MC
H-02c	CULEBRA	CALCIUM		680.0000			680.0000			mg/l	07/25/90	2	IT	MC
H-02c	CULEBRA	CARBON DISULFIDE	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	CESIUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	CESIUM	<	0.2000		<	0.2000	< .2	< .2	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	CHLORIDE		3700.0000			3600.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	CHLORIDE		2700.0000			0.0000			mg/l	07/25/90	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-02c	CULEBRA	CHLOROBENZENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	CHLOROETHANE	<	10.0000	<		200.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	CHLOROFORM	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	CHROMIUM		0.0600			0.0600	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	CHROMIUM		0.1000			0.1000	< .01	< .02	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	CHRYSENE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	COBALT	<	0.0500	<		0.0500	< 0.05	< 0.05	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	COBALT	<	0.5000	<		0.5000	< .05	< .05	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	COPPER	<	0.0250	<		0.0250	< 0.025	< 0.025	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	COPPER	<	0.2500	<		0.2500	< .025	< .025	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	CYANIDE		0.0100	NA		0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	CYANIDE	<	0.0100	NA		0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	DIMETHYL PHTHALATE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	ETHYLBENZENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	FLUORANTHENE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	FLUORENE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	FLUORESCEIN		16.0000			17.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	FLUORESCEIN		4.4000			4.6000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	FLUORIDE		2.4000	NA		0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	FLUORIDE		2.5000			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	HEXACHLOROBENZENE	<	10.0000	NA		0.0000		< 10	ug/l	12/13/89	1	IT	SV

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H-02c	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	IODIDE		4.0000			5.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	IRON		1.1000			1.1000	< 0.1	< 0.1	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	IRON		1.0000			1.0000	< .1	< .1	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	LEAD		0.0800			0.0900	< 0.05	< 0.05	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	LEAD	<	0.5000		<	0.5000	< .05	< .05	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	LITHIUM		0.2400			0.2400	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	LITHIUM		0.2000			0.2000	< .01	< .01	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	MAGNESIUM		150.0000			150.0000			mg/l	12/13/89	1	IT	MC
H-02c	CULEBRA	MAGNESIUM		160.0000			160.0000			mg/l	07/25/90	2	IT	MC
H-02c	CULEBRA	MANGANESE		0.1100			0.1000	< 0.015	< 0.015	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	MANGANESE	<	0.1500		<	0.1500	< .015	< .015	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	MERCURY	<	0.0002		<	0.0002	< .0002	< .0002	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	METHYL BROMIDE	<	10.0000		<	200.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	METHYL CHLORIDE	<	10.0000		<	200.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	METHYLENE CHLORIDE	<	5.0000		<	100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	MOLYBDENUM		0.0400			0.0400	< 0.02	< 0.02	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	MOLYBDENUM	<	0.2000		<	0.2000	< .02	< .02	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	NICKEL	<	0.0400		<	0.0400	< 0.04	< 0.04	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	NICKEL	<	0.4000		<	0.4000	< .04	< .04	mg/l	07/25/90	2	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-02c	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	NITRATE	<	0.0200			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000		< 50	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	PHENOL	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	PHENOLICS	<	0.0050		<	0.0100			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	PHENOLICS	<	0.0050			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	PHOSPHORUS		0.0400		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	PHOSPHORUS		0.0200			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	POTASSIUM		110.0000			110.0000			mg/l	12/13/89	1	IT	MC
H-02c	CULEBRA	POTASSIUM		100.0000			100.0000			mg/l	07/25/90	2	IT	MC
H-02c	CULEBRA	PYRENE	<	10.0000		NA	0.0000		< 10	ug/l	12/13/89	1	IT	SV
H-02c	CULEBRA	RESIDUE, FILTERABLE @ 180 C		10500.0000		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	RESIDUE, FILTERABLE @ 180 C		9300.0000			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		7.0000		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		62.0000			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< .005	< .005	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	SILICA		5.8000		NA	0.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	SILICA		6.2000			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	SILVER		0.0200			0.0200	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	SILVER	<	0.1000		<	0.1000	< .01	< .01	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	SODIUM		2700.0000			2700.0000			mg/l	12/13/89	1	IT	MC
H-02c	CULEBRA	SODIUM		2000.0000			2000.0000			mg/l	07/25/90	2	IT	MC
H-02c	CULEBRA	SPECIFIC CONDUCTANCE		12300.0000			12400.0000			uMhos/cm@25C	12/13/89	1	IT	GC
H-02c	CULEBRA	SPECIFIC CONDUCTANCE		13900.0000			14000.0000			uMhos/cm@25C	07/25/90	2	IT	GC
H-02c	CULEBRA	STRONTIUM		7.5000			7.3000	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT

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H-02c	CULEBRA	STRONTIUM		8.7000			8.8000	< .01	< .01	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	STYRENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	SULFATE		3200.0000			3000.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	SULFATE		2900.0000			0.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	TETRACHLOROETHYLENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	THALLIUM	<	1.0000	NA		0.0000	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	THALLIUM	<	0.0100	NA		0.0000	< .01	< .01	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	TITANIUM		0.0100			0.0100	< 0.01	< 0.01	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	TITANIUM	<	0.1000	<		0.1000	< .01	< .01	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	TOLUENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	TOTAL ORGANIC CARBON		4.0000			4.0000			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	TOTAL ORGANIC HALOGEN		0.1700			0.1400			mg/l	12/13/89	1	IT	GC
H-02c	CULEBRA	TOTAL ORGANIC HALOGEN		0.1100			0.0700			mg/l	07/25/90	2	IT	GC
H-02c	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	TRICHLOROETHYLENE	<	5.0000	<		100.0000	5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	VANADIUM	<	0.0500	<		0.0500	< 0.05	< 0.05	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	VANADIUM	<	0.5000	<		0.5000	< .05	< .05	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	VINYL ACETATE	<	10.0000	<		200.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	VINYL CHLORIDE	<	10.0000	<		200.0000	< 10	< 10	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	XYLENE	<	5.0000	<		100.0000	< 5	< 5	ug/l	12/13/89	1	IT	V
H-02c	CULEBRA	ZINC	<	0.0600			0.0600	< 0.02	< 0.02	mg/l	12/13/89	1	IT	MT
H-02c	CULEBRA	ZINC	<	0.2000	<		0.2000	< .02	< .02	mg/l	07/25/90	2	IT	MT
H-02c	CULEBRA	pH		6.6500			6.6500				12/13/89	1	IT	GC
H-02c	CULEBRA	pH		7.4400			7.4400				07/25/90	2	IT	GC
** H-03b1														
H-03b1	MAGENTA	1,1,1-TRICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	V

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H-03b1	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV

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H-03b1	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	4-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	ACETONE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	ACETONE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	ACETONE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	ALKALINITY (HCO3)		58.0000			52.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	ALKALINITY (HCO3)		40.0000			41.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	ALKALINITY (HCO3)		43.0000			41.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	ALKALINITY (HCO3)		36.0000			0.0000			mg/l	08/28/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	ALUMINUM	<	0.1000	<	0.1000	< 0.1	< 0.1		mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	ALUMINUM	<	1.0000	NA	0.0000	< 0.1	< 0.1		mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	ALUMINUM	<	1.0000	<	1.0000	< 0.1	< 0.1		mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	ALUMINUM	<	1.0000	<	1.0000	< 0.1	< 0.1		mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	ALUMINUM		0.3000		0.3000				mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	ANTHRACENE	<	1.0000	NA	0.0000				ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	ANTHRACENE	<	10.0000	NA	0.0000				ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	ANTHRACENE	<	10.0000	NA	0.0000				ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	ANTHRACENE	<	10.0000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	ANTIMONY	<	0.5000	<	0.5000	< 0.05	< 0.05		mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	ANTIMONY	<	0.5000	<	0.5000	< 0.05	< 0.05		mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	ANTIMONY		0.1100		0.1000				mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	AROCLOR 1016	<	0.5000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	AROCLOR 1221	<	0.5000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	AROCLOR 1232	<	0.5000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	AROCLOR 1242	<	0.5000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	AROCLOR 1248	<	0.5000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	AROCLOR 1254	<	1.0000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	AROCLOR 1260	<	1.0000	NA	0.0000				ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	ARSENIC		0.0200	NA	0.0000	< 0.01	< 0.01		mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	ARSENIC	<	0.0100	NA	0.0000	< 0.01	< 0.01		mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	ARSENIC	<	0.0500	<	0.0500	< 0.005	< 0.005		mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	ARSENIC	<	0.0050	NA	0.0000	< 0.005	< 0.005		mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	ARSENIC	<	0.0100	NA	0.0000				mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	BARIUM	<	0.1000	<	0.1000	< 0.1	< 0.1		mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	BARIUM	<	0.0500	NA	0.0000	< 0.005	< 0.005		mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	BARIUM	<	0.0500	<	0.0500	< 0.005	< 0.005		mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	BARIUM	<	0.0500	<	0.0500	< 0.005	< 0.005		mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	BARIUM	<	0.2000	<	0.2000				mg/l	08/28/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	BENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	BENZENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	BENZENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BENZO(A)PYRENE		6.5000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV

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H-03b1	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BERYLLIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	<0.005	< 0.005	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	BERYLLIUM	<	0.0050		<	0.0050			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE		11.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	BORON		4.5000		NA	0.0000	< 0.01	0.24	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	BORON		3.5000		NA	0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	BORON		3.4000			3.4000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	BORON		3.4000			3.4000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	BORON		3.3000			3.3000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	BROMIDE		23.0000		NA	0.0000			mg/l	07/01/85	1	IT	GC
H-03b1	MAGENTA	BROMIDE		6.0000		NA	0.0000			mg/l	09/16/86	2	IT	GC

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H-03b1	MAGENTA	BROMIDE		6.0000		NA	0.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	BROMIDE		6.0000			6.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	BROMIDE		6.0000			6.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	CADMIUM	<	0.0170		<	0.0180			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	CALCIUM		1000.0000		NA	0.0000			mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	CALCIUM		920.0000			930.0000			mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	CALCIUM		1000.0000			1000.0000			mg/l	03/16/89	4	IT	MC
H-03b1	MAGENTA	CALCIUM		1100.0000			1100.0000			mg/l	08/28/90	5	IT	MC
H-03b1	MAGENTA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	CESIUM		0.2000		NA	0.0000	< 0.1	0.1	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	CESIUM	<	0.0100		<	0.0100	< 0.1	< 0.1	mg/l	09/02/87	3	IT	ME

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H-03b1	MAGENTA	CESIUM	<	0.1200	<		0.1200	< 0.06	< 0.06	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	CESIUM	<	0.2000	<		0.2000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	CHLORIDE		3500.0000			3500.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	CHLORIDE		3400.0000			3300.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	CHLORIDE		3300.0000			3400.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	CHLORIDE		3200.0000			3200.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	CHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	CHLOROBENZENE	<	5.0000	NA		0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	CHLOROBENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	CHLOROBENZENE	<	5.0000	NA		0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	CHLOROETHANE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	CHLOROETHANE	<	10.0000	NA		0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	CHLOROETHANE	<	10.0000	NA		0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	CHLOROETHANE	<	10.0000	NA		0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	CHLOROFORM	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	CHLOROFORM	<	5.0000	NA		0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	CHLOROFORM	<	5.0000	NA		0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	CHLOROFORM	<	5.0000	NA		0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	CHROMIUM	<	0.0010	NA		0.0000	< 0.001	< 0.001	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	CHROMIUM	<	0.1000	NA		0.0000	< 0.01	0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	CHROMIUM	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	CHROMIUM		0.2000			0.2000	< 0.01	0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	CHROMIUM		0.1200			0.1200			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	CHRYSENE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	CHRYSENE	<	10.0000	NA		0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	CHRYSENE	<	10.0000	NA		0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	CHRYSENE	<	10.0000	NA		0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	09/02/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	COBALT		0.0040	NA		0.0000	< 0.001	< 0.001	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	COBALT	<	0.1000	NA		0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	COBALT	<	0.0500	<		0.0500			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	COPPER		0.0300			0.0300	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	COPPER	<	0.1000	NA		0.0000	< 0.01	0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	COPPER	<	0.1000	<		0.1000	0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	COPPER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	COPPER	<	0.0250	<		0.0250			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	CYANIDE	<	0.0200	NA		0.0000			mg/l	07/01/85	1	IT	GC
H-03b1	MAGENTA	CYANIDE	<	0.0200	NA		0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	CYANIDE	<	0.0200	NA		0.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	CYANIDE	<	0.0100	NA		0.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	CYANIDE	<	0.0100			0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	DI-N-BUTYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	DI-N-OCTYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	DIBENZOFURAN	<	1.0000	NA		0.0000			ug/l	07/01/85	1	IT	SV

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H-03b1	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	Eh		380.0000		NA	0.0000			mV	09/16/86	2	IT	GC
H-03b1	MAGENTA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	FLUORENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV

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H-03b1	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	FLUORIDE		1.8000			1.8000			mg/l	07/01/85	1	IT	GC
H-03b1	MAGENTA	FLUORIDE		1.9000		NA	0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	FLUORIDE		1.8000		NA	0.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	FLUORIDE		2.0000			2.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	FLUORIDE		2.2000			0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	IODIDE		1.6000			1.6000			mg/l	07/01/85	1	IT	GC

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H-03b1	MAGENTA	IODIDE		2.0000		NA	0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	IRON		0.1500			0.1400	0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	IRON		0.3000		NA	0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	IRON	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	IRON	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	IRON	<	0.1000		<	0.1000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	LEAD		0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	LEAD		0.1400			0.1400			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	LITHIUM		3.6000			3.6000	0.01	0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	LITHIUM		0.3300			0.3300	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	LITHIUM		0.3000			0.3000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	MAGNESIUM		330.0000		NA	0.0000			mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	MAGNESIUM		290.0000			300.0000			mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	MAGNESIUM		300.0000			290.0000			mg/l	03/16/89	4	IT	MC
H-03b1	MAGENTA	MAGNESIUM		270.0000			270.0000			mg/l	08/28/90	5	IT	MC
H-03b1	MAGENTA	MANGANESE		0.0400			0.0500	0.02	0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	MANGANESE	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/16/89	4	IT	MT

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H-03b1	MAGENTA	MANGANESE		0.0310			0.0300			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	MERCURY		0.0003			0.0003	0.0003	< 0.0002	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	MERCURY	<	0.0004		NA	0.0000	< 0.0002	< 0.0002	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	MERCURY	<	0.0004		NA	0.0000	< 0.0002	< 0.0002	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	MERCURY	<	0.0004		<	0.0004			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	METHYLENE CHLORIDE		14.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	MOLYBDENUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	MOLYBDENUM		0.0400		NA	0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	MOLYBDENUM		0.0300			0.0200	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	MOLYBDENUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	MOLYBDENUM		0.0500			0.0500			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV
H-03b1	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	09/02/87	3	IT	SV
H-03b1	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	03/16/89	4	IT	SV
H-03b1	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	SV
H-03b1	MAGENTA	N-NITROSO-DI-PHENYLAMINE		24.0000		NA	0.0000			ug/l	09/16/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-03b1	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		09/16/86	2	IT	SV
H-03b1	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	NICKEL		0.1300			0.1200	0.02	< 0.01	mg/l		07/01/85	1	IT	ME
H-03b1	MAGENTA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		09/16/86	2	IT	ME
H-03b1	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		09/02/87	3	IT	ME
H-03b1	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		03/16/89	4	IT	MT
H-03b1	MAGENTA	NICKEL		0.0600			0.0600			mg/l		08/28/90	5	IT	MT
H-03b1	MAGENTA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	07/01/85	1	IT	GC
H-03b1	MAGENTA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	09/16/86	2	IT	GC
H-03b1	MAGENTA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	09/02/87	3	IT	GC
H-03b1	MAGENTA	NITRATE	<	0.0200		<	0.0200			mg/l		03/16/89	4	IT	GC
H-03b1	MAGENTA	NITRATE	<	0.0200		<	0.0200			mg/l		08/28/90	5	IT	GC
H-03b1	MAGENTA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		09/16/86	2	IT	SV
H-03b1	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		09/16/86	2	IT	SV
H-03b1	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		09/16/86	2	IT	PC
H-03b1	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		09/02/87	3	IT	PC
H-03b1	MAGENTA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		09/16/86	2	IT	SV
H-03b1	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV

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H-03b1	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		09/16/86	2	IT	SV
H-03b1	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	PHENOL	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	PHENOLICS		0.0290			0.0290			mg/l		07/01/85	1	IT	GC
H-03b1	MAGENTA	PHENOLICS		0.0500		NA	0.0000			mg/l		09/16/86	2	IT	GC
H-03b1	MAGENTA	PHENOLICS		0.0530		NA	0.0000			mg/l		09/02/87	3	IT	GC
H-03b1	MAGENTA	PHENOLICS	<	0.0100		NA	0.0000			mg/l		03/16/89	4	IT	GC
H-03b1	MAGENTA	PHENOLICS	<	0.0050			0.0000			mg/l		08/28/90	5	IT	GC
H-03b1	MAGENTA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	07/01/85	1	IT	GC
H-03b1	MAGENTA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	09/16/86	2	IT	GC
H-03b1	MAGENTA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	09/02/87	3	IT	GC
H-03b1	MAGENTA	PHOSPHORUS		0.0100			0.0100			mg/l		03/16/89	4	IT	GC
H-03b1	MAGENTA	PHOSPHORUS		0.0300			0.0000			mg/l		08/28/90	5	IT	GC
H-03b1	MAGENTA	POTASSIUM		35.0000		NA	0.0000			mg/l		09/16/86	2	IT	ME
H-03b1	MAGENTA	POTASSIUM		36.0000			35.0000			mg/l		09/02/87	3	IT	ME
H-03b1	MAGENTA	POTASSIUM		34.0000			36.0000			mg/l		03/16/89	4	IT	MC
H-03b1	MAGENTA	POTASSIUM		30.0000			30.0000			mg/l		08/28/90	5	IT	MC
H-03b1	MAGENTA	PYRENE	<	1.0000		NA	0.0000			ug/l		07/01/85	1	IT	SV
H-03b1	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		09/16/86	2	IT	SV
H-03b1	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		09/02/87	3	IT	SV
H-03b1	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		03/16/89	4	IT	SV
H-03b1	MAGENTA	RESIDUE, FILTERABLE @ 180 C		8800.0000			9200.0000			mg/l		07/01/85	1	IT	GC
H-03b1	MAGENTA	RESIDUE, FILTERABLE @ 180 C		8500.0000		NA	0.0000			mg/l		09/16/86	2	IT	GC
H-03b1	MAGENTA	RESIDUE, FILTERABLE @ 180 C		15.0000			13.0000			mg/l		09/02/87	3	IT	GC

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H-03b1	MAGENTA	RESIDUE, FILTERABLE @ 180 C		8800.0000			8600.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	RESIDUE, FILTERABLE @ 180 C		9300.0000			0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		18.0000			19.0000			mg/l	07/01/85	1	IT	GC
H-03b1	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		43.0000		NA	0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		8100.0000			7800.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		43.0000			40.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		18.0000			0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	SELENIUM		0.0900		NA	0.0000	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	SELENIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	SELENIUM	<	0.0500		NA	0.0000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	SILICA		11.0000		NA	0.0000	< 0.1	< 0.1	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	SILICA		12.0000		NA	0.0000	< 0.2	< 0.2	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	SILICA		11.0000			11.0000	< 0.2	< 0.2	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	SILICA		4.5000			4.5000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	SILICA		5.5000			0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	SILVER		0.0300			0.0300			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	SODIUM		1700.0000		NA	0.0000			mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	SODIUM		1500.0000			1500.0000			mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	SODIUM		14500.0000			14500.0000			mg/l	03/16/89	4	IT	MC
H-03b1	MAGENTA	SODIUM		1400.0000			1400.0000			mg/l	08/28/90	5	IT	MC
H-03b1	MAGENTA	SPECIFIC CONDUCTANCE		11900.0000		NA	0.0000			umhos/cm@25C	07/01/85	1	IT	GC
H-03b1	MAGENTA	SPECIFIC CONDUCTANCE		13800.0000		NA	0.0000			umhos/cm@25C	09/16/86	2	IT	GC
H-03b1	MAGENTA	SPECIFIC CONDUCTANCE		12600.0000			12300.0000			umhos/cm@25C	09/02/87	3	IT	GC
H-03b1	MAGENTA	SPECIFIC CONDUCTANCE		11500.0000			11500.0000			uMhos/cm@25C	03/16/89	4	IT	GC
H-03b1	MAGENTA	SPECIFIC CONDUCTANCE		10300.0000			10310.0000			uMhos/cm@25C	08/28/90	5	IT	GC

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H-03b1	MAGENTA	STRONTIUM		17.0000			17.0000	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	STRONTIUM		13.0000		NA	0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	STRONTIUM		17.0000			18.0000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	STRONTIUM		17.0000			17.0000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	STRONTIUM		16.0000			16.0000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	STYRENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	STYRENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	STYRENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	SULFATE		1800.0000		NA	0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	SULFATE		2400.0000		NA	0.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	SULFATE		2000.0000			2100.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	SULFATE		2100.0000			0.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	THALLIUM	<	0.4000		NA	0.0000	< 0.004	< 0.004	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	THALLIUM	<	1.0000		NA	0.0000			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	TIN	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	TITANIUM		0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	TITANIUM	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	TITANIUM		0.3000			0.3000	< 0.1	< 0.1	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	TITANIUM		0.0200			0.0200			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	TOLUENE		2.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	TOLUENE		32.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V

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H-03b1	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	07/01/85	1	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC CARBON		4.0000		NA	0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC HALOGEN		0.4100		NA	0.0000			mg/l	07/01/85	1	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC HALOGEN		0.8500		NA	0.0000			mg/l	09/16/86	2	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	09/02/87	3	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	03/16/89	4	IT	GC
H-03b1	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	08/28/90	5	IT	GC
H-03b1	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	VANADIUM		0.0700			0.0700			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b1	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	< 10		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	XYLENE	<	1.0000		NA	0.0000			ug/l	07/01/85	1	IT	V
H-03b1	MAGENTA	XYLENE	<	5.0000		NA	0.0000			ug/l	09/16/86	2	IT	V
H-03b1	MAGENTA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/02/87	3	IT	V
H-03b1	MAGENTA	XYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/16/89	4	IT	V
H-03b1	MAGENTA	ZINC	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	07/01/85	1	IT	ME
H-03b1	MAGENTA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	09/16/86	2	IT	ME
H-03b1	MAGENTA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/02/87	3	IT	ME
H-03b1	MAGENTA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/89	4	IT	MT
H-03b1	MAGENTA	ZINC	<	0.0200		<	0.0200			mg/l	08/28/90	5	IT	MT
H-03b1	MAGENTA	pH		7.5700		NA	0.0000				07/01/85	1	IT	GC
H-03b1	MAGENTA	pH		7.1100			7.1200				09/16/86	2	IT	GC
H-03b1	MAGENTA	pH		6.5800			6.8000				09/02/87	3	IT	GC
H-03b1	MAGENTA	pH		6.9600			6.9700				03/16/89	4	IT	GC
H-03b1	MAGENTA	pH		6.5000			6.5100				08/28/90	5	IT	GC
** H-03b3														
H-03b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV

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H-03b3	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V

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H-03b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	< 10	ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000		ug/l	02/04/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	ACETONE		11.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	ACETONE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	ALKALINITY (HCO3)		52.0000			54.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	ALKALINITY (HCO3)		47.0000		NA	0.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	ALKALINITY (HCO3)		51.0000			51.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	ALKALINITY (HCO3)		49.0000		NA	0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	ALUMINUM	<	0.0100		NA	0.0000	< .01/<.	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	ALUMINUM		1.1000		NA	0.0000	< 0.1	< 0.1	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	ALUMINUM		1.0000		<	1.0000	< 0.1	< 0.1	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	ALUMINUM	<	2.0000		<	2.0000			mg/l	08/15/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	ANTIMONY		0.8000			0.8000	< 0.05	< 0.05	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	ANTIMONY		0.6000			0.6000	< 0.05	< 0.05	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	ANTIMONY	<	0.6000		<	0.6000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	AROCLOR 1016	<	0.5000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	AROCLOR 1221	<	0.5000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	AROCLOR 1232	<	0.5000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	AROCLOR 1242	<	0.5000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	AROCLOR 1248	<	0.5000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	AROCLOR 1254	<	1.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	AROCLOR 1260	<	1.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	ARSENIC		0.0240			0.0250	< 0.001	< 0.001	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	ARSENIC		0.0390		NA	0.0000	< 0.001	< 0.001	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	ARSENIC	<	0.1000		NA	0.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	BARIUM		0.0400			0.0500	< 0.01	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	BARIUM		0.0600		NA	0.0000	< 0.005	< 0.005	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	BARIUM	<	2.0000		<	2.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	BENZENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BENZOIC ACID		17.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BERYLLIUM		0.1400			0.1600	< 0.001	< 0.001	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME

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H-03b3	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	4.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		20.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BORON		34.0000	NA		0.0000	< 0.10	0.57	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	BORON		21.0000	NA		0.0000	< 0.01	< 0.01	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	BORON		24.0000			24.0000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	BORON		25.0000			25.0000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	BORON		22.0000			22.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	BROMIDE		1.9000	NA		0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	BROMIDE		39.0000	NA		0.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	BROMIDE		28.0000			27.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	BROMIDE		25.0000			25.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	BROMIDE		27.0000			27.0000			mg/l	08/15/90	5	IT	GC

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H-03b3	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	CADMIUM		0.0700			0.0700	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	CADMIUM	<	0.0500		<	0.0500			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	CALCIUM		1200.0000		NA	0.0000			mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	CALCIUM		1300.0000		NA	0.0000			mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	CALCIUM		1500.0000			1500.0000			mg/l	03/02/89	4	IT	MC
H-03b3	CULEBRA	CALCIUM		1300.0000			1300.0000			mg/l	08/15/90	5	IT	MC
H-03b3	CULEBRA	CARBON DISULFIDE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	CESIUM		1.6000			1.6000	< 0.01	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	CESIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	CESIUM		0.0700			0.0900	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	CESIUM	<	0.2000		<	0.2000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	CHLORIDE		31000.0000		NA	0.0000			mg/l	05/05/86	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	CHLORIDE		28000.0000		NA	0.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	CHLORIDE		27700.0000			28200.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	CHLORIDE		27000.0000			27000.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	CHROMIUM		0.0070			0.0070	< 0.001	< 0.001	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	CHROMIUM		0.3500		NA	0.0000	< 0.03	< 0.03	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	CHROMIUM		0.3000			0.3000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	CHROMIUM		0.4000			0.4000	0.02	0.02	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	CHROMIUM		0.1000			0.2000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	COBALT		0.1800			0.1300	< 0.001	< 0.001	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	05/05/86	2	IT	ME

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H-03b3	CULEBRA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	COBALT	<	0.1000			0.1000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	COBALT	<	0.5000	<		0.5000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	COPPER		0.0800	NA		0.0000	0.02	0.02	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	COPPER		0.2600	NA		0.0000	0.02	0.03	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	COPPER		0.1000			0.1000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	COPPER		0.1000			0.1000	< 0.01	0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	COPPER	<	0.2500	<		0.2500			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	CYANIDE	<	0.0200	<		0.0200			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	CYANIDE		0.1100	NA		0.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	CYANIDE	<	0.0100	NA		0.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	CYANIDE	<	0.0100			0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	DIBENZOFURAN	<	1.0000	NA		0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	03/02/89	4	IT	SV

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H-03b3	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	DICHLORODIFLUOROMETHANE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	Eh		444.0000		NA	0.0000			mV	02/04/85	1	IT	GC
H-03b3	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV

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H-03b3	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	FLUORIDE		1.6000		NA	0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	FLUORIDE		1.5000			1.5000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	FLUORIDE		1.6000		NA	0.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	FLUORIDE		1.5000			1.5000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	FLUORIDE		1.5000			0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	IODIDE		1.0000		NA	0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	08/24/87	3	IT	GC

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H-03b3	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	IRON		0.3400			0.4200	< 0.01	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	IRON		0.2400		NA	0.0000	< 0.01	< 0.01	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	IRON		0.2000			0.2000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	IRON		0.2000			0.2000	< 0.02	< 0.02	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	IRON	<	1.0000		<	1.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	LEAD	<	0.1000		NA	0.0000	< 0.10	< 0.10	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	LEAD		0.5000			0.5000	< 0.05	< 0.05	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	LEAD	<	0.5000		<	0.5000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	LITHIUM		0.6400			0.6400	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	LITHIUM		0.4000			0.4200	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	LITHIUM		0.4000			0.4000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	MAGNESIUM		780.0000		NA	0.0000			mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	MAGNESIUM		830.0000		NA	0.0000			mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	MAGNESIUM		750.0000			740.0000			mg/l	03/02/89	4	IT	MC
H-03b3	CULEBRA	MAGNESIUM		700.0000			710.0000			mg/l	08/15/90	5	IT	MC
H-03b3	CULEBRA	MANGANESE		0.1800		NA	0.0000	< 0.01	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	MANGANESE		0.1200		NA	0.0000	< 0.005	< 0.005	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	MANGANESE		0.1400			0.1400	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	MANGANESE		0.1300			0.1300	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	MANGANESE	<	0.1500		<	0.1500			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	02/04/85	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	MERCURY		0.0010		NA	0.0000	< 0.0002	< 0.0002	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	MERCURY		0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	MERCURY	<	0.0002		<	0.0002			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	12		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	MOLYBDENUM		0.0320			0.0280	< 0.001	< 0.001	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	MOLYBDENUM		0.0500		NA	0.0000	< 0.01	0.01	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	MOLYBDENUM		0.1800			0.1800	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	MOLYBDENUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	MOLYBDENUM	<	0.2000		<	0.2000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	03/02/89	4	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE		6.5000		NA	0.0000			ug/l	02/04/85	1	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	SV
H-03b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	08/24/87	3	IT	SV

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H-03b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	NICKEL		0.4400		NA	0.0000	0.02	0.02	mg/l		02/04/85	1	IT	ME
H-03b3	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.3	< 0.3	mg/l		05/05/86	2	IT	ME
H-03b3	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		08/24/87	3	IT	ME
H-03b3	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		03/02/89	4	IT	MT
H-03b3	CULEBRA	NICKEL	<	0.4000		<	0.4000			mg/l		08/15/90	4	IT	MT
H-03b3	CULEBRA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	02/04/85	1	IT	GC
H-03b3	CULEBRA	NITRATE		0.1000		NA	0.0000			mg/l	NO3-N	05/05/86	2	IT	GC
H-03b3	CULEBRA	NITRATE	<	0.2000		NA	0.0000			mg/l	NO3-N	08/24/87	3	IT	GC
H-03b3	CULEBRA	NITRATE	<	0.0200		<	0.0200			mg/l		03/02/89	4	IT	GC
H-03b3	CULEBRA	NITRATE	<	0.0200			0.0000			mg/l		08/15/90	5	IT	GC
H-03b3	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		05/05/86	2	IT	PC
H-03b3	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		08/24/87	3	IT	PC
H-03b3	CULEBRA	PENTACHLOROPHENOL		5.6000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV

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H-03b3	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	PHENOLICS		0.0020		NA	0.0000			mg/l		02/04/85	1	IT	GC
H-03b3	CULEBRA	PHENOLICS		0.0330		NA	0.0000			mg/l		05/05/86	2	IT	GC
H-03b3	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		08/24/87	3	IT	GC
H-03b3	CULEBRA	PHENOLICS	<	0.0100		NA	0.0000			mg/l		03/02/89	4	IT	GC
H-03b3	CULEBRA	PHENOLICS	<	0.0050		<	0.0100			mg/l		08/15/90	5	IT	GC
H-03b3	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	02/04/85	1	IT	GC
H-03b3	CULEBRA	PHOSPHATE		0.0100		NA	0.0000			mg/l	T-PO4-P	05/05/86	2	IT	GC
H-03b3	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	08/24/87	3	IT	GC
H-03b3	CULEBRA	PHOSPHORUS		0.0600		NA	0.0000			mg/l		03/02/89	4	IT	GC
H-03b3	CULEBRA	PHOSPHORUS	<	0.0100			0.0000			mg/l		08/15/90	5	IT	GC
H-03b3	CULEBRA	POTASSIUM		360.0000		NA	0.0000			mg/l		05/05/86	2	IT	ME
H-03b3	CULEBRA	POTASSIUM		530.0000		NA	0.0000			mg/l		08/24/87	3	IT	ME
H-03b3	CULEBRA	POTASSIUM		500.0000			490.0000			mg/l		03/02/89	4	IT	MC
H-03b3	CULEBRA	POTASSIUM		450.0000			450.0000			mg/l		08/15/90	5	IT	MC
H-03b3	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		02/04/85	1	IT	SV
H-03b3	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		05/05/86	2	IT	SV
H-03b3	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		08/24/87	3	IT	SV
H-03b3	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		03/02/89	4	IT	SV
H-03b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		55000.0000		NA	0.0000			mg/l		02/04/85	1	IT	GC
H-03b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		54000.0000		NA	0.0000			mg/l		05/05/86	2	IT	GC
H-03b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		54000.0000			53000.0000			mg/l		08/24/87	3	IT	GC

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H-03b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		53400.0000			53100.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		55000.0000			0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		96.0000		NA	0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		92.0000			100.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		18.0000			19.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		100.0000			0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	SELENIUM		0.0670			0.0980	< 0.001	< 0.001	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	SELENIUM	<	0.1000		NA	0.0000	< 0.001	< 0.001	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	SELENIUM	<	0.5000		NA	0.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	SILICA		8.8000			8.9000	5	5.1	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	SILICA		11.0000		NA	0.0000	< 0.2	< 0.2	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	SILICA		13.0000			13.0000	< 0.2	< 0.2	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	SILICA		4.9000			4.9000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	SILICA		4.5000			0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	SILVER	<	0.1000		<	0.1000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	SODIUM		17000.0000		NA	0.0000			mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	SODIUM		17000.0000		NA	0.0000			mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	SODIUM		17000.0000			17200.0000			mg/l	03/02/89	4	IT	MC
H-03b3	CULEBRA	SODIUM		16000.0000			16000.0000			mg/l	08/15/90	5	IT	MC
H-03b3	CULEBRA	SPECIFIC CONDUCTANCE		82000.0000		NA	0.0000			umhos/cm@25C	02/04/85	1	IT	GC
H-03b3	CULEBRA	SPECIFIC CONDUCTANCE		71500.0000		NA	0.0000			umhos/cm@25C	05/05/86	2	IT	GC
H-03b3	CULEBRA	SPECIFIC CONDUCTANCE		89700.0000			86500.0000			umhos/cm@25C	08/24/87	3	IT	GC
H-03b3	CULEBRA	SPECIFIC CONDUCTANCE		75100.0000			75500.0000			uMhos/cm@25C	03/02/89	4	IT	GC
H-03b3	CULEBRA	SPECIFIC CONDUCTANCE		66000.0000			66000.0000			uMhos/cm@25C	08/15/90	5	IT	GC

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H-03b3	CULEBRA	STRONTIUM		25.0000			25.0000	0.02	0.03	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	STRONTIUM		23.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	STRONTIUM		31.0000			32.0000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	STRONTIUM		23.0000			23.0000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	STRONTIUM		23.0000			23.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	STYRENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	SULFATE		4600.0000			4700.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	SULFATE		4800.0000			4700.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	SULFATE		4300.0000			4700.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	SULFATE		4700.0000			0.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	THALLIUM	<	10.0000		NA	0.0000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	TIN		0.6000			0.5000	< 0.04	< 0.04	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	TITANIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	TITANIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	TITANIUM		0.8000			0.8000	< 0.03	< 0.03	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	TITANIUM	<	0.1000		<	0.1000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000			1.0000			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.3000		NA	0.0000			mg/l	02/04/85	1	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.4200		NA	0.0000			mg/l	05/05/86	2	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC HALOGEN		1.9000			1.3000			mg/l	08/24/87	3	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.4200			0.2400			mg/l	03/02/89	4	IT	GC
H-03b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.1300			0.1400			mg/l	08/15/90	5	IT	GC
H-03b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	VANADIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	VANADIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	VANADIUM	<	0.5000		<	0.5000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-03b3	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	< 10		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	02/04/85	1	IT	V
H-03b3	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	05/05/86	2	IT	V
H-03b3	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	08/24/87	3	IT	V
H-03b3	CULEBRA	XYLENE	<	5.0000		NA	0.0000	< 5		ug/l	03/02/89	4	IT	V
H-03b3	CULEBRA	ZINC		0.0200		NA	0.0000	< 0.01	< 0.01	mg/l	02/04/85	1	IT	ME
H-03b3	CULEBRA	ZINC		0.1400		NA	0.0000	< 0.005	< 0.005	mg/l	05/05/86	2	IT	ME
H-03b3	CULEBRA	ZINC		0.2000			0.2000	< 0.01	< 0.01	mg/l	08/24/87	3	IT	ME
H-03b3	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/02/89	4	IT	MT
H-03b3	CULEBRA	ZINC	<	0.2000		<	0.2000			mg/l	08/15/90	5	IT	MT
H-03b3	CULEBRA	pH		7.6000		NA	0.0000				02/04/85	1	IT	GC
H-03b3	CULEBRA	pH		7.4200			7.4600				05/05/86	2	IT	GC
H-03b3	CULEBRA	pH		6.7300			6.7700				08/24/87	3	IT	GC
H-03b3	CULEBRA	pH		7.3300			7.3300				03/02/89	4	IT	GC
H-03b3	CULEBRA	pH		7.1600			7.1600				08/15/90	5	IT	GC
** H-04b														
H-04b	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V

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H-04b	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV

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H-04b	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000		ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000		ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000		ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000		ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000		ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000		ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000		ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000		ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000		ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000		ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000		ug/l	11/13/86	2	IT	SV

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H-04b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/25/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV

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H-04b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	ACETONE	<	10.0000		NA	0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	ALKALINITY (HCO3)		68.0000			68.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	ALKALINITY (HCO3)		58.0000		NA	0.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	ALKALINITY (HCO3)		66.0000			67.0000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	ALKALINITY (HCO3)		54.0000			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< .1	< .1	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	ALUMINUM	<	2.0000		<	2.0000			mg/l	09/11/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	ANTIMONY	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	ANTIMONY		0.7000		<	0.5000	< 0.05	< 0.05	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< .05	< .05	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	ANTIMONY	<	0.6000		<	0.6000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	AROCLOR 1016	<	0.5000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	AROCLOR 1221	<	0.5000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	AROCLOR 1232	<	0.5000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	AROCLOR 1242	<	0.5000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	AROCLOR 1248	<	0.5000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	AROCLOR 1254	<	1.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	AROCLOR 1260	<	1.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	ARSENIC		0.0400		NA	0.0000	< 0.01	< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	ARSENIC		0.0200		NA	0.0000	< 0.01	< 0.01	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	ARSENIC	<	0.0300		<	0.0300	< .003	< .003	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	ARSENIC	<	0.1000		NA	0.0000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	BARIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	BARIUM	<	2.0000		<	2.0000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V

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H-04b	CULEBRA	BENZENE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BENZO(A)PYRENE		6.5000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BERYLLIUM		0.0010		NA	0.0000	< 0.001	< 0.001	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	11/13/86	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	4.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BORON		23.0000		NA	0.0000	< 0.1	< 0.1	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	BORON		16.0000		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	BORON		16.0000			16.0000	< 0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	BORON		17.0000			17.0000	< .005	.006	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	BORON		17.0000			17.0000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	BROMIDE		64.0000		NA	0.0000			mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	BROMIDE		44.0000		NA	0.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	BROMIDE		42.0000			42.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	BROMIDE		90.0000			91.0000			mg/l	04/06/89	4	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	BROMIDE		44.0000			44.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	CADMIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	CADMIUM	<	0.0500		<	0.0500			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	CALCIUM		1100.0000			1100.0000			mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	CALCIUM		640.0000			640.0000			mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	CALCIUM		730.0000			720.0000			mg/l	04/06/89	4	IT	MC
H-04b	CULEBRA	CALCIUM		630.0000			640.0000			mg/l	09/11/90	5	IT	MC
H-04b	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	CESIUM		0.2000		NA	0.0000	< 0.1	< 0.1	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	CESIUM		0.1100			0.0800	< 0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	CESIUM	<	10.0000		<	10.0000	< .2	< .2	mg/l	04/06/89	4	IT	MT

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H-04b	CULEBRA	CESIUM	<	0.2000	<	0.2000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	CHLORIDE		12000.0000	NA	0.0000				mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	CHLORIDE		7500.0000	NA	0.0000				mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	CHLORIDE		7600.0000		7700.0000				mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	CHLORIDE		650.0000		580.0000				mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	CHLOROBENZENE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	CHLOROETHANE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000			T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000	< 10			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	CHLOROFORM	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	CHLOROFORM	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	CHLOROFORM	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	CHLOROFORM	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	CHROMIUM	<	0.0010	<	0.0010	< 0.001	< 0.001		mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	CHROMIUM		0.1000	NA	0.0000	< 0.05	< 0.05		mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	CHROMIUM		0.1000	<	0.1000	< 0.01	< 0.01		mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	CHROMIUM		0.3000		0.2000	.02	.02		mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	CHROMIUM		0.2000		0.2000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	CHRYSENE	<	1.0000	NA	0.0000				ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V

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H-04b	CULEBRA	COBALT		0.0590			0.0680	< 0.001	< 0.001	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	COBALT	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	COBALT	<	0.5000		<	0.5000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	COPPER		0.0400			0.0200	< 0.01	< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	COPPER		0.2000		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	COPPER	<	0.1000		<	0.1000	0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	COPPER	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	COPPER	<	0.2500		<	0.2500			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	CYANIDE	<	0.0100			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV

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H-04b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	Eh		494.0000		NA	0.0000			mV	07/20/85	1	IT	GC
H-04b	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	FLUORIDE		1.7000		NA	0.0000			mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	FLUORIDE		2.1000			2.2000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	FLUORIDE		1.8000			1.9000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	FLUORIDE		1.9000			1.9000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	FLUORIDE		2.1000			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	IODIDE		1.1000		NA	0.0000			mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	IODIDE		2.0000		NA	0.0000			mg/l	11/13/86	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04b	CULEBRA	IODIDE	<	2.0000	<	2.0000				mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	IODIDE	<	2.0000	<	2.0000				mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	IODIDE	<	2.0000	<	2.0000				mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	IRON		0.4200		0.4400	< 0.01		< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	IRON		0.4000	NA	0.0000	< 0.05		< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	IRON		0.6000		0.5000	< 0.01		< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	IRON		0.5000		0.5000	< .02		< .02	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	IRON	<	1.0000	<	1.0000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	ISOPHORONE	<	4.0000	NA	0.0000				ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	ISOPHORONE	<	10.0000	NA	0.0000				ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	ISOPHORONE	<	10.0000	NA	0.0000				ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	ISOPHORONE	<	10.0000	NA	0.0000				ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	LEAD		0.1000	NA	0.0000	< 0.01		< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	LEAD	<	0.5000	NA	0.0000	< 0.05		< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	LEAD	<	0.5000	<	0.5000	< 0.05		< 0.05	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	LEAD	<	0.5000	<	0.5000	< .05		< .05	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	LEAD	<	0.5000	<	0.5000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	LITHIUM		0.4100	NA	0.0000	< 0.05		< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	LITHIUM		0.5500		0.5500	< 0.01		< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	LITHIUM		0.4000		0.4000	< .01		< .01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	LITHIUM		0.3000		0.3000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	MAGNESIUM		470.0000		480.0000				mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	MAGNESIUM		430.0000		440.0000				mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	MAGNESIUM		400.0000		400.0000				mg/l	04/06/89	4	IT	MC
H-04b	CULEBRA	MAGNESIUM		390.0000		390.0000				mg/l	09/11/90	5	IT	MC
H-04b	CULEBRA	MANGANESE		0.1200		0.1200	0.01		0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	MANGANESE		0.1200	NA	0.0000	< 0.05		< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	MANGANESE		0.1400		0.1400	< 0.005		< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	MANGANESE		0.1800		0.1700	< .005		< .005	mg/l	04/06/89	4	IT	MT

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H-04b	CULEBRA	MANGANESE	<	0.1900	<		0.1900			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	MERCURY		0.0003			0.0003	0.0002	< 0.0002	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	MERCURY	<	0.0002	NA		0.0000	< 0.0002	< 0.0002	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	MERCURY		0.0015			0.0018	< 0.0002	< 0.0002	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	MERCURY	<	0.0002			0.0005	< .0002	< .0002	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	MERCURY	<	0.0004	<		0.0004			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000	< 10		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000	17		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	MOLYBDENUM		0.0700			0.0800	0.03	0.03	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	MOLYBDENUM		0.1100	NA		0.0000	< 0.05	0.06	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	MOLYBDENUM		0.1600			0.1700	< 0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	MOLYBDENUM		0.2000			0.2000	< .01	< .01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	MOLYBDENUM	<	0.2000	<		0.2000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000	NA		0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000	NA		0.0000			ug/l	07/20/85	1	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	11/13/86	2	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	09/25/87	3	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	04/06/89	4	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	1.0000	NA		0.0000			ug/l	07/20/85	1	IT	SV

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H-04b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	NICKEL		0.1900			0.1900	0.02	0.01	mg/l		07/20/85	1	IT	ME
H-04b	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		11/13/86	2	IT	ME
H-04b	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		09/25/87	3	IT	ME
H-04b	CULEBRA	NICKEL	<	0.3000		<	0.3000	< .03	< .03	mg/l		04/06/89	4	IT	MT
H-04b	CULEBRA	NICKEL	<	0.4000		<	0.4000			mg/l		09/11/90	5	IT	MT
H-04b	CULEBRA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	07/20/85	1	IT	GC
H-04b	CULEBRA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	11/13/86	2	IT	GC
H-04b	CULEBRA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	09/25/87	3	IT	GC
H-04b	CULEBRA	NITRATE	<	0.0200		<	0.0200			mg/l		04/06/89	4	IT	GC
H-04b	CULEBRA	NITRATE	<	0.0200		<	0.0200			mg/l		09/11/90	5	IT	GC
H-04b	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		11/13/86	2	IT	PC
H-04b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		09/25/87	3	IT	PC
H-04b	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV

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H-04b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	PHENOLICS		0.0070		NA	0.0000			mg/l		07/20/85	1	IT	GC
H-04b	CULEBRA	PHENOLICS		0.0040		NA	0.0000			mg/l		11/13/86	2	IT	GC
H-04b	CULEBRA	PHENOLICS		0.0120		NA	0.0000			mg/l		09/25/87	3	IT	GC
H-04b	CULEBRA	PHENOLICS		0.0260		NA	0.0000			mg/l		04/06/89	4	IT	GC
H-04b	CULEBRA	PHENOLICS	<	0.0050			0.0000			mg/l		09/11/90	5	IT	GC
H-04b	CULEBRA	PHOSPHATE		0.0300		NA	0.0000			mg/l	T-PO4-P	07/20/85	1	IT	GC
H-04b	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	11/13/86	2	IT	GC
H-04b	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	09/25/87	3	IT	GC
H-04b	CULEBRA	PHOSPHORUS		0.0200			0.0200			mg/l		04/06/89	4	IT	GC
H-04b	CULEBRA	PHOSPHORUS	<	0.0100			0.0000			mg/l		09/11/90	5	IT	GC
H-04b	CULEBRA	POTASSIUM		250.0000			260.0000			mg/l		11/13/86	2	IT	ME
H-04b	CULEBRA	POTASSIUM		240.0000			250.0000	N/A		mg/l		09/25/87	3	IT	ME
H-04b	CULEBRA	POTASSIUM		220.0000			220.0000			mg/l		04/06/89	4	IT	MC
H-04b	CULEBRA	POTASSIUM		170.0000			170.0000			mg/l		09/11/90	5	IT	MC
H-04b	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		07/20/85	1	IT	SV
H-04b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		11/13/86	2	IT	SV
H-04b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		09/25/87	3	IT	SV
H-04b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		04/06/89	4	IT	SV
H-04b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		20000.0000		NA	0.0000			mg/l		07/20/85	1	IT	GC

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H-04b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		23000.0000			22000.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		16000.0000		NA	0.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		20700.0000			20600.0000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		21000.0000			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		42.0000		NA	0.0000			mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		43.0000			36.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		32.0000		NA	0.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		95.0000			97.0000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		48.0000			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	SELENIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	SELENIUM		0.0300		NA	0.0000	< 0.01	< 0.01	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	SELENIUM	<	0.0500		NA	0.0000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	SILICA		14.0000		NA	0.0000	< 0.1	< 0.1	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	SILICA		14.0000		NA	0.0000	< 1	< 1	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	SILICA		13.0000			13.0000	< 0.2	< 0.2	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	SILICA		5.6000			5.5000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	SILICA		5.9000			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	SILVER	<	0.1000		<	0.1000	.02	.01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	SILVER	<	0.1000		<	0.1000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	SODIUM		6000.0000			6000.0000			mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	SODIUM		6300.0000			6200.0000	N/A		mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	SODIUM		5500.0000			5600.0000			mg/l	04/06/89	4	IT	MC
H-04b	CULEBRA	SODIUM		6000.0000			6000.0000			mg/l	09/11/90	5	IT	MC
H-04b	CULEBRA	SPECIFIC CONDUCTANCE		23600.0000		NA	0.0000			umhos/cm@25C	07/20/85	1	IT	GC
H-04b	CULEBRA	SPECIFIC CONDUCTANCE		26300.0000			26600.0000			umhos/cm@25C	11/13/86	2	IT	GC

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H-04b	CULEBRA	SPECIFIC CONDUCTANCE		26400.0000			27500.0000			umhos/cm@25C	09/25/87	3	IT	GC
H-04b	CULEBRA	SPECIFIC CONDUCTANCE		31000.0000			31000.0000			uMhos/cm@25C	04/06/89	4	IT	GC
H-04b	CULEBRA	SPECIFIC CONDUCTANCE		21900.0000			22000.0000			uMhos/cm@25C	09/11/90	5	IT	GC
H-04b	CULEBRA	STRONTIUM		15.0000			15.0000	< 0.01	< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	STRONTIUM		13.0000		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	STRONTIUM		16.0000			16.0000	< 0.01	< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	STRONTIUM		14.0000			14.0000	< .01	< .01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	STRONTIUM		13.0000			13.0000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	STYRENE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	SULFATE		6900.0000		NA	0.0000			mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	SULFATE		5100.0000		NA	0.0000			mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	SULFATE		5000.0000			5200.0000			mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	SULFATE		4800.0000			0.0000			mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	THALLIUM	<	4.0000		<	4.0000	< .004	< .004	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	THALLIUM	<	0.1000		NA	0.0000			mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	TIN		0.7000			0.5000	0.04	< 0.04	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	TITANIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	TITANIUM		0.3000		NA	0.0000	< 0.05	< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	TITANIUM		0.6000			0.4000	< 0.03	< 0.03	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/06/89	4	IT	MT

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H-04b	CULEBRA	TITANIUM	<	0.1000	<	0.1000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	TOLUENE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	TOLUENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	TOLUENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	TOLUENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	TOTAL ORGANIC CARBON		3.0000	NA	0.0000				mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC CARBON		3.0000	NA	0.0000				mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC CARBON		5.0000		4.0000				mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC CARBON		3.0000		3.0000				mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC CARBON		5.0000		4.0000				mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC HALOGEN		0.4600	NA	0.0000				mg/l	07/20/85	1	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC HALOGEN		0.0900	NA	0.0000				mg/l	11/13/86	2	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC HALOGEN		0.4400		0.8300				mg/l	09/25/87	3	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC HALOGEN		0.0500		0.0600				mg/l	04/06/89	4	IT	GC
H-04b	CULEBRA	TOTAL ORGANIC HALOGEN		0.0800		0.0600				mg/l	09/11/90	5	IT	GC
H-04b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	TRICHLOROETHYLENE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	VANADIUM	<	0.1000	<	0.1000	< 0.01		< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	VANADIUM	<	0.1000	<	0.1000	< .01		< .01	mg/l	04/06/89	4	IT	MT

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H-04b	CULEBRA	VANADIUM	<	0.5000	<	0.5000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	VINYL ACETATE	<	10.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	VINYL ACETATE	<	10.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	VINYL ACETATE	<	10.0000	NA	0.0000			T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	VINYL ACETATE	<	10.0000	NA	0.0000	< 10			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA	0.0000			T < 10	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA	0.0000	< 10			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	XYLENE	<	1.0000	NA	0.0000				ug/l	07/25/85	1	IT	V
H-04b	CULEBRA	XYLENE	<	5.0000	NA	0.0000				ug/l	11/13/86	2	IT	V
H-04b	CULEBRA	XYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/25/87	3	IT	V
H-04b	CULEBRA	XYLENE	<	5.0000	NA	0.0000	< 5			ug/l	04/06/89	4	IT	V
H-04b	CULEBRA	ZINC	<	0.0100	<	0.0100	< 0.01		< 0.01	mg/l	07/20/85	1	IT	ME
H-04b	CULEBRA	ZINC		0.4000	NA	0.0000	< 0.05		< 0.05	mg/l	11/13/86	2	IT	ME
H-04b	CULEBRA	ZINC		0.4000		0.3000	< 0.01		< 0.01	mg/l	09/25/87	3	IT	ME
H-04b	CULEBRA	ZINC		0.3000		0.3000	< .01		< .01	mg/l	04/06/89	4	IT	MT
H-04b	CULEBRA	ZINC	<	0.2000	<	0.2000				mg/l	09/11/90	5	IT	MT
H-04b	CULEBRA	pH		7.5900	NA	0.0000					07/20/85	1	IT	GC
H-04b	CULEBRA	pH		7.3900		7.4100					11/13/86	2	IT	GC
H-04b	CULEBRA	pH		6.1400		6.1900					09/25/87	3	IT	GC
H-04b	CULEBRA	pH		7.4600		7.4600					04/06/89	4	IT	GC
H-04b	CULEBRA	pH		6.6800		6.7100					09/11/90	5	IT	GC
** H-04c														
H-04c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000	NA	0.0000				ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000	NA	0.0000			T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000	NA	0.0000	T < 5.0		T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000	NA	0.0000	< 5			ug/l	04/21/89	4	IT	V

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H-04c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V

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H-04c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	1,3-DICHLOROBENZENE		15.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP. ACID BLANK WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000 < 10	ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000	ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000	ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000	ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000	ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000	ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000	ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000	ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000	ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000	ug/l	11/04/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV

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H-04c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	ACETONE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	ACETONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	ACETONE	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	ALKALINITY (HCO3)		100.0000			100.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	ALKALINITY (HCO3)		59.0000			60.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	ALKALINITY (HCO3)		74.0000		NA	0.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	ALKALINITY (HCO3)		61.0000			61.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	ALKALINITY (HCO3)		62.0000			0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	ALUMINUM	<	1.0000		<	1.0000	< .1	< .1	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	ALUMINUM	<	2.0000		<	2.0000			mg/l	10/02/90	5	IT	MT

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H-04c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	ANTIMONY		0.6000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	ANTIMONY	<	0.5000		<	0.5000	< .05	< .05	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	ANTIMONY	<	0.6000		<	0.6000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	AROCLOR 1016	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	AROCLOR 1221	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	AROCLOR 1232	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	AROCLOR 1242	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	AROCLOR 1248	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	AROCLOR 1254	<	21.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	AROCLOR 1260	<	21.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	ARSENIC	<	0.0300		NA	0.0000	< .003	< .003	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	ARSENIC	<	0.1000		NA	0.0000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	BARIUM		0.0600		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	BARIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	BARIUM	<	0.2000		<	0.2000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	BENZENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	BENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	BENZENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	BERYLLIUM	<	0.0500	<		0.0500	< .005	< .005	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	BERYLLIUM	<	0.0500	<		0.0500			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE		110.0000	NA		0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	BORON		11.0000	NA		0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	BORON		12.0000			12.0000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	BORON		12.0000			12.0000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	BORON		12.0000			12.0000	.011	.012	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	BORON		12.0000			12.0000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	BROMIDE		7.0000	NA		0.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	BROMIDE		8.0000			7.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	BROMIDE		7.0000			7.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	BROMIDE		6.0000	NA		0.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	BROMIDE		6.0000			6.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	BROMOFORM	<	5.0000	NA		0.0000			ug/l	11/04/86	1	IT	V

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H-04c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	CADMIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	CADMIUM	<	0.0500		<	0.0500			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	CALCIUM		1100.0000			1100.0000			mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	CALCIUM		610.0000			610.0000			mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	CALCIUM		640.0000			660.0000			mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	CALCIUM		700.0000			690.0000			mg/l	04/21/89	4	IT	MC
H-04c	MAGENTA	CALCIUM		630.0000			630.0000			mg/l	10/02/90	5	IT	MC
H-04c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	CESIUM		0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	CESIUM		0.0500			0.0600	0.02	0.04	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	CESIUM	<	10.0000		<	10.0000	< 1	< 1	mg/l	04/21/89	4	IT	MT

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H-04c	MAGENTA	CESIUM	<	0.1000	<		0.1000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	CHLORIDE		11000.0000			11000.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	CHLORIDE		8400.0000		NA	0.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	CHLORIDE		7600.0000		NA	0.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	CHLORIDE		8500.0000			8500.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	CHLORIDE		9000.0000			8900.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	CHROMIUM		0.2000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	CHROMIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	CHROMIUM	<	0.1000			0.1000	0.01	0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	CHROMIUM		0.2000			0.2000	.02	.02	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	CHROMIUM	<	0.1000		<	0.1000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V

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H-04c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	COBALT	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	COBALT	<	0.5000		<	0.5000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	COPPER		0.3000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	COPPER		0.2000			0.2000	0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	COPPER	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	COPPER	<	0.2500		<	0.2500			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	CYANIDE	<	0.0100		NA	0.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	CYANIDE	<	0.0100		NA	0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP. ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000		ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000		ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000		ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	FLUORIDE		2.2000		NA	0.0000		mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	FLUORIDE		2.5000			2.6000		mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	FLUORIDE		2.6000			2.6000		mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	FLUORIDE		2.6000			2.6000		mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	FLUORIDE		2.8000			0.0000		mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000		ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	IODIDE		1.0000		NA	0.0000		mg/l	11/04/86	1	IT	GC

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H-04c	MAGENTA	IODIDE	<	2.0000	<		2.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	IODIDE	<	2.0000	<		2.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	IODIDE		4.0000			4.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	IODIDE	<	2.0000	<		2.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	IRON		0.9000	NA		0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	IRON		0.3000			0.3000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	IRON		0.2000			0.2000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	IRON		1.1000			1.1000	< .02	< .02	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	IRON	<	1.0000	<		1.0000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	ISOPHORONE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	ISOPHORONE	<	10.0000	NA		0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	ISOPHORONE	<	10.0000	NA		0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	ISOPHORONE	<	10.0000	NA		0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	LEAD	<	0.5000	NA		0.0000	0.06	0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	LEAD	<	0.5000	<		0.5000	< 0.05	< 0.05	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	LEAD	<	0.5000	<		0.5000	< 0.05	< 0.05	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	LEAD	<	0.5000	<		0.5000	< .05	< .05	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	LEAD	<	0.5000	<		0.5000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	LITHIUM		0.4300	NA		0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	LITHIUM		0.4100			0.4100	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	LITHIUM		0.3900			0.3900	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	LITHIUM		0.4200			0.4200	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	LITHIUM		0.3900			0.3900			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	MAGNESIUM		470.0000			470.0000			mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	MAGNESIUM		490.0000			510.0000			mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	MAGNESIUM		430.0000			440.0000			mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	MAGNESIUM		420.0000			410.0000			mg/l	04/21/89	4	IT	MC
H-04c	MAGENTA	MAGNESIUM		400.0000			410.0000			mg/l	10/02/90	5	IT	MC
H-04c	MAGENTA	MANGANESE		0.4600	NA		0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	MANGANESE		0.1300			0.1200	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	MANGANESE		0.1100			0.1100	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	MANGANESE		0.2100			0.2100	< .005	< .005	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	MANGANESE	<	0.1500	<		0.1500			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	MERCURY	<	0.0002	NA		0.0000	< 0.0002	< 0.0002	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	MERCURY		0.0007			0.0007	< 0.0002	< 0.0002	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	MERCURY		0.0008	NA		0.0000	0.0002	< 0.0002	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	MERCURY	<	0.0002	<		0.0002	< .0002	< .0002	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	MERCURY	<	0.0002	<		0.0002			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000	T 13	T 26	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000	11		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	MOLYBDENUM	<	0.0500	NA		0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	MOLYBDENUM		0.0600			0.0700	0.02	0.02	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	MOLYBDENUM		0.0900			0.1000	< 0.05	< 0.05	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	MOLYBDENUM		0.1000	<		0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	MOLYBDENUM	<	0.2000	<		0.2000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	11/04/86	1	IT	SV
H-04c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	07/19/88	3	IT	SV

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H-04c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		11/04/86	1	IT	ME
H-04c	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		10/05/87	2	IT	ME
H-04c	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		07/19/88	3	IT	ME
H-04c	MAGENTA	NICKEL	<	0.3000		<	0.3000	< .03	< .03	mg/l		04/21/89	4	IT	MT
H-04c	MAGENTA	NICKEL	<	0.4000		<	0.4000			mg/l		10/02/90	5	IT	MT
H-04c	MAGENTA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	11/04/86	1	IT	GC
H-04c	MAGENTA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	10/05/87	2	IT	GC
H-04c	MAGENTA	NITRATE	<	0.0200		NA	0.0000			mg/l	NO3-N	07/19/88	3	IT	GC
H-04c	MAGENTA	NITRATE	<	0.0200		<	0.0200			mg/l		04/21/89	4	IT	GC
H-04c	MAGENTA	NITRATE	<	0.0200		<	0.0200			mg/l		10/02/90	5	IT	GC
H-04c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		11/04/86	1	IT	PC
H-04c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		10/05/87	2	IT	PC

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H-04c	MAGENTA	PCB	<	1.0000		NA		0.0000		ug/l		07/19/88	3	IT	PC
H-04c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA		0.0000		ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA		0.0000		ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA		0.0000		ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA		0.0000		ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	PHENANTHRENE	<	10.0000		NA		0.0000		ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	PHENANTHRENE	<	10.0000		NA		0.0000		ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	PHENANTHRENE	<	10.0000		NA		0.0000		ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	PHENANTHRENE	<	10.0000		NA		0.0000		ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	PHENOL	<	10.0000		NA		0.0000		ug/l		11/04/86	1	IT	SV
H-04c	MAGENTA	PHENOL	<	10.0000		NA		0.0000		ug/l		10/05/87	2	IT	SV
H-04c	MAGENTA	PHENOL	<	10.0000		NA		0.0000		ug/l		07/19/88	3	IT	SV
H-04c	MAGENTA	PHENOL	<	10.0000		NA		0.0000		ug/l		04/21/89	4	IT	SV
H-04c	MAGENTA	PHENOLICS		0.0150		NA		0.0000		mg/l		11/04/86	1	IT	GC
H-04c	MAGENTA	PHENOLICS		0.0140		NA		0.0000		mg/l		10/05/87	2	IT	GC
H-04c	MAGENTA	PHENOLICS	<	0.0050		NA		0.0000		mg/l		07/19/88	3	IT	GC
H-04c	MAGENTA	PHENOLICS		0.0370				0.0380		mg/l		04/21/89	4	IT	GC
H-04c	MAGENTA	PHENOLICS		0.0290		NA		0.0000		mg/l		10/02/90	5	IT	GC
H-04c	MAGENTA	PHOSPHATE		0.0600		NA		0.0000		mg/l	T-PO4-P	11/04/86	1	IT	GC
H-04c	MAGENTA	PHOSPHATE		0.0100		NA		0.0000		mg/l	T-PO4-P	10/05/87	2	IT	GC
H-04c	MAGENTA	PHOSPHATE		0.0200		NA		0.0000		mg/l	T-PO4-P	07/19/88	3	IT	GC
H-04c	MAGENTA	PHOSPHORUS	<	0.0100		NA		0.0000		mg/l		04/21/89	4	IT	GC
H-04c	MAGENTA	PHOSPHORUS	<	0.0100		NA		0.0000		mg/l		10/02/90	5	IT	GC
H-04c	MAGENTA	POTASSIUM		130.0000				140.0000		mg/l		11/04/86	1	IT	ME
H-04c	MAGENTA	POTASSIUM		100.0000				98.0000		mg/l		10/05/87	2	IT	ME
H-04c	MAGENTA	POTASSIUM		99.0000				100.0000		mg/l		07/19/88	3	IT	ME
H-04c	MAGENTA	POTASSIUM		110.0000				100.0000		mg/l		04/21/89	4	IT	MC
H-04c	MAGENTA	POTASSIUM		70.0000				70.0000		mg/l		10/02/90	5	IT	MC
H-04c	MAGENTA	PYRENE	<	10.0000		NA		0.0000		ug/l		11/04/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-04c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l	10/05/87	2	IT	SV
H-04c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l	07/19/88	3	IT	SV
H-04c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/89	4	IT	SV
H-04c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		22000.0000			23000.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		24000.0000			23000.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		23500.0000		NA	0.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		24400.0000			24300.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		24600.0000		NA	0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		27.0000			25.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		25.0000			21.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		26.0000		NA	0.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		56.0000			56.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		59.0000		NA	0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	SELENIUM		0.0400		NA	0.0000	< 0.01	< 0.01	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	SELENIUM	<	0.0500		NA	0.0000	< .005	< .005	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	SELENIUM	<	0.0500		NA	0.0000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	SILICA		10.0000		NA	0.0000	< 1	< 1	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	SILICA		12.0000			11.0000	< 0.2	< 0.2	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	SILICA		4.0000			4.1000			mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	SILICA		3.9000			3.9000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	SILICA		4.7000		NA	0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	SILVER		0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	SILVER	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	SILVER	<	0.1000		<	0.1000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	SODIUM		7500.0000			7500.0000			mg/l	11/04/86	1	IT	ME

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H-04c	MAGENTA	SODIUM		7300.0000			7200.0000			mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	SODIUM		7100.0000			7200.0000			mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	SODIUM		7100.0000			7100.0000			mg/l	04/21/89	4	IT	MC
H-04c	MAGENTA	SODIUM		3600.0000			3600.0000			mg/l	10/02/90	5	IT	MC
H-04c	MAGENTA	SPECIFIC CONDUCTANCE		32100.0000			32100.0000			umhos/cm@25C	11/04/86	1	IT	GC
H-04c	MAGENTA	SPECIFIC CONDUCTANCE		30600.0000			31000.0000			umhos/cm@25C	10/05/87	2	IT	GC
H-04c	MAGENTA	SPECIFIC CONDUCTANCE		30400.0000			30500.0000			umhos/cm@25C	07/19/88	3	IT	GC
H-04c	MAGENTA	SPECIFIC CONDUCTANCE		34000.0000			34300.0000			uMhos/cm@25C	04/21/89	4	IT	GC
H-04c	MAGENTA	SPECIFIC CONDUCTANCE		28800.0000			28800.0000			uMhos/cm@25C	10/02/90	5	IT	GC
H-04c	MAGENTA	STRONTIUM		13.0000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	STRONTIUM		14.0000			14.0000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	STRONTIUM		13.0000			13.0000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	STRONTIUM		12.0000			12.0000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	STRONTIUM		11.0000			11.0000							
H-04c	MAGENTA	STYRENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	STYRENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	SULFATE		7900.0000			7800.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	SULFATE		6700.0000		NA	0.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	SULFATE		8300.0000			8300.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	SULFATE		6200.0000		NA	0.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	SULFATE		7600.0000		NA	0.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V

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H-04c	MAGENTA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	THALLIUM	<	5.0000		NA	0.0000	< 0.005	< 0.005	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	THALLIUM	<	5.0000		NA	0.0000	< .005	< .005	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	THALLIUM	<	0.1000		NA	0.0000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	TITANIUM		0.4000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	TITANIUM		0.5000			0.4000	< 0.03	< 0.03	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	TITANIUM	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	TITANIUM	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	TITANIUM	<	0.1000		<	0.1000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	TOTAL ORGANIC CARBON		1.0000		NA	0.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC CARBON		3.0000			2.0000			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC CARBON		1.0000		<	1.0000			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC HALOGEN		0.0800		NA	0.0000			mg/l	11/04/86	1	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC HALOGEN		0.4900			0.5600			mg/l	10/05/87	2	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC HALOGEN		0.1800			0.3000			mg/l	07/19/88	3	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC HALOGEN		0.0600		<	0.0500			mg/l	04/21/89	4	IT	GC
H-04c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.1000		<	0.0500			mg/l	10/02/90	5	IT	GC
H-04c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V

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H-04c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	VANADIUM		0.1000			0.1000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	VANADIUM	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	VANADIUM	<	0.5000		<	0.5000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	< 10		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	XYLENE	<	5.0000		NA	0.0000			ug/l	11/04/86	1	IT	V
H-04c	MAGENTA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/05/87	2	IT	V
H-04c	MAGENTA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/19/88	3	IT	V
H-04c	MAGENTA	XYLENE	<	5.0000		NA	0.0000	< 5		ug/l	04/21/89	4	IT	V
H-04c	MAGENTA	ZINC	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	11/04/86	1	IT	ME
H-04c	MAGENTA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	10/05/87	2	IT	ME
H-04c	MAGENTA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/19/88	3	IT	ME
H-04c	MAGENTA	ZINC	<	0.1000		<	0.1000	< .01	< .01	mg/l	04/21/89	4	IT	MT
H-04c	MAGENTA	ZINC	<	0.2000		<	0.2000			mg/l	10/02/90	5	IT	MT
H-04c	MAGENTA	pH		7.9900			7.9400				11/04/86	1	IT	GC

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H-04c	MAGENTA	pH		6.4000			6.4800				10/05/87	2	IT	GC
H-04c	MAGENTA	pH		7.7100			7.6900				07/19/88	3	IT	GC
H-04c	MAGENTA	pH		7.6400			7.6500				04/21/89	4	IT	GC
H-04c	MAGENTA	pH		7.4300			7.4300				10/02/90	5	IT	GC
** H-05b														
H-05b	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV

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H-05b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV

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H-05b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000		ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		ug/l	02/24/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	ACETONE	<	10.0000		NA	0.0000	T < 10	T 43	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	ACETONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	08/27/85	1	IT	GC

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H-05b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	ALKALINITY (HCO3)		47.0000		NA	0.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	ALKALINITY (HCO3)		46.0000			46.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	ALKALINITY (HCO3)		42.0000			42.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	ALKALINITY (HCO3)		42.0000			37.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	ALKALINITY (HCO3)		41.0000			41.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	ALUMINUM		0.2300		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	ALUMINUM	<	10.0000		<	10.0000	< 0.1	< 0.1	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< .2	< .2	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	ANTIMONY		0.7700		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	ANTIMONY		0.7000			0.6000	< 0.06	< 0.06	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	ANTIMONY		0.6000			0.6000	< .06	< .06	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	ARSENIC		6.7000		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	ARSENIC		0.0420			0.0420	< 0.001	< 0.001	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	ARSENIC	<	0.0240		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	ARSENIC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	ARSENIC	<	0.1000		NA	0.0000	< .01	< .01	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	BARIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	02/24/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	BARIUM	<	2.0000	<		2.0000	< 0.2	< 0.2	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	BARIUM	<	2.0000	<		2.0000	< .2	< .2	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	BENZENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	BENZENE	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	BENZENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	BENZENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	BENZIDINE	<	4.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BENZO(A)PYRENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BENZOIC ACID	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BENZYL ALCOHOL	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BERYLLIUM	<	0.0100	<		0.0100	< 0.1	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	BERYLLIUM	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	08/23/89	4	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< .005	< .005	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	4.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	BORON		29.0000	NA		0.0000	< 0.1	< 0.1	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	BORON		33.0000			33.0000	0.11	0.11	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	BORON		35.0000			35.0000	< 0.01	< 0.01	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	BORON		31.0000			29.0000	< 0.02	< 0.02	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	BORON		30.0000			30.0000	< .02	< .02	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	BROMIDE		100.0000			87.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	BROMIDE		59.0000	NA		0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	BROMIDE		73.0000			73.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	BROMIDE		12.0000			12.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	BROMIDE		69.0000	NA		0.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	BROMOFORM	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	BROMOFORM	<	5.0000	NA		0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	BROMOFORM	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	BROMOFORM	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/21/86	2	IT	SV

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H-05b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	CADMIUM	<	0.0040		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	CADMIUM		0.1100			0.1100	< 0.005	< 0.005	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	CADMIUM		0.1000			0.1000	< .005	< .005	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	CALCIUM		1300.0000			1300.0000	0.2	0.2	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	CALCIUM		1400.0000		NA	0.0000			mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	CALCIUM		1500.0000			1500.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	CALCIUM		2000.0000			2000.0000			mg/l	08/23/89	4	IT	MC
H-05b	CULEBRA	CALCIUM		1500.0000			1500.0000			mg/l	05/02/90	5	IT	MC
H-05b	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	CESIUM	<	1.0000		NA	0.0000	< 1.0	< 1.0	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	CESIUM	<	0.2800		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	CESIUM	<	0.2000		<	2.0000	< .2	< .2	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	CHLORIDE		87000.0000		NA	0.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	CHLORIDE		89000.0000			91000.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	CHLORIDE		84100.0000		NA	0.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	CHLORIDE		86600.0000		NA	0.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	CHLORIDE		92100.0000		NA	0.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V

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H-05b	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	CHLOROFORM	<	2.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	CHROMIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	CHROMIUM	<	3.0000		<	3.0000	< 0.03	< 0.03	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	CHROMIUM		0.0160		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	CHROMIUM		0.2000			0.3000	0.01	0.02	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	CHROMIUM		0.3000			0.3000	.01	.01	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	COBALT		3.0000			2.9000	0.02	0.02	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	COBALT	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	COBALT	<	0.0100		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	COBALT	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	COBALT	<	0.5000		<	0.5000	< .05	< .05	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	COPPER		0.2600			0.2500	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	COPPER	<	1.0000		<	1.0000	0.02	0.02	mg/l	05/21/86	2	IT	ME

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H-05b	CULEBRA	COPPER	<	0.0100		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	COPPER	<	0.2500		<	0.2500	< 0.025	< 0.025	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	COPPER	<	0.2500		<	0.2500	< .025	< .025	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	CYANIDE	<	0.0100		<	0.0200			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	Eh		524.0000		NA	0.0000			mV	08/27/85	1	IT	GC
H-05b	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	FLUORIDE		1.3000		NA	0.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	FLUORIDE		0.8000			0.8000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	FLUORIDE		0.9000		NA	0.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	FLUORIDE		0.9000			0.9000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	FLUORIDE		0.9000			0.9000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV

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H-05b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	IODIDE		1.1000			1.1000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	IODIDE		1.3000		NA	0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	IRON		3.1000			3.0000	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	IRON		3.3000			3.1000	< 0.01	< 0.01	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	IRON		2.3000			2.3000	0.01	< 0.01	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	IRON		2.0000			2.0000	< 0.1	< 0.1	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	IRON		2.0000			2.0000	< .1	< .1	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	08/27/85	1	IT	SV
H-05b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	SV
H-05b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	02/24/88	3	IT	SV
H-05b	CULEBRA	LEAD		1.1000			0.9000	< 0.1	< 0.1	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	LEAD	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	LEAD	<	0.0400		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	LEAD	<	0.5000		<	0.5000	< .05	< .05	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	LITHIUM		0.7500		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	LITHIUM		1.0000			1.0000	< 0.01	< 0.01	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	LITHIUM		1.0000			1.0000	< .01	< .01	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	MAGNESIUM		1700.0000			1700.0000	< 0.1	< 0.1	mg/l	08/27/85	1	IT	ME

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H-05b	CULEBRA	MAGNESIUM		2200.0000		NA	0.0000			mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	MAGNESIUM		1800.0000			1800.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	MAGNESIUM		1700.0000			1800.0000			mg/l	08/23/89	4	IT	MC
H-05b	CULEBRA	MAGNESIUM		1800.0000			1700.0000			mg/l	05/02/90	5	IT	MC
H-05b	CULEBRA	MANGANESE		0.5200			0.5200	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	MANGANESE	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	MANGANESE		0.2100			0.2100	< 0.005	< 0.005	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	MANGANESE		0.3800			0.3800	< 0.015	< 0.015	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	MANGANESE		0.2300			0.2400	< .015	< .015	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	MERCURY		0.0005		NA	0.0000	0.0004	0.0004	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	MERCURY		0.0003		<	0.0002	< 0.0002	< 0.0002	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	MERCURY	<	0.0002		<	0.0002	0.0002	0.0002	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	MERCURY	<	0.0002		<	0.0002	< .0002	< .0002	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	METHYLENE CHLORIDE	<	20.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T 85	T 110	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	METHYLENE CHLORIDE		6.0000		NA	0.0000	T 10	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	MOLYBDENUM		0.1000			0.1200	0.03	0.04	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	MOLYBDENUM		0.1700			0.1400	< 0.01	< 0.01	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	MOLYBDENUM		0.0300		NA	0.0000			mg/l	02/24/88	3	IT	ME

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H-05b	CULEBRA	MOLYBDENUM		0.3000			0.3000	< 0.02	< 0.02	mg/l		08/23/89	4	IT	MT
H-05b	CULEBRA	MOLYBDENUM		0.3000			0.3000	< .02	< .02	mg/l		05/02/90	5	IT	MT
H-05b	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	4.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	NICKEL		1.7000			1.6000	< 0.01	< 0.01	mg/l		08/27/85	1	IT	ME
H-05b	CULEBRA	NICKEL	<	3.0000		<	3.0000	< 0.03	< 0.03	mg/l		05/21/86	2	IT	ME
H-05b	CULEBRA	NICKEL	<	0.0100		NA	0.0000			mg/l		02/24/88	3	IT	ME
H-05b	CULEBRA	NICKEL	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l		08/23/89	4	IT	MT
H-05b	CULEBRA	NICKEL	<	0.4000		<	0.4000	< .04	< .04	mg/l		05/02/90	5	IT	MT
H-05b	CULEBRA	NITRATE		0.4000			0.4000			mg/l	NO3-N	08/27/85	1	IT	GC
H-05b	CULEBRA	NITRATE		0.1000		<	0.1000			mg/l	NO3-N	05/21/86	2	IT	GC
H-05b	CULEBRA	NITRATE		0.0400		NA	0.0000			mg/l	NO3-N	02/24/88	3	IT	GC
H-05b	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l		08/23/89	4	IT	GC
H-05b	CULEBRA	NITRATE		0.0300			0.0400			mg/l		05/02/90	5	IT	GC
H-05b	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		05/21/86	2	IT	PC

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H-05b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		02/24/88	3	IT	PC
H-05b	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	PHENOLICS	<	0.0020		NA	0.0000			mg/l		08/27/85	1	IT	GC
H-05b	CULEBRA	PHENOLICS		0.0090		NA	0.0000			mg/l		05/21/86	2	IT	GC
H-05b	CULEBRA	PHENOLICS		0.0510		NA	0.0000			mg/l		02/24/88	3	IT	GC
H-05b	CULEBRA	PHENOLICS		0.0060		NA	0.0000			mg/l		08/23/89	4	IT	GC
H-05b	CULEBRA	PHENOLICS		0.1600		NA	0.0000			mg/l		05/02/90	5	IT	GC
H-05b	CULEBRA	PHOSPHATE		0.0600			0.0800			mg/l	T-PO4-P	08/27/85	1	IT	GC
H-05b	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	05/21/86	2	IT	GC
H-05b	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	02/24/88	3	IT	GC
H-05b	CULEBRA	PHOSPHORUS	<	0.1900		NA	0.0000			mg/l		08/23/89	4	IT	GC
H-05b	CULEBRA	PHOSPHORUS		0.0200		NA	0.0000			mg/l		05/02/90	5	IT	GC
H-05b	CULEBRA	POTASSIUM		1300.0000			1300.0000	< 0.01	< 0.01	mg/l		08/27/85	1	IT	ME
H-05b	CULEBRA	POTASSIUM		1100.0000		NA	0.0000			mg/l		05/21/86	2	IT	ME
H-05b	CULEBRA	POTASSIUM		1340.0000			1340.0000			mg/l		02/24/88	3	IT	ME
H-05b	CULEBRA	POTASSIUM		1000.0000			1000.0000			mg/l		08/23/89	4	IT	MC
H-05b	CULEBRA	POTASSIUM		1200.0000			1200.0000			mg/l		05/02/90	5	IT	MC
H-05b	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		08/27/85	1	IT	SV
H-05b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		05/21/86	2	IT	SV
H-05b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		02/24/88	3	IT	SV
H-05b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		144000.0000			141000.0000			mg/l		08/27/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		150000.0000		NA	0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		153000.0000			154000.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		154000.0000		NA	0.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		160000.0000			173000.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		840.0000			880.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		360.0000			420.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		760.0000			640.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		20.0000		NA	0.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		38.0000			34.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	SELENIUM		7.3000		NA	0.0000	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	SELENIUM	<	0.1000		<	0.1000	< 0.001	< 0.001	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	SELENIUM	<	0.0240		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	SELENIUM	<	5.0000		NA	0.0000	< .005	< .005	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	SILICA		17.0000			17.0000	< 0.2	< 0.2	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	SILICA	<	21.0000		<	21.0000	4.3	4.3	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	SILICA		2.8000		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	SILICA		3.6000			3.4000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	SILICA		2.7000			3.2000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	SILVER		0.0900		NA	0.1000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	SILVER		0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	SILVER		0.1000			0.1000	< .01	< .01	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	SODIUM		48000.0000			46000.0000	< 0.1	< 0.1	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	SODIUM		53000.0000		NA	0.0000			mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	SODIUM		52000.0000			52000.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	SODIUM		44000.0000			44000.0000			mg/l	08/23/89	4	IT	MC
H-05b	CULEBRA	SODIUM		55200.0000			55200.0000			mg/l	05/02/90	5	IT	MC
H-05b	CULEBRA	SPECIFIC CONDUCTANCE		131000.0000			138000.0000			umhos/cm@25C	08/27/85	1	IT	GC
H-05b	CULEBRA	SPECIFIC CONDUCTANCE		161000.0000		NA	0.0000			umhos/cm@25C	05/21/86	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	SPECIFIC CONDUCTANCE		242000.0000			241000.0000			umhos/cm@25C	02/24/88	3	IT	GC
H-05b	CULEBRA	SPECIFIC CONDUCTANCE		157000.0000			158000.0000			uMhos/cm@25C	08/23/89	4	IT	GC
H-05b	CULEBRA	SPECIFIC CONDUCTANCE		153000.0000			153000.0000			uMhos/cm@25C	05/02/90	5	IT	GC
H-05b	CULEBRA	STRONTIUM		16.0000			16.0000	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	STRONTIUM		32.0000			32.0000	< 0.01	< 0.01	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	STRONTIUM		34.0000			34.0000	< 0.01	< 0.01	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	STRONTIUM		27.0000			27.0000	< 0.01	< 0.01	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	STRONTIUM		26.0000			26.0000	< .01	< .01	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	SULFATE		6300.0000		NA	0.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	SULFATE		7000.0000		NA	0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	SULFATE		7000.0000		NA	0.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	SULFATE		5900.0000		NA	0.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	SULFATE		7900.0000			7500.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	THALLIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	THALLIUM	<	10.0000		NA	0.0000	< .01	< .01	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	TITANIUM		0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	TITANIUM		0.1000			0.1000	< 0.1	< 0.1	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	TITANIUM	<	0.0100		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	TITANIUM	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	TITANIUM	<	0.1000	<		0.1000	< .01	< .01	mg/l	05/02/90	5	IT	MT

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H-05b	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC CARBON		4.0000			3.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC CARBON		1.0000		<	1.0000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC CARBON		9.0000		NA	0.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC HALOGEN		1.7000		NA	0.0000			mg/l	08/27/85	1	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC HALOGEN		1.6000		NA	0.0000			mg/l	05/21/86	2	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC HALOGEN		8.2000			7.0000			mg/l	02/24/88	3	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC HALOGEN		3.9000		<	3.6000			mg/l	08/23/89	4	IT	GC
H-05b	CULEBRA	TOTAL ORGANIC HALOGEN		0.8900		NA	0.0000			mg/l	05/02/90	5	IT	GC
H-05b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	VANADIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	VANADIUM	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	VANADIUM	<	0.0500		<	0.0500	< .05	< .05	mg/l	05/02/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	08/27/85	1	IT	V
H-05b	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	05/21/86	2	IT	V
H-05b	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	02/24/88	3	IT	V
H-05b	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	05/02/90	5	IT	V
H-05b	CULEBRA	ZINC		0.9600			0.8800	< 0.01	< 0.01	mg/l	08/27/85	1	IT	ME
H-05b	CULEBRA	ZINC		2.5000			2.4000	< 0.005	< 0.005	mg/l	05/21/86	2	IT	ME
H-05b	CULEBRA	ZINC		0.0300		NA	0.0000			mg/l	02/24/88	3	IT	ME
H-05b	CULEBRA	ZINC		1.1000			1.0000	< 0.02	< 0.02	mg/l	08/23/89	4	IT	MT
H-05b	CULEBRA	ZINC		0.8000			0.8000	< .02	< .02	mg/l	05/02/90	5	IT	MT
H-05b	CULEBRA	pH		7.0400		NA	0.0000				08/27/85	1	IT	GC
H-05b	CULEBRA	pH		6.8400			6.9500				05/21/86	2	IT	GC
H-05b	CULEBRA	pH		7.0300			7.0300				02/24/88	3	IT	GC
H-05b	CULEBRA	pH		7.0200			7.0200				08/23/89	4	IT	GC
H-05b	CULEBRA	pH		8.3300			8.3300				05/02/90	5	IT	GC
** H-05c														
H-05c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V

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H-05c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV

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H-05c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	ACETONE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	ACETONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	ACETONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	ALKALINITY (HCO3)		70.0000			68.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	ALKALINITY (HCO3)		55.0000		NA	0.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	ALKALINITY (HCO3)		54.0000		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	ALKALINITY (HCO3)		55.0000			53.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	ALKALINITY (HCO3)		46.0000			49.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	ALUMINUM		1.0000		<	1.0000	< 0.1	< 0.1	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	ALUMINUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	ALUMINUM	<	2.0000		<	2.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	ANTIMONY	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	ANTIMONY		0.6000			0.5000	< 0.05	< 0.05	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	ANTIMONY	<	0.6000		<	0.6000	< 0.06	< 0.06	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	ANTIMONY	<	0.6000		<	0.6000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	ARSENIC	<	0.1000		NA	0.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	BARIUM	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	BARIUM	<	0.0100		<	0.0100	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	BARIUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	BARIUM	<	2.0000		<	2.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	BENZENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	BENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	BENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME

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H-05c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE		10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	BORON		10.0000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	BORON		12.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	BORON		11.0000			11.0000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	BORON		11.0000			11.0000	< 0.02	< 0.02	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	BORON		10.0000			10.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	BROMIDE		4.0000		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	BROMIDE		2.5000			2.5000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	BROMIDE		3.0000		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	BROMIDE	<	2.0000		<	2.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	BROMIDE	<	2.0000		<	2.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	CADMIUM	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	CADMIUM	<	0.0500		<	0.0500			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	CALCIUM		790.0000			800.0000			mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	CALCIUM		560.0000			560.0000			mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	CALCIUM		570.0000			570.0000			mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	CALCIUM		620.0000			620.0000			mg/l	09/14/89	4	IT	MC
H-05c	MAGENTA	CALCIUM		560.0000			560.0000			mg/l	05/16/90	5	IT	MC
H-05c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	CESIUM		0.2000		NA	0.0000	< 0.1	< 0.1	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	CESIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	CESIUM	<	0.2000		<	0.2000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	CHLORIDE		1600.0000		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	CHLORIDE		1000.0000		NA	0.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	CHLORIDE		1000.0000			1000.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	CHLORIDE		930.0000		NA	0.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	CHLORIDE		870.0000			860.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	CHROMIUM	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	CHROMIUM		0.2000			0.2000	0.02	0.02	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	CHROMIUM		0.1000			0.1000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	CHROMIUM	<	0.1000		<	0.1000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	COBALT		0.1000			0.1000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	COBALT	<	0.5000		<	0.5000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	COPPER		0.2000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	COPPER	<	0.1000		<	0.1000	0.01	0.02	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	COPPER	<	0.2500		<	0.2500	< 0.025	< 0.025	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	COPPER	<	0.2500		<	0.2500			mg/l	05/16/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	CYANIDE	<	0.0100		NA	0.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	CYANIDE	<	0.0100		NA	0.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	CYANIDE	<	0.0100		<	0.0100			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	FLUORIDE		2.5000		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	FLUORIDE		2.8000		NA	0.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	FLUORIDE		3.1000		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	FLUORIDE		2.6000		NA	0.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	FLUORIDE		2.9000			0.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV

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H-05c	MAGENTA	IODIDE	<	1.0000		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	IODIDE	<	2.0000		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	IRON		1.3000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	IRON		0.3000			0.3000	0.02	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	IRON		1.0000			1.0000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	IRON	<	1.0000			1.0000	< 0.1	< 0.1	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	IRON	<	1.0000		<	1.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	LEAD		0.1800			0.1800	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	LEAD		0.6000			0.6000	< 0.05	< 0.05	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	LEAD	<	0.5000		<	0.5000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	LITHIUM		0.2000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	LITHIUM		0.2200			0.2200	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	LITHIUM		0.2200			0.2200	0.01	0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	LITHIUM		0.1900			0.1900	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	LITHIUM		0.2000			0.2000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	MAGNESIUM		190.0000			190.0000			mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	MAGNESIUM		180.0000			180.0000			mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	MAGNESIUM		180.0000			180.0000			mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	MAGNESIUM		200.0000			200.0000			mg/l	09/14/89	4	IT	MC
H-05c	MAGENTA	MAGNESIUM		180.0000			180.0000			mg/l	05/16/90	5	IT	MC
H-05c	MAGENTA	MANGANESE	<	0.0500		NA	0.0000	< 0.05	0.05	mg/l	10/24/86	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	MANGANESE	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	MANGANESE	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	MANGANESE	<	0.1500	<		0.1500	< 0.015	, 0.015	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	MANGANESE	<	0.1500	<		0.1500			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	MERCURY	<	0.0002	NA		0.0000	< 0.0002	< 0.0002	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	MERCURY		0.0005			0.0005	0.0007	0.0005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	MERCURY	<	0.0002	<		0.0002			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	METHYL BROMIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	METHYL CHLORIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000	T 81	T 72	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000	T 8.7	T 7.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	MOLYBDENUM	<	0.0500	NA		0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	MOLYBDENUM		0.0500			0.0500	0.01	0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	MOLYBDENUM		0.0800			0.0600	0.10	0.11	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	MOLYBDENUM	<	0.2000	<		0.2000	< 0.02	< 0.02	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	MOLYBDENUM	<	0.2000	<		0.2000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l	08/18/88	3	IT	SV
H-05c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA		0.0000			ug/l	10/24/86	1	IT	SV
H-05c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA		0.0000			ug/l	03/03/88	2	IT	SV
H-05c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA		0.0000			ug/l	08/18/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-05c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV
H-05c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		10/24/86	1	IT	ME
H-05c	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		03/03/88	2	IT	ME
H-05c	MAGENTA	NICKEL	<	0.3000		<	0.0300	< 0.03	< 0.03	mg/l		08/18/88	3	IT	ME
H-05c	MAGENTA	NICKEL	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l		09/14/89	4	IT	MT
H-05c	MAGENTA	NICKEL	<	0.4000		<	0.4000			mg/l		05/16/90	5	IT	MT
H-05c	MAGENTA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	10/24/86	1	IT	GC
H-05c	MAGENTA	NITRATE		0.0200		NA	0.0000			mg/l	NO3-N	03/03/88	2	IT	GC
H-05c	MAGENTA	NITRATE	<	0.0200		NA	0.0000			mg/l	NO3-N	08/18/88	3	IT	GC
H-05c	MAGENTA	NITRATE	<	0.0200		NA	0.0000			mg/l		09/14/89	4	IT	GC
H-05c	MAGENTA	NITRATE	<	0.0200		<	0.0200			mg/l		05/16/90	5	IT	GC
H-05c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV
H-05c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV
H-05c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		10/24/86	1	IT	PC
H-05c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		03/03/88	2	IT	PC
H-05c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		08/18/88	3	IT	PC
H-05c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV
H-05c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV
H-05c	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV

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H-05c	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	PHENOLICS		0.0150			0.0160			mg/l		10/24/86	1	IT	GC
H-05c	MAGENTA	PHENOLICS		0.0100		NA	0.0000			mg/l		03/03/88	2	IT	GC
H-05c	MAGENTA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		08/18/88	3	IT	GC
H-05c	MAGENTA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		09/14/89	4	IT	GC
H-05c	MAGENTA	PHENOLICS		0.0100			0.0000			mg/l		05/16/90	5	IT	GC
H-05c	MAGENTA	PHOSPHATE		0.0400		NA	0.0000			mg/l	T-PO4-P	10/24/86	1	IT	GC
H-05c	MAGENTA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	03/03/88	2	IT	GC
H-05c	MAGENTA	PHOSPHATE		0.0100			0.0100			mg/l	T-PO4-P	08/18/88	3	IT	GC
H-05c	MAGENTA	PHOSPHORUS		0.0200		NA	0.0000			mg/l		09/14/89	4	IT	GC
H-05c	MAGENTA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		05/16/90	5	IT	GC
H-05c	MAGENTA	POTASSIUM		51.0000			52.0000			mg/l		10/24/86	1	IT	ME
H-05c	MAGENTA	POTASSIUM		38.0000			40.0000			mg/l		03/03/88	2	IT	ME
H-05c	MAGENTA	POTASSIUM		36.0000			38.0000			mg/l		08/18/88	3	IT	ME
H-05c	MAGENTA	POTASSIUM		36.0000			36.0000			mg/l		09/14/89	4	IT	MC
H-05c	MAGENTA	POTASSIUM		36.0000			36.0000			mg/l		05/16/90	5	IT	MC
H-05c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		10/24/86	1	IT	SV
H-05c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		03/03/88	2	IT	SV
H-05c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		08/18/88	3	IT	SV
H-05c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		6800.0000		NA	0.0000			mg/l		10/24/86	1	IT	GC
H-05c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		6900.0000			7400.0000			mg/l		03/03/88	2	IT	GC
H-05c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		7000.0000		NA	0.0000			mg/l		08/18/88	3	IT	GC
H-05c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		7100.0000		NA	0.0000			mg/l		09/14/89	4	IT	GC
H-05c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		7200.0000			0.0000			mg/l		05/16/90	5	IT	GC
H-05c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		7.0000		NA	0.0000			mg/l		10/24/86	1	IT	GC
H-05c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l		03/03/88	2	IT	GC
H-05c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		50.0000		NA	0.0000			mg/l		08/18/88	3	IT	GC
H-05c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		NA	0.0000			mg/l		09/14/89	4	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000			0.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	SELENIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	SELENIUM	<	0.0050		NA	0.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	SILICA		12.0000		NA	0.0000	< 1	< 1	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	SILICA		5.0000		NA	0.0000			mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	SILICA		4.6000			4.7000			mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	SILICA		4.8000		NA	0.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	SILICA		4.9000			4.4000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	SILVER	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	SILVER		0.0200			0.0200	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	SILVER		0.2000			0.2000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	SILVER	<	0.1000		<	0.1000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	SODIUM		1500.0000			1500.0000			mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	SODIUM		1420.0000			1420.0000			mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	SODIUM		1400.0000			1400.0000			mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	SODIUM		1200.0000			1200.0000			mg/l	09/14/89	4	IT	MC
H-05c	MAGENTA	SODIUM		1000.0000			1000.0000			mg/l	05/16/90	5	IT	MC
H-05c	MAGENTA	SPECIFIC CONDUCTANCE		9050.0000		NA	0.0000			umhos/cm@25C	10/24/86	1	IT	GC
H-05c	MAGENTA	SPECIFIC CONDUCTANCE		9000.0000			9050.0000			umhos/cm@25C	03/03/88	2	IT	GC
H-05c	MAGENTA	SPECIFIC CONDUCTANCE		9240.0000			9250.0000			umhos/cm@25C	08/18/88	3	IT	GC
H-05c	MAGENTA	SPECIFIC CONDUCTANCE		8632.0000			8642.0000			uMhos/cm@25C	09/14/89	4	IT	GC
H-05c	MAGENTA	SPECIFIC CONDUCTANCE		9100.0000			9100.0000			uMhos/cm@25C	05/16/90	5	IT	GC
H-05c	MAGENTA	STRONTIUM		8.4000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	STRONTIUM		9.5000			9.7000	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	STRONTIUM		9.5000			9.4000	0.02	0.1	mg/l	08/18/88	3	IT	ME

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H-05c	MAGENTA	STRONTIUM		11.0000			11.0000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	STRONTIUM		9.8000			9.8000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	STYRENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	SULFATE		4200.0000		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	SULFATE		3800.0000		NA	0.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	SULFATE		3000.0000		NA	0.0000			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	SULFATE		3300.0000		NA	0.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	SULFATE		3300.0000		NA	3300.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	THALLIUM	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	THALLIUM	<	0.2500		NA	0.0000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	TITANIUM	<	0.3000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	TITANIUM		0.4000			0.4000	0.03	0.03	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	TITANIUM		0.2000			0.1000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	TITANIUM	<	0.1000		<	0.1000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	08/18/88	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	TOTAL ORGANIC CARBON		3.0000			2.0000			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		NA	0.0000			mg/l	10/24/86	1	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500			0.0600			mg/l	03/03/88	2	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	08/18/88	3	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	09/14/89	4	IT	GC
H-05c	MAGENTA	TOTAL ORGANIC HALOGEN		0.0700		<	0.0500			mg/l	05/16/90	5	IT	GC
H-05c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	VANADIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	VANADIUM		0.2000			0.1000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	VANADIUM	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	VANADIUM	<	0.5000		<	0.5000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	08/18/88	3	IT	V
H-05c	MAGENTA	XYLENE	<	5.0000		NA	0.0000			ug/l	10/24/86	1	IT	V
H-05c	MAGENTA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/03/88	2	IT	V
H-05c	MAGENTA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	08/18/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-05c	MAGENTA	ZINC	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/24/86	1	IT	ME
H-05c	MAGENTA	ZINC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/03/88	2	IT	ME
H-05c	MAGENTA	ZINC		0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/18/88	3	IT	ME
H-05c	MAGENTA	ZINC	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	09/14/89	4	IT	MT
H-05c	MAGENTA	ZINC	<	0.2000		<	0.2000			mg/l	05/16/90	5	IT	MT
H-05c	MAGENTA	pH		7.5200			7.2300				10/24/86	1	IT	GC
H-05c	MAGENTA	pH		7.8400			7.8600				03/03/88	2	IT	GC
H-05c	MAGENTA	pH		7.4900			7.5000				08/18/88	3	IT	GC
H-05c	MAGENTA	pH		7.3800			7.3700				09/14/89	4	IT	GC
H-05c	MAGENTA	pH		8.3300			8.3300				05/16/90	5	IT	GC
** H-06b														
H-06b	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V

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H-06b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T< 10	16	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV

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H-06b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP. ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000 T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000		ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000		ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000		ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	ACETONE	<	10.0000		NA	0.0000		ug/l	09/15/85	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	ACETONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	ALKALINITY (HCO3)		100.0000		NA	0.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	ALKALINITY (HCO3)		100.0000			100.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	ALKALINITY (HCO3)		97.0000		NA	0.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	ALKALINITY (HCO3)		91.0000			92.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	ALKALINITY (HCO3)		93.0000		NA	0.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	ALUMINUM		0.1300		NA	0.0000	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	ALUMINUM	<	2.0000		<	2.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	ANTIMONY		0.8000			0.8000	< 0.05	< 0.05	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	ANTIMONY	<	0.6000		<	0.6000	< 0.06	< 0.06	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	ANTIMONY	<	0.6000		<	0.6000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	ARSENIC		78.0000		NA	0.0000	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	ARSENIC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	ARSENIC	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	ARSENIC	<	0.0100	NA		0.0000	< 0.01	< 0.01	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	ARSENIC	<	0.0100	NA		0.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	BARIUM	<	0.1000	<		0.1000	< 0.1	< 0.1	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	BARIUM		0.0600			0.0600	< 0.005	< 0.005	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	BARIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	BARIUM	<	2.0000	<		2.0000	< 0.2	< 0.2	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	BARIUM	<	2.0000	<		2.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	BENZENE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	BENZENE	<	5.0000	NA		0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	BENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	BENZENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	BENZIDINE	<	4.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BENZO(A)PYRENE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BENZOIC ACID	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BENZYL ALCOHOL	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BERYLLIUM		0.0200			0.0200	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	4.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	BORON		7.4000			6.8000	< 0.1	< 0.1	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	BORON		10.0000			9.9000	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	BORON		9.6000			9.6000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	BORON		9.7000			9.8000	< 0.02	< 0.02	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	BORON		9.8000			9.7000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	BROMIDE		67.0000		NA	0.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	BROMIDE		35.0000		NA	0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	BROMIDE		37.0000		NA	0.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	BROMIDE		35.0000		NA	0.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	BROMIDE	<	23.0000			22.0000			mg/l	02/12/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	CADMIUM	<	0.0500		<	0.0500			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	CALCIUM		1900.0000			1900.0000	0.3	0.3	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	CALCIUM		1800.0000			1700.0000			mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	CALCIUM		1700.0000			1800.0000	N/A		mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	CALCIUM		2100.0000			2100.0000			mg/l	07/24/89	4	IT	MC
H-06b	CULEBRA	CALCIUM		2100.0000			2100.0000			mg/l	02/12/90	5	IT	MC
H-06b	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	CESIUM	<	1.0000		<	1.0000	< 1.0	< 1.0	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	CESIUM		0.3000			0.3000	0.3	0.3	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	CESIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	CESIUM	<	0.1000		<	0.1000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	CHLORIDE		34000.0000		NA	0.0000			mg/l	09/15/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	CHLORIDE		33000.0000		NA	0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	CHLORIDE		31500.0000		NA	0.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	CHLORIDE		31600.0000			31800.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	CHLORIDE		28000.0000		NA	0.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	CHLOROFORM	<	2.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	CHROMIUM		0.2200			0.2100	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	CHROMIUM		0.4300			0.4600	< 0.01	0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	CHROMIUM		0.3000			0.3000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	CHROMIUM		0.3000			0.3000	0.02	0.02	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	CHROMIUM		0.2000			0.3000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	COBALT		0.9600			0.9200	0.02	0.02	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	COBALT		0.1200			0.1300	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	COBALT	<	0.5000	<		0.5000	< 0.05	< 0.05	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	COBALT		0.5000	<		0.5000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	COPPER		0.1200			0.1200	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	COPPER		0.1200			0.1300	< 0.01	0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	COPPER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	COPPER	<	0.2500	<		0.2500	< 0.025	< 0.025	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	COPPER	<	0.2500	<		0.2500			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	CYANIDE	<	0.0200	<		0.0200			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	CYANIDE	<	0.0400	NA		0.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	CYANIDE	<	0.0100	<		0.0200			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	CYANIDE	<	0.0100	NA		0.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	DIBENZOFURAN	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000	NA		0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V

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H-06b	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	Eh		514.0000		NA	0.0000			mV	09/15/85	1	IT	GC
H-06b	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	FLUORIDE		1.6000			1.5000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	FLUORIDE		1.3000			1.3000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	FLUORIDE		1.3000			1.3000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	FLUORIDE		1.3000			1.3000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	FLUORIDE		1.4000			1.4000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	FREON-113	<	50.0000		NA	0.0000	T< 50	M< 50	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV

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H-06b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	IODIDE	<	1.0000		<	1.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	IODIDE		0.9000		NA	0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	IRON		0.5500			0.5500	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	IRON		0.3500			0.3600	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	IRON		0.2000			0.2000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	IRON	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	IRON	<	1.0000		<	1.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	LEAD		0.4000			0.2000	< 0.1	< 0.1	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	LEAD		0.8000			0.8600	< 0.05	< 0.05	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	11/16/87	3	IT	ME

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H-06b	CULEBRA	LEAD	<	0.5000	<		0.5000	< 0.05	< 0.05	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	LEAD	<	0.5000	<		0.5000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	LITHIUM		0.5500			0.5500	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	LITHIUM		0.4100			0.4100	< 0.01	< 0.01	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	LITHIUM		0.5000			0.5000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	MAGNESIUM		740.0000			740.0000	< 0.1	< 0.1	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	MAGNESIUM		970.0000			950.0000			mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	MAGNESIUM		1000.0000			1100.0000	N/A		mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	MAGNESIUM		940.0000			940.0000			mg/l	07/24/89	4	IT	MC
H-06b	CULEBRA	MAGNESIUM		1000.0000			1000.0000			mg/l	02/12/90	5	IT	MC
H-06b	CULEBRA	MANGANESE		0.2000			0.2000	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	MANGANESE		0.2000			0.2000	< 0.005	< 0.005	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	MANGANESE		0.1500			0.1500	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	MANGANESE		0.2800			0.2800	< 0.015	< 0.015	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	MANGANESE		0.2500			0.2600			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	MERCURY		0.0012			0.0012	< 0.0002	0.0009	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	MERCURY	<	0.0002			0.0004	< 0.0002	< 0.0002	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	MERCURY	<	0.0002	<		0.0002			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000			ug/l	09/15/85	1	IT	V

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H-06b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	V
H-06b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		11/16/87	3	IT	V
H-06b	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l		02/12/90	5	IT	V
H-06b	CULEBRA	MOLYBDENUM		0.0400			0.0400	< 0.01	< 0.01	mg/l		09/15/85	1	IT	ME
H-06b	CULEBRA	MOLYBDENUM		0.2500			0.1500	0.02	< 0.01	mg/l		07/28/86	2	IT	ME
H-06b	CULEBRA	MOLYBDENUM		0.5000			0.5000	< 0.01	< 0.01	mg/l		11/16/87	3	IT	ME
H-06b	CULEBRA	MOLYBDENUM		0.2000			0.2000	< 0.02	< 0.02	mg/l		07/24/89	4	IT	MT
H-06b	CULEBRA	MOLYBDENUM	<	0.2000		<	0.2000			mg/l		02/12/90	5	IT	MT
H-06b	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	4.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	NICKEL		0.5600			0.5600	< 0.01	< 0.01	mg/l		09/15/85	1	IT	ME
H-06b	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		07/28/86	2	IT	ME
H-06b	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		11/16/87	3	IT	ME
H-06b	CULEBRA	NICKEL	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l		07/24/89	4	IT	MT
H-06b	CULEBRA	NICKEL	<	0.4000		<	0.4000			mg/l		02/12/90	5	IT	MT
H-06b	CULEBRA	NITRATE		0.2000			0.2000			mg/l	NO3-N	09/15/85	1	IT	GC
H-06b	CULEBRA	NITRATE		0.2000			0.2000			mg/l	NO3-N	07/28/86	2	IT	GC
H-06b	CULEBRA	NITRATE	<	0.2000		NA	0.0000			mg/l	NO3-N	11/16/87	3	IT	GC
H-06b	CULEBRA	NITRATE		0.0700			0.0700			mg/l		07/24/89	4	IT	GC
H-06b	CULEBRA	NITRATE		0.0800		NA	0.0000			mg/l		02/12/90	5	IT	GC
H-06b	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-06b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		07/28/86	2	IT	PC
H-06b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		11/16/87	3	IT	PC
H-06b	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		09/15/85	1	IT	SV
H-06b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/28/86	2	IT	SV
H-06b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		11/16/87	3	IT	SV
H-06b	CULEBRA	PHENOLICS		0.0040		NA	0.0000			mg/l		09/15/85	1	IT	GC
H-06b	CULEBRA	PHENOLICS		0.0170			0.0140			mg/l		07/28/86	2	IT	GC
H-06b	CULEBRA	PHENOLICS		0.0080		NA	0.0000			mg/l		11/16/87	3	IT	GC
H-06b	CULEBRA	PHENOLICS		0.0090		NA	0.0000			mg/l		07/24/89	4	IT	GC
H-06b	CULEBRA	PHENOLICS		0.5500		NA	0.0000			mg/l		02/12/90	5	IT	GC
H-06b	CULEBRA	PHOSPHATE		0.0200			0.0100			mg/l	T-PO4-P	09/15/85	1	IT	GC
H-06b	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	07/28/86	2	IT	GC
H-06b	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	11/16/87	3	IT	GC
H-06b	CULEBRA	PHOSPHORUS	<	0.0200		NA	0.0000			mg/l		07/24/89	4	IT	GC
H-06b	CULEBRA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		02/12/90	5	IT	GC
H-06b	CULEBRA	POTASSIUM		480.0000			490.0000	< 0.01	< 0.01	mg/l		09/15/85	1	IT	ME
H-06b	CULEBRA	POTASSIUM		350.0000			340.0000			mg/l		07/28/86	2	IT	ME
H-06b	CULEBRA	POTASSIUM		480.0000			490.0000	N/A		mg/l		11/16/87	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06b	CULEBRA	POTASSIUM		350.0000			350.0000			mg/l	07/24/89	4	IT	MC
H-06b	CULEBRA	POTASSIUM		600.0000			500.0000			mg/l	02/12/90	5	IT	MC
H-06b	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	SV
H-06b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	SV
H-06b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	11/16/87	3	IT	SV
H-06b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		58000.0000			58000.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		59000.0000			59000.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		60300.0000			60800.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		59600.0000			60300.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		66000.0000			66000.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		240.0000			260.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		190.0000			160.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		8.0000			7.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		190.0000			190.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	8.0000			7.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	SELENIUM		1.3000		NA	0.0000	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	SELENIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	SELENIUM	<	0.5000		NA	0.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	SILICA		19.0000			20.0000	< 0.2	< 0.2	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	SILICA		26.0000			24.0000	< 0.2	< 0.2	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	SILICA		21.0000			20.0000	< 0.2	< 0.2	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	SILICA		8.3000			8.3000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	SILICA		8.3000			8.3000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	SILVER	<	0.1000			0.1000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	SODIUM		15000.0000			15000.0000	< 0.1	< 0.1	mg/l	09/15/85	1	IT	ME

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H-06b	CULEBRA	SODIUM		17000.0000		NA	0.0000			mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	SODIUM		17800.0000			18000.0000	N/A		mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	SODIUM		14600.0000			14800.0000			mg/l	07/24/89	4	IT	MC
H-06b	CULEBRA	SODIUM		15000.0000			15500.0000			mg/l	02/12/90	5	IT	MC
H-06b	CULEBRA	SPECIFIC CONDUCTANCE		80400.0000		NA	0.0000			umhos/cm@25C	09/15/85	1	IT	GC
H-06b	CULEBRA	SPECIFIC CONDUCTANCE		69100.0000		NA	0.0000			umhos/cm@25C	07/28/86	2	IT	GC
H-06b	CULEBRA	SPECIFIC CONDUCTANCE		108000.0000			112000.0000			umhos/cm@25C	11/16/87	3	IT	GC
H-06b	CULEBRA	SPECIFIC CONDUCTANCE		74509.0000			74625.0000			umhos/cm@25C	07/24/89	4	IT	GC
H-06b	CULEBRA	SPECIFIC CONDUCTANCE		77600.0000			77800.0000			umhos/cm@25C	02/12/90	5	IT	GC
H-06b	CULEBRA	STRONTIUM		24.0000			24.0000	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	STRONTIUM		25.0000			25.0000	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	STRONTIUM		33.0000			34.0000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	STRONTIUM		31.0000			31.0000	< 0.01	< 0.01	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	STRONTIUM		30.0000			30.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	SULFATE		3000.0000		NA	0.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	SULFATE		3300.0000			3500.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	SULFATE		3400.0000		NA	0.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	SULFATE		3100.0000			3600.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	SULFATE		3400.0000			3400.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	THALLIUM	<	10.0000		NA	0.0000	< 0.01	< 0.01	mg/l	07/24/89	4	IT	MT

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H-06b	CULEBRA	THALLIUM	<	10.0000		NA	0.0000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	TITANIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	TITANIUM		0.6000			0.6000	< 0.03	< 0.03	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	TITANIUM		0.5000			0.6000	< 0.03	< 0.03	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	TITANIUM	<	0.1000		<	0.1000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC CARBON		6.0000			4.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC CARBON		2.0000			1.0000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC CARBON		7.0000			7.0000			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC HALOGEN		0.9700		NA	0.0000			mg/l	09/15/85	1	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC HALOGEN		0.9200		NA	0.0000			mg/l	07/28/86	2	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC HALOGEN		2.0000			3.0000			mg/l	11/16/87	3	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC HALOGEN		0.2700			0.3000			mg/l	07/24/89	4	IT	GC
H-06b	CULEBRA	TOTAL ORGANIC HALOGEN		0.1800			0.1400			mg/l	02/12/90	5	IT	GC
H-06b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V

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H-06b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	TURBIDITY		4.3000			4.4000			NTU	07/24/89	4	IT	GC
H-06b	CULEBRA	VANADIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	VANADIUM	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	VANADIUM	<	0.5000		<	0.5000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	09/15/85	1	IT	V
H-06b	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	07/28/86	2	IT	V
H-06b	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/16/87	3	IT	V
H-06b	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	02/12/90	5	IT	V
H-06b	CULEBRA	ZINC		0.0600			0.0700	< 0.01	< 0.01	mg/l	09/15/85	1	IT	ME
H-06b	CULEBRA	ZINC		0.1000			0.1000	< 0.01	< 0.01	mg/l	07/28/86	2	IT	ME
H-06b	CULEBRA	ZINC		0.1000			0.1000	< 0.01	< 0.01	mg/l	11/16/87	3	IT	ME
H-06b	CULEBRA	ZINC	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	07/24/89	4	IT	MT
H-06b	CULEBRA	ZINC	<	0.2000		<	0.2000			mg/l	02/12/90	5	IT	MT
H-06b	CULEBRA	pH		7.1900		NA	0.0000				09/15/85	1	IT	GC
H-06b	CULEBRA	pH		7.0600			7.0800				07/28/86	2	IT	GC
H-06b	CULEBRA	pH		5.9200			6.0400				11/16/87	3	IT	GC
H-06b	CULEBRA	pH		6.7000			6.7700				07/24/89	4	IT	GC
H-06b	CULEBRA	pH		6.9000			6.9000				02/12/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
** H-06c														
H-06c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V

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H-06c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	2-BUTANONE	<	10.0000		NA	0.0000	T< 10	M 13	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	2-HEXANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV

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H-06c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T 26	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V

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H-06c	MAGENTA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	ACETONE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	ACETONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	ACETONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	ALKALINITY (HCO3)		51.0000			54.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	ALKALINITY (HCO3)		52.0000		NA	0.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	ALKALINITY (HCO3)		52.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	ALKALINITY (HCO3)		51.0000		NA	0.0000			mg/l	08/04/89	4	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	ALKALINITY (HCO3)		51.0000			54.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	ALUMINUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	ALUMINUM	<	2.0000		<	2.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	ANTIMONY	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	ANTIMONY	<	0.6000		<	0.6000	< 0.06	< 0.06	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	ANTIMONY	<	0.6000		<	0.6000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	ARSENIC	<	0.0100		NA	0.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	BARIUM	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	BARIUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	BARIUM	<	2.0000		<	2.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	BENZENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	BENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	BENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	BERYLLIUM	<	0.0500		<	0.0500			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV

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H-06c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	BORON		2.4000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	BORON		2.1000			2.1000	0.01	0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	BORON		2.4000			2.4000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	BORON		2.3000			2.3000	< 0.02	< 0.02	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	BORON		2.3000			2.4000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	BROMIDE		1.0000		NA	0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	BROMIDE	<	2.0000		NA	0.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	BROMIDE	<	2.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	BROMIDE	<	2.0000		<	2.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	BROMIDE	<	2.0000		<	2.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	BROMOFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	CADMIUM	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	CADMIUM	<	0.0500		<	0.0500			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	CALCIUM		630.0000			610.0000			mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	CALCIUM		500.0000			500.0000	N/A		mg/l	11/04/87	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	CALCIUM		590.0000			590.0000			mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	CALCIUM		550.0000			560.0000			mg/l	08/04/89	4	IT	MC
H-06c	MAGENTA	CALCIUM		570.0000			570.0000			mg/l	03/15/90	5	IT	MC
H-06c	MAGENTA	CALCIUM HARDNESS		0.0000			0.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	CESIUM		0.3000		NA	0.0000	< 0.1	0.1	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	CESIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	CESIUM	<	0.2000		<	0.2000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	CHLORIDE		430.0000			430.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	CHLORIDE		420.0000		NA	0.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	CHLORIDE		390.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	CHLORIDE		470.0000			450.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	CHLORIDE		390.0000		NA	0.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	CHLOROBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	CHLOROETHANE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	CHLOROFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	CHROMIUM	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	CHROMIUM	<	0.1000			0.1000	0.02	0.03	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	CHROMIUM	<	0.1000		<	0.1000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	COBALT	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	COBALT	<	0.5000		<	0.5000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	COPPER	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	COPPER		0.3400		<	0.2500	< 0.025	< 0.025	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	COPPER	<	0.2500		<	0.2500			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	11/04/87	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	CYANIDE	<	0.0200		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	CYANIDE	<	0.1000		<	0.0200			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	CYANIDE	<	0.0100		<	0.0200			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	ETHYLBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	FLUORIDE		1.7000			1.7000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	FLUORIDE		2.0000			2.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	FLUORIDE		2.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	FLUORIDE		1.9000			1.9000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	FLUORIDE		1.9000			1.9000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV

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H-06c	MAGENTA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	IODIDE	<	1.0000		NA	0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	IODIDE	<	2.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	IODIDE	<	2.0000		<	2.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	IRON		0.3000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	IRON		0.2000			0.2000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	IRON		0.4000			0.4000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	IRON	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	IRON	<	1.0000		<	1.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV
H-06c	MAGENTA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/26/88	3	IT	SV
H-06c	MAGENTA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	LEAD	<	0.5000		<	0.5000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	LITHIUM		0.1900		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	LITHIUM		0.2200			0.2200	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	LITHIUM		0.2200			0.2200	0.01	0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	LITHIUM		0.2200			0.2100	< 0.01	< 0.01	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	LITHIUM		0.2100			0.2100			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	MAGNESIUM		170.0000			170.0000			mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	MAGNESIUM		170.0000			170.0000	N/A		mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	MAGNESIUM		170.0000			170.0000			mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	MAGNESIUM		150.0000			150.0000			mg/l	08/04/89	4	IT	MC
H-06c	MAGENTA	MAGNESIUM		170.0000			170.0000			mg/l	03/15/90	5	IT	MC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	MANGANESE	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	MANGANESE	<	0.1500		<	0.1500	< 0.015	< 0.015	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	MANGANESE	<	0.1500		<	0.1500			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	MERCURY	<	0.0002		NA	0.0000			mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	MERCURY		0.0006			0.0003	< 0.0002	< 0.0002	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	MERCURY	<	0.0004		<	0.0004			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	METHYL BROMIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T 13	T 7.4	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T < 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	MOLYBDENUM		0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	MOLYBDENUM		0.0500			0.0500	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	MOLYBDENUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	MOLYBDENUM	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	MOLYBDENUM	<	0.2000		<	0.2000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	SV
H-06c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	11/04/87	2	IT	SV

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H-06c	MAGENTA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		10/01/86	1	IT	ME
H-06c	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		11/04/87	2	IT	ME
H-06c	MAGENTA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		07/26/88	3	IT	ME
H-06c	MAGENTA	NICKEL	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l		08/04/89	4	IT	MT
H-06c	MAGENTA	NICKEL	<	0.4000		<	0.4000			mg/l		03/15/90	5	IT	MT
H-06c	MAGENTA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	10/01/86	1	IT	GC
H-06c	MAGENTA	NITRATE	<	0.1000		NA	0.0000			mg/l	NO3-N	11/04/87	2	IT	GC
H-06c	MAGENTA	NITRATE	<	0.0200		NA	0.0000			mg/l	NO3-N	07/26/88	3	IT	GC
H-06c	MAGENTA	NITRATE		7.3000			7.2000			mg/l		08/04/89	4	IT	GC
H-06c	MAGENTA	NITRATE	<	0.0200		<	0.0200			mg/l		03/15/90	5	IT	GC
H-06c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		10/01/86	1	IT	PC
H-06c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		11/04/87	2	IT	PC
H-06c	MAGENTA	PCB	<	1.0000		NA	0.0000			ug/l		07/26/88	3	IT	PC
H-06c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV

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H-06c	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	PHENOLICS		0.0040		NA	0.0000			mg/l		10/01/86	1	IT	GC
H-06c	MAGENTA	PHENOLICS		0.0140		NA	0.0000			mg/l		11/04/87	2	IT	GC
H-06c	MAGENTA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		07/26/88	3	IT	GC
H-06c	MAGENTA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		08/04/89	4	IT	GC
H-06c	MAGENTA	PHENOLICS	<	0.0050			0.0000			mg/l		03/15/90	5	IT	GC
H-06c	MAGENTA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	10/01/86	1	IT	GC
H-06c	MAGENTA	PHOSPHATE		0.0100			0.0100			mg/l	T-PO4-P	11/04/87	2	IT	GC
H-06c	MAGENTA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	07/26/88	3	IT	GC
H-06c	MAGENTA	PHOSPHORUS		0.0100		NA	0.0000			mg/l		08/04/89	4	IT	GC
H-06c	MAGENTA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		03/15/90	5	IT	GC
H-06c	MAGENTA	POTASSIUM		26.0000			26.0000			mg/l		10/01/86	1	IT	ME
H-06c	MAGENTA	POTASSIUM		18.0000			18.0000	N/A		mg/l		11/04/87	2	IT	ME
H-06c	MAGENTA	POTASSIUM		18.0000			18.0000			mg/l		07/26/88	3	IT	ME
H-06c	MAGENTA	POTASSIUM		7.0000			8.0000			mg/l		08/04/89	4	IT	MC
H-06c	MAGENTA	POTASSIUM		20.0000			20.0000			mg/l		03/15/90	5	IT	MC
H-06c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		10/01/86	1	IT	SV
H-06c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		11/04/87	2	IT	SV
H-06c	MAGENTA	PYRENE	<	10.0000		NA	0.0000			ug/l		07/26/88	3	IT	SV
H-06c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		4600.0000			4600.0000			mg/l		10/01/86	1	IT	GC
H-06c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		4800.0000		NA	0.0000			mg/l		11/04/87	2	IT	GC
H-06c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		4800.0000		NA	0.0000			mg/l		07/26/88	3	IT	GC
H-06c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		4800.0000			4800.0000			mg/l		08/04/89	4	IT	GC
H-06c	MAGENTA	RESIDUE, FILTERABLE @ 180 C		4800.0000			4800.0000			mg/l		03/15/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-06c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		13.0000		NA	0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		5.0000			6.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		29.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	RESIDUE, NONFILTERABLE @ 105 C		10.0000			7.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	SELENIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	SELENIUM	<	0.5000		NA	0.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	SILICA		13.0000		NA	0.0000	< 1	< 1	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	SILICA		11.0000			11.0000	< 0.2	< 0.2	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	SILICA		5.4000		NA	0.0000			mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	SILICA		5.0000			5.2000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	SILICA		5.1000			5.1000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	SILVER	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	SILVER	<	0.1000		<	0.1000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	SODIUM		1100.0000			1000.0000			mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	SODIUM		650.0000			650.0000	N/A		mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	SODIUM		640.0000			630.0000			mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	SODIUM		590.0000			590.0000			mg/l	08/04/89	4	IT	MC
H-06c	MAGENTA	SODIUM		570.0000			590.0000			mg/l	03/15/90	5	IT	MC
H-06c	MAGENTA	SPECIFIC CONDUCTANCE		5550.0000			5570.0000			umhos/cm@25C	10/01/86	1	IT	GC
H-06c	MAGENTA	SPECIFIC CONDUCTANCE		5450.0000			5440.0000			umhos/cm@25C	11/04/87	2	IT	GC
H-06c	MAGENTA	SPECIFIC CONDUCTANCE		3860.0000			3880.0000			umhos/cm@25C	07/26/88	3	IT	GC
H-06c	MAGENTA	SPECIFIC CONDUCTANCE		5796.0000			5808.0000			umhos/cm@25C	08/04/89	4	IT	GC

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H-06c	MAGENTA	SPECIFIC CONDUCTANCE		6600.0000			6600.0000			uMhos/cm@25C	03/15/90	5	IT	GC
H-06c	MAGENTA	STRONTIUM		7.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	STRONTIUM		8.6000			8.7000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	STRONTIUM		9.4000			9.3000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	STRONTIUM		9.8000			9.8000	< 0.01	< 0.01	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	STRONTIUM		10.0000			10.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	STYRENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	STYRENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	SULFATE		2400.0000			2400.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	SULFATE		2400.0000		NA	0.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	SULFATE		2600.0000		NA	0.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	SULFATE		2520.0000		NA	0.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	SULFATE		2600.0000			2500.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	THALLIUM	<	0.0050		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	THALLIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	THALLIUM	<	0.1000		NA	0.0000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	TITANIUM	<	0.3000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	TITANIUM	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	TITANIUM	<	0.1000		<	0.1000			mg/l	03/15/90	5	IT	MT

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H-06c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	TOLUENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	TOTAL HARDNESS		0.0000		NA	0.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC CARBON		1.0000		<	1.0000			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC HALOGEN		0.0500		NA	0.0000			mg/l	10/01/86	1	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC HALOGEN		0.0700			0.0500			mg/l	11/04/87	2	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500			0.0600			mg/l	07/26/88	3	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	08/04/89	4	IT	GC
H-06c	MAGENTA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	03/15/90	5	IT	GC
H-06c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME

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H-06c	MAGENTA	VANADIUM	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	VANADIUM	<	0.5000		<	0.5000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	VINYL ACETATE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	XYLENE	<	5.0000		NA	0.0000			ug/l	10/01/86	1	IT	V
H-06c	MAGENTA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/04/87	2	IT	V
H-06c	MAGENTA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	07/26/88	3	IT	V
H-06c	MAGENTA	XYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	03/15/90	5	IT	V
H-06c	MAGENTA	ZINC	<	0.1000		NA	0.0000	< 0.05	< 0.05	mg/l	10/01/86	1	IT	ME
H-06c	MAGENTA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/04/87	2	IT	ME
H-06c	MAGENTA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	07/26/88	3	IT	ME
H-06c	MAGENTA	ZINC	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	08/04/89	4	IT	MT
H-06c	MAGENTA	ZINC	<	0.2000		<	0.2000			mg/l	03/15/90	5	IT	MT
H-06c	MAGENTA	pH		7.2100		NA	0.0000				10/01/86	1	IT	GC
H-06c	MAGENTA	pH		6.1000			6.1300				11/04/87	2	IT	GC
H-06c	MAGENTA	pH		7.1900			7.2100			--	07/26/88	3	IT	GC
H-06c	MAGENTA	pH		6.6000			6.6500				08/04/89	4	IT	GC
H-06c	MAGENTA	pH		7.4500			7.4600				03/15/90	5	IT	GC
** H-07b1														
H-07b1	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V

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H-07b1	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV

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H-07b1	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV

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H-07b1	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	ALKALINITY (HCO3)		130.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	ALKALINITY (HCO3)		130.0000			130.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	ALKALINITY (HCO3)		120.0000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	ALKALINITY (HCO3)		110.0000			110.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	ALKALINITY (HCO3)		92.0000		NA	0.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	ALUMINUM	<	0.1000		NA	0.0000	< 0.10	< 0.10	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< .2	< .2	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	ANTIMONY	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	ANTIMONY	<	0.6000		<	0.6000	< .06	< .06	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	ARSENIC		0.0050		NA	0.0000	< 0.001	< 0.001	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	ARSENIC		0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME

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H-07b1	CULEBRA	ARSENIC		0.0040		NA	0.0000	< 0.003	< 0.003	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	ARSENIC	<	0.0100		NA	0.0000	< .01	< .01	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	BARIUM		0.0100		NA	0.0000	< 0.005	< 0.005	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	BARIUM	<	2.0000		<	2.0000	< .2	< .2	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BERYLLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	03/27/86	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	BORON		0.7400		NA	0.0000	< 0.01	< 0.01	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	BORON		0.8000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	BORON		0.7000			0.7000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	BORON		0.8000			0.8000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	BORON		0.9000			0.9000	0.04	0.03	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	BROMIDE		1.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	BROMIDE	<	2.0000		NA	0.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	BROMIDE	<	2.0000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	BROMIDE		3.0000		NA	0.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	BROMIDE	<	2.0000		<	2.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	CADMIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	0.006	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< .005	< .005	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	CALCIUM		540.0000		NA	0.0000			mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	CALCIUM		620.0000			580.0000			mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	CALCIUM		570.0000			560.0000			mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	CALCIUM		650.0000			650.0000			mg/l	05/19/89	4	IT	MC
H-07b1	CULEBRA	CALCIUM		670.0000			660.0000			mg/l	11/09/90	5	IT	MC
H-07b1	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	CESIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	CESIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	CESIUM		0.0100			0.0100	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	CESIUM	<	0.2000		<	0.2000	< 0.2	< 0.2	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	CESIUM	<	0.1000		<	0.1000	< .1	< .1	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	CHLORIDE		700.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	CHLORIDE		310.0000		NA	0.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	CHLORIDE		290.0000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	CHLORIDE		250.0000			250.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	CHLORIDE		280.0000			280.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V

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H-07b1	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	CHROMIUM		0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	CHROMIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	CHROMIUM		0.2000			0.2000	0.01	0.02	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	CHROMIUM		0.2000			0.2000	0.01	0.01	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	COBALT	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	COBALT	<	0.5000		<	0.5000	< .05	< .05	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	COPPER	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	COPPER	<	0.1000		NA	0.0000	0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	COPPER	<	0.2500		<	0.2500	< .025	< .025	mg/l	11/09/90	5	IT	MT

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H-07b1	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	CYANIDE	<	0.0010		NA	0.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV

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H-07b1	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	Eh		391.0000		NA	0.0000			mV	03/27/86	1	IT	GC
H-07b1	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	FLUORIDE		1.2000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	FLUORIDE		1.5000			1.5000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	FLUORIDE		1.5000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	FLUORIDE		1.5000			1.5000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	FLUORIDE		1.5000		NA	0.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	IRON		0.0800		NA	0.0000	< 0.01	< 0.01	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	IRON	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	IRON	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	IRON		0.3000			0.3000	< 0.02	< 0.02	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	IRON	<	1.0000			1.0000	< .1	< .1	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	LEAD	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	LEAD	<	0.5000		<	0.5000	< .05	< .05	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	LITHIUM		0.1200		NA	0.0000	0.01	0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	LITHIUM		0.1200			0.1200	0.01	0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	LITHIUM		0.1100			0.1100	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	LITHIUM	<	0.1000		<	0.1000	< .01	< .01	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	MAGNESIUM		130.0000		NA	0.0000			mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	MAGNESIUM		140.0000			130.0000			mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	MAGNESIUM		130.0000			120.0000			mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	MAGNESIUM		130.0000			130.0000			mg/l	05/19/89	4	IT	MC
H-07b1	CULEBRA	MAGNESIUM		140.0000			140.0000			mg/l	11/09/90	5	IT	MC
H-07b1	CULEBRA	MANGANESE		0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	03/27/86	1	IT	ME

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H-07b1	CULEBRA	MANGANESE		0.0700		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	MANGANESE		0.0600			0.0500	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	MANGANESE	<	0.1500		<	0.1500	< .015	< .015	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	MERCURY	<	0.0020		<	0.0020	< .0002	< .0002	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	METHYLENE CHLORIDE		11.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T 9.8	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	MOLYBDENUM		0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	MOLYBDENUM		0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	MOLYBDENUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	MOLYBDENUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	MOLYBDENUM	<	0.2000		<	0.2000	< .02	< .02	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV
H-07b1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	SV
H-07b1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	SV
H-07b1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	04/25/88	3	IT	SV

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H-07b1	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV
H-07b1	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	NICKEL	<	0.0300		NA	0.0000	< 0.03	< 0.03	mg/l		03/27/86	1	IT	ME
H-07b1	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		02/25/87	2	IT	ME
H-07b1	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		04/25/88	3	IT	ME
H-07b1	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		05/19/89	4	IT	MT
H-07b1	CULEBRA	NICKEL	<	0.4000		<	0.4000	< .04	< .04	mg/l		11/09/90	5	IT	MT
H-07b1	CULEBRA	NITRATE		0.7000		NA	0.0000			mg/l	NO3-N	03/27/86	1	IT	GC
H-07b1	CULEBRA	NITRATE		0.8000		NA	0.0000			mg/l	NO3-N	02/25/87	2	IT	GC
H-07b1	CULEBRA	NITRATE		0.7000		NA	0.0000			mg/l	NO3-N	04/25/88	3	IT	GC
H-07b1	CULEBRA	NITRATE		0.7400			0.7300			mg/l		05/19/89	4	IT	GC
H-07b1	CULEBRA	NITRATE		0.9000			0.9000			mg/l		11/09/90	5	IT	GC
H-07b1	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV
H-07b1	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV
H-07b1	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		02/25/87	2	IT	PC
H-07b1	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		04/25/88	3	IT	PC
H-07b1	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV
H-07b1	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV
H-07b1	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV

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H-07b1	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	PHENOLICS		0.0420		NA	0.0000			mg/l		03/27/86	1	IT	GC
H-07b1	CULEBRA	PHENOLICS	<	0.0500		NA	0.0000			mg/l		02/25/87	2	IT	GC
H-07b1	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		04/25/88	3	IT	GC
H-07b1	CULEBRA	PHENOLICS		0.0060		NA	0.0000			mg/l		05/19/89	4	IT	GC
H-07b1	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		11/09/90	5	IT	GC
H-07b1	CULEBRA	PHOSPHATE		0.0800		NA	0.0000			mg/l	T-PO4-P	03/27/86	1	IT	GC
H-07b1	CULEBRA	PHOSPHATE		0.0200			0.0200			mg/l	T-PO4-P	02/25/87	2	IT	GC
H-07b1	CULEBRA	PHOSPHATE		0.0300		NA	0.0000			mg/l	T-PO4-P	04/25/88	3	IT	GC
H-07b1	CULEBRA	PHOSPHORUS		0.0400		NA	0.0000			mg/l		05/19/89	4	IT	GC
H-07b1	CULEBRA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		11/09/90	5	IT	GC
H-07b1	CULEBRA	POTASSIUM		7.0000		NA	0.0000			mg/l		03/27/86	1	IT	ME
H-07b1	CULEBRA	POTASSIUM		8.0000		NA	0.0000			mg/l		02/25/87	2	IT	ME
H-07b1	CULEBRA	POTASSIUM		8.2000			8.4000			mg/l		04/25/88	3	IT	ME
H-07b1	CULEBRA	POTASSIUM		7.2000			7.3000			mg/l		05/19/89	4	IT	MC
H-07b1	CULEBRA	POTASSIUM	<	50.0000		<	50.0000			mg/l		11/09/90	5	IT	MC
H-07b1	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		03/27/86	1	IT	SV
H-07b1	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		02/25/87	2	IT	SV
H-07b1	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		04/25/88	3	IT	SV
H-07b1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3400.0000		NA	0.0000			mg/l		03/27/86	1	IT	GC
H-07b1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3500.0000		NA	0.0000			mg/l		02/25/87	2	IT	GC
H-07b1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3400.0000			3200.0000			mg/l		04/25/88	3	IT	GC
H-07b1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3500.0000			3600.0000			mg/l		05/19/89	4	IT	GC
H-07b1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3500.0000		NA	0.0000			mg/l		11/09/90	5	IT	GC
H-07b1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		3.0000		NA	1.0000			mg/l		03/27/86	1	IT	GC
H-07b1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		120.0000		NA	0.0000			mg/l		02/25/87	2	IT	GC
H-07b1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l		04/25/88	3	IT	GC
H-07b1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		13.0000			13.0000			mg/l		05/19/89	4	IT	GC
H-07b1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		NA	0.0000			mg/l		11/09/90	5	IT	GC

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H-07b1	CULEBRA	SELENIUM		0.0060		NA	0.0000	< 0.001	< 0.001	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	SELENIUM		0.0120		NA	0.0000	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< .005	< .005	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	SILICA		43.0000		NA	0.0000	< 0.2	< 0.2	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	SILICA		46.0000		NA	0.0000	< 0.2	< 0.2	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	SILICA		20.0000		NA	0.0000			mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	SILICA		20.0000			20.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	SILICA		23.0000		NA	0.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	SILVER	<	0.1000		<	0.1000	< .01	< .01	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	SODIUM		210.0000		NA	0.0000			mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	SODIUM		210.0000			210.0000			mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	SODIUM		200.0000			200.0000			mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	SODIUM		170.0000			170.0000			mg/l	05/19/89	4	IT	MC
H-07b1	CULEBRA	SODIUM		100.0000			100.0000			mg/l	11/09/90	5	IT	MC
H-07b1	CULEBRA	SPECIFIC CONDUCTANCE		3390.0000		NA	0.0000			umhos/cm@25C	03/27/86	1	IT	GC
H-07b1	CULEBRA	SPECIFIC CONDUCTANCE		4120.0000		NA	0.0000			umhos/cm@25C	02/25/87	2	IT	GC
H-07b1	CULEBRA	SPECIFIC CONDUCTANCE		3970.0000			3980.0000			umhos/cm@25C	04/25/88	3	IT	GC
H-07b1	CULEBRA	SPECIFIC CONDUCTANCE		4510.0000		NA	0.0000			uMhos/cm@25C	05/19/89	4	IT	GC
H-07b1	CULEBRA	SPECIFIC CONDUCTANCE		3760.0000			3760.0000			uMhos/cm@25C	11/09/90	5	IT	GC
H-07b1	CULEBRA	STRONTIUM		5.8000		NA	0.0000	0.01	0.01	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	STRONTIUM		8.7000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	STRONTIUM		8.4000			8.4000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	STRONTIUM		8.2000			8.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	STRONTIUM		8.5000			8.5000	< .01	< .01	mg/l	11/09/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	SULFATE		2300.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	SULFATE		1700.0000		NA	0.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	SULFATE		2000.0000		NA	0.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	SULFATE		1700.0000			1700.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	SULFATE		2100.0000			2100.0000			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	THALLIUM	<	0.1000			0.0000	< .01	< .01	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	TIN	<	0.4000		NA	0.0000	< 0.04	< 0.04	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	TITANIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	TITANIUM		0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	TITANIUM	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< .01	< .01	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000			1.0000			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC CARBON		8.0000			8.0000			mg/l	11/09/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-07b1	CULEBRA	TOTAL ORGANIC HALOGEN		0.2100		NA	0.0000			mg/l	03/27/86	1	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	02/25/87	2	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	04/25/88	3	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	05/19/89	4	IT	GC
H-07b1	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500			0.0600			mg/l	11/09/90	5	IT	GC
H-07b1	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	VANADIUM		0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME
H-07b1	CULEBRA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	VANADIUM		0.1000			0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	VANADIUM	<	0.5000		<	0.5000	< .05	< .05	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	03/27/86	1	IT	V
H-07b1	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	02/25/87	2	IT	V
H-07b1	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/25/88	3	IT	V
H-07b1	CULEBRA	ZINC		0.0200		NA	0.0000	< 0.005	< 0.005	mg/l	03/27/86	1	IT	ME
H-07b1	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/25/87	2	IT	ME

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H-07b1	CULEBRA	ZINC	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	04/25/88	3	IT	ME
H-07b1	CULEBRA	ZINC	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	05/19/89	4	IT	MT
H-07b1	CULEBRA	ZINC	<	0.2000	<		0.2000	< .02	< .02	mg/l	11/09/90	5	IT	MT
H-07b1	CULEBRA	pH		7.5000	NA		0.0000				03/27/86	1	IT	GC
H-07b1	CULEBRA	pH		7.3800			7.3800				02/25/87	2	IT	GC
H-07b1	CULEBRA	pH		6.9500			6.9800				04/25/88	3	IT	GC
H-07b1	CULEBRA	pH		7.0000			7.0000				05/19/89	4	IT	GC
H-07b1	CULEBRA	pH		7.1400			7.1200				11/09/90	5	IT	GC
** H-08b														
H-08b	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,1-DICHLOROETHANE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	SV

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H-08b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	1,2-DICHLOROETHANE		2.5000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV

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H-08b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP. ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-08b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000		ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		ug/l	06/08/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-08b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	ACETONE	<	20.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	ALKALINITY (HCO3)		94.0000		NA	0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	ALKALINITY (HCO3)		96.0000			98.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	ALKALINITY (HCO3)		95.0000			94.0000			mg/l	06/08/88	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-08b	CULEBRA	ALUMINUM	<	0.0100		<	0.0100	< 0.01	0.02	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	ALUMINUM	<	0.1000		<	0.1000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	ANTIMONY	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	ANTIMONY	<	0.2000		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	ARSENIC		0.0020		<	0.0010	< 0.001	< 0.001	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	ARSENIC	<	0.0200		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	BARIUM		0.0110			0.0110			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-08b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		1.1000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BORON		0.0600		NA	0.0000	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	BORON		0.5000		NA	0.0000	< 0.01	< 0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	BORON		0.5800			0.5700			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	BROMIDE	<	1.0000		NA	0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	BROMIDE	<	2.0000		NA	0.0000			mg/l	02/11/87	2	IT	GC

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H-08b	CULEBRA	BROMIDE	<	2.0000	<	2.0000				mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	BROMOFORM	<	1.0000	NA	0.0000				ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	BROMOFORM	<	5.0000	NA	0.0000				ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	BROMOFORM	<	5.0000	NA	0.0000			T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000	NA	0.0000				ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	CADMIUM	<	0.0500	NA	0.0000	< 0.005		< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	CADMIUM	<	0.0030	NA	0.0000				mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	CALCIUM		540.0000		540.0000	< 0.1		< 0.1	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	CALCIUM		560.0000		560.0000				mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	CALCIUM		610.0000		600.0000				mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	CARBON DISULFIDE	<	1.0000	NA	1.0000				ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	CARBON DISULFIDE	<	5.0000	NA	0.0000				ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	CARBON DISULFIDE	<	5.0000	NA	0.0000			T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	CARBON TETRACHLORIDE	<	1.0000	NA	1.0000				ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000	NA	0.0000				ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000	NA	0.0000			T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	CESIUM	<	1.0000	<	1.0000	< 0.10		< 0.10	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	CESIUM		0.2000	NA	0.0000	< 0.1		< 0.1	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	CESIUM	<	0.2400	NA	0.0000				mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	CHLORIDE		33.0000		33.0000				mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	CHLORIDE		36.0000	NA	0.0000				mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	CHLORIDE		33.0000	NA	0.0000				mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	CHLOROBENZENE	<	1.0000	NA	0.0000				ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000				ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	CHLOROETHANE	<	1.0000	NA	0.0000				ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000				ug/l	02/11/87	2	IT	V

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H-08b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	CHROMIUM		0.0100			0.0100	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	CHROMIUM	<	0.1000		NA	0.0000	0.02	0.02	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	CHROMIUM		0.0050		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	COBALT		0.0800			0.0700	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	COBALT	<	0.0070		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	COPPER		0.0200			0.0200	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	COPPER	<	0.1000		NA	0.0000	0.02	0.02	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	COPPER		0.1100		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	CYANIDE		0.1000		NA	0.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-08b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0		ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0		ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	DICHLORODIFLUOROMETHANE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0		ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	Eh		456.0000		NA	0.0000			mV	01/22/86	1	IT	GC
H-08b	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	FLUORIDE		2.4000			2.5000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	FLUORIDE		2.4000		NA	0.0000			mg/l	02/11/87	2	IT	GC

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H-08b	CULEBRA	FLUORIDE		0.2000		NA	0.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	IRON		0.0500			0.0500	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	IRON	<	0.1000		NA	0.0000	0.01	< 0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	IRON		0.0500			0.0500			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	LEAD		0.0600			0.0600	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	LEAD	<	0.0300		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	LITHIUM		0.1200		NA	0.0000	< 0.01	< 0.01	mg/l	02/11/87	2	IT	ME

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H-08b	CULEBRA	LITHIUM		0.1200		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	MAGNESIUM		170.0000			170.0000	< 0.1	< 0.1	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	MAGNESIUM		160.0000			160.0000			mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	MAGNESIUM		170.0000			160.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	MANGANESE	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	MANGANESE	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	MANGANESE	<	0.0050		<	0.0050			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	MERCURY		0.0002			0.0002			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	MOLYBDENUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	MOLYBDENUM		0.0200		NA	0.0000	0.02	0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	MOLYBDENUM		0.0080		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	SV

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H-08b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		02/11/87	2	IT	SV
H-08b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		06/08/88	3	IT	SV
H-08b	CULEBRA	NICKEL		0.0300			0.0300	< 0.01	< 0.01	mg/l		01/22/86	1	IT	ME
H-08b	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		02/11/87	2	IT	ME
H-08b	CULEBRA	NICKEL		0.0300		NA	0.0000			mg/l		06/08/88	3	IT	ME
H-08b	CULEBRA	NITRATE		1.4000		NA	0.0000			mg/l	NO3-N	01/22/86	1	IT	GC
H-08b	CULEBRA	NITRATE		1.4000		NA	0.0000			mg/l	NO3-N	02/11/87	2	IT	GC
H-08b	CULEBRA	NITRATE		0.9000		NA	0.0000			mg/l	NO3-N	06/08/88	3	IT	GC
H-08b	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		01/22/86	1	IT	SV
H-08b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		02/11/87	2	IT	SV
H-08b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		06/08/88	3	IT	SV
H-08b	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		01/22/86	1	IT	SV
H-08b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		02/11/87	2	IT	SV
H-08b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		06/08/88	3	IT	SV
H-08b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		02/11/87	2	IT	PC
H-08b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		06/08/88	3	IT	PC
H-08b	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		01/22/86	1	IT	SV
H-08b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		02/11/87	2	IT	SV
H-08b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		06/08/88	3	IT	SV
H-08b	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		01/22/86	1	IT	SV
H-08b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		02/11/87	2	IT	SV
H-08b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		06/08/88	3	IT	SV
H-08b	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		01/22/86	1	IT	SV
H-08b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		02/11/87	2	IT	SV
H-08b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		06/08/88	3	IT	SV
H-08b	CULEBRA	PHENOLICS		0.0120			0.0900			mg/l		01/22/86	1	IT	GC
H-08b	CULEBRA	PHENOLICS	<	0.0500		NA	0.0000			mg/l		02/11/87	2	IT	GC
H-08b	CULEBRA	PHENOLICS		0.1650		NA	0.0000			mg/l		06/08/88	3	IT	GC
H-08b	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	01/22/86	1	IT	GC

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H-08b	CULEBRA	PHOSPHATE	<	0.0100	<		0.0100			mg/l T-PO4-P	02/11/87	2	IT	GC
H-08b	CULEBRA	PHOSPHATE		0.0200	NA		0.0000			mg/l T-PO4-P	06/08/88	3	IT	GC
H-08b	CULEBRA	POTASSIUM		3.7000			3.7000	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	POTASSIUM		4.0000			4.1000			mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	POTASSIUM		4.4000			4.5000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	PYRENE	<	1.0000	NA		0.0000			ug/l	01/22/86	1	IT	SV
H-08b	CULEBRA	PYRENE	<	10.0000	NA		0.0000			ug/l	02/11/87	2	IT	SV
H-08b	CULEBRA	PYRENE	<	10.0000	NA		0.0000			ug/l	06/08/88	3	IT	SV
H-08b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3100.0000			3200.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3100.0000			3100.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		2900.0000			2900.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		18.0000	NA		0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		12.0000			14.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000	<		4.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	SELENIUM	<	0.0010	<		0.0010	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	SELENIUM	<	0.5000	NA		0.0000	< 0.005	< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	SELENIUM	<	0.0400	NA		0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	SILICA		26.0000			25.0000	< 0.2	< 0.2	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	SILICA		27.0000	NA		0.0000	< 0.2	< 0.2	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	SILICA		11.0000	NA		0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	SILVER	<	0.1000	NA		0.0000	0.01	0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	SILVER	<	0.0200	NA		0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	SODIUM		51.0000			51.0000	< 0.1	< 0.1	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	SODIUM		55.0000			54.0000			mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	SODIUM		55.0000			55.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	SPECIFIC CONDUCTANCE		3270.0000	NA		0.0000			umhos/cm@25C	01/22/86	1	IT	GC
H-08b	CULEBRA	SPECIFIC CONDUCTANCE		3160.0000			3110.0000			umhos/cm@25C	02/11/87	2	IT	GC
H-08b	CULEBRA	SPECIFIC CONDUCTANCE		3150.0000			3140.0000			umhos/cm@25C	06/08/88	3	IT	GC
H-08b	CULEBRA	STRONTIUM		5.9000			5.9000	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-08b	CULEBRA	STRONTIUM		7.4000		NA	0.0000	< 0.01	< 0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	STRONTIUM		4.1000			4.2000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	SULFATE		1700.0000			1600.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	SULFATE		1700.0000		NA	0.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	SULFATE		1900.0000		NA	0.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	THALLIUM	<	0.0500		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	TITANIUM	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	TITANIUM	<	0.0070		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	TOTAL ORGANIC CARBON		14.0000		NA	0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		NA	0.0000			mg/l	01/22/86	1	IT	GC
H-08b	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		NA	0.0000			mg/l	02/11/87	2	IT	GC
H-08b	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	06/08/88	3	IT	GC
H-08b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V

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H-08b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	VANADIUM		0.0400			0.0400			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	01/22/86	1	IT	V
H-08b	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	02/11/87	2	IT	V
H-08b	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/08/88	3	IT	V
H-08b	CULEBRA	ZINC		0.0200			0.0200	< 0.01	< 0.01	mg/l	01/22/86	1	IT	ME
H-08b	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/11/87	2	IT	ME
H-08b	CULEBRA	ZINC		0.2400		NA	0.0000			mg/l	06/08/88	3	IT	ME
H-08b	CULEBRA	pH		7.9000		NA	0.0000				01/22/86	1	IT	GC
H-08b	CULEBRA	pH		7.4500			7.4600				02/11/87	2	IT	GC
H-08b	CULEBRA	pH		7.1500			7.1400				06/08/88	3	IT	GC
** H-09b														
H-09b	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V

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H-09b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V

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H-09b	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	1,3-DICHLOROBENZENE		20.0000		NA	0.0000		13 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV

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H-09b	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2-BUTANONE		46.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000		< 20 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	ACETONE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	ALKALINITY (HCO3)		120.0000			120.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	ALKALINITY (HCO3)		120.0000			120.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	ALKALINITY (HCO3)		120.0000			120.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	ALKALINITY (HCO3)		120.0000			0.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	ALUMINUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	ALUMINUM	<	0.2000		<	0.2000	< .2	< .2	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV

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H-09b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	ANTIMONY	<	0.5000		NA	0.0000	< 0.5	< 0.05	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	ANTIMONY		0.0800			0.1300	< 0.05	< 0.05	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	ANTIMONY		0.0900			0.1200	< .06	< .06	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	AROCLOR 1016	<	0.5000		NA	0.0000		< .5 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	AROCLOR 1221	<	0.5000		NA	0.0000		< .5 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	AROCLOR 1232	<	0.5000		NA	0.0000		< .5 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	AROCLOR 1242	<	0.5000		NA	0.0000		< .5 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	AROCLOR 1248	<	0.5000		NA	0.0000		< .5 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	AROCLOR 1254	<	1.0000		NA	0.0000		<1.0 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	AROCLOR 1260	<	1.0000		NA	0.0000		<1.0 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	ARSENIC	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	ARSENIC	<	0.0100		NA	0.0000	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	BARIUM	<	0.2000		<	0.2000	< .2	< .2	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	BENZENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV

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H-09b	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000		< 50 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	BERYLLIUM	<	0.0050		<	0.0500	< .005	< .005	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	BORON	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	BORON		0.7000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	BORON		0.7000			0.7000	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	BORON		0.6000			0.5300	< .02	< .02	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	BROMIDE		1.0000			1.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	BROMIDE	<	1.0000		<	1.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	BROMIDE	<	2.0000		NA	0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	BROMIDE	<	2.0000		<	2.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	CADMIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME

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H-09b	CULEBRA	CADMIUM	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	CADMIUM		0.0090			0.0140	< .005	< .005	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	CALCIUM		560.0000			560.0000	< 0.1	< 0.1	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	CALCIUM		630.0000			630.0000			mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	CALCIUM		690.0000			600.0000			mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	CALCIUM		650.0000			580.0000			mg/l	01/19/90	4	IT	MC
H-09b	CULEBRA	CARBON DISULFIDE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	CARBON DISULFIDE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	CARBON DISULFIDE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	CARBON DISULFIDE	<	5.0000	NA		0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	CARBON TETRACHLORIDE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	CARBON TETRACHLORIDE	<	5.0000	NA		0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	CESIUM		0.2000			0.2000	0.1	0.2	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	CESIUM	<	0.1000	NA		0.0000	< 0.1	< 0.1	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	CESIUM		0.0300			0.0300	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	CESIUM	<	0.2000	<		0.2000	< .2	< .2	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	CHLORIDE		200.0000	NA		0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	CHLORIDE		190.0000			190.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	CHLORIDE		180.0000	NA		0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	CHLORIDE		160.0000			160.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	CHLOROBENZENE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	CHLOROBENZENE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	CHLOROBENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	CHLOROBENZENE	<	5.0000	NA		0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	CHLOROETHANE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	CHLOROETHANE	<	10.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	CHLOROETHANE	<	10.0000	NA		0.0000		T < 10	ug/l	06/21/88	3	IT	V

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H-09b	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	CHROMIUM		0.0400			0.0600	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	CHROMIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	CHROMIUM		0.0400			0.0400	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	CHROMIUM		0.0200			0.0400	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	COBALT		0.1100			0.1200	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	COBALT	<	0.0100			0.0200	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	COBALT	<	0.0500		<	0.0500	< .05	< .05	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	COPPER		0.0300			0.0300	0.02	0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	COPPER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	COPPER	<	0.0250		<	0.0250	< .025	< .025	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	CYANIDE		0.2400		NA	0.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV

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H-09b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV

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H-09b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	Eh		452.0000		NA	0.0000			mV	11/14/85	1	IT	GC
H-09b	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	FLUORENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	FLUORIDE		2.6000		NA	0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	FLUORIDE		3.2000		NA	0.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	FLUORIDE		3.1000		NA	0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	FLUORIDE		3.5000		NA	0.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	FREON-113	<	50.0000		NA	0.0000	< 50 T	< 50 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	IODIDE	<	1.0000		<	1.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	IRON	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	IRON	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	IRON		0.1200			0.1000	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	IRON	<	0.1000		<	0.1000	< .1	< .1	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	11/14/85	1	IT	SV
H-09b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	SV
H-09b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	06/21/88	3	IT	SV
H-09b	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	LEAD		0.1200			0.1300	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	LEAD	<	0.0500			0.0600	< 0.05	< 0.05	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	LEAD		0.0600			0.1100	< .05	< .05	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	LITHIUM		0.1700		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	LITHIUM		0.2000			0.1900	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	LITHIUM		0.2000			0.2000	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	MAGNESIUM		140.0000			140.0000	< 0.1	< 0.1	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	MAGNESIUM		150.0000			150.0000			mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	MAGNESIUM		140.0000			120.0000			mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	MAGNESIUM		160.0000			130.0000			mg/l	01/19/90	4	IT	MC
H-09b	CULEBRA	MANGANESE		0.0600			0.0600	0.03	0.03	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	MANGANESE	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	MANGANESE		0.0180			0.0190	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	MANGANESE		0.2100			0.0330	< .015	< .015	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	MERCURY		0.0041		NA	0.0000	0.0003	< 0.0002	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	MERCURY		0.0002		<	0.0002	0.0002	< 0.0002	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	MERCURY	<	0.0002		<	0.0002	< .0002	< .0002	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T 5.8	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	METHYLENE CHLORIDE	<	6.0000		NA	0.0000	15 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	MOLYBDENUM		0.0400			0.0200	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	MOLYBDENUM		0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	MOLYBDENUM		0.0500			0.0500	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	MOLYBDENUM		0.0500			0.0500	< .02	< .02	mg/l	01/19/90	4	IT	MT

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H-09b	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	NICKEL		0.1300			0.1200	< 0.01	< 0.01	mg/l		11/14/85	1	IT	ME
H-09b	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		01/28/87	2	IT	ME
H-09b	CULEBRA	NICKEL	<	0.0300			0.0300	< 0.03	< 0.03	mg/l		06/21/88	3	IT	ME
H-09b	CULEBRA	NICKEL	<	0.0400		<	0.0400	< .04	< .04	mg/l		01/19/90	4	IT	MT
H-09b	CULEBRA	NITRATE		0.2000		NA	0.0000			mg/l	NO3-N	11/14/85	1	IT	GC
H-09b	CULEBRA	NITRATE		0.5000			0.4000			mg/l	NO3-N	01/28/87	2	IT	GC
H-09b	CULEBRA	NITRATE		0.1100			0.1200			mg/l	NO3-N	06/21/88	3	IT	GC
H-09b	CULEBRA	NITRATE		0.1100			0.1100			mg/l		01/19/90	4	IT	GC
H-09b	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV

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H-09b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		01/28/87	2	IT	PC
H-09b	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		06/21/88	3	IT	PC
H-09b	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000		< 50 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV
H-09b	CULEBRA	PHENOL	<	10.0000		NA	0.0000		< 10 M	ug/l		01/19/90	4	IT	SV
H-09b	CULEBRA	PHENOLICS		0.0160		NA	0.0000			mg/l		11/14/85	1	IT	GC
H-09b	CULEBRA	PHENOLICS	<	0.0500		NA	0.0000			mg/l		01/28/87	2	IT	GC
H-09b	CULEBRA	PHENOLICS	<	0.0100		NA	0.0000			mg/l		06/21/88	3	IT	GC
H-09b	CULEBRA	PHENOLICS		0.0060		NA	0.0000			mg/l		01/19/90	4	IT	GC
H-09b	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	11/14/85	1	IT	GC
H-09b	CULEBRA	PHOSPHATE		0.0100		<	0.0100			mg/l	T-PO4-P	01/28/87	2	IT	GC
H-09b	CULEBRA	PHOSPHATE		0.0200			0.0300			mg/l	T-PO4-P	06/21/88	3	IT	GC
H-09b	CULEBRA	PHOSPHORUS	<	0.0100		<	0.0100			mg/l		01/19/90	4	IT	GC
H-09b	CULEBRA	POTASSIUM		7.7000			7.4000	< 0.01	< 0.01	mg/l		11/14/85	1	IT	ME
H-09b	CULEBRA	POTASSIUM		7.0000			7.0000			mg/l		01/28/87	2	IT	ME
H-09b	CULEBRA	POTASSIUM		8.2000			7.9000			mg/l		06/21/88	3	IT	ME
H-09b	CULEBRA	POTASSIUM		8.3000			8.2000			mg/l		01/19/90	4	IT	MC
H-09b	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		11/14/85	1	IT	SV
H-09b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		01/28/87	2	IT	SV
H-09b	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		06/21/88	3	IT	SV

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H-09b	CULEBRA	PYRENE	<	10.0000		NA	0.0000		< 10 M	ug/l	01/19/90	4	IT	SV
H-09b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3300.0000			3300.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3300.0000			3300.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3100.0000			3100.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3300.0000			3300.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		9.0000		NA	0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		10.0000			6.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	SELENIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	SELENIUM		0.0120		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< .005	< .005	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	SILICA		18.0000			19.0000	0.23	2.6	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	SILICA		30.0000		NA	0.0000	< 0.2	< 0.2	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	SILICA		12.0000			13.0000			mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	SILICA		12.0000			12.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	SILVER	<	0.0100			0.0100	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	SILVER		0.0200			0.0300	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	SODIUM		150.0000			150.0000	< 0.1	< 0.1	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	SODIUM		150.0000			160.0000			mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	SODIUM		140.0000			140.0000			mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	SODIUM		100.0000			100.0000			mg/l	01/19/90	4	IT	MC
H-09b	CULEBRA	SODIUM		100.0000			100.0000			mg/l	01/19/90	4	IT	MC
H-09b	CULEBRA	SPECIFIC CONDUCTANCE		3860.0000		NA	0.0000			umhos/cm@25C	11/14/85	1	IT	GC
H-09b	CULEBRA	SPECIFIC CONDUCTANCE		4900.0000		NA	0.0000			umhos/cm@25C	01/28/87	2	IT	GC
H-09b	CULEBRA	SPECIFIC CONDUCTANCE		3420.0000			3460.0000			umhos/cm@25C	06/21/88	3	IT	GC
H-09b	CULEBRA	SPECIFIC CONDUCTANCE		3590.0000			3590.0000			umhos/cm@25C	01/19/90	4	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-09b	CULEBRA	STRONTIUM		7.2000			6.9000	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	STRONTIUM		7.2000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	STRONTIUM		8.0000			8.1000	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	STRONTIUM		7.5000			6.4000	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	STYRENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	SULFATE		1600.0000			1300.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	SULFATE		1700.0000		NA	0.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	SULFATE		1600.0000		NA	0.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	SULFATE		1800.0000			1900.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	THALLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	THALLIUM	<	10.0000		NA	0.0000	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	TITANIUM		0.0600			0.0600	< 0.01	0.04	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	TITANIUM	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	TITANIUM		0.1300			0.1100	0.01	0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	TITANIUM		0.0100		<	0.0100	< .01	< .01	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	TOTAL ORGANIC CARBON		3.0000		NA	0.0000			mg/l	01/28/87	2	IT	GC

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H-09b	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000	<		1.0000			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	TOTAL ORGANIC CARBON		1.0000	<		1.0000			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	TOTAL ORGANIC HALOGEN		0.2200	NA		0.0000			mg/l	11/14/85	1	IT	GC
H-09b	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500	NA		0.0000			mg/l	01/28/87	2	IT	GC
H-09b	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	06/21/88	3	IT	GC
H-09b	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	01/19/90	4	IT	GC
H-09b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	TRICHLOROETHYLENE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	VANADIUM		0.0300			0.0500	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	VANADIUM	<	0.0500	<		0.0500	< .05	< .05	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	01/28/87	2	IT	V
H-09b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000	< 10 T	< 10 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	XYLENE	<	1.0000	NA		0.0000			ug/l	11/14/85	1	IT	V
H-09b	CULEBRA	XYLENE	<	5.0000	NA		0.0000			ug/l	01/28/87	2	IT	V

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H-09b	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/21/88	3	IT	V
H-09b	CULEBRA	XYLENE	<	5.0000		NA	0.0000	< 5 T	< 5 M	ug/l	01/19/90	4	IT	V
H-09b	CULEBRA	ZINC		0.0200			0.0200	< 0.01	< 0.01	mg/l	11/14/85	1	IT	ME
H-09b	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/28/87	2	IT	ME
H-09b	CULEBRA	ZINC	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/21/88	3	IT	ME
H-09b	CULEBRA	ZINC	<	0.0200		<	0.0200	< .02	< .02	mg/l	01/19/90	4	IT	MT
H-09b	CULEBRA	pH		7.5000			7.9800				11/14/85	1	IT	GC
H-09b	CULEBRA	pH		7.4400			7.4600				01/28/87	2	IT	GC
H-09b	CULEBRA	pH		7.0300			7.0800				06/21/88	3	IT	GC
H-09b	CULEBRA	pH		7.4100			7.4200				01/19/90	4	IT	GC
** H-11b3														
H-11b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV

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H-11b3	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV

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H-11b3	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-11b3	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV

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H-11b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	4-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	ACETONE		16.0000		NA	0.0000		T 19	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	10/17/90	5	IT	GC

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H-11b3	CULEBRA	ALKALINITY (HCO3)		52.0000			54.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	ALKALINITY (HCO3)		52.0000		NA	0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	ALKALINITY (HCO3)		54.0000		NA	0.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	ALKALINITY (HCO3)		44.0000			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	ALUMINUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	ALUMINUM	<	2.0000		<	2.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	ANTIMONY		0.9000			0.9000	< 0.05	< 0.05	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	ANTIMONY	<	0.6000		<	0.6000	< 0.06	< 0.06	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	ANTIMONY	<	0.6000		<	0.6000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	ARSENIC		0.1500			0.1500	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	ARSENIC		0.0400			0.0400	< 0.001	< 0.001	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	ARSENIC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	ARSENIC	<	0.1000		NA	0.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	BARIUM		0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	BARIUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	BARIUM	<	2.0000		<	2.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-11b3	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BERYLLIUM		0.0010			0.0010	0.001	0.001	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV

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H-11b3	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		97.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		12.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	4.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BORON		13.0000		NA	0.0000	< 0.10	< 0.10	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	BORON		30.0000		NA	0.0000	0.03	0.03	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	BORON		30.0000			30.0000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	BORON		30.0000			30.0000	< 0.02	< 0.02	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	BORON		31.0000			31.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	BROMIDE		100.0000			100.0000			mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	BROMIDE		48.0000		NA	0.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	BROMIDE		52.0000		NA	0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	BROMIDE		21.0000			17.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	BROMIDE		51.0000		NA	0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	CADMIUM		0.0500			0.0600	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	CADMIUM		0.0900			0.0900	< 0.005	0.006	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	CADMIUM		0.0600			0.0600			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	CALCIUM		1400.0000		NA	0.0000			mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	CALCIUM		1370.0000			1350.0000			mg/l	09/15/87	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-11b3	CULEBRA	CALCIUM		1500.0000			1500.0000			mg/l	10/25/89	4	IT	MC
H-11b3	CULEBRA	CALCIUM		1500.0000			1500.0000			mg/l	10/17/90	5	IT	MC
H-11b3	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	CESIUM		0.3000			0.2800	0.03	0.04	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	CESIUM		0.5000		NA	0.0000	0.2	0.2	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	CESIUM		0.5600			0.5300	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	CESIUM	<	0.1000		<	0.1000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	CHLORIDE		65000.0000			65000.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	CHLORIDE		63000.0000			64000.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	CHLORIDE		73400.0000		NA	0.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	CHLORIDE		56000.0000			56000.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	CHROMIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	CHROMIUM		0.3200		NA	0.0000	< 0.01	< 0.01	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	CHROMIUM		0.3000			0.4000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-11b3	CULEBRA	CHROMIUM		0.4000			0.4000	0.02	0.04	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	CHROMIUM		0.4000			0.4000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	COBALT		0.0300		NA	0.0000	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	COBALT	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	COBALT	<	0.5000		<	0.5000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	COPPER		0.2600			0.2500	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	COPPER		0.1600		NA	0.0000	< 0.01	0.01	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	COPPER		0.1000			0.1000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	COPPER	<	0.2500		<	0.2500	< 0.025	< 0.025	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	COPPER	<	0.2500		<	0.2500			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	CYANIDE		0.1500		NA	0.0000			mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	CYANIDE	<	0.0400		NA	0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	CYANIDE	<	0.0100			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV

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H-11b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	DICHLORODIFLUOROMETHANE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	Eh		501.0000		NA	0.0000			mV	06/04/85	1	IT	GC
H-11b3	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	FLUORIDE		1.0000			1.0000			mg/l	06/04/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-11b3	CULEBRA	FLUORIDE		1.2000			1.2000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	FLUORIDE		1.0000		NA	0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	FLUORIDE		1.1000			1.2000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	FLUORIDE		1.1000			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	IODIDE		1.1000		NA	0.0000			mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	IODIDE		0.4800		NA	0.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	IRON		0.7100			0.6100	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	IRON	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	IRON		0.3000			0.3000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	IRON	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	IRON	<	1.0000		<	1.0000			mg/l	10/17/90	5	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-11b3	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	LEAD		0.1900		NA	0.0000	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	LEAD		0.5200		NA	0.0000	< 0.05	< 0.05	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	LEAD		0.5000			0.5000	< 0.05	0.06	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	LEAD		0.6000			0.6000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	LITHIUM		9.5000			9.5000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	LITHIUM		0.6000			0.6000	< 0.01	< 0.01	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	LITHIUM		0.5000			0.5000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	MAGNESIUM		1100.0000		NA	0.0000			mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	MAGNESIUM		1080.0000			1070.0000			mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	MAGNESIUM		1200.0000			1200.0000			mg/l	10/25/89	4	IT	MC
H-11b3	CULEBRA	MAGNESIUM		1100.0000			1100.0000			mg/l	10/17/90	5	IT	MC
H-11b3	CULEBRA	MANGANESE		0.3900			0.3900	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	MANGANESE		0.2200		NA	0.0000	< 0.005	< 0.005	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	MANGANESE		0.2300			0.2300	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	MANGANESE		0.2300			0.2300	< 0.015	< 0.015	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	MANGANESE		0.2200			0.2300			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	MERCURY	<	0.0004		<	0.0004	< 0.0002	< 0.0002	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	MERCURY	<	0.0002		<	0.0002			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V

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H-11b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	V
H-11b3	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		09/15/87	3	IT	V
H-11b3	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l		06/04/85	1	IT	V
H-11b3	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	V
H-11b3	CULEBRA	METHYLENE CHLORIDE		8.0000		NA	0.0000		T < 5.0	ug/l		09/15/87	3	IT	V
H-11b3	CULEBRA	MOLYBDENUM		0.0320		NA	0.0000	< 0.001	< 0.001	mg/l		06/04/85	1	IT	ME
H-11b3	CULEBRA	MOLYBDENUM		0.2500		NA	0.0000	< 0.01	0.01	mg/l		06/04/86	2	IT	ME
H-11b3	CULEBRA	MOLYBDENUM		0.2600			0.2600	< 0.01	< 0.01	mg/l		09/15/87	3	IT	ME
H-11b3	CULEBRA	MOLYBDENUM		0.2000			0.2000	< 0.02	< 0.02	mg/l		10/25/89	4	IT	MT
H-11b3	CULEBRA	MOLYBDENUM		0.3000			0.3000			mg/l		10/17/90	5	IT	MT
H-11b3	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	NICKEL		1.1000			1.1000	< 0.01	< 0.01	mg/l		06/04/85	1	IT	ME
H-11b3	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		06/04/86	2	IT	ME
H-11b3	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		09/15/87	3	IT	ME
H-11b3	CULEBRA	NICKEL	<	0.4000		<	0.4000	< 0.04	< 0.04	mg/l		10/25/89	4	IT	MT
H-11b3	CULEBRA	NICKEL	<	0.4000		<	0.4000			mg/l		10/17/90	5	IT	MT
H-11b3	CULEBRA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	06/04/85	1	IT	GC
H-11b3	CULEBRA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	06/04/86	2	IT	GC
H-11b3	CULEBRA	NITRATE	<	0.3000		NA	0.0000			mg/l	NO3-N	09/15/87	3	IT	GC
H-11b3	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l		10/25/89	4	IT	GC
H-11b3	CULEBRA	NITRATE	<	0.0200			0.0000			mg/l		10/17/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-11b3	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		06/04/86	2	IT	PC
H-11b3	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		09/15/87	3	IT	PC
H-11b3	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		06/04/86	2	IT	SV
H-11b3	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		06/04/85	1	IT	SV
H-11b3	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		09/15/87	3	IT	SV
H-11b3	CULEBRA	PHENOLICS		0.0090		NA	0.0000			mg/l		06/04/85	1	IT	GC
H-11b3	CULEBRA	PHENOLICS	<	0.0020			0.0060			mg/l		06/04/86	2	IT	GC
H-11b3	CULEBRA	PHENOLICS		0.0200		NA	0.0000			mg/l		09/15/87	3	IT	GC
H-11b3	CULEBRA	PHENOLICS		0.0100		NA	0.0000			mg/l		10/25/89	4	IT	GC
H-11b3	CULEBRA	PHENOLICS	<	0.0050			0.0000			mg/l		10/17/90	5	IT	GC
H-11b3	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	06/04/85	1	IT	GC
H-11b3	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	06/04/86	2	IT	GC
H-11b3	CULEBRA	PHOSPHATE		0.0100		NA	0.0000			mg/l	T-PO4-P	09/15/87	3	IT	GC
H-11b3	CULEBRA	PHOSPHORUS		0.0400		NA	0.0000			mg/l		10/25/89	4	IT	GC
H-11b3	CULEBRA	PHOSPHORUS	<	0.0100			0.0000			mg/l		10/17/90	5	IT	GC
H-11b3	CULEBRA	POTASSIUM		720.0000		NA	0.0000			mg/l		06/04/86	2	IT	ME
H-11b3	CULEBRA	POTASSIUM		980.0000			990.0000			mg/l		09/15/87	3	IT	ME
H-11b3	CULEBRA	POTASSIUM		780.0000			800.0000			mg/l		10/25/89	4	IT	MC

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H-11b3	CULEBRA	POTASSIUM		680.0000			670.0000			mg/l	10/17/90	5	IT	MC
H-11b3	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	SV
H-11b3	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	SV
H-11b3	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	09/15/87	3	IT	SV
H-11b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		122000.0000		NA	0.0000			mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		121000.0000			121000.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		120000.0000		NA	0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		116000.0000			116000.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	RESIDUE, FILTERABLE @ 180 C		113000.0000			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		220.0000		NA	0.0000			mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		170.0000			170.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		130.0000			110.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		40.0000			39.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		640.0000			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	SELENIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	SELENIUM	<	0.1000		<	0.1000	0.001	0.001	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	SELENIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	SELENIUM	<	0.0500		NA	0.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	SILICA		15.0000			15.0000	< 0.2	0.51	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	SILICA		150.0000		NA	0.0000	0.45	0.47	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	SILICA		12.0000			12.0000	< 0.2	< 0.2	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	SILICA		4.7000			4.5000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	SILICA		4.1000			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	SILVER		0.2000			0.2000	0.01	0.02	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	SILVER		0.1000			0.1000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	SODIUM		38000.0000		NA	0.0000			mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	SODIUM		44000.0000			43000.0000			mg/l	09/15/87	3	IT	ME

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H-11b3	CULEBRA	SODIUM		35000.0000			34000.0000			mg/l	10/25/89	4	IT	MC
H-11b3	CULEBRA	SODIUM		40000.0000			41000.0000			mg/l	10/17/90	5	IT	MC
H-11b3	CULEBRA	SPECIFIC CONDUCTANCE		135000.0000		NA	0.0000			umhos/cm@25C	06/04/85	1	IT	GC
H-11b3	CULEBRA	SPECIFIC CONDUCTANCE		126000.0000		NA	0.0000			umhos/cm@25C	06/04/86	2	IT	GC
H-11b3	CULEBRA	SPECIFIC CONDUCTANCE		193000.0000			194000.0000			umhos/cm@25C	09/15/87	3	IT	GC
H-11b3	CULEBRA	SPECIFIC CONDUCTANCE		126000.0000			126000.0000			uMhos/cm@25C	10/25/89	4	IT	GC
H-11b3	CULEBRA	SPECIFIC CONDUCTANCE		112000.0000			112000.0000			uMhos/cm@25C	10/17/90	5	IT	GC
H-11b3	CULEBRA	STRONTIUM		18.0000			18.0000	0.02	0.02	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	STRONTIUM		18.0000		NA	0.0000	0.04	0.05	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	STRONTIUM		32.0000			32.0000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	STRONTIUM		23.0000			24.0000	< 0.01	< 0.01	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	STRONTIUM		21.0000			21.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	SULFATE		6100.0000			6100.0000			mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	SULFATE		6200.0000		NA	0.0000			mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	SULFATE		6200.0000		NA	0.0000			mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	SULFATE		7400.0000			0.0000			mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	THALLIUM	<	10.0000		NA	0.0000	< 0.01	< 0.01	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	THALLIUM	<	10.0000		NA	0.0000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	TIN		0.6000			0.7000	< 0.04	< 0.04	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	TITANIUM		0.0200			0.0400	< 0.01	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	TITANIUM		0.6900		NA	0.0000	< 0.03	< 0.03	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	TITANIUM		0.5000			0.5000	< 0.03	< 0.03	mg/l	09/15/87	3	IT	ME

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H-11b3	CULEBRA	TITANIUM	<	0.1000	<	0.1000	< 0.01		< 0.01	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	TITANIUM		0.1000		0.1000				mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	TOLUENE	<	1.0000	NA	0.0000				ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	TOLUENE	<	5.0000	NA	0.0000				ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	TOLUENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	TOTAL ORGANIC CARBON		2.0000	NA	0.0000				mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000	NA	0.0000				mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC CARBON		2.0000	<	1.0000				mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000	<	1.0000				mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC CARBON		3.0000		2.0000				mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC HALOGEN		1.5000	NA	0.0000				mg/l	06/04/85	1	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.8800	NA	0.0000				mg/l	06/04/86	2	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC HALOGEN		11.0000		15.0000				mg/l	09/15/87	3	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.3700		0.3500				mg/l	10/25/89	4	IT	GC
H-11b3	CULEBRA	TOTAL ORGANIC HALOGEN		0.0600	<	0.0500				mg/l	10/17/90	5	IT	GC
H-11b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000	NA	0.0000				ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA	0.0000				ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000				ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	TRICHLOROETHYLENE	<	1.0000	NA	0.0000				ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA	0.0000				ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000	NA	0.0000				ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	VANADIUM		0.2000		0.2000	< 0.01		< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	VANADIUM	<	0.5000	<	0.5000	< 0.05		< 0.05	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	VANADIUM	<	0.5000	<	0.5000				mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	VINYL ACETATE	<	10.0000	NA	0.0000				ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	VINYL ACETATE	<	10.0000	NA	0.0000				ug/l	06/04/86	2	IT	V

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H-11b3	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	06/04/85	1	IT	V
H-11b3	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	06/04/86	2	IT	V
H-11b3	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	09/15/87	3	IT	V
H-11b3	CULEBRA	ZINC		0.0700			0.0600	0.02	< 0.01	mg/l	06/04/85	1	IT	ME
H-11b3	CULEBRA	ZINC		0.1400		NA	0.0000	< 0.01	< 0.01	mg/l	06/04/86	2	IT	ME
H-11b3	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	09/15/87	3	IT	ME
H-11b3	CULEBRA	ZINC	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	10/25/89	4	IT	MT
H-11b3	CULEBRA	ZINC	<	0.2000		<	0.2000			mg/l	10/17/90	5	IT	MT
H-11b3	CULEBRA	pH		7.1800		NA	0.0000				06/04/85	1	IT	GC
H-11b3	CULEBRA	pH		7.1800			7.2100				06/04/86	2	IT	GC
H-11b3	CULEBRA	pH		6.8700			6.9700				09/15/87	3	IT	GC
H-11b3	CULEBRA	pH		7.0700			7.0700				10/25/89	4	IT	GC
H-11b3	CULEBRA	pH		7.0600			7.0600				10/17/90	5	IT	GC
** H-12														
H-12	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-12	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	1,2-DIPHENYLHYDRAZINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV

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H-12	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	2-BUTANONE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV

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H-12	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	2-HEXANONE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV

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H-12	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	ACETONE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V

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H-12	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	ALKALINITY (HCO3)		56.0000		NA	0.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	ALKALINITY (HCO3)		62.0000			69.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	ALKALINITY (HCO3)		46.0000			48.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	ALUMINUM		0.6600		NA	0.0000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	ANTIMONY		1.0000		NA	0.0000	< 0.05	< 0.05	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	ANTIMONY		1.9000			2.0000	< 0.05	< 0.05	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	ARSENIC		18.0000		NA	0.0000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	ARSENIC		0.1700		NA	0.0000	< 0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	BARIUM		1.2000			1.2000	0.12	0.12	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	BENZENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-12	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BERYLLIUM		0.0250			0.0230	< 0.001	< 0.001	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	4.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		38.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV

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H-12	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		16.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	BORON		35.0000		NA	0.0000	< 0.1	< 0.1	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	BORON		39.0000		NA	0.0000	< 0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	BORON		41.0000			41.0000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	BROMIDE		140.0000			150.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	BROMIDE		77.0000		NA	0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	BROMIDE		86.0000			88.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	BROMOFORM	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	CADMIUM		0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	CADMIUM		0.1500			0.1500	< 0.005	< 0.005	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	CALCIUM		1900.0000			1800.0000	0.2	0.2	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	CALCIUM		1600.0000			1500.0000			mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	CALCIUM		1700.0000			1700.0000			mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	CARBON DISULFIDE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	CESIUM	<	10.0000		NA	0.0000	< 1.0	< 1.0	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	CESIUM		0.9000		NA	0.0000	< 0.1	< 0.1	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	CHLORIDE		80000.0000		NA	0.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	CHLORIDE		78000.0000			79000.0000			mg/l	01/16/87	2	IT	GC

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H-12	CULEBRA	CHLORIDE		78200.0000			78600.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	CHLOROBENZENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	CHLOROETHANE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	CHLOROFORM	<	2.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	CHLOROFORM	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	CHROMIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	CHROMIUM		0.3000		NA	0.0000	0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	CHROMIUM		0.7000			0.8000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	COBALT		2.9000			1.9000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	COBALT		0.2000			0.2000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	COPPER		0.4500			0.4500	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	COPPER	<	0.1000		NA	0.0000	0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	COPPER		0.1000			0.1000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	CYANIDE	<	0.0200		<	0.0500			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV

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H-12	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	ETHYLBENZENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	Eh		514.0000		NA	0.0000			mV	08/09/85	1	IT	GC
H-12	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV

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H-12	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	FLUORIDE		1.1000			1.2000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	FLUORIDE		1.1000			1.1000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	FLUORIDE		1.1000			1.2000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV
H-12	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	IODIDE		1.6000		NA	0.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	IRON		0.5600		NA	0.0000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	IRON		2.6000		NA	0.0000	< 0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	IRON		1.8000			1.8000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-12	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	12/14/88	3	IT	SV
H-12	CULEBRA	LEAD		0.1800		NA	0.0000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	LEAD		1.2000			1.2000	< 0.05	< 0.05	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	LITHIUM		0.7300		NA	0.0000	< 0.01	0.02	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	LITHIUM		10.0000			11.0000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	MAGNESIUM		1400.0000			1400.0000	< 0.1	< 0.1	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	MAGNESIUM		2000.0000			2000.0000			mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	MAGNESIUM		1700.0000			1700.0000			mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	MANGANESE		0.6400			0.6400	0.01	0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	MANGANESE		0.1600		NA	0.0000	< 0.005	< 0.005	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	MERCURY		0.0010			0.0009	0.0006	0.0006	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	MERCURY	<	0.0004		NA	0.0000	< 0.0002	< 0.0002	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	METHYL BROMIDE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	METHYL CHLORIDE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	METHYLENE CHLORIDE	<	20.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	METHYLENE CHLORIDE		5.6000			5.3000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	MOLYBDENUM		15.0000		NA	0.0000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	MOLYBDENUM		0.3500		NA	0.0000	< 0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	MOLYBDENUM		0.3200			0.3200	< 0.05	0.05	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV
H-12	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-12	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	4.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	NICKEL		0.8400			0.8400	< 0.01	< 0.01	mg/l		08/09/85	1	IT	ME
H-12	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		01/16/87	2	IT	ME
H-12	CULEBRA	NICKEL		0.4000			0.4000	< 0.03	< 0.03	mg/l		12/14/88	3	IT	ME
H-12	CULEBRA	NITRATE	<	0.1000		<	0.1000			mg/l	NO3-N	08/09/85	1	IT	GC
H-12	CULEBRA	NITRATE		0.8000			0.9000			mg/l	NO3-N	01/16/87	2	IT	GC
H-12	CULEBRA	NITRATE	<	0.0200		<	0.0200			mg/l	NO3-N	12/14/88	3	IT	GC
H-12	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		01/16/87	2	IT	PC
H-12	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		12/14/88	3	IT	PC
H-12	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV

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H-12	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	PHENOLICS		0.0050			0.0170			mg/l		08/09/85	1	IT	GC
H-12	CULEBRA	PHENOLICS	<	0.0050		<	0.0050			mg/l		01/16/87	2	IT	GC
H-12	CULEBRA	PHENOLICS	<	0.0290			1.1000			mg/l		12/14/88	3	IT	GC
H-12	CULEBRA	PHOSPHATE		0.0900		NA	0.0000			mg/l	T-PO4-P	08/09/85	1	IT	GC
H-12	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	01/16/87	2	IT	GC
H-12	CULEBRA	PHOSPHATE		0.0100		<	0.0100			mg/l	T-PO4-P	12/14/88	3	IT	GC
H-12	CULEBRA	POTASSIUM		1500.0000			1500.0000	< 0.01	< 0.01	mg/l		08/09/85	1	IT	ME
H-12	CULEBRA	POTASSIUM		1600.0000			1600.0000			mg/l		01/16/87	2	IT	ME
H-12	CULEBRA	POTASSIUM		1300.0000			1380.0000			mg/l		12/14/88	3	IT	ME
H-12	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		08/09/85	1	IT	SV
H-12	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		01/16/87	2	IT	SV
H-12	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		12/14/88	3	IT	SV
H-12	CULEBRA	RESIDUE, FILTERABLE @ 180 C		143000.0000			142000.0000			mg/l		08/09/85	1	IT	GC
H-12	CULEBRA	RESIDUE, FILTERABLE @ 180 C		140000.0000		NA	0.0000			mg/l		01/16/87	2	IT	GC
H-12	CULEBRA	RESIDUE, FILTERABLE @ 180 C		130000.0000			124000.0000			mg/l		12/14/88	3	IT	GC
H-12	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		280.0000			280.0000			mg/l		08/09/85	1	IT	GC
H-12	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		240.0000		NA	0.0000			mg/l		01/16/87	2	IT	GC
H-12	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		86.0000			84.0000			mg/l		12/14/88	3	IT	GC
H-12	CULEBRA	SELENIUM		0.6000		NA	0.0000	< 0.001	< 0.001	mg/l		08/09/85	1	IT	ME
H-12	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l		01/16/87	2	IT	ME
H-12	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l		12/14/88	3	IT	ME
H-12	CULEBRA	SILICA		42.0000			48.0000	< 0.1	< 0.1	mg/l		08/09/85	1	IT	ME
H-12	CULEBRA	SILICA		11.0000		NA	0.0000	< 0.2	< 0.2	mg/l		01/16/87	2	IT	ME
H-12	CULEBRA	SILICA		2.8000			2.6000			mg/l		12/14/88	3	IT	ME
H-12	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l		01/16/87	2	IT	ME
H-12	CULEBRA	SILVER		0.2000			0.2000	< 0.01	< 0.01	mg/l		12/14/88	3	IT	ME
H-12	CULEBRA	SODIUM		45000.0000			44000.0000	< 0.1	< 0.1	mg/l		08/09/85	1	IT	ME

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H-12	CULEBRA	SODIUM		52000.0000			51000.0000			mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	SODIUM		44500.0000			44000.0000			mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	SPECIFIC CONDUCTANCE		140000.0000		NA	0.0000			umhos/cm@25C	08/09/85	1	IT	GC
H-12	CULEBRA	SPECIFIC CONDUCTANCE		216000.0000		NA	0.0000			umhos/cm@25C	01/16/87	2	IT	GC
H-12	CULEBRA	SPECIFIC CONDUCTANCE		129000.0000			129000.0000			umhos/cm@25C	12/14/88	3	IT	GC
H-12	CULEBRA	STRONTIUM		18.0000			18.0000	< 0.01	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	STRONTIUM		38.0000		NA	0.0000	0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	STRONTIUM		34.0000			35.0000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	STYRENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	SULFATE		5900.0000		NA	0.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	SULFATE		8200.0000		NA	0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	SULFATE		7500.0000		NA	0.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	THALLIUM	<	2.5000		NA	0.0000	< 0.005	< 0.005	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	TITANIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	TITANIUM	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	TITANIUM	<	0.1000			0.1000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	TOLUENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	08/09/85	1	IT	GC
H-12	CULEBRA	TOTAL ORGANIC CARBON		15.0000		NA	0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	TOTAL ORGANIC HALOGEN		1.4000		NA	0.0000			mg/l	08/09/85	1	IT	GC

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H-12	CULEBRA	TOTAL ORGANIC HALOGEN		0.1800		NA	0.0000			mg/l	01/16/87	2	IT	GC
H-12	CULEBRA	TOTAL ORGANIC HALOGEN		1.0000			0.7200			mg/l	12/14/88	3	IT	GC
H-12	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	TRICHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	TRICHLOROFLUOROMETHANE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	VANADIUM		0.3000			0.3000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	VINYL ACETATE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	VINYL CHLORIDE	<	10.0000		<	10.0000		T < 10	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	08/09/85	1	IT	V
H-12	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	01/16/87	2	IT	V
H-12	CULEBRA	XYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	12/14/88	3	IT	V
H-12	CULEBRA	ZINC		2.2000			2.2000	0.53	< 0.01	mg/l	08/09/85	1	IT	ME
H-12	CULEBRA	ZINC		0.3000		NA	0.0000	< 0.01	< 0.01	mg/l	01/16/87	2	IT	ME
H-12	CULEBRA	ZINC		0.3000			0.3000	< 0.01	< 0.01	mg/l	12/14/88	3	IT	ME
H-12	CULEBRA	pH		7.3300		NA	0.0000				08/09/85	1	IT	GC
H-12	CULEBRA	pH		6.8100			6.9200				01/16/87	2	IT	GC
H-12	CULEBRA	pH		6.9700			6.9800				12/14/88	3	IT	GC

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** H-14														
H-14	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-14	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-14	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV

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H-14	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	4-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV

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H-14	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	ALKALINITY (HCO3)		40.0000			40.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	ALKALINITY (HCO3)		39.0000		NA	0.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	ALKALINITY (HCO3)		37.0000			37.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	ALUMINUM		1.0000			1.0000	< 0.1	< 0.1	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	ANTIMONY		0.6000		NA	0.0000	< 0.05	< 0.05	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	ANTIMONY		0.6000			0.6000	< 0.05	< 0.05	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	ANTIMONY		0.5000			0.5000	< 0.05	< 0.05	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	AROCLOR 1016	<	0.5000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	AROCLOR 1221	<	0.5000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	AROCLOR 1232	<	0.5000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	AROCLOR 1242	<	0.5000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	AROCLOR 1248	<	0.5000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	AROCLOR 1254	<	1.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	AROCLOR 1260	<	1.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-14	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BENZO(B)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-14	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	BORON		11.0000	NA		0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	BORON		11.0000			11.0000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	BORON		11.0000			11.0000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	BROMIDE		14.0000	NA		0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	BROMIDE		11.0000			11.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	BROMIDE		15.0000			14.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	BROMOFORM	<	5.0000	NA		0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	BROMOFORM	<	5.0000	NA		0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	BROMOFORM	<	5.0000	NA		0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	CADMIUM	<	0.0500	NA		0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	CADMIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	CADMIUM		0.0600			0.0600	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-14	CULEBRA	CALCIUM		1800.0000			1800.0000			mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	CALCIUM		1700.0000			1700.0000			mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	CALCIUM		2000.0000			1900.0000			mg/l	04/21/89	3	IT	MC
H-14	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	CESIUM		0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	CESIUM	<	0.6000		<	0.6000	< 0.06	< 0.06	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	CHLORIDE		8200.0000		NA	0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	CHLORIDE		7900.0000		NA	0.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	CHLORIDE		9000.0000			9000.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	CHROMIUM		0.2000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	CHROMIUM		0.3000			0.3000	0.01	0.02	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	CHROMIUM		0.4000			0.4000	0.02	0.02	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV

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H-14	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	COPPER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	COPPER		0.1000			0.1000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	COPPER		0.1000			0.1000	< 0.01	0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	CYANIDE	<	0.0200		<	0.0500			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V

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H-14	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	FLUORIDE		0.8000		NA	0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	FLUORIDE		1.6000		NA	0.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEB	FLUORIDE		1.7000			1.7000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV

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H-14	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	IRON		0.4000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	IRON		0.3000			0.3000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	IRON		0.6000			0.6000	< 0.02	< 0.02	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	05/26/87	1	IT	SV
H-14	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	01/27/88	2	IT	SV
H-14	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	04/21/89	3	IT	SV
H-14	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	LEAD		0.5000			0.5000	< 0.05	< 0.05	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	LITHIUM		0.4700		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	LITHIUM		0.4400			0.4400	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	LITHIUM		0.5100			0.5100	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	MAGNESIUM		530.0000			530.0000			mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	MAGNESIUM		500.0000			500.0000			mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	MAGNESIUM		570.0000			560.0000			mg/l	04/21/89	3	IT	MC
H-14	CULEBRA	MANGANESE	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	MANGANESE		0.0900			0.0900	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	MANGANESE		0.1300			0.1200	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	01/27/88	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-14	CULEBRA	MERCURY		0.0004			0.0003	0.0004	0.0003	mg/l		04/21/89	3	IT	MT
H-14	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	V
H-14	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l		01/27/88	2	IT	V
H-14	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	V
H-14	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	V
H-14	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		01/27/88	2	IT	V
H-14	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	V
H-14	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	V
H-14	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l		01/27/88	2	IT	V
H-14	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000			ug/l		04/21/89	3	IT	V
H-14	CULEBRA	MOLYBDENUM		0.0600		NA	0.0000	0.02	0.03	mg/l		05/26/87	1	IT	ME
H-14	CULEBRA	MOLYBDENUM		0.0700			0.0700	< 0.01	< 0.01	mg/l		01/27/88	2	IT	ME
H-14	CULEBRA	MOLYBDENUM		0.2000			0.2000	< 0.01	< 0.01	mg/l		04/21/89	3	IT	MT
H-14	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		05/26/87	1	IT	ME
H-14	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		01/27/88	2	IT	ME
H-14	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		04/21/89	3	IT	MT
H-14	CULEBRA	NITRATE		0.4000		NA	0.0000			mg/l	NO3-N	05/26/87	1	IT	GC
H-14	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l	NO3-N	01/27/88	2	IT	GC
H-14	CULEBRA	NITRATE	<	0.0200		<	0.0200			mg/l		04/21/89	3	IT	GC
H-14	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV

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H-14	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		05/26/87	1	IT	PC
H-14	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		01/27/88	2	IT	PC
H-14	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	PHENOLICS		0.0680		NA	0.0000			mg/l		05/26/87	1	IT	GC
H-14	CULEBRA	PHENOLICS		0.0900		NA	0.0000			mg/l		01/27/88	2	IT	GC
H-14	CULEBRA	PHENOLICS		0.1400		NA	0.0000			mg/l		04/21/89	3	IT	GC
H-14	CULEBRA	PHOSPHATE		0.0200			0.0400			mg/l	T-PO4-P	05/26/87	1	IT	GC
H-14	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	01/27/88	2	IT	GC
H-14	CULEBRA	PHOSPHORUS		0.0400			0.0500			mg/l		04/21/89	3	IT	GC
H-14	CULEBRA	POTASSIUM		250.0000		NA	0.0000			mg/l		05/26/87	1	IT	ME
H-14	CULEBRA	POTASSIUM		240.0000			240.0000			mg/l		01/27/88	2	IT	ME
H-14	CULEBRA	POTASSIUM		250.0000			240.0000			mg/l		04/21/89	3	IT	MC
H-14	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		05/26/87	1	IT	SV
H-14	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		01/27/88	2	IT	SV
H-14	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		04/21/89	3	IT	SV
H-14	CULEBRA	RESIDUE, FILTERABLE @ 180 C		18000.0000		NA	0.0000			mg/l		05/26/87	1	IT	GC

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H-14	CULEBRA	RESIDUE, FILTERABLE @ 180 C		17200.0000			17200.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	RESIDUE, FILTERABLE @ 180 C		16500.0000			14900.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		14.0000		NA	0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		62.0000			60.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		71.0000			68.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	SILICA		14.0000		NA	0.0000	< 0.2	< 0.2	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	SILICA		14.0000			14.0000	< 0.2	< 0.2	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	SILICA		5.5000			5.4000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	SODIUM		3300.0000		NA	0.0000			mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	SODIUM		3300.0000			3300.0000			mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	SODIUM		3800.0000			3800.0000			mg/l	04/21/89	3	IT	MC
H-14	CULEBRA	SPECIFIC CONDUCTANCE		25200.0000			24800.0000			umhos/cm@25C	05/26/87	1	IT	GC
H-14	CULEBRA	SPECIFIC CONDUCTANCE		27700.0000			28200.0000			umhos/cm@25C	01/27/88	2	IT	GC
H-14	CULEBRA	SPECIFIC CONDUCTANCE		27000.0000			26900.0000			uMhos/cm@25C	04/21/89	3	IT	GC
H-14	CULEBRA	STRONTIUM		31.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	STRONTIUM		33.0000			33.0000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	STRONTIUM		32.0000			32.0000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	SULFATE		1500.0000		NA	0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	SULFATE		1900.0000		NA	0.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	SULFATE		1900.0000			1800.0000			mg/l	04/21/89	3	IT	GC

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H-14	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	THALLIUM	<	5.0000		NA	0.0000	< 0.005	< 0.005	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	THALLIUM	<	5.0000		NA	0.0000	< 0.005	< 0.005	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	TIN		0.6000		NA	0.0000	< 0.04	< 0.04	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	TITANIUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	TITANIUM		0.5000			0.5000	< 0.03	< 0.03	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	TITANIUM		0.1000			0.1000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	TOTAL ORGANIC CARBON		1.0000		<	1.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	TOTAL ORGANIC HALOGEN		0.0800		NA	0.0000			mg/l	05/26/87	1	IT	GC
H-14	CULEBRA	TOTAL ORGANIC HALOGEN		1.2000			0.9800			mg/l	01/27/88	2	IT	GC
H-14	CULEBRA	TOTAL ORGANIC HALOGEN		0.2400			0.3900			mg/l	04/21/89	3	IT	GC
H-14	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	VANADIUM		0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	VANADIUM		0.2000			0.1000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME

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H-14	CULEBRA	VANADIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	XYLENE	<	5.0000	NA		0.0000			ug/l	05/26/87	1	IT	V
H-14	CULEBRA	XYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	01/27/88	2	IT	V
H-14	CULEBRA	XYLENE	<	5.0000	NA		0.0000			ug/l	04/21/89	3	IT	V
H-14	CULEBRA	ZINC	<	0.1000	NA		0.0000	< 0.01	< 0.01	mg/l	05/26/87	1	IT	ME
H-14	CULEBRA	ZINC	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	01/27/88	2	IT	ME
H-14	CULEBRA	ZINC	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	04/21/89	3	IT	MT
H-14	CULEBRA	pH		7.5000			7.5400				05/26/87	1	IT	GC
H-14	CULEBRA	pH		6.5400			6.6500				01/27/88	2	IT	GC
H-14	CULEBRA	pH		7.4800			7.4800				04/21/89	3	IT	GC
** H-15														
H-15	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	01/13/88	2	IT	V

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H-15	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,2,4-TRICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	1,2-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	1,3-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	1,4-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,4,5-TRICHLOROPHENOL	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,4,6-TRICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,4-DICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-15	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,4-DIMETHYLPHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,4-DINITROPHENOL	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,4-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2,6-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	2-CHLORONAPHTHALENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2-CHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-15	CULEBRA	2-METHYLNAPHTHALENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2-NITROANILINE	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	2-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	3,3'-DICHLOROBENZIDINE	<	40.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	3,4-BENZOFLUORANTHENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	3-NITROANILINE	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4,6-DINITRO-O-CRESOL	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4-CHLOROANILINE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV

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H-15	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	4-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4-NITROANILINE	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	4-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	ACENAPHTHENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	ACENAPHTHYLENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	ACETONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	ALKALINITY (HCO3)		36.0000			36.0000			mg/l	05/11/87	1	IT	GC

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H-15	CULEBRA	ALKALINITY (HCO3)		32.0000		NA	0.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	ALKALINITY (HCO3)		38.0000		NA	0.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	ALUMINUM	<	10.0000		NA	0.0000	< 0.1	< 0.1	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	ALUMINUM	<	10.0000		<	10.0000	< 0.1	< 0.1	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	ALUMINUM	<	10.0000		<	10.0000	< 0.1	< 0.1	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	ANTHRACENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	ANTIMONY	<	5.0000		NA	0.0000	< 0.05	< 0.05	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	ANTIMONY	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	ANTIMONY		7.0000			7.0000	< 0.05	< 0.05	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	ARSENIC	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	ARSENIC	<	1.0000		<	1.0000	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	BARIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	BARIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	BARIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	BENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	BENZO(A)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BENZO(A)PYRENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BENZO(G,H,I)PERYLENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV

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H-15	CULEBRA	BENZO(K)FLUORANTHENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BENZOIC ACID	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BENZYL ALCOHOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BERYLLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	BERYLLIUM		0.5000		<	0.5000	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		64.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		22.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		44.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	BORON		48.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	BORON		44.0000			44.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	BORON		50.0000			50.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	BROMIDE		100.0000			100.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	BROMIDE		99.0000			100.0000			mg/l	01/13/88	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-15	CULEBRA	BROMIDE		94.0000			99.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	BUTYL BENZYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	CADMIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	CADMIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	CADMIUM		0.7000			0.7000	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	CALCIUM		2000.0000		NA	0.0000			mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	CALCIUM		1400.0000			1400.0000			mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	CALCIUM		1600.0000			1600.0000			mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	CESIUM		0.2400		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	CESIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	CESIUM		0.4000			0.4000	< 0.06	< 0.06	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	CHLORIDE		140000.0000			140000.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	CHLORIDE		134000.0000		NA	0.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	CHLORIDE		135000.0000		NA	0.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V

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H-15	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	CHROMIUM	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	CHROMIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	CHROMIUM		3.0000			3.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	CHRYSENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	COBALT	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	COBALT	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	COBALT		1.0000			1.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	COPPER	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	COPPER	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	COPPER		2.0000			2.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	CYANIDE	<	0.0100		<	0.0200			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	DI-N-BUTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	DI-N-OCTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV

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H-15	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	20.0000		NA	0.0000		ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000		ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000		ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	DIBENZOFURAN	<	20.0000		NA	0.0000		ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000		ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000		ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		ug/l	05/11/87	1	IT	V
H-15	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000 T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		ug/l	05/11/87	1	IT	V
H-15	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000 T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	DIETHYL PHTHALATE	<	20.0000		NA	0.0000		ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000		ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000		ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	DIMETHYL PHTHALATE	<	20.0000		NA	0.0000		ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000		ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000		ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		ug/l	05/11/87	1	IT	V
H-15	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000 T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	FLUORANTHENE	<	20.0000		NA	0.0000		ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000		ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000		ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	FLUORENE	<	20.0000		NA	0.0000		ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	FLUORENE	<	10.0000		NA	0.0000		ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	FLUORENE	<	10.0000		NA	0.0000		ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	FLUORIDE		0.7000		NA	0.0000		mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	FLUORIDE		0.7000		NA	0.0000		mg/l	01/13/88	2	IT	GC

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H-15	CULEBRA	FLUORIDE		0.6000		NA	0.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	HEXACHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	HEXACHLOROBUTADIENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	HEXACHLOROETHANE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	IRON	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	IRON		3.0000			3.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	IRON		3.0000			3.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	ISOPHORONE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	LEAD	<	5.0000		NA	0.0000	< 0.05	< 0.05	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	LEAD	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	LEAD		7.0000			7.0000	< 0.05	< 0.05	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	LITHIUM		0.7000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME

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H-15	CULEBRA	LITHIUM		0.8000			0.8000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	LITHIUM		0.9000			0.9000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	MAGNESIUM		2300.0000		NA	0.0000			mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	MAGNESIUM		2600.0000			2600.0000			mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	MAGNESIUM		2700.0000			2700.0000			mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	MANGANESE	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	MANGANESE		0.6000			0.6000	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	MANGANESE	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	MERCURY	<	0.0002		NA	0.0000	0.0004	0.0009	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	MERCURY	<	0.0020		NA	0.0000	< 0.0002	< 0.0002	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	MERCURY	<	0.4000		<	0.4000	< 0.0002	< 0.0002	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T 9.6	T 14	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	MOLYBDENUM		0.2000		NA	0.0000	0.03	0.02	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	MOLYBDENUM		0.5200			0.5200	0.02	0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	MOLYBDENUM		0.2900			0.2700	< 0.05	< 0.05	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV

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H-15	CULEBRA	NAPHTHALENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	NICKEL	<	3.0000		NA	0.0000	< 0.03	< 0.03	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	NICKEL	<	3.0000		<	3.0000	< 0.03	< 0.03	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	NICKEL	<	3.0000		<	3.0000	< 0.03	< 0.03	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	NITRATE		0.5000		NA	0.0000			mg/l NO3-N	05/11/87	1	IT	GC
H-15	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l NO3-N	01/13/88	2	IT	GC
H-15	CULEBRA	NITRATE	<	0.0200		NA	0.0000			mg/l NO3-N	11/07/88	3	IT	GC
H-15	CULEBRA	NITROBENZENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	P-CHLORO-M-CRESOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l	05/11/87	1	IT	PC
H-15	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l	01/13/88	2	IT	PC
H-15	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l	11/07/88	3	IT	PC
H-15	CULEBRA	PENTACHLOROPHENOL	<	100.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	PHENANTHRENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	PHENOL	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	PHENOLICS	<	0.0080		NA	0.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	PHENOLICS		0.0390		NA	0.0000			mg/l	01/13/88	2	IT	GC

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H-15	CULEBRA	PHENOLICS		0.0260		NA	0.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l T-PO4-P	05/11/87	1	IT	GC
H-15	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l T-PO4-P	01/13/88	2	IT	GC
H-15	CULEBRA	PHOSPHATE		0.0100			0.0100			mg/l T-PO4-P	11/07/88	3	IT	GC
H-15	CULEBRA	POTASSIUM		1800.0000		NA	0.0000			mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	POTASSIUM		1800.0000			1800.0000			mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	POTASSIUM		1800.0000			1900.0000			mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	PYRENE	<	20.0000		NA	0.0000			ug/l	05/11/87	1	IT	SV
H-15	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	01/13/88	2	IT	SV
H-15	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l	11/07/88	3	IT	SV
H-15	CULEBRA	RESIDUE, FILTERABLE @ 180 C		230000.0000		NA	0.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	RESIDUE, FILTERABLE @ 180 C		230000.0000			232000.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	RESIDUE, FILTERABLE @ 180 C		246000.0000			244000.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		680.0000		NA	0.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		54.0000			68.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		930.0000			820.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	SELENIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	SILICA	<	20.0000		NA	0.0000	< 0.2	< 0.2	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	SILICA	<	21.0000		<	21.0000	< 0.2	< 0.2	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	SILICA		1.6000		NA	0.0000			mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	SILVER	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	SILVER	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	SILVER		1.0000			1.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	SODIUM		84000.0000		NA	0.0000			mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	SODIUM		78900.0000			78900.0000			mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	SODIUM		71000.0000			71000.0000			mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	SPECIFIC CONDUCTANCE		358000.0000			368000.0000			umhos/cm@25C	05/11/87	1	IT	GC

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H-15	CULEBRA	SPECIFIC CONDUCTANCE		410000.0000			405000.0000			umhos/cm@25C	01/13/88	2	IT	GC
H-15	CULEBRA	SPECIFIC CONDUCTANCE		210000.0000			210000.0000			umhos/cm@25C	11/07/88	3	IT	GC
H-15	CULEBRA	STRONTIUM		30.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	STRONTIUM		30.0000			31.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	STRONTIUM		31.0000			31.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	SULFATE		6300.0000		NA	0.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	SULFATE		7500.0000		NA	0.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	SULFATE		5500.0000			5700.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	THALLIUM	<	2.5000		NA	0.0000	< 0.005	< 0.005	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	TIN	<	4.0000		NA	0.0000	< 0.04	< 0.04	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	TITANIUM	<	0.5000		NA	0.0000	< 0.1	< 0.1	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	TITANIUM	<	3.0000		<	3.0000	< 0.03	< 0.03	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	TITANIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	TOTAL ORGANIC CARBON		1.0000			2.0000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	TOTAL ORGANIC CARBON		2.0000			1.0000			mg/l	01/13/88	2	IT	GC
H-15	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	TOTAL ORGANIC HALOGEN		8.1000			6.7000			mg/l	05/11/87	1	IT	GC
H-15	CULEBRA	TOTAL ORGANIC HALOGEN		2.5000			2.8000			mg/l	01/13/88	2	IT	GC

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H-15	CULEBRA	TOTAL ORGANIC HALOGEN		1.3000			1.1000			mg/l	11/07/88	3	IT	GC
H-15	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	VANADIUM	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	VANADIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	VANADIUM		1.0000			1.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	05/11/87	1	IT	V
H-15	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	01/13/88	2	IT	V
H-15	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	11/07/88	3	IT	V
H-15	CULEBRA	ZINC	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	05/11/87	1	IT	ME
H-15	CULEBRA	ZINC	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	01/13/88	2	IT	ME
H-15	CULEBRA	ZINC		1.0000			1.0000	< 0.01	< 0.01	mg/l	11/07/88	3	IT	ME
H-15	CULEBRA	pH		6.5900			6.6200				05/11/87	1	IT	GC
H-15	CULEBRA	pH		6.8000		NA	0.0000				01/13/88	2	IT	GC
H-15	CULEBRA	pH		6.5500			6.5800				11/07/88	3	IT	GC

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** H-17														
H-17	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-17	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	ACETONE		29.0000		NA	0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	10/27/87	1	IT	GC
H-17	CULEBRA	ALKALINITY (HCO3)		43.0000		NA	0.0000			mg/l	10/27/87	1	IT	GC
H-17	CULEBRA	ALUMINUM		2.0000			3.0000	< 0.1	< 0.1	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	ANTIMONY		2.5000			2.5000	< 0.05	< 0.05	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	ARSENIC	<	0.0500			0.0500	< 0.005	< 0.005	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	BARIUM		0.1200			0.1300	< 0.005	< 0.005	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV

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H-17	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	BORON		39.0000			40.0000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	BROMIDE		75.0000		NA	0.0000			mg/l	10/27/87	1	IT	GC
H-17	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	CADMIUM		0.2400			0.2500	< 0.005	< 0.005	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	CALCIUM		1500.0000			1500.0000			mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	CESIUM		5.0000			5.0000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	CHLORIDE		87300.0000		NA	0.0000			mg/l	10/27/87	1	IT	GC
H-17	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	CHROMIUM		1.1000			1.2000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	COBALT		0.4000			0.4000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	COPPER		0.6000			0.6000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	CYANIDE	<	0.0400		NA	0.0000			mg/l	10/27/87	1	IT	GC
H-17	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV
H-17	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/27/87	1	IT	SV

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H-17	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	FLUORIDE		1.3000			1.2000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	IRON		1.2000			1.2000	< 0.01	< 0.01	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	LEAD		2.0000			2.2000	< 0.05	< 0.05	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	LITHIUM		1.0000			0.9600	< 0.01	< 0.01	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	MAGNESIUM		1700.0000			1700.0000			mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	MANGANESE		0.1600			0.1700	< 0.005	< 0.005	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	MOLYBDENUM		0.2400			0.2200	< 0.01	< 0.01	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	NICKEL		0.7000			0.7000	< 0.03	< 0.03	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	NITRATE	<	0.2000		NA	0.0000			mg/l	NO3-N	10/27/87	1	IT	GC
H-17	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV

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H-17	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		10/27/87	1	IT	PC
H-17	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	PHENOLICS		0.0470		NA	0.0000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	10/27/87	1	IT	GC
H-17	CULEBRA	POTASSIUM		1400.0000			1400.0000			mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		10/27/87	1	IT	SV
H-17	CULEBRA	RESIDUE, FILTERABLE @ 180 C		151000.0000			151000.0000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		230.0000			250.0000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	SELENIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	SILICA		12.0000			13.0000	< 0.2	< 0.2	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	SILVER		0.3000			0.4000	< 0.01	< 0.01	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	SODIUM		54700.0000			55000.0000			mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	SPECIFIC CONDUCTANCE		224000.0000											
H-17	CULEBRA	STRONTIUM		37.0000			37.0000	< 0.01	< 0.01	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	SULFATE		7000.0000		NA	0.0000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	TITANIUM		1.3000			1.4000	< 0.03	< 0.03	mg/l		10/27/87	1	IT	ME
H-17	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	TOTAL ORGANIC HALOGEN		6.5000			7.8000			mg/l		10/27/87	1	IT	GC
H-17	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V
H-17	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l		10/27/87	1	IT	V

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H-17	CULEBRA	VANADIUM		0.5000			0.5000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	XYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	10/27/87	1	IT	V
H-17	CULEBRA	ZINC		0.2000			0.2000	< 0.01	< 0.01	mg/l	10/27/87	1	IT	ME
H-17	CULEBRA	pH		6.6400			6.6700				10/27/87	1	IT	GC
** H-18														
H-18	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T 13	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/07/88	2	IT	V

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H-18	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T 12	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	ACETONE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	ALKALINITY (HCO3)		54.0000		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	ALKALINITY (HCO3)		50.0000		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	ALKALINITY (HCO3)		56.0000		NA	0.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	ALUMINUM	<	2.0000		<	2.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	ANTIMONY	<	0.6000		<	0.6000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	ARSENIC	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	11/10/87	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	ARSENIC	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	ARSENIC	<	0.1000	NA		0.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	BARIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	BARIUM	<	0.0500	<		0.0500	0.005	< 0.005	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	BARIUM	<	2.0000	<		2.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	BENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	BENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	BENZENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA		0.0000			ug/l	04/07/88	2	IT	SV

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H-18	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	BORON		16.0000			15.0000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	BORON		17.0000			17.0000	0.01	0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	BORON		16.0000			16.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	BROMIDE		17.0000		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	BROMIDE		14.0000		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	BROMIDE		14.0000			14.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	CADMIUM	<	0.0500		<	0.0500			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	CALCIUM		980.0000			980.0000			mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	CALCIUM		1100.0000			1100.0000			mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	CALCIUM		1200.0000			1200.0000			mg/l	04/10/90	3	IT	MC
H-18	CULEBRA	CALCIUM HARDNESS		0.0000			0.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	CESIUM		0.3900			0.3900	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	CESIUM	<	0.0500		<	0.0500	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	CESIUM		0.7000			0.8000			mg/l	04/10/90	3	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	CHLORIDE		12000.0000		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	CHLORIDE		12500.0000		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	CHLORIDE		13000.0000			13000.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	CHROMIUM		0.2000			0.2000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	COBALT	<	0.1000		<	0.1000	0.02	0.02	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	COBALT	<	0.5000		<	0.5000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	COPPER		0.1000			0.2000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	COPPER	<	0.2500		<	0.2500			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	04/10/90	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	FLUORIDE		1.9000		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	FLUORIDE		1.6000		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	FLUORIDE		1.7000			1.7000			mg/l	04/10/90	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	IRON		0.2000			0.2000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	IRON		0.3000			0.4000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	IRON	<	1.0000		<	1.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	11/10/87	1	IT	SV
H-18	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	04/07/88	2	IT	SV
H-18	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	LEAD	<	0.5000		<	0.5000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	LITHIUM		0.2500			0.2500	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	LITHIUM		0.3100			0.3100	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	LITHIUM		0.2000			0.1000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	MAGNESIUM		500.0000			520.0000			mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	MAGNESIUM		480.0000			480.0000			mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	MAGNESIUM		520.0000			520.0000			mg/l	04/10/90	3	IT	MC
H-18	CULEBRA	MANGANESE		0.1400			0.1400	< 0.005	< 0.005	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	MANGANESE		0.1800			0.1800	< 0.005	< 0.005	mg/l	04/07/88	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
H-18	CULEBRA	MANGANESE		0.2100			0.2000			mg/l		04/10/90	3	IT	MT
H-18	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	0.0003	mg/l		11/10/87	1	IT	ME
H-18	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l		04/07/88	2	IT	ME
H-18	CULEBRA	MERCURY	<	0.0002	<		0.0002			mg/l		04/10/90	3	IT	MT
H-18	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l		11/10/87	1	IT	V
H-18	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l		04/07/88	2	IT	V
H-18	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000	T< 10	M< 10	ug/l		04/10/90	3	IT	V
H-18	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l		11/10/87	1	IT	V
H-18	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l		04/07/88	2	IT	V
H-18	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000	T< 10	M< 10	ug/l		04/10/90	3	IT	V
H-18	CULEBRA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l		11/10/87	1	IT	V
H-18	CULEBRA	METHYLENE CHLORIDE		5.5000	NA		0.0000		T 5.7	ug/l		04/07/88	2	IT	V
H-18	CULEBRA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000	T 6	M< 5	ug/l		04/10/90	3	IT	V
H-18	CULEBRA	MOLYBDENUM		0.0500			0.0600	< 0.01	< 0.01	mg/l		11/10/87	1	IT	ME
H-18	CULEBRA	MOLYBDENUM	<	2.0000	<		2.0000	< 0.01	< 0.01	mg/l		04/07/88	2	IT	ME
H-18	CULEBRA	MOLYBDENUM	<	0.2000	<		0.2000			mg/l		04/10/90	3	IT	MT
H-18	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA		0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA		0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA		0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	NAPHTHALENE	<	10.0000	NA		0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	NAPHTHALENE	<	10.0000	NA		0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	NICKEL	<	0.3000	<		0.3000	< 0.03	< 0.03	mg/l		11/10/87	1	IT	ME
H-18	CULEBRA	NICKEL	<	0.3000	<		0.3000	< 0.03	< 0.03	mg/l		04/07/88	2	IT	ME
H-18	CULEBRA	NICKEL	<	0.4000	<		0.4000			mg/l		04/10/90	3	IT	MT
H-18	CULEBRA	NITRATE	<	0.2000	NA		0.0000			mg/l	NO3-N	11/10/87	1	IT	GC
H-18	CULEBRA	NITRATE	<	0.0200	NA		0.0000			mg/l	NO3-N	04/07/88	2	IT	GC
H-18	CULEBRA	NITRATE	<	0.2000	NA		0.0000			mg/l		04/10/90	3	IT	GC
H-18	CULEBRA	NITROBENZENE	<	10.0000	NA		0.0000			ug/l		11/10/87	1	IT	SV

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H-18	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		11/10/87	1	IT	PC
H-18	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		04/07/88	2	IT	PC
H-18	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	PHENOLICS		0.0410		NA	0.0000			mg/l		11/10/87	1	IT	GC
H-18	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		04/07/88	2	IT	GC
H-18	CULEBRA	PHENOLICS		0.1200		NA	0.0000			mg/l		04/10/90	3	IT	GC
H-18	CULEBRA	PHOSPHATE		0.0300		NA	0.0000			mg/l	T-PO4-P	11/10/87	1	IT	GC
H-18	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	04/07/88	2	IT	GC
H-18	CULEBRA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		04/10/90	3	IT	GC
H-18	CULEBRA	POTASSIUM		240.0000			240.0000			mg/l		11/10/87	1	IT	ME
H-18	CULEBRA	POTASSIUM		220.0000			230.0000			mg/l		04/07/88	2	IT	ME
H-18	CULEBRA	POTASSIUM		300.0000			200.0000			mg/l		04/10/90	3	IT	MC
H-18	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		11/10/87	1	IT	SV
H-18	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		04/07/88	2	IT	SV
H-18	CULEBRA	RESIDUE, FILTERABLE @ 180 C		24000.0000		NA	0.0000			mg/l		11/10/87	1	IT	GC
H-18	CULEBRA	RESIDUE, FILTERABLE @ 180 C		27900.0000		NA	0.0000			mg/l		04/07/88	2	IT	GC
H-18	CULEBRA	RESIDUE, FILTERABLE @ 180 C		31000.0000			31000.0000			mg/l		04/10/90	3	IT	GC
H-18	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		25.0000			25.0000			mg/l		11/10/87	1	IT	GC
H-18	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		6.0000		NA	0.0000			mg/l		04/07/88	2	IT	GC
H-18	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000			7.0000			mg/l		04/10/90	3	IT	GC
H-18	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l		11/10/87	1	IT	ME

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H-18	CULEBRA	SELENIUM	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	SELENIUM	<	0.5000	NA		0.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	SILICA		13.0000			12.0000	0.32	0.42	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	SILICA		5.3000			5.3000			mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	SILICA		5.1000	NA		0.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	SILVER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	SILVER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	SILVER	<	0.1000	<		0.1000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	SODIUM		6900.0000			6800.0000			mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	SODIUM		8000.0000			8000.0000			mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	SODIUM		8000.0000			8000.0000			mg/l	04/10/90	3	IT	MC
H-18	CULEBRA	SPECIFIC CONDUCTANCE		36300.0000			36400.0000			umhos/cm@25C	11/10/87	1	IT	GC
H-18	CULEBRA	SPECIFIC CONDUCTANCE		39200.0000			39600.0000			umhos/cm@25C	04/07/88	2	IT	GC
H-18	CULEBRA	SPECIFIC CONDUCTANCE		39300.0000			39300.0000			uMhos/cm@25C	04/10/90	3	IT	GC
H-18	CULEBRA	STRONTIUM		15.0000			15.0000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	STRONTIUM		16.0000			16.0000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	STRONTIUM		15.0000			15.0000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	STYRENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	STYRENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	STYRENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	SULFATE		3700.0000	NA		0.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	SULFATE		3800.0000	NA		0.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	SULFATE		5200.0000	NA		0.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	TETRACHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	TETRACHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	TETRACHLOROETHYLENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	THALLIUM	<	5.0000	<		5.0000	< 0.005	< 0.005	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	THALLIUM	<	5.0000	<		5.0000	< 0.005	< 0.005	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	THALLIUM	<	0.5000	NA		0.0000			mg/l	04/10/90	3	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
H-18	CULEBRA	TITANIUM	<	0.3000	<		0.3000	< 0.03	< 0.03	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	TITANIUM		0.6000			0.6000	< 0.03	< 0.03	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	TITANIUM	<	0.1000	<		0.1000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	TOLUENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	TOLUENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	TOLUENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	TOTAL HARDNESS		0.0000	NA		0.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000	<		1.0000			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	TOTAL ORGANIC CARBON		4.0000			5.0000			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	TOTAL ORGANIC HALOGEN		0.3500			0.4600			mg/l	11/10/87	1	IT	GC
H-18	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	04/07/88	2	IT	GC
H-18	CULEBRA	TOTAL ORGANIC HALOGEN		0.4300			0.4100			mg/l	04/10/90	3	IT	GC
H-18	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	VANADIUM	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	VANADIUM		0.1000			0.2000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	VANADIUM	<	0.5000	<		0.5000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000		T < 10	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000		T < 10	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	11/10/87	1	IT	V

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H-18	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T< 10	M< 10	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	11/10/87	1	IT	V
H-18	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/07/88	2	IT	V
H-18	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T< 5	M< 5	ug/l	04/10/90	3	IT	V
H-18	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/10/87	1	IT	ME
H-18	CULEBRA	ZINC	<	0.1000			0.1000	< 0.01	< 0.01	mg/l	04/07/88	2	IT	ME
H-18	CULEBRA	ZINC	<	0.2000		<	0.2000			mg/l	04/10/90	3	IT	MT
H-18	CULEBRA	pH		5.9700			6.0300				11/10/87	1	IT	GC
H-18	CULEBRA	pH		7.1600			7.2000				04/07/88	2	IT	GC
H-18	CULEBRA	pH		7.5900			7.6000				04/10/90	3	IT	GC
** MOBLEY WELL														
MOBLEY WELL	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	06/16/87	1	IT	HP
MOBLEY WELL	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	04/14/88	2	IT	HP
MOBLEY WELL	CULEBRA	2,4-D	<	0.0050		NA	0.0000			mg/l	06/16/87	1	IT	HP
MOBLEY WELL	CULEBRA	2,4-D	<	0.0050		NA	0.0000			mg/l	04/14/88	2	IT	HP
MOBLEY WELL	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	ALKALINITY (HCO3)		140.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	ALUMINUM		0.2000			0.2000	< 0.1	< 0.1	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	ANTIMONY		0.1200			0.1500	< 0.05	< 0.05	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	ARSENIC		0.0080		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	ARSENIC		0.0050			0.0050	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME

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MOBLEY WELL	CULEBRA	BARIUM		0.0090		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	BARIUM		0.0160			0.0170	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	BORON		1.6000			1.7000	0.03	< 0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	BROMIDE		5.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	BROMOFORM	<	2.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	CADMIUM	<	0.0030		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	CADMIUM	<	0.0100		NA	0.0000	< 0.001	< 0.001	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	CALCIUM		620.0000			610.0000			mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	CESIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	CHLORIDE		450.0000			440.0000			mg/l	06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	CHLORIDE		430.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	CHROMIUM	<	0.0200		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	CHROMIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	COBALT		0.0200			0.0300	< 0.01	< 0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	COLOR		10.0000		NA	0.0000			CU	06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	COPPER		0.0090		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	COPPER		0.0400			0.0500	0.01	0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V

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MOBLEY WELL	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l		06/16/87	1	IT	HP
MOBLEY WELL	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l		04/14/88	2	IT	HP
MOBLEY WELL	CULEBRA	FLUORIDE		2.4000			2.3000			mg/l		06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	FLUORIDE		2.2000		NA	0.0000			mg/l		04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l		04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	IRON		0.0600		NA	0.0000			mg/l		06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	IRON		0.0600			0.0600	0.04	< 0.01	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	LEAD	<	0.0050		NA	0.0000			mg/l		06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	LEAD	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	LINDANE	<	0.0400		NA	0.0000			ug/l		06/16/87	1	IT	HP
MOBLEY WELL	CULEBRA	LINDANE	<	0.0400		NA	0.0000			ug/l		04/14/88	2	IT	HP
MOBLEY WELL	CULEBRA	LITHIUM		0.2000			0.2000	< 0.01	< 0.01	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	LSI CORROSIVITY		1.5700		NA	0.0000					06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	MAGNESIUM		140.0000			140.0000			mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	MANGANESE		0.0030		NA	0.0000			mg/l		06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	MANGANESE		0.0080			0.0090	< 0.005	< 0.005	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	MBAS		0.0500			0.0400			mg/l		06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	MERCURY	<	0.0002		NA	0.0000			mg/l		06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		06/16/87	1	IT	HP
MOBLEY WELL	CULEBRA	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		04/14/88	2	IT	HP
MOBLEY WELL	CULEBRA	MOLYBDENUM	<	10.0000		<	10.0000	< 0.01	< 0.01	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	NICKEL		0.0400			0.0400	< 0.03	< 0.03	mg/l		04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	NITRATE		1.6000		NA	0.0000			mg/l	NO3-N	06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	NITRATE		1.2000		NA	0.0000			mg/l	NO3-N	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	ODOR		1.4000		NA	0.0000			T.O.N.		06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l		06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	04/14/88	2	IT	GC

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MOBLEY WELL	CULEBRA	POTASSIUM		10.0000			10.0000			mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3800.0000		NA	0.0000			mg/l	06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		3800.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	SELENIUM		0.0030		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	SELENIUM		0.0110		NA	0.0000	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	SILICA		19.0000		NA	0.0000			mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	SILVER	<	0.0060		NA	0.0000			mg/l	06/16/87	1	IT	ME
MOBLEY WELL	CULEBRA	SILVER	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	SODIUM		280.0000			280.0000			mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	SPECIFIC CONDUCTANCE		4530.0000		NA	0.0000			umhos/cm@25C	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	STRONTIUM		9.1000			9.2000	< 0.01	< 0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	SULFATE		1900.0000			2000.0000			mg/l	06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	SULFATE		2100.0000		NA	0.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	TITANIUM		0.3000			0.3300	< 0.03	< 0.03	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	04/14/88	2	IT	GC
MOBLEY WELL	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	06/16/87	1	IT	HP
MOBLEY WELL	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	04/14/88	2	IT	HP
MOBLEY WELL	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	TURBIDITY		2.7700			2.7400			NTU	06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	VANADIUM		0.0800			0.0900	< 0.01	< 0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	VINYL CHLORIDE	<	1.0000		NA	0.0000			ug/l	06/16/87	1	IT	V
MOBLEY WELL	CULEBRA	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	04/14/88	2	IT	V
MOBLEY WELL	CULEBRA	ZINC		0.0210		NA	0.0000			mg/l	06/16/87	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
MOBLEY WELL	CULEBRA	ZINC	<	0.0100			0.0100	< 0.01	< 0.01	mg/l	04/14/88	2	IT	ME
MOBLEY WELL	CULEBRA	pH		7.3700		NA	0.0000				06/16/87	1	IT	GC
MOBLEY WELL	CULEBRA	pH		7.1000		NA	0.0000				04/14/88	2	IT	GC
** P-14														
P-14	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-14	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV

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P-14	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2-BUTANONE		10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	2-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV

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P-14	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV

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P-14	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	ACETONE		27.0000		NA	0.0000		T 46	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	ACETONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	ALKALINITY (HCO3)		100.0000		NA	0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	ALKALINITY (HCO3)		100.0000			100.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	ALKALINITY (HCO3)		100.0000		NA	0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	ALUMINUM	<	0.1000		<	0.1000	< 0.10	< 0.10	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	ANTIMONY		0.8900			0.8900	< 0.05	< 0.05	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	ARSENIC	<	0.1000		<	0.1000	< 0.001	< 0.001	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	ARSENIC	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/16/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-14	CULEBRA	BARIUM	<	0.1000	<		0.1000	< 0.10	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	BARIUM		0.0760			0.0790	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	BARIUM	<	0.1000	<		0.0100	0.01	0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	BENZENE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	BENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	BENZENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BERYLLIUM		0.0060			0.0070	< 0.005	< 0.005	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	BERYLLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV

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P-14	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	BORON		0.7000			0.6000	< 0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	BORON		0.8200			0.8200	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	BORON		0.7000			0.7000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	BROMIDE		24.0000			24.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	BROMIDE		17.0000		NA	0.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	BROMIDE		16.0000		NA	0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	CADMIUM		0.0580			0.0660	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	CADMIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	CALCIUM		3900.0000			3900.0000			mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	CALCIUM		3500.0000		NA	0.0000			mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	CALCIUM		3400.0000			3400.0000			mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V

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P-14	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	CESIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	CESIUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	CESIUM	<	0.0200		<	0.0200	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	CHLORIDE		14000.0000		NA	0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	CHLORIDE		15000.0000			15000.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	CHLORIDE		14300.0000		NA	0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	CHROMIUM		0.0800			0.0800	< 0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	CHROMIUM		0.3900			0.4200	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	COBALT		0.6200			0.6300	0.03	0.01	mg/l	02/27/86	1	IT	ME

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P-14	CULEBRA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	COBALT	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	COPPER		0.0800			0.0700	< 0.01	0.02	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	COPPER		0.1100			0.1300	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	COPPER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	CYANIDE	<	0.0200	<		0.0200			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	03/16/88	3	IT	SV

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P-14	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	Eh		446.0000			441.0000			mV	02/27/86	1	IT	GC
P-14	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	FLUORIDE		1.2000		NA	0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	FLUORIDE		1.4000			1.4000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	FLUORIDE		1.2000		NA	0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-14	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	IRON		1.6000			1.7000	0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	IRON		2.0000			2.1000	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	IRON		1.7000			1.8000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	SV
P-14	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	06/18/87	2	IT	SV
P-14	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/16/88	3	IT	SV
P-14	CULEBRA	LEAD		0.5400			0.5500	0.02	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	LEAD		0.6500			0.6800	< 0.05	< 0.05	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	LITHIUM		2.7000			2.7000	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	LITHIUM		0.5000			0.5100	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	MAGNESIUM		760.0000			760.0000			mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	MAGNESIUM		910.0000			890.0000			mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	MAGNESIUM		880.0000			870.0000			mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	MANGANESE		0.2300			0.2300	< 0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	MANGANESE		0.3000			0.3000	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	MANGANESE		0.3100			0.3000	< 0.005	< 0.005	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	MERCURY	<	0.0002			0.0002	< 0.0002	< 0.0002	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	02/27/86	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
P-14	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		06/18/87	2	IT	V
P-14	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l		03/16/88	3	IT	V
P-14	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	V
P-14	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l		06/18/87	2	IT	V
P-14	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T 31	T 32	ug/l		03/16/88	3	IT	V
P-14	CULEBRA	MOLYBDENUM		0.0400			0.0500	< 0.01	< 0.01	mg/l		02/27/86	1	IT	ME
P-14	CULEBRA	MOLYBDENUM		0.1100			0.1200	0.03	0.02	mg/l		06/18/87	2	IT	ME
P-14	CULEBRA	MOLYBDENUM		0.0800			0.0700	0.01	0.01	mg/l		03/16/88	3	IT	ME
P-14	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	NICKEL		0.3100			0.3100	< 0.01	< 0.01	mg/l		02/27/86	1	IT	ME
P-14	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		06/18/87	2	IT	ME
P-14	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		03/16/88	3	IT	ME
P-14	CULEBRA	NITRATE		0.2000		NA	0.0000			mg/l	NO3-N	02/27/86	1	IT	GC
P-14	CULEBRA	NITRATE		0.6000		NA	0.0000			mg/l	NO3-N	06/18/87	2	IT	GC
P-14	CULEBRA	NITRATE		0.0300		NA	0.0000			mg/l	NO3-N	03/16/88	3	IT	GC
P-14	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
P-14	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		06/18/87	2	IT	PC
P-14	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		03/16/88	3	IT	PC
P-14	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	PHENOLICS		0.0190		NA	0.0000			mg/l		02/27/86	1	IT	GC
P-14	CULEBRA	PHENOLICS		0.0170		NA	0.0000			mg/l		06/18/87	2	IT	GC
P-14	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		03/16/88	3	IT	GC
P-14	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	02/27/86	1	IT	GC
P-14	CULEBRA	PHOSPHATE		0.0200			0.0200			mg/l	T-PO4-P	06/18/87	2	IT	GC
P-14	CULEBRA	PHOSPHATE	<	0.0200		<	0.0200			mg/l	T-PO4-P	03/16/88	3	IT	GC
P-14	CULEBRA	POTASSIUM		44.0000			45.0000			mg/l		02/27/86	1	IT	ME
P-14	CULEBRA	POTASSIUM		50.0000		NA	0.0000			mg/l		06/18/87	2	IT	ME
P-14	CULEBRA	POTASSIUM		48.0000			48.0000			mg/l		03/16/88	3	IT	ME
P-14	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		02/27/86	1	IT	SV
P-14	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		06/18/87	2	IT	SV
P-14	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		03/16/88	3	IT	SV
P-14	CULEBRA	RESIDUE, FILTERABLE @ 180 C		26000.0000			26000.0000			mg/l		02/27/86	1	IT	GC
P-14	CULEBRA	RESIDUE, FILTERABLE @ 180 C		29000.0000			29000.0000			mg/l		06/18/87	2	IT	GC
P-14	CULEBRA	RESIDUE, FILTERABLE @ 180 C		29400.0000			28800.0000			mg/l		03/16/88	3	IT	GC
P-14	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		95.0000		NA	0.0000			mg/l		02/27/86	1	IT	GC
P-14	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		38.0000			49.0000			mg/l		06/18/87	2	IT	GC
P-14	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l		03/16/88	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-14	CULEBRA	SELENIUM	<	0.1000		<	0.1000	< 0.001	< 0.001	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	SILICA		32.0000			31.0000	< 0.2	0.6	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	SILICA		33.0000			33.0000	< 0.2	< 0.2	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	SILICA		14.0000			14.0000			mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	SILVER		0.2600			0.2600	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	SODIUM		3700.0000			3800.0000			mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	SODIUM		4100.0000		NA	0.0000			mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	SODIUM		4600.0000			4600.0000			mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	SPECIFIC CONDUCTANCE		42300.0000		NA	0.0000			umhos/cm@25C	02/27/86	1	IT	GC
P-14	CULEBRA	SPECIFIC CONDUCTANCE		37600.0000			37900.0000			umhos/cm@25C	06/18/87	2	IT	GC
P-14	CULEBRA	SPECIFIC CONDUCTANCE		36000.0000			36000.0000			umhos/cm@25C	03/16/88	3	IT	GC
P-14	CULEBRA	STRONTIUM		48.0000			47.0000	< 0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	STRONTIUM		47.0000			48.0000	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	STRONTIUM		55.0000			55.0000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	SULFATE		1700.0000			1500.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	SULFATE		1400.0000		NA	0.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	SULFATE		1600.0000		NA	0.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	THALLIUM	<	5.0000		<	5.0000	< 0.005	< 0.005	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	THALLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	TIN		0.5600			0.4600	< 0.04	< 0.04	mg/l	06/18/87	2	IT	ME

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P-14	CULEBRA	TITANIUM	<	0.1000	<		0.1000	< 0.1	< 0.1	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	TITANIUM		0.6800			0.6800	< 0.3	< 0.3	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	TITANIUM		0.5000			0.6000	< 0.03	< 0.03	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	TOLUENE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	TOLUENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	TOLUENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	TOTAL ORGANIC CARBON		2.0000	NA		0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	TOTAL ORGANIC CARBON		1.0000			2.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	TOTAL ORGANIC CARBON		2.0000			1.0000			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	TOTAL ORGANIC HALOGEN		0.7600	NA		0.0000			mg/l	02/27/86	1	IT	GC
P-14	CULEBRA	TOTAL ORGANIC HALOGEN		1.0000			2.0000			mg/l	06/18/87	2	IT	GC
P-14	CULEBRA	TOTAL ORGANIC HALOGEN		0.2500			0.4100			mg/l	03/16/88	3	IT	GC
P-14	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	TRICHLOROETHYLENE	<	5.0000	NA		0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	VANADIUM		0.2300			0.2400	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	VANADIUM	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	VINYL ACETATE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	VINYL CHLORIDE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	03/16/88	3	IT	V

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P-14	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	02/27/86	1	IT	V
P-14	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	06/18/87	2	IT	V
P-14	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/16/88	3	IT	V
P-14	CULEBRA	ZINC		0.1000			0.1000	< 0.01	< 0.01	mg/l	02/27/86	1	IT	ME
P-14	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	06/18/87	2	IT	ME
P-14	CULEBRA	ZINC		0.2000			0.1000	< 0.01	< 0.01	mg/l	03/16/88	3	IT	ME
P-14	CULEBRA	pH		7.0100		NA	0.0000				02/27/86	1	IT	GC
P-14	CULEBRA	pH		6.7500			6.8000				06/18/87	2	IT	GC
P-14	CULEBRA	pH		6.6800			6.7200				03/16/88	3	IT	GC
** P-17														
P-17	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-17	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV

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P-17	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV

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P-17	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V

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P-17	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	ALKALINITY (HCO3)		54.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	ALKALINITY (HCO3)		53.0000			53.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	ALKALINITY (HCO3)		54.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	ALUMINUM		1.0000		<	1.0000	< 0.1/<0	< 0.10	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	ALUMINUM		2.0000		NA	0.0000	< 0.1	< 0.1	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	ALUMINUM		1.0000			1.0000	< 0.1	< 0.1	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV

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P-17	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	ANTIMONY		1.4000		NA	0.0000	< 0.05	< 0.05	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	ANTIMONY		1.5000			1.4000	< 0.05	< 0.05	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	ARSENIC		0.3200			0.2900	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	ARSENIC		0.1700		NA	0.0000	< 0.005	< 0.005	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	ARSENIC	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	BARIUM		0.0600			0.0500	< 0.05	< 0.05	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	BARIUM		0.1100		NA	0.0000	0.008	0.007	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	BARIUM		0.0600			0.0600	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-17	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	BORON		36.0000			35.0000	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	BORON		32.0000		NA	0.0000	0.02	0.02	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	BORON		36.0000			36.0000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	BROMIDE		97.0000			100.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	BROMIDE		69.0000		NA	0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	BROMIDE		84.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	CADMIUM		0.1000		NA	0.0000	< 0.005	< 0.005	mg/l	12/18/86	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-17	CULEBRA	CADMIUM		0.1200			0.1200	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	CALCIUM		1700.0000			1600.0000			mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	CALCIUM		2400.0000			2400.0000			mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	CALCIUM		1600.0000			1600.0000			mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.10	< 0.10	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	CESIUM		0.6000		NA	0.0000	< 0.1	< 0.1	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	CESIUM		0.1800			0.1600	0.03	0.04	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	CHLORIDE		51000.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	CHLORIDE		60000.0000			60000.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	CHLORIDE		47000.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	CHROMIUM		0.4000			0.3700	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	CHROMIUM		0.6000		NA	0.0000	0.02	0.02	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	CHROMIUM		0.6000			0.6000	< 0.01	0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV

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P-17	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	COBALT		0.1300			0.1100	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	COBALT		0.2000		NA	0.0000	< 0.01	< 0.01	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	COBALT		0.2000			0.2000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	COPPER		0.1400			0.1200	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	COPPER		0.5000		NA	0.0000	0.03	0.03	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	COPPER		0.2000			0.2000	0.01	0.02	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	CYANIDE	<	0.0400		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V

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P-17	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	Eh		426.0000		NA	0.0000			mV	03/17/86	1	IT	GC
P-17	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	FLUORIDE		1.2000			1.2000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	FLUORIDE		1.4000		NA	0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	FLUORIDE		1.1000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV

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P-17	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	IODIDE		7.3000			7.3000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	IRON		3.9000			3.8000	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	IRON		2.8000		NA	0.0000	< 0.01	< 0.01	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	IRON		3.3000			3.3000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	LEAD		1.1000			1.0000	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	LEAD		1.1000		NA	0.0000	0.05	< 0.05	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	LEAD		1.1000			1.1000	< 0.05	< 0.05	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	LITHIUM		0.6600		NA	0.0000	< 0.01	0.02	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	LITHIUM		0.9000			0.9000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	MAGNESIUM		1600.0000			1500.0000			mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	MAGNESIUM		1600.0000			1600.0000			mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	MAGNESIUM		1800.0000			1800.0000			mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	MANGANESE		0.7900			0.8100	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	MANGANESE		0.9000		NA	0.0000	< 0.005	< 0.005	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	MANGANESE		1.2000			1.2000	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	03/17/86	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-17	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	0.0003	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	MOLYBDENUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	MOLYBDENUM		0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	MOLYBDENUM		0.2000			0.2200	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	SV
P-17	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	SV
P-17	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l	10/21/87	3	IT	SV
P-17	CULEBRA	NICKEL		1.1000			1.1000	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	NICKEL		0.3000		<	0.3000	< 0.03	< 0.03	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	NITRATE		0.3000		NA	0.0000			mg/l NO3-N	03/17/86	1	IT	GC
P-17	CULEBRA	NITRATE		0.1000			0.2000			mg/l NO3-N	12/18/86	2	IT	GC
P-17	CULEBRA	NITRATE	<	0.2000		NA	0.0000			mg/l NO3-N	10/21/87	3	IT	GC

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P-17	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		03/17/86	1	IT	SV
P-17	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		12/18/86	2	IT	SV
P-17	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		10/21/87	3	IT	SV
P-17	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		03/17/86	1	IT	SV
P-17	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		12/18/86	2	IT	SV
P-17	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		10/21/87	3	IT	SV
P-17	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		12/18/86	2	IT	PC
P-17	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		10/21/87	3	IT	PC
P-17	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		03/17/86	1	IT	SV
P-17	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		12/18/86	2	IT	SV
P-17	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		10/21/87	3	IT	SV
P-17	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		03/17/86	1	IT	SV
P-17	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		12/18/86	2	IT	SV
P-17	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		10/21/87	3	IT	SV
P-17	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		03/17/86	1	IT	SV
P-17	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		12/18/86	2	IT	SV
P-17	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		10/21/87	3	IT	SV
P-17	CULEBRA	PHENOLICS		0.0040			0.0020			mg/l		03/17/86	1	IT	GC
P-17	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		12/18/86	2	IT	GC
P-17	CULEBRA	PHENOLICS		0.0050		NA	0.0000			mg/l		10/21/87	3	IT	GC
P-17	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	03/17/86	1	IT	GC
P-17	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	12/18/86	2	IT	GC
P-17	CULEBRA	PHOSPHATE		0.0200		NA	0.0000			mg/l	T-PO4-P	10/21/87	3	IT	GC
P-17	CULEBRA	POTASSIUM		800.0000			790.0000			mg/l		03/17/86	1	IT	ME
P-17	CULEBRA	POTASSIUM		1200.0000			1200.0000			mg/l		12/18/86	2	IT	ME
P-17	CULEBRA	POTASSIUM		930.0000			910.0000			mg/l		10/21/87	3	IT	ME
P-17	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		03/17/86	1	IT	SV
P-17	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		12/18/86	2	IT	SV
P-17	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		10/21/87	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-17	CULEBRA	RESIDUE, FILTERABLE @ 180 C		88000.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	RESIDUE, FILTERABLE @ 180 C		90000.0000			90000.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	RESIDUE, FILTERABLE @ 180 C		84000.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		340.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		160.0000			200.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		22.0000			25.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	SELENIUM	<	1.0000		NA	0.0000	< 0.001	< 0.001	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	SELENIUM		0.0330		NA	0.0000	< 0.005	< 0.005	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	SELENIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	SILICA	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	SILICA		13.0000		NA	0.0000	0.3	0.3	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	SILICA		13.0000			13.0000	< 0.2	< 0.2	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	SILVER		0.3000		NA	0.0000	0.01	0.02	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	SILVER		0.2000			0.2000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	SODIUM		29000.0000			29000.0000			mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	SODIUM		28000.0000			28000.0000			mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	SODIUM		29000.0000			29000.0000			mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	SPECIFIC CONDUCTANCE		120000.0000		NA	0.0000			umhos/cm@25C	03/17/86	1	IT	GC
P-17	CULEBRA	SPECIFIC CONDUCTANCE		104000.0000			104000.0000			umhos/cm@25C	12/18/86	2	IT	GC
P-17	CULEBRA	SPECIFIC CONDUCTANCE		142000.0000			141000.0000			umhos/cm@25C	10/21/87	3	IT	GC
P-17	CULEBRA	STRONTIUM		28.0000			28.0000	0.01	0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	STRONTIUM		36.0000		NA	0.0000	0.01	0.01	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	STRONTIUM		36.0000			36.0000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	SULFATE		6400.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	SULFATE		7100.0000			7300.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	SULFATE		5500.0000		NA	0.0000			mg/l	10/21/87	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
P-17	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	TITANIUM		0.4000		NA	0.0000	< 0.1	< 0.1	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	TITANIUM		1.0000		NA	0.0000	< 0.03	< 0.03	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	TITANIUM		1.0000			0.9000	< 0.03	< 0.03	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	TOTAL ORGANIC HALOGEN		0.2300		NA	0.0000			mg/l	03/17/86	1	IT	GC
P-17	CULEBRA	TOTAL ORGANIC HALOGEN		1.8000		NA	0.0000			mg/l	12/18/86	2	IT	GC
P-17	CULEBRA	TOTAL ORGANIC HALOGEN		2.1000			2.9000			mg/l	10/21/87	3	IT	GC
P-17	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	VANADIUM		0.3000			0.3000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V

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P-17	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	03/17/86	1	IT	V
P-17	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	12/18/86	2	IT	V
P-17	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	10/21/87	3	IT	V
P-17	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/17/86	1	IT	ME
P-17	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	12/18/86	2	IT	ME
P-17	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	10/21/87	3	IT	ME
P-17	CULEBRA	pH		7.0200		NA	0.0000				03/17/86	1	IT	GC
P-17	CULEBRA	pH		7.0100		NA	0.0000				12/18/86	2	IT	GC
P-17	CULEBRA	pH		6.2400			6.3300				10/21/87	3	IT	GC
** POKER TRAP WINDMILL														
POKER TRAP WINDMILL	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	12/19/87	1	IT	HP
POKER TRAP WINDMILL	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	07/07/88	2	IT	HP
POKER TRAP WINDMILL	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
POKER TRAP WINDMILL	CULEBRA	2,4-D	<	0.0050		NA		0.0000		mg/l	12/19/87	1	IT	HP
POKER TRAP WINDMILL	CULEBRA	2,4-D	<	0.0050		NA		0.0000		mg/l	07/07/88	2	IT	HP
POKER TRAP WINDMILL	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2-METHYLPHENOL	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2-NITROANILINE	<	50.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	2-NITROPHENOL	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	3-NITROANILINE	<	50.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4-CHLOROANILINE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4-METHYLPHENOL	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4-NITROANILINE	<	50.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	4-NITROPHENOL	<	50.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	ACENAPHTHENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA		0.0000		ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	ALKALINITY (CO3)		0.0000		NA		0.0000		mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	ALKALINITY (CO3)		0.0000		NA		0.0000		mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	ALKALINITY (HCO3)		100.0000		NA		0.0000		mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	ALKALINITY (HCO3)		79.0000		NA		0.0000		mg/l	07/07/88	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
POKER TRAP WINDMILL	CULEBRA	ALUMINUM	<	0.5000	<		0.5000	< 0.1	< 0.1	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	ALUMINUM	<	0.1000			0.2000	< 0.10	< 0.10	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	ANTIMONY	<	0.2500	<		0.2500	< 0.05	< 0.05	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	ANTIMONY	<	0.0500			0.1500	< 0.05	< 0.05	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	ANTIMONY		0.0500			0.1000	< 0.05	< 0.05	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	BARIUM	<	0.0250	<		0.0250	< 0.005	< 0.005	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	BARIUM		0.0100			0.0210	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	BARIUM		0.0100			0.0150	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BERYLLIUM	<	0.0250	<		0.0250	< 0.005	< 0.005	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	BERYLLIUM	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	BERYLLIUM	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	BORON		0.2000			0.2100	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	BORON		0.3400			0.3600	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	BROMIDE	<	2.0000	<		2.0000			mg/l	12/19/87	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
POKER TRAP WINDMILL	CULEBRA	BROMIDE	<	2.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	CADMIUM	<	0.0250		<	0.0250	< 0.005	< 0.005	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	CADMIUM	<	0.0050			0.0230	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	CADMIUM	<	0.0050			0.0080	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	CALCIUM		420.0000			410.0000			mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	CALCIUM		450.0000			420.0000			mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	CESIUM		0.0100			0.0100	0.01	0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	CHLORIDE		24.0000		NA	0.0000			mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	CHLORIDE		31.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	CHROMIUM	<	0.0500			0.0700	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	CHROMIUM		0.0300			0.1500	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	CHROMIUM		0.0300			0.0600	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	COBALT	<	0.0500		<	0.0500	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	COBALT	<	0.0100			0.0500	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	COLOR		60.0000		NA	0.0000			CU	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	COLOR	<	1.0000		NA	0.0000			CU	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	COPPER	<	0.0500		<	0.0500	0.01	0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	COPPER	<	0.0100			0.0700	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	COPPER	<	0.0100			0.0300	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
POKER TRAP WINDMILL	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l	12/19/87	1	IT	HP
POKER TRAP WINDMILL	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l	07/07/88	2	IT	HP
POKER TRAP WINDMILL	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	FLUORIDE		0.9000		NA	0.0000			mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	FLUORIDE		2.9000		NA	0.0000			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	IRON	<	0.0500		<	0.0500	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	IRON		0.0200			0.0500	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	IRON		0.0200			0.0300	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	LEAD	<	0.2500		<	0.2500	< 0.05	< 0.05	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	LEAD		0.0900		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	LEAD	<	0.0050		<	0.0500	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME

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POKER TRAP WINDMILL	CULEBRA	LINDANE	<	0.0400		NA	0.0000			ug/l		12/19/87	1	IT	HP
POKER TRAP WINDMILL	CULEBRA	LINDANE	<	0.0400		NA	0.0000			ug/l		07/07/88	2	IT	HP
POKER TRAP WINDMILL	CULEBRA	LITHIUM		0.1200			0.1200	< 0.01	< 0.01	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	LITHIUM		0.0800			0.0800	< 0.01	< 0.01	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	LSI CORROSIVITY		-0.2500		NA	0.0000					12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	LSI CORROSIVITY		0.1000		NA	0.0000			--		07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	MAGNESIUM		82.0000			82.0000			mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	MAGNESIUM		82.0000			72.0000			mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	MAGNESIUM		81.0000			71.0000			mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	MANGANESE		0.0470			0.0480	< 0.005	< 0.005	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	MANGANESE		0.0100			0.0110	< 0.005	< 0.005	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	MANGANESE		0.0090			0.0150	< 0.005	< 0.005	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	MBAS	<	0.0250		NA	0.0000			mg/l		12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	MBAS	<	0.0250		NA	0.0000			mg/l		07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	MERCURY		0.0008			0.0009	0.0008	0.0007	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	MERCURY		0.0007		NA	0.0000	< 0.0002	< 0.0002	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		12/19/87	1	IT	HP
POKER TRAP WINDMILL	CULEBRA	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		07/07/88	2	IT	HP
POKER TRAP WINDMILL	CULEBRA	MOLYBDENUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	MOLYBDENUM	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	NICKEL	<	0.1500		<	0.1500	< 0.03	< 0.03	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	NICKEL	<	0.0300		<	0.0300	< 0.03	< 0.03	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	NICKEL	<	0.0300			0.0700	< 0.03	< 0.03	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	NITRATE		2.9000		NA	0.0000			mg/l	NO3-N	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	NITRATE		2.4000			2.3000			mg/l	NO3-N	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
POKER TRAP WINDMILL	CULEBRA	ODOR		9.0000		NA	0.0000			T.O.N.		12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	ODOR		1.0000		NA	0.0000			T.O.N.		07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		07/07/88	2	IT	PC
POKER TRAP WINDMILL	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	PHENOLICS		0.0240		NA	0.0000			mg/l		12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	PHENOLICS		0.0730			0.0630			mg/l		07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	PHOSPHATE		0.0700		NA	0.0000			mg/l	T-PO4-P	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	PHOSPHATE		0.0400		NA	0.0000			mg/l	T-PO4-P	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	POTASSIUM		3.2000			3.2000			mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	POTASSIUM		3.7000			3.7000			mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
POKER TRAP WINDMILL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		2200.0000		NA	0.0000			mg/l		12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	RESIDUE, FILTERABLE @ 180 C		2200.0000			2200.0000			mg/l		07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		160.0000			130.0000			mg/l		12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		19.0000			13.0000			mg/l		07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	SELENIUM		0.0090		NA	0.0000	< 0.005	< 0.005	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	SILICA		27.0000			26.0000	< 0.2	< 0.2	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	SILICA		14.0000		NA	0.0000			mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	SILVER	<	0.0500		<	0.0500	< 0.01	< 0.01	mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	SILVER		0.0100			0.0100	< 0.01	< 0.01	mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	SODIUM		43.0000			43.0000			mg/l		12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	SODIUM		420.0000			420.0000			mg/l		07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	SPECIFIC CONDUCTANCE		2400.0000		NA	0.0000			umhos/cm@25C		12/19/87	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
POKER TRAP WINDMILL	CULEBRA	SPECIFIC CONDUCTANCE		2450.0000			2470.0000			umhos/cm@25C	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	STRONTIUM		4.6000			4.7000	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	STRONTIUM		4.9000			4.9000	0.01	0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	SULFATE		1400.0000		NA	0.0000			mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	SULFATE		1300.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	THALLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	TITANIUM		0.3400			0.3800	< 0.03	< 0.03	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	TITANIUM		0.1500			0.6300	< 0.03	< 0.03	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	TITANIUM		0.2900			0.4000	< 0.03	< 0.03	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	TOTAL ORGANIC CARBON		1.0000			1.0000			mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	12/19/87	1	IT	HP
POKER TRAP WINDMILL	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	07/07/88	2	IT	HP
POKER TRAP WINDMILL	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	TURBIDITY		40.0000		NA	0.0000			NTU	12/19/87	1	IT	GC
POKER TRAP WINDMILL	CULEBRA	TURBIDITY		1.0000		NA	0.0000			NTU	07/07/88	2	IT	GC
POKER TRAP WINDMILL	CULEBRA	VANADIUM	<	0.0500		<	0.0500	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	VANADIUM		0.0200			0.0600	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	12/19/87	1	IT	V
POKER TRAP WINDMILL	CULEBRA	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	07/07/88	2	IT	V
POKER TRAP WINDMILL	CULEBRA	ZINC		0.9200			0.9100	< 0.01	< 0.01	mg/l	12/19/87	1	IT	ME
POKER TRAP WINDMILL	CULEBRA	ZINC		0.0500			0.0600	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
POKER TRAP WINDMILL	CULEBRA	pH		7.0900		NA	0.0000				12/19/87	1	IT	GC

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POKER TRAP WINDMILL	CULEBRA	pH		7.4500		NA	0.0000			--	07/07/88	2	IT	GC
** RANCH WELL														
RANCH WELL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	12/20/87	2	IT	HP
RANCH WELL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	04/20/88	3	IT	HP
RANCH WELL	DEWEY LAKE	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	12/20/87	2	IT	HP
RANCH WELL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	04/20/88	3	IT	HP
RANCH WELL	DEWEY LAKE	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV

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RANCH WELL	DEWEY LAKE	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	ACETONE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	ALKALINITY (CO3)		0.0000			0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	06/20/90	5	IT	GC

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RANCH WELL	DEWEY LAKE	ALKALINITY (HCO3)		220.0000			220.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	ALKALINITY (HCO3)		250.0000			250.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	ALKALINITY (HCO3)		240.0000			240.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	ALKALINITY (HCO3)		230.0000			230.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	ALUMINUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	ALUMINUM	<	0.2000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	ALUMINUM	<	2.0000		<	2.0000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	ANTIMONY		0.1500			0.1600	< 0.05	< 0.05	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	ANTIMONY		0.1000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	ANTIMONY		0.1100			0.1100			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	ARSENIC		0.0040			0.0030	< 0.001	< 0.001	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	ARSENIC	<	0.0100		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	ARSENIC	<	0.0100		NA	0.0000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	BARIUM		0.0100			0.0100	< 0.005	< 0.005	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	BARIUM		0.0140			0.0150	< 0.005	< 0.005	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	BARIUM		0.0070			0.0070	< 0.005	< 0.005	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	BARIUM	<	0.2000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	BARIUM	<	0.2000		<	0.2000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	BENZENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
RANCH WELL	DEWEY LAKE	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	BORON		0.2000			0.1800	0.04	0.04	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	BORON		0.1900			0.1800	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	BORON		0.2100		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	BORON		0.3300			0.3200			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	BROMIDE		2.3000		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	BROMIDE		3.0000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	BROMIDE	<	2.0000		<	2.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	BROMIDE	<	2.0000			0.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	BROMOFORM	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	CADMIUM		0.0080			0.0100	< 0.005	< 0.005	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	CADMIUM		0.0090		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	CADMIUM		0.0090			0.0100			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	CALCIUM		390.0000			340.0000			mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	CALCIUM		340.0000			330.0000			mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	CALCIUM		320.0000		NA	0.0000			mg/l	07/27/89	4	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
RANCH WELL	DEWEY LAKE	CALCIUM		550.0000			550.0000			mg/l	06/20/90	5	IT	MC
RANCH WELL	DEWEY LAKE	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	CESIUM		0.1000			0.1000	0.1	0.1	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	CESIUM		0.0300			0.0300	0.02	0.02	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	CESIUM	<	0.1000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	CESIUM	<	0.2000		<	0.2000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	CHLORIDE		390.0000			390.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	CHLORIDE		470.0000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	CHLORIDE		440.0000		NA	0.0000			mg/l	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	CHLORIDE		330.0000		NA	0.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	CHLORIDE		340.0000			0.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	CHLOROFORM		1.5000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	CHROMIUM		0.0200			0.0400	< 0.01	< 0.01	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	CHROMIUM		0.0400			0.0500	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	CHROMIUM		0.0400			0.0600	< 0.01	< 0.01	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	CHROMIUM		0.0700		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	CHROMIUM	<	0.0100			0.0100			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	CHRYSENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	COBALT	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	COBALT		0.0100			0.0200	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	COBALT	<	0.0500		NA	0.0000			mg/l	07/27/89	4	IT	MT

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RANCH WELL	DEWEY LAKE	COBALT	<	0.0500	<	0.0500				mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	COLOR	<	1.0000	NA	0.0000				CU	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	COLOR	<	1.0000	NA	0.0000				CU	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	COPPER	<	0.0100		0.0200	< 0.01		< 0.01	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	COPPER	<	0.0100		0.0100	0.01		< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	COPPER	<	0.0100	<	0.0100	< 0.01		< 0.01	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	COPPER	<	0.0250	<	0.0250				mg/l	06/20/90	4	IT	MT
RANCH WELL	DEWEY LAKE	COPPER	<	0.0250	NA	0.0000				mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	CYANIDE	<	0.0200	NA	0.0000				mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	CYANIDE	<	0.0100	NA	0.0000				mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	CYANIDE	<	0.0100		0.0000				mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	DI-N-BUTYL PHTHALATE		11.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	DI-N-OCTYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	DIBENZOFURAN	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	5.0000	NA	0.0000				ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	5.0000	NA	0.0000				ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000	NA	0.0000			T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	DIETHYL PHTHALATE		24.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	DIMETHYL PHTHALATE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	ENDRIN	<	0.0200	NA	0.0000				ug/l	12/20/87	2	IT	HP
RANCH WELL	DEWEY LAKE	ENDRIN	<	0.0200	NA	0.0000				ug/l	04/20/88	3	IT	HP
RANCH WELL	DEWEY LAKE	ETHYLBENZENE	<	5.0000	NA	0.0000				ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	FLUORANTHENE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	FLUORENE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	FLUORIDE		1.0000		1.0000				mg/l	06/18/86	1	IT	GC

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RANCH WELL	DEWEY LAKE	FLUORIDE		1.7000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	FLUORIDE		0.9000		NA	0.0000			mg/l	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	FLUORIDE		1.0000			1.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	FLUORIDE		1.0000			0.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	IODIDE		0.9600		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	IODIDE	<	2.0000		<	2.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	IODIDE	<	2.0000		<	2.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	IODIDE	<	2.0000		<	2.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	IRON		0.0200			0.0200	< 0.01	< 0.01	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	IRON		0.0300			0.0400	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	IRON	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	IRON	<	0.1000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	IRON	<	0.1000		<	0.1000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	LANGELIER SATURATION INDEX		0.1700		NA	0.0000				06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	LEAD	<	0.0500			0.0700	< 0.05	< 0.05	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	LEAD		0.0700			0.0900	< 0.05	< 0.05	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	LEAD	<	0.0500		<	0.0800	< 0.05	< 0.05	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	LEAD		0.0700		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	LEAD		0.0600			0.0600			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	LINDANE	<	0.0400		NA	0.0000			ug/l	12/20/87	2	IT	HP
RANCH WELL	DEWEY LAKE	LINDANE	<	0.0400		NA	0.0000			ug/l	04/20/88	3	IT	HP
RANCH WELL	DEWEY LAKE	LITHIUM		0.0220			0.0220	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	LITHIUM		12.0000		NA	0.0000			mg/l	07/27/89	4	IT	MT

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RANCH WELL	DEWEY LAKE	LITHIUM	<	0.1000	<	0.1000				mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	LSI CORROSIVITY		-0.2200	NA	0.0000					12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	LSI CORROSIVITY		0.0200	NA	0.0000					04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	MAGNESIUM		200.0000		180.0000				mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	MAGNESIUM		230.0000		230.0000				mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	MAGNESIUM		180.0000	NA	0.0000				mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	MAGNESIUM		150.0000		150.0000				mg/l	06/20/90	5	IT	MC
RANCH WELL	DEWEY LAKE	MANGANESE	<	0.0050	<	0.0050	< 0.005		< 0.005	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	MANGANESE	<	0.0050	<	0.0050	< 0.005		< 0.005	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	MANGANESE	<	0.0050	<	0.0050	< 0.005		< 0.005	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	MANGANESE	<	0.0150	NA	0.0000				mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	MANGANESE	<	0.0150	<	0.0150				mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	MBAS		0.0400		0.0300				mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	MBAS		0.0700		0.0500				mg/l	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	MERCURY	<	0.0002		0.0004	< 0.0002		< 0.0002	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	MERCURY		0.0007		0.0008	0.0003		< 0.0002	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	MERCURY	<	0.0002	<	0.0002	< 0.0002		< 0.0002	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	MERCURY	<	0.0002	NA	0.0000				mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	MERCURY	<	0.0002	<	0.0002				mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	METHOXYCHLOR	<	0.0010	NA	0.0000				mg/l	12/20/87	2	IT	HP
RANCH WELL	DEWEY LAKE	METHOXYCHLOR	<	0.0010	NA	0.0000				mg/l	04/20/88	3	IT	HP
RANCH WELL	DEWEY LAKE	METHYL BROMIDE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	METHYL CHLORIDE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	METHYLENE CHLORIDE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	MOLYBDENUM	<	0.0100	<	0.0100	< 0.01		< 0.01	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	MOLYBDENUM		0.0200		0.0200	< 0.01		< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	MOLYBDENUM		0.0300	NA	0.0000				mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	MOLYBDENUM		0.0400		0.0400				mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA	0.0000				ug/l	06/18/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
RANCH WELL	DEWEY LAKE	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	NICKEL	<	0.0300		<	0.0300	< 0.03	< 0.03	mg/l		06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	NICKEL	<	0.0300		<	0.0300	< 0.03	< 0.03	mg/l		12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	NICKEL	<	0.0400		NA	0.0000			mg/l		07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	NICKEL	<	0.0400		<	0.0400			mg/l		06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	NITRATE		120.0000			110.0000			mg/l	NO3-N	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	NITRATE		120.0000		NA	0.0000			mg/l	NO3-N	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	NITRATE		110.0000		NA	0.0000			mg/l	NO3-N	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	NITRATE		110.0000		NA	0.0000			mg/l		07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	NITRATE		71.0000			71.0000			mg/l		06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	ODOR		4.0000		NA	0.0000			T.O.N.		12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	ODOR		1.0000		NA	0.0000			T.O.N.		04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	PCB	<	1.0000		NA	0.0000			ug/l		06/18/86	1	IT	PC
RANCH WELL	DEWEY LAKE	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	PHENOL	<	10.0000		NA	0.0000			ug/l		06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	PHENOLICS		0.0190			0.0240			mg/l		06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	PHENOLICS		0.0070		NA	0.0000			mg/l		12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	PHENOLICS	<	0.0050		NA	0.0000			mg/l		07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	PHENOLICS	<	0.0050			0.0000			mg/l		06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	PHOSPHATE		0.0400			0.0500			mg/l	T-PO4-P	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	PHOSPHORUS		0.0200		NA	0.0000			mg/l		07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	PHOSPHORUS	<	0.0100		<	0.0100			mg/l		06/20/90	5	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
RANCH WELL	DEWEY LAKE	POTASSIUM		3.7000			3.6000			mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	POTASSIUM		5.1000			5.1000			mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	POTASSIUM	<	5.0000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	POTASSIUM	<	5.0000		<	5.0000			mg/l	06/20/90	5	IT	MC
RANCH WELL	DEWEY LAKE	PYRENE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	SV
RANCH WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3300.0000		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3200.0000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		2900.0000			3100.0000			mg/l	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		2800.0000			2800.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3000.0000			3000.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C		6.7000		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C		31.0000			32.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C	<	4.0000		<	4.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	SELENIUM		0.0360			0.0370	< 0.001	< 0.001	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	SELENIUM		0.0790		NA	0.0000	< 0.005	< 0.005	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	SELENIUM		0.0550		NA	0.0000	< 0.005	< 0.005	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	SELENIUM	<	0.0500		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	SELENIUM	<	0.0500		NA	0.0000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	SILICA		42.0000			38.0000	0.78	0.82	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	SILICA		49.0000			48.0000	< 0.2	< 0.2	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	SILICA		23.0000		NA	0.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	SILICA		20.0000			0.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	SILVER	<	0.0100			0.0100	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	SILVER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	SILVER		0.0200		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	SILVER		0.0200			0.0200			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	SODIUM		190.0000			170.0000			mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	SODIUM		240.0000			240.0000			mg/l	12/20/87	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
RANCH WELL	DEWEY LAKE	SODIUM		130.0000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	SODIUM		220.0000			220.0000			mg/l	06/20/90	5	IT	MC
RANCH WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		4050.0000		NA	0.0000			umhos/cm@25C	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		4460.0000			4480.0000			umhos/cm@25C	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		3442.0000		NA	0.0000			uMhos/cm@25C	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	SPECIFIC CONDUCTANCE		3650.0000			3670.0000			uMhos/cm@25C	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	STRONTIUM		3.2000			3.2000	0.05	0.05	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	STRONTIUM		3.0000			3.1000	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	STRONTIUM		5.1000			5.1000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	STRONTIUM		5.1000			5.1000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	STYRENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	SULFATE		920.0000		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	SULFATE		920.0000		NA	0.0000			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	SULFATE		1000.0000		NA	0.0000			mg/l	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	SULFATE		770.0000			740.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	SULFATE		1400.0000			1400.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	THALLIUM	<	0.5000		<	0.5000	< 0.005	< 0.0	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	THALLIUM	<	0.1000		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	THALLIUM	<	1.0000		NA	0.0000			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	TITANIUM		0.1500			0.1500	< 0.03	< 0.03	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	TITANIUM		0.2700			0.2700	< 0.03	< 0.03	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	TITANIUM	<	0.0100		<	0.0100			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	TITANIUM		0.0100			0.0100			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	TOLUENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC CARBON		3.0000		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC CARBON		3.0000			3.0000			mg/l	12/20/87	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC CARBON		3.0000			4.0000			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC CARBON		3.0000			2.0000			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN		0.4000		NA	0.0000			mg/l	06/18/86	1	IT	GC
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN		0.0600		<	0.0500			mg/l	07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	06/20/90	5	IT	GC
RANCH WELL	DEWEY LAKE	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	12/20/87	2	IT	HP
RANCH WELL	DEWEY LAKE	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	04/20/88	3	IT	HP
RANCH WELL	DEWEY LAKE	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	TURBIDITY		0.9000		NA	0.0000			NTU	12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	TURBIDITY		2.0000			2.2000			NTU	04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	VANADIUM		0.0700			0.0700	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	VANADIUM		0.0700		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	VANADIUM		0.0500			0.0500			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	12/20/87	2	IT	V
RANCH WELL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	04/20/88	3	IT	V
RANCH WELL	DEWEY LAKE	XYLENE	<	5.0000		NA	0.0000			ug/l	06/18/86	1	IT	V
RANCH WELL	DEWEY LAKE	ZINC		0.1700			0.1500	< 0.01	< 0.01	mg/l	06/18/86	1	IT	ME
RANCH WELL	DEWEY LAKE	ZINC		0.0600			0.0600	< 0.01	< 0.01	mg/l	12/20/87	2	IT	ME
RANCH WELL	DEWEY LAKE	ZINC		0.0900			0.0900	< 0.01	< 0.01	mg/l	04/20/88	3	IT	ME
RANCH WELL	DEWEY LAKE	ZINC		0.1100		NA	0.0000			mg/l	07/27/89	4	IT	MT
RANCH WELL	DEWEY LAKE	ZINC		0.0200			0.0200			mg/l	06/20/90	5	IT	MT
RANCH WELL	DEWEY LAKE	pH		7.6800			7.7700				06/18/86	1	IT	GC

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RANCH WELL	DEWEY LAKE	pH		6.9400			6.9200				12/20/87	2	IT	GC
RANCH WELL	DEWEY LAKE	pH		7.0400		NA	0.0000				04/20/88	3	IT	GC
RANCH WELL	DEWEY LAKE	pH		6.9100		NA	0.0000				07/27/89	4	IT	GC
RANCH WELL	DEWEY LAKE	pH		7.2000			7.2000				06/20/90	5	IT	GC
** TWIN WELLS - PASTURE														
TWIN WELLS - PASTURE	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,1,2,2-TETRACHLOROETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,1,2-TRICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,1-DICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,2,4-TRICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	1,2-DICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	1,2-DICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,2-DICHLOROPROPANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,3-DICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	1,3-DICHLOROPROPYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	1,4-DICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	08/03/88	2	IT	HP
TWIN WELLS - PASTURE	DEWEY LAKE	2,4,5-TRICHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2,4,6-TRICHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	08/03/88	2	IT	HP
TWIN WELLS - PASTURE	DEWEY LAKE	2,4-DICHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2,4-DIMETHYLPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2,4-DINITROPHENOL	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2,4-DINITROTOLUENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	2,6-DINITROTOLUENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2-BUTANONE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	2-CHLOROETHYLVINYL ETHER	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	2-CHLORONAPHTHALENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2-CHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2-HEXANONE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	2-METHYLNAPHTHALENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2-METHYLPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2-NITROANILINE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	2-NITROPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	3,3'-DICHLOROBENZIDINE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	3,4-BENZOFLUORANTHENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	3-NITROANILINE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4,6-DINITRO-O-CRESOL	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4-BROMOPHENYL PHENYL ETHER	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4-CHLOROANILINE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4-CHLOROPHENYL PHENYL ETHER	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4-METHYL-2-PENTANONE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	4-METHYLPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4-NITROANILINE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	4-NITROPHENOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ACENAPHTHENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ACENAPHTHYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ACETONE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	ACROLEIN	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	ACRYLONITRILE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	ALKALINITY (HCO3)		230.0000			220.0000			mg/l	01/30/86	1	IT	GC

WATER QUALITY SAMPLING
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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	ALKALINITY (HCO3)		220.0000		NA	0.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	ALKALINITY (HCO3)		210.0000			220.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	ALUMINUM	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	ALUMINUM	<	0.2000		<	0.2000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ALUMINUM	<	0.2000		<	0.2000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ANILINE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ANTHRACENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ANTIMONY	<	0.0600		<	0.0600			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ANTIMONY	<	0.0600		<	0.0600			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ARSENIC		0.0060			0.0060	< 0.001	< 0.001	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	ARSENIC		0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	ARSENIC	<	0.0100		NA	0.0000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ARSENIC	<	0.0100		NA	0.0000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	BARIUM		0.1300			0.1300	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	BARIUM	<	0.2000		<	0.2000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	BARIUM	<	0.2000		<	0.2000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	BENZENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	BENZIDINE	<	8.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BENZO(A)ANTHRACENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BENZO(A)PYRENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BENZO(G,H,I)PERYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BENZO(K)FLUORANTHENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BENZOIC ACID	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BENZYL ALCOHOL	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	BERYLLIUM	<	0.0050		<	0.0050			mg/l	05/30/90	4	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	BIS(2-CHLOROETHOXY)METHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BIS(2-CHLOROETHYL)ETHER	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BIS(2-CHLOROISOPROPYL)ETHER	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BIS(2-ETHYLHEXYL)PHTHALATE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BIS(CHLOROMETHYL)ETHER	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	BORON		0.1600		NA	0.0000	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	BORON		0.1300			0.1300			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	BORON		0.1500			0.1600			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	BROMIDE	<	1.0000		NA	0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	BROMIDE		8.0000			8.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	BROMIDE		3.0000			0.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	BROMOFORM	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	BUTYL BENZYL PHTHALATE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	CADMIUM	<	0.0010		NA	0.0000	< 0.001	< 0.001	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CADMIUM	<	0.0050		<	0.0050			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CALCIUM		82.0000			80.0000			mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	CALCIUM		79.0000			78.0000			mg/l	10/20/89	3	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	CALCIUM		77.0000			77.0000			mg/l	05/30/90	4	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	CALCIUM HARDNESS (CaCO3)		268.0000		NA	0.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CARBON DISULFIDE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CARBON TETRACHLORIDE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CARBONATE (CO3)		0.0000		NA	0.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	CESIUM	<	0.1000		<	0.1000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CESIUM	<	0.2000		<	0.2000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CHLORIDE		47.0000			47.0000			mg/l	01/30/86	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	CHLORIDE		39.0000		NA	0.0000			mg/l	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CHLORIDE		40.0000		NA	0.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CHLORIDE		35.0000			0.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CHLOROETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CHLOROFORM	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	CHROMIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	CHROMIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	CHROMIUM		0.0300			0.0300			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CHROMIUM		0.0200			0.0200			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CHRYSENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	COBALT	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	COBALT	<	0.0500		<	0.0500			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	COBALT		0.0500			0.0500			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	COLOR	<	1.0000		NA	0.0000			CU	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	COPPER	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	COPPER	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	COPPER	<	0.0250		<	0.0250			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	COPPER		0.0480			0.0470			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	CYANIDE	<	0.0200		<	0.0200			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CYANIDE	<	0.0100		<	0.0200			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	CYANIDE	<	0.0100		<	0.0200			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	DI-N-BUTYL PHTHALATE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	DI-N-OCTYL PHTHALATE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	DIBENZO(A,H)ANTHRACENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	DIBENZOFURAN	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	DICHLOROBROMOMETHANE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000	NA		0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	DIETHYL PHTHALATE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	DIMETHYL PHTHALATE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ENDRIN	<	0.0200	NA		0.0000			ug/l	08/03/88	2	IT	HP
TWIN WELLS - PASTURE	DEWEY LAKE	ETHYLBENZENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	Eh		419.0000	NA		0.0000			mV	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	FLUORANTHENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	FLUORENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	FLUORIDE		0.7000	NA		0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	FLUORIDE		0.7000	NA		0.0000			mg/l	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	FLUORIDE		0.6000	NA		0.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	FLUORIDE		0.6000			0.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	HEXACHLOROBENZENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	HEXACHLOROBUTADIENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	HEXACHLOROCYCLOPENTADIENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	HEXACHLOROETHANE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	INDENO(1,2,3-CD)PYRENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	IODIDE	<	1.0000	NA		0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	IODIDE	<	2.0000	<		2.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	IODIDE	<	2.0000	<		2.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	IRON		0.3900			0.2900	0.05	0.03	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	IRON	<	0.0100	<		0.0100	< 0.01	< 0.01	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	IRON	<	0.1000			0.1000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	IRON	<	0.1000	<		0.1000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ISOPHORONE	<	8.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	LANGELIER SATURATION INDEX		0.2600	NA		0.0000			NA	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	LEAD	<	0.0500	<		0.0500	< 0.05	< 0.05	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	LEAD	<	0.0050	NA		0.0000	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	LEAD	<	0.0500	<		0.0500			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	LEAD	<	0.0500	<		0.0500			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	LINDANE	<	0.0400	NA		0.0000			ug/l	08/03/88	2	IT	HP
TWIN WELLS - PASTURE	DEWEY LAKE	LITHIUM		0.0300			0.0300			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	LITHIUM	<	0.1000	<		0.1000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	LSI CORROSIVITY		0.0100	NA		0.0000				08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	MAGNESIUM		24.0000			23.0000			mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	MAGNESIUM		24.0000			24.0000			mg/l	10/20/89	3	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	MAGNESIUM		24.0000			24.0000			mg/l	05/30/90	4	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	MANGANESE	<	0.0500	NA		0.0000	< 0.05	< 0.05	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	MANGANESE	<	0.0050	<		0.0050	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	MANGANESE	<	0.0150	<		0.0150			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	MANGANESE		0.0190			0.0190			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	MBAS		0.1300			0.1300			mg/l	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	MERCURY		0.0002			0.0003	< 0.0002	< 0.0002	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	MERCURY		0.0004			0.0003	0.0003	0.0004	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	MERCURY	<	0.0002	<		0.0002			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	MERCURY		0.0002	<		0.0002			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	METHOXYCHLOR	<	0.0010	NA		0.0000			mg/l	08/03/88	2	IT	HP
TWIN WELLS - PASTURE	DEWEY LAKE	METHYL BROMIDE	<	20.0000	NA		0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	METHYL CHLORIDE	<	20.0000	NA		0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	METHYLENE CHLORIDE	<	20.0000	NA		0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	MOLYBDENUM		0.0200			0.0300	0.04	0.03	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	MOLYBDENUM	<	0.0200	<		0.0200			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	MOLYBDENUM	<	0.0200	<		0.0200			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	N-NITROSO-DI-METHYLAMINE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	N-NITROSO-DI-PHENYLAMINE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	NAPHTHALENE	<	2.0000	NA		0.0000			ug/l	01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	NICKEL		0.0300			0.0200	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS		DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	NICKEL	<	0.0400	<		0.0400			mg/l		10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	NICKEL	<	0.0400	<		0.0400			mg/l		05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	NITRATE		7.8000		NA	0.0000			mg/l	NO3-N	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	NITRATE		6.2000		NA	0.0000			mg/l	NO3-N	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	NITRATE		7.8000		NA	0.0000			mg/l		10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	NITRATE		9.2000			0.0000			mg/l		05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	NITROBENZENE	<	2.0000		NA	0.0000			ug/l		01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	ODOR	<	1.0000		NA	0.0000			T.O.N.		08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	P-CHLORO-M-CRESOL	<	2.0000		NA	0.0000			ug/l		01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000		NA	0.0000	T < 1.0		ug/l		08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	PENTACHLOROPHENOL	<	2.0000		NA	0.0000			ug/l		01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	PHENANTHRENE	<	2.0000		NA	0.0000			ug/l		01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	PHENOL	<	2.0000		NA	0.0000			ug/l		01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	PHENOLICS		0.0200		NA	0.0000			mg/l		01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	PHENOLICS	<	0.0050		NA	0.0000			mg/l		10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	PHENOLICS	<	0.0050			0.0000			mg/l		05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	PHOSPHORUS		0.0200		NA	0.0000			mg/l		10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	PHOSPHORUS	<	0.0100	<		0.0100			mg/l		05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	POTASSIUM		3.7000			3.7000			mg/l		01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	POTASSIUM	<	5.0000	<		5.0000			mg/l		10/20/89	3	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	POTASSIUM	<	5.0000	<		5.0000			mg/l		05/30/90	4	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	PYRENE	<	2.0000		NA	0.0000			ug/l		01/30/86	1	IT	SV
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		400.0000		NA	0.0000			mg/l		01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		390.0000		NA	0.0000			mg/l		08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		400.0000			410.0000			mg/l		10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		410.0000			0.0000			mg/l		05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C		13.0000			11.0000			mg/l		01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C		4.0000	<		4.0000			mg/l		10/20/89	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	RESIDUE, NONFILTERABLE @ 105 C	<	9.0000			6.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SELENIUM	<	0.1000		NA	0.0000	< 0.001	< 0.001	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	SELENIUM	<	0.0500		NA	0.0000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	SELENIUM	<	0.0500		NA	0.0000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	SILICA		43.0000			42.0000	< 0.2	< 0.2	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	SILICA		19.0000			19.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SILICA		18.0000			18.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SILVER	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	SILVER		0.0100			0.0100			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	SILVER	<	0.0100		<	0.0100			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	SODIUM		26.0000			26.0000			mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	SODIUM		9.0000			9.0000			mg/l	10/20/89	3	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	SODIUM		23.0000			22.0000			mg/l	05/30/90	4	IT	MC
TWIN WELLS - PASTURE	DEWEY LAKE	SPECIFIC CONDUCTANCE		682.0000		NA	0.0000			umhos/cm@25C	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SPECIFIC CONDUCTANCE		597.0000			596.0000			uMhos/cm@25C	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SPECIFIC CONDUCTANCE		1030.0000			1030.0000			uMhos/cm@25C	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	STRONTIUM		0.6000			0.6000	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	STRONTIUM		1.1000			1.0000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	STRONTIUM		1.0000			1.0000			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	STYRENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	SULFATE		270.0000		NA	0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SULFATE		55.0000		NA	0.0000			mg/l	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SULFATE		50.0000		NA	0.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	SULFATE		59.0000		NA	0.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TETRACHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	THALLIUM	<	0.1000		NA	0.0000			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	THALLIUM	<	0.0100		NA	0.0000			mg/l	05/30/90	4	IT	MT

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	TITANIUM	<	0.1000		<	0.1000	< 0.1	0.2	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	TITANIUM	<	0.0100		<	0.0100			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	TITANIUM	<	0.0100		<	0.0100			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	TOLUENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	TOTAL ORGANIC CARBON		4.0000		NA	0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TOTAL ORGANIC HALOGEN		0.0500		NA	0.0000			mg/l	01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	10/20/89	3	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	05/30/90	4	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	08/03/88	2	IT	HP
TWIN WELLS - PASTURE	DEWEY LAKE	TRANS-1,2-DICHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	TRICHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	TRICHLOROFLUOROMETHANE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	TURBIDITY	<	1.0000		NA	0.0000			NTU	08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	VANADIUM	<	0.0500		<	0.0500			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	VANADIUM	<	0.0500		<	0.0500			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	VINYL ACETATE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	VINYL CHLORIDE	<	20.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	08/03/88	2	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	XYLENE	<	2.0000		NA	0.0000			ug/l	01/30/86	1	IT	V
TWIN WELLS - PASTURE	DEWEY LAKE	ZINC	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	01/30/86	1	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	ZINC		0.3100			0.3100	< 0.01	< 0.01	mg/l	08/03/88	2	IT	ME
TWIN WELLS - PASTURE	DEWEY LAKE	ZINC		0.2200			0.2200			mg/l	10/20/89	3	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	ZINC		0.5200			0.5200			mg/l	05/30/90	4	IT	MT
TWIN WELLS - PASTURE	DEWEY LAKE	pH		8.0000			8.0300				01/30/86	1	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	pH		7.4800		NA	0.0000				08/03/88	2	IT	GC
TWIN WELLS - PASTURE	DEWEY LAKE	pH		7.4100			7.4100				10/20/89	3	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
TWIN WELLS - PASTURE	DEWEY LAKE	pH		7.5400			7.5500				05/30/90	4	IT	GC
** UNGER WINDMILL														
UNGER WINDMILL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	11/18/87	1	IT	HP
UNGER WINDMILL	DEWEY LAKE	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	07/06/88	2	IT	HP
UNGER WINDMILL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	11/18/87	1	IT	HP
UNGER WINDMILL	DEWEY LAKE	2,4-D	<	0.0050		NA	0.0000			mg/l	07/06/88	2	IT	HP
UNGER WINDMILL	DEWEY LAKE	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	BARIUM		0.0110			0.0110	< 0.005	< 0.005	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	BARIUM		0.0360			0.0660	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	BARIUM		0.0150			0.0460	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	CADMIUM		0.0100			0.0090	< 0.005	< 0.005	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	CADMIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	CHLORIDE		270.0000		NA	0.0000			mg/l	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	CHLORIDE		280.0000		NA	0.0000			mg/l	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
UNGER WINDMILL	DEWEY LAKE	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	CHROMIUM		0.1200		NA	0.0000	0.01	0.02	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	CHROMIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	COLOR		10.0000		NA	0.0000			CU	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	COLOR	<	1.0000		NA	0.0000			CU	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	COPPER		0.0200			0.0200	0.01	0.01	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	COPPER		0.1600			0.3300	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	COPPER		0.0400			0.2100	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	ENDRIN	<	0.0200		NA	0.0000			ug/l	11/18/87	1	IT	HP
UNGER WINDMILL	DEWEY LAKE	ENDRIN	<	0.0200		NA	0.0000			ug/l	07/06/88	2	IT	HP
UNGER WINDMILL	DEWEY LAKE	FLUORIDE		2.1000		NA	0.0000			mg/l	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	FLUORIDE		2.1000		NA	0.0000			mg/l	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	IRON		0.1000			0.1000	< 0.01	< 0.01	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	IRON		0.1100			0.2000	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	IRON		0.0400			0.1100	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	LEAD		0.0900			0.0900	< 0.05	< 0.05	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	LEAD	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	LINDANE	<	0.0400		NA	0.0000			ug/l	11/18/87	1	IT	HP
UNGER WINDMILL	DEWEY LAKE	LINDANE	<	0.0400		NA	0.0000			ug/l	07/06/88	2	IT	HP
UNGER WINDMILL	DEWEY LAKE	LSI CORROSIVITY		0.0900		NA	0.0000				11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	LSI CORROSIVITY		-0.3000		NA	0.0000			--	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	MANGANESE	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	MANGANESE		0.0490			0.0600	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	MBAS	<	0.0250		<	0.0250			mg/l	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	MBAS	<	0.0250		NA	0.0000			mg/l	07/06/88	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
UNGER WINDMILL	DEWEY LAKE	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	MERCURY	<	0.0004	NA		0.0000	< 0.0002	< 0.0002	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	METHOXYCHLOR	<	0.0010	NA		0.0000			mg/l	11/18/87	1	IT	HP
UNGER WINDMILL	DEWEY LAKE	METHOXYCHLOR	<	0.0010	NA		0.0000			mg/l	07/06/88	2	IT	HP
UNGER WINDMILL	DEWEY LAKE	NITRATE		2.4000			2.5000			mg/l NO3-N	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	NITRATE		2.5000	NA		0.0000			mg/l NO3-N	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	ODOR		0.0000	NA		0.0000			T.O.N.	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	ODOR		1.0000	NA		0.0000			T.O.N.	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	P-DICHLOROBENZENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3300.0000	NA		0.0000			mg/l	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	RESIDUE, FILTERABLE @ 180 C		3200.0000	NA		0.0000			mg/l	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	SELENIUM		0.0220	NA		0.0000	< 0.005	< 0.005	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	SELENIUM		0.0150	NA		0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	SILVER		0.0100			0.0100	< 0.01	< 0.01	mg/l	11/18/87	1	IT	ME
UNGER WINDMILL	DEWEY LAKE	SILVER	<	0.0050	NA		0.0000	< 0.005	< 0.005	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	SULFATE		1400.0000			1300.0000			mg/l	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	SULFATE		850.0000	NA		0.0000			mg/l	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	TETRACHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	TOXAPHENE	<	0.0005	NA		0.0000			mg/l	11/18/87	1	IT	HP
UNGER WINDMILL	DEWEY LAKE	TOXAPHENE	<	0.0005	NA		0.0000			mg/l	07/06/88	2	IT	HP
UNGER WINDMILL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	TRICHLOROETHYLENE	<	1.0000	NA		0.0000		T < 1.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	TURBIDITY		3.0000			3.0000			NTU	11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	TURBIDITY		2.0000	NA		0.0000			NTU	07/06/88	2	IT	GC
UNGER WINDMILL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000	NA		0.0000		T < 2.0	ug/l	11/18/87	1	IT	V
UNGER WINDMILL	DEWEY LAKE	VINYL CHLORIDE	<	2.0000	NA		0.0000		T < 2.0	ug/l	07/06/88	2	IT	V
UNGER WINDMILL	DEWEY LAKE	ZINC		0.1900			0.1800	< 0.01	< 0.01	mg/l	11/18/87	1	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
UNGER WINDMILL	DEWEY LAKE	ZINC		0.1800			0.1900	< 0.01	< 0.01	mg/l	07/06/88	2	IT	ME
UNGER WINDMILL	DEWEY LAKE	pH		7.2600			7.2200				11/18/87	1	IT	GC
UNGER WINDMILL	DEWEY LAKE	pH		6.9700		NA	0.0000			--	07/06/88	2	IT	GC
** USGS-1														
USGS-1	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	04/12/88	1	IT	HP
USGS-1	CULEBRA	2,4,5-TP (SILVEX)	<	0.0005		NA	0.0000			mg/l	07/07/88	2	IT	HP
USGS-1	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,4-D	<	0.0050		NA	0.0000			mg/l	04/12/88	1	IT	HP
USGS-1	CULEBRA	2,4-D	<	0.0050		NA	0.0000			mg/l	07/07/88	2	IT	HP
USGS-1	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV

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USGS-1	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	ALKALINITY (HCO3)		110.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	ALKALINITY (HCO3)		101.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	ALUMINUM		1.0000			1.0000	< 0.1	< 0.1	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	ALUMINUM	<	0.1000			0.8000	< 0.1	< 0.1	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	ALUMINUM		0.3000			0.7000	< 0.1	< 0.1	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	ANTIMONY		0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	ANTIMONY		0.1800			0.3800	< 0.05	< 0.05	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	ANTIMONY		0.0800			0.4500	< 0.05	< 0.05	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	BARIUM		0.0900			0.0900	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME

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USGS-1	CULEBRA	BARIUM		0.0090			0.0470	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	BARIUM		0.0160			0.0340	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	BENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BERYLLIUM		0.0100			0.0100	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	BORON		0.7800			0.7800	0.023	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	BORON		0.6800			0.6800	0.02	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	BROMIDE		6.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	BROMIDE	<	2.0000		<	2.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	CADMIUM	<	0.0010		<	0.0010	< 0.001	< 0.001	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	CADMIUM		0.0170			0.0460	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	CADMIUM	<	0.0050			0.0520	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	CALCIUM		540.0000			540.0000			mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	CALCIUM		700.0000			690.0000			mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
USGS-1	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	CESIUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	CESIUM	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	CHLORIDE		600.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	CHLORIDE		680.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	CHLOROFORM		1.3000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	CHROMIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	CHROMIUM		0.1000			0.2500	0.01	0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	CHROMIUM		0.0300			0.3100	0.01	0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	COBALT		0.2000			0.1000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	COBALT	<	0.0100			0.1100	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	COBALT		0.0300			0.0900	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	COLOR	<	1.0000		NA	0.0000			CU	07/07/88	2	IT	GC
USGS-1	CULEBRA	COPPER		0.4000			0.4000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	COPPER	<	0.0100			0.2100	0.01	0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	COPPER		0.0300			0.1400	0.01	0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l	04/12/88	1	IT	HP

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USGS-1	CULEBRA	ENDRIN	<	0.0200		NA	0.0000			ug/l	07/07/88	2	IT	HP
USGS-1	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	FLUORIDE		1.9000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	FLUORIDE		2.1000			2.2000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	IRON		0.2000			0.2000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	IRON	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/07/88	2	IT	SV
USGS-1	CULEBRA	LEAD	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	LEAD	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	LINDANE	<	0.0400		NA	0.0000			ug/l	04/12/88	1	IT	HP
USGS-1	CULEBRA	LINDANE	<	0.0400		NA	0.0000			ug/l	07/07/88	2	IT	HP
USGS-1	CULEBRA	LITHIUM		0.1000			0.1000	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	LITHIUM		0.1200			0.1200	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	LSI CORROSIVITY		0.1400		NA	0.0000			--	07/07/88	2	IT	GC
USGS-1	CULEBRA	MAGNESIUM		110.0000			110.0000			mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	MAGNESIUM		130.0000			120.0000			mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	MANGANESE		0.0110			0.0190	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	MANGANESE		0.0060			0.0210	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	MBAS		0.0270			0.0320			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	04/12/88	1	IT	ME

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USGS-1	CULEBRA	MERCURY		0.0007		NA	0.0000	< 0.0002	< 0.0002	mg/l		07/07/88	2	IT	ME
USGS-1	CULEBRA	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		04/12/88	1	IT	HP
USGS-1	CULEBRA	METHOXYCHLOR	<	0.0010		NA	0.0000			mg/l		07/07/88	2	IT	HP
USGS-1	CULEBRA	MOLYBDENUM	<	5.0000		<	5.0000	< 0.01	< 0.01	mg/l		04/12/88	1	IT	ME
USGS-1	CULEBRA	MOLYBDENUM	<	0.0500		<	0.0500	< 0.05	< 0.05	mg/l		07/07/88	2	IT	ME
USGS-1	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		04/12/88	1	IT	ME
USGS-1	CULEBRA	NICKEL		0.0500			0.1400	< 0.03	< 0.03	mg/l		07/07/88	2	IT	ME
USGS-1	CULEBRA	NICKEL	<	0.0300			0.1700	< 0.03	< 0.03	mg/l		07/07/88	2	IT	ME
USGS-1	CULEBRA	NITRATE		4.0000		NA	0.0000			mg/l	NO3-N	04/12/88	1	IT	GC
USGS-1	CULEBRA	NITRATE		4.4000		NA	0.0000			mg/l	NO3-N	07/07/88	2	IT	GC
USGS-1	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	ODOR	<	1.0000		NA	0.0000			T.O.N.		07/07/88	2	IT	GC
USGS-1	CULEBRA	P-CHLORO-N-CRESOL	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		04/12/88	1	IT	V
USGS-1	CULEBRA	P-DICHLOROBENZENE	<	1.0000		NA	0.0000		T < 1.0	ug/l		07/07/88	2	IT	V
USGS-1	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		07/07/88	2	IT	PC
USGS-1	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	PHENOLICS		0.0060		NA	0.0000			mg/l		07/07/88	2	IT	GC
USGS-1	CULEBRA	PHOSPHATE		0.0200			0.0300			mg/l	T-PO4-P	04/12/88	1	IT	GC
USGS-1	CULEBRA	PHOSPHATE		0.0200			0.0200			mg/l	T-PO4-P	07/07/88	2	IT	GC
USGS-1	CULEBRA	POTASSIUM		14.0000			14.0000			mg/l		04/12/88	1	IT	ME
USGS-1	CULEBRA	POTASSIUM		13.0000			13.0000			mg/l		07/07/88	2	IT	ME
USGS-1	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		07/07/88	2	IT	SV
USGS-1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		2100.0000		NA	0.0000			mg/l		04/12/88	1	IT	GC

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USGS-1	CULEBRA	RESIDUE, FILTERABLE @ 180 C		4000.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		7.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		26.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	SILICA	<	0.4000		NA	0.0000			mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	SILICA		14.0000		NA	0.0000			mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	SILVER	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	SILVER		0.0400			0.1000	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	SILVER		0.0100			0.1300	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	SODIUM		420.0000			430.0000			mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	SODIUM		440.0000			440.0000			mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	SPECIFIC CONDUCTANCE		5200.0000			5220.0000			umhos/cm@25C	04/12/88	1	IT	GC
USGS-1	CULEBRA	SPECIFIC CONDUCTANCE		5010.0000		NA	0.0000			umhos/cm@25C	07/07/88	2	IT	GC
USGS-1	CULEBRA	STRONTIUM		7.5000			7.4000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	STRONTIUM		7.0000			7.0000	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	SULFATE		2100.0000		NA	0.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	SULFATE		1600.0000		NA	0.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	THALLIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	TITANIUM		0.8000			0.7000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	TITANIUM		1.6000			3.2000	< 0.03	< 0.03	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	TITANIUM		0.0800			1.6000	< 0.03	< 0.03	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	07/07/88	2	IT	GC
USGS-1	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500			0.0600			mg/l	04/12/88	1	IT	GC
USGS-1	CULEBRA	TOTAL ORGANIC HALOGEN		0.0900		<	0.0500			mg/l	07/07/88	2	IT	GC

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USGS-1	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	04/12/88	1	IT	HP
USGS-1	CULEBRA	TOXAPHENE	<	0.0005		NA	0.0000			mg/l	07/07/88	2	IT	HP
USGS-1	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000		T < 1.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	TURBIDITY		1.0000		NA	0.0000			NTU	07/07/88	2	IT	GC
USGS-1	CULEBRA	VANADIUM		0.3000			0.3000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	VANADIUM		0.0800			0.1300	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	VANADIUM		0.0500			0.1500	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	04/12/88	1	IT	V
USGS-1	CULEBRA	VINYL CHLORIDE	<	2.0000		NA	0.0000		T < 2.0	ug/l	07/07/88	2	IT	V
USGS-1	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/12/88	1	IT	ME
USGS-1	CULEBRA	ZINC		0.3600			0.3700	< 0.01	< 0.01	mg/l	07/07/88	2	IT	ME
USGS-1	CULEBRA	pH		7.3500			7.3600				04/12/88	1	IT	GC
USGS-1	CULEBRA	pH		7.2000		NA	0.0000			--	07/07/88	2	IT	GC
** WIPP-13														
WIPP-13	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	02/16/87	1	IT	GC
WIPP-13	CULEBRA	ALKALINITY (HCO3)		120.0000		NA	0.0000			mg/l	02/16/87	1	IT	GC
WIPP-13	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	ANTIMONY		0.9000		NA	0.0000	< 0.05	< 0.05	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	BARIUM		0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	BORON		11.0000		NA	0.0000	< 0.01	< 0.01	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	BROMIDE		39.0000		NA	0.0000			mg/l	02/16/87	1	IT	GC
WIPP-13	CULEBRA	CADMIUM		0.0700		NA	0.0000	< 0.005	< 0.005	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	CALCIUM		1450.0000			1490.0000			mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	CESIUM		0.5000		NA	0.0000	< 0.1	< 0.1	mg/l	02/16/87	1	IT	ME
WIPP-13	CULEBRA	CHLORIDE		36000.0000		NA	0.0000			mg/l	02/16/87	1	IT	GC

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WIPP-13	CULEBRA	CHROMIUM		0.4000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	COBALT		0.1000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	COPPER		0.2000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	FLUORIDE		1.4000			1.4000			mg/l		02/16/87	1	IT	GC
WIPP-13	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l		02/16/87	1	IT	GC
WIPP-13	CULEBRA	IRON		0.4000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	LEAD		0.7000		NA	0.0000	< 0.05	< 0.05	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	LITHIUM		0.3500		NA	0.0000	0.01	0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	MAGNESIUM		1010.0000			1030.0000			mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	MANGANESE		0.4600		NA	0.0000	< 0.005	< 0.005	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	MOLYBDENUM		0.0600		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	NITRATE		0.3000		NA	0.0000			mg/l	NO3-N	02/16/87	1	IT	GC
WIPP-13	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	02/16/87	1	IT	GC
WIPP-13	CULEBRA	POTASSIUM		340.0000			330.0000			mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	RESIDUE, FILTERABLE @ 180 C		67000.0000		NA	0.0000			mg/l		02/16/87	1	IT	GC
WIPP-13	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		130.0000		NA	0.0000			mg/l		02/16/87	1	IT	GC
WIPP-13	CULEBRA	SELENIUM	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	SILICA		16.0000		NA	0.0000	< 0.2	< 0.2	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	SILVER		0.1000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	SODIUM		19000.0000			19000.0000			mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	SPECIFIC CONDUCTANCE		96700.0000		NA	0.0000			umhos/cm@25C		02/16/87	1	IT	GC
WIPP-13	CULEBRA	STRONTIUM		25.0000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	SULFATE		4500.0000		NA	0.0000			mg/l		02/16/87	1	IT	GC
WIPP-13	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	TITANIUM		0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l		02/16/87	1	IT	ME
WIPP-13	CULEBRA	pH		6.7400		NA	0.0000					02/16/87	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
** WIPP-19														
WIPP-19	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,1-DICHLOROETHANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,2-DICHLOROETHANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V

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WIPP-19	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,4-DINITROPHENOL	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V

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WIPP-19	CULEBRA	2-BUTANONE	<	10.0000		<	10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		<	10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2-CHLOROPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	2-HEXANONE	<	10.0000		<	10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2-METHYLPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2-NITROANILINE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2-NITROANILINE	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	2-NITROPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		<	20.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV

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WIPP-19	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	3-NITROANILINE	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4-CHLOROANILINE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		<	10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4-METHYLPHENOL	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4-NITROANILINE	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	4-NITROPHENOL	<	50.0000		<	50.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV

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WIPP-19	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	ACENAPHTHENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	ACENAPHTHYLENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	ACETONE		71.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	ACETONE		18.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	ACETONE		45.0000			33.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	ALKALINITY (HCO3)		73.0000		NA	0.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	ALKALINITY (HCO3)		58.0000		NA	0.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	ALKALINITY (HCO3)		61.0000			60.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	ALKALINITY (HCO3)		54.0000		NA	0.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	ALKALINITY (HCO3)		56.0000		NA	0.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	ALUMINUM	<	10.0000		<	10.0000	< 0.1	< 0.1	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	ALUMINUM	<	10.0000		<	10.0000	< 0.1	< 0.1	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	ALUMINUM	<	10.0000		<	10.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	ALUMINUM	<	20.0000		<	20.0000	< 0.2	< 0.2	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	ALUMINUM	<	0.2000		<	0.2000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	ANTHRACENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	ANTIMONY	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	ANTIMONY	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	02/12/88	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-19	CULEBRA	ANTIMONY		1.0800			1.1000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	ANTIMONY	<	6.0000	<		6.0000	< 0.06	< 0.06	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	ANTIMONY	<	0.6000	<		0.6000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	ARSENIC	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	ARSENIC	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	ARSENIC	<	0.0200	<		0.0200			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	ARSENIC	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	ARSENIC	<	0.0200	NA		0.0000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	BARIUM	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	BARIUM	<	0.5000	<		0.5000	< 0.005	< 0.005	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	BARIUM	<	0.5000	<		0.5000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	BARIUM	<	20.0000	<		20.0000	< 0.2	< 0.2	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	BARIUM	<	2.0000	<		2.0000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	BENZENE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	BENZENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	BENZENE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BENZO(A)PYRENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BENZO(A)PYRENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BENZOIC ACID	<	50.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV

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WIPP-19	CULEBRA	BENZOIC ACID	<	50.0000	<	50.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BENZOIC ACID	<	50.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BENZYL ALCOHOL	<	10.0000	<	10.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BENZYL ALCOHOL	<	10.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BERYLLIUM	<	0.5000	<	0.5000	< 0.005	< 0.005		mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	BERYLLIUM	<	0.5000	<	0.5000	< 0.005	< 0.005		mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	BERYLLIUM	<	0.5000	<	0.5000				mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	BERYLLIUM	<	0.5000	<	0.5000	< 0.005	< 0.005		mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	BERYLLIUM	<	0.0500	<	0.0500				mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	<	10.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	<	10.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	<	10.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	<	10.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	BORON		33.0000		33.0000	< 0.01	< 0.01		mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	BORON		30.0000		30.0000	< 0.01	< 0.01		mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	BORON		34.0000		33.0000				mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	BORON		30.0000		30.0000	< 0.02	< 0.02		mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	BORON		26.0000		26.0000				mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	BROMIDE		130.0000	NA	0.0000				mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	BROMIDE		95.0000		94.0000				mg/l	02/12/88	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-19	CULEBRA	BROMIDE		78.0000			78.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	BROMIDE		21.0000			21.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	BROMIDE		49.0000			48.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	BROMOFORM	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	CADMIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	CADMIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	CADMIUM	<	0.0030		<	0.0040			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	CADMIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	CADMIUM	<	0.0500		<	0.0500			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	CALCIUM		1900.0000			1900.0000			mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	CALCIUM		1600.0000			1600.0000			mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	CALCIUM		1800.0000			1800.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	CALCIUM		1700.0000			1700.0000			mg/l	11/03/89	4	IT	MC
WIPP-19	CULEBRA	CALCIUM		1400.0000			1400.0000			mg/l	06/13/90	5	IT	MC
WIPP-19	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	CARBON DISULFIDE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	CESIUM		0.4200			0.4600	< 0.1	< 0.1	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	CESIUM	<	0.5000		<	0.5000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	CESIUM	<	0.2400		<	0.2400			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	CESIUM		0.1000			0.1000	0.1	< 0.1	mg/l	11/03/89	4	IT	MT

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WIPP-19	CULEBRA	CESIUM	<	0.2000	<	0.2000				mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	CHLORIDE		58000.0000	NA	0.0000				mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	CHLORIDE		46100.0000	NA	0.0000				mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	CHLORIDE		38900.0000	NA	0.0000				mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	CHLORIDE		38400.0000	NA	0.0000				mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	CHLORIDE		37900.0000	NA	0.0000				mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000				ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	CHLOROBENZENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	CHLOROBENZENE	<	5.0000	<	5.0000			T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	CHLOROETHANE	<	10.0000	NA	0.0000			T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	CHLOROETHANE	<	10.0000	<	10.0000			T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	CHLOROFORM	<	5.0000	NA	0.0000				ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	CHLOROFORM	<	5.0000	NA	0.0000			T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	CHLOROFORM	<	5.0000	<	5.0000			T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	CHROMIUM	<	1.0000	<	1.0000	< 0.01	< 0.01		mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	CHROMIUM	<	1.0000	<	1.0000	< 0.01	< 0.01		mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	CHROMIUM		0.0060		0.0060				mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	CHROMIUM		2.0000		2.0000	0.01	0.02		mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	CHROMIUM		0.1000		0.1000				mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	CHRYSENE	<	10.0000	<	10.0000				ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	CHRYSENE	<	10.0000	NA	0.0000				ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000				ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	NA	0.0000			T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000	<	5.0000			T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	COBALT	<	1.0000	<	1.0000	< 0.01	< 0.01		mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	COBALT	<	0.1000	<	0.1000	< 0.01	< 0.01		mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	COBALT	<	0.0070	<	0.0080				mg/l	08/29/88	3	IT	ME

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WIPP-19	CULEBRA	COBALT	<	5.0000	<		5.0000	< 0.05	< 0.05	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	COBALT	<	0.5000	<		0.5000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	COPPER	<	1.0000	<		1.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	COPPER	<	1.0000	<		1.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	COPPER		0.0130			0.1100			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	COPPER	<	2.5000	<		2.5000	< 0.025	< 0.025	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	COPPER	<	0.2500	<		0.2500			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	CYANIDE	<	0.0400	NA		0.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	CYANIDE	<	0.0100	NA		0.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	CYANIDE	<	0.0200	NA		0.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	CYANIDE	<	0.0100	NA		0.0200			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	CYANIDE	<	0.0100	NA		0.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	DIBENZOFURAN	<	10.0000	<		10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	DIBENZOFURAN	<	10.0000	NA		0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-19	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	DIETHYL PHTHALATE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	ETHYLBENZENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	FLUORANTHENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	FLUORENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	FLUORIDE		0.8000			0.8000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	FLUORIDE		0.9000		NA	0.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	FLUORIDE		1.0000		NA	0.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	FLUORIDE		1.0000			1.1000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	FLUORIDE		1.0000			1.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	HEXACHLOROBENZENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV

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WIPP-19	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	HEXACHLOROETHANE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	IODIDE		18.0000			18.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	IRON	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	IRON		1.0000			1.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	IRON		2.0000			2.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	IRON	<	10.0000		<	10.0000	< 0.1	< 0.1	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	IRON	<	1.0000		<	1.0000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	SV
WIPP-19	CULEBRA	ISOPHORONE	<	10.0000		<	10.0000			ug/l	02/12/88	2	IT	SV
WIPP-19	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	08/29/88	3	IT	SV
WIPP-19	CULEBRA	LEAD	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	LEAD		1.3000			1.2000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	LEAD	<	0.0300		<	0.0400			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	LEAD	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	LEAD	<	0.5000		<	0.5000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	LITHIUM		3.4000			3.4000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	LITHIUM		1.0000			1.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	LITHIUM		0.7300			0.6800			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	LITHIUM		0.4700			0.4700	< 0.01	< 0.01	mg/l	11/03/89	4	IT	MT

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WIPP-19	CULEBRA	LITHIUM		0.6000			0.5000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	MAGNESIUM		2400.0000			2400.0000			mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	MAGNESIUM		1700.0000			1700.0000			mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	MAGNESIUM		1500.0000			1500.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	MAGNESIUM		1400.0000			1400.0000			mg/l	11/03/89	4	IT	MC
WIPP-19	CULEBRA	MAGNESIUM		1000.0000			1000.0000			mg/l	06/13/90	5	IT	MC
WIPP-19	CULEBRA	MANGANESE		4.2000			4.2000	< 0.005	< 0.005	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	MANGANESE		3.1000			3.1000	< 0.005	< 0.005	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	MANGANESE		2.0000			2.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	MANGANESE		1.6000			1.5000	< 0.015	< 0.015	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	MANGANESE		0.8000			0.8000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	MERCURY	<	0.0002	<		0.0002	< 0.0002	< 0.0002	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	MERCURY	<	0.0020	NA		0.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	MERCURY		0.0003			0.0003	< .0002	< .0002	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	MERCURY	<	0.0002	<		0.0002			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	METHYL BROMIDE	<	10.0000	NA		0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	METHYL BROMIDE	<	10.0000	<		10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	METHYL CHLORIDE	<	10.0000	NA		0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	METHYL CHLORIDE	<	10.0000	<		10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	METHYLENE CHLORIDE	<	10.0000	NA		0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	METHYLENE CHLORIDE	<	5.0000	NA		0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	METHYLENE CHLORIDE	<	5.0000	<		5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	MOLYBDENUM	<	0.0500	NA		0.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	MOLYBDENUM		0.1700			0.1700	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	MOLYBDENUM		0.0240			0.0290			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	MOLYBDENUM	<	2.0000	<		2.0000	< 0.02	< 0.02	mg/l	11/03/89	4	IT	MT

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WIPP-19	CULEBRA	MOLYBDENUM	<	0.2000	<	0.2000				mg/l		06/13/90	5	IT	MT
WIPP-19	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA	0.0000				ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	<	10.0000				ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000	NA	0.0000				ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA	0.0000				ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	<	10.0000				ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA	0.0000				ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	NAPHTHALENE	<	10.0000	NA	0.0000				ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	NAPHTHALENE	<	10.0000	<	10.0000				ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	NAPHTHALENE	<	10.0000	NA	0.0000				ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	NICKEL	<	3.0000	<	3.0000	<	0.03	< 0.03	mg/l		07/14/87	1	IT	ME
WIPP-19	CULEBRA	NICKEL	<	3.0000	<	3.0000	<	0.03	< 0.03	mg/l		02/12/88	2	IT	ME
WIPP-19	CULEBRA	NICKEL	<	0.0200	<	0.0300				mg/l		08/29/88	3	IT	ME
WIPP-19	CULEBRA	NICKEL	<	4.0000	<	4.0000	<	0.04	< 0.04	mg/l		11/03/89	4	IT	MT
WIPP-19	CULEBRA	NICKEL	<	0.4000	<	0.4000				mg/l		06/13/90	5	IT	MT
WIPP-19	CULEBRA	NITRATE		0.9000	NA	0.0000				mg/l	NO3-N	07/14/87	1	IT	GC
WIPP-19	CULEBRA	NITRATE		0.1100		0.1200				mg/l	NO3-N	02/12/88	2	IT	GC
WIPP-19	CULEBRA	NITRATE	<	0.0200	NA	0.0000				mg/l	NO3-N	08/29/88	3	IT	GC
WIPP-19	CULEBRA	NITRATE	<	0.0200	NA	0.0000				mg/l		11/03/89	4	IT	GC
WIPP-19	CULEBRA	NITRATE	<	0.0200	<	0.0200				mg/l		06/13/90	5	IT	GC
WIPP-19	CULEBRA	NITROBENZENE	<	10.0000	NA	0.0000				ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	NITROBENZENE	<	10.0000	<	10.0000				ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	NITROBENZENE	<	10.0000	NA	0.0000				ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000	NA	0.0000				ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000	<	10.0000				ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000	NA	0.0000				ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	PCB	<	1.0000	NA	0.0000				ug/l		07/14/87	1	IT	PC
WIPP-19	CULEBRA	PCB	<	1.0000	NA	0.0000				ug/l		02/12/88	2	IT	PC
WIPP-19	CULEBRA	PCB	<	1.0000	NA	0.0000				ug/l		08/29/88	3	IT	PC

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WIPP-19	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	PENTACHLOROPHENOL	<	50.0000		<	50.0000			ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	PHENANTHRENE	<	10.0000		<	10.0000			ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	PHENOL	<	10.0000		<	10.0000			ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	PHENOLICS		0.0190		NA	0.0000			mg/l		07/14/87	1	IT	GC
WIPP-19	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		02/12/88	2	IT	GC
WIPP-19	CULEBRA	PHENOLICS		0.0970		NA	0.0000			mg/l		08/29/88	3	IT	GC
WIPP-19	CULEBRA	PHENOLICS		0.0060		NA	0.0000			mg/l		11/03/89	4	IT	GC
WIPP-19	CULEBRA	PHENOLICS	<	0.0050		<	0.0100			mg/l		06/13/90	5	IT	GC
WIPP-19	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	07/14/87	1	IT	GC
WIPP-19	CULEBRA	PHOSPHATE	<	0.0100		NA	0.0000			mg/l	T-PO4-P	02/12/88	2	IT	GC
WIPP-19	CULEBRA	PHOSPHATE		0.0300		NA	0.0000			mg/l	T-PO4-P	08/29/88	3	IT	GC
WIPP-19	CULEBRA	PHOSPHORUS		0.0100		NA	0.0000			mg/l		11/03/89	4	IT	GC
WIPP-19	CULEBRA	PHOSPHORUS	<	0.0100		NA	0.0000			mg/l		06/13/90	5	IT	GC
WIPP-19	CULEBRA	POTASSIUM		850.0000		NA	0.0000			mg/l		07/14/87	1	IT	ME
WIPP-19	CULEBRA	POTASSIUM		910.0000			890.0000			mg/l		02/12/88	2	IT	ME
WIPP-19	CULEBRA	POTASSIUM		760.0000			740.0000			mg/l		08/29/88	3	IT	ME
WIPP-19	CULEBRA	POTASSIUM		600.0000			610.0000			mg/l		11/03/89	4	IT	MC
WIPP-19	CULEBRA	POTASSIUM		600.0000			580.0000			mg/l		06/13/90	5	IT	MC
WIPP-19	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		07/14/87	1	IT	SV
WIPP-19	CULEBRA	PYRENE	<	10.0000		<	10.0000			ug/l		02/12/88	2	IT	SV
WIPP-19	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		08/29/88	3	IT	SV
WIPP-19	CULEBRA	RESIDUE, FILTERABLE @ 180 C		110000.0000			110000.0000			mg/l		07/14/87	1	IT	GC
WIPP-19	CULEBRA	RESIDUE, FILTERABLE @ 180 C		85400.0000		NA	0.0000			mg/l		02/12/88	2	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-19	CULEBRA	RESIDUE, FILTERABLE @ 180 C		79000.0000			77000.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	RESIDUE, FILTERABLE @ 180 C		80000.0000			79200.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	RESIDUE, FILTERABLE @ 180 C		77200.0000			74500.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		330.0000			330.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		59.0000		NA	0.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		17.0000			16.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		20.0000			20.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		19.0000			16.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	SELENIUM	<	0.0400		<	0.0400			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	SELENIUM	<	0.5000		<	0.5000	< 0.005	< 0.005	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	SELENIUM	<	0.5000		NA	0.0000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	SILICA		21.0000			21.0000	< 0.2	< 0.2	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	SILICA	<	4.2000		NA	0.0000			mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	SILICA		4.3000		NA	0.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	SILICA		4.4000			4.4000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	SILICA		4.3000		NA	0.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	SILVER	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	SILVER	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	SILVER	<	0.0200		<	0.0200			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	SILVER	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	SILVER	<	0.1000		<	0.1000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	SODIUM		30000.0000		NA	0.0000			mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	SODIUM		26500.0000			26500.0000			mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	SODIUM		30900.0000			31200.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	SODIUM		23000.0000			23000.0000			mg/l	11/03/89	4	IT	MC
WIPP-19	CULEBRA	SODIUM		31000.0000			31000.0000			mg/l	06/13/90	5	IT	MC
WIPP-19	CULEBRA	SPECIFIC CONDUCTANCE		184000.0000			179000.0000			umhos/cm@25C	07/14/87	1	IT	GC

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WIPP-19	CULEBRA	SPECIFIC CONDUCTANCE		158000.0000			159000.0000			umhos/cm@25C	02/12/88	2	IT	GC
WIPP-19	CULEBRA	SPECIFIC CONDUCTANCE		90600.0000			90900.0000			umhos/cm@25C	08/29/88	3	IT	GC
WIPP-19	CULEBRA	SPECIFIC CONDUCTANCE		92238.0000			92458.0000			uMhos/cm@25C	11/03/89	4	IT	GC
WIPP-19	CULEBRA	SPECIFIC CONDUCTANCE		90800.0000			91100.0000			uMhos/cm@25C	06/13/90	5	IT	GC
WIPP-19	CULEBRA	STRONTIUM		44.0000			45.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	STRONTIUM		35.0000			36.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	STRONTIUM		28.0000			28.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	STRONTIUM		28.0000			28.0000	< 0.01	< 0.01	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	STRONTIUM		22.0000			22.0000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	STYRENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	STYRENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	SULFATE		5400.0000		NA	0.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	SULFATE		5700.0000		NA	0.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	SULFATE		5500.0000			5400.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	SULFATE		5600.0000		NA	0.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	SULFATE		5000.0000		NA	0.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	THALLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	THALLIUM	<	5.0000		NA	0.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	THALLIUM	<	10.0000		<	10.0000	< 0.01	< 0.01	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	THALLIUM	<	0.1000		NA	0.0000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	TIN	<	4.0000		<	4.0000	< 0.04	< 0.04	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	TITANIUM	<	3.0000		<	3.0000	< 0.03	< 0.03	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	TITANIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	TITANIUM	<	0.0070		<	0.0080			mg/l	08/29/88	3	IT	ME

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WIPP-19	CULEBRA	TITANIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	TITANIUM	<	0.1000		<	0.1000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	TOLUENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	TOLUENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	TOTAL ORGANIC CARBON		7.0000			7.0000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC CARBON		7.0000			7.0000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC CARBON		5.0000			5.0000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC CARBON		1.0000			2.0000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC CARBON		7.0000			5.0000			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC HALOGEN		0.7900			1.1000			mg/l	07/14/87	1	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC HALOGEN		1.1000			1.6000			mg/l	02/12/88	2	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC HALOGEN		1.6000			4.8000			mg/l	08/29/88	3	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC HALOGEN		1.1000			3.2000			mg/l	11/03/89	4	IT	GC
WIPP-19	CULEBRA	TOTAL ORGANIC HALOGEN		0.5900			0.5400			mg/l	06/13/90	5	IT	GC
WIPP-19	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	TRICHLOROETHYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	VANADIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	VANADIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	VANADIUM		1.0000			1.0000			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	VANADIUM	<	5.0000		<	5.0000	< 0.05	< 0.05	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	VANADIUM	<	0.5000		<	0.5000			mg/l	06/13/90	5	IT	MT

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WIPP-19	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	VINYL ACETATE	<	10.0000		<	10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	VINYL CHLORIDE	<	10.0000		<	10.0000		T < 10	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	07/14/87	1	IT	V
WIPP-19	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	02/12/88	2	IT	V
WIPP-19	CULEBRA	XYLENE	<	5.0000		<	5.0000		T < 5.0	ug/l	08/29/88	3	IT	V
WIPP-19	CULEBRA	ZINC	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	07/14/87	1	IT	ME
WIPP-19	CULEBRA	ZINC		3.0000			1.0000	< 0.01	< 0.01	mg/l	02/12/88	2	IT	ME
WIPP-19	CULEBRA	ZINC		0.0510			0.1470			mg/l	08/29/88	3	IT	ME
WIPP-19	CULEBRA	ZINC	<	2.0000		<	2.0000	< 0.02	< 0.02	mg/l	11/03/89	4	IT	MT
WIPP-19	CULEBRA	ZINC	<	0.2000		<	0.2000			mg/l	06/13/90	5	IT	MT
WIPP-19	CULEBRA	pH		7.0700			7.0500				07/14/87	1	IT	GC
WIPP-19	CULEBRA	pH		6.6700			6.7600				02/12/88	2	IT	GC
WIPP-19	CULEBRA	pH		6.9100		NA	0.0000				08/29/88	3	IT	GC
WIPP-19	CULEBRA	pH		7.2700			7.2700				11/03/89	4	IT	GC
WIPP-19	CULEBRA	pH		7.2400			7.2400				06/13/90	5	IT	GC
** WIPP-25														
WIPP-25	CULEBRA	1,1,1-TRICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,1,2-TRICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V

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WIPP-25	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,1-DICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,1-DICHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,2,4-TRICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	1,2,4-TRICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	1,2-DICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	1,2-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	1,2-DICHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,2-DICHLOROPROPANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	1,3-DICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	1,3-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	1,3-DICHLOROPROPYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	1,4-DICHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	1,4-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2,4,5-TRICHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,4,5-TRICHLOROPHENOL	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	2,4,6-TRICHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,4,6-TRICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2,4-DICHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,4-DICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2,4-DIMETHYLPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,4-DIMETHYLPHENOL	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2,4-DINITROPHENOL	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,4-DINITROPHENOL	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2,4-DINITROTOLUENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,4-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2,6-DINITROTOLUENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2,6-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2-BUTANONE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	2-CHLORONAPHTHALENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2-CHLORONAPHTHALENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2-CHLOROPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2-CHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2-HEXANONE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	2-METHYLNAPHTHALENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2-METHYLNAPHTHALENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2-METHYLPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2-NITROANILINE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2-NITROANILINE	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	2-NITROPHENOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	2-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	3,3'-DICHLOROBENZIDINE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	3,3'-DICHLOROBENZIDINE	<	40.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	3,4-BENZOFLUORANTHENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	3,4-BENZOFLUORANTHENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	3-NITROANILINE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	3-NITROANILINE	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4,6-DINITRO-O-CRESOL	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	4,6-DINITRO-O-CRESOL	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV

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WIPP-25	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	20.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4-CHLOROANILINE	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	4-CHLOROANILINE	<	20.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4-CHLOROANILINE	<	10.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	20.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4-METHYL-2-PENTANONE	<	20.0000	NA		0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000	NA		0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	4-METHYLPHENOL	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	4-METHYLPHENOL	<	20.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4-METHYLPHENOL	<	10.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4-NITROANILINE	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	4-NITROANILINE	<	100.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4-NITROANILINE	<	50.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	4-NITROPHENOL	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	4-NITROPHENOL	<	100.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	4-NITROPHENOL	<	50.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	ACENAPHTHENE	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	ACENAPHTHENE	<	20.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	ACENAPHTHENE	<	10.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	ACENAPHTHYLENE	<	2.0000	NA		0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	ACENAPHTHYLENE	<	20.0000	NA		0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	ACENAPHTHYLENE	<	10.0000	NA		0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	ACETONE		21.0000	NA		0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	ACETONE	<	10.0000	NA		0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	ACETONE	<	10.0000	NA		0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	ACROLEIN	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	ACRYLONITRILE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	ALKALINITY (HCO3)		120.0000		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	ALKALINITY (HCO3)		100.0000			100.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	ALKALINITY (HCO3)		130.0000		NA	0.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	ALKALINITY (HCO3)		120.0000			120.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	ALUMINUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	ANILINE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	ANTHRACENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	ANTHRACENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	ANTIMONY	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	ANTIMONY	<	0.0600		<	0.0600	< 0.06	< 0.06	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	ARSENIC		0.2700		NA	0.0000	< 0.001	< 0.001	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	ARSENIC	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	ARSENIC	<	0.0050		NA	0.0000	< 0.005	< 0.005	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	ARSENIC	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.05	< 0.05	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	BARIUM	<	2.0000		<	2.0000	< 0.2	< 0.2	mg/l	06/27/89	4	IT	MT

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WIPP-25	CULEBRA	BENZENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	BENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	BENZIDINE	<	8.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZO(A)ANTHRACENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZO(A)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BENZO(A)PYRENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZO(A)PYRENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BENZO(G,H,I)PERYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZO(G,H,I)PERYLENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BENZO(K)FLUORANTHENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZO(K)FLUORANTHENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BENZOIC ACID	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZOIC ACID	<	100.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BENZYL ALCOHOL	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BENZYL ALCOHOL	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		280.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	BIS(CHLOROMETHYL)ETHER	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BORON		1.7000		NA	0.0000	< 0.01	< 0.01	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	BORON		1.5000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	BORON		1.8000			1.8000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	BORON		1.7000			1.7000	< 0.02	< 0.02	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	BROMIDE		4.0000			4.4000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	BROMIDE		4.0000			4.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	BROMIDE		4.0000			4.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	BROMIDE		6.0000			5.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	BROMOFORM	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	BUTYL BENZYL PHTHALATE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	BUTYL BENZYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	CADMIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	CADMIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	CALCIUM		1200.0000			1100.0000			mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	CALCIUM		1100.0000			1100.0000			mg/l	04/15/87	2	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	CALCIUM		1100.0000			1100.0000			mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	CALCIUM		1300.0000		NA	0.0000			mg/l	06/27/89	4	IT	MC
WIPP-25	CULEBRA	CARBON DISULFIDE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	CARBON TETRACHLORIDE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	CESIUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	CESIUM		0.0100			0.0100	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	CESIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	CHLORIDE		6200.0000		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	CHLORIDE		6500.0000		NA	0.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	CHLORIDE		6500.0000		NA	0.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	CHLORIDE		6500.0000		NA	0.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	CHLOROBENZENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	CHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	CHLOROFORM	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	CHROMIUM	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	CHROMIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	CHROMIUM		0.2000			0.2000	0.01	0.01	mg/l	06/27/89	4	IT	MT

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WIPP-25	CULEBRA	CHRYSENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	CHRYSENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.1	< 0.1	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	COBALT	<	0.0500		<	0.5000	< 0.05	< 0.05	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	COPPER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	COPPER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	COPPER	<	0.2500		<	0.2500	< 0.025	< 0.025	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	CYANIDE	<	0.0200		<	0.0200			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	CYANIDE	<	0.0100		NA	0.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	DI-N-BUTYL PHTHALATE		3.5000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	DI-N-BUTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	DI-N-OCTYL PHTHALATE		33.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	DI-N-OCTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	DIBENZOFURAN	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	DIBENZOFURAN	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV

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WIPP-25	CULEBRA	DIBROMOCHLOROMETHANE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000	T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000	NA		0.0000 T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	DICHLOROBROMOMETHANE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000	T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000	NA		0.0000 T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	DIETHYL PHTHALATE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	DIETHYL PHTHALATE	<	20.0000	NA		0.0000		ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	DIETHYL PHTHALATE	<	10.0000	NA		0.0000		ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	DIMETHYL PHTHALATE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	DIMETHYL PHTHALATE	<	20.0000	NA		0.0000		ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	DIMETHYL PHTHALATE	<	10.0000	NA		0.0000		ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	ETHYLBENZENE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	ETHYLBENZENE	<	5.0000	NA		0.0000	T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	ETHYLBENZENE	<	5.0000	NA		0.0000 T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	Eh		438.0000	NA		0.0000		mV	02/12/86	1	IT	GC
WIPP-25	CULEBRA	FLUORANTHENE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	FLUORANTHENE	<	20.0000	NA		0.0000		ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	FLUORANTHENE	<	10.0000	NA		0.0000		ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	FLUORENE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	FLUORENE	<	20.0000	NA		0.0000		ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	FLUORENE	<	10.0000	NA		0.0000		ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	FLUORIDE		1.6000			1.6000		mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	FLUORIDE		1.5000	NA		0.0000		mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	FLUORIDE		1.5000	NA		0.0000		mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	FLUORIDE		1.4000			1.4000		mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	HEXACHLOROBENZENE	<	2.0000	NA		0.0000		ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	HEXACHLOROBENZENE	<	20.0000	NA		0.0000		ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	HEXACHLOROBENZENE	<	10.0000	NA		0.0000		ug/l	03/28/88	3	IT	SV

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WIPP-25	CULEBRA	HEXACHLOROBUTADIENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	HEXACHLOROBUTADIENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	HEXACHLOROETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	HEXACHLOROETHANE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	IODIDE	<	1.0000		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	IRON		0.4500		NA	0.0000	< 0.01	< 0.01	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	IRON		0.2000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	IRON		0.8000			0.8000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	IRON		1.0000			1.0000	< 0.1	< 0.1	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	ISOPHORONE	<	8.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	ISOPHORONE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV
WIPP-25	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	LITHIUM		0.2400		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	LITHIUM		0.2600			0.2600	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	LITHIUM		0.2300			0.2300	< 0.01	< 0.01	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	MAGNESIUM		350.0000			330.0000			mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	MAGNESIUM		330.0000			340.0000			mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	MAGNESIUM		330.0000			330.0000			mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	MAGNESIUM		350.0000		NA	0.0000			mg/l	06/27/89	4	IT	MC
WIPP-25	CULEBRA	MANGANESE		0.1100		NA	0.0000	0.02	0.01	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	MANGANESE		0.1100		NA	0.0000	< 0.005	< 0.005	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	MANGANESE		0.1300			0.1300	< 0.005	< 0.005	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	MANGANESE	<	0.1500		<	0.1500	< 0.015	< 0.015	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	MERCURY		0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	METHYL BROMIDE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	METHYL CHLORIDE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	METHYLENE CHLORIDE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000	T 41	T 35	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	MOLYBDENUM		0.0300			0.0400	< 0.01	< 0.01	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	MOLYBDENUM		0.0600		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	MOLYBDENUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	MOLYBDENUM	<	0.2000		NA	0.0000	< 0.02	< 0.02	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	SV
WIPP-25	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	20.0000		NA	0.0000			ug/l	04/15/87	2	IT	SV
WIPP-25	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l	03/28/88	3	IT	SV

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WIPP-25	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	NAPHTHALENE	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	NAPHTHALENE	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	NAPHTHALENE	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	NICKEL	<	0.3000	NA		0.0000	< 0.03	< 0.03	mg/l		02/12/86	1	IT	ME
WIPP-25	CULEBRA	NICKEL	<	0.3000	NA		0.0000	< 0.03	< 0.03	mg/l		04/15/87	2	IT	ME
WIPP-25	CULEBRA	NICKEL	<	0.3000	<		0.3000	< 0.03	< 0.03	mg/l		03/28/88	3	IT	ME
WIPP-25	CULEBRA	NICKEL	<	0.4000	<		0.4000	< 0.04	< 0.04	mg/l		06/27/89	4	IT	MT
WIPP-25	CULEBRA	NITRATE		3.6000			3.5000			mg/l	NO3-N	02/12/86	1	IT	GC
WIPP-25	CULEBRA	NITRATE		3.0000	NA		0.0000			mg/l	NO3-N	04/15/87	2	IT	GC
WIPP-25	CULEBRA	NITRATE		2.6000	NA		0.0000			mg/l	NO3-N	03/28/88	3	IT	GC
WIPP-25	CULEBRA	NITRATE		1.8000			1.8000			mg/l		06/27/89	4	IT	GC
WIPP-25	CULEBRA	NITROBENZENE	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	NITROBENZENE	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	NITROBENZENE	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	P-CHLORO-M-CRESOL	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	P-CHLORO-M-CRESOL	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	PCB	<	1.0000	NA		0.0000			ug/l		04/15/87	2	IT	PC
WIPP-25	CULEBRA	PCB	<	1.0000	NA		0.0000			ug/l		03/28/88	3	IT	PC
WIPP-25	CULEBRA	PENTACHLOROPHENOL	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	PENTACHLOROPHENOL	<	100.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	PENTACHLOROPHENOL	<	50.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	PHENANTHRENE	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	PHENANTHRENE	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	PHENANTHRENE	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	PHENOL	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV

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WIPP-25	CULEBRA	PHENOL	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	PHENOL	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	PHENOLICS		0.0130	NA		0.0000			mg/l		02/12/86	1	IT	GC
WIPP-25	CULEBRA	PHENOLICS		0.0060	NA		0.0000			mg/l		04/15/87	2	IT	GC
WIPP-25	CULEBRA	PHENOLICS		0.1060	NA		0.0000			mg/l		03/28/88	3	IT	GC
WIPP-25	CULEBRA	PHENOLICS	<	0.0050	NA		0.0000			mg/l		06/27/89	4	IT	GC
WIPP-25	CULEBRA	PHOSPHATE	<	0.0100	NA		0.0000			mg/l	T-PO4-P	02/12/86	1	IT	GC
WIPP-25	CULEBRA	PHOSPHATE		0.0200	NA		0.0000			mg/l	T-PO4-P	04/15/87	2	IT	GC
WIPP-25	CULEBRA	PHOSPHATE		0.0300	NA		0.0000			mg/l	T-PO4-P	03/28/88	3	IT	GC
WIPP-25	CULEBRA	PHOSPHORUS		0.0200	NA		0.0000			mg/l		06/27/89	4	IT	GC
WIPP-25	CULEBRA	POTASSIUM		110.0000			100.0000			mg/l		02/12/86	1	IT	ME
WIPP-25	CULEBRA	POTASSIUM		120.0000	NA		0.0000			mg/l		04/15/87	2	IT	ME
WIPP-25	CULEBRA	POTASSIUM		150.0000			150.0000			mg/l		03/28/88	3	IT	ME
WIPP-25	CULEBRA	POTASSIUM		160.0000	NA		0.0000			mg/l		06/27/89	4	IT	MC
WIPP-25	CULEBRA	PYRENE	<	2.0000	NA		0.0000			ug/l		02/12/86	1	IT	SV
WIPP-25	CULEBRA	PYRENE	<	20.0000	NA		0.0000			ug/l		04/15/87	2	IT	SV
WIPP-25	CULEBRA	PYRENE	<	10.0000	NA		0.0000			ug/l		03/28/88	3	IT	SV
WIPP-25	CULEBRA	RESIDUE, FILTERABLE @ 180 C		14000.0000	NA		0.0000			mg/l		02/12/86	1	IT	GC
WIPP-25	CULEBRA	RESIDUE, FILTERABLE @ 180 C		14000.0000	NA		0.0000			mg/l		04/15/87	2	IT	GC
WIPP-25	CULEBRA	RESIDUE, FILTERABLE @ 180 C		14800.0000	NA		0.0000			mg/l		03/28/88	3	IT	GC
WIPP-25	CULEBRA	RESIDUE, FILTERABLE @ 180 C		14500.0000			14500.0000			mg/l		06/27/89	4	IT	GC
WIPP-25	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		45.0000	NA		0.0000			mg/l		02/12/86	1	IT	GC
WIPP-25	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		37.0000	NA		0.0000			mg/l		04/15/87	2	IT	GC
WIPP-25	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		29.0000			24.0000			mg/l		03/28/88	3	IT	GC
WIPP-25	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		6.0000			13.0000			mg/l		06/27/89	4	IT	GC
WIPP-25	CULEBRA	SELENIUM	<	0.1000	NA		0.0000	< 0.01	< 0.01	mg/l		02/12/86	1	IT	ME
WIPP-25	CULEBRA	SELENIUM	<	0.0500	NA		0.0000	< 0.005	< 0.005	mg/l		04/15/87	2	IT	ME
WIPP-25	CULEBRA	SELENIUM	<	0.5000	NA		0.0000	< 0.005	< 0.005	mg/l		03/28/88	3	IT	ME
WIPP-25	CULEBRA	SELENIUM	<	0.0500	NA		0.0000	< 0.005	< 0.005	mg/l		06/27/89	4	IT	MT

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WIPP-25	CULEBRA	SILICA		31.0000		NA	0.0000	< 0.21	< 0.21	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	SILICA		32.0000		NA	0.0000	< 0.2	< 0.2	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	SILICA		13.0000			13.0000			mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	SILICA		14.0000			14.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	SILVER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	SILVER		0.1000			0.1000	< 0.01	< 0.01	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	SODIUM		3400.0000			3300.0000			mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	SODIUM		3400.0000		NA	0.0000			mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	SODIUM		3300.0000			3300.0000			mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	SODIUM		3800.0000		NA	0.0000			mg/l	06/27/89	4	IT	MC
WIPP-25	CULEBRA	SPECIFIC CONDUCTANCE		20800.0000		NA	0.0000			umhos/cm@25C	02/12/86	1	IT	GC
WIPP-25	CULEBRA	SPECIFIC CONDUCTANCE		21500.0000			21500.0000			umhos/cm@25C	04/15/87	2	IT	GC
WIPP-25	CULEBRA	SPECIFIC CONDUCTANCE		21900.0000			22000.0000			umhos/cm@25C	03/28/88	3	IT	GC
WIPP-25	CULEBRA	SPECIFIC CONDUCTANCE		25107.0000			25237.0000			uMhos/cm@25C	06/27/89	4	IT	GC
WIPP-25	CULEBRA	STRONTIUM		1.3900			1.4200	< 0.01	< 0.01	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	STRONTIUM		1.8000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	STRONTIUM		19.0000			19.0000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	STRONTIUM		18.0000		NA	0.0000	< 0.01	< 0.01	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	STYRENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	STYRENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	SULFATE		2400.0000		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	SULFATE		2400.0000			2300.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	SULFATE		2600.0000		NA	0.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	SULFATE		2100.0000			1800.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	TETRACHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V

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WIPP-25	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	THALLIUM	<	5.0000		NA	0.0000	< 0.005	< 0.005	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	THALLIUM	<	10.0000		NA	0.0000	< 0.01	< 0.01	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	TIN	<	0.4000		NA	0.0000	< 0.04	< 0.04	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	TITANIUM		0.8000		NA	0.0000	< 0.1	0.2	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	TITANIUM	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	TITANIUM		0.3000			0.3000	< 0.03	< 0.03	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	TITANIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	TOLUENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	TOLUENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	TOTAL ORGANIC CARBON		2.0000		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC CARBON		4.0000			4.0000			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		<	1.0000			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC HALOGEN		0.3800		NA	0.0000			mg/l	02/12/86	1	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	04/15/87	2	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500		<	0.0500			mg/l	03/28/88	3	IT	GC
WIPP-25	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.5000			0.0700			mg/l	06/27/89	4	IT	GC
WIPP-25	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	TRICHLOROETHYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	TRICHLOROFLUOROMETHANE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	TURBIDITY		15.5000			14.9000			NTU	06/27/89	4	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-25	CULEBRA	VANADIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	VANADIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	VANADIUM	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	VINYL ACETATE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	VINYL CHLORIDE	<	20.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000	T < 10	T < 10	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	XYLENE	<	2.0000		NA	0.0000			ug/l	02/12/86	1	IT	V
WIPP-25	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/15/87	2	IT	V
WIPP-25	CULEBRA	XYLENE	<	5.0000		NA	0.0000	T < 5.0	T < 5.0	ug/l	03/28/88	3	IT	V
WIPP-25	CULEBRA	ZINC		0.0800		NA	0.0000	< 0.05	< 0.05	mg/l	02/12/86	1	IT	ME
WIPP-25	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/15/87	2	IT	ME
WIPP-25	CULEBRA	ZINC	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	03/28/88	3	IT	ME
WIPP-25	CULEBRA	ZINC	<	0.2000		<	0.2000	< 0.02	< 0.02	mg/l	06/27/89	4	IT	MT
WIPP-25	CULEBRA	pH		7.7200		NA	0.0000				02/12/86	1	IT	GC
WIPP-25	CULEBRA	pH		7.2300			7.2600				04/15/87	2	IT	GC
WIPP-25	CULEBRA	pH		7.0000			7.0400				03/28/88	3	IT	GC
WIPP-25	CULEBRA	pH		7.1100			7.1100				06/27/89	4	IT	GC
** WIPP-26														
WIPP-26	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V

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WIPP-26	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	1,2,4-TRICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	1,2,4-TRICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	1,2-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	1,2-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	1,3-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	1,3-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	1,4-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	1,4-DICHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,4,5-TRICHLOROPHENOL	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	2,4,5-TRICHLOROPHENOL	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,4,6-TRICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2,4,6-TRICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,4-DICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2,4-DICHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,4-DIMETHYLPHENOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2,4-DIMETHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,4-DINITROPHENOL	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2,4-DINITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,4-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2,4-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2,6-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2,6-DINITROTOLUENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2-BUTANONE		55.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2-CHLORONAPHTHALENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2-CHLORONAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV

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WIPP-26	CULEBRA	2-CHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2-CHLOROPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2-METHYLNAPHTHALENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2-METHYLNAPHTHALENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2-NITROANILINE	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	2-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	2-NITROPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	3,3'-DICHLOROBENZIDINE	<	40.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	3,3'-DICHLOROBENZIDINE	<	20.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	3,4-BENZOFLUORANTHENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	3,4-BENZOFLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	3-NITROANILINE	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	3-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4,6-DINITRO-O-CRESOL	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4,6-DINITRO-O-CRESOL	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV

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WIPP-26	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4-CHLOROANILINE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4-CHLOROANILINE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4-METHYLPHENOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4-NITROANILINE	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4-NITROANILINE	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	4-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	4-NITROPHENOL	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	ACENAPHTHENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	ACENAPHTHENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	ACENAPHTHYLENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	ACENAPHTHYLENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	ACETONE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	ACETONE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	ALKALINITY (HCO3)		130.0000		NA	0.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	ALKALINITY (HCO3)		110.0000			110.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	ALKALINITY (HCO3)		110.0000		NA	0.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	ALUMINUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	ALUMINUM	<	1.0000		NA	0.0000	< 0.1	< 0.1	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	ALUMINUM	<	1.0000		<	1.0000	< 0.1	< 0.1	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	ANTHRACENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	ANTIMONY	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	ANTIMONY	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	ARSENIC	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	ARSENIC	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	ARSENIC	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	BARIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	BARIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	BENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	BENZENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	BENZO(A)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BENZO(A)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BENZO(A)PYRENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BENZO(A)PYRENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BENZO(G,H,I)PERYLENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BENZO(G,H,I)PERYLENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BENZO(K)FLUORANTHENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BENZO(K)FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BENZOIC ACID	<	100.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BENZOIC ACID	<	50.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BENZYL ALCOHOL	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BENZYL ALCOHOL	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BERYLLIUM	<	0.0050		<	0.0050	< 0.005	< 0.005	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	BERYLLIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	BERYLLIUM	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		260.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE		14.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	BORON	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	BORON		1.4000		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	BORON		1.3000			1.3000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	BROMIDE		12.0000		NA	0.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	BROMIDE		3.0000			3.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	BROMIDE		7.0000			7.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	BUTYL BENZYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	BUTYL BENZYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	CADMIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	CADMIUM		0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	CALCIUM		1800.0000			1800.0000	< 0.1	< 0.1	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	CALCIUM		1100.0000			1100.0000			mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	CALCIUM		1200.0000			1100.0000			mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	CESIUM	<	0.1000		<	0.1000	0.1	0.2	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	CESIUM		0.0900		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	CESIUM	<	0.0200		<	0.0200	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	CHLORIDE		10000.0000			8900.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	CHLORIDE		3200.0000		NA	0.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	CHLORIDE		5500.0000		NA	0.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	CHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	CHROMIUM		0.3500			0.3500	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	CHROMIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	CHROMIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	CHRYSENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	CHRYSENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	COBALT		0.4400			0.4400	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	COBALT	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	COBALT	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	COPPER		0.0600			0.0700	0.02	0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	COPPER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	COPPER	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	04/14/88	3	IT	GC

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WIPP-26	CULEBRA	DI-N-BUTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	DI-N-BUTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	DI-N-BUTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	DI-N-OCTYL PHTHALATE		21.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	DI-N-OCTYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	DIBENZOFURAN	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	DIBENZOFURAN	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	DIETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	DIETHYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	DIETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	DIMETHYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	DIMETHYL PHTHALATE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	Eh		462.0000		NA	0.0000			mV	11/25/85	1	IT	GC
WIPP-26	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	FLUORANTHENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	FLUORANTHENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	FLUORENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	FLUORENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	FLUORIDE		1.3000			1.3000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	FLUORIDE		1.5000		NA	0.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	FLUORIDE		1.6000		NA	0.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	HEXACHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	HEXACHLOROBENZENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	HEXACHLOROBUTADIENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	HEXACHLOROBUTADIENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	HEXACHLOROETHANE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	HEXACHLOROETHANE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	IODIDE	<	1.0000		<	1.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	IODIDE	<	2.0000		<	2.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	IRON	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	IRON	<	0.1000		NA	0.0000	0.05	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	IRON	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	11/25/85	1	IT	SV
WIPP-26	CULEBRA	ISOPHORONE	<	20.0000		NA	0.0000			ug/l	04/01/87	2	IT	SV
WIPP-26	CULEBRA	ISOPHORONE	<	10.0000		NA	0.0000			ug/l	04/14/88	3	IT	SV
WIPP-26	CULEBRA	LEAD		0.3100			0.3200	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	LEAD	<	0.5000		NA	0.0000	< 0.05	< 0.05	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	LEAD	<	0.5000		<	0.5000	< 0.05	< 0.05	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	LITHIUM		0.2500		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	LITHIUM		0.2600			0.2700	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	MAGNESIUM		370.0000			380.0000	< 0.1	< 0.1	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	MAGNESIUM		330.0000			330.0000			mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	MAGNESIUM		330.0000			330.0000			mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	MANGANESE		0.0900			0.0900	0.03	0.03	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	MANGANESE	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	MANGANESE	<	0.0500		<	0.0500	< 0.005	< 0.005	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	MERCURY	<	0.0002		<	0.0002	0.0004	0.0003	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	MERCURY	<	0.0002		<	0.0002	< 0.0002	< 0.0002	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	METHYLENE CHLORIDE		11.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	METHYLENE CHLORIDE	<	5.0000		NA	0.0000		T 41	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	MOLYBDENUM	<	0.0100		<	0.0100	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	MOLYBDENUM	<	0.0100		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	MOLYBDENUM	<	2.0000		<	2.0000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME

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WIPP-26	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	NAPHTHALENE	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	NAPHTHALENE	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	NICKEL		0.3500			0.3500	< 0.01	< 0.01	mg/l		11/25/85	1	IT	ME
WIPP-26	CULEBRA	NICKEL	<	0.3000		NA	0.0000	< 0.03	< 0.03	mg/l		04/01/87	2	IT	ME
WIPP-26	CULEBRA	NICKEL	<	0.3000		<	0.3000	< 0.03	< 0.03	mg/l		04/14/88	3	IT	ME
WIPP-26	CULEBRA	NITRATE		5.8000			5.6000			mg/l	NO3-N	11/25/85	1	IT	GC
WIPP-26	CULEBRA	NITRATE		5.2000			5.3000			mg/l	NO3-N	04/01/87	2	IT	GC
WIPP-26	CULEBRA	NITRATE		3.6000		NA	0.0000			mg/l	NO3-N	04/14/88	3	IT	GC
WIPP-26	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	NITROBENZENE	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	NITROBENZENE	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	P-CHLORO-M-CRESOL	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	P-CHLORO-M-CRESOL	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		04/01/87	2	IT	PC
WIPP-26	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		04/14/88	3	IT	PC
WIPP-26	CULEBRA	PENTACHLOROPHENOL	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	PENTACHLOROPHENOL	<	100.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	PENTACHLOROPHENOL	<	50.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	PHENANTHRENE	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV

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WIPP-26	CULEBRA	PHENANTHRENE	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	PHENOL	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	PHENOL	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	PHENOLICS		0.0030		NA	0.0000			mg/l		11/25/85	1	IT	GC
WIPP-26	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		04/01/87	2	IT	GC
WIPP-26	CULEBRA	PHENOLICS		0.0120		NA	0.0000			mg/l		04/14/88	3	IT	GC
WIPP-26	CULEBRA	PHOSPHATE		0.0800		NA	0.0000			mg/l	T-PO4-P	11/25/85	1	IT	GC
WIPP-26	CULEBRA	PHOSPHATE		0.0100			0.0100			mg/l	T-PO4-P	04/01/87	2	IT	GC
WIPP-26	CULEBRA	PHOSPHATE		0.0400		NA	0.0000			mg/l	T-PO4-P	04/14/88	3	IT	GC
WIPP-26	CULEBRA	POTASSIUM		350.0000			350.0000	< 0.01	< 0.01	mg/l		11/25/85	1	IT	ME
WIPP-26	CULEBRA	POTASSIUM		210.0000		NA	0.0000			mg/l		04/01/87	2	IT	ME
WIPP-26	CULEBRA	POTASSIUM		189.0000			190.0000			mg/l		04/14/88	3	IT	ME
WIPP-26	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		11/25/85	1	IT	SV
WIPP-26	CULEBRA	PYRENE	<	20.0000		NA	0.0000			ug/l		04/01/87	2	IT	SV
WIPP-26	CULEBRA	PYRENE	<	10.0000		NA	0.0000			ug/l		04/14/88	3	IT	SV
WIPP-26	CULEBRA	RESIDUE, FILTERABLE @ 180 C		18000.0000		NA	0.0000			mg/l		11/25/85	1	IT	GC
WIPP-26	CULEBRA	RESIDUE, FILTERABLE @ 180 C		13000.0000		NA	0.0000			mg/l		04/01/87	2	IT	GC
WIPP-26	CULEBRA	RESIDUE, FILTERABLE @ 180 C		12800.0000			12900.0000			mg/l		04/14/88	3	IT	GC
WIPP-26	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		18.0000			32.0000			mg/l		11/25/85	1	IT	GC
WIPP-26	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		30.0000		NA	0.0000			mg/l		04/01/87	2	IT	GC
WIPP-26	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		29.0000			30.0000			mg/l		04/14/88	3	IT	GC
WIPP-26	CULEBRA	SELENIUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l		11/25/85	1	IT	ME
WIPP-26	CULEBRA	SELENIUM	<	0.0500		NA	0.0000	< 0.005	< 0.005	mg/l		04/01/87	2	IT	ME
WIPP-26	CULEBRA	SELENIUM		0.0220		NA	0.0000	< 0.005	< 0.005	mg/l		04/14/88	3	IT	ME
WIPP-26	CULEBRA	SILICA		29.0000			30.0000	2.1	1.9	mg/l		11/25/85	1	IT	ME
WIPP-26	CULEBRA	SILICA		36.0000		NA	0.0000	< 0.2	< 0.2	mg/l		04/01/87	2	IT	ME
WIPP-26	CULEBRA	SILICA		15.0000		NA	0.0000			mg/l		04/14/88	3	IT	ME
WIPP-26	CULEBRA	SILVER	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l		04/01/87	2	IT	ME

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WIPP-26	CULEBRA	SILVER	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	SODIUM		4200.0000			4100.0000	< 0.1	< 0.1	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	SODIUM		2900.0000	NA		0.0000			mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	SODIUM		2600.0000			2600.0000			mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	SPECIFIC CONDUCTANCE		25800.0000	NA		0.0000			umhos/cm@25C	11/25/85	1	IT	GC
WIPP-26	CULEBRA	SPECIFIC CONDUCTANCE		19900.0000			19900.0000			umhos/cm@25C	04/01/87	2	IT	GC
WIPP-26	CULEBRA	SPECIFIC CONDUCTANCE		19400.0000			19500.0000			umhos/cm@25C	04/14/88	3	IT	GC
WIPP-26	CULEBRA	STRONTIUM		17.0000			17.0000	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	STRONTIUM		18.0000	NA		0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	STRONTIUM		18.0000			19.0000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	STYRENE	<	1.0000	NA		0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	STYRENE	<	5.0000	NA		0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	STYRENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	SULFATE		2000.0000			1900.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	SULFATE		1900.0000			1900.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	SULFATE		2500.0000			2300.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	TETRACHLOROETHYLENE	<	1.0000	NA		0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	TETRACHLOROETHYLENE	<	5.0000	NA		0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	TETRACHLOROETHYLENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	THALLIUM	<	0.5000	NA		0.0000	< 0.005	< 0.005	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	THALLIUM	<	0.0500	<		0.0500	< 0.005	< 0.005	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	TIN	<	0.4000	NA		0.0000	< 0.04	< 0.04	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	TITANIUM		0.0800			0.0700	0.04	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	TITANIUM		0.3000	NA		0.0000	< 0.03	< 0.03	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	TITANIUM	<	0.3000	<		0.3000	< 0.03	< 0.03	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	TOLUENE	<	1.0000	NA		0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	TOLUENE	<	5.0000	NA		0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	TOLUENE	<	5.0000	NA		0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000	NA		0.0000			mg/l	11/25/85	1	IT	GC

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-26	CULEBRA	TOTAL ORGANIC CARBON		2.0000			2.0000			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000	<		1.0000			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	TOTAL ORGANIC HALOGEN		0.0700		NA	0.0000			mg/l	11/25/85	1	IT	GC
WIPP-26	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500			0.0800			mg/l	04/01/87	2	IT	GC
WIPP-26	CULEBRA	TOTAL ORGANIC HALOGEN	<	0.0500	<		0.0500			mg/l	04/14/88	3	IT	GC
WIPP-26	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	VANADIUM	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	VANADIUM	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	11/25/85	1	IT	V
WIPP-26	CULEBRA	XYLENE	<	5.0000		NA	0.0000			ug/l	04/01/87	2	IT	V
WIPP-26	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	04/14/88	3	IT	V
WIPP-26	CULEBRA	ZINC		0.0200			0.0200	< 0.01	< 0.01	mg/l	11/25/85	1	IT	ME
WIPP-26	CULEBRA	ZINC	<	0.1000		NA	0.0000	< 0.01	< 0.01	mg/l	04/01/87	2	IT	ME
WIPP-26	CULEBRA	ZINC	<	0.1000	<		0.1000	< 0.01	< 0.01	mg/l	04/14/88	3	IT	ME
WIPP-26	CULEBRA	pH		7.3500		NA	0.0000				11/25/85	1	IT	GC
WIPP-26	CULEBRA	pH		7.1000			7.1300				04/01/87	2	IT	GC

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WIPP-26	CULEBRA	pH		6.8700			6.9000				04/14/88	3	IT	GC
** WIPP-29														
WIPP-29	CULEBRA	1,1,1-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,1,1-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,1,2,2-TETRACHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,1,2-TRICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,1,2-TRICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,1-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,1-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,1-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,1-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,2,4-TRICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	1,2,4-TRICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	1,2-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	1,2-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	1,2-DICHLOROETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,2-DICHLOROETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,2-DICHLOROPROPANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,2-DICHLOROPROPANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	1,3-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	1,3-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	1,3-DICHLOROPROPYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	1,4-DICHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	1,4-DICHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,3,7,8-TETRACHLOROBENZO-P-DIOXIN	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,4,5-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV

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WIPP-29	CULEBRA	2,4,5-TRICHLOROPHENOL	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,4,6-TRICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,4,6-TRICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,4-DICHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,4-DICHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,4-DIMETHYLPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,4-DIMETHYLPHENOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,4-DINITROPHENOL	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,4-DINITROPHENOL	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,4-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,4-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2,6-DINITROTOLUENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2,6-DINITROTOLUENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	2-BUTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	2-CHLOROETHYLVINYL ETHER	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	2-CHLORONAPHTHALENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2-CHLORONAPHTHALENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2-CHLOROPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2-CHLOROPHENOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	2-HEXANONE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	2-METHYLNAPHTHALENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2-METHYLNAPHTHALENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	2-NITROANILINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2-NITROANILINE	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-29	CULEBRA	2-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	2-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	3,3'-DICHLOROBENZIDINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	3,3'-DICHLOROBENZIDINE	<	40.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	3,4-BENZOFLUORANTHENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	3,4-BENZOFLUORANTHENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	3-NITROANILINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	3-NITROANILINE	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4,6-DINITRO-O-CRESOL	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4,6-DINITRO-O-CRESOL	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4-BROMOPHENYL PHENYL ETHER	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4-CHLOROANILINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4-CHLOROANILINE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4-CHLOROPHENYL PHENYL ETHER	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	4-METHYL-2-PENTANONE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	4-METHYLPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4-METHYLPHENOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4-NITROANILINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4-NITROANILINE	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	4-NITROPHENOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	4-NITROPHENOL	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	ACENAPHTHENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	ACENAPHTHENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	ACENAPHTHYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	ACENAPHTHYLENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	ACETONE	<	20.0000		NA	0.0000			ug/l	12/14/85	1	IT	V

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WIPP-29	CULEBRA	ACETONE		28.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	ACROLEIN	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	ACRYLONITRILE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	ALKALINITY (CO3)		0.0000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	ALKALINITY (CO3)		0.0000			0.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	ALKALINITY (HCO3)		170.0000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	ALKALINITY (HCO3)		180.0000			180.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	ALUMINUM		0.4600			0.5600	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	ALUMINUM	<	10.0000		NA	0.0000	< 0.1	< 0.1	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	ANILINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	ANTHRACENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	ANTHRACENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	ANTIMONY		10.0000		NA	0.0000	< 0.05	< 0.05	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	ARSENIC	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	ARSENIC	<	5.0000		NA	0.0000	< 0.005	< 0.005	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	BARIUM	<	0.1000		<	0.1000	< 0.1	< 0.1	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	BARIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	BENZENE	<	1.0000		NA	1.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	BENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	BENZIDINE	<	4.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BENZO(A)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BENZO(A)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BENZO(A)PYRENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BENZO(A)PYRENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BENZO(G,H,I)PERYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BENZO(G,H,I)PERYLENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BENZO(K)FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BENZO(K)FLUORANTHENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BENZOIC ACID	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV

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WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-29	CULEBRA	BENZOIC ACID	<	100.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BENZYL ALCOHOL	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BENZYL ALCOHOL	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BERYLLIUM		0.0500			0.0500	< 0.005	< 0.005	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	BERYLLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BIS(2-CHLOROETHOXY)METHANE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BIS(2-CHLOROETHYL)ETHER	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BIS(2-CHLOROISOPROPYL)ETHER	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BIS(2-ETHYLHEXYL)PHTHALATE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	BORON		5.8000			5.8000	< 0.1	< 0.1	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	BORON		6.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	BROMIDE		100.0000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	BROMIDE		54.0000		NA	0.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	BROMOFORM	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	BROMOFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	BUTYL BENZYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	BUTYL BENZYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	CADMIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	CALCIUM		630.0000			630.0000	< 0.1	< 0.1	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	CALCIUM		600.0000		NA	600.0000			mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	CARBON DISULFIDE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	CARBON DISULFIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	CARBON TETRACHLORIDE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	CARBON TETRACHLORIDE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	CESIUM	<	1.0000		<	1.0000	< 0.10	< 0.10	mg/l	12/14/85	1	IT	ME

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WIPP-29	CULEBRA	CESIUM		0.3000		NA	0.0000	< 0.1	< 0.1	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	CHLORIDE		180000.0000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	CHLORIDE		160000.0000			160000.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	CHLORIDE		160000.0000			160000.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	CHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	CHLOROBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	CHLOROETHANE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	CHLOROFORM	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	CHLOROFORM	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	CHROMIUM		2.0000			2.2000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	CHROMIUM		0.8000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	CHRYSENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	CHRYSENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	CIS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	COBALT		7.8000			7.9000	< 0.01	0.03	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	COBALT	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	COPPER		0.4300			0.3800	0.02	0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	COPPER	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	CYANIDE	<	0.0200		NA	0.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	DI-N-BUTYL PHTHALATE		3.5000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	DI-N-BUTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	DI-N-OCTYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	DI-N-OCTYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	DIBENZO(A,H)ANTHRACENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	DIBENZOFURAN	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	DIBENZOFURAN	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV

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WIPP-29	CULEBRA	DIBROMOCHLOROMETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	DIBROMOCHLOROMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	DICHLOROBROMOMETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	DICHLOROBROMOMETHANE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	DIETHYL PHTHALATE		1.2000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	DIETHYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	DIMETHYL PHTHALATE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	DIMETHYL PHTHALATE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	ETHYLBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	ETHYLBENZENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	Eh		441.0000		NA	0.0000			mV	12/14/85	1	IT	GC
WIPP-29	CULEBRA	FLUORANTHENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	FLUORANTHENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	FLUORENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	FLUORENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	FLUORIDE		0.9000			0.9000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	FLUORIDE		1.1000		NA	0.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	HEXACHLOROBENZENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	HEXACHLOROBENZENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	HEXACHLOROBUTADIENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	HEXACHLOROBUTADIENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	HEXACHLOROCYCLOPENTADIENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	HEXACHLOROETHANE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	HEXACHLOROETHANE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	INDENO(1,2,3-CD)PYRENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	IODIDE		2.1000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	IODIDE	<	2.0000		NA	0.0000			mg/l	03/11/87	2	IT	GC

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WIPP-29	CULEBRA	IRON		2.1000			1.9000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	IRON	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	ISOPHORONE	<	4.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	ISOPHORONE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	LEAD		2.9000			3.2000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	LEAD	<	5.0000		NA	0.0000	< 0.05	< 0.05	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	LITHIUM		0.6800		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	MAGNESIUM		6300.0000			6400.0000	< 0.1	< 0.1	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	MAGNESIUM		5900.0000		NA	0.0000			mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	MANGANESE		1.8000			1.8000	0.03	0.02	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	MANGANESE		1.1000		NA	0.0000	< 0.005	< 0.005	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	MERCURY	<	0.0002		<	0.0002	0.0003	0.0006	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	MERCURY	<	0.0002		NA	0.0000	< 0.0002	< 0.0002	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	METHYL BROMIDE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	METHYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	METHYLENE CHLORIDE	<	10.0000		NA	0.0000		T 55	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	MOLYBDENUM	<	0.1000		<	0.1000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	MOLYBDENUM		0.2800		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	N-NITROSO-DI-METHYLAMINE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	N-NITROSO-DI-N-PROPYLAMINE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	N-NITROSO-DI-PHENYLAMINE		11.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	N-NITROSO-DI-PHENYLAMINE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	NAPHTHALENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	SV
WIPP-29	CULEBRA	NAPHTHALENE	<	20.0000		NA	0.0000			ug/l	03/11/87	2	IT	SV
WIPP-29	CULEBRA	NICKEL		4.4000			4.2000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	NICKEL	<	3.0000		NA	0.0000	< 0.03	< 0.03	mg/l	03/11/87	2	IT	ME

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WIPP-29	CULEBRA	NITRATE		0.1000		NA	0.0000			mg/l	NO3-N	12/14/85	1	IT	GC
WIPP-29	CULEBRA	NITRATE		1.5000			1.6000			mg/l	NO3-N	03/11/87	2	IT	GC
WIPP-29	CULEBRA	NITROBENZENE	<	1.0000		NA	0.0000			ug/l		12/14/85	1	IT	SV
WIPP-29	CULEBRA	NITROBENZENE	<	20.0000		NA	0.0000			ug/l		03/11/87	2	IT	SV
WIPP-29	CULEBRA	P-CHLORO-M-CRESOL	<	1.0000		NA	0.0000			ug/l		12/14/85	1	IT	SV
WIPP-29	CULEBRA	P-CHLORO-M-CRESOL	<	20.0000		NA	0.0000			ug/l		03/11/87	2	IT	SV
WIPP-29	CULEBRA	PCB	<	1.0000		NA	0.0000			ug/l		03/11/87	2	IT	PC
WIPP-29	CULEBRA	PENTACHLOROPHENOL		3.9000		NA	0.0000			ug/l		12/14/85	1	IT	SV
WIPP-29	CULEBRA	PENTACHLOROPHENOL	<	100.0000		NA	0.0000			ug/l		03/11/87	2	IT	SV
WIPP-29	CULEBRA	PHENANTHRENE	<	1.0000		NA	0.0000			ug/l		12/14/85	1	IT	SV
WIPP-29	CULEBRA	PHENANTHRENE	<	20.0000		NA	0.0000			ug/l		03/11/87	2	IT	SV
WIPP-29	CULEBRA	PHENOL	<	1.0000		NA	0.0000			ug/l		12/14/85	1	IT	SV
WIPP-29	CULEBRA	PHENOL	<	20.0000		NA	0.0000			ug/l		03/11/87	2	IT	SV
WIPP-29	CULEBRA	PHENOLICS		0.0040		NA	0.0000			mg/l		12/14/85	1	IT	GC
WIPP-29	CULEBRA	PHENOLICS	<	0.0050		NA	0.0000			mg/l		03/11/87	2	IT	GC
WIPP-29	CULEBRA	PHOSPHATE		0.0400			0.0500			mg/l	T-PO4-P	12/14/85	1	IT	GC
WIPP-29	CULEBRA	PHOSPHATE	<	0.0100		<	0.0100			mg/l	T-PO4-P	03/11/87	2	IT	GC
WIPP-29	CULEBRA	POTASSIUM		23000.0000			23000.0000	< 0.01	< 0.01	mg/l		12/14/85	1	IT	ME
WIPP-29	CULEBRA	POTASSIUM		21000.0000		NA	0.0000			mg/l		03/11/87	2	IT	ME
WIPP-29	CULEBRA	PYRENE	<	1.0000		NA	0.0000			ug/l		12/14/85	1	IT	SV
WIPP-29	CULEBRA	PYRENE	<	20.0000		NA	0.0000			ug/l		03/11/87	2	IT	SV
WIPP-29	CULEBRA	RESIDUE, FILTERABLE @ 180 C		330000.0000		NA	0.0000			mg/l		12/14/85	1	IT	GC
WIPP-29	CULEBRA	RESIDUE, FILTERABLE @ 180 C		290000.0000		NA	0.0000			mg/l		03/11/87	2	IT	GC
WIPP-29	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		1500.0000		NA	0.0000			mg/l		12/14/85	1	IT	GC
WIPP-29	CULEBRA	RESIDUE, NONFILTERABLE @ 105 C		830.0000		NA	0.0000			mg/l		03/11/87	2	IT	GC
WIPP-29	CULEBRA	SELENIUM	<	1.0000		<	1.0000	< 0.01	< 0.01	mg/l		12/14/85	1	IT	ME
WIPP-29	CULEBRA	SELENIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l		03/11/87	2	IT	ME
WIPP-29	CULEBRA	SILICA		49.0000			53.0000	0.44	0.44	mg/l		12/14/85	1	IT	ME
WIPP-29	CULEBRA	SILICA		27.0000		NA	0.0000	< 0.2	< 0.2	mg/l		03/11/87	2	IT	ME

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DATA BASE OF
CHEMICAL ANALYSIS

WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-29	CULEBRA	SILVER	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	SODIUM		89000.0000			91000.0000	< 0.1	< 0.1	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	SODIUM		94000.0000		NA	0.0000			mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	SPECIFIC CONDUCTANCE		330000.0000		NA	0.0000			umhos/cm@25C	12/14/85	1	IT	GC
WIPP-29	CULEBRA	SPECIFIC CONDUCTANCE		43600.0000		NA	0.0000			umhos/cm@25C	03/11/87	2	IT	GC
WIPP-29	CULEBRA	STRONTIUM		9.0000			8.9000	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	STRONTIUM		21.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	STYRENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	STYRENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	SULFATE		17000.0000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	SULFATE		17000.0000			17000.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	TETRACHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	TETRACHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	THALLIUM	<	0.5000		NA	0.0000	< 0.005	< 0.005	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	TIN	<	4.0000		NA	0.0000	< 0.04	< 0.04	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	TITANIUM		0.3300			0.2800	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	TITANIUM	<	3.0000		NA	0.0000	< 0.03	< 0.03	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	TOLUENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	TOLUENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	TOTAL ORGANIC CARBON	<	1.0000		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	TOTAL ORGANIC CARBON		2.0000			3.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	TOTAL ORGANIC HALOGEN		0.5400		NA	0.0000			mg/l	12/14/85	1	IT	GC
WIPP-29	CULEBRA	TOTAL ORGANIC HALOGEN		2.8000		NA	0.0000			mg/l	03/11/87	2	IT	GC
WIPP-29	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	TRANS-1,2-DICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	TRANS-1,3-DICHLOROPROPENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	TRICHLOROETHYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	TRICHLOROETHYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	VANADIUM	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME

WATER QUALITY SAMPLING
DATA BASE OF
CHEMICAL ANALYSIS

WELL #	ZONE	PARAMETER	V	VALUE	S	D	DUP.	ACID BLANK	WATER BLANK	UNITS	DATE	RND	LAB	C
WIPP-29	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	VINYL ACETATE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	VINYL CHLORIDE	<	10.0000		NA	0.0000		T < 10	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	XYLENE	<	1.0000		NA	0.0000			ug/l	12/14/85	1	IT	V
WIPP-29	CULEBRA	XYLENE	<	5.0000		NA	0.0000		T < 5.0	ug/l	03/11/87	2	IT	V
WIPP-29	CULEBRA	ZINC		0.4500			0.5500	< 0.01	< 0.01	mg/l	12/14/85	1	IT	ME
WIPP-29	CULEBRA	ZINC	<	1.0000		NA	0.0000	< 0.01	< 0.01	mg/l	03/11/87	2	IT	ME
WIPP-29	CULEBRA	pH		6.5700		NA	0.0000				12/14/85	1	IT	GC
WIPP-29	CULEBRA	pH		6.2800		NA	0.0000				03/11/87	2	IT	GC

APPENDIX CLI

CONTRACTOR REPORT

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UC—721

Long-Term Climate Variability at the Waste Isolation Pilot Plant, Southeastern New Mexico, USA

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Long-Term Climate Variability at the Waste Isolation Pilot Plant, Southeastern New Mexico, USA*

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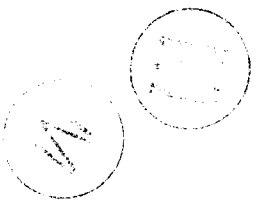

ABSTRACT

The United States Department of Energy is developing the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico for the disposal of transuranic wastes generated by defense programs. Because changes in climate during the next 10,000 years (10 ka) may affect performance of the repository, an understanding of long-term climate variability is essential for evaluating regulatory compliance.

Fluctuations in global climate corresponding to glaciation and deglaciation of the northern hemisphere have been regular in both frequency and amplitude for at least 780 ka. Coolest and wettest conditions in the past have occurred at the WIPP during glacial maxima, when the North American ice sheet reached its southern limit roughly 1200 km north of the WIPP and deflected the jet stream southward. Average precipitation in southeastern New Mexico during the last glacial maximum 22 to 18 ka before present (BP) was approximately twice that of the present. Driest conditions (precipitation approximately 90% of present) occurred 6.5 to 4.5 ka BP, after the ice sheet had retreated to its present location. Wet periods of unknown duration have occurred since the retreat of the ice sheet, but none have exceeded glacial conditions. Global climate models suggest that anthropogenic climate changes (i.e., warming caused by an increased greenhouse effect) will not result in an increase in precipitation at the WIPP. The climate of the last glacial maximum is therefore suitable for use as a cooler and wetter limit for variability during the next 10 ka.

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1. Introduction

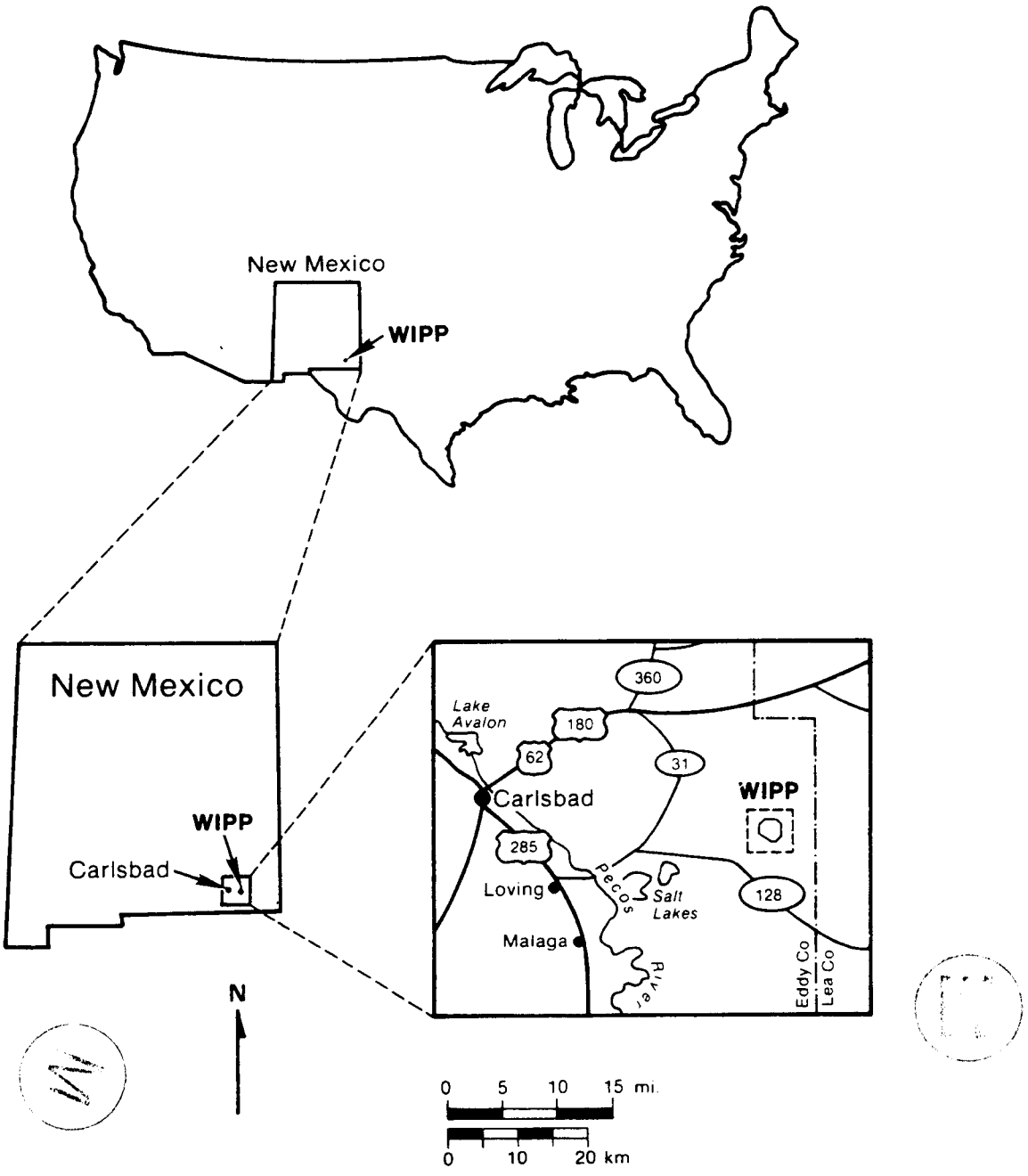
The Waste Isolation Pilot Plant (WIPP), located 42 km east of Carlsbad, New Mexico (Figure 1), is being evaluated by the United States Department of Energy (DOE) for disposal of transuranic wastes generated since 1970 by defense programs. The repository is excavated approximately 655 m below the ground surface in bedded halite of the Late Permian Salado Formation, deposited approximately 255 million years before the present (255 Ma BP).

Before the WIPP can be used for long-term disposal of transuranic waste, the DOE must demonstrate compliance with the United States Environmental Protection Agency's (EPA) *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Waste* (40 CFR 191) (U.S. EPA, 1985), hereafter referred to as the standard. Although the standard was vacated by a Federal Court of Appeals in 1987 and is undergoing revision, by agreement with the State of New Mexico, the DOE is continuing to evaluate repository performance with respect to the regulation as first promulgated until a new version is available (U.S. DOE and the State of New Mexico, 1981, as modified in 1984 and 1987).

The standard requires that the DOE consider "all significant processes and events that may affect the disposal system" during the 10,000 years (10 ka) following decommissioning. The performance assessment being conducted for the DOE by Sandia National Laboratories is therefore examining, among other things, the likelihood and consequences of long-term changes in climate. Climatic changes have the potential to affect repository performance directly, by altering groundwater recharge and flow in the region, and indirectly, by changing human land-use patterns in the region. Increases in precipitation are of primary concern because they may result in increased groundwater flow and, in the event of a breach of the repository, increased transport of radionuclides to the accessible environment.

2. Modern Climate at the WIPP

At present, the climate at the WIPP is arid to semiarid. Mean annual precipitation at the WIPP has been estimated to be between 28 and 34 cm/yr (Hunter, 1985). At Carlsbad, 100 m lower than the WIPP, 53-yr (1931-1983) annual means for precipitation and temperature are 32 cm/yr and 17.1°C (University of New Mexico, 1989). Short-term variation about the annual means can be considerable, and historic weather data cannot be used to predict long-term climatic shifts. For example, the 105-yr (1878 to 1982) precipitation record from Roswell, 135 km northwest of the WIPP and 60 m



TRI-6342-223-1

Figure 1. Location of the WIPP (after Bertram-Howery and Hunter, 1989).

higher, shows an annual mean of 27 cm/yr with a high of 84 cm/yr and a low of 11 cm/yr (Hunter, 1985).

The climate of southeastern New Mexico is monsoonal: most of the precipitation falls in late summer, when solar warming of the continent creates an atmospheric pressure gradient that draws moist air inland from the Gulf of Mexico (Cole, 1975). The coincidence of precipitation and temperature maxima is typical of a monsoonal climate (Figure 2). Much of the rain falls during localized and often intense summer thunderstorms, and winters are cool and generally dry. Both temperature and precipitation are dependent on elevation, and local climates vary with topography. At lower elevations throughout the region, including the vicinity of the WIPP, potential evaporation greatly exceeds precipitation. Freshwater pan evaporation in the region is estimated to exceed 274 cm/yr (Hunter, 1985). Surface runoff and infiltration of rainwater into the subsurface are limited. Hunter (1985) concluded from a literature review that within the vicinity of the WIPP an average of 96 percent of precipitation is lost to evapotranspiration. Evapotranspiration values may be significantly higher or lower locally.

3. Climatic Change

Presently available long-term climate models are incapable of resolution on the spatial scales required (e.g., Hansen and others, 1988; Mitchell, 1989; Houghton and others, 1990), and it is not realistic to predict the climate of southeastern New Mexico for the next 10 ka. Instead, this report reviews evidence of past climatic changes in the region, and establishes limits on future precipitation based on known and modeled past extremes. Much of the available paleoclimatic data only record long-term average levels of precipitation, and these limits do not reflect the high variability apparent in the modern short-term data. The precipitation record presented here primarily reflects gradual shifts in long-term mean values.

A fundamental assumption, analogous to that made by Spaulding (1985) in a study of climatic variability at the Nevada Test Site, is that climatic extremes of the next 10 ka will not exceed those associated with glaciations and deglaciations that have recurred repeatedly in the northern hemisphere since the late Pliocene (2.5 Ma BP). The possibility that human-induced changes in the composition of the earth's atmosphere may influence future climates complicates projections of this cyclic pattern into the future, but, as presently modeled (e.g., Mitchell, 1989; Houghton and others, 1990), such changes do not appear likely to have a negative effect on the performance of the WIPP. The highest past precipitation levels in southeastern New Mexico,

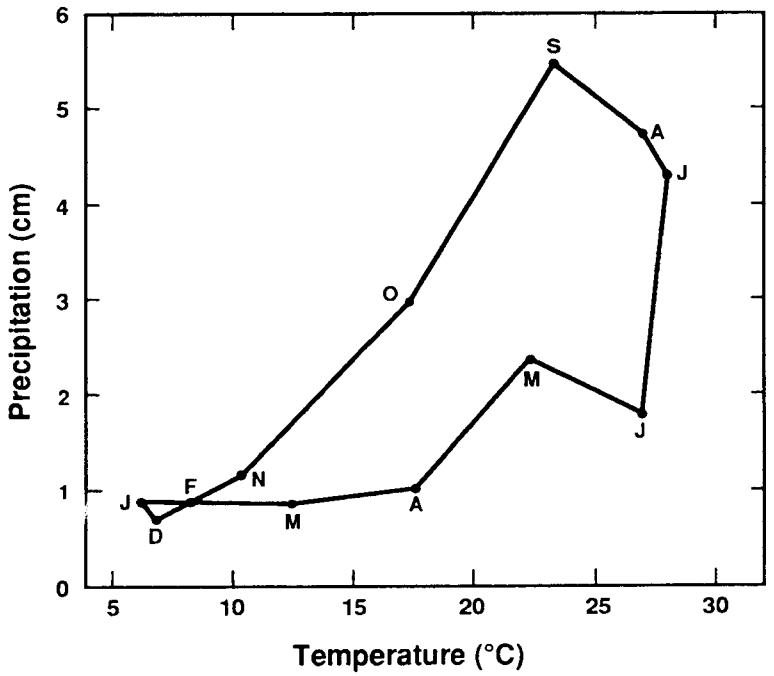


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Figure 2. Climatograph showing 30-yr (1951-1980) monthly precipitation and temperature means recorded at the Carlsbad, New Mexico airport, approximately 45 km west of the WIPP and 50 m lower (data from NOAA, 1989).

up to twice those of the present, occurred during full-glacial conditions associated with global cooling (e.g., Van Devender and others, 1987; other sources cited below). Presently available greenhouse models, however, predict average equilibrium global warming of 1.8 to 5.2°C for carbon dioxide concentrations twice present levels (Mitchell, 1989; Houghton and other, 1990), a condition that could delay the start of renewed glaciation. Published model predictions of precipitation trends accompanying greenhouse warming are less consistent and less reliable than temperature predictions, but none suggest significantly higher levels of precipitation in southern New Mexico than those of the present (Washington and Meehl, 1984; Wilson and Mitchell, 1987; Schlesinger and Mitchell, 1987; Houghton and others, 1990). Because long-term increases in recharge are improbable without increases in precipitation, the highest-risk climatic change that will be considered here is, therefore, a return to the glacial extremes of the past.

Data that can be used to interpret paleoclimates in southeastern New Mexico and the surrounding region come from a variety of sources, and indicate an alternation of arid and subarid to subhumid climates throughout the Pleistocene. Prior to 18 ka BP, radiometric dates are relatively scarce, and the record is incomplete. From 18 ka BP to the present, however, the climatic record is relatively complete and temporally well constrained by radiocarbon dates. This report cites extensive floral, faunal, and lacustrine data from the region that permit reconstructions of precipitation and temperature during the late Pleistocene and Holocene. These data span the transition from the last full-glacial maximum to the present interglacial period, and, given the global consistency of glacial fluctuations as described below, they can be taken to be broadly representative of extremes for the entire Pleistocene.

4. Variability in Global Climate Over the Last 2.5 Million Years

Core samples of datable marine sediments provide a continuous record that reveals as many as 50 glaciation/deglaciation events in the last 2.5 Ma. Specifically, correlations have been made between major glacial events and variables such as the ratio of $^{18}O/^{16}O$ measured in the remains of calcareous foraminifera and past sea-surface temperatures determined from planktonic assemblages (Ruddiman and Wright, 1987). In addition, glacial cycles have been observed in the past composition of the earth's atmosphere preserved in polar glacial ice (Langway and others, 1985; Jouzel and others, 1987; Barnola and others, 1987) and in a $^{18}O/^{16}O$ record from calcite vein fillings in Nevada (Winograd and others, 1988).

Oxygen isotope ratios from oceanic foraminifera provide the most direct evidence, because they reflect past volumes of glacial ice (Imbrie and others, 1984). Evaporation fractionates ^{18}O and ^{16}O isotopes in water, producing a vapor relatively enriched in ^{16}O and residual seawater relatively enriched in ^{18}O. Glacial ice sheets store large volumes of ^{16}O-enriched meteoric water, thereby preventing the remixing of the two isotope fractions and significantly altering $\delta^{18}O$ values in the world's oceans.* Foraminifera preserve samples of past $\delta^{18}O$ values when they extract oxygen from seawater and incorporate it into calcareous body parts. Abundant fossil remains permit the construction of detailed records such as that shown in Figure 3, covering the last 780 ka. High positive values of $\delta^{18}O$ reflect glacial maxima, and negative values reflect warm interglacial periods. Because the largest volumes of glacial ice were incorporated in the North American sheet, $\delta^{18}O$ fluctuations can be interpreted directly as a first order record of North American glaciation and deglaciation (Mix, 1987; Ruddiman and Wright, 1987). Because the correlation is quantitative, the isotopic record indicates that the most recent glacial event was as severe as any within the last 780 ka. It also indicates that the present value is at or near that of a glacial minimum.

Sea-surface temperature records, although not as closely tied to glacial events, show the same alternating pattern. Temperatures at the surface of northern hemisphere oceans, as determined from the fossil assemblages of planktonic foraminiferal species, were measurably colder during glaciation and warmer during interglacial periods (Ruddiman, 1987).

Samples from the ice sheets of Greenland and Antarctica and calcite vein fillings in Nevada provide independent confirmation of the oceanic data (Langway and others, 1985; Jouzel and others, 1987; Barnola and others, 1987; Winograd and others, 1988). Glacial ice preserves $\delta^{18}O$ and δD values of the precipitation that formed the ice, and, because fractionation of the isotopes is temperature dependent, fluctuations can be interpreted quantitatively as changes in local mean temperature. Bubbles of air trapped within the ice can also be sampled to give a measure of past CO_2 concentrations in the atmosphere, which, because of the importance of CO_2 in the earth's greenhouse effect, correlate well with the isotopic temperature record. Figure 4 shows

---

* By convention, $^{18}O/^{16}O$ ratios are reported as:

$$\delta^{18}O = 1000 \times \frac{(^{18}O/^{16}O_{sample} - {}^{18}O/^{16}O_{reference})}{{}^{18}O/^{16}O_{reference}}$$

Deuterium/hydrogen ratios (D/H) are similarly reported as δD values.

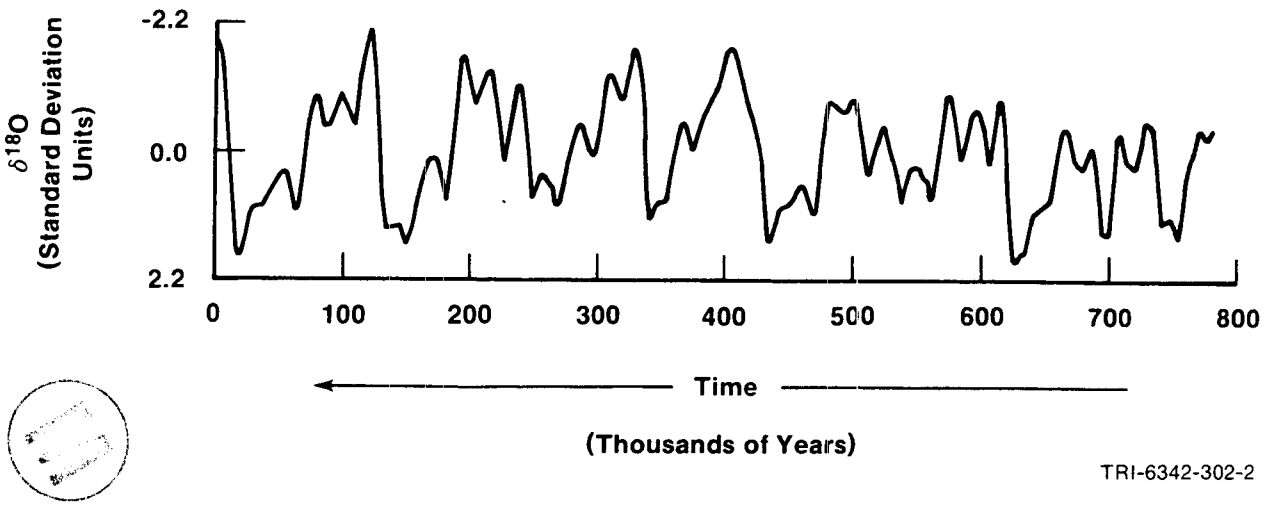

Figure 3. Foraminiferal $\delta^{18}0$ record of the last 780,000 years. Curve reflects $\delta^{18}0$ variations from five deep-sea core samples. Data have been normalized, stacked, and smoothed with a nine-point Gaussian filter (Imbrie, and others, 1984).

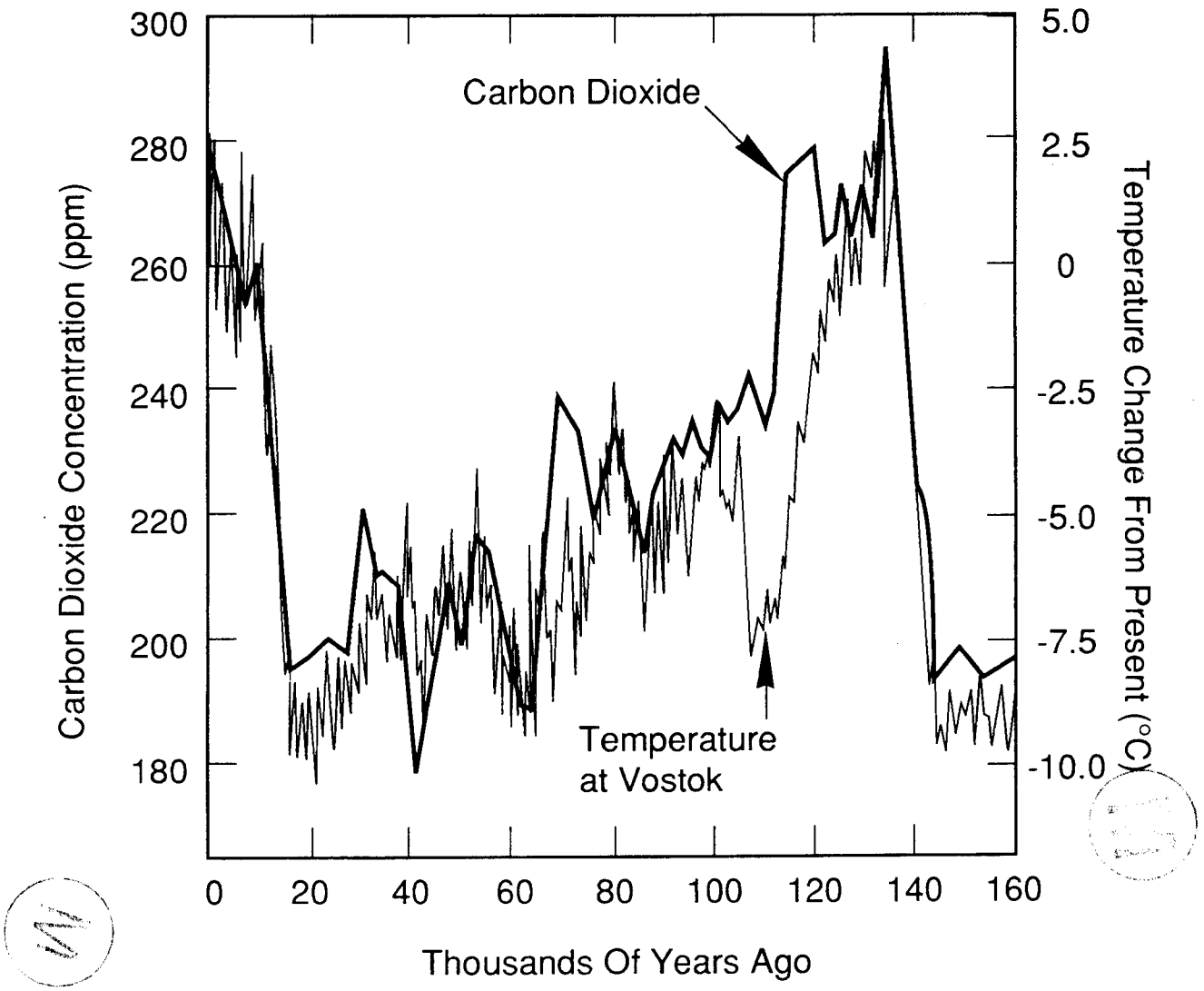

Figure 4. Atmospheric CO_2 concentration and δD temperature record from the Vostok, Antartica, ice core for the last 160 ka (modified from Schneider, 1990; after Barnola and others, 1987).

the 160-ka record of CO_2 concentration and temperature as determined from the D/H ratio at Vostok in East Antarctica. With some minor discrepancies, the two curves reveal the same basic glacial chronology visible in the last 160 ka of the oceanic $\delta^{18}O$ record shown in Figure 3. The $\delta^{18}O$ record from 50 ka to 310 ka BP from calcite vein fillings in Devils Hole, Nevada, reflects changes in local surface temperature as well as other, less well quantified, factors, including groundwater travel time. This record also shows a chronology similar to that of Figure 3, although peaks in the calcite curve are shifted toward increasingly older times earlier in the record relative to the oceanic curve. The reason for this phase shift, which reaches 28 ka at 272 ka BP, is not known (Winograd and others, 1988).

5. Stability of Glacial Cycles

The causes of glaciation and deglaciation are complex and not fully understood (Ruddiman and Wright, 1987), but the strong periodicity of the isotopic record indicates that climatic alternations have been systematic in the past. Spectral analysis of the foraminiferal $\delta^{18}O$ curve for the last 780 ka shows that within that time the primary control on the periodicity of glacial events has been variation in global insolation caused by irregularities in the earth's orbit (Figure 5). Observed periods of 19, 23, 41, and 100 ka in the oceanic $\delta^{18}O$ curve correspond to calculated periods of northern hemisphere summer insolation minima of 19 and 23 ka related to the precession of the earth's axis, 41 ka related to the tilt of earth's axis, and 94, 125, and 413 ka related to the eccentricity of the earth's orbit (Milankovitch, 1941; Hays and others, 1976; Imbrie and others, 1984; Imbrie, 1985). Calculations based on astronomical observations indicate that orbital parameters have not changed significantly in the last 5 Ma (Berger, 1984), and geological evidence suggests they may have been stable for as long as 300 Ma (Anderson, 1984; Heckel, 1986).

Longer-term global climatic changes, such as the beginning of the present pattern of glaciation and deglaciation 2.5 Ma BP, have been attributed to changes in the configuration of the earth's continents, which in turn controls both the potential distribution of ice sheets and global circulation patterns (e.g., Crowell and Frakes, 1970; Caputo and Crowell, 1985; Crowley and others, 1986; Hyde and others, 1990). Continental masses move at plate-tectonic rates of centimeters per year, several orders of magnitude too low to affect glacial processes within the next 10 ka. Vertical uplift or subsidence of large continental regions may also affect global climate by changing circulation patterns (e.g., Ruddiman and Kutzbach, 1989), but, again, maximum uplift rates are at least an order of magnitude too low to change present circulation patterns within the next 10 ka.

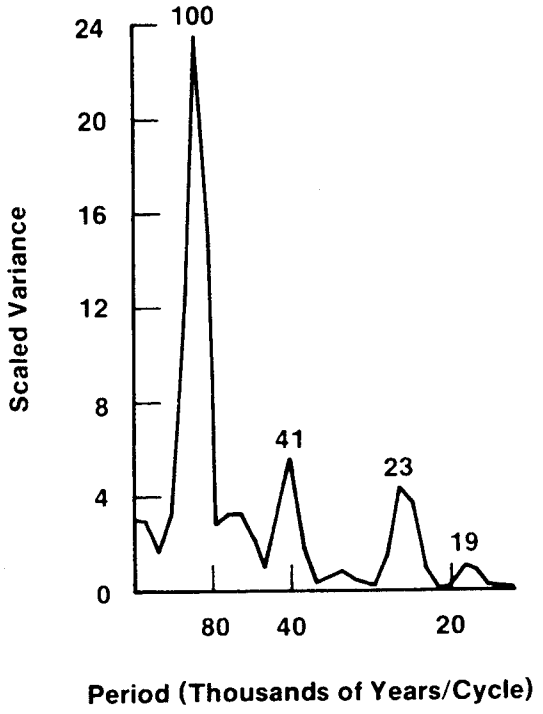

Figure 5. Spectral analysis of the foraminiferal $\delta^{18}O$ record presented in Figure 3, showing periodicity of glaciation and deglaciation (after Imbrie, 1985).

The long-term pattern of the cycles of glaciation and deglaciation provides the basis for concluding that climatic extremes of the next 10 ka will remain within past limits. The relative amplitudes of past glacial cycles (Figure 3) imply that future glaciations will be no more severe than the last one. The periodicity of the pattern indicates that although glacial minima such as that of the present are relatively brief, glacial advances are, in general, slow and the next full maximum will not occur for many tens of thousands of years. Predictions about the precise timing of future glacial events are not straightforward, however. Higher resolution records, such as those available from polar ice cores, show that some glacial advances can occur relatively rapidly. Modeling of glacial processes is complicated by uncertainties about feedback processes involved in the growth of ice sheets, but extrapolation of the isotopic curve of Figure 3 using a relatively simple model for nonlinear climate response to insolation change suggests that, in the absence of anthropogenic effects, the next full glacial maximum could occur in approximately 60 ka (Imbrie and Imbrie, 1980). These observations, combined with the climatic data discussed below, justify the choice of the late Pleistocene full-glacial climate as a conservative upper limit for precipitation during the next 10 ka.

6. Pleistocene and Holocene Climates of Southeastern New Mexico

Early and middle Pleistocene paleoclimatic data for southeastern New Mexico and the surrounding region are incomplete, and permit neither continuous reconstructions of paleoclimates nor direct correlations between climate and glaciation prior to the last glacial maximum 22 to 18 ka BP. Stratigraphic and pedologic data from several locations (Figure 6), however, indicate that cyclical alternation of wetter and drier climates in southeastern New Mexico had begun by the early Pleistocene. Fluvial gravels in the Gatuña Formation exposed in the Pecos River Valley of eastern New Mexico suggest relatively wetter conditions 1.4 Ma BP and again 600 ka BP (Bachman, 1987). The Mescalero caliche, exposed locally over much of southeastern New Mexico, has been interpreted as indicating relatively drier conditions 510 ka BP (Lambert and Carter, 1987), and loosely dated spring deposits in Nash Draw west of the WIPP imply wetter conditions again later in the Pleistocene (Bachman, 1981, 1987). The Blackwater Draw Formation of the southern High Plains of eastern New Mexico and western Texas, time-correlative to both the Gatuña Formation and the Mescalero caliche, contains alternating soil and eolian sand horizons that show at least six climatic cycles beginning more than 1.4 Ma BP and continuing to the present (Holliday, 1989a). The duration, frequency, and total number of Pleistocene climatic cycles in southeastern New Mexico have not been established.

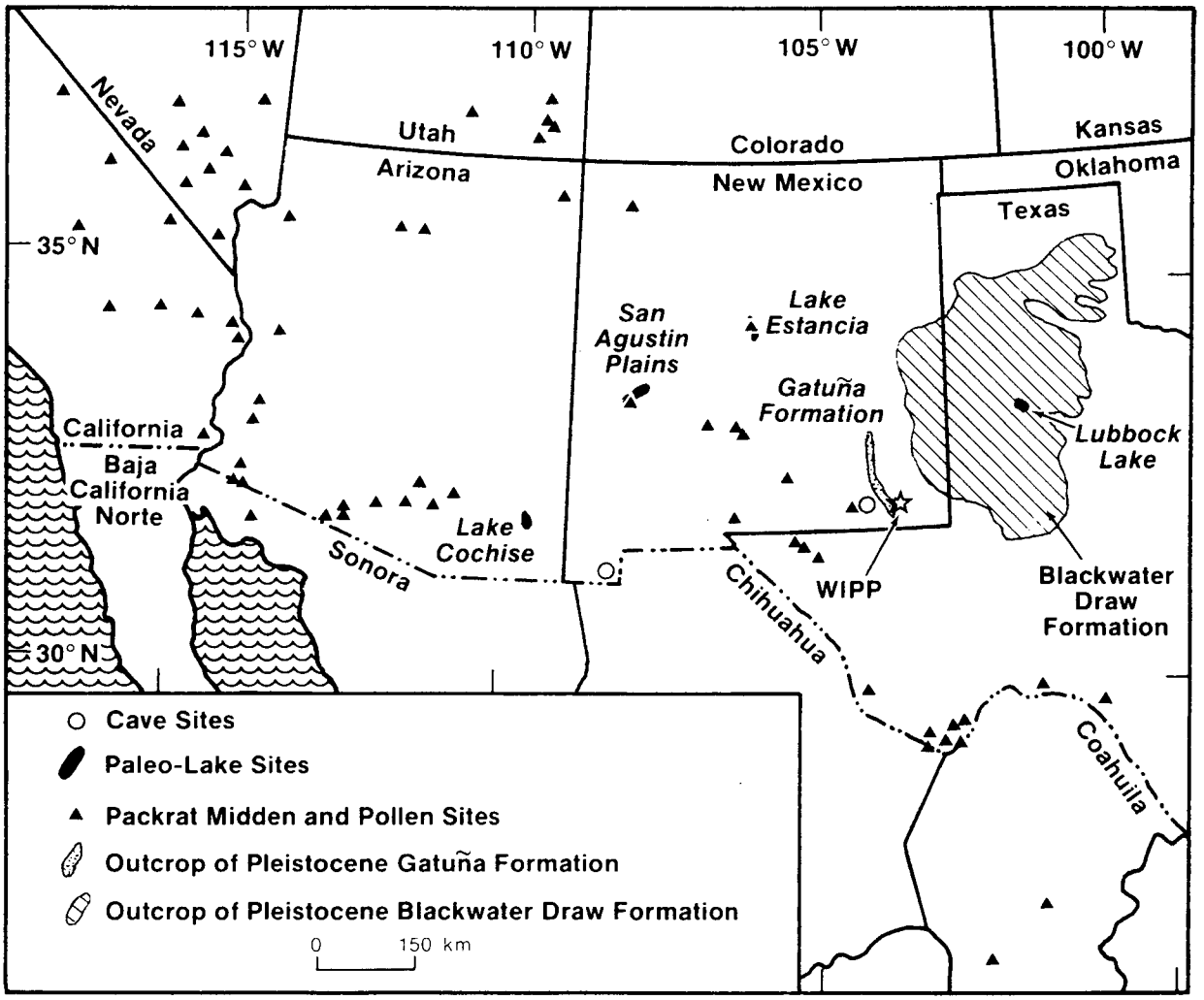

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Figure 6. Location map for paleoclimate data. Data from Bachman (1981); Markgraf and others (1983); Harris (1987); Pierce (1987); Van Devender and others (1987); Waters (1989); Bachhuber (1989); Holliday (1989a); Van Devender (1990); Allen (1991); Phillips and others (1992).

Data used to construct the more detailed climatic record for the latest Pleistocene and Holocene come from multiple lines of evidence dated primarily using carbon-14 techniques. Packrat middens examined at sites throughout the southwestern United States, including locations in southeastern New Mexico, preserve local plant communities and, in some cases, insect remains (Van Devender, 1980, 1990; Van Devender and others, 1984, 1987; Elias, 1987; Elias and Van Devender, 1990). Pollen assemblages have been analyzed from lacustrine deposits in western New Mexico, western Texas, and other locations in the southwestern United States (Martin and Mehringer, 1965; Markgraf and others, 1984; Bryant and Holloway, 1985; Van Devender and others, 1987). Faunal data come from gastropod assemblages from western Texas (Pierce, 1987), ostracode assemblages from western New Mexico (Markgraf and others, 1984; Forester, 1987; Phillips and others, 1992), and vertebrate remains from caves in southern New Mexico (Harris, 1987, 1988). Stable-isotope data are available from ostracodes in western New Mexico (Phillips and others, 1992) and groundwater samples in northwestern New Mexico (Phillips and others, 1986). Paleo-lake level data are available from sites throughout the southwestern United States (Reeves, 1973; Smith and Anderson, 1982; Markgraf and others, 1983, 1984; Benson and Thompson, 1987; Holliday and Allen, 1987; Bachhuber, 1989; Waters, 1989; Wells and others, 1989; Enzel and others, 1989; Benson and others, 1990; Allen, 1991). Figure 6 shows the locations of key sites discussed here and in the references cited.

Because decreases in temperature and increases in precipitation produce similar environmental changes, not all data cited uniquely require the paleoclimatic interpretation presented in this report (Figure 7). For example, lake-level increases can, in theory, result solely from decreased evaporation at lower temperatures. Interpretations drawn individually from each of the data sets are consistent with the overall trends shown in Figure 7, however, and the pattern of change is confirmed by global general circulation climate models (Kutzbach and Guetter, 1986; COHMAP Members, 1988). Furthermore, specific floral and faunal assemblages are sufficiently sensitive to precipitation and temperature effects to distinguish between the two (e.g., Van Devender and others, 1987; Pierce, 1987; Van Devender; 1990). The paleoclimates described here are those that best explain data from all sources.

Prior to the last glacial maximum 22 to 18 ka BP, evidence from mid-Wisconsin faunal assemblages in caves in southern New Mexico, including the presence of extralimital species such as the desert tortoise that are now restricted to warmer climates, suggests warm summers and mild, relatively dry winters (Harris, 1987, 1988). Lacustrine evidence confirms the interpretation that conditions prior to and during the glacial advance that

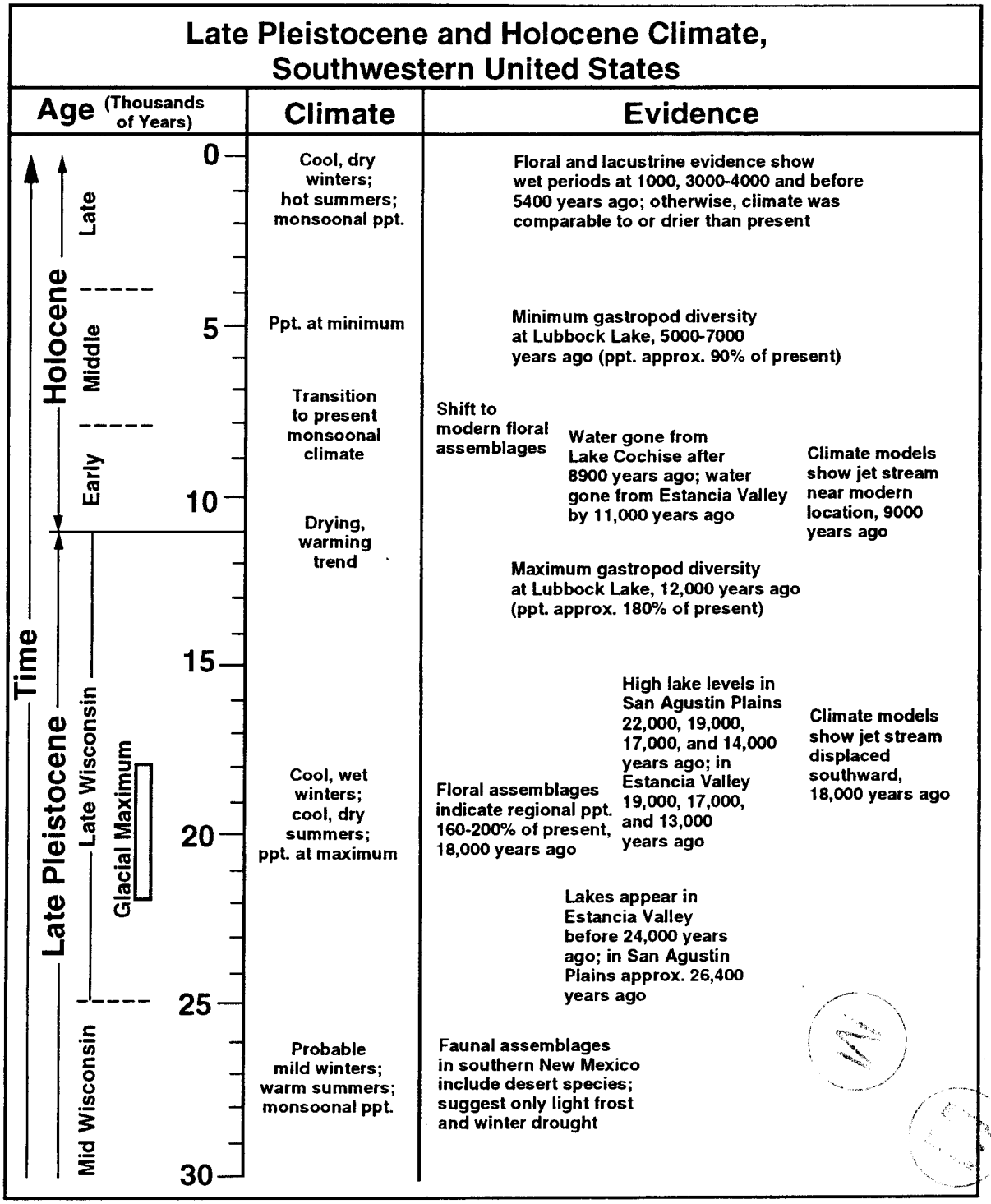

Figure 7. Late Pleistocene and Holocene climate, southwestern United States. Time scale after Van Devender and others (1987). Climate references cited in text.

were generally drier than those at the glacial maximum. Permanent water did not appear in what was later to be a major lake in the Estancia Valley in central New Mexico until sometime before 24 ka BP (Bachhuber, 1989). Late-Pleistocene lake levels in the San Agustin Plains in western New Mexico remained low until approximately 26.4 ka BP, and the $\delta^{18}O$ record from ostracode shells suggests that mean annual temperatures at that location did not decrease significantly until approximately 22 ka BP (Phillips and others, 1992).

Ample floral and lacustrine evidence documents cooler and wetter conditions in southeastern New Mexico and the surrounding region during the glacial peak (Van Devender and others, 1987; Pierce, 1987; Bachhuber, 1989; Allen, 1991; Phillips and others, 1992). These changes were not caused by the immediate proximity of glacial ice. None of the Pleistocene continental glaciations advanced farther southwest than northeastern Kansas, and the most recent, late Wisconsin, ice sheet reached its limit in South Dakota, roughly 1200 km from the WIPP (Andrews, 1987). Discontinuous alpine glaciers formed at the highest elevations throughout the Rocky Mountains, but these isolated ice masses were symptoms, rather than causes, of cooler and wetter conditions, and had little influence on regional climate at lower elevations. The closest such glacier to the WIPP was on the northeast face of Sierra Blanca Peak in the Sacramento Mountains, 220 km to the northwest (Richmond, 1962).

Global climate models indicate that the dominant glacial effect in southeastern New Mexico was the disruption and southward displacement of the westerly jet stream by the physical mass of the ice sheet to the north (Figure 8) (Manabe and Broccoli, 1985; Kutzbach and Guetter, 1986; COHMAP members, 1988). At the glacial peak, climate models show that major Pacific storm systems followed the jet stream across New Mexico and the southern Rocky Mountains, and winters were wetter and longer than either at the present or during the previous interglacial period.

Field evidence does not support the suggestion (Galloway, 1970, 1983; Brakenridge, 1978) that higher lake levels and changed faunal and floral assemblages at the glacial maximum could have resulted solely from lowered temperatures. Plant communities indicate that, regionally, the decrease in mean annual temperatures below present values was significantly less than the 7 to 12°C required by cold and dry climate models (Van Devender and others, 1987; Van Devender, 1990). Interpretation of stable-isotope data from groundwater samples from northwestern New Mexico suggest mean annual temperatures were 5 to 7°C colder than at present at that location (Phillips and others, 1986). Isotopic data from ostracode shells in the San Agustin Plains suggest mean annual temperatures there may have been 8.3°C colder than

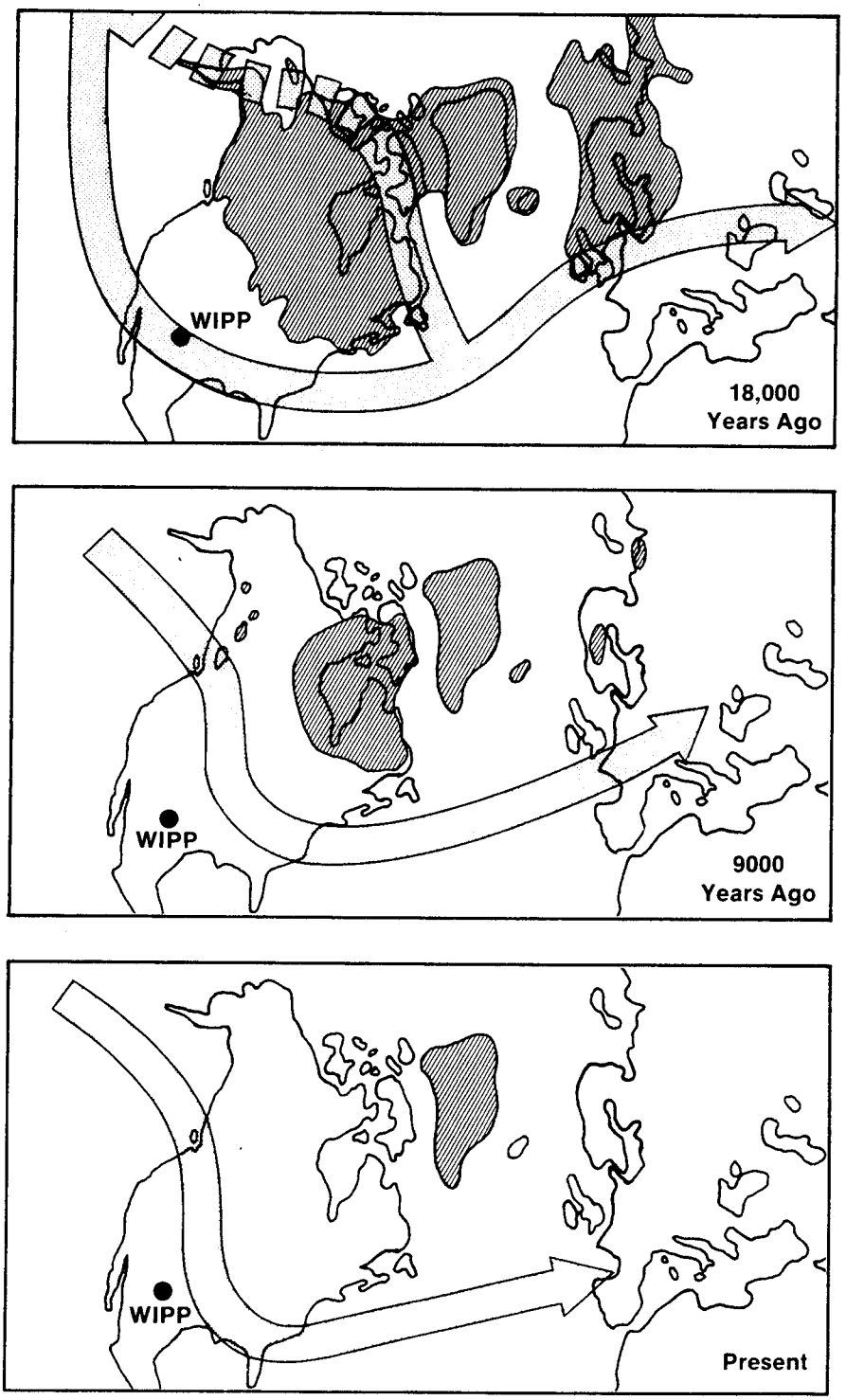

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Figure 8. Distribution of northern hemisphere ice sheets and modeled position of jet stream at 18 ka BP, and present (from COHMAP Members, 1988). Ice shown with dark pattern, jet stream shown with arrow (broken where disrupted or weak).

at present at approximately 21 ka BP, but hydrologic modeling of the basin indicates lake levels were controlled by precipitation rather than evaporation throughout the glacial advance and retreat (Phillips and others, 1992). Gastropod assemblages at Lubbock Lake in western Texas suggest mean annual temperatures 5°C below present values (Pierce, 1987). High water levels in playas in western Texas reflect an increase in runoff best explained by substantially higher levels of precipitation (Reeves, 1973).

Floral and faunal evidence taken together indicate that mean annual precipitation throughout the region at the last glacial maximum was 60 to 100 percent more than today (Spaulding and Graumlich, 1986; Pierce, 1987; Van Devender and others, 1987). Floral evidence also suggests that winters may have continued to be relatively mild, perhaps because the glacial mass blocked the southward movement of arctic air. Summers at the glacial maximum were cooler and drier than at present, without a strongly developed monsoon (Van Devender and others, 1987). Piñons, oaks, and junipers grew at lower elevations throughout southern New Mexico (Van Devender and others, 1987; Van Devender, 1990), probably including the vicinity of the WIPP.

According to climatic modeling, the jet stream shifted northward following the gradual retreat of the ice sheet after 18 ka BP (Figure 8), and the climate responded accordingly. By the Pleistocene/Holocene boundary approximately 11 ka BP, conditions were significantly warmer and drier than previously, although still dominated by winter storms and still wetter than today (Van Devender and others, 1987). Major decreases in total precipitation and the shift toward the modern monsoonal climate did not occur until the margins of the ice sheet had retreated into northeastern Canada in the early Holocene.

Evidence for the late Pleistocene and early Holocene drying trend comes from several sources. In contrast to the northern Great Basin, where lake levels continued to rise until between 15 and 13.5 ka BP (Benson and others, 1990), lake levels in southern New Mexico and the surrounding region decreased following the glacial maximum. Permanent water disappeared from late-Pleistocene lakes in the Estancia Valley between 12 and 11 ka BP, following a series of fluctuations in lake levels with progressively lower high stands at approximately 19, 17, and 13 ka BP (Allen, 1991). Lake Cochise (the modern Willcox Playa) in southeastern Arizona was dry after 8.5 ka BP, following two high stands prior to 14 ka BP and a third between 14 and 13 ka BP (Waters, 1989). Modeling of lake levels in the San Agustin Plains shows high stands at progressively lower elevations at approximately 22, 19, 17, and 14 ka BP (Phillips and others, 1992). Water remained in lakes in the San Agustin Plains until 5 ka BP, but ostracode assemblages suggest an increase in salinity by 8 ka BP, and the pollen record shows a gradual shift

at that location from a spruce-pine forest 18 to 15 ka BP to a juniper-pine forest by 10 ka BP (Markgraf and others, 1984). Packrat middens in Eddy County, New Mexico, indicate that desert-grassland and desert-scrub communities predominated at lower elevations between 10.5 and 10 ka BP (Van Devender, 1980). Soil studies indicate drier conditions at Lubbock Lake after 10 ka BP, although marshes and small lakes persisted at the site until the construction of a dam and reservoir in 1936 (Holliday and Allen, 1987). Based on a decrease in diversity of both terrestrial and aquatic gastropod species, Pierce (1987) estimated a drop in annual precipitation at Lubbock Lake from a high of 80 cm/yr (nearly twice the modern level at that location of 45 cm/yr) at 12 ka BP to 40 cm/yr by 7 ka BP.

Coincident with this decrease in precipitation, evidence from vole remains recovered from caves in southern New Mexico (Harris, 1988) and from plant communities throughout the southwestern United States (Van Devender and others, 1987) indicates a rise in summer temperatures. Mean annual temperatures interpreted from the isotopic composition of groundwater samples from northwestern New Mexico also show a sharp rise in the early Holocene (Phillips and others, 1986).

By middle-Holocene time, the climate was similar to that of the present, with hot, monsoon-dominated summers and cold, dry winters. The pattern has persisted to the present, but not without significant local variations. Soil studies show the southern High Plains were drier from 6.5 to 4.5 ka BP (Holliday, 1989b) than before or since. Gastropod data from Lubbock Lake indicate the driest conditions from 7 to 5 ka BP (precipitation approximately 90 percent of present, mean annual temperature 2.5°C higher than present), with a cooler and wetter period at 1 ka BP (precipitation approximately 145 percent of present, mean annual temperature 2.5°C lower than present) (Pierce, 1987). Plant assemblages from southwestern Arizona suggest steadily decreasing precipitation from the middle Holocene to the present, except for a brief wet period around 990 years ago (Van Devender and others, 1987). Stratigraphic work at Lake Cochise shows two mid-Holocene lake stands, one near or before 5.4 ka BP and one between or before 3 to 4 ka BP, but both were relatively short-lived, and neither reached the maximum depths of the late-Pleistocene high stand that existed before 14 ka BP (Waters, 1989).

Precipitation maxima during these Holocene wet periods were less in both magnitude and duration than those of the late Pleistocene. Enzel and others (1989) observed comparable Holocene wet periods recorded in playa deposits in the Mojave Desert 3620 ± 70 and 390 ± 90 years ago, and related them to short-term changes in global circulation patterns that resulted in increased winter storm activity in the region. Historical records over the last several hundred years indicate numerous lower intensity climatic

fluctuations, some too short in duration to affect floral and faunal assemblages, which may also be the result of temporary changes in global circulation (Neilson, 1986). Sunspot cycles and the related changes in the amount of energy emitted by the sun have been linked to historical climatic changes elsewhere in the world (e.g., Lamb, 1972), but the validity of the correlation is uncertain (Robock, 1979; Stuiver, 1980). Correlations also have been proposed between volcanic activity and climatic change (Robock, 1979; Palais and Sigurdsson, 1989; Bryson, 1989). In general, however, causes for past short-term changes are unknown, and it is impossible at present to predict the amplitude or frequency of recurrence. Despite this uncertainty, the past record does support the conclusion that future short-term fluctuations in southeastern New Mexico will not be as severe as the long-term climatic changes created by major ice sheets in the northern hemisphere. Full-glacial conditions remain a conservative upper limit for mean annual precipitation at the WIPP during the next 10 ka.

7. Climatic Implications of Data from WIPP Groundwater Samples

Isotopic data from groundwater samples collected in the vicinity of the WIPP from the Late Permian Rustler and Dewey Lake Formations that overlie the Salado Formation are generally consistent with the climatic changes described above. Lambert (1986) and Lambert and Harvey (1987) concluded that although deuterium/hydrogen and $^{18}O/^{16}O$ ratios indicate a meteoric origin for water in the confined aquifers, they are sufficiently distinct from modern surface water values to suggest that the contribution of modern recharge to the system is slight. Chapman (1986) disagreed with this interpretation, noting similar ratios in the presumably young waters of the Roswell Artesian Basin immediately to the north, and she concluded that stable-isotope data from the WIPP area do not permit definitive interpretations about the age of the groundwater. Tritium data are less ambiguous. Low tritium levels in all WIPP-area samples indicate minimal contributions from the atmosphere since 1950 (Lambert, 1987; Lambert and Harvey, 1987). The four internally consistent radiocarbon analyses currently available for water samples from the Rustler and Dewey Lake Formations support this interpretation. Modeled minimum ages in each case are between 12 and 16 ka, suggesting that both units have had little recharge since the period immediately following the late Pleistocene glacial maximum (Lambert and Harvey, 1987). Lambert and Carter (1987) presented uranium isotope data that also support this interpretation: observed high $^{234}U/^{238}U$ activity ratios require a conservative minimum residence time in the Culebra Dolomite of several thousands of years and more probably reflect minimum ages of 10 to 30 ka. Chapman (1988) questioned the validity of equating isotope residence times with groundwater age, but agreed that high $^{234}U/^{238}U$ activity ratios occur in

regions of low transmissivity, where flow is presumably slower and residence times are longer.

Lambert (1991) used groundwater isotope data, along with supporting evidence from $^{87}Sr/^{86}Sr$ ratios in vein fillings, to argue that the Rustler Formation has been essentially a closed hydrologic system for the last 12 ka. In his interpretation, significant recharge last occurred during the late Pleistocene, and the present flow field reflects the slow draining of the aquifer. If this interpretation is correct, recharge may not occur again until precipitation levels are substantially higher than at present.

Other data suggest that, isotopic evidence notwithstanding, some recharge may be occurring at the present. Anomalous increases in water levels have been observed at seven WIPP-area wells since 1988 (Beauheim, 1989). Recharge from the surface cannot be ruled out as a cause for these rises, although no specific link to precipitation events has been demonstrated. Other possible causes include decreases in discharge, changes in reservoir volume related to incomplete recovery from the transient pressure changes associated with the pumping test itself, changes in reservoir volume related to external changes in the regional stress field, or undetected recharge from other aquifers or from the surface through existing boreholes (Beauheim, 1989). Numerical modeling of groundwater flow in the WIPP area indicates that, although it is hydraulically possible for present flow to reflect late Pleistocene recharge (Davies, 1989), some component of modern vertical recharge is also compatible with observed conditions (Haug and others, 1987; Davies, 1989). Major ion chemical analyses of groundwater samples support the interpretation of vertical recharge south of the WIPP, where low salinities may be the result of mixing with fresh surface water (Chapman, 1988). Lambert (1991) suggests instead that water chemistry has remained essentially unchanged from the late Pleistocene and is a function of host rock composition, noting that groundwater salinity correlates well with the distribution of halite in the Rustler Formation.

Questions about recharge to the Rustler Formation and the true age of WIPP-area groundwater remain unanswered. In the absence of definitive data, this report makes no assumptions about groundwater age.

8. Discussion and Conclusions

Speculation about future climate variability must be based on observed past fluctuations. The largest global climatic changes in the last 2.5 Ma have been those associated with glaciation and deglaciation in the northern hemisphere. The high degree of consistency in both frequency and intensity

displayed in the glacial record indicates that an accurate interpretation of past climatic cycles does provide a useful guide for estimating future changes.

Geologic data from southeastern New Mexico and the surrounding region show repeated alternations of wetter and drier climates throughout the Pleistocene. Floral, faunal, and lacustrine data permit detailed and quantitative reconstructions of precipitation that can be linked directly to glacial events of the late Pleistocene and Holocene. Figure 9 shows estimated mean annual precipitation for the WIPP for the last 30 ka, interpolated from the composite regional data cited above and based on present average precipitation at the site of 30 cm/yr (Brinster, 1991). This plot should be interpreted with caution, because its resolution and accuracy are limited by the nature of the data used to construct it. Floral and faunal assemblages may change gradually and show only a limited response to climatic fluctuations that occur at frequencies higher than the typical life span of the organisms in question. For long-lived species such as trees, resolution may be limited to hundreds or even thousands of years (Neilson, 1986). Sedimentation in lakes and playas has the potential to record higher frequency fluctuations, including single-storm events, but only under a limited range of circumstances. Once water levels reach a spill point, for example, lakes show only a limited response to further increases in precipitation. Dry playas generally show little response to decreases in precipitation. A more complete record of precipitation would almost certainly show far more variability than that implied by the plot presented here. Specifically, Figure 9 may fail to record abnormal precipitation lows during the Holocene, it may underestimate the number of high-precipitation peaks during the same period, and it may underestimate the magnitude of relatively brief precipitation maxima during the late Pleistocene. Although the magnitude of the long-term shift in precipitation is adequately documented by the data reviewed here, the amplitude of the higher-frequency fluctuations in both the late Pleistocene and the Holocene is not well constrained, and the climate may have been wetter or drier than shown for some intervals.

With these observations in mind, three significant conclusions can be drawn from the climatic record of southeastern New Mexico and the surrounding region. First, maximum precipitation in southeastern New Mexico in the past coincided with the maximum advance of the North American ice sheet. Minimum precipitation occurred after the ice sheet had retreated to its present limits. Second, past maximum long-term average precipitation levels were roughly twice present levels. Minimum levels may have been 90 percent of present levels. Third, short-term fluctuations in precipitation have occurred during both the glacial maximum and the present, relatively dry,

interglacial period, but fluctuations during the present interglacial period have not exceeded the upper limits of the glacial maximum.

It would be unrealistic to attempt a direct extrapolation of the precipitation curve of Figure 9 into the future. Too little is known about the relatively short-term behavior of global circulation patterns, and it is at present impossible to predict the probability of a recurrence of a wetter climate such as that of approximately 1000 years ago. The long-term stability of patterns of glaciation and deglaciation, however, do permit the conclusion that future climatic extremes are unlikely to exceed those of the late Pleistocene. Furthermore, the periodicity of glacial events suggests that a return to full glacial conditions is highly unlikely within the next 10,000 years.

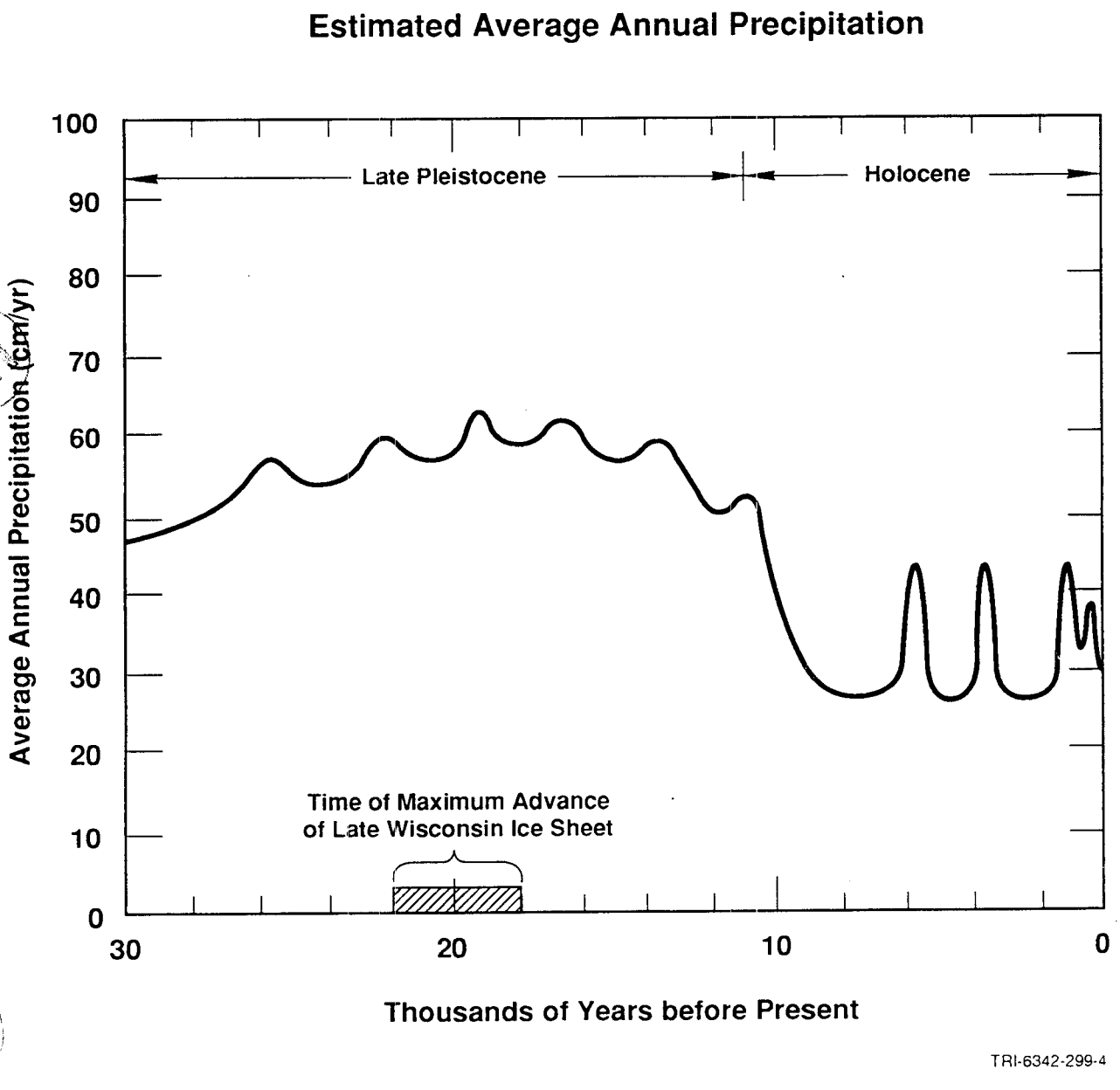

Figure 9. Estimated mean annual precipitation at the WIPP during the late Pleistocene and Holocene. Amplitudes of relatively high-frequency fluctuations are less well constrained than the amplitude of the shift from glacial conditions of the Pleistocene to interglacial conditions of the Holocene. Data from Van Devender and others (1987); Pierce (1987); Waters (1989); Allen (1991); Phillips and others (1992); and other sources cited in text.

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APPENDIX CLP

CLOSURE PLAN

CHAPTER I

CLOSURE PLANS, POST-CLOSURE PLANS, AND FINANCIAL REQUIREMENTS

(From the WIPP RCRA Part B Permit Application, Rev. 6)

CHAPTER I
CLOSURE PLANS, POST-CLOSURE PLANS, AND FINANCIAL REQUIREMENTS
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CHAPTER I
CLOSURE PLANS, POST-CLOSURE PLANS, AND FINANCIAL REQUIREMENTS

Introduction

This chapter contains the Closure Plan that describes the activities necessary to close the Waste Isolation Pilot Plant (WIPP) facility after termination of the operating permit. Since the current plans for operations extend over several decades, the Department of Energy (DOE) will periodically reapply for an operating permit in accordance with Title 20 of the New Mexico Administrative Code, Chapter 4, Part 1 (20 NMAC 4.1), Subpart IX, §270.10(h). Consequently, this Closure Plan describes several types of closure. The first type is panel closure, which occurs as underground hazardous waste management units (HWMU) are filled. Secondly, final closure at the end of the Disposal Phase is described. Finally, in the event a new permit is not issued prior to expiration of an existing permit, a modification to this Closure Plan will be sought to perform contingency closure. Contingency closure defers the final closure of waste management facilities such as the Waste Handling Building (WHB), the conveyances, the shafts, and the haulage ways because these will be needed to continue operations with non-mixed Transuranic (TRU) waste.

The HWMUs addressed in this Closure Plan include the aboveground HWMU in the WHB, the parking area HWMU, and Panels 1 through 8, each consisting of seven rooms. In addition, the disposal area access drifts shown as E-300, E-140, W-30, and W-170 between S-1600 and S-3650 on Figure I-1 may, at some time in the future, be needed for waste disposal as discussed in Section D-9a(3)(f). These access drifts, if used for disposal, are also subject to the contents of this Closure Plan.

This plan is submitted to the New Mexico Environment Department (NMED) and the U.S. Environmental Protection Agency (EPA) in accordance with 20 NMAC 4.1, Subpart IX, §270.14(b)(13). Closure at the panel level will include the construction of barriers to limit the emission of hazardous waste constituents from the panel into the mine ventilation air stream below levels that meet environmental performance standards as described in Section D-9d(3)[1]

[1] As discussed in Section D-9d(3), the mechanism for air emissions prior to closure is different than the mechanism after closure. Prior to closure, volatile organic compounds (VOC) will diffuse through drum filters based on the concentration gradient between the disposal room and the drum headspace. These VOCs are swept away by the ventilation system, thereby maintaining a concentration gradient that is assumed to be constant. Hence, the VOCs in the ventilation stream are a function of the number of containers only. After closure, the panel air will reach an equilibrium concentration with the drum headspace and no more diffusion will occur. The only mechanism for release into the mine ventilation system is due to pressure that builds up in the closed panel. This pressure arises from the creep closure mechanism that is reducing the volume of the rooms and from the postulated generation of gas as the result of microbial degradation of organic matter in the waste. Consequently, the emissions after panel closure are a direct function of pressurization processes and rates within the panel. Details of these factors are found in Appendix I1 and in Section D-9b.

and to mitigate the impacts of methane buildup and deflagration that may be postulated for some closed panels. Closure also includes the implementation of institutional controls to limit access, the implementation of passive institutional controls, and the long-term monitoring to assess disposal system performance. Until final closure is complete and has been certified in accordance with 20 NMAC 4.1, Subpart V, §264.115, a copy of the approved plan and all approved revisions will be on file at the WIPP facility and will be available to the Secretary of the NMED or the EPA Region VI Administrator upon request.

I-1 Closure Plan

This Closure Plan is prepared in accordance with the requirements of 20 NMAC 4.1, Subpart V, Closure and Post-Closure, Use and Management of Containers, and Miscellaneous Units. The WIPP underground HWMUs, including Panels 1 through 8 and the disposal area access drifts, designated as Panels 9 and 10 on Figure I-1, will be closed to meet the performance standards in 20 NMAC 4.1, Subpart V, §264.601. The WIPP surface facilities including Waste Handling Building Container Storage Unit and the Parking Area Container Storage Unit will be closed in accordance with 20 NMAC 4.1, Subpart V, §264.178. For final facility closure, this plan also includes closure and sealing of the facility shafts in accordance with 20 NMAC 4.1, Subpart V, §264.601.

Following completion of waste emplacement in each underground HWMU, the HWMU will be closed. The DOE will notify the NMED of the closure of each underground HWMU. For the purpose of this Closure Plan, panel closure is defined as the process of rendering HWMUs in the underground repository inactive and closed according to the facility Closure Plan. The Closure Plan addresses requirements for future monitoring that are deemed necessary for the post-closure period, including monitoring closed panels prior to final facility closure.

For the purposes of this Closure Plan, final facility closure is defined as closure that will occur when all waste disposal areas are filled or when the WIPP achieves its capacity of 6.2 million cubic feet (ft^3) (175,600 cubic meters (m^3)) of TRU waste. At final facility closure, the surface container storage areas will be closed, and equipment that can be decontaminated and used at other facilities will be cleaned and sent off site. Equipment that cannot be decontaminated plus any derived waste resulting from decontamination will be placed in the last open underground HWMU. Stockpiled salt may be placed in the underground; it may be used as the core material for the berm component of the permanent marker system; or it must be otherwise disposed of in accordance with Sections 2 and 3 of the Minerals Act of 1947 (30 U.S.C. §§602 and 603). In addition, shafts and boreholes which lie within the WIPP Site Boundary and penetrate the Salado will be plugged and sealed, and surface and subsurface facilities and equipment will be decontaminated and removed. Final facility closure will be completed to demonstrate compliance with the Closure Performance Standards contained in 20 NMAC 4.1, Subpart V §264.111, 178, and 601.

In the event the DOE fails to obtain an extension of the hazardous waste permit in accordance with 20 NMAC 4.1, Part IX, §270.51 or fails to obtain a new permit in accordance with 20 NMAC 4.1, Part IX, §270.10(h), the DOE will modify this Closure Plan to accommodate a contingency closure. Under contingency closure, storage units will undergo clean closure in accordance with

20 NMAC 4.1, Part V, §264.178 waste handling equipment, shafts, and haulage ways will be inspected for hazardous waste residues (using, among other techniques, the principle of co-detection in Appendix I3) and decontaminated as necessary, and underground HWMUs that contain radioactive mixed waste will be closed in accordance with the panel closure design described in this Closure Plan. Final facility closure, however, will be redefined and a request for a time extension for final closure will be requested. A copy of this Closure Plan will be maintained at the WIPP facility and at the DOE Carlsbad Area Office. The primary contact person at the WIPP facility is:

Manager, Carlsbad Area Office
U.S. Department of Energy
Waste Isolation Pilot Plant
P. O. Box 3090
Carlsbad, New Mexico 88221-3090
(505) 234-7300

I-1a Closure Performance Standard (20 NMAC 4.1, Subpart V, §264.111)

The closure performance standard specified in 20 NMAC 4.1, Subpart V, §264.111, states that the closure must be performed in a manner that minimizes the need for further maintenance; that minimizes, controls, or eliminates the escape of hazardous waste; and that conforms to the closure requirements of §264.178 and §264.601. These standards are discussed in the following paragraphs.

I-1a(1) Container Storage Units

Closure of the container storage units on the surface will be accomplished by removing all waste and waste residues. Identification of waste contamination will be based, among other techniques, on the principle of co-detection as described in Appendix I3. Co-detection uses very sensitive radiation detection equipment to determine if there has been a release of TRU waste, including hazardous waste components, from a container. This allows the DOE to detect releases that are not detectable from visible evidence such as stains or discoloration. Visual inspection and operating records will also be used to identify areas where decontamination is necessary. Contaminated surfaces will be decontaminated until radioactivity is below free release limits. Once surfaces are determined to be free of radioactive waste constituents, they will be tested for hazardous waste contamination. These surface decontamination activities will ensure the removal of waste residues to levels determined to be protective of human health and the environment. The facility is expected to require no decontamination at closure because any waste spilled or released during operations will be contained and removed immediately. Solid waste management units associated with the repository described in Chapter J of the permit application will be subject to closure. In the event portions of these units cannot be decontaminated, they will be remediated and the resultant wastes will be managed as derived waste.

Once the container storage units are decontaminated and certified to be clean, no further maintenance is required. The facilities and equipment in these units will be reused for other purposes as needed.

I-1a(2) Miscellaneous Unit

Post-closure migration of hazardous waste or hazardous waste constituents to ground or surface waters or to the atmosphere, above levels that will harm human health or the environment will not occur due to facility engineering and the geological isolation of the unit. The engineering aspects of closure are centered on the use of panel closures on each of the HWMUs in the underground and final facility seals placed in the shafts. The design of the panel closure system is based on the criteria that the closure system for closed HWMU panels will prevent migration of hazardous waste constituents in concentrations above health-based levels beyond the WIPP land withdrawal boundary during the 35-year operational and facility closure period and to withstand any flammable gas deflagration that may occur prior to final facility closure. The DOE has developed a design which is flexible in that components may be added or deleted to accommodate the conditions and waste characteristics encountered at the time of panel closure.

Consistent with the definitions in 20 NMAC 4.1, Subpart I, §260.10, the process of panel closure is considered partial closure because it is a process of rendering a part of the repository inactive and closed according to the approved HWMU partial closure plan. Panel closure will be considered complete when the panel closure system is emplaced and operational, when that HWMU and related equipment and structures have been decontaminated (if necessary), and when the NMED has been notified of the closure.

Shaft seals are designed to provide effective barriers to the inward migration of ground water and the outward migration of gas and contaminated brine over two discrete time periods. Several components become effective immediately and are expected to function for 100 years. Other components become effective more slowly, but provide permanent isolation of the waste. The conceptual shaft seal design is discussed in Appendix I2. Final seal designs are now undergoing final review and will be provided to the NMED by October 1, 1996. Preliminary copies of the final seal design drawings are attached to this application in Appendix I2 for NMED's review. The final seal design package, which will include final design drawings, will be certified by a professional engineer prior to submittal to the NMED.

The facility will be finally closed (i.e., decontaminated and decommissioned) to minimize the need for continued maintenance. Protection of human health and the environment includes, but is not limited to:

- Prevention of any releases that may have adverse effects on human health or the environment due to the migration of waste constituents in the groundwater or in the subsurface environment.

- Prevention of any releases that may have adverse effects on human health or the environment due to migration of waste constituents in surface water, in wetlands, or on the soil surface.

- Prevention of any release that may have adverse effects on human health or the environment due to migration of waste constituents in the air.

As part of final facility closure, surface recontouring and reclamation will establish a stable vegetative cover, and further surface maintenance will not be necessary to protect human health and the environment. Prior to cessation of active controls, monuments will be emplaced to serve as long-term site markers to discourage activities that would penetrate the facility or impair the ability of the salt formation to isolate the waste from the surface environment for at least 10,000 years. The federal government will maintain administrative responsibility for the repository site in perpetuity and will limit future use of the area.

If, during panel or final facility closure activities, unexpected events require modification of this Closure Plan to demonstrate compliance with closure performance standards, a Closure Plan amendment will be submitted (see Section I-1d[5]).

I-1a(3) Post-Closure Care

The post-closure care period will begin after completion of the first panel closure and will continue for 30 years after final facility closure. The post-closure care period may be shortened or lengthened at the discretion of the regulatory agency based on evidence that human health and the environment are being protected or that they are at risk. During the post-closure period, the WIPP shall be maintained in a manner that complies with the environmental performance standards in 20 NMAC 4.1, Part V, §264.601. Post-closure activities are described in Section I-2.

I-1b Requirements

The DOE proposes a sequential process for the closure of individual HWMUs at the WIPP. Each underground HWMU will undergo panel closure when waste emplacement in that panel is complete. Following waste emplacement in each underground HWMU, construction-side ventilation will be terminated and waste-disposal-side ventilation will be established in the next underground HWMU to be used, and the underground HWMU containing the waste will be closed. The DOE will notify the NMED of the closure of each of the underground HWMUs as they are sequentially filled on a HWMU-by-HWMU basis. The HWMUs in the WHB and in the parking area will be closed as part of final facility closure of the WIPP facility.

The DOE will notify the Secretary of the NMED in writing at least 60 days prior to the date on which closure activities are scheduled to begin.

I-1c Maximum Waste Inventory

The WIPP will receive no more than 6.2 million ft^3 (175,600 m^3) of TRU mixed waste. Excavations are mined as needed during operations to maintain a reserve of disposal areas. The amount of waste placed in each room is limited by structural and physical considerations of equipment and design. Waste volumes include waste received from off-site generator locations as well as derived waste from disposal and decontamination operations. Maximum waste volumes in the disposal panels are calculated as follows: for 100 percent 55-gallon drums--11,502 7-packs consisting of 80,514 drums and 591,800 ft^3 (16,760 m^3) of waste; for 100 percent standard waste boxes (SWB)--11,580 SWBs and 767,750 ft^3 (21,740 m^3) of waste; for remote handled (RH)--730 canisters containing 22,940 ft^3 (650 m^3) of waste. Since the waste

can arrive in any combination of 7-packs and SWBs, a fixed volume is not set for each panel. Furthermore, the placement of backfill materials to modify chemical nature of brines over the long-term will likely result in fewer containers per panel as described in Section D-9a. For planning purposes, a mix of 60 percent drums and 40 percent SWBs is used. This equates to 662,400 ft^3 (18,750 m^3) of contact handled (CH) TRU and 22,900 ft^3 (649 m^3) of RH TRU per panel. A number of 81,000 containers is used in design calculations since for air dispersion modeling, it is important to maximize the number of container vents through which volatile organic compounds (VOC) may be released. In reality, using the 40 percent-60 percent mix, there would be only 51,000 containers in a panel, containing 56,000 vents (2 vents per SWB). The areas designated as Panels 9 and 10 in Figure I-1 will not be used for RH waste.

The maximum extent of operations during the term of this permit is expected to be Panels 1 through 4 and Panels 9 and 10 as shown on Figure I-1, the WHB container storage unit, and the parking area container storage unit. Note that panels 4, 9, and 10 are scheduled for excavation only under this permit. If other waste management units are permitted during the Disposal Phase, this Closure Plan will be revised to include the additional waste management units. At any given time during disposal operations, it is anticipated that two rooms may be receiving waste for disposal at the same time. The overlap is necessary because RH TRU mixed waste emplacement in a room will precede CH TRU mixed waste emplacement in that room. Consequently, CH TRU mixed waste may be emplaced in one room of a panel while RH TRU mixed waste is emplaced in another room of the same panel. HWMU panels in which disposal has been completed (i.e., in which RH and CH TRU mixed waste emplacement activities have ceased) will undergo panel closure.

I-1d Schedule for Closure

For the purpose of establishing a schedule for closure, an operating and closure period of no more than 35 years (25 years for disposal operations and 10 years for closure) is assumed. This operating period may be extended or shortened depending on a number of factors, including the rate of waste approved for shipment to the WIPP facility and the schedules of TRU mixed waste generator sites, and future decommissioning activities.

I-1d(1) Schedule for Panel Closure

The anticipated schedule for the closure of each of the underground HWMUs known as Panels 1 through 8, is shown in Figure I-2. This schedule assumes there will be little contamination within the exhaust drift of the panel. The following assumptions are made in estimating the time that closure will be initiated at each HWMU: RH emplacement precedes CH emplacement and does not impede CH throughput; waste operations are assumed to begin in July 1998 for planning purposes; throughput for CH waste is 784 drums per week (7 pallets per day, 4 days per week, 28 drums per pallet); and the capacity of a panel is 81,000 drums. Under these assumptions, a minimum of 104 weeks is needed to emplace the waste. Allowing a 25 percent contingency for maintenance delays and time to transition from one room to another, it is estimated that a panel will be filled 2.5 years after emplacement is initiated. This means that

underground HWMUs will be ready for closure according to the schedule in Table I-1. These dates are estimates for planning and permitting purposes. Actual dates may vary depending on the availability of waste from the generator sites. Waste availability at maximum throughput is not anticipated immediately as assumed here.

In the schedule in Figure I-2, notification of intent to close occurs 30 days before placing the final waste in a panel. Once a panel is full, the DOE will initially block ventilation through the panel as described in Section D-10a(3)(b) and then will assess the closure area for ground conditions and contamination so that a definitive schedule and closure design can be determined. If as the result of this assessment the DOE determines that a panel closure cannot be emplaced in accordance with the schedule in this Closure Plan, a modification will be submitted requesting an extension to the time for closure.

I-1d(2) Schedule for Final Facility Closure

The Disposal Phase for the WIPP facility is expected to require a period of 25 years beginning with the first receipt of TRU waste at the WIPP facility and followed by a period ranging from seven to ten years for decontamination, decommissioning, and final closure. Assuming the first waste receipt occurs in July 1998, the Disposal Phase may extend until 2023, and so the latest expected year of final closure of the WIPP facility (i.e., date of final closure certification) would be 2033. If, as is currently projected, the WIPP facility is dismantled at closure, all surface and subsurface facilities (except the hot cell portion of the WHB, which will remain as an artifact of the Permanent Marker System [PMS]) will be disassembled and either salvaged or disposed in accordance with applicable standards. In addition, asphalt and crushed caliche that was used for paving will be removed, and the area will be recontoured and revegetated in accordance with a land management plan. A detailed closure schedule will be submitted in writing to the Secretary of the NMED, along with the notification of closure. Throughout the closure period, all necessary steps will be taken to prevent threats to human health and the environment in compliance with all applicable Resource Conservation and Recovery Act (RCRA) permit requirements. Figure I-3 presents the best estimate of a final facility closure schedule .

The schedule for final facility closure is considered to be a best estimate because closure of the facility is driven by policies and practices established for the decontamination, if necessary, and decommissioning of radioactively contaminated facilities. These required activities include extensive radiological contamination surveys and hazardous constituent surveys using, among other techniques, the principle of co-detection. Surveys will be performed at all areas of the WIPP site where hazardous waste were managed. These surveys, along with historical radiological survey records, will provide the basis for release of structures, equipment, and components for disposal or decontamination for release off site. Specifications will be developed for each structure to be removed. A cost benefit analysis will be needed to evaluate decontamination options if extensive decontamination is necessary. Individual equipment surveys, structure surveys, and debris surveys will be required prior to disposition. Size-reduction techniques may be required to dispose of mixed or radioactive waste at the WIPP site. Current DOE policy, as reflected in the WIPP facility Safety Analysis Report (SAR), requires the

preparation of a final decommissioning and decontamination (D&D) plan immediately prior to final facility closure. In this way, the specific conditions of the facility at the time D&D is initiated will be addressed. Section I-1e(2) provides a more detailed discussion of final facility closure activities.

Figure I-3 shows the schedule for the final facility closure consisting of decontamination, as needed, of the TRU waste-handling equipment, and of the aboveground equipment and facilities, including closure of surface HWMUs; decontamination of the shaft and haulage ways; disposal of decontamination derived wastes in the last open underground HWMU; and subsequent closure of this underground HWMU. Subsequent activities will include installation of repository shaft seals.

An overall schedule for final facility closure, showing currently scheduled dates for the start and end of final facility closure activities is shown in Table I-2. The dates assume a start up date of June 1998 and hazardous waste permit effective dates of September 1996, September 2006, and September 2016. Details for panel closures are shown on Table I-1.

I-1d(3) Extension for Closure Time

As indicated by the closure schedule represented in Figure I-3, the activities necessary to perform facility closure of the WIPP facility will require more than 180 days to complete because of additional stringent requirements for managing radioactive materials. Therefore, the DOE is requesting an extension of the 180-day final closure requirement in accordance with 20 NMAC 4.1, Subpart V, §264.113. During the extended closure period, the DOE will continue to demonstrate compliance with applicable permit requirements and will take all steps necessary to prevent threats to human health and the environment as a result of TRU mixed waste management at the WIPP facility including all of the applicable measures in Chapter F of this application.

In addition, according to the schedules in Figure I-3, the final derived wastes that are generated as the result of decontamination activities will not be disposed of for 16 months after the initiation of final facility closure. In accordance with 20 NMAC 4.1, Subpart V, §264.113(a), the DOE requests an extension of the 90-day limit to dispose of final derived waste resulting from the closure process. This request is necessitated by the fact that the radioactive nature of the derived waste makes placement in the WIPP the best disposition, and the removal of these wastes will, by necessity, take longer than 90 days in accordance with the closure schedules. During this extended period of time, the DOE will take all steps to prevent threats to human health and the environment, including compliance with all applicable permit requirements. These steps include all of the applicable preparedness and prevention measures in Chapter F of this permit application, including Section F-4g, Flammable Gas Control.

Finally, in the event the hazardous waste permit is not renewed as assumed in the schedule, the DOE will submit a modification to the Closure Plan to implement a contingency closure that will allow the DOE to continue to operate for the disposal of non-mixed TRU waste. This modification will include a request for an extension of the time for final facility closure. This modified Closure Plan will be submitted to the NMED for approval.

I-1d(4) Amendment of the Closure Plan

If it becomes necessary to amend the Closure Plan for the WIPP facility, the DOE will submit, in accordance with 20 NMAC 4.1, Subpart IX, §270.42, a written notification of or request for a permit modification describing any change in operation or facility design that affects the Closure Plan. The written notification or request will include a copy of the amended Closure Plan for approval by the NMED. The DOE will submit a written notification of or request for a permit modification to authorize a change in the approved plan, if:

- There are changes in operating plans or in the waste management unit facility design that affect the Closure Plan
- There is a change in the expected year of closure
- Unexpected events occur during panel or final facility closure that require modification of the approved Closure Plan
- Changes in state or federal laws affect the Closure Plan
- DOE fails to obtain permits for continued operations as discussed above

The DOE will submit a written request for a permit modification with a copy of the amended Closure Plan at least 60 days prior to the proposed change in facility design or operation or within 60 days of the occurrence of an unexpected event that affects the Closure Plan. If the unexpected event occurs during final closure, the permit modification will be requested within 30 days of the occurrence. If the Secretary of the NMED requests a modification of the Closure Plan, a plan modified in accordance with the request will be submitted within 60 days of notification or within 30 days, if the change in facility condition occurs during final closure.

I-1e Closure Activities

Closure activities include those instituted for panel closure (i.e., closure of filled underground HWMUs), contingency closure (i.e., closure of surface HWMUs and decontamination of other waste handling areas), and final facility closure (i.e., closure of surface HWMUs, D&D of surface facilities and the areas surrounding the WHB, and placement of repository shaft seals). Panel closure systems will be emplaced to separate areas of the facility and to isolate panels. Appendices I1 and I2 provide panel closure system and shaft seal designs. All closure activities will meet the applicable quality assurance (QA)/quality control (QC) program standards in place at the WIPP facility. Facility monitoring procedures in place during operations will remain in place through final closure, as applicable.

I-1e(1) Panel Closure

Following completion of waste emplacement in each underground HWMU, disposal-side ventilation will be established in the next panel to be used, and the panel containing the waste will be closed. A panel closure system will be emplaced in the panel access drifts, in accordance

with the design in Appendix I1 and the schedule in Figure I-2 and Table I-1. The panel closure system is designed to meet the following requirements that were established by the DOE for the design:

- the panel closure system shall limit the migration of VOCs to the compliance point so that compliance is achieved by at least one order of magnitude
- the panel closure system shall consider potential flow of VOCs through the disturbed rock zone (DRZ) in addition to flow through closure components
- the panel closure system shall perform its intended functions under loads generated by creep closure of the tunnels
- the panel closure system shall perform its intended function under the conditions of a postulated methane explosion
- the nominal operational life of the closure system is 35 years
- the panel closure system for each individual panel shall not require routine maintenance during its operational life
- the panel closure system shall address the most severe ground conditions expected in the waste disposal area
- the design class of the panel closure system shall be IIIb (which means that it is to be built to generally accepted national design and construction standards)
- the design and construction shall follow conventional mining practices
- structural analysis shall use data acquired from the WIPP underground
- materials shall be compatible with their emplacement environment and function
- treatment of surfaces in the closure areas shall be considered in the design
- thermal cracking of concrete shall be addressed
- during construction, a QA/QC program shall be established to verify material properties and construction practices
- construction of the panel closure system shall consider shaft and underground access and services for materials handling

The performance standard for air emissions from the WIPP facility is established in Section D-9d(3) and Table D-6. These are reiterated in the detailed design report, Appendix I1, Table A-1, as the closed panel release limits. Releases must be below these limits for the facility to remain in compliance with standards to protect human health and the environment. The

following panel closure design has been shown, through analysis, to meet these standards, if emplaced in accordance with the specifications in Appendix I1.

The final panel closure design in Appendix I1 was prepared with the assumption that there would be no backfill in the disposal rooms. With the inclusion of backfill, the design has been re-examined and it has been determined that the changes are insignificant for several reasons. First, the backfill has no effect on the gas generation rate so that the values used in the design for gas generation and methane buildup remain the same. Second, the quantity of backfill is sufficient to fill one-tenth of the void volume in the room. This results in more rapid pressurization of the room, however, the effect is small and will only be important after the facility is sealed. Third, the reduced volume will result in a faster accumulation of methane. This would not result in a revision of the design. Instead, it would change the criteria for installing explosion walls. The DOE believes the 20-year criterion is still appropriate, since the design report (Figure 2-14 in Appendix I1) shows that it takes 25-years to reach explosive limits. A ten percent reduction in this time is still beyond 20 years. Furthermore, the chances that methane will be generated initially are minimized by the fact that the closed panels will be initially oxic and may remain so for a long time after facility closure.

The design for the panel closure system calls for a composite panel barrier system consisting of a rigid concrete plug with or without removal of the DRZ, and either an explosion-isolation wall or a construction-isolation wall. The design basis for this closure is such that the migration of hazardous waste constituents from closed panels during the operational and closure period would result in concentrations well below health-based standards. The source term used as the design basis included the average concentrations of VOCs from CH waste containers as measured in headspace gases through January 1995. Appendix C2 discusses the methodology for calculating average concentrations. The VOCs are assumed to have been released by diffusion through the container vents and are assumed to be in equilibrium with the air in the panel. Emissions from the closed panel occur at a rate determined by gas generation within the waste and creep closure of the panel. The derivation of the emission rate is discussed in Appendix D9. Due to the relatively small amount of RH waste (approximately 5 percent of the total waste volume), VOC emissions from RH waste are assumed to contribute insignificantly to total VOC emissions. Analysis in Appendix D9 shows that emissions result in VOC concentrations at the site boundary below health-based limits; therefore, an adequate margin of safety also exists for potential RH waste VOC emissions. This design meets the environmental performance standard.

Figures I-4 and I-5 show a diagram of the panel closure design and installation envelopes. Appendix I1 provides the detailed design and the design analysis for the panel closure system. The panel closure design is such that components can be added or removed or their shapes adjusted depending on the particular ground conditions at the time of installation. For example, in Figure I-4, Option A represents the likely closure of panels less than 20 years old at the time of final facility closure and whose entries are sufficiently intact such that DRZ removal is not needed. These would likely include Panels 6 through 8. Option B represents the preferred option for panels that will be closed for more than 20 years prior to final facility closure and whose entries are reasonably intact at time of closure. These will likely be Panels 2 through 5. Option C may be desirable for panels whose entries require DRZ removal and whose closure precedes final facility closure by less than 20 years. This is the likely configuration of the closure

for Panels 9 and 10. Finally, Option D may be appropriate for panels whose entries require significant removal of the DRZ and whose closure will precede final facility closure by more than 20 years. Panel 1 is the most likely candidate for this type of closure.

The 20-year limit in the design selection process is based on what the DOE believes to be conservative analytical results that indicate methane, being generated by waste degradation at the rate of 0.1 mole per drum per year, will not reach flammable concentrations for at least 20 years. As part of the decision making process on design selection, an investigation of the DRZ would precede the selection of the concrete component and the specification of the amount of excavation that is needed. These investigations could be done using geophysical methods (such as ground penetrating radar) or drill holes. Drill holes can be investigated using video cameras or "scratchers".

The DOE believes that design Options A through D will function adequately as panel closures given the current state of knowledge about gas generation, the understanding of the DRZ, the expected characteristics of the waste, and the inability of monitoring techniques to accurately detect extremely small concentrations of VOCs. However, in the event sufficient information is collected that allows the DOE to make less conservative assumptions regarding these items, the designs A through D may prove to be significantly more protection than is actually needed. Consequently, the DOE has retained as a design concept, Option E, which is simply the explosion wall portion of Options B and D. Option E represents a significantly simpler panel closure system that the DOE would use if either of the following criteria are met as indicated:

- Gas generation rates are smaller. Current (unreported) work being performed by Sandia National Laboratories indicates that microbial gas generation rates under humid conditions are close to zero, and/or

- Average headspace concentrations are less than the averages used in the calculations. As new wastes are generated, the use of organic solvents is expected to be reduced drastically. Some compounds, such as carbon tetrachloride, have already been banned from use at some generator sites.

As stated previously, the DOE will evaluate these criteria at the time a panel closure is needed and will select the proper closure design. If a design different from those listed above is identified, the appropriate permit modification will be sought.

I-1e(2) Decontamination and Decommissioning

Decontamination is defined as those activities which are performed to remove contamination from surfaces and equipment that are not intended to be disposed of. The policy at the WIPP will be to decontaminate as many areas as possible, consistent with radiation protection policy. Decontamination is part of all closure activities and is a necessary activity in the clean closure of the surface container management units. Decontamination is performed using, among other techniques, the principles of co-detection as described in Appendix I3.

Decommissioning is the process of removing equipment, facilities, or surface areas from further use and rendering a facility to a final condition. Decommissioning is part of final facility closure

only and will involve the removal of equipment, buildings, closure of the shafts, and establishing active and passive institutional controls for the facility.

The objective of D&D activities at the WIPP facility is to return the surface to as close to the preconstruction condition as reasonably possible, while protecting the health and safety of the public and the environment. D&D activities are discussed in the "Conceptual Decontamination and Decommissioning Plan for the Waste Isolation Pilot Plant" (DOE, 1995a). Major activities planned to accomplish this objective include, but are not limited to the following:

1. Review of operational records for historical information on releases
2. Visual examination of surface structures for evidence of spills or releases
3. Performance of site contamination surveys
4. Decontamination, if necessary, of usable equipment, materials, and structures including surface facilities and areas surrounding the WHB.
5. Disposal of equipment/materials that cannot be decontaminated but that meet waste acceptance criteria in an HWMU
6. Dismantling of surface facilities
7. Dismantling of underground facilities at the time the panels are closed
8. Emplacement of final panel closure system
9. Emplacement of fill material in the underground, if required[2]
10. Emplacement of shaft seals[3]
11. Regrading the surface to approximately original contours
12. Initiation of active controls which includes monitoring and installation of the PMS

These activities, in addition to common techniques such as visual inspection and records, will be performed using the best technology available at the time of closure, and will be conducted in a manner that maintains personnel exposure to radiation levels as low as reasonably achievable and exposure to hazardous constituents to levels deemed acceptable by the DOE as discussed in Section D-9d(3). This Closure Plan will be amended prior to the initiation of closure activities to specify the D&D methods to be used, if appropriate.

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[2]Recent studies have shown that fill outside the waste emplacement region has negligible benefits for minimizing subsidence. Consequently, this function has been deleted from the WIPP base design. Such fills may, however, have long-term benefits and may prove to be desirable in the future. If need be, they will be included in future revisions of the Closure Plan.

[3]For the purposes of planning, the conclusion of shaft sealing is used by the DOE as the end of closure activities and the beginning of the Post-Closure Care Period.

Health and Safety

Before final closure activities begin, health physics personnel will conduct a hazards survey of the unit(s) being closed. A release of radionuclides could also indicate a release of hazardous constituents, in accordance with co-detection principles. If radionuclides are not detected, sampling for hazardous constituents may still be performed if there is evidence that a spill or release has occurred. The purpose of the hazards survey will be to identify potential contamination concerns that may present hazards to workers during the closure activities and to specify any control measures necessary to reduce worker risk. This survey will provide the information necessary for the health physics personnel to identify worker qualifications, personal protective equipment (PPE), safety awareness, work permits, exposure control programs, and emergency coordination that will be required to perform closure related activities.

I-1e(2)(a) Determine the Extent of Contamination

The first activities performed as part of decontamination include those needed to determine the extent of any contamination that needs to be removed prior to decommissioning a facility. This includes activities 1 to 3 above and, as can be seen by the schedules in Figures I-3 and I-4 (Items B and C), these surveys are anticipated to take ten months to perform, including obtaining the results of any sample analyses. The process of identifying areas that require decontamination include three sources of information. First, operating records will be reviewed to determine where contamination has previously been found as the result of historical releases and spills. Even though releases and spills will have been cleaned up at the time of occurrence, newer equipment and technology may allow further cleaning. Second, surfaces of facilities and structures will be examined visually for evidence of spills or releases. Finally, extensive detailed contamination surveys will be performed to document the level of cleanliness for all surface structures and equipment. If equipment or areas are identified as contaminated, a plan and procedure(s) will be developed and implemented to address decontamination-related questions, including:

- Should the component be decontaminated or disposed of as waste?
- What is the most cost-effective method of decontaminating the component?
- Will the decontamination procedures adequately contain the contamination?

The principle of co-detection will be used in determining the presence of hazardous waste and hazardous waste residues in areas where spills or releases have occurred. Co-detection is described in Appendix I3 and simply means that if radioactive contamination is found, it will be assumed that hazardous constituent contamination also occurs. Once cleanup of the radioactivity has been completed, the surface will be sampled for hazardous constituents to determine that they, too, have been cleaned up. Sampling will be in accordance with written procedures in the WIPP Site Effluent Hazardous Material Sampling Plans (Westinghouse, 1994), which provides for sampling protocols including QA/QC, organizational responsibilities, sample plan development, sample control, and laboratory selection and use. Sampling is established consistent with EPA's document SW-846 (EPA, 1986).

I-1e(2)(b) Decontamination Activities

Once the extent of contamination is known, decontamination activities will be planned. Radiological control and the control of hazardous waste residues are the primary criteria used in the design of decontamination activities. Radiation control procedures require that careful planning and execution be used in decontamination activities to prevent the exposure of workers beyond reasonable occupational levels and to prevent the further spread of contamination. Careful control of entry, cleanup, and ventilation are vital components of radiation decontamination. The level of care mandated by DOE orders and occupational protection requirements is what results in closure activities that will exceed the 180-days allowed in 20 NMAC 4.1, Subpart V. Decontamination activities are included as item 4 above and is shown on the schedules for contingency closure and final facility closure (Figures I-3 and I-4) as activities D, E, and F. These activities are anticipated to have a duration of 20 months for both contingency closure and for final facility closure. The result of these activities is the clean closure of the surface container management units. Under contingency closure, the other areas that have been decontaminated will not be closed. Instead they will remain in use for continued waste management activities involving non-mixed waste. Under final facility closure, other areas that are decontaminated are eligible for closure.

The "Start Clean—Stay Clean" operating philosophy of the WIPP Project will provide for minimum need for decontamination. However, the need for decontamination techniques may arise.

Decontamination activities will be coordinated with closure activities so that areas that have been decontaminated will not be recontaminated. All waste resulting from decontamination activities will be surveyed and analyzed for the presence of contaminants. The waste will be characterized as hazardous, mixed, or radioactive and will be packaged and handled appropriately. Mixed and radioactive waste will be classified as TRU mixed waste managed in accordance with the applicable DOE Order(s) in place at the time of closure. Derived mixed waste collected during decontamination activities that are generated before repository shafts have been sealed will be emplaced in the facility, if appropriate, or will be managed together with decontamination derived waste collected after the underground is closed. This waste will be classified and shipped off site to an appropriate, permitted facility for treatment, if necessary, and for disposal.

Removal of Hazardous Waste Residues

Because of the type of waste management activities that will occur at the WIPP facility, waste residues that may be encountered during the operation of the facility and at closure may include derived waste. Derived wastes result from the management of the waste containers or may be collected as part of the closure activities (such as those during which wipes were used to sample the containers and equipment for potential radioactive contamination or those involving solidified decontamination solutions, the handling of equipment designated for disposal, and the handling of residues collected as a result of spill cleanup). Derived wastes collected during the operation and closure of the WIPP facility will be identified and managed as TRU mixed wastes. These wastes will be disposed of in the open-disposal HWMU. D&D derived wastes and equipment designated for disposal will be placed in the last HWMU panel before closure of that unit.

Surface Container Storage Units

The procedures employed for waste receipt at the WIPP facility allow no opportunity for any waste spillage to occur outside the WHB. TRU mixed waste is shipped to the WIPP facility in approved shipping containers (e.g., TRUPACT-IIs or shielded road casks) that are not opened until they are inside the WHB. Therefore, no soil in the parking area or elsewhere in the vicinity of the WHB will become contaminated with TRU mixed waste constituents as a result of TRU mixed waste management activities, and an evaluation of the soils in the vicinity of the WHB is unnecessary.

The "Start Clean—Stay Clean" operating philosophy of the WIPP Project will minimize the need for decontamination of the WHB during decommissioning and closure. Procedures for opening shipping containers in the WHB limit the opportunity for waste spillage.

Should the need for decontamination of the WHB arise, the following methods may be employed, as appropriate, for the hazardous constituent/contaminant type and extent:

- Chemical cleaning (e.g., water, mild detergent cleanser, and polyvinyl alcohol)
- Nonchemical cleaning (e.g., sandblasting, grinding, high-pressure water spray, scabbler pistons and needle scalers, ice-blast technology, dry-ice blasting)
- Removal of contaminated components such as pipe and ductwork

Waste generated as a result of WHB decontamination activities will be managed as derived waste in accordance with applicable permit requirements and will be emplaced in the last open HWMU for disposal.

Equipment and Underground Waste Handling Areas

The waste hoist conveyance and associated waste handling equipment, as well as waste handling areas outside the disposal areas in the underground, will be decontaminated as needed as part of both contingency and final facility closure. Procedures for detection and sampling will be as described above. Equipment cleanup will be as above using chemical or nonchemical techniques. Contaminated areas in the underground will be managed on a case-by-case basis and may either be removed or entombed.

Personnel Decontamination

PPE worn by personnel performing closure activities in areas determined to be contaminated will be disposed of appropriately. Disposable PPE used in such areas will be placed into containers and managed as TRU mixed waste. Non-disposable PPE will be decontaminated, if possible. Non-disposable PPE that cannot be decontaminated will be managed as TRU mixed waste.

In accordance with DOE policy, TRU mixed waste PPE will be considered to be contaminated with all of the hazardous waste constituents contained in the containers that have been managed within the unit being closed. Wastes collected as a result of closure activities and that may be

contaminated with radioactive and hazardous constituents will be considered TRU mixed wastes. These wastes will be managed as derived wastes, as described in Section D-10a(3)(a). Such waste, collected as the result of closure of the WIPP facility, will be disposed of in the final open HWMU.

Cleanup Criteria

Radiation decontamination will be less than or equal to the following levels, or to whatever lesser levels that may be established by DOE Order at the time of cleanup:

Contamination Type	Loose[4]	Fixed plus removable
alpha contamination (α)	20 dpm/100 cm^2	500 dpm/100 cm^2
beta-gamma contamination (β-γ)	200 dpm/100 cm^2	1000 dpm/100 cm^2

Hazardous waste decontamination will be conducted in accordance with standards in 40 CFR Part 264, Subpart S.

Final Contamination Sampling and Quality Assurance

Verification samples will be analyzed by an approved laboratory that has been qualified by the DOE according to a written program with strict criteria. The QA requirements of EPA/SW-846, "Test Methods for Evaluating Solid Waste," will be met for hazardous constituent sampling and analyses.

Quality Assurance/Quality Control

Because decisions about closure activities may be based, in part, on analyses of potentially contaminated surfaces and media, a program to ensure reliability of analytical data is essential. Data reliability will be ensured by following a QA/QC program that mandates adequate precision and accuracy of laboratory analyses. Field documentation will be used to document the conditions under which each sample is collected. The documented QA/QC program in place at the WIPP facility meets DOE QA requirements.

Field blanks and duplicate samples will be collected in the field to determine potential errors introduced in the data from sample collection and handling activities. To determine the potential for cross-contamination, rinsate blanks (consisting of rinsate from decontaminated sampling equipment) will be collected and analyzed. At least one rinsate blank will be collected for every 20 field samples. Duplicate samples will be collected at a frequency of one duplicate sample for every ten field samples. In no case will less than one rinsate blank or duplicate sample be collected for a field-sampling effort. These blank and duplicate samples will be identified and

[4]The unit "dpm" stands for "disintegration per minute" and is the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

treated as separate samples. Acceptance criteria for QA/QC hazardous constituent sample analyses will be compatible with the most recent version of EPA SW-846 or other applicable EPA guidance.

I-1e(2)(c) Dismantling

Final facility closure will include dismantling of structures on the surface and in the underground. These are items 6 and 7 above and are represented as Activity G in the final facility closure schedule in Figure I-4. During dismantling, priority will be given to contaminated structures and equipment that cannot be decontaminated to assure these are properly disposed of in the remaining open underground HWMU in a timely manner. All such facilities and equipment are expected to be removed and disposed of 16 months after the initiation of closure. Dismantling of the balance of the facility, including those structures and equipment that are not included in the application and are not used for TRU mixed waste management, is anticipated to take an additional 66 months. It should be noted that the placement of D&D waste into the final underground HWMU may, by necessity, involve the placement of uncontainerized bulk materials such as concrete components, building framing, structural members, disassembled or partially disassembled equipment, or containerized materials in non-standard waste boxes. Such placement will only occur if it can be shown that it is protective of human health and the environment and all items are described in an amendment to the Closure Plan. Identification of bulk items is not possible at this time since their size and quantity will depend on the extent of non-removable contamination.

I-1e(2)(d) Closure of Open Underground HWMU

The closure of the final underground HWMU is shown by Activity H in Figure I-3. This closure will be consistent with the description in Section I-1e(1) and the design in Appendix I1. Detailed closure schedules for underground HWMUs are given in Figure I-2 and Table I1.

I-1e(2)(e) Final Facility Closure

Final facility closure includes several activities designed to assure both the short-term isolation of the waste and the long-term integrity of the disposal system. These include the placement of plugs in boreholes that penetrate the salt and the placement of the repository sealing system. In addition, the surface will be returned to as near its original condition as practicable, and will be readied for the construction of markers and monuments that will provide permanent marking of the repository location and contents.

Figure I-6 identifies where ten existing boreholes overlie the proximate area of the repository footprint. Of these identified boreholes in Figure I-6, all but ERDA-9 are terminated hundreds of feet above the repository horizon. Only ERDA-9, which is accounted for in long-term performance modeling, is drilled through the repository horizon, near the WIPP excavations.

To mitigate the potential for migration beyond the repository horizon, the DOE has specified that borehole seals be designed to limit the volume of water that could be introduced to the repository from the overlying water-bearing zones and to limit the volume of contaminated brine released from the repository to the surface or water-bearing zones.

Borehole plugging activities have been underway since the 1970s, from the early days of the development of the WIPP facility. Early in the exploratory phase of the project, a number of boreholes were sunk in Lea and Eddy counties. After the WIPP site was situated in its current location, an evaluation of all vertical penetrations was made by Christensen and Peterson (1981).

As an initial criterion, any borehole that connects a fluid-producing zone with the repository horizon becomes a plugging candidate.

Grout plugging procedures are routinely performed in standard oil-field operations; however, quantitative measurements of plug performance are rarely obtained. The Bell Canyon Test reported by Christensen and Peterson (1981) was a field test demonstration of the use of cementitious plugging materials and modification of existing industrial emplacement techniques to suit repository plugging requirements. Cement emplacement technology was found to be "generally adequate to satisfy repository plugging requirements." Christensen and Peterson (1981) also report "that grouts can be effective in sealing boreholes, if proper care is exercised in matching physical properties of the local rock with grout mixtures. Further, the reduction in fluid flow provided by even limited length plugs is far in excess of that required by bounding safety assessments for the WIPP." The governing regulations for plugging and/or abandonment of boreholes are summarized in Table I-3.

The proposed repository sealing system design will prevent water from entering the repository and will prevent gases or brines from migrating out of the repository. The proposed design includes the following subsystems and associated principal functions:

- Near-surface: to prevent subsidence at and around the shafts
- Rustler Formation: to prevent subsidence at and around the shafts and to ensure compliance with federal and State of New Mexico groundwater protection requirements
- Salado Formation: to prevent transporting hazardous waste constituents from the WIPP repository beyond the unit boundary

The repository sealing system will consist of natural and engineered barriers within the WIPP repository that will withstand forces expected to be present because of rock creep, hydraulic pressure, and probable collapses in the repository and will meet the closure requirements of 20 NMAC 4.1, Subpart V. Appendix I2 presents the repository sealing system design basis and performance evaluations. The design in Appendix I2 is conceptual. The DOE is currently preparing a final seal design report. This report will be provided to the NMED by October 1, 1996. The design drawings that will be included in the final design report are included in Appendix I2. These drawings are stamped preliminary because the final peer review has not been conducted. These drawings, in their final form, will accompany the final design report.

Once shaft sealing is completed, the DOE will consider closure complete and will provide the NMED with a certification of such within 60 days.

I-1e(2)(f) Final Contouring and Revegetation

In the preparation of its Final Environmental Impact Statement (DOE, 1980), the DOE committed to restore the site to as near to its original condition as is practicable. This involves removal of access roads, unneeded utilities, fences, and any other structures built by the DOE to support WIPP operations. Provisions would be left for active post-closure controls of the site and for the installation of long-term markers and monuments for the purpose of permanently marking the location of the repository and waste. Section I-1e(3) discusses the active and long-term controls proposed for the WIPP. Installation of borehole seals are anticipated to take 12 months, shaft seals 52 months, and final surface contouring 8 months.

I-1e(2)(g) Closure, Monuments, and Records

A record of the WIPP Project shall be listed in the public domain in accordance with the requirements of 20 NMAC 4.1, Subpart V, §264.116. Active access controls will be employed for at least the first 100 years after final facility closure. In addition, a passive control system consisting of monuments or markers shall be erected at the site to inform future generations of the location of the WIPP repository (see "Permanent Marker Conceptual Design Report" [DOE, 1995b]).

Closure of the WIPP facility will contribute to the following:

- Prevention of the intrusion of fluids into the repository by sealing the shafts
- Prevention of human intrusion after closure
- Minimization of future physical and environmental surveillance

Detailed records shall be filed with local, state, and federal government agencies to ensure that the location of the WIPP facility is easily determined and that appropriate notifications and restrictions are given to anyone who applies to drill in the area. This information, together with land survey data, will be on record with the U.S. Geological Survey and other agencies. The federal government will maintain permanent administrative authority over those aspects of land management assigned by law. Details of post-closure activities are in Section I-2.

I-1e(3) Performance of the Closed Facility

20 NMAC 4.1, Subpart V, §264.601 requires that a miscellaneous unit be closed in a manner that protects human health and the environment. The following addresses the performance of the closed facility during the 30-year post closure period.

The principal barriers to the movement of hazardous constituents from the facility or the movement of waters into the facility are the halite of the Salado Formation (natural barrier) and the repository seals (engineered barrier). Data and calculations that support this discussion and presented The majority of the calculations performed for the repository are focused on long-term performance and making predictions of performance over 10,000 years. In the short term, the repository is reaching a steady state configuration where the hypothetical brine inflow rate is

affected by the increasing pressure in the repository due to gas generation and creep closure. These three phenomena are related in the numerical modeling.

I-1e(3)(a) Gas Generation

Gas generation affects repository pressure, which in turn is an important parameter in other processes such as creep closure, interbed fracture, and two-phase flow. The computer simulation of this process[5] uses an average-stoichiometry model to estimate the potential for gas generation in the waste disposal region. Parameter values for the average-stoichiometry gas generation model are summarized in Table I-4 and detailed in Appendix D16, §D16-5.

Gas generation processes considered in the simulation include anoxic corrosion and microbial degradation. Radiolysis is not included in the model on the basis of laboratory experiments and model calculations that demonstrate the process to be an insignificant gas generation mechanism compared to corrosion and biodegradation. For the purpose of calculating repository pressure and fluid flow, the properties of the generated gas are assumed to be those of H_2.

Specific to the simulation, anoxic corrosion of ferrous metals and microbial degradation of cellulosics, plastics, and rubbers is assumed to occur and generate gas at rates limited only by the availability of brine and solid reactants. Assuming that all cellulosics, plastics, and rubbers are available to degrade and participate in the gas generation process is a conservative assumption. This is because there are no reasonable mechanisms to mix microbes, moisture, cellulosics and nutrients in order to sustain degradation. Biodegradation is considered to have a 50 percent chance of occurring, primarily due to uncertainties in the long-term survival of microbes (Brush, 1995, pp. B-19 to B-24). These assumptions serve to maximize gas generation rates.

Anoxic corrosion is represented by an equation that accounts for corrosion only of the steel content in the repository by the two reactions expected to dominate corrosion rates. Because the total quantity of aluminum and aluminum alloys is a small fraction of the quantity of iron-based metals, corrosion of aluminum is omitted for simplicity. As corrosion proceeds the steel content of the repository is depleted over time. Brine is also consumed as gas generation proceeds. Effects of wicking (the retention of brine in a capillary fringe) on the corrosion gas generation rates are incorporated in the analysis through the use of a wicking parameter, as explained in Appendix D16, §D16-5. The DOE assumes no passivation of steel by interaction with microbial degradation reactions, a process capable of preventing anoxic corrosion. Important parameters in the corrosion equation are assigned fixed values, as summarized in Table I-4.

Similar to modeling anoxic corrosion, microbial degradation is represented by an equation with the inventory of cellulosics, plastic, and rubber material also depleted with time. Biodegradable materials are depleted at a rate dependent on the amount of liquid present. It is assumed that

[5]The DOE uses the code BRAGFLO to simulate repository. This code was developed by the Sandia National Laboratories specifically for the WIPP and is being used for the DOE's demonstration of compliance to long-term repository performance standards.

the microbial degradation process neither produces nor consumes water. Depending on parameter values, gas generation by microbial degradation in the computer simulation can continue until all degradable materials or available brine are consumed. Important parameters used to model microbial degradation are summarized in Table I-4 and discussed further in Appendix D16, §D16-5.

I-1e(3)(b) Brine Inflow

For the computer simulation used in this analysis, the DOE conceptualized the Salado as a porous medium composed of several rock types arranged in layers, through which fluid flow occurs according to Darcy's Law. This model was chosen because it can be simulated using standard numerical techniques and because it is the most conservative of the three mechanisms in that is predicts the maximum rate and cumulative volume of brine inflow. Two rock types, impure halite and anhydrite, are used to represent the intact Salado. Near the repository, the DRZ has increased permeability compared to intact rock and offers little resistance to flow between anhydrite interbeds and the repository. Except for the DRZ and anhydrite interbeds, under certain circumstances, this simulation assumes spatially constant properties for Salado rock types based on observations of compositional and structural regularity in layers exposed by the repository. The inference is that there is little variation in large-scale averages of rock or flow properties across the disposal system. Assumptions about Salado flow in general are presented in Appendix D16, §D16-6. This model serves to maximize the potential brine inflow to the repository.

Table I-5 shows various parameter values used in modeling the impure halite. Supported by four hydraulic tests in the WIPP underground believed to represent far-field conditions and stratigraphic variation in the Salado, the median value for permeability calculated for this region is 3.4×10^{-22} square feet (3.16×10^{-23} square meters [m^2]). Additional information on parameter values is contained in Appendix D16, §D16-6, including the distinction between rock compressibility and pore compressibility used in the simulation.

Gas may not be able to flow through or into intact, halite-rich strata of the Salado under realistic conditions for the repository. As halite is modeled as 100 percent brine saturated, the capillary resistance of the rock must be overcome to displace brine from pores and drive gas into the rock. This condition represents the concept of threshold pressure. While the permeability of halite is known to be low, its threshold pressure has never been measured. An empirical relationship between threshold pressure and permeability in non-WIPP rocks (Davies, 1991, pp.17–19) suggests that threshold pressure will be sufficiently high and gas will not be able to flow into the halite-rich strata of the Salado under any conditions foreseeable for the WIPP. Values used by the DOE for impure halite threshold pressure are set to prevent the flow of gas into this material. This is a conservative assumption, because gas flow into impure or pure halite would decrease the pressure in the repository and the driving force available for flow.

Three distinct anhydrite interbeds are modeled in the computer simulation representing MB 138, anhydrite layers a and b, and MB 139. The three interbeds are assigned identical parameter values, and these values are initially spatially constant. The interbeds differ only in stratigraphic location and thickness. The three interbeds are included in the model simulation, because they exist in the disturbed region around the repository within which fluid is expected to be able to

flow with relative ease compared to the surrounding formation. MB 139 and anhydrite layers a and b are present within the DRZ that forms around excavations; MB 138 may be above the DRZ, and is of no consequence during the post-closure period.

In the computer simulation, brine flows from the Salado and into the repository in response to fluid potential gradients that form over time. Due to the low permeability of the impure halite and relatively small surface area of the excavation, direct brine flow between the impure halite and the repository is limited. The interbeds, however, can serve as conduits for brine flow between the impure halite and the repository. Conceptually, brine flows laterally along higher-permeability interbeds towards or away from the repository and vertically between the interbeds and the lower-permeability halite. Because the interbeds have a very large contact area with adjacent halite-rich rock, even very small flux from the halite into the interbeds (for brine inflow) or to the halite from the interbeds (for brine outflow) can accumulate into a significant quantity of brine. In this manner, halite serves as a source or sink for brine in the repository. It is expected that, due to density differences between gas and brine and their stratification within the repository, brine outflow will dominate in underlying MB 139, and gas outflow will occur in anhydrite a and b or overlying MB 138. Parameters associated with the interbeds are shown in Table I-6.

I-1e(3)(c) Rock Properties

Creep closure is the focus of the computer model that implements the repository processes associated with rock properties in the repository rooms and the shafts. The amount of waste consolidation resulting from creep closure, and the time it takes to consolidate the waste, are governed by properties of the waste (waste strength), properties of the surrounding rock, the dimensions and location of the room, and the quantities and pressure of fluids present in the room. Creep closure of waste disposal areas will cause their volume to decrease as the Salado deforms to consolidate and encapsulate the waste, changing waste porosity and permeability. Waste strength and fluid pressure may act to resist creep closure.

Fluids that could affect closure are brine that may enter the repository from the Salado, air present in the repository when it is sealed, and gas produced by reactions occurring during waste degradation. Closure and consolidation slowed by fluid pressure in the repository can be quantified according to the principle of effective stress:

$$\sigma_T = \sigma_e + p \qquad (1)$$

where σ_T is the stress caused by the weight of the overlying rock and brine (an essentially constant value), p is the pressure of the repository pore fluid, and σ_e is the stress that is applied to the waste skeleton or matrix. In this formulation, the waste is considered a skeleton structure immersed in pore fluids. As the pore pressure increases, an increasing amount of overburden stress is supported by pore fluid pressure, and less overburden stress is supported by the strength of the waste matrix. Due to waste strength, waste consolidation can cease even if pore fluid pressures do not reach lithostatic. If gas and brine quantities in the repository stabilize, creep closure will act to establish a constant pressure and void volume.

Two material-response models are required for closure analyses within the disposal room. The first describes how the halite in the formation surrounding the waste deforms (creeps) as a function of time and stress. The second model describes the state of consolidation of the waste as a function of applied stress.

Halite deformation is predicted using a multimechanism deformation (M-D) steady-state creep model with workhardening/recovery transient response (Model 1). At the WIPP, there are potentially three distinct creep mechanisms involved, which are governed by the temperature and shear stress at a given location in the surroundings at any given time. WIPP conditions are expected to be isothermal so temperature is treated as a constant value. All three mechanisms can be active at the same time because of the large range of stress states that occur around underground rooms and shafts.

The focus of the mechanistic part of the model is definition of steady-state creep strain, with transient creep strain described through a multiplier on the steady-state rate, thus accommodating both transient changes in stress loading and loading. More information is presented in Munson et al. (1995).

The volumetric plasticity part of the model is the mathematical model for room closure and waste consolidation. The experimental data used in this model are summarized and interpreted in Butcher et al. (1991, pp. 65-76) and Luker et al. (1991). The volumetric plasticity model and M-D model are numerically implemented.

As a boundary condition, the computer code requires estimates of the fluid pressure and, hence, the initial quantity of gas present in a disposal room. These estimates are obtained using the average-stoichiometry model of gas generation with different rates of gas generation that reflect different assumptions about the quantity of brine that might be available in a waste disposal room. The different rates of gas generation used in the analysis bound the possible conditions for gas content in the repository. With the volumetric plasticity model and the fluid pressure boundary condition, the code calculates the void volume of the disposal room through time.

In the computer simulation, the time-dependent effects of creep closure on volume are linked to the fluid flow via a look-up table, which relates porosity or void volume to: a) time after sealing, and b) gas pressure. At the beginning of a time step, the fluid flow code evaluates the pressure of a cell in the waste disposal region. The code then consults the look-up table to find the void volume of the cell appropriate for a given time and pressure. The void volume in the cell is iteratively adjusted during a time step solution for consistency with gas generation, fluid movement, and repository pressure. The look-up table method of incorporating the dynamic effect of creep closure in the simulation has been compared to more complex techniques that are computationally impractical. In these comparisons, the porosity surface method was found to be a reasonable representation of behavior observed in more complex models. Parameter values used in the computer simulation for repository and panel closure are given in Appendix D16, Section D16-7.

The four shafts connecting the repository to the surface are represented in the computer simulation with a single shaft. This single shaft has a cross section and volume equal to the total cross section and volume of the four actual shafts and is separated from the waste disposal

region in the model by the true north-south distance from the waste to the nearest shaft (the Waste Shaft).

Seal component materials and properties used in the simulation are given in Table I-7. From top to bottom, the seal system is represented in the simulation by the following materials (see Appendix I2):

- an earthen fill region above the Rustler Formation
- a clay region in the Rustler Formation (designated Rustler Compacted Clay in Table I-7)
- an asphalt region at the top of the Salado
- three concrete sections (upper, middle, lower) within the Salado
- a thick section of compacted crushed salt within the Salado
- an upper compacted clay region within the Salado (designated Upper Salado Compacted Clay in Table I-7)
- a lower compacted clay region within the Salado (designated Lower Salado Compacted Clay in Table I-7)
- a basal clay component below MB 138 (designated Bottom Clay in Table I-7)
- a lower concrete section at the repository horizon (shaft station concrete monolith)

Conceptually, the simulation considers the maturation of the DRZ surrounding the shaft with respect to variation in the rate of DRZ healing with depth, time, and the type of adjacent seal material. For example, the DRZ in the halite adjacent to concrete members is assumed to heal very rapidly because of the rigidity of the concrete and the high lithostatic stress. Against less rigid seal components and at higher elevations in the shaft, the DRZ is assumed to heal more slowly. Depending on shaft material properties and depth of emplacement, the simulation also considers potential time-dependent consolidation.

To reflect shaft material consolidation and DRZ maturation, effective permeabilities of selected shaft regions are adjusted with time in a stepwise fashion (Table I-7). In some halite shaft regions enhanced flow is expected through the surrounding DRZ, before healing occurs. In this case, the increased permeability is modeled by increasing the permeability of the adjacent shaft seal component. In some cases, this adjustment acts to counteract the expected decrease in permeability resulting from consolidation. The increase in permeability noted for concrete from 1.8×10^{-19} to 10^{-14} m^2 is conservative; the permeability of concrete within the Salado section of the shaft is not expected to degrade to the permeability of silty-sand, and, in fact, physical and hydraulic properties of concrete seals are expected to remain stable over the long-term. Note that Appendix D16, §D16-8 lists only the initial permeability for shaft materials within the Salado and not the effective permeabilities calculated for each time step presented in Table I-7.

I-1e(3)(d) Contaminant Transport Calculations

A computer simulation of disposal system performance has been completed for the DOE's demonstration of no-migration. This simulation, along with supporting documentation, is due to be submitted to the EPA in June 1996. Those portions of the simulation that are applicable to the closed panel and sealed shaft configurations, are summarized here as background for the subsequent discussions of pathways and environmental protection and to support the DOE's demonstration of compliance with the environmental performance standards in 20 NMAC 4.1, Subpart V, §264.601.

The computer simulation for the no-migration determination was conducted to predict disposal system performance over 10,000 years. Only the first 300 years are discussed here. This period goes sufficiently beyond the post-closure period to depict trends in the calculations.

Caution should to be exercised in using this simulation for interpreting repository performance prior to shaft sealing and during the first 100 years of the simulation. This is due to several reasons:

- The simulation assumes higher gas generation rates than anticipated in order to assure sufficient gas is present to evaluate the disposal system performance.
- The simulation assumes anoxic conditions exist from the outset and the gas generation rates are those observed for anoxic conditions. It is anticipated that oxic conditions will prevail during the initial closure period, during which time there will likely be no gas generation.
- The model does not account for any dewatering of the DRZ that may have occurred during operations when the excavated surfaces were exposed to the ventilation system.
- The model assumes the repository is filled instantaneously.

These limitations notwithstanding, the modeling process and the results, along with the raw and interpreted data, are useful in the discussion of repository performance during the period covered by the hazardous waste permits. A summary of the output for the first 300 years is shown in Table I-8.

The conceptual model used in this simulation includes creep closure of the waste-disposal panels, a process that will act to consolidate waste in the disposal areas. The altered stress field created by the excavation will also result in a system of fractures surrounding the excavation and the shaft, referred to as a DRZ. The conceptual model considers brine inflow to the waste-disposal panels in response to pressure gradients created by the excavation. Opposing brine inflow is the pressure increase expected in the repository resulting from creep closure and waste-generated gas. In general pressure increases due to closure and gas generation, may retard consolidation of the waste region and cause brine and gas to migrate away from the repository. The conceptual model includes two-phase flow from the repository and dilation or fracturing of interbeds, a process capable of accelerating the mass transport of contaminants.

The primary software code used in the simulation is BRAGFLO (BRine And Gas FLOw). BRAGFLO calculates the overall movement of gas and brine in the disposal unit formations and defines the flow fields for contaminant migration post-processing codes. BRAGFLO also contains the submodels for estimating gas generation in the repository, disposal room closure and consolidation, and interbed fracturing. Changes in void volume of the waste resulting from creep closure are coupled to BRAGFLO through SANTOS, a code that provides a look-up table used as a reference to track changes in room volume.

Actual quantities of hazardous constituents in waste containers can only be approximated from available waste characterization data. Furthermore, actual quantities available for transport are controlled by both the waste form and hazardous constituent mobility or immobility in the post-closure environment. Mobility is in turn controlled by long-term physical and chemical processes (e.g., availability of transport media and release mechanisms). Given these constraints, this simulation defines the source term, where appropriate, as the maximum concentration of hazardous constituents in a particular phase.

For the sealed shaft configuration, weighted average concentration for each VOC is used as the source term concentration in cases where waste characterization data are available. Weighted headspace concentrations are corrected for void volume conditions expected in the repository. In cases where no waste characterization data are available, saturated vapor concentrations are used to represent source term concentrations for VOCs. Because waste characterization data are also not available for semi-volatile compounds, saturated vapor concentrations are also assumed for this class of organic constituents. Releases of gas to the soil is modeled, therefore soil-based concentrations are calculated assuming gas-available porosity within shaft seals and within anhydrite markers beds at the subsurface disposal unit boundaries and then compared to health based limits for soil.

The DOE concludes that an organic liquid-phase source term is required only if compliance cannot be demonstrated for organic gas-phase compounds using bounding calculations. For these bounding calculations, the assumptions of no partitioning between the gas and the liquid phases ensures that maximum concentrations are used for the gas-phase source term. Because organic constituents must partition into the liquid phase from the gas phase according to Henry's Law, the concentrations in the brine phase must be less than that for the gas phase. If compliance can be demonstrated for the organic gas phase, liquid-phase compliance is also demonstrated.

The simulation results presented in Figures I-7 to I-12 and discussed below are based on a conservative assumption of higher than expected gas generation rates. Gas generation is purposely modeled in this manner to maximize the potential for migration of brine and gas away from the repository and into the anhydrite interbeds and sealed shaft. The modeling approach implemented is conservative, based on the assumption that the entire inventory of ferrous metals, cellulosics, plastics, and rubbers in the waste is available to generate gas. No credit is taken for the 50 percent probability that biodegradation may not occur and result in lower gas generation rates.

The simulation indicates that average pressure in the waste disposal region increases with time (Figure I-7). The pressure increase is primarily attributed to gas being generated more quickly

than pressure can be relieved by fluids flowing out of the anhydrite layers or up the sealed shaft. Smaller contributions to the pressure build-up occur through reduction of void volume by creep closure. For the high gas generation conditions assumed, pressure rises rapidly from atmospheric pressure to about 725 lb/in.^{2} (5 MPa) over the first 100 years after shaft seal placement. The total amount of gas generated by biodegradation and by anoxic corrosion during 300 years is shown in Figure I-8. Approximately 420 moles of gas per drum are generated during the first 100 years.

The simulation shows that brine flows into the repository from the DRZ and the far field (Figure I-9). At the same time, the pore volume (void space) present in the repository is being reduced by creep closure, as shown in Figure I-10. Eighty-nine percent of the brine inflow occurs during the first 50 years, (562 m^3 of brine per panel). Total void volume in a panel decreases from 37,099 to 16,709 m^3 during the first 50 years. The closure rate subsequently slows. (The minimum pore volume is achieved after 1060 years.)

The average brine saturation in the panel is depicted in Figure I-11. The initial increase in brine saturation during the first 50 years is due to brine inflow, to rapid creep closure, and a sharp reduction in pore volume in the waste. Once the repository ceases to close, brine consumption due to corrosion causes brine saturation to decrease. Figure I-11 shows this transition as a sharp increase in average brine saturation to just above five percent (at 50 years) followed by a steady decrease.

The simulation indicates the consumption of ferrous metals occurs by corrosion (Figure I-12). Figure I-12 shows similar behavior involving consumption of the inventory of biodegradable materials. In order for biodegradation and corrosion to take place sufficient brine must be present to inundate the waste. However, microbial degradation is assumed to proceed at inundated rates even in the absence of brine. The moisture originally present in the waste, together with the brine flowing into the repository, are consumed by the ongoing corrosion but is not consumed by biodegradation processes. Both processes eventually are limited by the lack of brine and proceed at much lower rates. As noted earlier, the reduction in brine inflow (and resulting brine availability) is a direct consequence of the pressure increase from gas generation and creep closure.

The simulation indicates no brine leaving the waste disposal region during the post-closure period. This conclusion results from two factors. First, the pressure never gets high enough to drive brine or gas from the disposal zone. Second, a comparison of calculated brine saturation in the waste region (see Appendix D16, §D16-7) with the estimated residual brine saturation (S_{br}) of the waste. As described in Appendix D16, §D16-7, S_{br} is the brine saturation required to permeate the waste matrix sufficiently to create an incipient network of interconnected pores. Wetting phase relative permeability begins at the residual brine saturation; below this point, brine existing in the waste matrix remains immobile.

Appendix D16, §D16-7 discusses the bases for the residual brine saturation of the post-closure waste region. Essentially, this demonstration takes advantage of literature-based data of residual brine saturations measured for unconsolidated analog materials. As an analog, the waste region is initially unconsolidated; the degree of consolidation increases rapidly with decreasing pore volume relatively early into the simulation, as indicated in Figure I-10.

I-2 Post-Closure Plan

The post-closure care period begins after completion of closure of the first HWMU unit and continues for 30 years after final facility closure. The DOE's post-closure care period may be shortened or lengthened at the discretion of the NMED, based on evidence that human health and the environment are being protected or are at risk. During the post-closure period, the WIPP shall be maintained in a manner that complies with the environmental performance standards applicable to the facility. During this period, the DOE will employ active institutional controls as necessary.

This post-closure plan focuses on activities following final facility closure. However, some discussion of post-closure following panel closure is warranted since some panel closures will occur long before final facility closure. As discussed in Section I-1e(1), panel closures have been designed to require no post-closure maintenance. The DOE has defined a post-closure care program for closed panels that has three aspects. These are routine inspection of the openings in the vicinity of the closures, the sampling of ventilation air for harmful constituents, and a VOC Confirmatory Monitoring Program. The rules of the Mine Safety Health and Administration drive the implementation of the first two programs. These rules require that underground mines monitor air quality to assure good breathing air whenever personnel are underground and that mine operators provide safe ground conditions for personnel in areas that require access. Routine monitoring of the openings in the access ways to panels will be continued and these openings will be maintained for as long as access into them is needed. This includes continued reading of installed geomechanical instrumentation, sounding the areas, visual inspection and maintenance activities such as scaling, mining, or bolting as required and as described in Section D-10d(1). In addition, all areas in the underground that are occupied by personnel are checked prior to each day's work activities for accumulations of harmful gases, including methane. Action levels for increasing ventilation to areas that show high levels of harmful gases are specified as described in Section F-4g.

These monitoring programs will be carried out during the period between the closure of the first panel and the initiation of final facility closure for the underground facility. The DOE has prepared a VOC Confirmatory Monitoring Plan (VCMP) which will be implemented to confirm that the assumptions and predictions used to demonstrate compliance to the environmental performance standards are valid. Validity is shown when observed emissions are equal to or less than those predicted. The VCMP is provided in Appendix D20. The VCMP includes monitoring design, sampling and analysis procedures and quality assurance objectives. This plan is submitted in compliance with 20 NMAC 4.1, Subpart V, §264.602 and §270.23(a)(2).

In this application, the DOE demonstrates the theoretical compliance with the environmental performance standards of 20 NMAC 4.1, Subpart V, §264.601(c). This VCMP describes a sampling and analysis program to confirm the theoretical calculations. The monitoring program is capable of quantifying VOC concentrations in the ambient mine air at the WIPP. The VCMP addresses the following information requirements:

- Rationale for the design of the monitoring program, based on possible pathways, operations, engineered and natural barriers, and monitoring locations optimized for detection.

- Descriptions of the specific elements of the monitoring program including the type of monitoring, the location of stations, the frequency of sampling, the target analytes, the schedule for implementation, the equipment used, the sampling and analytical techniques, and the data recording and reporting procedures.

The DOE's intent is to collect air samples upstream and down stream of Panel 1 beginning just prior to waste emplacement and proceeding until at least six months following completion of panel closure. The DOE will continue monitoring until the criterion for terminating monitoring are met. These criterion are established in Appendix D20 for each target analyte.

The current VOC monitoring program uses EPA Compendium Method TO-14. The DOE has had success with TO-14 at the WIPP if care is taken in placing sampler to avoid high dust and if stringent cleaning requirements are imposed for the clean canisters. This is necessary because of the extremely low concentrations that are being monitored. The DOE is evaluating the use of the Fourier Transform Infra-Red (FTIR) technique for monitoring VOCs at WIPP. This method is being used successfully at other locations and has recently been approved by the EPA for measuring the concentration of VOCs in the headspace gases of drums of TRU waste. If FTIR becomes viable, the monitoring plan will be revised and the revisions will be submitted to the NMED for approval prior to implementation.

The VCMP will be run under a Quality Assurance Plan that conforms to the document entitled "EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations". Quality Assurance criteria for the target analytes are presented in Table D-10. Definitions of these criteria are given in Appendix D20 along with a discussion of other aspects of the Quality Assurance Program including sample handling, calibration, analytical procedures, data reduction, validation and reporting, performance and system audits, preventive maintenance, and corrective actions.

I-2a Post-Closure Plan after Final Facility Closure

A number of regulations deal with the period of time that begins once the WIPP has undergone final facility closure and decommissioning. Under 40 CFR Part 191, the period consists of an active control period and a passive control period; only 100 years of the active control period can be used in performance assessment. Under the no-migration standard in 40 CFR §268.6, the EPA is interested in the measures the DOE will take in terms of long-term passive institutional controls "...such as land withdrawal, records, and markers--to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits at the site may have terminated." (EPA, 1990) The Land Withdrawal Act (LWA) of 1992 requires that the DOE prepare and submit a post-decommissioning land management plan. 20 NMAC 4.1, Subpart V, §264.117 requires post-closure care, including monitoring, security, and property use. Because of the numerous regulations, the DOE has prepared a single strategy for post-closure management of the WIPP. This strategy consists of three elements: 1) active controls, 2) monitoring, and 3) passive controls. Although only the first and second elements occur within the post-closure period covered by this permit, all three elements are described.

I-2a(1) Active Institutional Controls

Once a facility is decommissioned, positive actions (referred to as "active institutional controls") should be taken to assure proper maintenance and monitoring. The EPA, in 40 CFR Part 191, §191.14(a) has specified that active controls should be maintained for as long as practicable and that no more than 100 years of active institutional control can be assumed in predictions of long-term performance. This assumption assures that future protection and control does not rely on positive actions by future generations.

The DOE's active institutional control program has a primary objective of addressing all applicable requirements, including restoring the WIPP site as nearly as possible to its original condition, and thereby equalizing any preference over other areas for development by humans in the future. Restoration of the WIPP site includes any necessary remedial actions or cleanup of releases resulting from decommissioning. In addition, as part of the active institutional control program, the DOE will implement monitoring systems suitable for assessing disposal system performance if such monitoring is feasible.

The DOE currently plans to implement the active institutional control program in five steps, each of which are described in more detail below:

Step 1 - Identification of Active Institutional Control Measures

The first step in the process of implementing the active institutional control program is to identify measures needed to satisfy the active institutional control requirements. It is anticipated that certain characteristics of active institutional control measures, such as minimizing bias toward the site, warning of potential hazards, providing meaningful data, preserving knowledge, using state-of-the-art technology, implementing such measures for at least 100 years, addressing the standards, and deterring systematic development, will be identified and used to judge the usefulness of active institutional control programs.

A detailed explanation of the active institutional controls selected by the DOE as part of this first step is provided in Appendix I4, entitled WIPP Active Access Controls after Disposal, Design Concept Description. This is the DOE's reference design for active institutional controls. The reference design will be reviewed periodically and updated as appropriate during WIPP disposal operations. The ongoing review and evaluation ensure that the active institutional controls implemented are appropriate for the conditions that may exist at that time. The DOE will review the reference design prior to implementation and all affected regulatory agencies will be consulted as part of this review.

As part of the active institutional controls program, the DOE has developed a set of design criteria upon which the reference design is based. These design criteria provide a description of how the active institutional controls will be implemented. These are as follows:

- A fence line shall be established to control access to the repository's footprint area (the waste disposal area projected to the surface). A standard wire fence shall be erected along the perimeter of the repository surface footprint. The fence shall have gates placed approximately midway along each of the four sides.

- An unpaved roadway along the perimeter of the barbed wire fence shall be constructed to provide ready vehicle access to any point around the fenced perimeter, to facilitate inspection and maintenance of the fence line, and to permit visual observation of the repository footprint to the extent permitted by the lay of the land. This roadway shall connect to the paved south access road.

- To ensure visual notification, the fence line shall be posted with signs having as a minimum, a legend reading "Danger—Unauthorized Personnel Keep Out" and a warning against entering the area without specific permission of the DOE (or other local authority such as the Eddy County Sheriff's Office).

- Contractual arrangements shall be developed to ensure that periodic inspection and necessary corrective maintenance is conducted on the fence line, its associated warning signs, and the roadway. The DOE will maintain control over all contractual work and will maintain, in the operating record, the results of all inspections and maintenance activities.

- Through direct DOE staffing support and/or contractual arrangements, procedures shall be established to provide routine periodic patrols and surveillances of the protected area by personnel trained in security surveillance and investigation.

- Processes will be developed for monitoring and controlling the long-term testing requirements of the PMS.

- Processes will be developed for implementing the period monitoring requirements of the disposal system's monitoring program. Initially, the procedures currently in place in such documents as the Environmental Monitoring Plan (DOE, 1994) will be used.

- Recommendations will be developed for modifications to the active institutional controls appropriate for access control and surveillance upon installation of the PMS.

- Guidelines will be developed for recommending mitigating actions to be taken to address any abnormal conditions identified during periodic surveillance and inspections.

- Reports of activities associated with the post-disposal active access controls shall be prepared in accordance with regulatory requirements for submittal to the appropriate regulatory and legislative authority.

Details on meeting these criteria are found in Appendix I4.

Step 2 - Preparation of a Post-Decommissioning Land Management Plan

Section 13(b) of the LWA requires the DOE to prepare and submit by October 30, 1997, a plan for managing the land withdrawal area after decommissioning the WIPP facility. This plan will include a description of both the active and passive institutional controls that will be imposed

after decommissioning is complete. This plan will be prepared in consultation with the Department of Interior and the state of New Mexico.

Step 3 - Gathering of Data Necessary for Implementing Active Institutional Control Measures

It may be useful to gather additional data to support implementation of the referenced Active Institutional Control Design. This includes an ongoing assessment of conditions that could affect active institutional controls. Information regarding land use and population trends gathered during the Disposal Phase will be taken into account in implementing post-closure surveillance.

Step 4 - Preparation of the Active Institutional Control Plan

An active institutional control plan will be prepared as part of the overall site D&D strategy. This will be done in accordance with a written plan, which will be initiated prior to actual plant closure, and will contain all the information needed to implement the active and passive institutional controls for the WIPP facility. Active institutional control planning will be based on the reference design and will take into account the most current information regarding the facility and its vicinity and will make use of state-of-the-art materials and techniques. This plan will include acceptable decontamination levels, sampling and analysis plans, and QA/QC specifications.

Step 5 - Implementation of Active Institutional Control Measures

Most of the active institutional control measures, such as long-term site monitoring and site remedial actions, will be implemented simultaneously with decommissioning. However, it may be possible to implement some measures earlier. For example, salt disposal may begin prior to final plant closure. Reclamation and restoration of unused disturbed surface areas has already begun. Guarding and maintenance activities, which are already in place, could evolve into an appropriate type of post-closure activity.

I-2a(2) Monitoring

Because the WIPP is a mined geological repository that is designed to permanently isolate contaminants, no post-closure monitoring for the detection of releases is needed since the migration of contaminants is unlikely during the disposal and Post-Closure Care Periods. This is substantiated by the analysis of closure system performance as described in Section I-1e(6). However, the NMED has indicated that it is their policy to require the DOE to perform groundwater monitoring regardless of whether or not the WIPP is eligible for a groundwater monitoring waiver. Because of this, the DOE has prepared a post closure groundwater monitoring plan for implementation after the completion of final facility closure. Post-closure groundwater monitoring will involve a continuation of the monitoring plan in Appendix D18 as described in Section D-10d(1)(a). The frequency will be changed to biannually after final facility closure is complete. In addition, the final target analyte list shown in Table D-12 may be adjusted based on final volume of waste.

I-2a(3) Passive Institutional Controls

Passive institutional controls include markers that warn of the presence of buried nuclear waste and identify: 1) the boundary of the disposal area footprint, 2) external records about the WIPP repository, and 3) continued federal ownership.

Passive institutional controls, as opposed to active institutional controls, are controls that once established, can be expected to remain effective with minimal human surveillance and maintenance, or maintenance resulting from normal governmental activities. Passive controls may be instituted at the site, a remote location, or both.

With regards to passive controls, the DOE interprets the phrase "federal ownership and regulations regarding land or resource use" to mean that the DOE or some successor agency with nuclear waste management expertise will retain administrative control over the land. "Administrative control" means that the federal agency responsible for the land will institute regulations that impose appropriate restriction on land use and development. Regarding the WIPP facility, the DOE interprets the term "markers" to include any on-site structures engineered and constructed as a means of preserving knowledge of the location of the wastes and conveying associated hazards. The DOE interprets "records" to include any written information regarding the site and its contents, which are maintained to preserve knowledge of the site. The DOE intends to use passive institutional controls (ownership, markers, and records) throughout the entire controlled area.

In the proposed No-Migration Determination for the WIPP facility (EPA, 1990), the EPA discussed the use of passive controls as part of an overall strategy to protect a land disposal facility and to decrease the likelihood of human disruption. The EPA believes that, in the context of RCRA no-migration variance decisions, the question of human intrusion, either during operations or after closure, is best addressed through a consideration of the likelihood of intrusion, and the imposition of controls to make such intrusions unlikely events. The EPA emphasizes that this approach to human intrusion is consistent with its general approach under RCRA, both in permitting and variances. Under RCRA, the EPA typically relies on institutional controls (both active and passive) imposed through general regulatory standards and site-specific conditions (e.g., in RCRA permits) to ensure that access to a hazardous waste disposal site is appropriately restricted. The EPA believes that any permanent no-migration variance for the WIPP will have to impose long-term passive institutional controls, such as land withdrawal, records, and markers—to ensure that the likelihood of human intrusion is appropriately reduced, even after active control of the facility has ceased and any permits at the site may have terminated.

The DOE is committed to retaining control over the WIPP site for as long as possible. Accordingly, an extensive system of explanatory markers and records will be instituted to warn future generations about the location and dangers of these wastes. The agency assumed that society in general will retain knowledge about these wastes and that future societies should be able to deter systematic or persistent exploitation of a disposal site.

The objective of the DOE's passive institutional control program for the WIPP is to accomplish the following:

- Ensure a record of the disposal site and its contents are preserved
- Warn those who attempt to enter the disposal site vicinity of the hazards associated with activities that would disturb the subsurface

The DOE believes that passive institutional controls will render human intrusion sufficiently unlikely so that the possibility need not be included in the long-term performance calculations.

A substantial amount of work has been completed in the area of passive institutional controls at the WIPP facility.

- *DOE Ownership.* The DOE has been successful in gaining control of the entire surface of the 16-section WIPP site and the entire subsurface, except for Section 31 where DOE control extends over the surface and the first 6,000 feet (ft) (1,829 meters [m]) of the subsurface, including the acquisition of oil, gas, and potash leases. The area now under the control of the DOE includes the following sections in Township 22 South, Range 31 East: 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, and 34.

- *Land Use Controls.* Land use controls have been implemented addressing allowable uses of the withdrawal area.

Beyond land ownership and implementation of use controls, which are the key preclosure passive controls, there are six steps that have been identified for the WIPP passive institutional control program.

Step 1 - Definition of Passive Institutional Controls Appropriate for the WIPP

The process of defining the passive institutional controls for the WIPP disposal site is based on the controls identified in 40 CFR Part 191, §191.12. This includes items such as records, markers, monuments, legal documentation, federal control, land use restrictions, and other methods of preserving knowledge.

The current conceptual design for post-closure passive institutional controls is described in the Permanent Marker Design Report (DOE, 1995b). The design includes:

- Large surface monuments and earthen structures to mark the repository footprint
- One or more on-site buried rooms for the long-term storage of messages describing the nature of the repository
- Small subsurface markers
- Off-site archival storage of information pertaining to the WIPP, including its potential hazards

Shaft-Location Markers

The controlled area will be identified by these passive institutional controls. Markers showing the locations of shafts will consist of permanent surveyor markings engraved with the site elevation and coordinates. The markers will be firmly anchored to the shaft plug and will also contain site description, date of closure, land survey data, and other information required by applicable regulations. A uniform system of coordinates will be adopted. The definitions of these coordinates will be included in the permanent records.

Permanent Marker System

A PMS designed to minimize the possibility of inadvertent human intrusion into the repository over the long-term, following the cessation of active controls, will be implemented at the WIPP facility. The PMS will be comprised of messages, surface monument markers, small subsurface warning markers, on-site rooms for long-term storage of messages, archival storage of WIPP information off-site, and large earthen structures marking the WIPP repository footprint on the surface. The PMS is still in the conceptual design process and will evolve prior to closure, based on activities to test marker effectiveness during disposal, decommissioning, and active access controls periods. Actual construction of the PMS will be completed 100 years following closure of the WIPP facility, in accordance with WIPP Active Access Controls After Disposal Design Concept Description (March 1995b).

The PMS will provide a durable record of the repository's existence, and its design will provide reasonable assurance that it will endure for at least 10,000 years. The system will be clearly visible from any portion of the repository's surface footprint. The current PMS design basis, proposed for detailed design, consists of a large earthen berm enclosing the perimeter of the repository's surface footprint. The design basis for the berm is for a minimum width of 100 ft (30 m) and a height of 31 ft (10 m), with a 1.3 horizontal to 1.0 vertical slope. The berm would be designed to provide a dielectric or magnetic anomaly when compared to the local surface characteristics. Large monoliths would be arranged just inside the berm. The number of monoliths would be sufficient to allow future generations to reconstruct monolith orientation with several monoliths missing. An information center would be placed at the center of the monoliths, and two storage rooms would be buried about 20 ft (6 m) below the footprint. The PMS components will be designed and constructed to resist erosional and depositional effects. Construction materials will be selected for durability under the local climatic conditions and the predicted changes to those conditions in the long term.

Monuments will be engraved with the most critical warning information in a concise format, inscribed to a minimum depth of 0.5 inches (1.3 centimeters). More detailed information regarding the repository content, caution against intrusion, and the time of emplacement will be provided in protected vaults buried underground and in a surface information center. The information will be provided in multi-language translation and will include an assortment of symbols, pictographs, and diagrams to convey danger of intrusion. Universal symbols will enhance the likelihood of understanding by people of different backgrounds. To minimize the likelihood of future salvaging, the marking system will use materials with as little intrinsic value as is reasonable.

Subsurface markers would be less than 2 ft (0.6 m) in the longest dimension, made of inert material, and spaced so that they are likely to be discovered by drilling crews and professional archaeologists. The warning message would be engraved so that slight erosion or fracture of the marker would not render it completely unintelligible. In addition, the markers would be buried at a greater depth than that used for plowing/tilling operations or for amateur archaeological excavation, so that such activities would be unlikely to disturb them. Further details on the subsurface markers may be obtained from the WIPP Active Access Controls After Disposal Design Concept Description (March 1995b).

Written Records

Written documentation of the WIPP will be placed in local, state, and federal agencies. Documentation will also be provided to international entities and commercial organizations that act as resource information centers for the petroleum and gas industries. Records will use the most stable and durable media available at the time that the record deposits are made. These records will describe the location of the repository; the nature and hazard of the waste; the geologic, geochemical, and hydrologic data pertinent to waste containment; and environmental monitoring data from preoperational baseline and summaries of data collected during D&D activities. Overall record selection for storage at the agencies selected will be in accordance with federal, state, and local regulations.

Specific documents which will be included in the archived information portfolio include:

- Detailed maps describing the exact location of the repository
- The SAR and the addenda which describes the disposal phase of the WIPP
- The Final Environmental Impact Statement for WIPP and the Supplement(s) to the Environmental Impact Statement
- The No-Migration Variance Petition and the No-Migration Determination for Disposal
- The RCRA Permit
- The Certification of Compliance with 40 CFR Part 191 and associated application
- Environmental and ecological background data collected during the preoperational phase of WIPP and summaries of data collected during the disposal and decommissioning phases of WIPP
- Records of the waste containers' contents and disposal locations within the WIPP repository
- Drawings defining the construction and configuration of the repository and shafts

- Drawings, procedures, and the design report(s) describing how the waste was emplaced; how the repository was decommissioned, closed and sealed; and how the shafts were sealed

The organization identified as the record holder responsible for the permanent storage of this information is the National Archives. In addition, other locations for this information will include publicly funded organizations which may expend the resources necessary to preserve the documents in well-controlled environments. However, the most likely strategy for long-term protection of the information is through widespread distribution. The information will be submitted to the following facilities and organizations for archiving:

- Library of Congress
- Within the states of New Mexico and Texas
  - The state archives
  - The state library
  - The city libraries of population centers exceeding 15,000 within 150 miles of Carlsbad
- The state libraries of the remaining 48 states
- The local office of the Bureau of Land Management
- The local office of the Bureau of Mines
- The local office of the Bureau of Reclamation
- The national library and national archives of the nations worldwide which possess nuclear weapons and/or operate nuclear power generating plants
- The archive of the United Nations
- The national archive and libraries of the signatory nations to the nuclear non-proliferation treaty
- The U.S. Nuclear Regulatory Commission
- The 53 federal regional depository libraries
- The American Nuclear Society

This list of receiving organizations will be reviewed and expanded, as appropriate, as the time of the actual transfer of the information approaches.

Location and hazards information will be submitted to various federal and state of New Mexico mapping agencies to ensure that the WIPP location and drilling or mining restrictions are

identified on widely distributed maps used by almost all public and private organizations. These agencies include:

- Bureau of Land Management
- U.S. Geological Survey
- Library of Congress
- National Archives and Records Service
- Defense Mapping Agency
- International Boundary Commission
- Federal Highway Administration
- New Mexico State Highway Department Planning and Research Division, Cartography Section

To ensure widespread of location information on the WIPP site and the hazards associated with the emplaced waste, detailed maps and descriptions of the hazardous material will be sent to national and international professional societies of cartographers and geographers. Weitzberg (1982) suggests the following organizations and societies receive this location and hazards information:

- The American Congress on Surveying and Mapping
- The American Society of Cartographers
- The Commission for the Geological Map of the World
- The International Cartographic Association
- The American Geographical Society
- The Association of American Geographers
- The International Geographical Union
- The Society of Women Geographers
- The American Geological Institute
- The American Geophysical Union
- The American Society of Professional Geographers

- The National Geographic Society

- The Federal Aviation Administration

Step 2 - Development of a Passive Institutional Control Implementation Plan

Once the appropriate passive institutional controls have been defined, a strategy will be prepared that includes final design, construction, and implementation. The strategy will identify site-specific information needs and approaches to obtaining needed technical and non-technical information.

There are some passive institutional control activities that can be implemented prior to the end of operations. For example, once wastes are permanently placed in the repository, appropriate notations can be made in land records.

Step 3 - Design and Implementation of Pre-decommissioning Passive Controls

Pre-decommissioning passive controls, such as land records, will be implemented and evaluated to the extent possible. For example, the effectiveness of DOE's land management plans will be assessed periodically to assure only acceptable land use is in effect. Closure records and plots for panel closures will be filed with Eddy County, New Mexico.

Step 4 - Implementation of Programs to Collect Needed Information

Programs may be necessary to support implementation of passive institutional control activities with site-specific information.

Planned Evaluations. Upon closure of the WIPP at the conclusion of the Disposal Phase, active controls will be implemented to control access to the site. In addition, monitoring systems will be managed to detect significant deviations in repository performance. With active control provided over the site, the schedule for construction of the PMS is a management option which could be extended for decades. In that the design of the PMS has a 10,000-year lifetime goal, it is prudent that the DOE conduct some testing of the construction materials planned for use as permanent marker material.

Berms. One aspect of the testing is the construction of a section of the berm. The overall size (height and width) of the test section of the berm will match the design of the permanent marker berm. However, the test berm length will be shorter than the full-sized berm. A section approximately 164 to 328 ft (50 to 100 m) long will be sufficient to test a number of different configurations. Included within the test section will be varying thicknesses of the salt core, the caliche layer, and the top layer of riprap and soil material. The DOE will construct a section of the berm for the purpose of evaluating materials and construction techniques. Actual construction and testing will be initiated during the Disposal Phase to provide sufficient time for testing.

Monuments. Another aspect of passive institutional controls to be evaluated during testing is monuments. The major considerations that will be evaluated include the following:

- Procuring, shipping, erecting test monuments, and evaluating long-term environmental effects of wind, rain, and shifting sand for various types of dimensional stone
- Evaluating the magnetic signature provided by sample permanent magnets buried within the berm to determine optimum locations and spacing
- Evaluating the affects of various soils used as protective backfill for dimensional stone
- Evaluating the effects of chemical interaction with the backfill material
- Evaluating the environmental effects on the berm caused by wind, rain, and shifting sand
- Evaluating the effects of plant root intrusion into the berm and potential for salt dissolution and berm slumping
- Evaluating the effectiveness of sample radar reflectors buried within the berm at various distances

Messages. Messages will also need to be evaluated during the testing program. The primary aspects of the messages program to be evaluated include the following:

- Evaluation of message text by presenting it to groups indigenous to the countries whose language is represented in the message
- Evaluation of message text by presenting it to linguists to assess the likelihood that the messages will continue to be understood through time

Step 5 - Design of Post-Decommissioning Passive Institutional Controls

This activity will use results derived from information gathering programs to make final decisions on passive institutional control measures. Passive institutional control implementation plans will be included as a portion of the WIPP long-term protection strategy and will include maintaining federal ownership, markers and monuments, surface modifications and controls, permanent written records, legal records, and land use identification and restriction.

Step 6 - Implementation of Post-Decommissioning Passive Institutional Controls

The final step involves constructing and installing the post-decommissioning passive institutional control measures. Additionally, a system for reviewing and approving the markers and other passive measures would be established.

I-3 Notices Required for Disposal Facilities

I-3a Certification of Closure

Within 60 days after completion of closure activities for an HWMU, the DOE will submit to the Secretary of the NMED, via certified mail, a certification that the unit (or, at final closure, the

facility) has been closed in accordance with the specifications of this Closure Plan. The certification will be signed by the cognizant DOE Manager and by an independent registered professional engineer. Documentation supporting the independent registered engineer's certification will be furnished to the Secretary of the NMED with the certification.

I-3b Survey Plat

Within 60 days of closure activities for an HWMU or within 60 days of final facility closure, the DOE will submit to the Secretary of the NMED, via certified mail, a survey plat indicating the location and dimensions of hazardous waste disposal units with respect to permanently surveyed benchmarks. The plat will be prepared and certified by a professional land surveyor and will contain a prominently displayed note that states the DOE's obligation to restrict disturbance of the hazardous waste disposal unit. In addition, the land records in the Eddy County Courthouse, Carlsbad, New Mexico, will be updated through filing of the final survey plats.

I-3c Post-Closure Certification

Within 60 days of completion of the post-closure care period for each hazardous waste disposal unit and for final facility closure, the DOE will submit to the Secretary of the NMED, via certified mail, documentation that post-closure care was performed in accordance with the specifications of the approved post-closure plan. The certification will be signed by the cognizant DOE Manager and by an independent registered professional engineer. Documentation supporting the independent registered engineer's certification and a copy of the certification will be furnished to the Secretary of the NMED.

I-3d Post-Closure Notices

Within 60 days after certification of closure of each hazardous waste disposal unit or final facility closure, the DOE will submit to the Secretary of the NMED, and other applicable local and federal government agencies, a record of the type, location, and quantity of hazardous wastes disposed of in the disposal unit of the facility. Plans exist for extensive archiving of records beyond those required in 20 NMAC 4.1, Subpart V, §264.119. These are discussed in I-2a(3).

I-4 Closure Cost Estimates

In accordance with 20 NMAC 4.1, Subpart V, §264.140(c), the WIPP facility, as a federal facility, is exempt from the requirement to provide cost estimates for closure actions.

I-5 Financial Assurance Mechanism for Closure

In accordance with 20 NMAC 4.1, Subpart V, §264.140(c), the WIPP facility, as a federal facility, is exempt from the requirement to provide financial assurance mechanisms for closure actions.

I-6 Post-Closure Cost Estimate

In accordance with 20 NMAC 4.1, Subpart V, §264.140(c), the WIPP facility, as a federal facility, is exempt from the requirement to provide cost estimates for post-closure actions.

I-7 Financial Assurance Mechanism for Post-Closure Care

In accordance with 20 NMAC 4.1, Subpart V, §264.140(c), the WIPP facility, as a federal facility, is exempt from the requirement to provide financial assurance mechanisms for post-closure actions.

I-8 Liability Requirement

In accordance with 20 NMAC 4.1, Subpart V, §264.140(c), the WIPP facility, as a federal facility, is exempt from the requirement to provide liability insurance.

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TABLES

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TABLE I-1
ANTICIPATED EARLIEST CLOSURE DATES FOR THE UNDERGROUND HWMUS

HWMU	OPERATIONS START	OPERATIONS END	CLOSURE START	CLOSURE END
PANEL 1	7/98	1/01	2/01	6/01
PANEL 2	1/01	7/03	8/03	12/04
PANEL 3	7/03	1/06	2/06	6/06
PANEL 4	1/06	7/08	8/08	12/09
PANEL 5	7/08	1/11	2/11	6/11
PANEL 6	1/11	7/13	8/13	12/14
PANEL 7	7/13	1/16	2/16	6/16
PANEL 8	1/16	7/18	8/18	12/19
PANEL 9	7/18	1/21	2/21	SEE NOTE 4
PANEL 10	1/21	7/23	8/23	SEE NOTE 4

NOTE 1: Only Panels 1 to 3 will be closed under the permit covered by this application. Closure schedules for Panels 4 through 10 are projected assuming new permits will be issued in 2005 and 2015.

NOTE 2: The point of closure start is defined as 60-days following notification to the NMED of closure.

NOTE 3: The point of closure end is defined as 180-days following placement of final waste in the panel.

NOTE 4: The time to close these areas may be extended depending on the nature and extent of the disturbed rock zone. The excavations that constitute these panels will have been opened for as many as 40 years so that the preparation for closure may take longer than the time allotted in Figure I-2. If this extension is needed, it will be requested as an amendment to the Closure Plan.

TABLE I-2
ANTICIPATED OVERALL SCHEDULE FOR CLOSURE ACTIVITIES

ACTIVITY	FINAL FACILITY CLOSURE	
	START	STOP
Notify NMED of Intent to Close WIPP (or to Implement Contingency Closure)	August 2023	N/A
Perform Contamination Surveys in both Surface Storage Areas	August 2023	February 2024
Sample Analysis	October 2023	May 2024
Decontamination as Necessary of both Surface Storage Areas	April 2024	November 2024
Final Contamination Surveys of both Surface Storage Areas	December 2024	July 2025
Sample Analysis	April 2025	November 2025
Prepare and Submit Container Management Unit Closure Certification	December 2025	March 2026
Dispose of Closure-Derived Waste	September 2023	November 2024
Closure of Open HWMU Panel	December 2024*	July 2025
Install Borehole Seals	August 2025	July 2026
Install Repository Seals	April 2026	July 2030
Recontour and Revegetate	August 2030	March 2031
Prepare and Submit Final (Contingency) Closure Certification	August 2030	March 2031
Post-closure Monitoring	May 2031	N/A

N/A--Not Applicable
Refer to Figures I-3 and I-4 for precise activity titles.

*This assumes the final waste is placed in this unit in November 2024 and notification of closure for this HWMU is submitted to the NMED in October 2024.

TABLE I-3
GOVERNING REGULATIONS FOR BOREHOLE ABANDONMENT

Federal or State Land	Type of Well or Borehole	Governing Regulation	Summary of Requirements
Both	Groundwater Surveillance	State and federal regulation in effect at time of abandonment	Monitor wells no longer in use shall be plugged in such a manner as to preclude migration of surface runoff or groundwater along the length of the well. Where possible, this shall be accomplished by removing the well casing and pumping expanding cement from the bottom to the top of the well. If the casing cannot be removed, the casing shall be ripped or perforated along its entire length if possible, and grouted. Filling with bentonite pellets from the bottom to the top is an acceptable alternative to pressure grouting.
Federal	Oil and Gas Wells	40 CFR Part 3160, §§ 3162.3-4	The operator shall promptly plug and abandon, in accordance with a plan first approved in writing or prescribed by the authorized officer.
Federal	Potash	40 CFR Part 3590, § 3593.1	(b) Surface boreholes for development or holes for prospecting shall be abandoned to the satisfaction of the authorizing officer by cementing and/or casing or by other methods approved in advance by the authorized officer. The holes shall also be abandoned in a manner to protect the surface and not endanger any present or future underground operation, any deposit of oil, gas, or other mineral substances, or any aquifer.
State	Oil and Gas Well Outside the Oil-Potash Area	State of New Mexico, Oil Conservation Division, Rule 202 (eff. 3-1-91)	B. Plugging (1) Prior to abandonment, the well shall be plugged in a manner to permanently confine all oil, gas, and water in the separate strata where they were originally found. This can be accomplished by using mud-laden fluid, cement, and plugs singly or in combination as approved by the Division on the notice of intention to plug. (2) The exact location of plugged and abandoned wells shall be marked by the operator with a steel marker not less than four inches (4") in diameter, set in cement, and extending at least four feet (4') above mean ground level. The metal of the marker shall be permanently engraved, welded, or stamped with the operator name, lease name, and well number and location, including unit letter, section, township, and range.
State	Oil and Gas Wells Inside the Oil-Potash Area	State of New Mexico, Oil Conservation Division, Order No. R-111-P (eff. 4-21-88)	F. Plugging and Abandonment of Wells (1) All existing and future wells that are drilled within the potash area, shall be plugged in accordance with the general rules established by the Division. A solid cement plug shall be provided through the salt section and any water-bearing horizon to prevent liquids or gases from entering the hole above or below the salt selection. It shall have suitable proportions—but no greater than three (3) percent of calcium chloride by weight—of cement considered to be the desired mixture when possible.

TABLE I-4
AVERAGE-STOICHIOMETRY GAS GENERATION MODEL PARAMETER VALUES

Parameter (units)	Values Used in Calculation[a]
Inundated Corrosion Rate for Steel without CO_2 Present (m/s)	7.94×10^{-15}
Inundated Corrosion Rate for Steel with CO_2 Present (m/s)	1.03×10^{-13}
Humid Corrosion Rate for Steel	0
Gas Generation Rate for Microbial Degradation Under Humid Conditions (mol/kg * s)	6.34×10^{-10}
Gas Generation Rate for Microbial Degradation under Brine-Inundated Conditions (mol/kg * s)	4.92×10^{-9}
Factor β for Microbial Reaction Rates (unitless)	0.5
Anoxic Corrosion Stoichiometric Factor X (unitless)	1.0
Average Density of Cellulosics in CH Waste (kg/m^3)	54.0
Average Density of Cellulosics in RH Waste (kg/m^3)	17.0
Average Density of Iron-Based Materials in CH Waste (kg/m^3)	170.0
Average Density of Iron-Based Materials in RH Waste (kg/m^3)	100.0
Average Density of Plastics in CH Waste (kg/m^3)	34.0
Average Density of Plastics in RH Waste (kg/m^3)	15.0
Average Density of Rubber in CH Waste (kg/m^3)	10.0
Average Density of Rubber in RH Waste (kg/m^3)	3.3
Bulk Density of Iron Containers, CH Waste (kg/m^3)	139.0
Bulk Density of Iron Containers, RH Waste (kg/m^3)	2.59×10^{3}
Bulk Density of Plastic Liners, CH Waste (kg/m^3)	26.0
Bulk Density of Plastic Liners, RH Waste (kg/m^3)	3.1
BIR Total Volume of RH Waste (m^3)	7.08×10^{3}
BIR Total Volume of CH Waste (m^3)	1.69×10^{5}
Wicking Saturation (unitless)	0.5

[a] Median values were used based on the data and parameter distributions contained in Appendix D16, §D16-5

TABLE I-5
SALADO FORMATION HALITE PARAMETER VALUES

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	3.16×10^{-23}
Effective Porosity (%)	1.0
Threshold Pressure, P_t (Pa)[b]	3.41×10^{7}
Residual Brine Saturation, S_{br} (unitless)[c]	0.3
Residual Gas Saturation, S_{gr} (unitless)[c]	0.2
Pore Distribution, λ (unitless)[c]	0.7
Maximum Capillary Pressure (Pa)	10^{8}
Rock Compressibility[d] (1/Pa)	9.75×10^{-11}

[a] Median values were used based on the data and parameter distributions contained in Appendix D16, Section D16-6.

[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$ where PCT_A and PCT_EXP are constants and k is the permeability.

[c] Two-phase flow: Brooks-Corey model used in this simulation.

[d] Pore compressibility = Rock compressibility/effective porosity.

TABLE I-6
SALADO FORMATION ANHYDRITE INTERBEDS A AND B AND MARKER BEDS 138 AND 139 PARAMETER VALUES

Parameter (units)	Value Used in Calculation[a]
Permeability (m^2)	1.29×10^{-19}
Effective Porosity (%)	1.1
Threshold Pressure, P_t (Pa)[b]	9.74×10^{5}
Residual Brine Saturation, S_{br} (unitless)[c]	0.084
Residual Gas Saturation, S_{gr} (unitless)[c]	0.077
Pore Distribution, λ (unitless)[c]	0.644
Maximum Capillary Pressure (Pa)	10^{8}
Rock Compressibility[d] (1/Pa)	8.26×10^{-11}

[a] Median values were used based on the data and parameter distributions contained in Appendix D16, Section D16-6.

[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$ where PCT_A and PCT_EXP are constants and k is the permeability.

[c] Two-phase flow: Brooks-Corey model used in the simulation.

[d] Pore compressibility = Rock compressibility/effective porosity.

TABLE I-7
SHAFT MATERIALS PARAMETER VALUES

Parameter (units)	Value Used in Calculation[a]
All Shaft Materials	
Residual Brine Saturation, S_{br} (unitless)[c]	0.2
Residual Gas Saturation, S_{gr} (unitless)[c]	0.2
Pore Distribution, λ (unitless)[c]	0.94
Maximum Capillary Pressure (Pa)	10^8
Clay Shaft Materials	
Permeability (m^2) - Rustler Compacted Clay (T = 0 - 10,000 yrs.)	5.00×10^{-19}
Permeability (m^2) - Upper Salado Compacted Clay (T = 0 - 10 yrs.)	7.65×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T = 10 - 25 yrs.)	5.02×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T = 25 - 50 yrs.)	3.02×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T = 50 - 100 yrs.)	1.16×10^{-17}
Permeability (m^2) - Upper Salado Compacted Clay (T > 100 yrs.)	5.00×10^{-17}
Permeability (m^2) - Lower Salado Compacted Clay (T = 0 - 10 yrs.)	9.32×10^{-17}
Permeability (m^2) - Lower Salado Compacted Clay (T = 10 - 25 yrs.)	1.74×10^{-17}
Permeability (m^2) - Lower Salado Compacted Clay (T = 25 - 50 yrs.)	7.07×10^{-19}
Permeability (m^2) - Lower Salado Compacted Clay (T > 50 yrs.)	5.00×10^{-19}
Permeability (m^2) - Bottom Clay (T = 0 - 10,000 yrs.)	5.00×10^{-19}
Thickness (m) - Rustler Compacted Clay	94.3
Thickness (m) - Upper Salado Compacted Clay	104.85
Thickness (m) - Lower Salado Compacted Clay	23.9
Thickness (m) - Bottom Clay	9.24
Effective Porosity (%) - Rustler Compacted Clay	24.0
Effective Porosity (%) - Upper and Lower Salado Compacted Clays and Bottom Clay	24.0
Threshold Pressure P_t (Pa) - All Clays[b]	2.0×10^5 to 1.20×10^6
Pore-Volume Compressibility (1/Pa) - Rustler Compacted Clay	1.96×10^{-9}
Pore-Volume Compressibility (1/Pa) - Upper Salado Compacted Clay	1.81×10^{-9}
Pore-Volume Compressibility (1/Pa) - Lower Salado Compacted Clay and Bottom Clay	1.59×10^{-9}
Salt Shaft Material	
Permeability (m^2) - Salt (T = 0 - 10 yrs.)	1.74×10^{-15}
Permeability (m^2) - Salt (T = 10 - 25 yrs.)	1.66×10^{-15}
Permeability (m^2) - Salt (T = 25 - 50 yrs.)	1.65×10^{-15}
Permeability (m^2) - Salt (T = 50 - 100 yrs.)	6.83×10^{-18}
Permeability (m^2) - Salt (T = 100 - 200 yrs.)	5.27×10^{-20}
Permeability (m^2) - Salt (T > 200 yrs.)	5.35×10^{-21}
Thickness (m) - Salt	171.37
Effective Porosity (%) - Salt	5.0
Threshold Pressure P_t (Pa) - Salt (T = 0 - 10 yrs.)[b]	7.16×10^4
Threshold Pressure P_t (Pa) - Salt (T = 10 - 25 yrs.)[b]	7.28×10^4

TABLE I-7
SHAFT MATERIALS PARAMETER VALUES
(CONTINUED)

Parameter (units)	Value Used in Calculation[a]
Threshold Pressure P_t (Pa) - Salt (T = 25 - 50 yrs.)[b]	7.29×10^{4}
Threshold Pressure P_t (Pa) - Salt (T = 50 - 100 yrs.)[b]	4.87×10^{5}
Threshold Pressure P_t (Pa) - Salt (T = 100 - 200 yrs.)[b]	2.62×10^{6}
Threshold Pressure P_t (Pa) - Salt (T > 200 yrs.)[b]	5.78×10^{6}
Pore-Volume Compressibility (1/Pa) - Salt	1.60×10^{-9}
Concrete Shaft Materials	
Permeability (m^2) - Concrete (T = 0 - 400 yrs.)	1.78×10^{-19}
Permeability (m^2) - Concrete (T > 400 yrs.) and Concrete Monolith (T = 0 - 10,000 yrs.)	10^{-14}
Thickness (m) - Concrete	45.72
Thickness (m) - Concrete Monolith	9.08
Effective Porosity (%)	5.00
Threshold Pressure P_t (Pa) - Concrete (T = 0 - 400 yrs.) [b]	1.72×10^{6}
Threshold Pressure P_t (Pa) - Concrete (T > 400 yrs.)[b] and Concrete Monolith (T = 0 - 10,000 yrs.)	3.91×10^{4}
Pore-Volume Compressibility (1/Pa) - Concrete and Concrete Monolith	2.64×10^{-9}
Asphalt Shaft Material	
Permeability (m^2) - (T = 0 - 10,000 yrs.)	1×10^{-20}
Thickness (m)	37.28
Effective Porosity (%)	1.00
Threshold Pressure P_t (Pa)[b]	0.00
Pore-Volume Compressibility (1/Pa)	2.97×10^{-8}
Earthen Fill Material Above Rustler	
Permeability (m^2) (T = 0 - 10,000 yrs.)	10^{-14}
Thickness (m)	165.06
Effective Porosity (%)	32.0
Threshold Pressure P_t (Pa)[b]	3.91×10^{4}
Maximum Capillary Pressure (Pa)	10^{8}
Pore-Volume Compressibility (1/Pa)	3.1×10^{-8}

[a] Median values were used based on the data and parameter distributions contained in Appendix D16, Section 16-8.

[b] Threshold pressure (P_t) determined from the relationship: $P_t = PCT\_A \cdot k^{PCT\_EXP}$ where PCT_A and PCT_EXP are constants and k is the permeability.

[c] Two-phase flow: Brooks-Corey model is used in this simulation.

FIGURES

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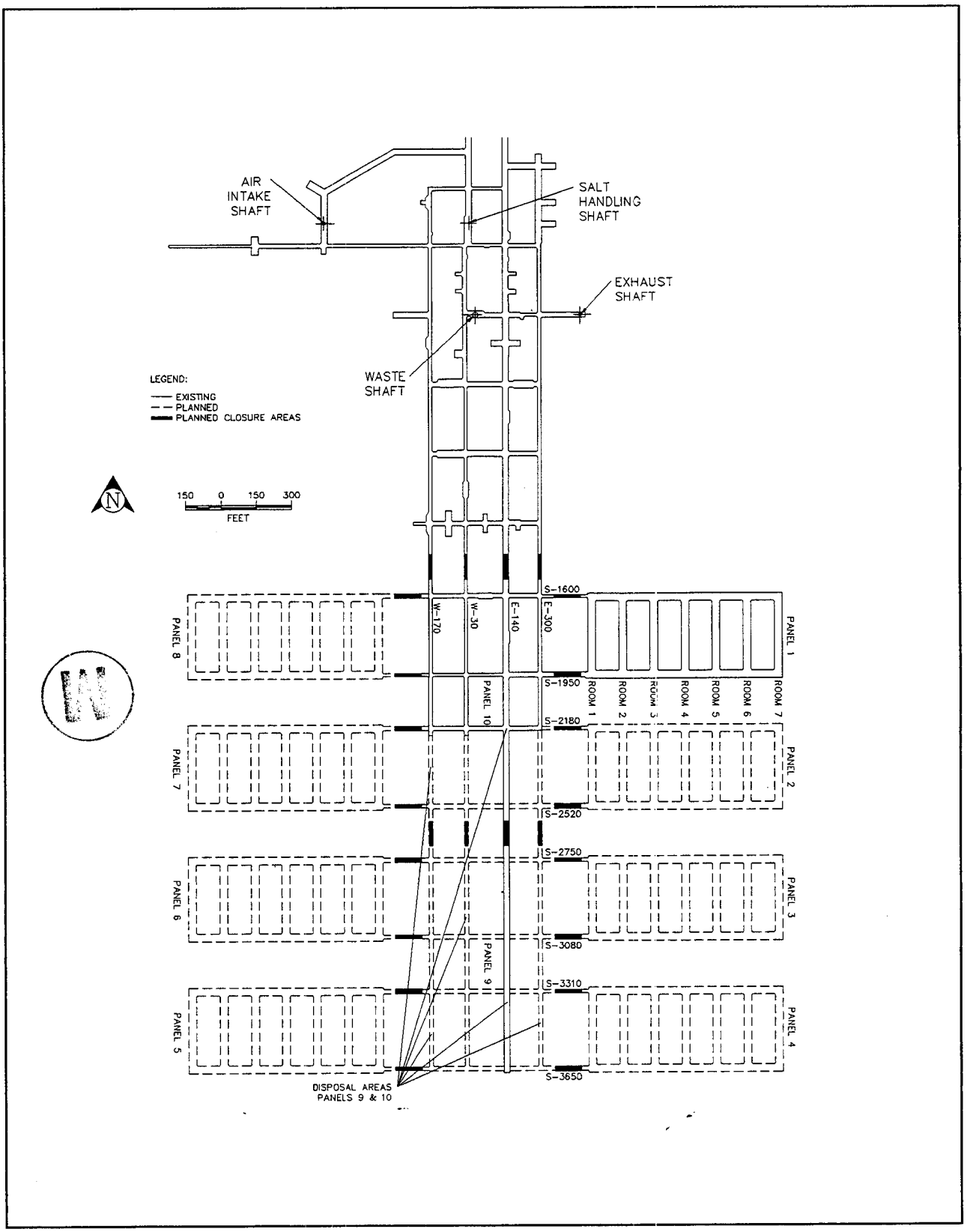


Figure I-1
Location of Underground HWMUs and Anticipated Closure Locations

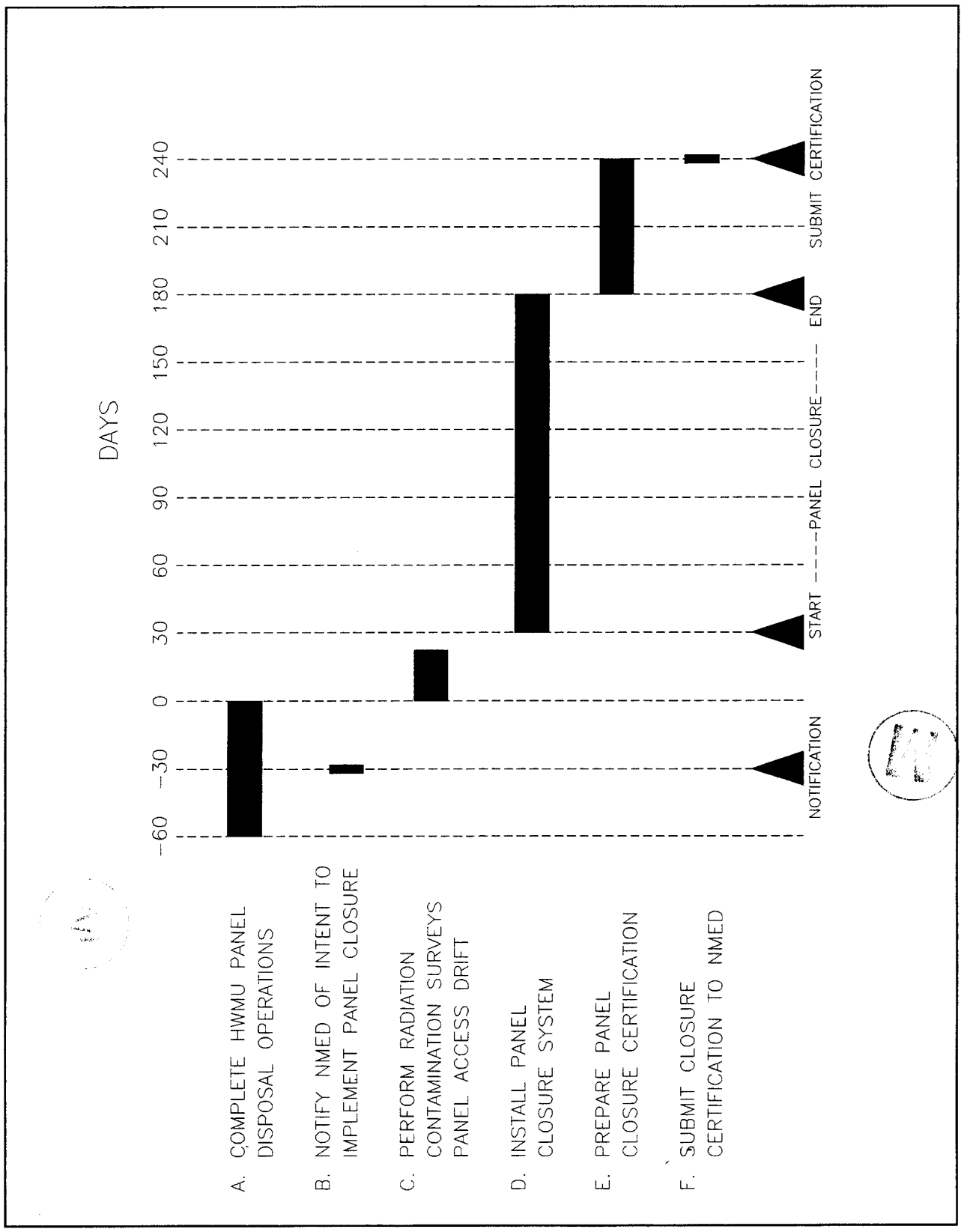


Figure I-2
WIPP Panel Closure Schedule

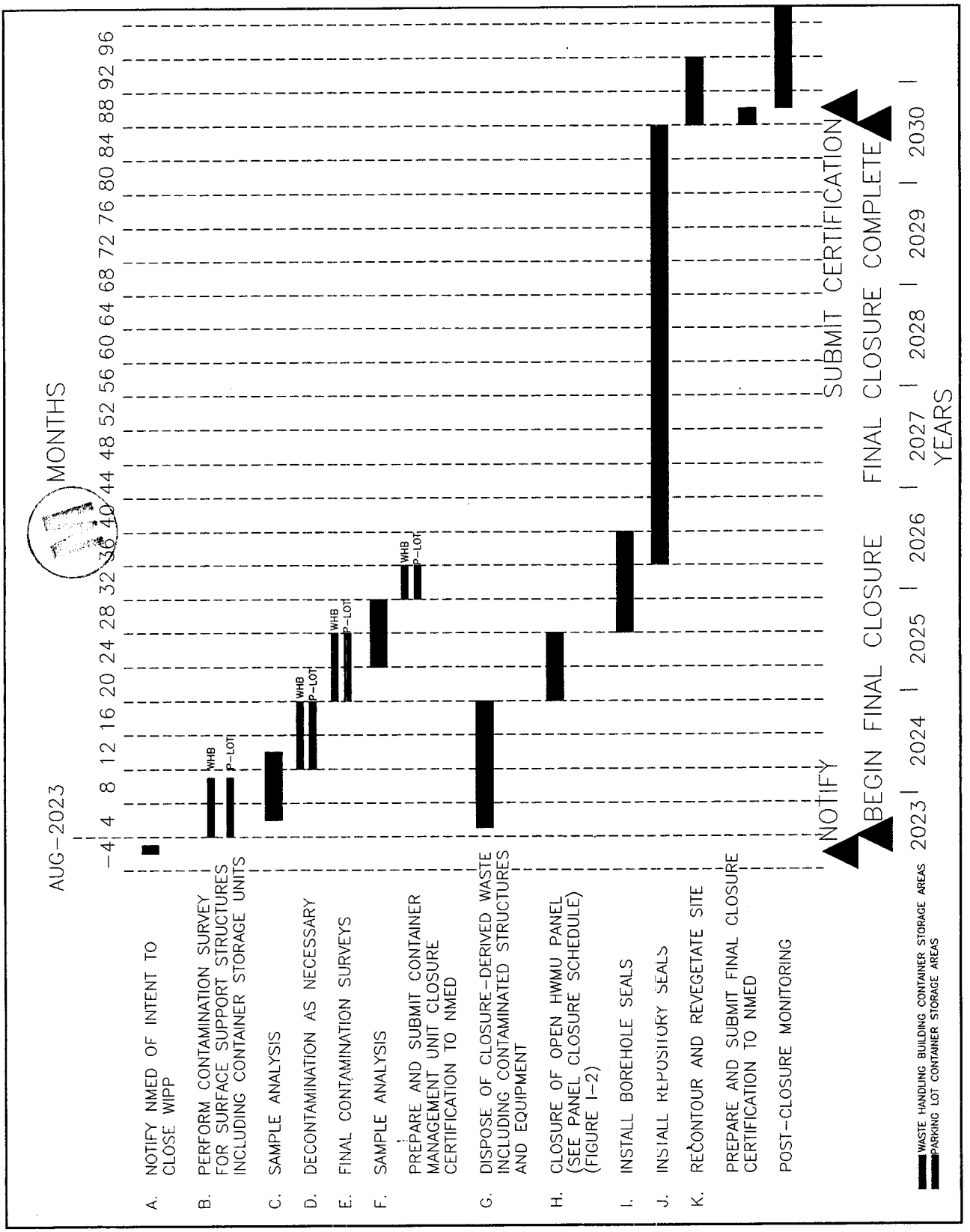
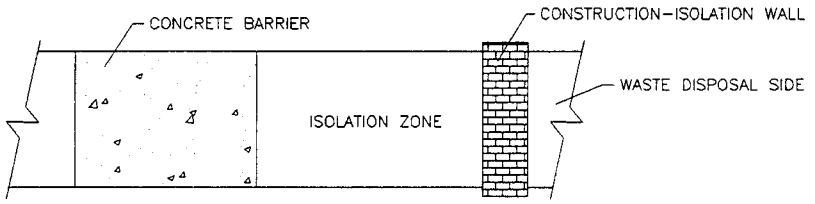
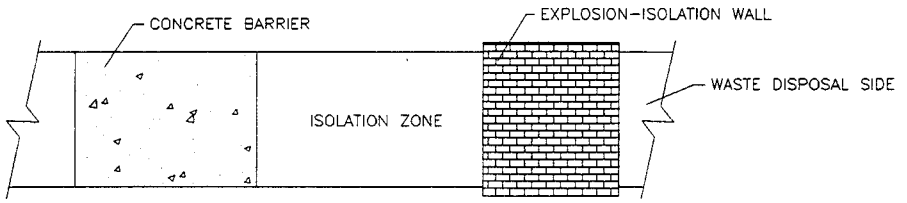


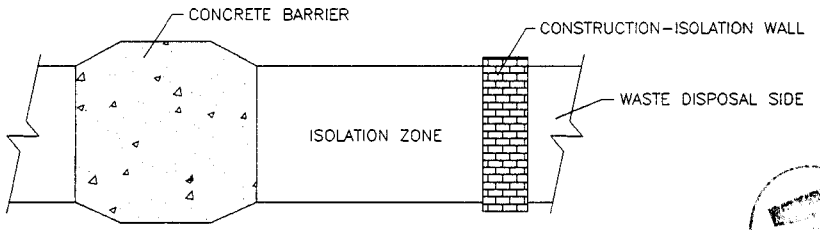
Figure I-3
WIPP Facility Final Closure Schedule



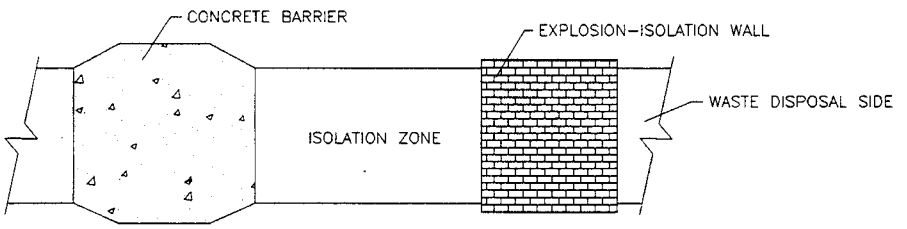
OPTION A. CONSTRUCTION ISOLATION WALL AND CONCRETE BARRIER WITHOUT DRZ REMOVED



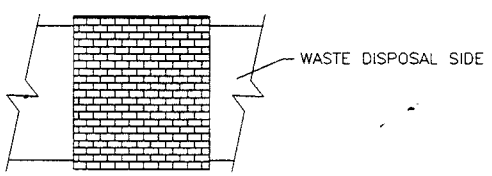
OPTION B. EXPLOSION ISOLATION WALL AND CONCRETE BARRIER WITHOUT DRZ REMOVED



OPTION C. CONSTRUCTION ISOLATION WALL AND CONCRETE BARRIER WITH DRZ REMOVED



OPTION D. EXPLOSION ISOLATION WALL AND CONCRETE BARRIER WITH DRZ REMOVED



OPTION E. CINDERBLOCK BARRIER/EXPLOSION-ISOLATION WALL

Figure I-4
Design of a Panel Closure System

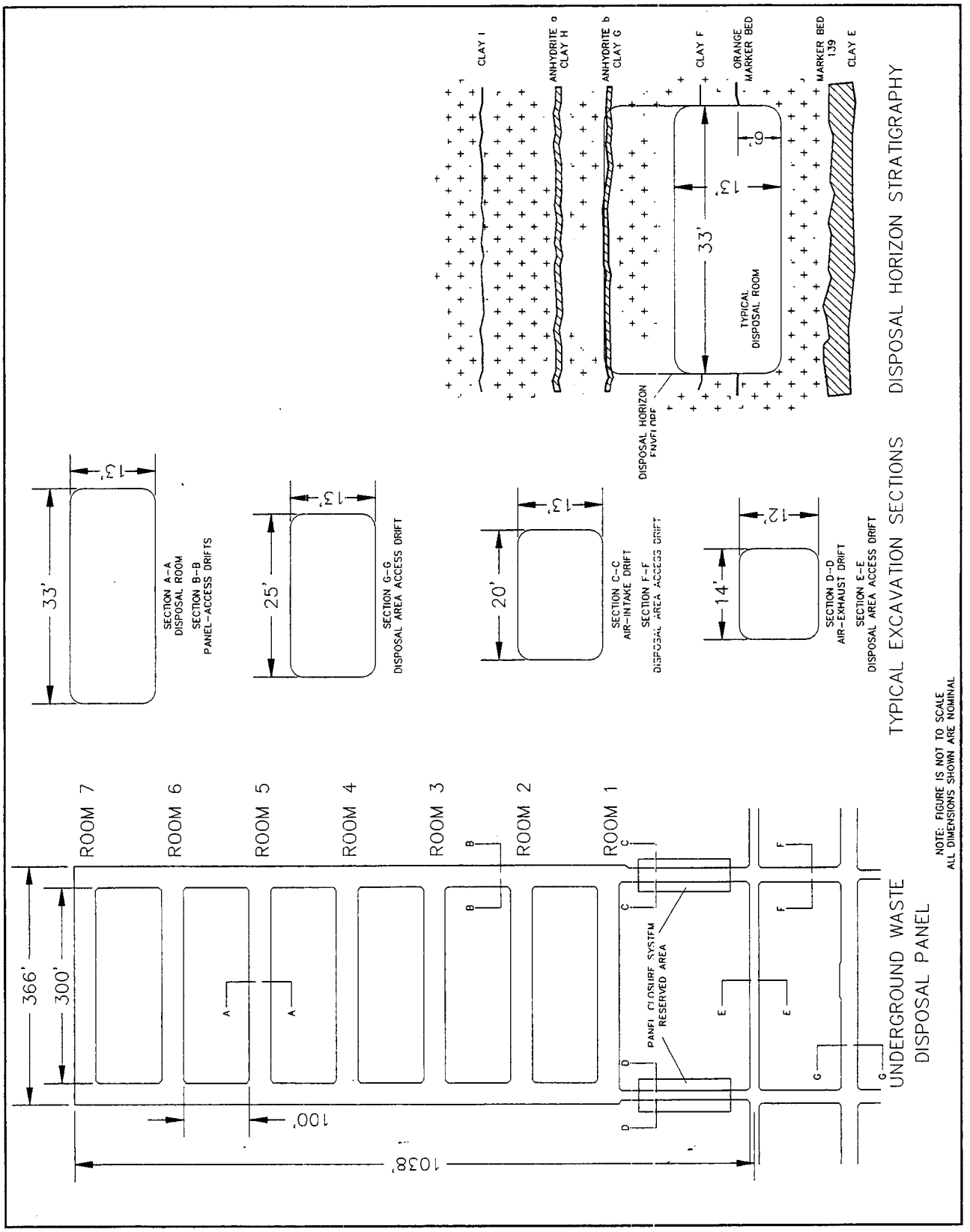
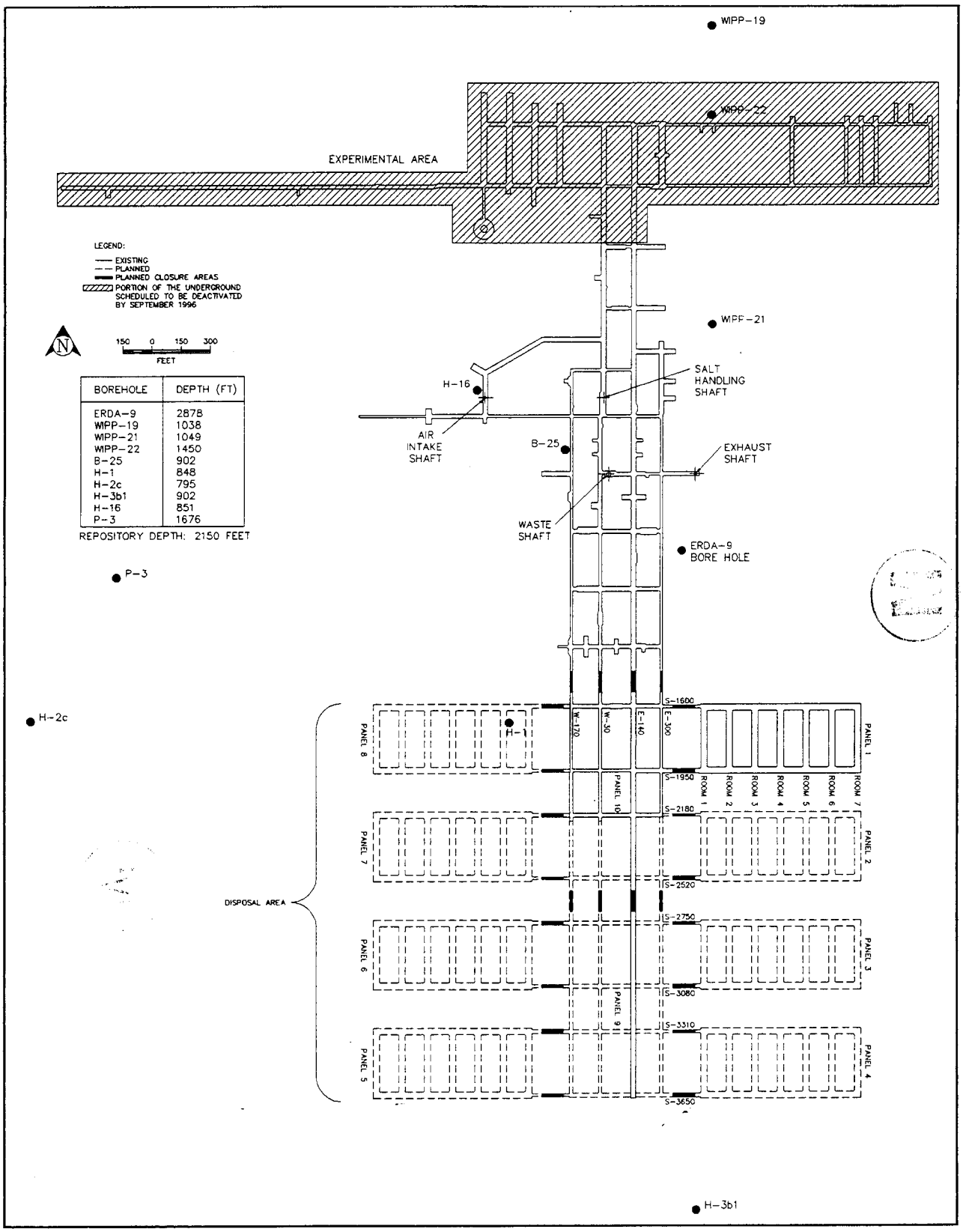


Figure I-5
Typical Disposal Panel



BOREHOLE	DEPTH (FT)
ERDA-9	2878
WIPP-19	1038
WIPP-21	1049
WIPP-22	1450
B-25	902
H-1	848
H-2c	795
H-3b1	902
H-16	851
P-3	1676

REPOSITORY DEPTH: 2150 FEET

Figure I-6
Approximate Locations of Boreholes in Relation to the WIPP Underground

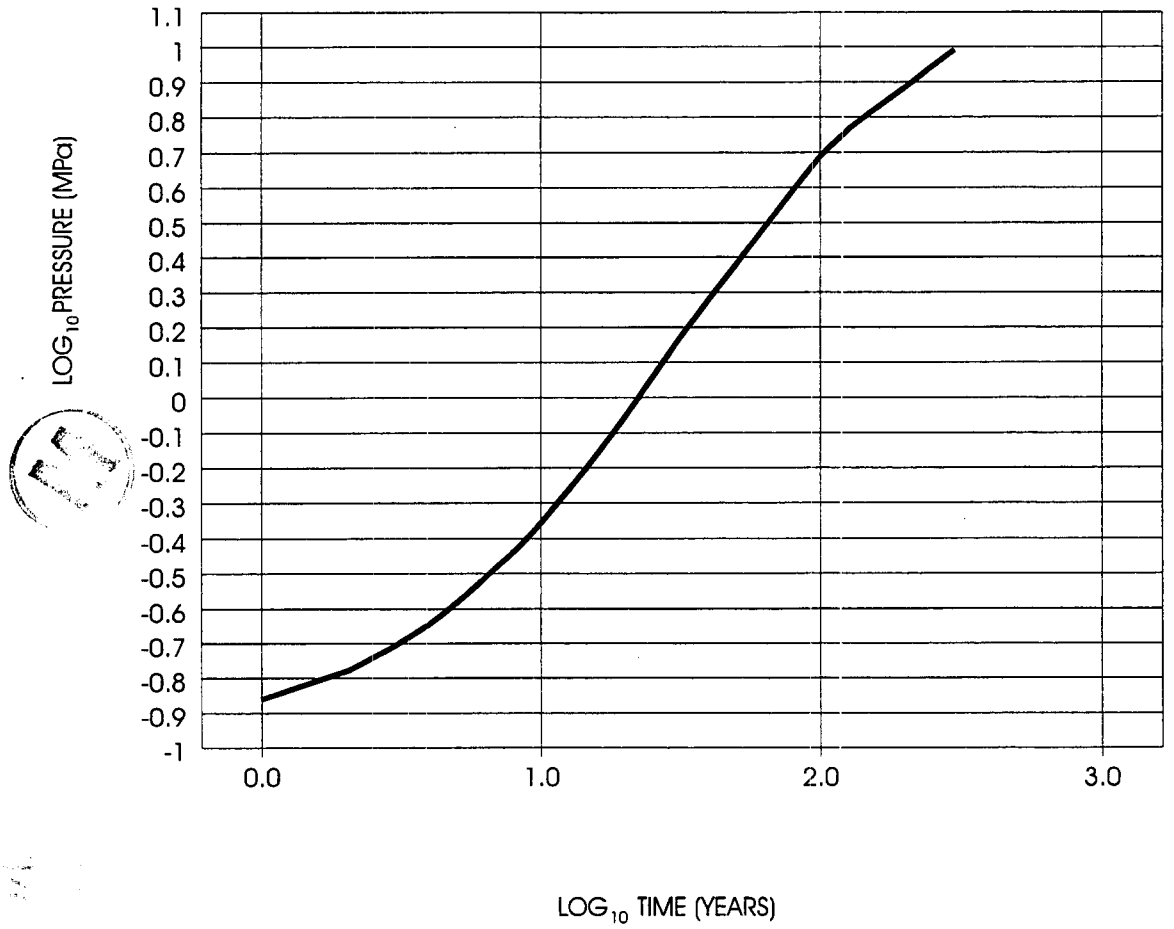


Figure I-7

Predicted Change in Disposal Region Pressure Following Shaft Sealing

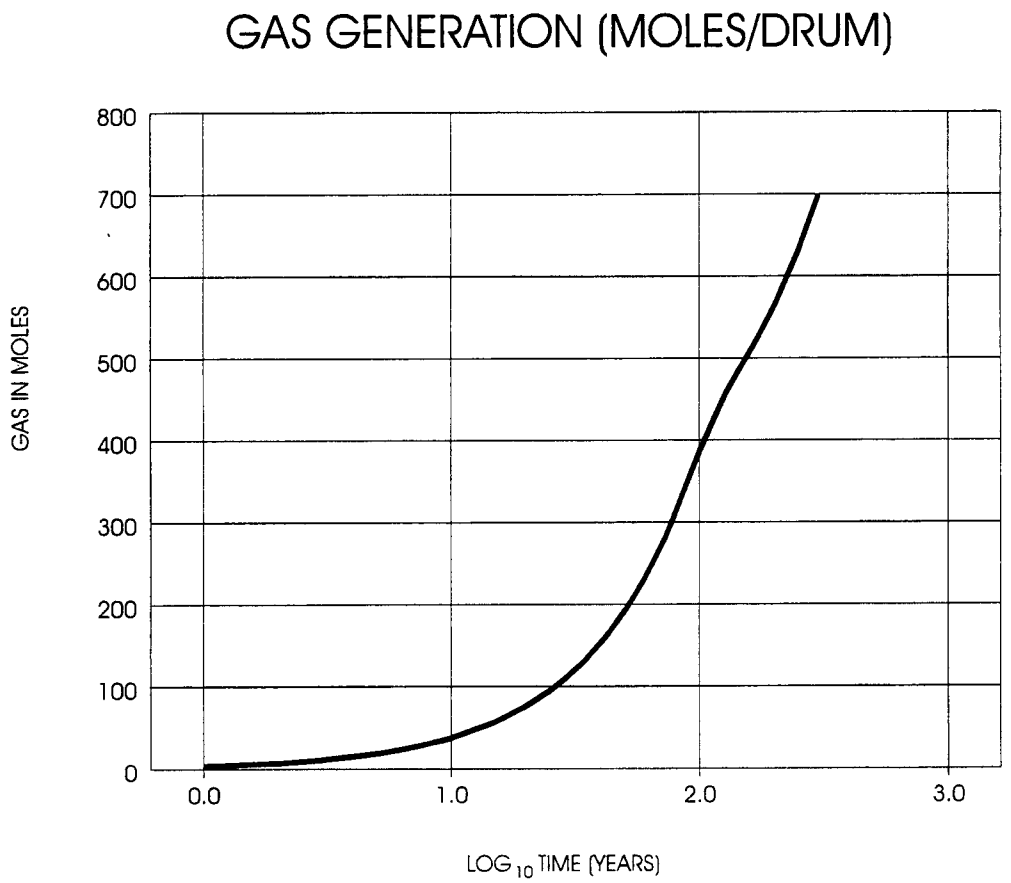


Figure I-8

Predicted Cumulative Volume of Gas Generated Per Drum of Waste

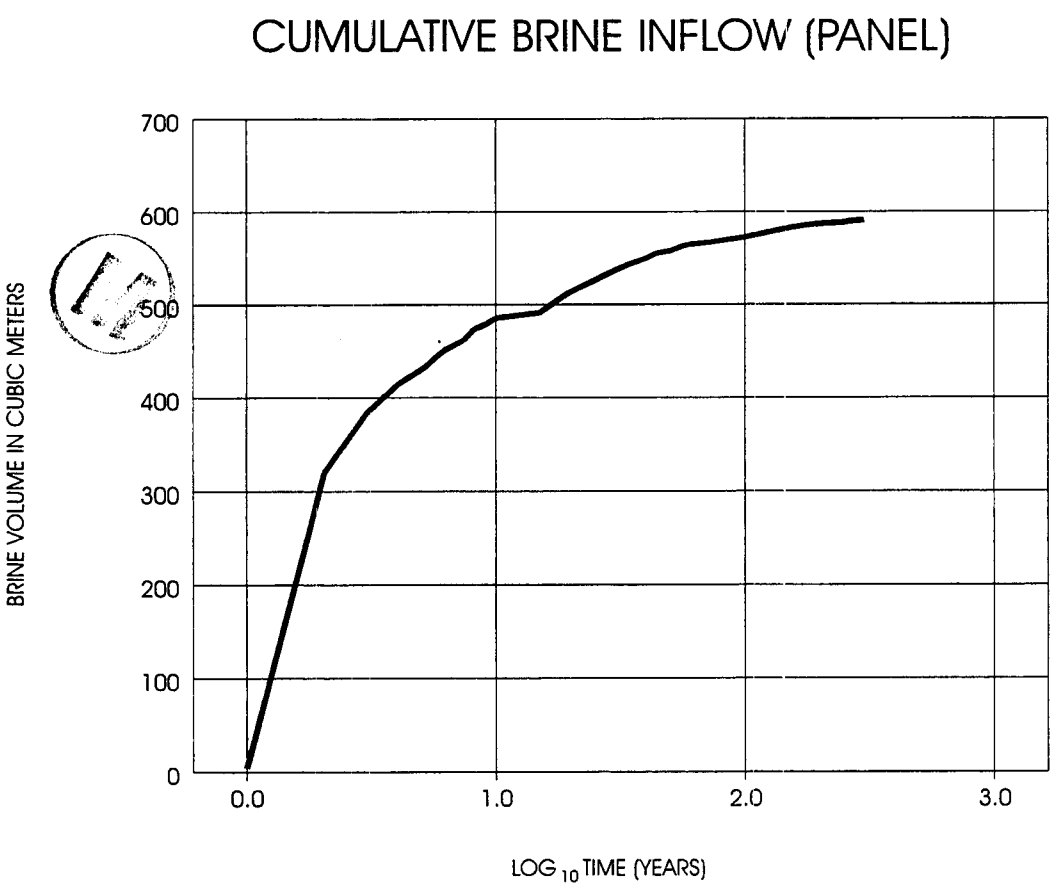


Figure I-9

Predicted Cumulative Brine Inflow into a Closed Waste Panel

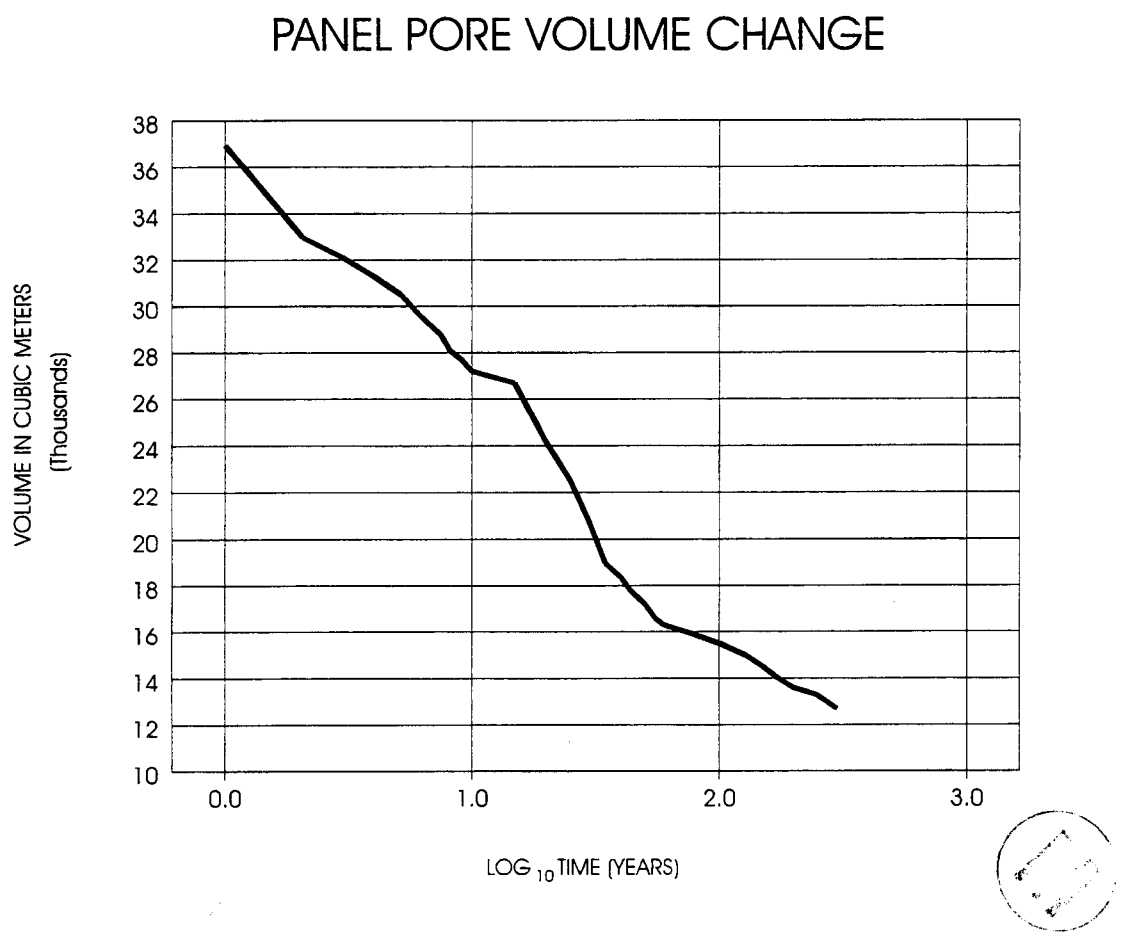


Figure I-10

Predicted Change in Panel Pore Volume Due to Creep Closure

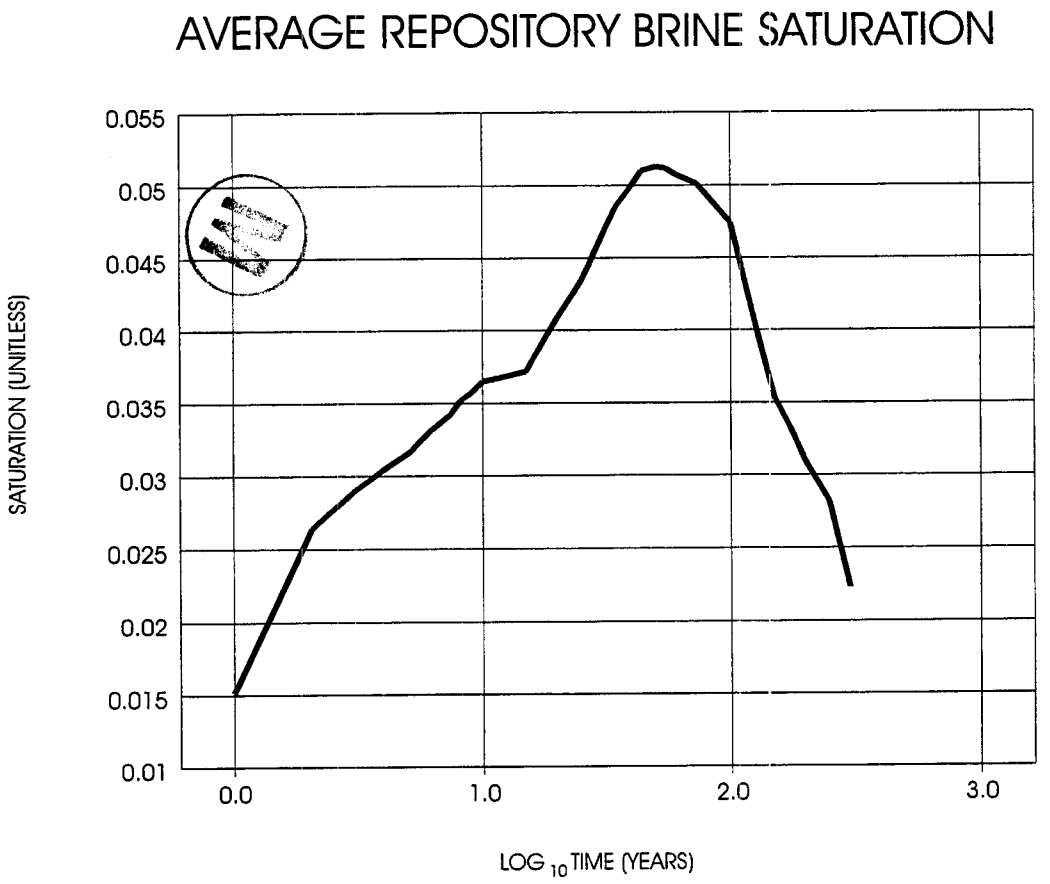


Figure I-11

Predicted Average Brine Saturation Within the Repository

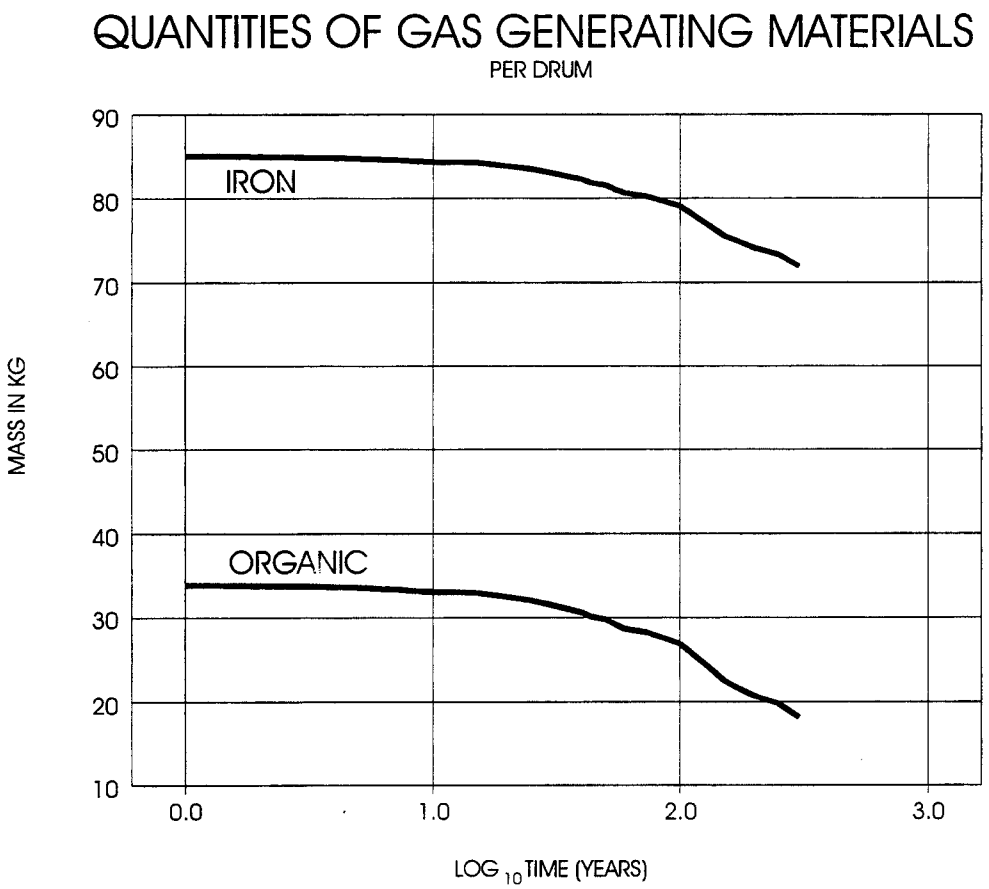


Figure I-12

Predicted Change in the Quantity of Gas Generating Material In Each Drum

APPENDIX I1

CONCEPTUAL DESIGN FOR OPERATIONAL PHASE CLOSURE SYSTEMS

DETAILED DESIGN REPORT FOR AN OPERATIONAL PHASE PANEL-CLOSURE SYSTEM

DOE/WIPP-96-2150

Any comments or questions regarding this report
should be directed to the U.S. Department of Energy
WIPP Project Office
P.O. Box 3090
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Westinghouse Electric Corporation
Waste Isolation Division
P.O. Box 2078
Carlsbad, New Mexico 88221

This report was prepared for the U.S. Department of Energy by the Engineering Department of the Management and Operating Contractor, Waste Isolation Pilot Plant, under Contract No. DE-AC04-86AL31950.

Certification

I certify under penalty of law that this document was prepared under my supervision for Westinghouse Electric Corporation, Waste Isolation Division, Waste Isolation Pilot Plant, by IT Corporation according to the IT Environmental Engineering and Services Quality Assurance Program. This program is designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

John B. Case, P.E.

John B. Case, P.E.
New Mexico
Certification No. 8049
Expires December 31, 1997

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List of Abbreviations/Acronyms

ACI	American Concrete Institute
AISC	American Institute for Steel Construction
*CFR	Code of Federal Regulations
cm	centimeter
°C	degrees celsius
°F	degrees Fahrenheit
DOE	U.S. Department of Energy
DRZ	disturbed rock zone
EEP	Excavation Effects Program
ESC	expansive salt-saturated concrete
FLAC	Fast Lagrangian Analysis of Continua
ft	foot (feet)
GPR	ground-penetrating radar
Kips	1,000 pounds
m	meter(s)
MB 139	Marker Bed 139
MPa	megapascal(s)
MSHA	Mine Safety and Health Administration
NaCl	sodium chloride
NMVP	no-migration variance petition
psi	pound(s) per square inch
RCRA	Resource Conservation and Recovery Act
SMC	Salado Mass Concrete
TRU	transuranic
VOC	volatile organic compound(s)
Westinghouse	Westinghouse Electric Corporation
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

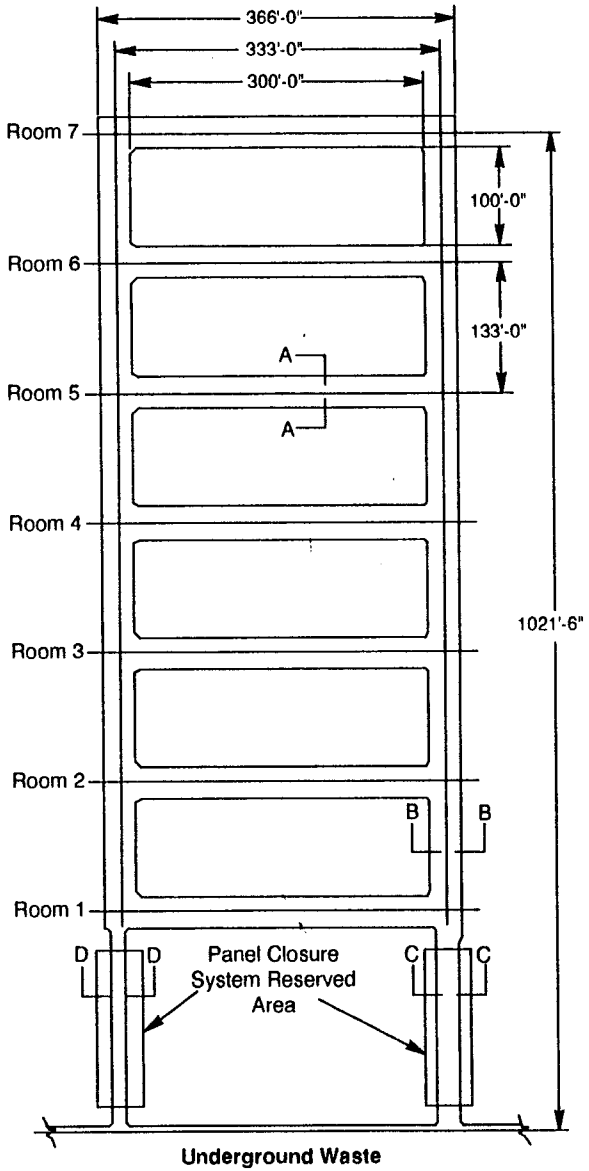
Executive Summary

Scope. Under contract to Westinghouse Electric Corporation (Westinghouse), Waste Isolation Division (WID), IT Corporation has prepared a detailed design of a panel-closure system for the Waste Isolation Pilot Plant (WIPP). Preparation of this detailed design of an operational-phase closure system is required to support a Resource Conservation and Recovery Act (RCRA) Part B permit application and a no-migration variance petition. This report describes the detailed design for a panel-closure system specific to the WIPP site. The recommended panel-closure system will adequately isolate the waste-emplacement panels for at least 35 years.

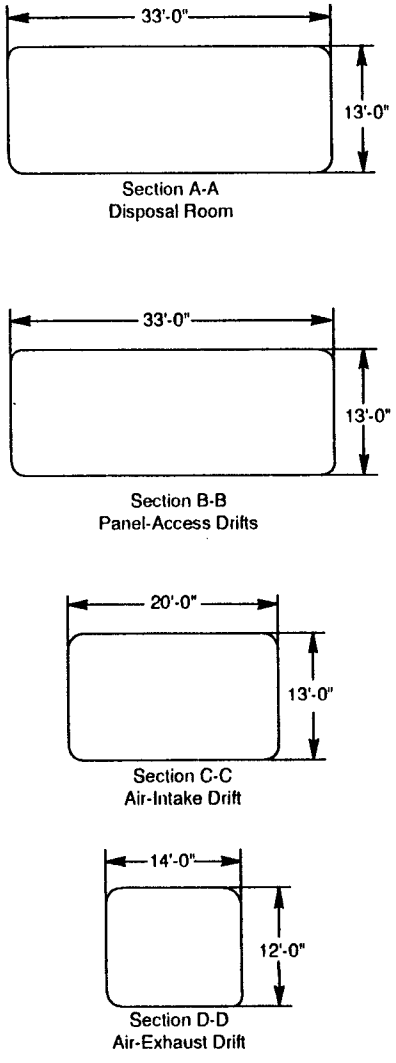
Purpose. This report provides detailed design and material engineering specifications for the construction, emplacement, and interface-grouting associated with a panel-closure system at the WIPP repository, which would ensure that an effective panel-closure system is in place for at least 35 years. The panel-closure system provides assurance that the limit for the migration of volatile organic compounds (VOC) will be met at the point of compliance, the WIPP site boundary. This assurance is obtained through the inherent flexibility of the panel-closure system. The panel-closure system will be located in the air-intake and air-exhaust drifts (Figure ES-1). The system components have been designed to maintain their intended functional requirements under loads generated from salt creep, internal pressure, and a postulated methane explosion. The design complies with regulatory requirements for a panel-closure system promulgated by RCRA and the Mine Health and Safety Administration (MSHA). The design uses common construction practices according to existing standards.

Background. The engineering design considers a range of expected subsurface conditions at the location of a panel-closure system. The geology is predominantly halite with interbedded anhydrite at the repository horizon. During the operational period, the panel-closure system would be subject to creep from the surrounding host rock that contains trace amounts of brine.

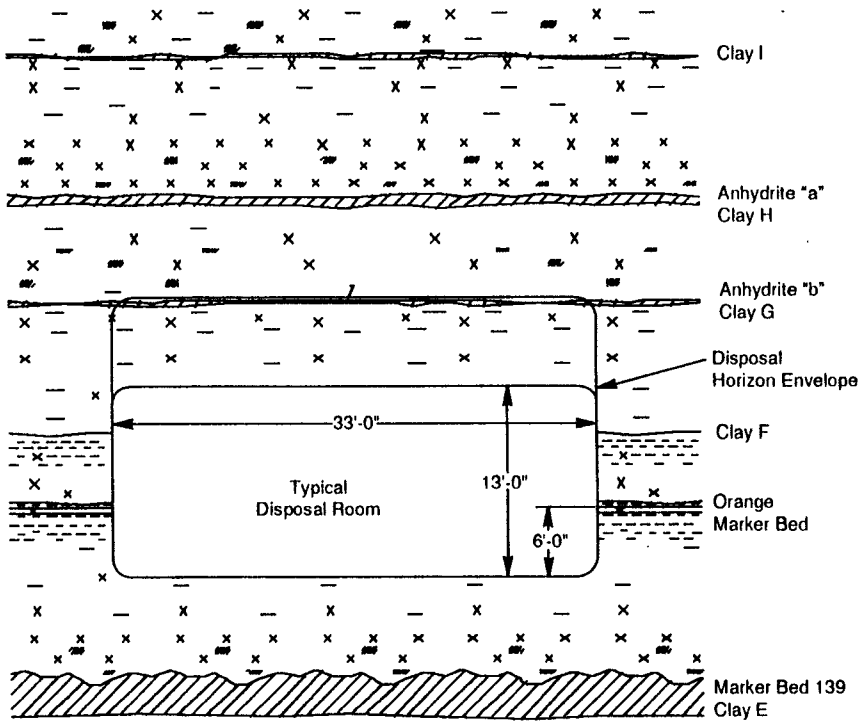
During the conceptual design stage, two air-flow models were evaluated: (1) unrestricted flow and (2) restricted flow through the panel-closure system. The "unrestricted" air flow model is defined as a model in which the gas pressure that develops is at or very near atmospheric pressure such that there exists no back pressure in the disposal areas. Flow is unrestricted in this model. The "restricted" air flow model is defined as a model in which the



Underground Waste Disposal Panel



Typical Excavation Sections



Disposal Horizon Stratigraphy

Note: Figure is Not to Scale
All Dimensions Shown are Nominal

Figure ES-1
Typical Facilities-Typical Disposal Panel
(After Westinghouse, 1995c)

back pressure in the waste emplacement panels develops due to the restriction of flow through the barrier, and the surrounding disturbed rock zone. The analysis was based on an assumed gas generation rate of 8,200 moles per panel per year (0.1 moles per drum per year) due to microbial degradation, an expected volumetric closure rate of 28,000 cubic feet (800 cubic meters) per year due to salt creep, the expected headspace concentration for a series of nine VOCs, and the expected air dispersion from the exhaust shaft to the WIPP site boundary. The analysis indicated that the panel-closure system would limit the concentration of each VOC at the WIPP site boundary to a small fraction of the health-based exposure limits during the operational period.

Alternate Designs. Various options were evaluated considering active systems, passive systems, and composite systems. Consideration of the aforementioned factors led to the selection of a passive panel-closure system consisting of: (1) a standard concrete barrier, rectangular in shape, or (2) an enlarged tapered concrete barrier. Options (1) and (2) will be grouted at the interface and may contain an explosion-isolation wall or a construction-isolation wall. This system provides flexibility for a range of ground conditions likely to be encountered in the underground repository. No other special requirements for engineered components beyond the normal requirements for fire suppression and methane explosion or deflagration containment exist for the panel-closure system during the operational period.

The panel-closure system design incorporates mitigative measures to address the treatment of fractures and therefore minimizes the potential migration of contaminants. The design option for mitigating fractures includes excavating the disturbed rock zone (DRZ) and emplacing an enlarged concrete barrier.

To be effective, the excavation and installation of the panel-closure system must be completed within a short time frame to minimize disturbance to the surrounding salt. A rigid concrete barrier will promote interface stress buildup, as fractures are expected to heal with time. For this purpose, the main concrete barrier would be tapered to reduce shear stress and to increase compressive stress along the interface zone. If ground conditions are more favorable, the design can be simplified to a standard concrete barrier with an explosion-isolation or construction-isolation wall without DRZ removal.[1]

[1]DRZ removal is used in the context of the removal of fractured rock.

Design Classification. Procedure WP 09-CN3023 (Westinghouse, 1995a) was used to establish a design classification for the panel-closure system. It uses a decision-flow-logic process to designate the panel-closure system as a Class IIIB structure. This is because during the methane explosion the concrete barrier would not fail.

Design Evaluations. To investigate several key design issues, design evaluations were performed. These design evaluations can be divided into those that satisfy (1) the operational requirements of the system and (2) the structural and material requirements of the system.

The conclusions reached from the evaluations addressing the operational requirements are as follows:

- Based on an air-flow model used to predict the mass flow rate of carbon tetrachloride through the panel-closure system for the alternatives, the air-flow analysis suggests that the fully enlarged barrier provides the highest protection for restricting VOCs during the operational period of 35 years.

- Results of the Fast Lagrangian Analysis of Continua (FLAC) analyses show that the recommended enlarged configuration is a circular rib-segment excavated to Clay G and under MB 139. Interface grouting would be performed at the upper boundary of the concrete barrier.

- The results of the transver plane-strain models show that hig er stresses would form in MB 139 following excavation, but that after installation of the panel-closure system, the barrier confinement will result in an increase in barrier-confining stress and a reduction in shear stress. The main concrete barrier would provide substantial uniform confining stresses as the barrier is subjected to secondary salt creep.

- The removal of the fractured salt prior to installation of the main concrete barrier would reduce the potential for flexure. The fracturing of MB 139 and the attendant fracturing of the floor could reduce structural load resistance (structural stiffness), which could initially result in barrier flexure and shear. With the removal of MB 139, the fractured salt stiffens the surrounding rock and results in the development of more uniform compression.

- The trade-off study also showed that a panel-closure system with an enlarged concrete barrier with the removal of the fractured salt roof and anhydrite in the floor was found to be the most protective.

The conclusions reached from the design evaluations addressing the structural and material requirements of the panel-closure system are as follows:

- Existing information on the heat of hydration of the concrete supports placing concrete with a low cement content to reduce the temperature rise associated with hydration. Plasticizers might be used to achieve the required slump at the required strength. A thermal analysis, coupled with a salt creep analysis, suggests installation of the enlarged barrier at or below ambient temperatures to adequately control hydration temperatures.

- In addition to installation at or below ambient temperatures, the concrete used in the main barrier would exhibit the following:

  - An 8 inch (0.2 meter) slump after 3 hours of intermittent mixing

  - A less-than-25-degree Fahrenheit heat rise prior to installation

  - An unconfined compressive strength of 4,000 pounds per square inch (psi) (28 megapascals [MPa]) after 28 days

  - Volume stability

  - Minimal entrained air.

- The trace amounts of brine from the salt at the repository horizon will not degrade the main concrete barrier for at least 35 years.

- In 20 years, the open passage above the waste stack would be reduced in size. Further, rooms with bulkheads at each end would be isolated in the panel. It is unlikely that a long passage with an open geometry would exist; therefore, the dynamic analysis considered a deflagration with a peak explosive pressure of 240 psi (1.7 MPa).

- The heat-transfer analysis shows that elevated temperatures would occur within the salt and the explosion-isolation wall; however, the elevated temperatures will be isolated by the panel-closure system. Temperature gradients will not significantly affect the stability of the wall.

- The fractures in the roof and floor could be affected by expanding gas products reaching pressures on the order of 240 psi (1.7 MPa). Because the peak internal pressure from the deflagration is only one fifth of the pressure, fractures could not propagate beyond the barrier.

A composite system is selected for the design with various components to provide flexibility. These design options are described below.

Design Options. Figure ES-2 illustrates the options developed to satisfy the requirements for the panel-closure system. The basis for selecting an option depends on conditions at the panel-closure system locations as would be documented by future subsurface investigations.

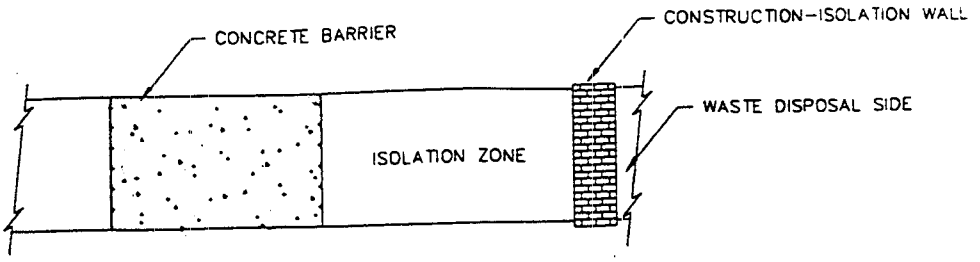
These design options provide flexibility in satisfying the design migration limit for the flow of VOCs out of the waste-emplacement panel. An enlarged concrete barrier would be selected for the air-intake and air-exhaust drifts that have fractured rock to eliminate significant flow of VOCs. Several methods are available for detecting the location and extent of fractures in the DRZ for optimum placement of an enlarged concrete barrier. These detection methods include ground-penetrating radar (GPR) and inspection of observation boreholes.

For future waste panels, GPR would be used to monitor fracture development. Radar surveys would be conducted shortly after excavation to provide a baseline for comparison to future radar surveys. GPR would be used periodically to monitor the development of brittle deformation in the new air-intake and air-exhaust drifts of a panel.

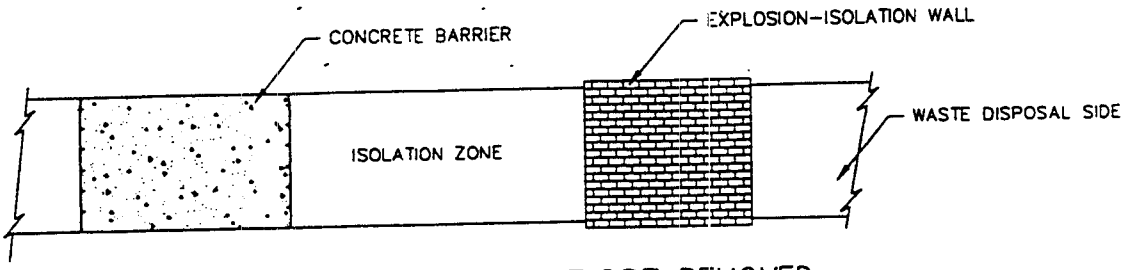
Observation boreholes would be drilled into the roof or floor of an excavation and would be inspected for fractures and bed separation. Observations in the boreholes can be made with a small video camera, or a simple scratch rod.

While no specific requirements exist for barricading inactive waste areas under the MSHA, their intent is to safely isolate these abandoned areas from active workings using barricades of "substantial construction." A previous analysis (DOE, 1995) examined the issue of methane gas generation from transuranic waste and the potential consequence in closed areas. The principal concern is whether an explosive mixture of methane with an ignition source would result in deflagration. If a methane explosion is considered possible, a concrete block wall of sufficient thickness will be used to resist dynamic and salt creep loads. A construction isolation wall will be used in the absence of explosive conditions.

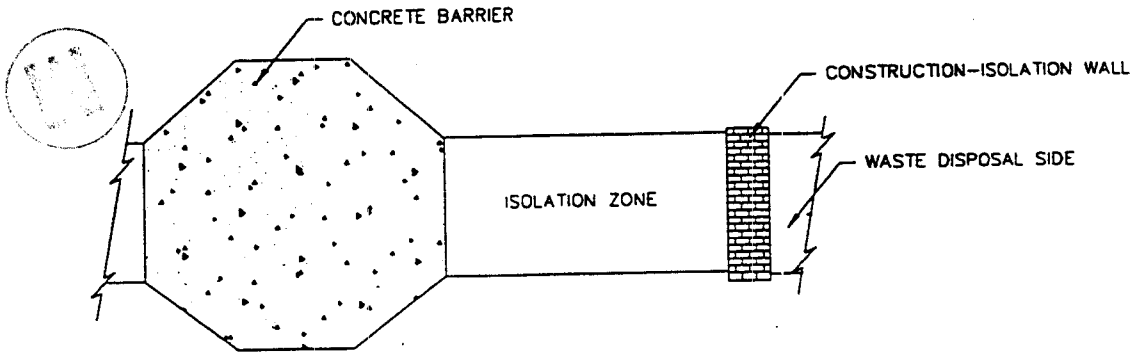
It was shown (DOE, 1995) that an explosive atmosphere may exist after approximately 20 years. A panel-closure system with a closure life less than 20 years would not require an explosion-isolation wall, because an explosive mixture could not accumulate. A construction-isolation wall will suffice to provide isolation during construction of the main concrete barrier.



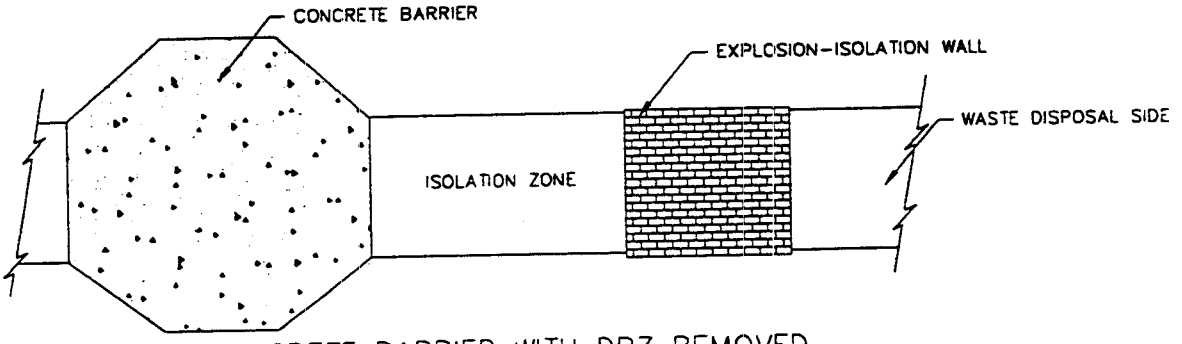
A. CONCRETE BARRIER WITHOUT DRZ REMOVED AND CONSTRUCTION ISOLATION WALL



B. CONCRETE BARRIER WITHOUT DRZ REMOVED AND EXPLOSION ISOLATION WALL



C. CONCRETE BARRIER WITH DRZ REMOVED AND CONSTRUCTION ISOLATION WALL



D. CONCRETE BARRIER WITH DRZ REMOVED AND EXPLOSION ISOLATION WALL

Figure ES-2
Main Barrier with Wall Combinations

Design Components. The enlarged concrete barrier will be located at the optimum location in the air-intake and air-exhaust drifts following observation of subsurface conditions. The enlarged concrete barrier will be composed of plain concrete with sufficient unconfined compressive strength. The barrier will consist of a circular rib segment excavated into the surrounding salt where the central portion of the barrier will extend just beyond Clay G and MB 139. FLAC analyses showed that plain concrete will develop adequate confined compressive strength.

The enlarged concrete barrier will be placed in four cells, with construction joints formed perpendicular to the direction of potential air flow. The concrete will be placed through 6-inch (15.2 centimeter) diameter steel pipes and will be vibrated from outside the formwork. The formwork is designed to withstand the hydrostatic loads that would occur during installation with minimal bracing onto exposed salt surfaces. This will be accomplished by a series of steel plates that are stiffened by angle iron, with load reactions carried by spacer rods. Some exterior bracing will be required when the concrete is poured into the first cell at the location for the enlarged concrete barrier. All structural steel will be American Society of Testing and Materials [grade] A36 in conformance with the latest standards specified by the American Institute for Steel Construction. After concrete placement, the formwork will be left in place and will stiffen the enlarged concrete barrier if nonuniform reactive loadings should occur after panel closure.

After completion of the enlarged concrete barrier installation, it will be grouted through a series of grout supply and air return lines that terminate in grout boxes. The boxes will be mounted near the top of the barrier. The grout will be injected through one set of lines and returned through a second set of air lines.

An explosion-isolation wall, constructed with concrete-blocks, will mitigate the effects of a methane explosion. The explosion-isolation wall would consist of 3,500 psi (24 MPa) concrete blocks mortared together with a bonding agent. The concrete-block wall design complies with MSHA requirements, because it consists of noncombustible materials of "substantial construction." The concrete-block walls will be keyed into the salt. For the WIPP, an explosion-isolation wall is designed to resist loading from salt creep.

The compliance of the detailed design was evaluated against the design requirements established for the panel-closure system. The design complies with all aspects of the design basis established for the panel-closure system.

1.0 Introduction

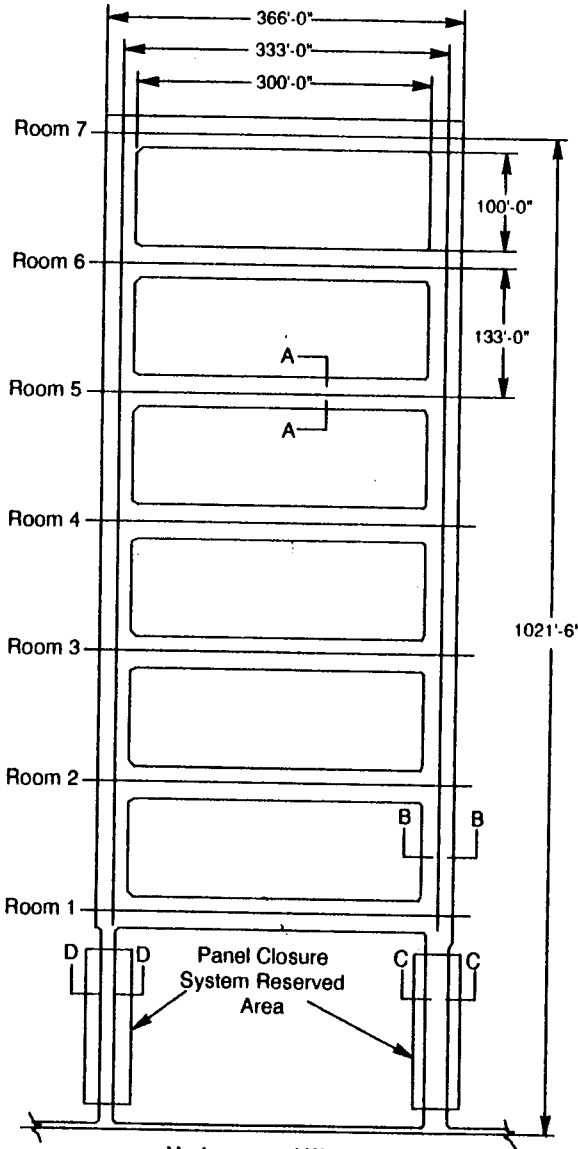
The Waste Isolation Pilot Plant (WIPP), a U.S. Department of Energy (DOE) research facility located near Carlsbad, New Mexico, was established to demonstrate the safe disposal of defense-generated transuranic (TRU) waste. The WIPP repository is approximately 2,150 feet (ft) (655 meters [m]) below the surface, in the Salado Formation. The WIPP facility consists of a northern experimental area, a shaft-pillar area, and a waste-emplacement area.

One important aspect of future repository operations at the WIPP is the activities associated with closure of waste-emplacement panels. Each panel consists of air-intake and air-exhaust drifts, panel-access drifts, and seven rooms (Figure 1-1). After completion of waste-emplacement activities, each panel will be closed, while waste emplacement may be occurring in the other panel(s). The closure of individual panels during the operational period will be conducted in compliance with project-specific health, safety, and environmental performance criteria.

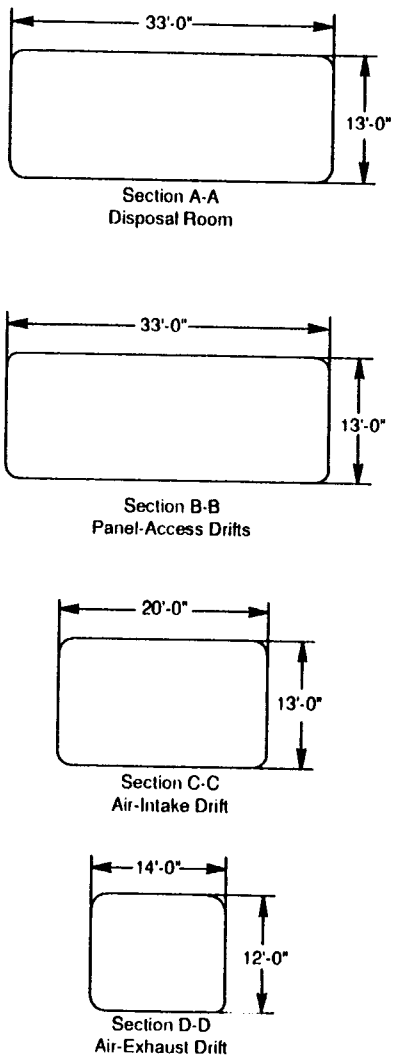
1.1 Scope

This report provides information on the detailed design and material engineering specifications for the construction, installation, and interface grouting associated with a panel-closure system for a minimum operational period of 35 years. The panel-closure system design provides assurance that the limit for the migration of volatile organic compounds (VOC) will be met at the point of compliance, the WIPP site boundary. This assurance is obtained through the inherent flexibility of the panel closure system. The panel-closure system will be located in the air-intake and air-exhaust drifts to each panel (Figure 1-1). The panel-closure system design maintains its intended functional requirements under loads generated from salt creep, internal panel pressure, and a postulated methane explosion. The design complies with regulatory requirements for a panel-closure system promulgated by the Resource Conservation and Recovery Act (RCRA) and Mine Safety and Health Administration (MSHA).

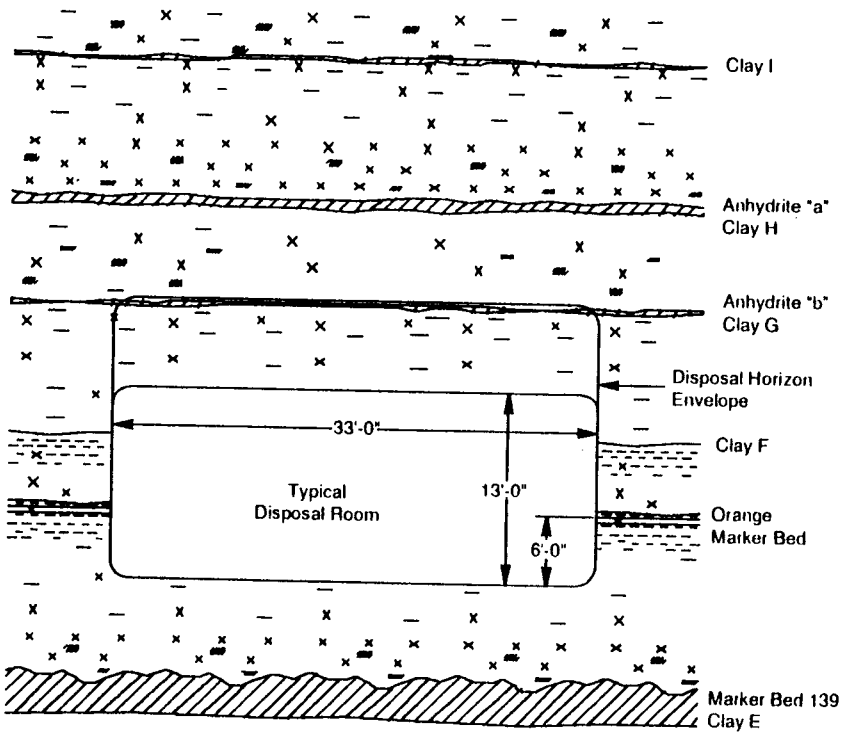
Figure 1-2 illustrates the design process used for preparing the detailed design. The design process commenced with the evaluation of the performance requirements of the panel-closure system through review of the work performed in developing the conceptual design and the "Underground Hazardous Waste Management Unit Closure Criteria for the Waste Isolation Pilot Plant Operation Phase" (Westinghouse, 1995b). The various design evaluations were



Underground Waste Disposal Panel



Typical Excavation Sections



Disposal Horizon Stratigraphy

Note: Figure is Not to Scale
All Dimensions Shown are Nominal

Figure 1-1
Typical Facilities-Typical Disposal Panel
(After Westinghouse, 1995c)

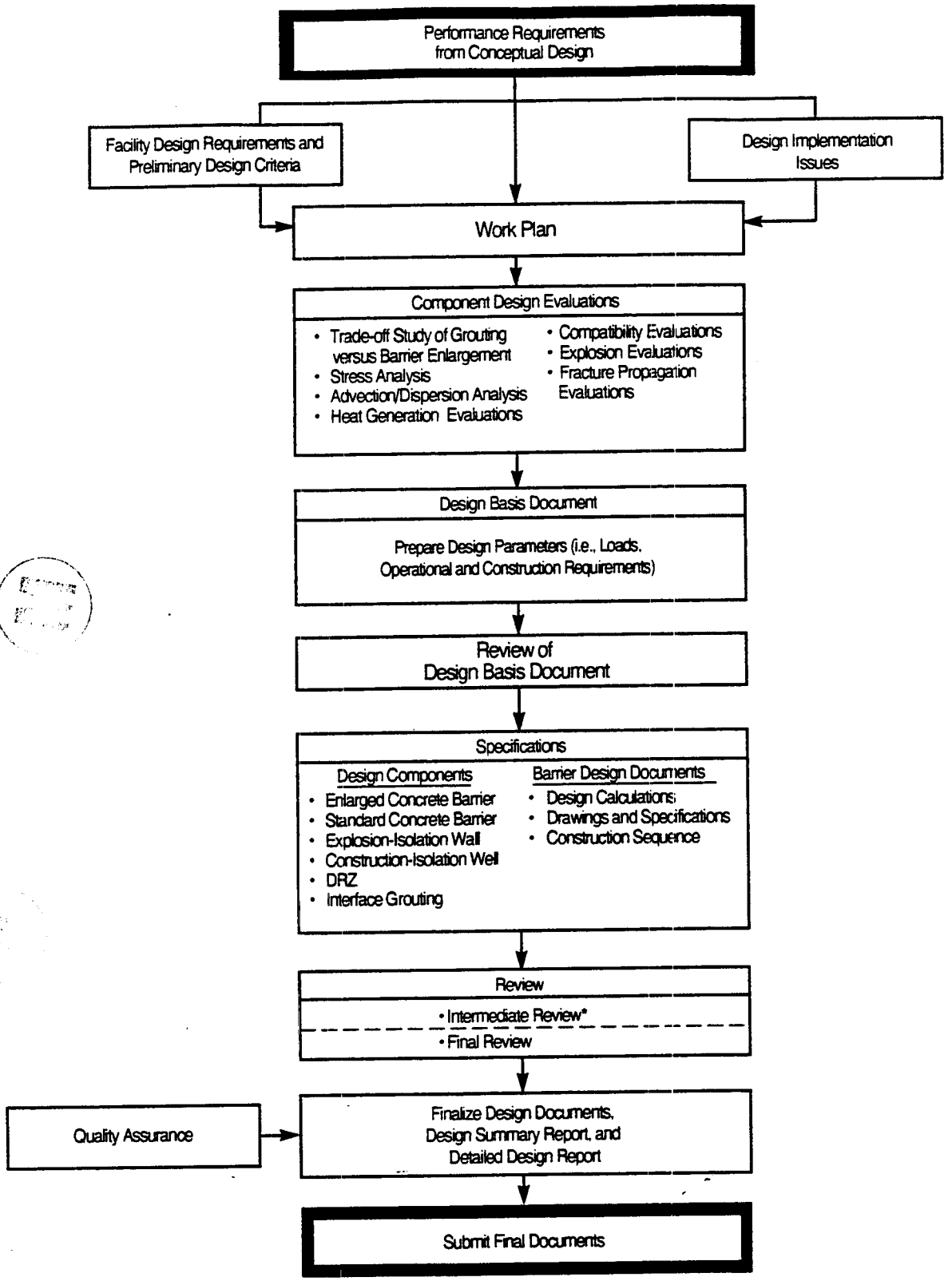


Figure 1-2
Design Process for the Panel-Closure System

performed to address specific design-implementation issues identified by the project. The results of these design evaluations are presented in this report.

1.2 Design Classification

Procedure WP 09-CN3023 (Westinghouse, 1995a) was used to establish a design classification for the panel-closure system. The design classification for the panel-closure system evolved from addressing the short-term operational issues regarding the reduction of VOC migration. Figure 1-3 shows the decision flow logic process used to designate the panel-closure system as a Class IIIB structure.

1.3 Regulatory Requirements

The following subsections discuss the regulatory requirements specified in RCRA and MSHA for the panel-closure system.

1.3.1 Resource Conservation and Recovery Act (40 CFR 264, 268, and 270)

In accordance with Title 40, Code of Federal Regulations (CFR), Part 264, Subpart X (40 CFR 264, Subpart X), "Miscellaneous Units," and 40 CFR 270.23, "Specific Part B Information Requirements for Miscellaneous Units," a RCRA Part B permit application has been submitted for the WIPP facility. According to 40 CFR 268.6, the DOE has opted to pursue a no-migration variance petition (NMVP) instead of treating waste to meet the land disposal restrictions (40 CFR 268) (EPA, 1995).

1.3.2 Protection of the Environment and Human Health

Both the draft NMVP and the WIPP RCRA Part B permit application indicate that VOCs must not exceed health-based standards beyond the WIPP site boundary. Worker exposure to VOCs, and VOC emissions will not pose greater than a 10^{-6} excess cancer risk to the nearest resident in order to meet health-based standards. The panel-closure system design incorporates measures to mitigate VOC migration for compliance with these standards.

1.3.3 Closure Requirements (20 New Mexico Administrative Code 4.1, Subpart V)

The DOE will notify the Secretary of the New Mexico Environment Department in writing at least 60 days prior to the date on which partial and final closure activities are scheduled to begin.

A. Select a system structure or component for classification. (Start with a mitigating item)

B. Is the system, structure, or component required to mitigate the consequences of an accident?

C. Would the system, structure, or component failure result in loss of safety functions of a Design Class I components?

D. Does the system, structure, or component provide any function related to nuclear materials?

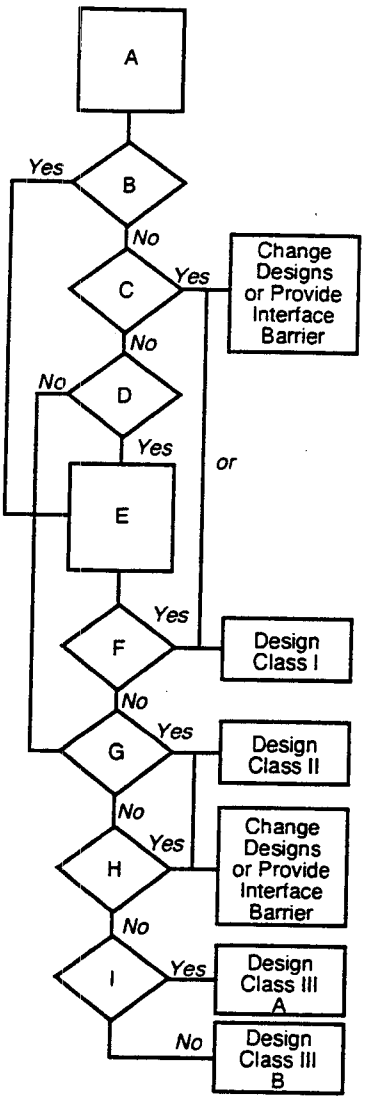
E. Select a conservative accident scenario and perform safety analysis.

F. Does the cumulative radiological consequences following the accident exceed 25 Rem whole body or 75 Rem organ dose commitment to an individual at the Zone I boundary

G. Does the structure, system, operation or component conform to the Class II criteria as defined in Attachment 2?

H. Would the structure, system, operation or component failure result in loss of the required function of a Class II component?

I. Are special design requirements necessary to ensure that failure of the system, structure, or component will NOT result in a significant shutdown of the facility or inhibit accessibility or maintainability of required equipment or have special significance to health and safety of operations personnel?



B. _____YES __X__ NO
Describe requirement

C. _____YES __X__ NO
Failure mode and affected class I component

D. _____YES __X__ NO
Describe function

E. _____YES __N/A__ NO
Attach safety analysis

F. _____YES _____NO
Calculate dose rates
N/A
(Attach calculations to this form)

G. _____YES __X__ NO
Criteria
N/A

H. _____YES __X__ NO
Failure mode and affected Class II component

I. _____YES __X__ NO
Requirements

Figure 1-3
Design Classification of the Panel-Closure System
(Modified from Westinghouse, 1995a)

1.3.4 Mining Safety and Health Administration

The significance of small natural-gas occurrences within the WIPP repository is within the classification of Category IV for natural gas under the MSHA (30 CFR 57, Subpart T) (MSHA, 1987). These regulations include the hazards of methane gas and volatile dust. Category IV "applies to mines in which non-combustible ore is extracted and which liberate a concentration of methane that is not explosive nor capable of forming explosive mixtures with air based on the history of the mine or the geological area in which the mine is located." For "barriers and stoppings," the regulations provide for noncombustible materials (where appropriate) for the specific mine category and require that "barriers and stoppings" be of "substantial construction." Substantial construction implies construction of such strength, material, and workmanship that the barrier could withstand air blasts, methane detonation or deflagration, blasting shock, and ground movement expected in the mining environment.

1.4 Report Organization

This report presents the engineering package for the detailed design of the panel-closure system. Chapter 2.0 presents the design evaluations. Chapter 3.0 describes the design and Chapter 4.0 presents the Constructability Design Calculations Index. Chapter 5.0 shows the technical specifications. Chapter 6.0 presents the design drawings. The conclusions are presented in Chapter 7.0 and the references presented in Chapter 8.0. Appendices to this report provide detailed information to support the information contained in Chapters 2.0 through 7.0 of this report.

2.0 Design Evaluations

This chapter presents the results of the various design evaluations that support the panel-closure system: (1) analyses addressing the operational requirements, and (2) analyses addressing the structural and material requirements. The first group includes air-flow analyses, an advection/dispersion analysis, and stress analyses using the Fast Lagrangian Analysis of Continua (FLAC) (Itasca, 1995), which support a trade-off study comparing grouting to removal of fracture zones in both the roof and floor. The second group addresses the issue of material compatibility with the host rock and heat-generation that may cause thermal cracking in the main concrete barriers during cement hydration. The second group also includes methane-explosion and fracture-propagation evaluations to address the dynamic pressure and subsequent temperatures generated by a postulated methane explosion.

2.1 Analyses Addressing Operational Requirements

The panel-closure system incorporates design features to address a range of ground conditions, including the most severe ground conditions expected in the air-intake and air-exhaust drifts. The alternatives for dealing with the most severe ground conditions include excavating the fractured disturbed rock zone (DRZ)[2] and installing an enlarged concrete barrier or partially enlarged concrete barrier with interface grouting or emplacing a standard concrete barrier with formation grouting. To evaluate the effectiveness of these alternatives for a panel-closure system, air-flow analyses and structural analyses were performed. The air-flow analyses examined the flow of VOCs through the panel-closure system for these alternatives.

The flow of VOCs is influenced by interface stress development. At the interface, the flow was assumed to be equivalent to a fracture zone. To investigate interface-stress development and the influence of barrier shape, structural analyses were performed for the main concrete barrier. These structural analyses were then used to determine the loads on the main concrete barrier.

The following sections address the air-flow analyses, the advection/dispersion analysis, and the stress analyses that support the trade-off study for designs with or without DRZ removal for overall protection of human health and the environment and compliance at the WIPP site boundary.

[2]DRZ removal is used in the context of the removal of fractured rock in the DRZ.

2.1.1 Air-Flow Analyses

The purpose of the air-flow analysis was to evaluate the trade-offs among a standard concrete barrier with formation grouting, a partially enlarged concrete barrier with partial DRZ removal (roof), and a fully enlarged concrete barrier with complete DRZ removal. Subsequent analyses were performed to evaluate air flow for these alternatives. The air-flow model (DOE, 1995) was used to evaluate the effective intrinsic barrier permeability of the main concrete barrier for these alternatives and to assess VOC flow performance.

In previous studies (DOE, 1995), two air-flow models were evaluated: 1) unrestricted flow, and 2) restricted flow through a panel-closure system. Unrestricted air flow is defined as flow in which the gas pressure develops at or very near atmospheric pressure. No back pressure exists in the waste emplacement areas. Restricted flow is defined as flow in which a back pressure develops due to the restriction of flow through the barrier and the surrounding disturbed rock zone. The analyses were based on an assumed gas generation rate of 8,200 moles per panel per year (0.1 moles per drum per year) due to microbial degradation, an expected volumetric closure rate of 28,000 ft^3 (800 m^3) per year due to salt creep, the expected headspace concentration for nine VOCs, and the expected air dispersion from the exhaust shaft to point of compliance, the WIPP site boundary. The previous analyses indicated that the panel-closure system would limit the concentration (Figures 2-1 and 2-2) of each VOC to a small fraction of the health-based exposure levels during the operational period at the WIPP site boundary.

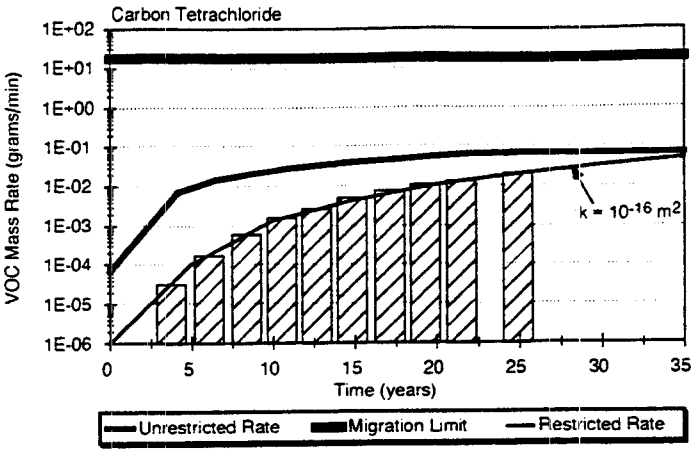
2.1.1.1 Evaluation Procedure

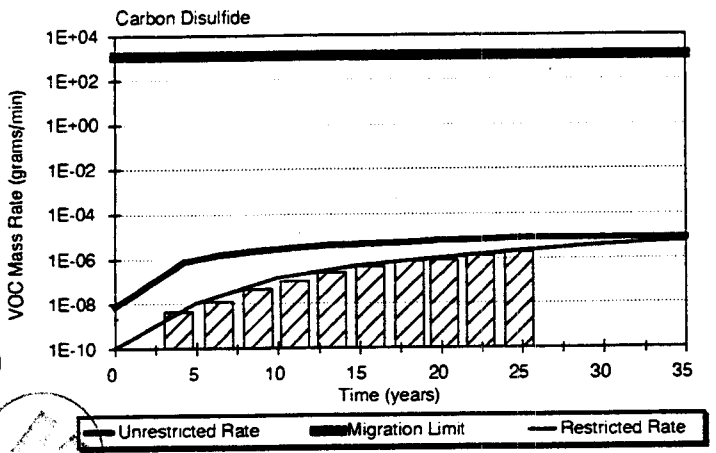
In the following analysis, the gases generated in the waste-emplacement area are in part compressed in the void space within a panel and in part flow into the main return air. The following assumptions were made in this model:

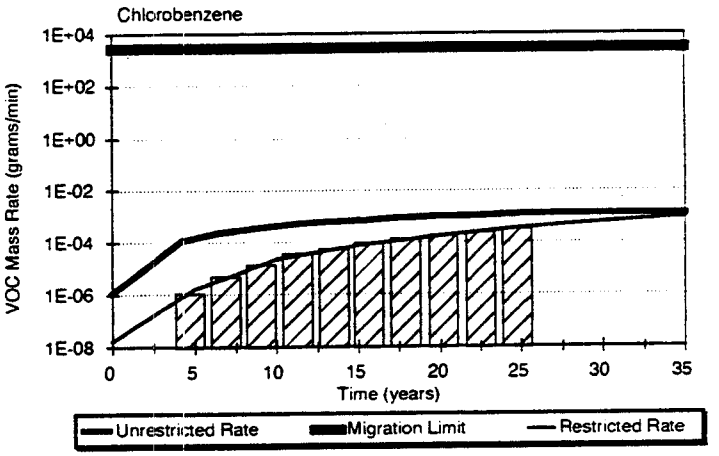
- That the gases (including VOCs) within the void space will obey the ideal gas law. The gases will be generated at a rate of 0.1 moles per drum per year and will be stored by an increase in gas pressure. The rate of pressure buildup will be so gradual that it occurs at constant temperature.

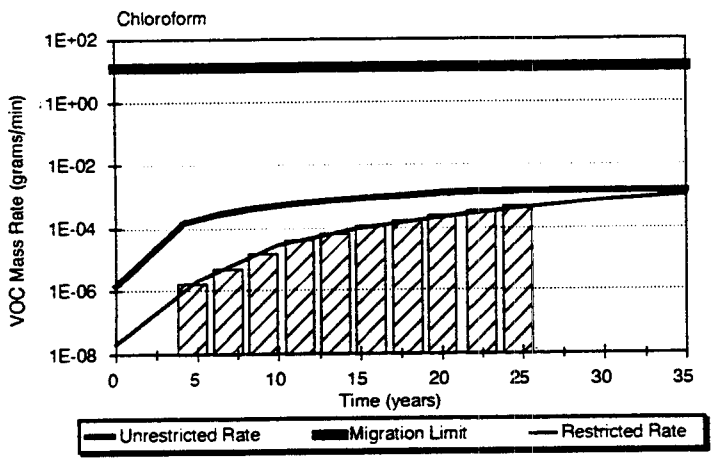
- That volumetric reduction due to creep will reduce the void space at a rate of 28,000 ft^3 (800 m^3) per year and will result in pressurization.

- That the flow of gas out of the panel will obey Darcy's law under quasisteady-state conditions. Under quasisteady-state conditions, the air pressure within the panel-closure system will change so gradually that the compressive storage of the air within the void space of the panel-closure system could be neglected.









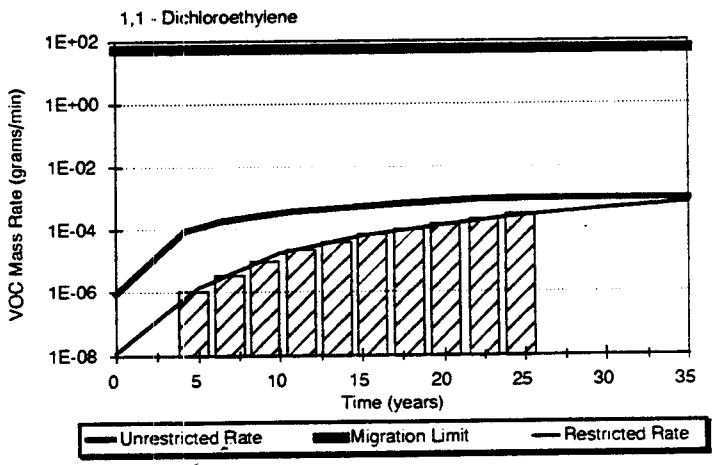


Figure 2-1

Closed-Panel Release Rate Versus Limit Comparison for Carbon Tetrachloride and Other VOCs

(After DOE, 1995)

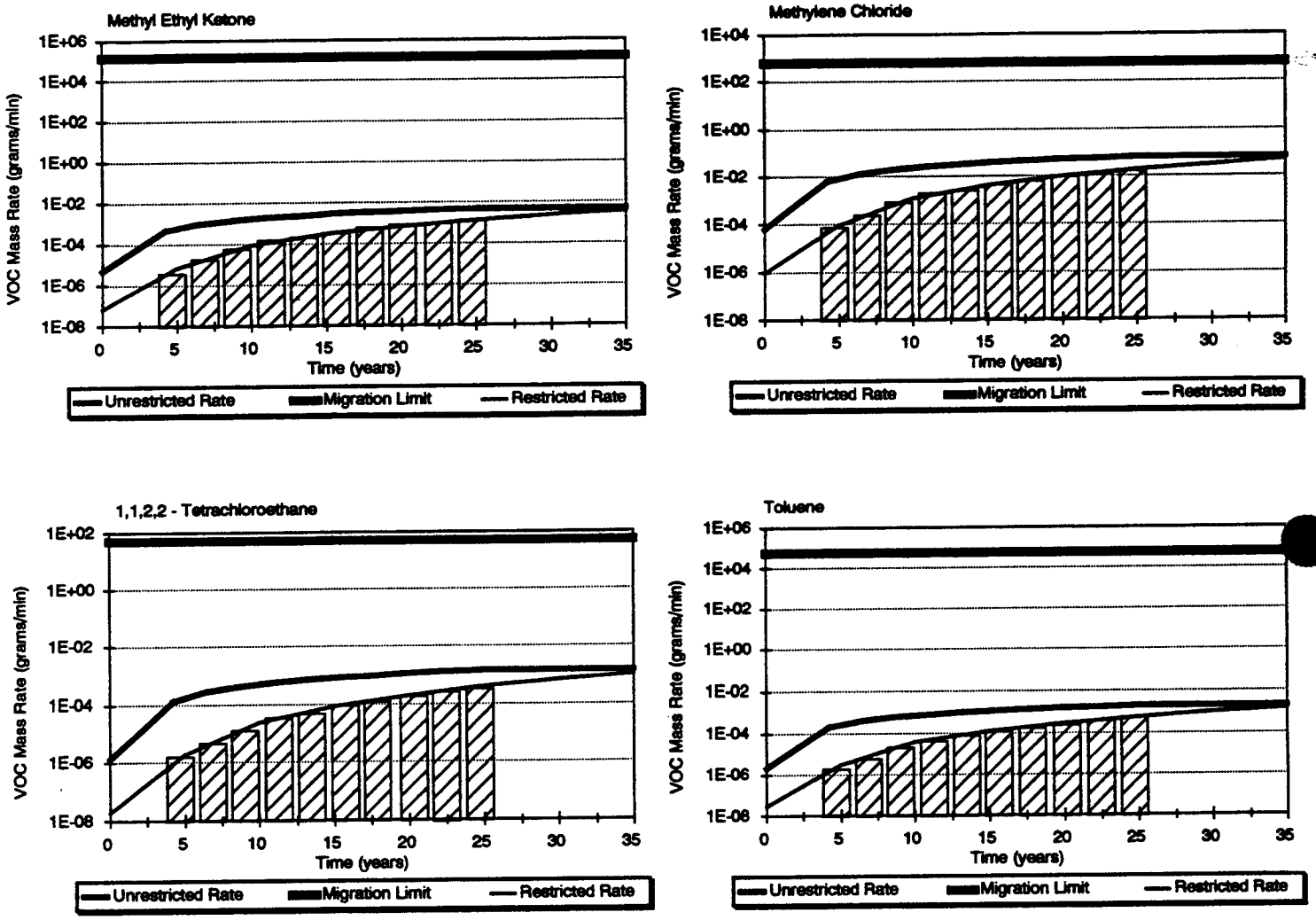


Figure 2-2

Closed-Panel Release Rate Versus Limit Comparison for Other VOCs

(After DOE, 1995)

- That the rates of gas generation, air outflow, and change in compressive storage will balance.
- That hydrodynamic dispersion will be neglected in the analysis.
- That the analysis will consider the superposition of flow rates from individual panels according to the operating schedule for an operational life of at least 35 years.

The air flow under these assumptions follows a nonlinear first-order ordinary differential equation. The model is characterized by molar gas generation and a reduction in void volume that results in an increase in air pressure.

The problem can be stated by solving the system of nonlinear ordinary differential equations as derived in Appendix A:

$$\frac{dP}{dt} = R * T * \frac{\left(g_r - \frac{P}{RT} * C * \frac{P - P_{atm}}{\gamma}\right) * V - n\frac{dV}{dt}}{V^2}$$

$$\frac{dn}{dt} = g_r - \frac{P}{R*T} * C * \frac{P - Patm}{\gamma}$$

where

dt	=	Change in time (years)
R	=	Universal gas constant
T	=	Absolute temperature
n	=	Moles of gas in the panel that is a function of time
P	=	Pressure
P_{atm}	=	Atmospheric pressure
C	=	Conductance of the panel-closure system = $K_s * \frac{A}{L}$
K_s	=	Air conductivity of the panel-closure system
A	=	Cross sectional area of the panel-closure system
L	=	Flow path length of the panel-closure system
γ	=	Air density
g_r	=	Gas generation rate
V	=	Panel volume

$\frac{dV}{dt}$ = Panel volumetric-closure rate

$\frac{dP}{dt}$ = Panel-pressure rate

$\frac{dn}{dt}$ = Panel-molar storage rate.

The above relationships are subject to the following initial conditions: (1) that the pressure in the panel will be atmospheric, and (2) the moles equals the moles of gas occupying the initial panel void volume at the temperature of the repository.

The analysis assumed that the volume of the waste is equal to the total waste capacity of a panel (600,000 ft^3 [16,990 m^3]) (DOE, 1994a) times the assumed average solid volume of the waste drums (23 percent) (IT, 1994). The analysis uses a solid waste volume equal to 138,000 ft^3 (3,910 m^3) for the panel and this volume remains constant during the operational life of the panel. The analysis then evaluates the void volume at panel closure, approximately four years after panel excavation.

The waste-emplacement capacity of a panel includes the seven rooms and the panel-access drifts from Room 1 to Room 7. The analysis uses closure rate and total closure data from the Geotechnical Analysis Report (DOE, 1994b). A combination of field data and empirical analysis is used to determine long-term closure rates for 35 years as presented in Appendix B.

The effective conductivity (K_s) can be further expressed in terms of an effective intrinsic panel-closure system permeability as (Freeze and Cherry, 1979):

$$K_s = \frac{k_s * \rho * g}{\mu}$$

where

K_s = Air conductivity
k_s = Effective concrete barrier permeability (m^2)

ρ = Mass density
g = Acceleration due to gravity
μ = Absolute viscosity.

The calculations assumed that the cross-sectional area for flow through the DRZ and the panel-closure system will equal 9 times the air-intake and air-exhaust area or that the DRZ extends out 3 radii from the center. Case and Kelsall (1986) evaluated permeability measurements performed by Peterson et al. (1985). These data showed a zone of increased permeability (10^{-18} to 10^{-20} ft^2 [10^{-19} m^2 to 10^{-21} m^2]) from (3 to 42 ft [1 to 14 m]). The boundary of the DRZ used in the analysis falls within their range.

The effective intrinsic permeability was calculated by considering the permeabilities over their respective areas of the various media, as presented in Table 2-1. The assumed flow path length equaled 26 ft (7.92 m). The effective permeability was equal to 1×10^{-15} ft^2 (10^{-16} m^2) for the standard concrete barrier with formation grouting. For an enlarged concrete barrier with complete DRZ removal, the effective permeability would equal 1×10^{-16} ft^2 (10^{-17} m^2).

Table 2-1
Intrinsic Permeability of Flow Components

Component	Intrinsic Permeability		Reference
	ft^2	m^2	
Dilated salt	10^{-18}	10^{-19}	Cook and Case, 1991
Fractured salt (grouted)	10^{-15}	10^{-16}	DOE, 1995
Clay seams	10^{-16}	10^{-17}	Freeze and Cherry, 1979
Concrete barrier	10^{-18}	10^{-19}	Gulick and Wakeley, 1989
Marker Bed 139	10^{-15}	10^{-16}	DOE, 1995
Interface zone	10^{-10}	10^{-11}	Fernandez et al., 1994

2.1.1.2 Modeling Results

Figure 2-3 shows that, after closure, the pressure within the panel will build up gradually, due to the large compressibility of the panel void space relative to the air flow rate out of the

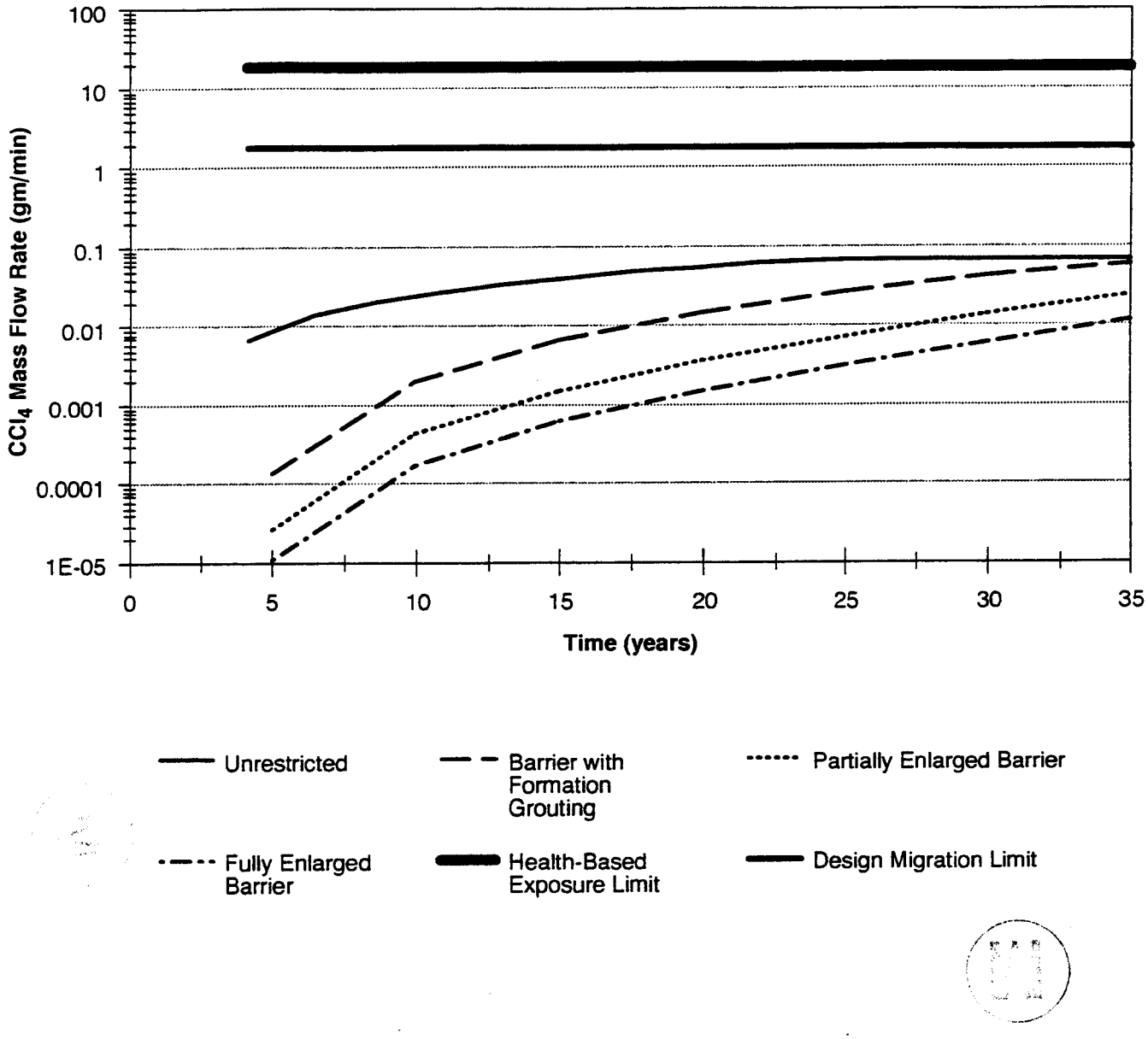


Figure 2-3
Air-Flow Analyses Using Several Alternatives

panel. The panel-closure system will be effective in restricting flow to a value less than the unrestricted flow rate during this period.

2.1.1.3 Conclusions

The air-flow model (DOE, 1995) was used to predict the performance of a grouted standard concrete barrier, a partially enlarged concrete barrier, and a fully enlarged concrete barrier for the mass flow rate of carbon tetrachloride. The analysis suggests that the alternate barrier systems would be effective in restricting air flow over the operational period and that the panel-closure system will restrict flow to at least 1 order of magnitude below the health-based migration limit in preventing the release of VOCs (Figure 2-3).

2.1.2 Advection/Dispersion Evaluation

The purpose of the advection/dispersion evaluation was to assess contaminant transport time through various media. The panel-closure system will be constructed to reduce the air flow-rate by using compressive storage in the panel void space. The model (DOE, 1995) showed that the panel-closure system will restrict transient flow for at least the operational period to an effective gas-generation rate that is substantially less than the steady state flow rate of about 35,000 ft^3 (1,000 m^3) per year.

2.1.2.1 Evaluation Procedure

As panel pressure develops with time, the gases generated from the waste will travel through the panel-closure system to the active underground workings. The model (DOE, 1995) considered that the VOC concentration front will instantaneously develop in the active underground workings and the gases would advect due to velocity variations as panel pressures increased. The more detailed analysis presented below considers the flow distribution and how the concentration of VOCs would be affected by the mechanisms of advection and dispersion. If movement were slow through the panel-closure system, the breakthrough would be delayed.

The relative significance of each of the air-flow zones can be evaluated by studying flow conductance. The flow conductance through the panel-closure system is given by the equation:

$$C = \sum \frac{K_i * A_i}{L_i}$$

where:

C	= Flow conductance
K_i	= Air conductivity of the ith component
A_i	= Cross sectional area of the ith component
L_i	= Length.

The conductance through the panel-closure system will depend on the cross-sectional area and the length. Table 2-2 summarizes the values for each component. The calculations show that flow through fractured salt and MB 139 will dominate the conductance.

Table 2-2
Air Conductance Through System Components

Component	Effective Porosity	Air Conductivity (meters per second)	Approximate Cross-Sectional Area ($meter^2$)	Conductance per Unit Length ($meter^3$ per second)
Dilated salt	0.001	6.2×10^{-14}	170	1.0×10^{-11}
Fractured salt	0.040	6.2×10^{-10}	16	9.9×10^{-9}
Clay seams	0.400	6.2×10^{-12}	0.09	5.6×10^{-13}
Marker Bed 139	0.040	6.2×10^{-11}	11	6.8×10^{-10}
Concrete barrier	0.200	6.2×10^{-14}	27	1.7×10^{-12}

The contaminant breakthrough of VOCs through the panel-closure system under the assumption of advection will occur when the contaminant front traversed the length. The average linear velocity equals the Darcy flux divided by the effective porosity for the various flow components. The average linear velocity that varies with time is given by:

$$V(p(t))_{avg_i} = \frac{K_i * (p(t) - p_{atm})}{n_e * L * \gamma}$$

where:

$V(p(t))_{avg_i}$	=	Average linear velocity for the ith component
K_i	=	Air conductivity
$p(t)$	=	Panel pressure as a function of time
P_{atm}	=	Atmospheric pressure
L	=	Length of the barrier
γ	=	Air density
n_e	=	Effective porosity.

The second evaluation of the air-flow modeling evaluated the effects of hydrodynamic dispersion on contaminant transport, using a one-dimensional dispersion model. This model was chosen to evaluate the effects of dispersion on VOC migration rates through the panel-closure system. To isolate the effects of mechanical dispersion, molecular diffusion was considered insignificant. The advection-dispersion equation is given by Freeze and Cherry (1979):

$$C = \frac{C_0}{2}\left[erfc\left(\frac{L - V_x * t}{2\sqrt{D_L * t}}\right) + exp\left(\frac{V_x}{D_l}\right) erfc\left(\frac{L + V_x * t}{2\sqrt{D_L * t}}\right)\right]$$

where

$$D_L = a_L V_x + D^*$$

and

erfc	=	Complimentary error function
D_L	=	Longitudinal coefficient of dispersion
a_L	=	Dispersivity
V_x	=	Average linear velocity
C	=	Concentration of contaminant at time t
D^*	=	Molecular diffusion
C_0	=	Initial concentration
t	=	Time
L	=	Length.

- That the air-flow velocity will be constant.
- That the gases (including VOCs) within the void space will obey the ideal gas law.
- That the flow of air out of the panel will obey Darcy's law under quasisteady-state conditions. Under quasisteady-state conditions, the air pressure within the panel-closure system will change so gradually that the compressive storage of air within the void space of the air-intake and air-exhaust drifts will be neglected.
- That two-phase flow and interactions between air and brine will be neglected, although the resaturation of salt would tend to reduce the flow of VOCs through the barrier system.

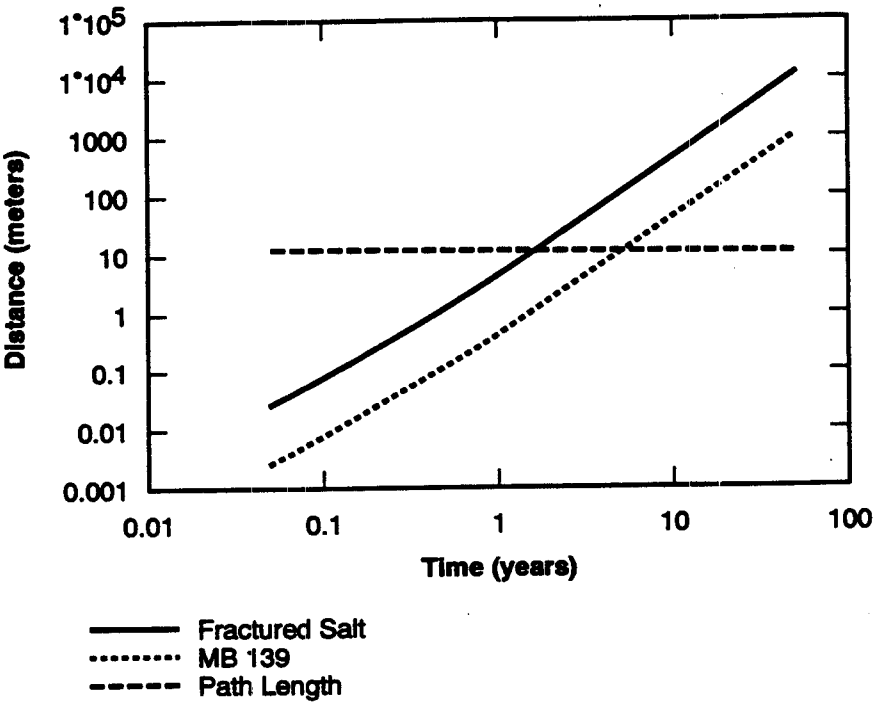
The air-flow velocity was calculated for each component of the panel-closure system using the maximum pressure determined from the air-flow model (DOE, 1995). Once a constant velocity was calculated for each component, the concentration as a function of time was determined for each of the panel-closure system components: fractured salt, fractured anhydrite, clay seams, and the standard concrete barrier.[3] To study the effects of dispersion, a range of different dispersivities was used. Mass flow as a function of time was then determined for carbon tetrachloride and was summed over all components of the panel-closure system.

2.1.2.2 Modeling Results

In the model presented for air flow, the pressure varies as a function of time for flow through the panel-closure system. This will result in a change in the average linear velocity as a function of time that was calculated for each of the various components: fractured salt, MB 139, clay seams, and the panel-closure system. The average linear velocity was then integrated over time.

Breakthrough times for a panel-closure system length of 40 ft (12 m) were computed (Figure 2-4). The analysis suggests that contaminant breakthrough through fracture zones may occur within one to several years, while contaminant breakthrough in the barrier and the dilated salt would not be expected during the WIPP operational period. The analysis shows that for fractured components with high air conductivity and low fracture porosity, large linear velocities result, with breakthrough occurring within months of panel closure. For the

[3]No credit is taken for the explosion isolation or construction isolation wall which is a conservative assumption.



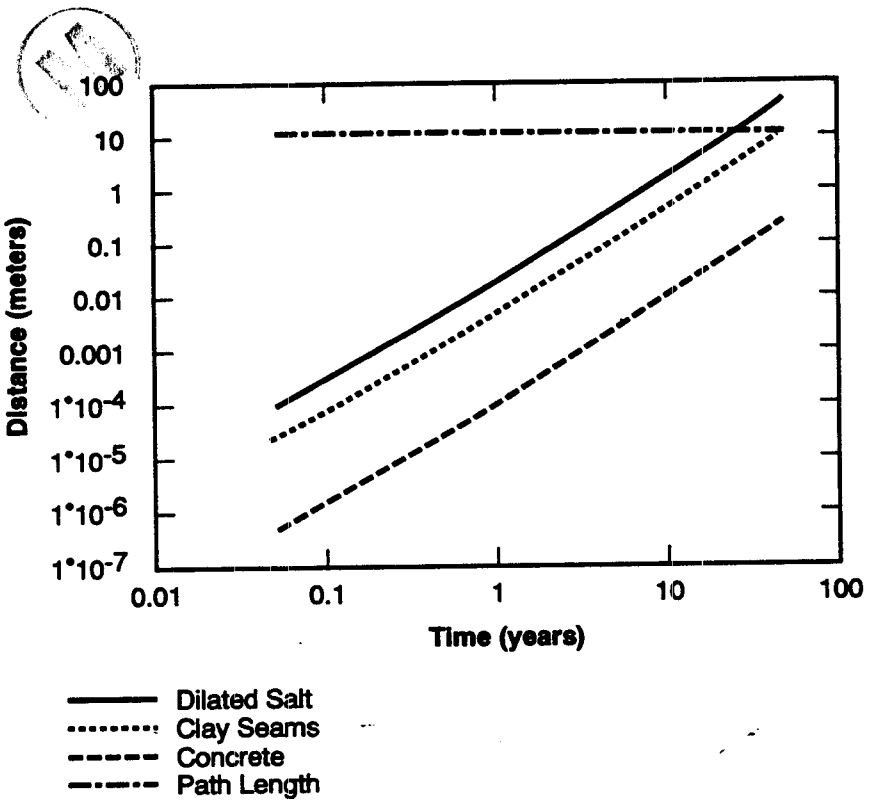


Figure 2-4
Breakthrough Time for VOCs through Several Media

other components, with much lower air conductivity and higher effective porosity the breakthrough would occur many years after panel closure.

In summary, the results of more detailed air-flow modeling suggest the appropriateness of the model for the instantaneous breakthrough of contaminants and the insignificance of dispersion. The results of the air-flow model emphasize the importance of treating fracture zones, either by removal or by grouting for restricting the flow of VOCs.

The results from the second evaluation support the conclusion that breakthrough of VOCs will occur rapidly through the dominant paths of the fractured salt and fractured anhydrite. Because of this, the effects of dispersion will be insignificant on the VOC mass flux.

2.1.2.3 Conclusion

In conclusion, because air-flow modeling results show that breakthrough will occur rapidly and that the effects of hydrodynamic dispersion will be insignificant, the air-flow model (DOE, 1995) is conservative and appropriate.

2.1.3 Stress Analysis

The purpose of the stress analysis was to evaluate the interaction of the main concrete barrier of the panel-closure system with the surrounding salt for different combinations and geometries. The panel-closure system will consist of: (1) a standard concrete barrier or (2) an enlarged concrete barrier. Options (1) and (2) will contain interface grouting and be combined with an explosion-isolation or construction-isolation wall. The walls will isolate the concrete barrier from the waste-emplacement panel and the effects of a postulated methane explosion. Stresses are expected to develop in the concrete-barrier component due to continued primary and secondary creep closure of the air-intake and air-exhaust drifts after installation of the concrete barrier. An estimate of the stress levels expected in the concrete barrier determined the deformability and strength required for the concrete. The development of stresses in the salt around the concrete barrier was also evaluated to estimate the time required for DRZ healing for these options.

2.1.3.1 Evaluation Procedure

The evaluation was performed using the FLAC computer code (Itasca, 1995). Six detailed structural-analysis models were prepared to evaluate the salt/structural interaction of the proposed system. These models included two transverse-plane strain models across the air-intake and air-exhaust drifts associated with a waste-emplacement panel, two long

axisymmetric models, and two short axisymmetric models. The properties used in these models were taken from the Backfill Engineering Analysis Report (IT, 1994) as presented in Appendix C.

2.1.3.2 FLAC Models

Since 1991, FLAC has been used to model underground excavations at the WIPP. FLAC is a two-dimensional, explicit finite difference code that simulates the behavior of rock and soil-like structures. The WIPP Reference Creep Law is built into FLAC and has been verified to U.S. Nuclear Regulatory Commission standards (Itasca, 1995). In addition, FLAC has been verified against the WIPP Second Benchmark Problem (Krieg, 1984). The following subsections describe the geometry and boundary conditions of the model used in the FLAC analysis.

Plane-Strain Model Geometry. Two cross-sectional transverse plane-strain models were run using the air-intake and air exhaust drift geometries. These models used a simplified stratigraphy for approximately 250 ft (75 m) above and below the excavation horizon (Figure 2-5). The models included the interaction of the excavation and the main concrete barrier with MB 139 over time. The cross-sectional dimension of the air-intake drift is 13 by 20 ft (4 by 6 m), while the air-exhaust drift is 12 by 14 ft (3.6 m by 4.3 m). Each model was run with the initial excavation and allowed to creep for a period of 5 years,[4] the time expected for panel excavation and waste emplacement. After 5 years, the drift at the concrete barrier location was excavated just beyond Clay G and Clay E, removing MB 139, and the ribs were excavated to curved segments between these clays. Each model was then run for an additional month simulating the time required to excavate the enlarged area and install the concrete barrier. After the enlarged excavation was open for one month, the model was continued with the installed concrete barrier. The actual construction schedule may be longer for the enlarged barrier; however, the effects on long-term interface stress buildup will be insignificant. As the stresses increased in the concrete barrier and the surrounding salt the model was run for an additional 35 years, representing the required period of performance for a concrete barrier.

[4]For Panel One, the period between excavation and barrier emplacement would be greater than 5 years. A longer period of time might result in more bed separation. However, since fractured salt is removed to Clay G and the barrier is placed over a short period, the design is considered robust, and the effects of a longer period for Panel One are insignificant.

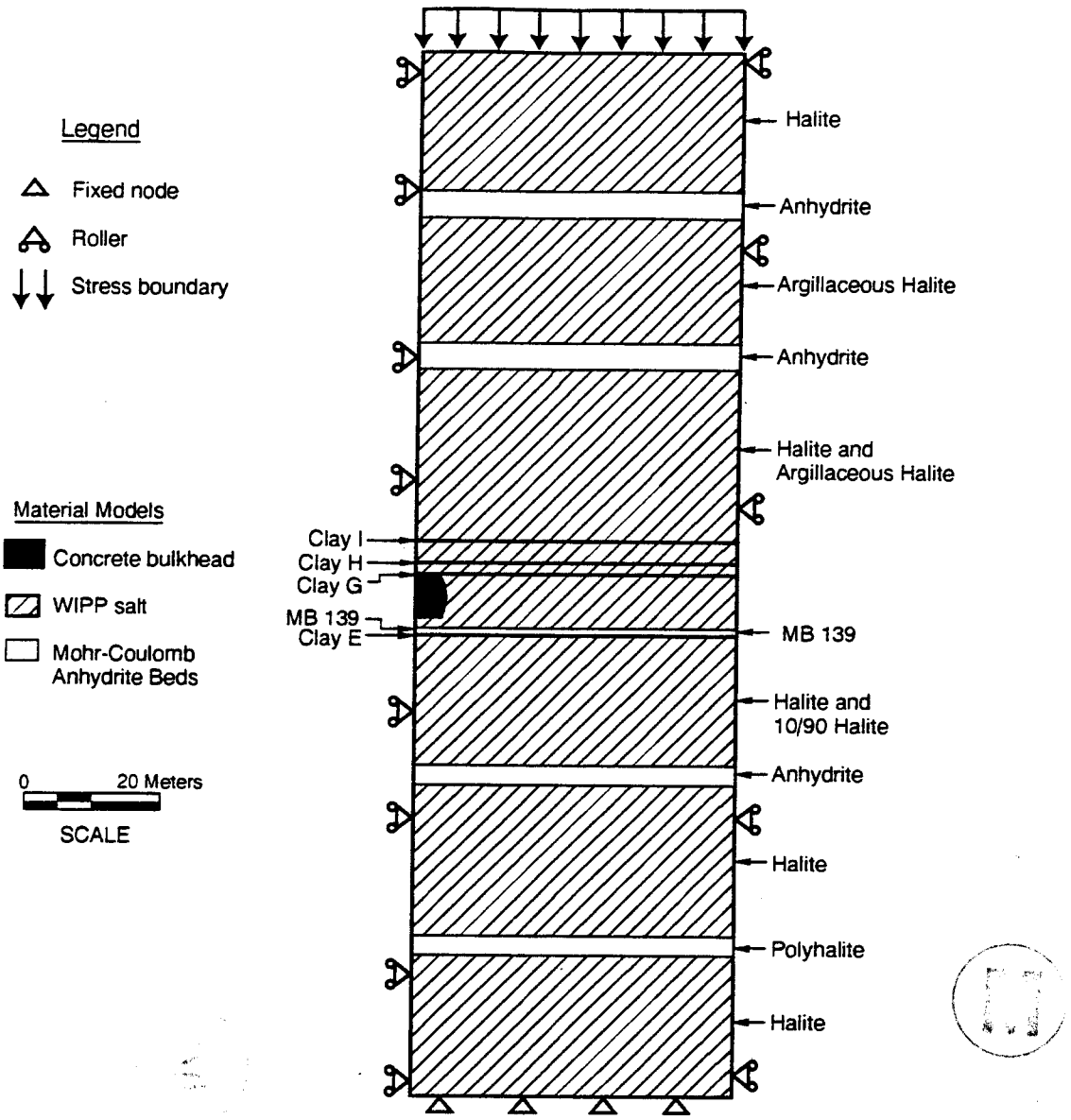


Figure 2-5
Transverse Model for FLAC Analysis

Axisymmetric Models. Four axisymmetric models were run to evaluate the long-term loadings expected on the ends of the concrete barrier. The models (Figure 2-6) were simplified using a homogeneous salt and radial loading. The model for the concrete barrier was symmetrical around the central axis. The cases illustrate that the presence of the barrier ends will result in a longer cylindrical barrier, and that the shorter barrier with the two plug ends will result in a more tapered shape.

Material Properties Used in Modeling. The material properties used for the reference stratigraphy presented in the Backfill Engineering Analysis Report (IT, 1994) were used in the FLAC analysis. These properties (Appendix C) included the elastic, primary creep, and secondary creep constitutive properties of the halite, polyhalitic halite, and argillaceous halite. They also included the elastic properties of the anhydrite and the concrete.

Modeling Results—Transverse Plane-Strain Models. The results of the transverse plane-strain models suggest that higher stresses will form in MB 139 following excavation, but that after barrier emplacement, an increase in barrier-confining stress and a reduction of shear stress will occur in and around the barrier. The results further suggest that substantial uniform confining stresses will develop as the barrier is subjected to the secondary salt creep.

Modeling Results—Axisymmetric Models. The results of the axisymmetric models agree with the results of the transverse models for the prediction of interface stress and suggest the appropriateness of an axisymmetric model to evaluate the long-term stress abutment zone effects. The modeling results for the longer cylindrical barrier suggest that the radial stresses increase by a factor of 2 at the ends of the barrier. The high-stress concentration at the ends of the barrier extends a distance of several meters. Tensile stress develops at the ends of the longer cylindrical barrier. The short axisymmetric barrier, with the design achieving a more tapered configuration, shows that a more uniform state of compression develops all around the barrier. The principal stress results after a period of 30 years for this barrier with DRZ removal are presented in Figure 2-7. These results show that the barrier is in a state of overall compression.

2.1.3.3 Stress Analysis of the Concrete Barrier on an Elastic Foundation

An analysis was performed treating the concrete barrier as a beam on an elastic foundation. After several years it is expected that loads would develop uniformly in the concrete barrier; however, the concrete barrier may be subjected initially to nonuniform loading (Figure 2-8).

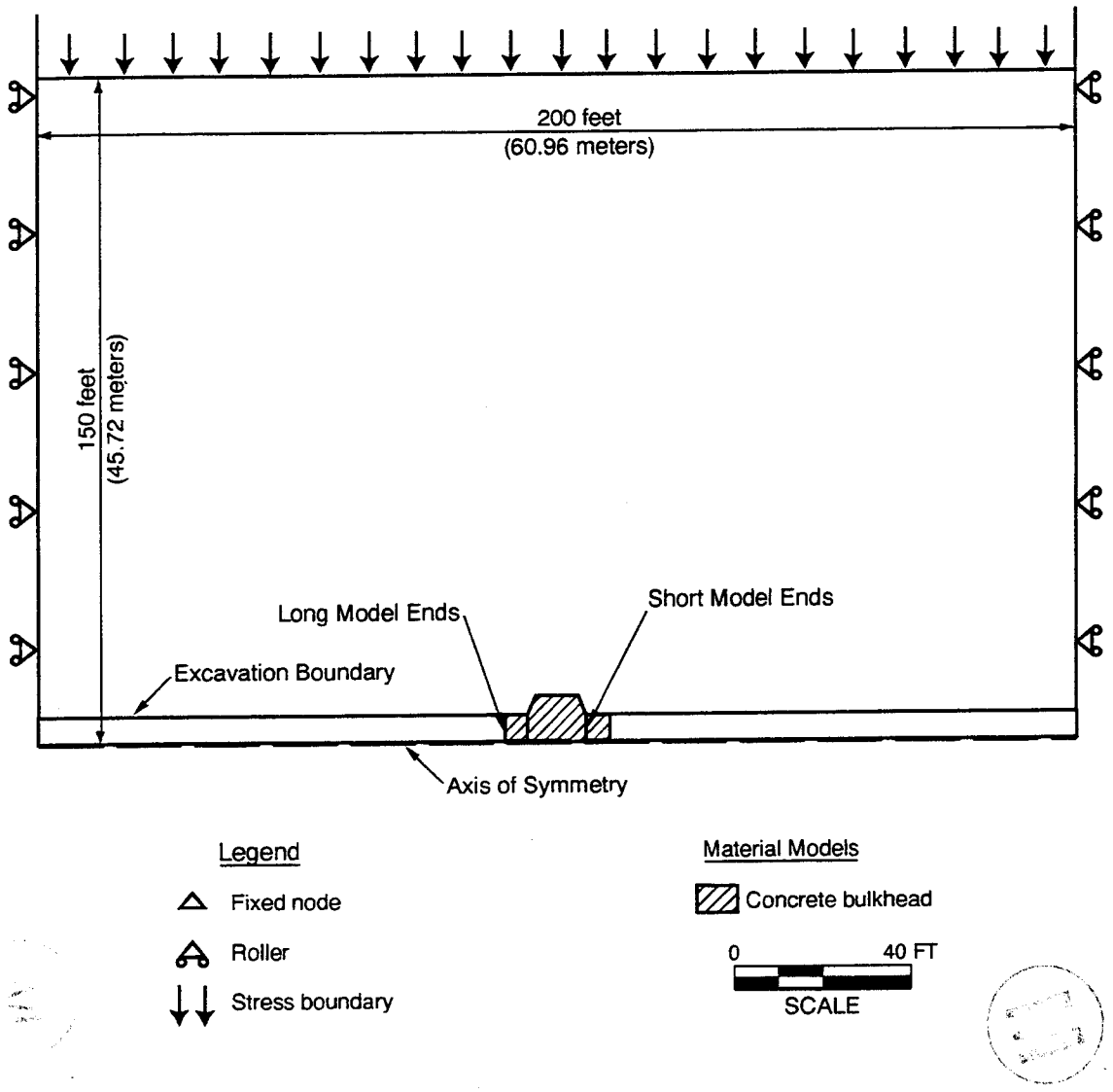


Figure 2-6
Axisymmetric Models for FLAC Analysis

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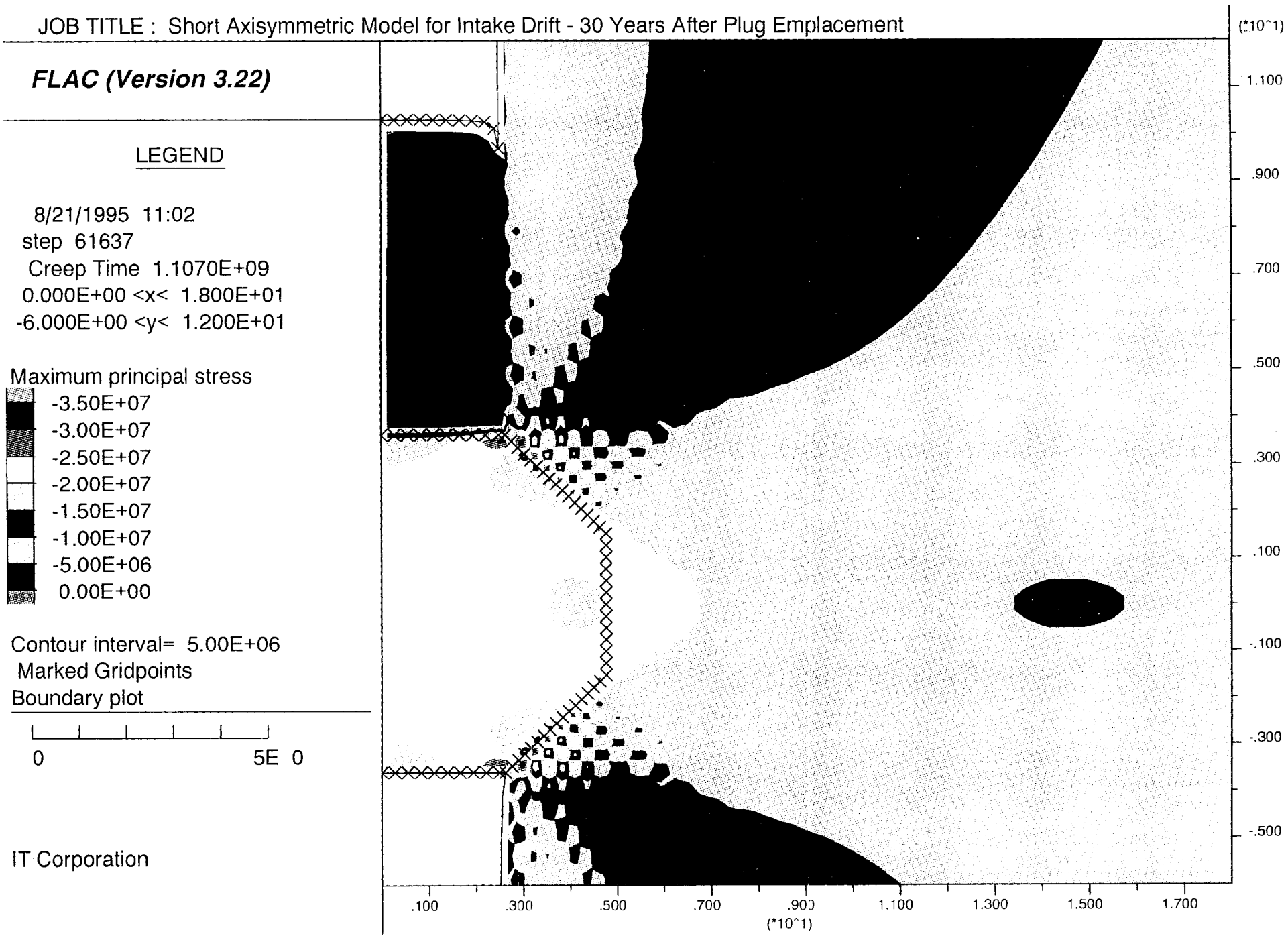

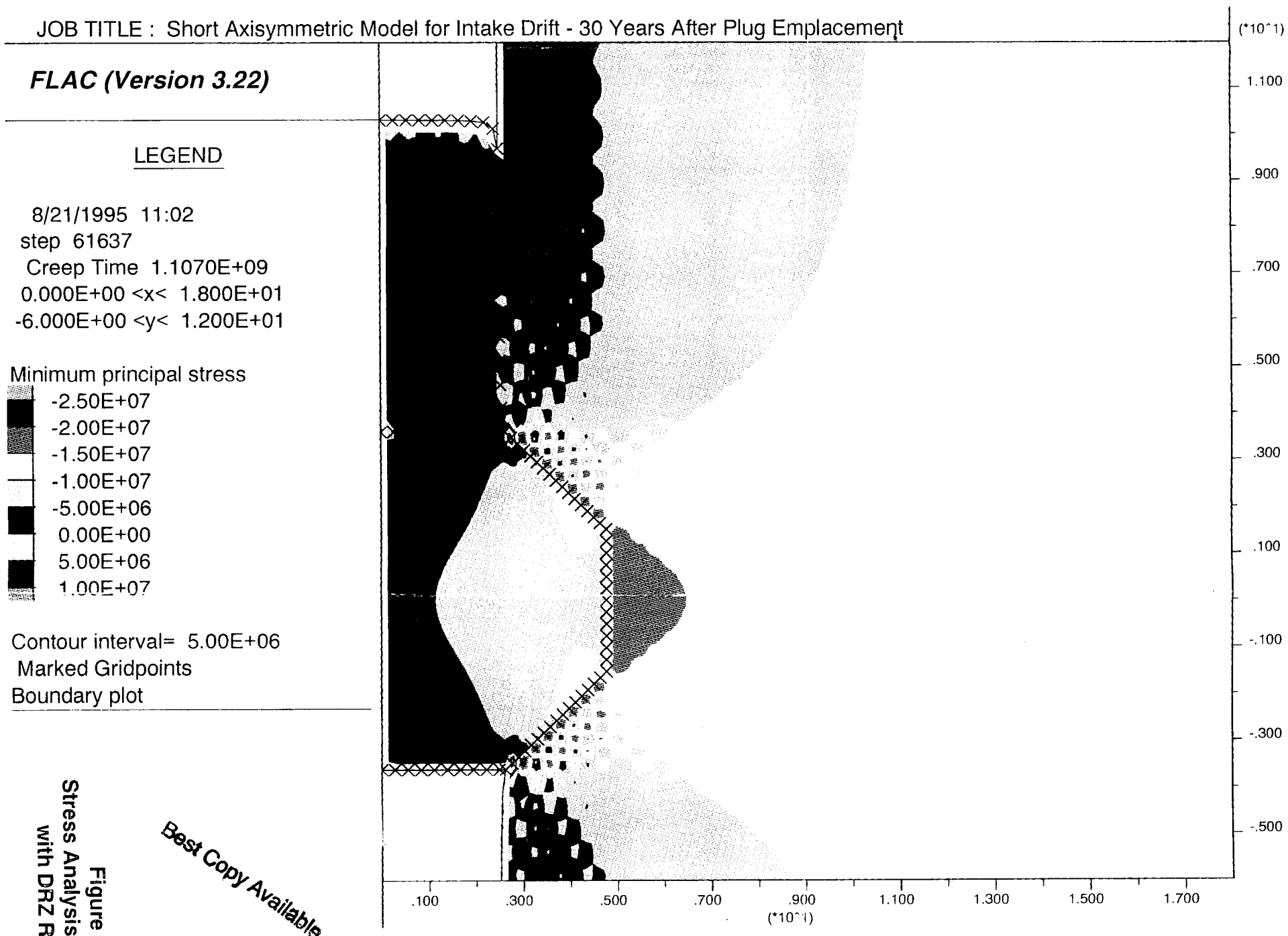

Figure 2-7
Stress Analysis of a Barrier
with DRZ Removal

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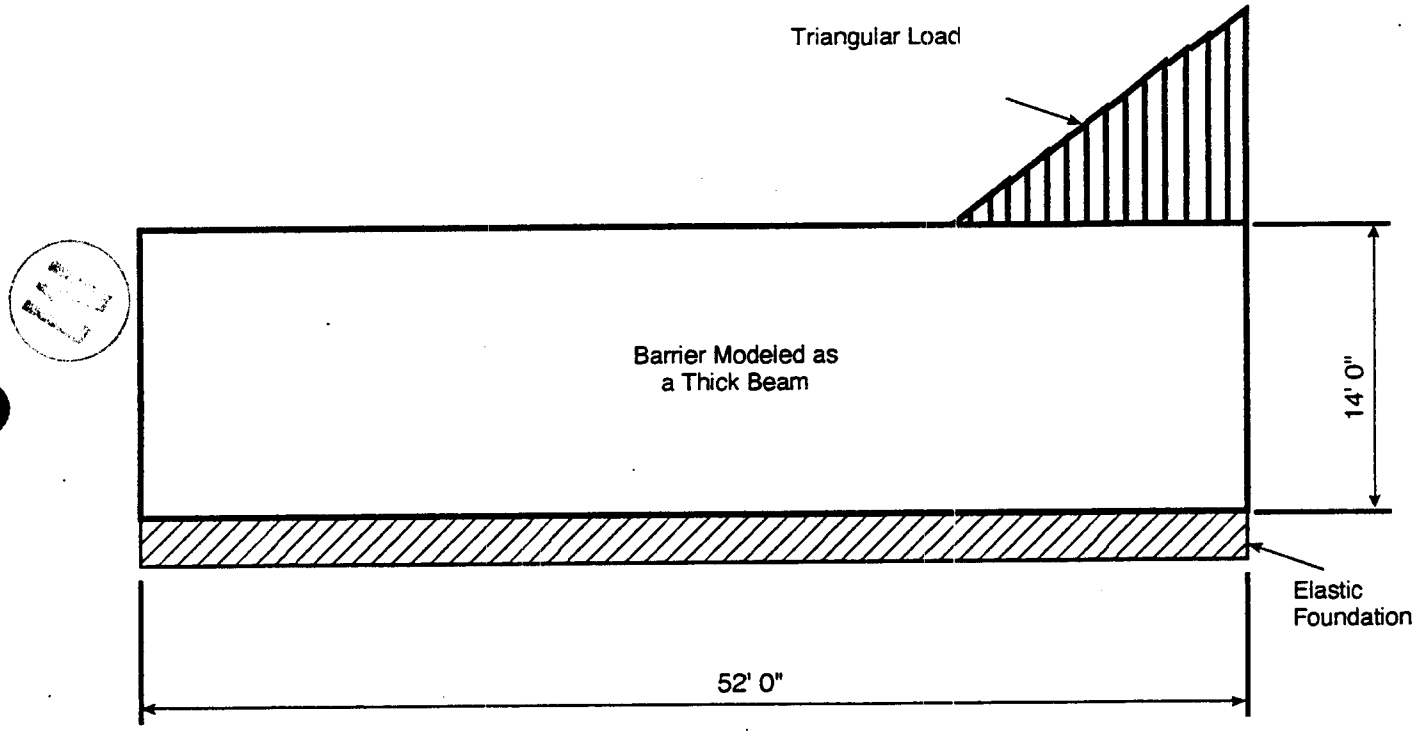


Figure 2-8
Stress Analysis of a Barrier on Elastic Foundation

The analysis of the concrete barrier on an elastic foundation shows that, for various assumed loadings that will develop, the amount of flexure and transverse shear was minimal and would result in insignificant nonuniform load reactions and failure of plain concrete in flexural tension or shear (Figure 2-9). The only manner in which flexure will develop would be through nonuniform loading. The assumed approximate stress gradient for the first room for the Chabannes solution (DOE, 1995) at a distance of 80 ft (24 m) equals 300 pounds per square inch (psi) (2.1 megapascals [MPa]) over 50 ft (15 m). The analysis evaluated the effects of varying the modulus of subgrade reaction for the barrier (equal to 500,000 psi [3,500 MPa]). The results suggest that the potential for flexural tension and shear will be greater when loads were resisted by fractured salt. The removal of fractured salt from the central portion of the excavation should result in a more uniform loading on the barrier and stiffer resistance in reaction that reduces short-term flexural tension and shear.

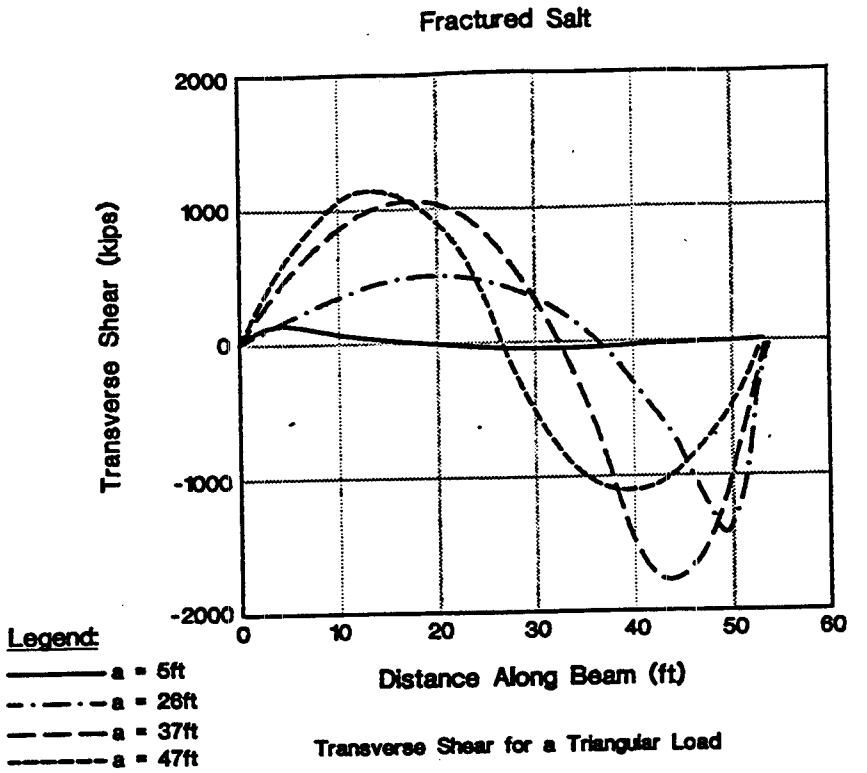
2.1.3.4 Interface Stress Buildup

Previous small-scale sealing studies (Case and Kelsall, 1986) showed that stress in seals in contact with salt develop rapidly (Figure 2-10). As an example, in the 3 ft- (91- centimeter [cm])-diameter plug for the Small Scale Seal Performance Test, interface stress developed to about 1,000 psi (7 MPa) within 1,000 hours. An analysis was conducted to evaluate the effects of concrete barrier stiffness on the recovery of the DRZ for the alternatives. The technical approach to the standard analysis considered an infinitely long cylindrical concrete barrier[5] in an infinite medium (DOE, 1995). Figure 2-11 illustrates that interface stresses for the standard concrete barrier with formation grouting would develop more slowly than the enlarged concrete barrier, resulting in less healing of the surrounding DRZ for at least the 35-year operational period.

2.1.4 Tradeoff Study of Formation Grouting versus DRZ Removal

The purpose of this study was to evaluate the tradeoffs of formation grouting versus DRZ removal for the alternatives for overall protection of human health and the environment. The tradeoff study considered compliance with the design migration limit, barrier effectiveness, and implementability of the design at the WIPP. This evaluation was performed qualitatively through examination of the results of air-flow and stress analyses as presented in previous sections. The alternatives included a standard concrete barrier with formation grouting, a

[5]A cylindrical concrete barrier develops interface stress less rapidly than a spherical concrete barrier. However, the analysis of a cylindrical barrier provides a relative comparison of the effects of fractured salt on the development of interface stress for a long cylindrical barrier.



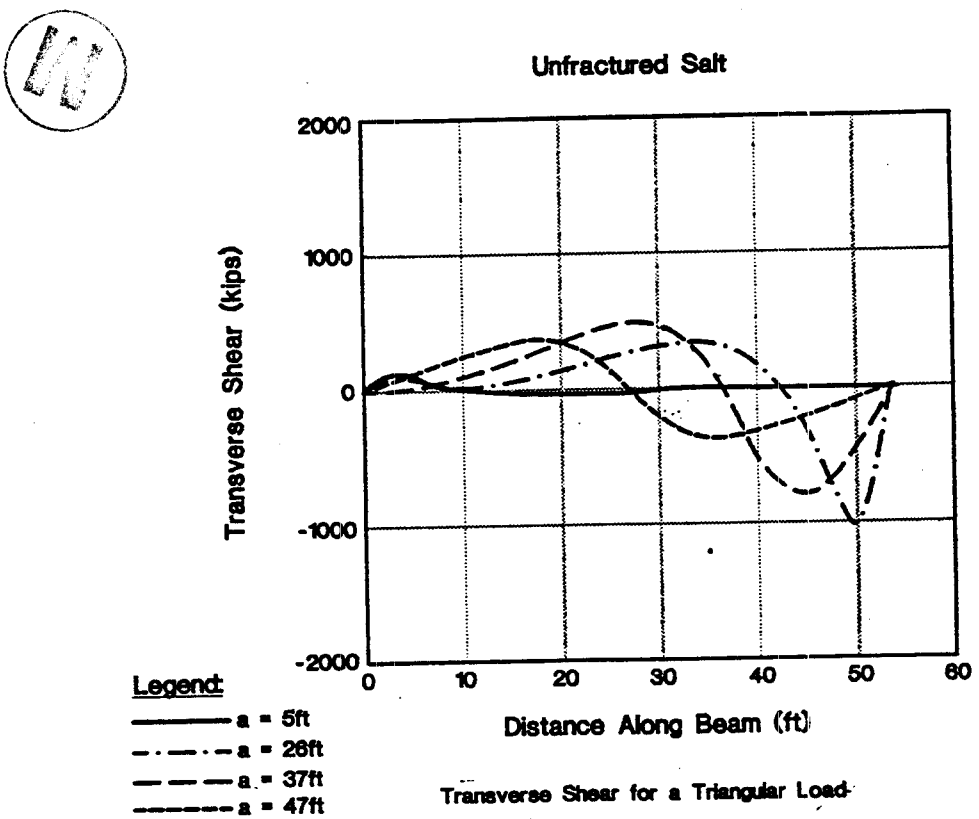


Figure 2-9
Reactive Barrier Loads

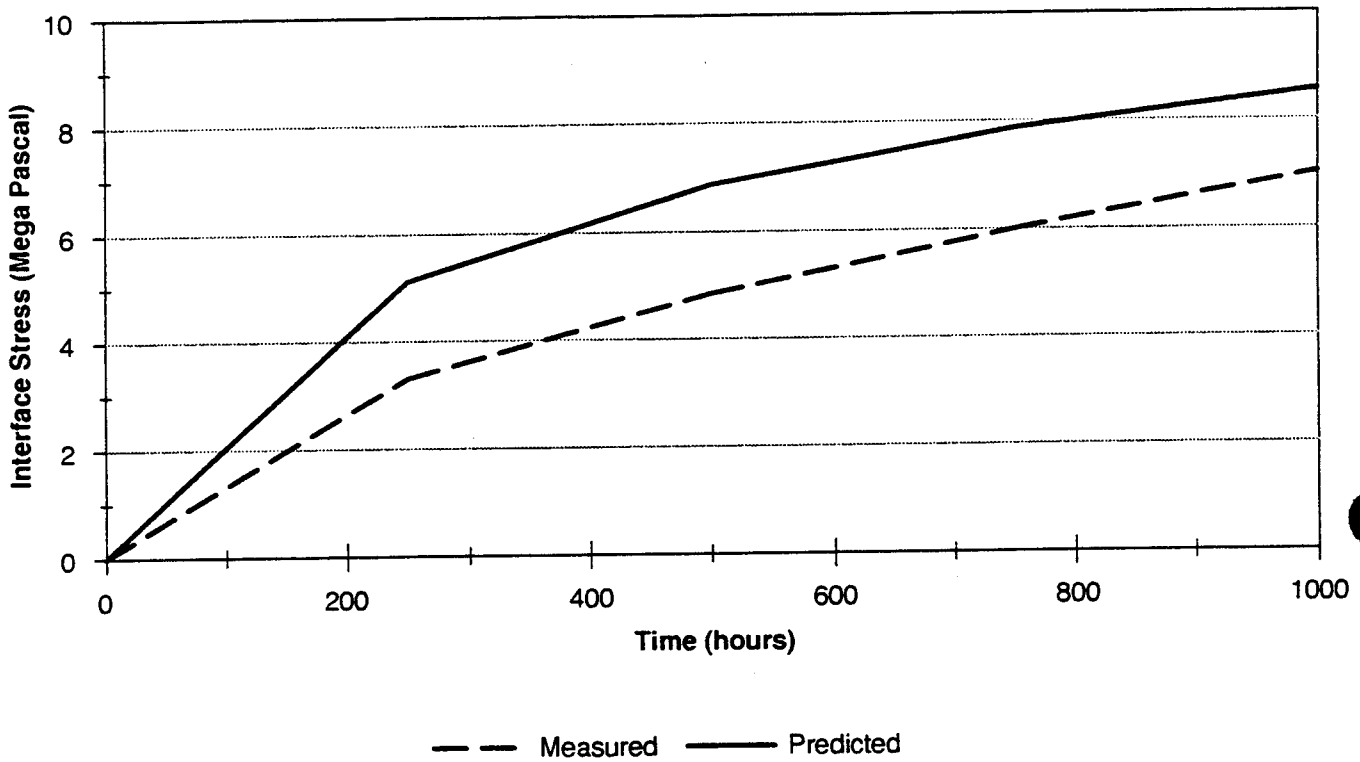


Figure 2-10
Development of Interface Stress in the Large 91-cm-Diameter Plug (After Case and Kelsall, 1986)

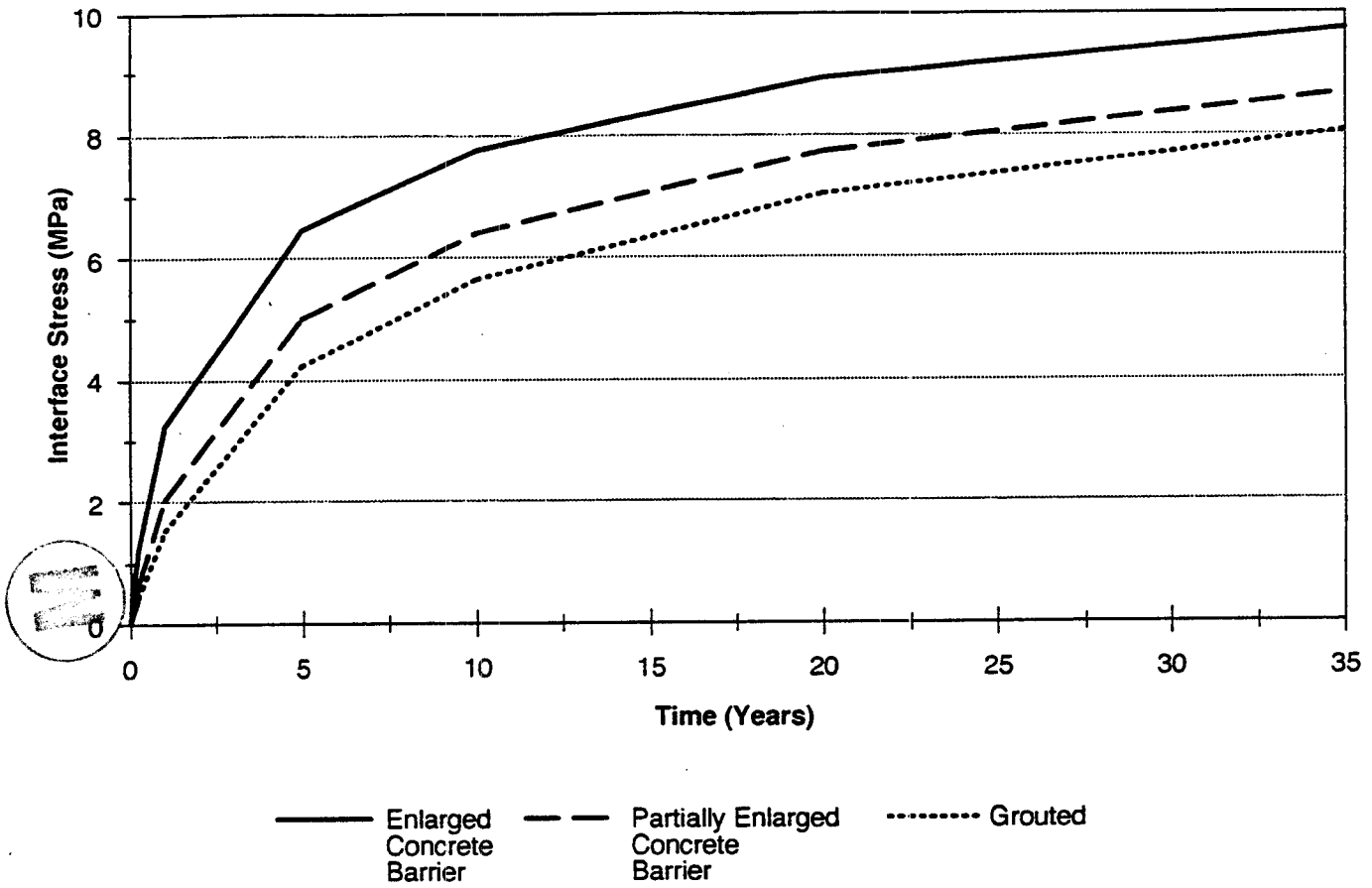


Figure 2-11
Effect of Enlarging Barrier on Interface Stress

partially enlarged concrete barrier with DRZ removal in the roof, and a fully enlarged barrier with complete DRZ removal. In all cases, the most severe ground conditions were considered. Existing information and the previous modeling efforts were combined to provide insight to the performance of the alternatives.

Bench-scale tests done by Terra-Tek showed the importance of interface zone permeability (Fernandez, et al., 1994). For sealed boreholes, flow occurs either through the seal matrix or through the interface zone. These tests showed that the "effective barrier permeability" for flow through the interface zone to be 1 to 2 orders of magnitude greater than the permeability of the plug material. This result supports the theory that the interface zone behaves like a fracture, in that at low effective stress levels, the interface opens and exhibits high conductivity. At higher stress levels, the interface closes and exhibits a much lower conductivity that is independent of effective stress. These studies suggest that the excavation of a more circular shape that reduces stress concentrations and the emplacement of a sufficiently strong barrier that would reduce shear stresses, and increase confining stresses at the interface zone is preferable.

The discussion presented above allows an evaluation of the compliance of the alternatives with the design migration limit and a qualitative evaluation of the effectiveness of the alternatives in light of the previous stress analyses performed. The stress analyses performed suggested that for the barrier with formation grouting, there is a greater potential for barrier flexure when fractures in the surrounding rock are present, and that the interface stress would develop more slowly because of the compliance of these fractures. This will then result in potentially higher VOCs flow through the interface zone, and reduced effectiveness. The development of lower interface stresses would result in lower confining stresses in the surrounding DRZ, and a slower rate of DRZ healing.

In evaluating the tradeoffs among the alternatives, it was noted that all three alternatives could be implemented. Technologies exist for the placement of a barrier with formation grouting (DOE, 1995). Further, methods are available for the excavation of an enlarged barrier with DRZ removal. Fernandez et al., 1989 evaluated various techniques for enlargement of barriers. These included the use of expansive agents, and hydraulic splitters in addition to the methods for continuous mining. The use of expansive agents could be used in the floor to excavate to below MB 139. While the use of these more labor intensive methods would take longer and make barrier emplacement more difficult, the techniques are

nevertheless available. The alternatives involving rock removal can be implemented in the underground WIPP repository.

In conclusion, the evaluations addressing the operational requirements of the panel-closure system show that, for the most severe ground conditions to be encountered, the maximum protection is provided when an enlarged concrete barrier is used. The severity of the ground conditions relate to the size and age of the air-intake and air-exhaust drifts, and the distance to the room intersections. The longer the time period between excavation, and panel closure, the greater the degree of fracturing that could occur. For example, the period of time for Panel 1 has been much longer than the four year period currently planned for other panels. Where the time between excavation and panel is short, fracturing may be absent or inconsequential, and the design can be simplified to a standard barrier with no DRZ removal.

2.2 Structural and Material Requirements

This section presents evaluations relating to the structural and material requirements for the panel-closure system.

2.2.1 Material-Compatibility Evaluations

The purpose of the material-compatibility evaluations is to select the most suitable concrete and grout materials for a panel-closure system. This section evaluates the concrete and grout compositions and their geochemical compatibility with the host rock and brine. This section also evaluates the geotechnical properties and permeabilities of a concrete/grout to liquid phase and gaseous phase contaminants (brine and VOCs, respectively).

2.2.1.1 Evaluation Procedure

Project information was reviewed for appropriate concrete-barrier materials that would minimize VOC migration and cement hydration for candidate materials.

2.2.1.2 Concrete-Barrier Material Candidates

The selection of candidate materials for use as concrete and grout in a panel-closure system requires that numerous criteria be satisfied in terms of the 35-year period of performance. The materials must be chemically compatible with the host rock and brine (Salado Formation) without chemical degradation. Concrete used in the main concrete barrier must be sufficiently strong enough to support lithostatic loads and resist the compressive stress of the creeping salt. The concrete must cure at a low heat of hydration. If the concrete evolves heat too rapidly (i.e., greater than 14 degrees celsius (°C) (25 degrees Fahrenheit [°F]), it may

experience rapid slump loss before hardening and excessive thermal stress after hardening. Slump loss directly affects the workability and pumpability of the concrete. The workability of the concrete must allow ample time and the pumpability must be adequate for installation. The most desirable characteristics for achieving adequate pumpability were a 4-hour working time (Wakeley et al., 1994). The concrete must perform under large-scale installation conditions. Grout must form a tight seal between the concrete barrier and the host rock.

Wakeley et al. (1993) studied and developed (Gulick and Wakeley, 1989) salt-saturated concrete and grout in the floor of the WIPP repository for six years (Appendix D). Then the concrete and grout plugs along with some host rock were overcored. The study concluded that little or no deterioration occurred to the concrete or grout. Overall the compressive strengths increased with time with the lowest values from samples taken in the DRZ. Reaction rims with increased permeability were noted on anhydrite surrounding the plugs, suggesting interaction between the grout or concrete and host rock. There was also evidence of halite dissolution in the anhydrite zone near the plugs; however, the presence of halite facilitated better bonding between the grout or concrete and the host rock. Crystallization of new phases was also noted on free surfaces, indicating that strongly ionic, magnesium-bearing fluids were present and moving. The movement of the fluid improved the bonding with the host rock.

Gulick and Wakeley (1989) proposed expansive salt-saturated concrete (ESC) (Appendix E) and grout mixtures that yielded favorable results for suitability in a panel-closure system. The formulation for their grout mixture is indicated in Table 2-3.

Table 2-3
Salt-Saturated Grout (BCT-1F)

Component	Percent of Total Mass
Class H cement	48.3
Class C fly ash	16.2
Cal seal® (plaster)	5.7
Sodium chloride	7.9
Dispersant	0.78
Defoamer	0.02
Water	21.1

Class H cement is a standard oil-well cement that has been used extensively in grouts and concretes in underground applications. Class C fly ash contributes expansive properties to concrete. Cal Seal® (a plaster of paris, manufactured by Halliburton) also develops expansive properties in mixtures containing Class H cement. Expansive components that are added to the concrete or grout mixtures enhance bonding with the host rock.

Wakeley et al. (1993) later researched concrete mixtures that would behave optimally under the type of large-scale installation conditions associated with the panel-closure system. The concrete mixture was also designed to keep the temperature due to heat of hydration less than 14°C (25°F). The concrete mixture that resulted from this study was termed the Salado Mass Concrete (SMC), and it superseded ESC as the performance mixture (Wakeley et al., 1993). Table 2-4 summarizes the SMC composition.

Table 2-4
Salado Mass Concrete

Component	Percent of Total Mass
Class H cement	4.93
Chem Comp III	2.85
Class F fly ash	6.82
Fine aggregate	33.58
Coarse aggregate	43.02
Sodium chloride	2.18
Defoaming agent	0.15
Sodium citrate	0.09
Water	6.38

Class F fly ash increases the aluminum content of the concrete mixture, which decreases the heat of hydration and increases the setting speed. A mixture of fine and coarse aggregate decreases the porosity of the concrete, and the fine aggregate contributes more silica over time.

For Class M cement and Class F fly ash addition of sodium chloride to the mixture ensures that the water content of the concrete is in equilibrium with the host rock to minimize dissolution, and inhibit deterioration of the concrete. The use of defoaming agents inhibit air entrainment in the concrete mixture.

Wakeley et al. (1994) studied under laboratory conditions the effects of various compositions of brines and concretes, including the SMC formulation. The study evaluated the susceptibility of concretes to chemical degradation by brines. Both pastes containing no aggregate, and mortars containing fine aggregate were formulated and tested in simulated brines containing magnesium and sulfate concentrations representing the brines at the repository horizon. The study concluded that high-magnesium brines exacerbated the deterioration of pastes and mortars; mortars deteriorated more rapidly than pastes. This study concluded that loss of calcium was the primary cause of weakened concrete materials. The use of salt in mortars with an expansive component slowed the rate of deterioration. These experiments were carried out under extreme experimental conditions unrepresentative of the trace amount of brine that will be encountered during large-scale installation of the concrete barriers.

2.2.1.3 VOC Interaction

Theoretically, if the pH of the VOCs is too low, it could negatively impact the structural integrity of the concrete barrier. The higher the VOC pH, the less likelihood for physical degradation of the concrete barrier. Using a portland cement with a pH greater than 12 should ensure the integrity of the concrete barrier.

2.2.1.4 Cement Hydration

Mathewson (1981) reported that the aggregate mineralogy significantly affects the curing/hydrating process by generating heat and alkali fluids, which can have deleterious effects on the strength of the concrete. Minerals susceptible to an alkali-aggregate reaction are hydrated silicates, opaline shale, chert, siliceous limestones, rhyolite, and dacite. Nonreactive minerals include quartz, feldspar, calcite, and the ferromagnesium minerals.

2.2.1.5 Conclusions

Previous studies suggest the application of the SMC to the design of the panel-closure system. This concrete possesses characteristics of low heat of hydration and workability. Because of the trace amounts of brine and the impermeable nature of the concrete, a standard concrete with a low heat of hydration and similar workability was considered acceptable. Therefore,

the design specifies a plain cement concrete mix that must be verified with testing. The cement will be Portland cement, type II modified, with pozzalan or type IV, to limit the heat of hydration of the resultant mix.

2.2.2 Heat-Generation Evaluations

Heat-generation studies evaluated the effects of the heat of hydration for the installation of the concrete barrier. The curing of concrete is facilitated by hydration in that the water present in the mixture reacts with calcium and silica to incorporate water into the resulting mineral phase. This process is an exothermic reaction, resulting in a temperature increase in the concrete barrier and host rock. This temperature increase causes a thermal expansion of the concrete barrier and increases the interface stress. As the concrete cools, the interface stress decreases, and tensile strain may occur at the interface.

2.2.2.1 Evaluation Procedure

The one-dimensional radial numerical and analytical model SHAFT.SEAL (Case et al., 1992) solves for temperature and stress as a function of radial position, in either the barrier or the surrounding host rock. The model uses the implicit finite-difference method (Carnahan et al., 1990) to analyze the temperature rise and fall following completion of the hydration. The model assumes radial conductive heat transfer to the surrounding host rock.

The analysis used thermal and thermomechanical properties from previous modeling efforts (Case and Kelsall, 1986; Van Sambeek and Stormont, 1987). The proposed concrete mixture exhibits a double-humped hydration curve (Figure 2-12) (Van Sambeek and Stormont, 1987). The first "hump" results from a reaction that occurs shortly after the mixing of the concrete. The double-hump manifestation in the temperature-versus-time data of the expansive salt-based concrete reduces the maximum temperature by increasing the time over which the hydration takes place. This is beneficial in large volumes of concrete where the dissipation of heat in the interior of the concrete barrier is slow. The analyses used input properties for the candidate material as determined from laboratory studies (Van Sambeek and Stormont, 1987), with modifications made to account for a reduced heat of hydration for the SMC. Table 2-5 summarizes the properties used in the analysis. The placement temperature was selected at ambient temperature.

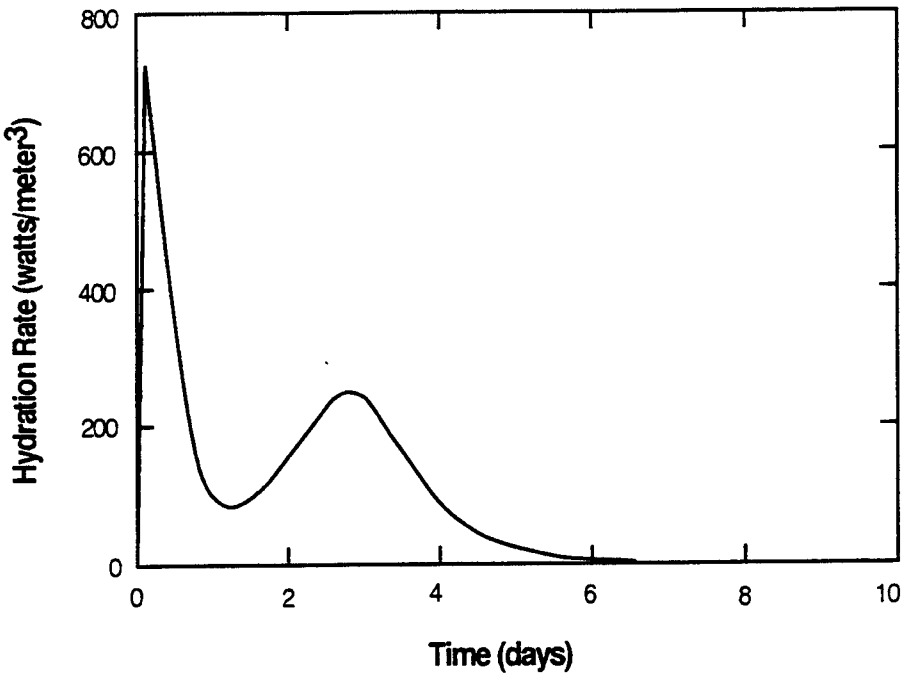


Figure 2-12
Heat of Hydration for Expansive Salt Concrete
(After Van Sambeek and Stormont, 1987)

Table 2-5

Thermal and Thermomechanical Properties for SHAFT.SEAL Analysis

Property	Value
Barrier properties: Plug diameter	10 meters
Concrete placement temperature	28°C
Concrete Properties: Specific heat Thermal conductivity Density Young's Modulus Poisson's ratio Thermal expansion coefficient	 980 joules/(kilogram-Celsius) 2.1 watts/(meters-Celsius) 2,280 kilograms/cubic meter 28,000 MPa 0.20 12.6×10^{-6} 1/°C
Rock properties: Specific heat Thermal conductivity Density Rock temperature Young's Modulus Poisson's ratio Thermal expansion coefficient	 860 joules/(kilogram-Celsius) 4.94 watts/(meters-Celsius) 2,300 kilograms/cubic meter 28°C 31,000 MPa 0.25 45.0×10^{-6} 1/°C

2.2.2.2 Modeling Results

The modeling results include the temperature and stress distributions in the concrete barrier and the surrounding host rock at various times (Figure 2-13). The thermal analysis shows that temperatures initially rise uniformly due to cement hydration, maintaining a high radial thermal gradient within the interface zone. Thermal gradients decreased with time as hydration nears completion, and the heat thermally diffuses to the surrounding rock. After 28 days, temperatures rose to about 45°C (102°F), inducing a thermal gradient and thermal stress at the interface zone. After this time, the temperatures fell and approached the in situ rock temperature after an additional 28 days. The temperatures suggest that the heat pulse will be short and that the placement of the concrete, combined with the high thermal diffusivity of the salt, will control hydration temperatures to an acceptable level. The stress analysis suggests that tensile stress in the concrete will be offset by the rapid buildup of compressive stress, due to salt creep of the host rock.

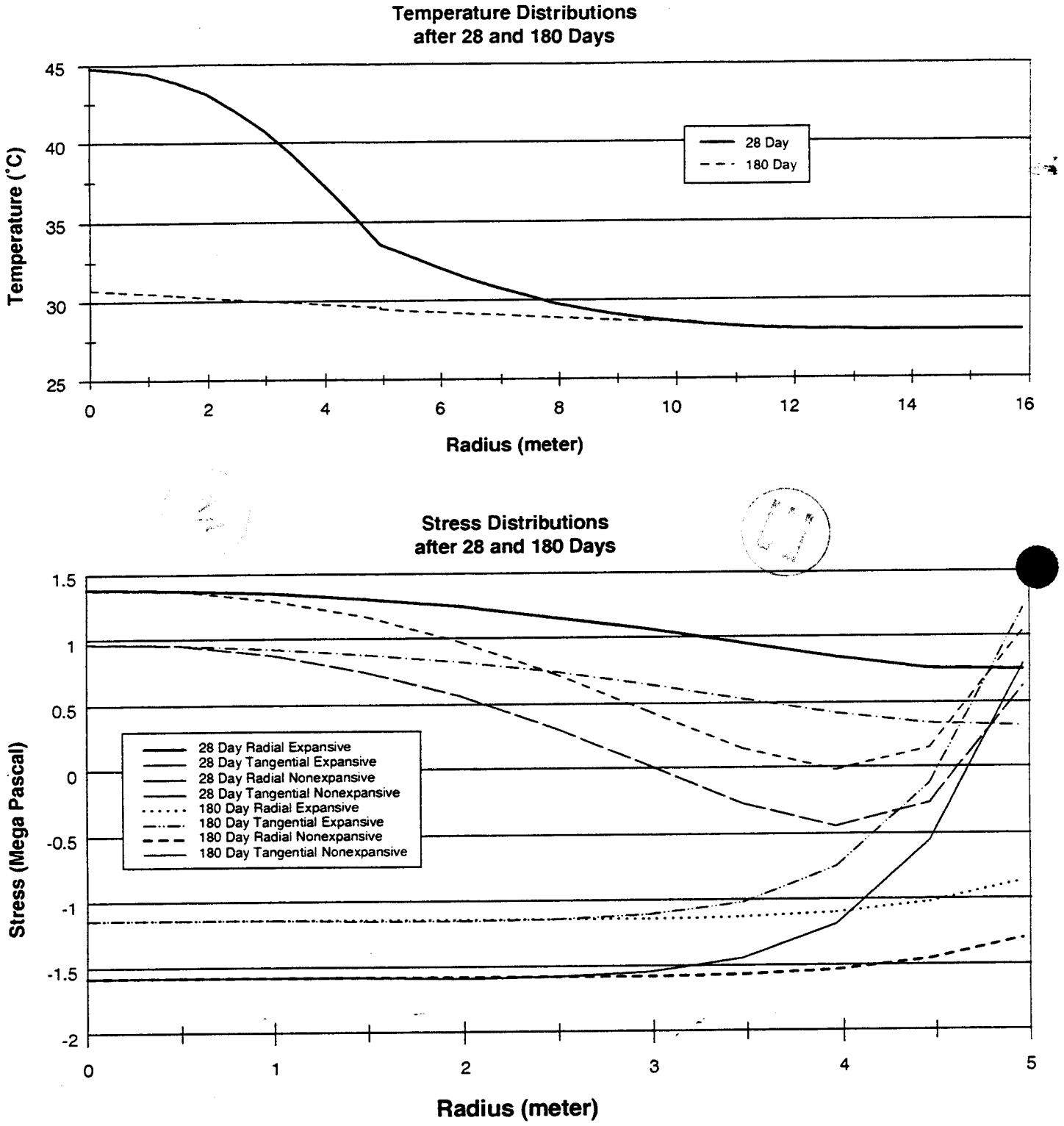


Figure 2-13

Temperature and Stress Distributions for Concrete Barrier

2.2.2.3 Conclusions

Hydration temperatures will be controlled through the selection of an appropriate concrete to reduce the potential for tensile cracking and separation at the interface zone. A thermal analysis using information on the heat of hydration of the concrete coupled with a salt-creep analysis suggests that, for the size of pour, placing the concrete at ambient temperature will control hydration temperatures. Finally, because steel formwork will be used during installation, such formwork will conduct heat away from the face of the concrete and thereby cool the concrete.

2.2.3 Explosion Evaluations

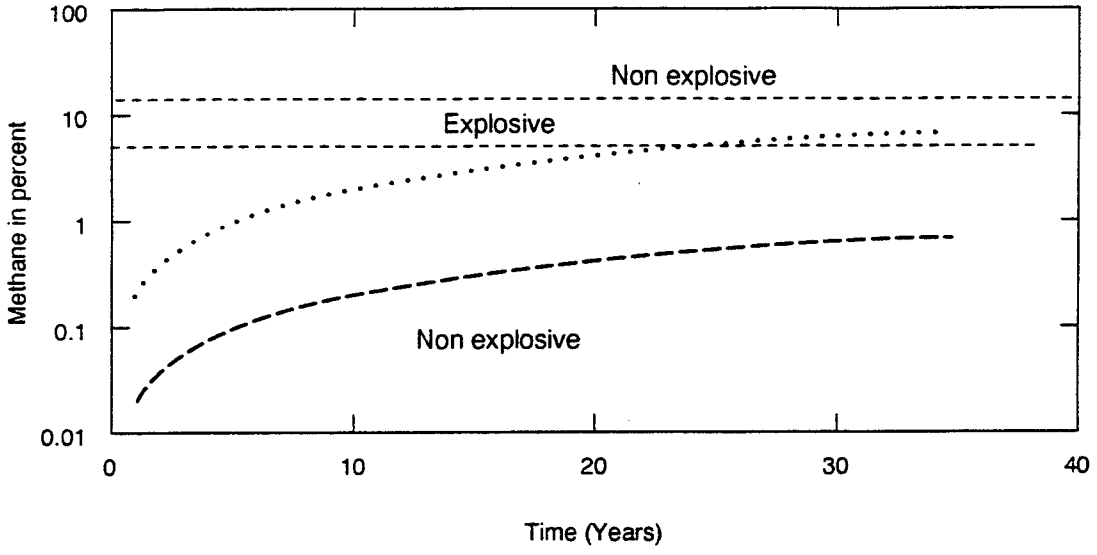
The methane-explosion evaluation focused on the pressure and thermal effects of such an explosion on the explosion-isolation wall. The DOE (1995) suggests that gas-generation rates, due to microbial degradation, might range from 0.01 to 0.1 moles per drum per year, with methane comprising 70 percent of the gas. It is estimated that the potential for a methane explosion would not occur prior to closure of the first waste-emplacement panel for a gas generation rate of 0.1 moles per drum per year. Such an explosion could occur approximately 20 years after closure of the first panel. This time is determined by comparing the percent volume concentration to the explosive limits for methane as shown in Figure 2-14.

If the composition of the air in the closed panel were 18 percent oxygen, the explosive range will be from about 5 to 15 percent methane by volume. Above 15 percent methane, the atmosphere in an abandoned waste-emplacement panel would be "fuel rich" and would not be capable of sustaining an explosion. With a reduction in the amount of oxygen available, the explosive range narrows, and the potential will be nonexistent below a 12 percent oxygen composition.

A methane explosion would generate an initial pressure transient that would impinge on the explosion-isolation wall. Subsequently, temperatures would rise in the panel, as well as raise the temperature in the explosion-isolation wall.

2.2.3.1 Evaluation Procedure

Two analyses were conducted to evaluate methane-explosion effects: 1) a dynamic analysis, and 2) a thermal heat-transfer analysis of the explosion-isolation wall. After an explosion, the explosion-isolation wall would be subjected to short-term dynamic loading. The design pressure can be calculated as the maximum pressure times the dynamic load factor (Biggs, 1964). The dynamic load factor will depend on the shape of the pressure-time transient. An



Gas generation rate = 0.1 moles/drum/year

Gas generation rate = 0.01 moles/drum/year

Figure 2-14
Methane Concentrations in the Waste Panel Over Time (After DOE, 1995)

explosion will result in a wave front that will rise instantaneously and then drop gradually. In this study, the transient pressure pulse is idealized as having an instantaneous rise and an exponential decay (Figure 2-15).

In the event of a hydrocarbon explosion: either (1) deflagration will result in a rapid rise of pressure, with no transition to a detonation, or (2) a detonation wave front will propagate as a supersonic shockwave. The transition to a detonation is a function of two parameters: (1) the methane concentration at the time of the explosion, and (2) the ability for a wave front to form. In underground excavations, the latter condition typically requires a reasonably long passage through which the combustion wave travels and transforms to a detonation. After 20 years, the open passage above the waste stack will be reduced in size, and it is unlikely that a long passage with an open geometry will exist. Further, individual rooms will be isolated by bulkheads at each end. Therefore, the dynamic analysis considers a deflagration.

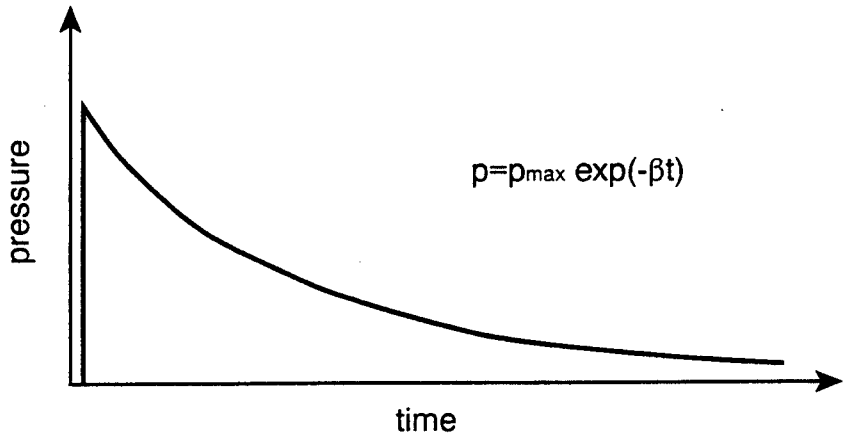
The second analysis involves a thermal analysis with a heat-transfer model (Appendix F). The heat-transfer model under the postulated explosion within the panel considers the heat balance between the gas and the walls of the panel for a stoichiometric mixture of methane. The rate at which the gas temperature will rise within the panel depends on (1) the number of moles of methane, (2) the specific heat capacity of the gas and the heat transfer to the salt and the walls through radiation, (3) convection along the vertical and horizontal surfaces, and (4) conduction within the salt and walls. Because the properties involved in the heat transfer analysis are temperature-dependent, a numerical model was run using the explicit finite difference method. The model provided the necessary information for evaluating thermal effects in selecting the size of the explosion-isolation wall.

2.2.3.2 Analysis Results

The peak explosive pressure was taken from the pressure rising from a deflagration that is about 8 times the ambient pressure (2 atmospheres) at the time of the explosion. This results in a peak pressure of 240 psi (1.7 MPa).[6]

The dynamic load factor will depend on the natural frequency of the explosion-isolation wall. The value for the dynamic load factor approaches a value of 2, with increased natural

[6]The analysis is conservative in that the presence of the waste drums would result in dampening of the explosion.



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p = Pressure

p_{max} = Maximum pressure

t = Time

β = Shape factor for experimental curve

Figure 2-15
Pressure Pulse Versus Time

frequency for a variety of exponential curves (Figure 2-16). Based upon this loading, an explosion-isolation wall was designed to adsorb the energy from such an explosion.

The thermal-analysis results are presented in Figures 2-17 through 2-19. Figure 2-17 shows the gas temperature, the salt-wall temperature, and concrete wall temperature following the explosion. In the analysis, the gas reached a temperature of 2,500 Kelvin after about 20 seconds and then declined with time. The gas approached ambient temperatures after about 1.5 hours. Figures 2-18 and 2-19 show the temperature distribution as a function of distance into the walls. The results show that, at the initial time, the heat transfer from combustion gas to the salt and walls will result in a large temperature gradient at the wall. At later times, heat will be conducted through the wall, and the salt and the thermal gradient will be reduced. After 2 hours, the elevated temperature in the wall will propagate a maximum of 6 inches (15 cm) into the wall. Because the explosion-isolation wall is designed to resist creep deformation, temperature gradients will not significantly affect the stability of the wall.

2.2.3.3 Conclusions

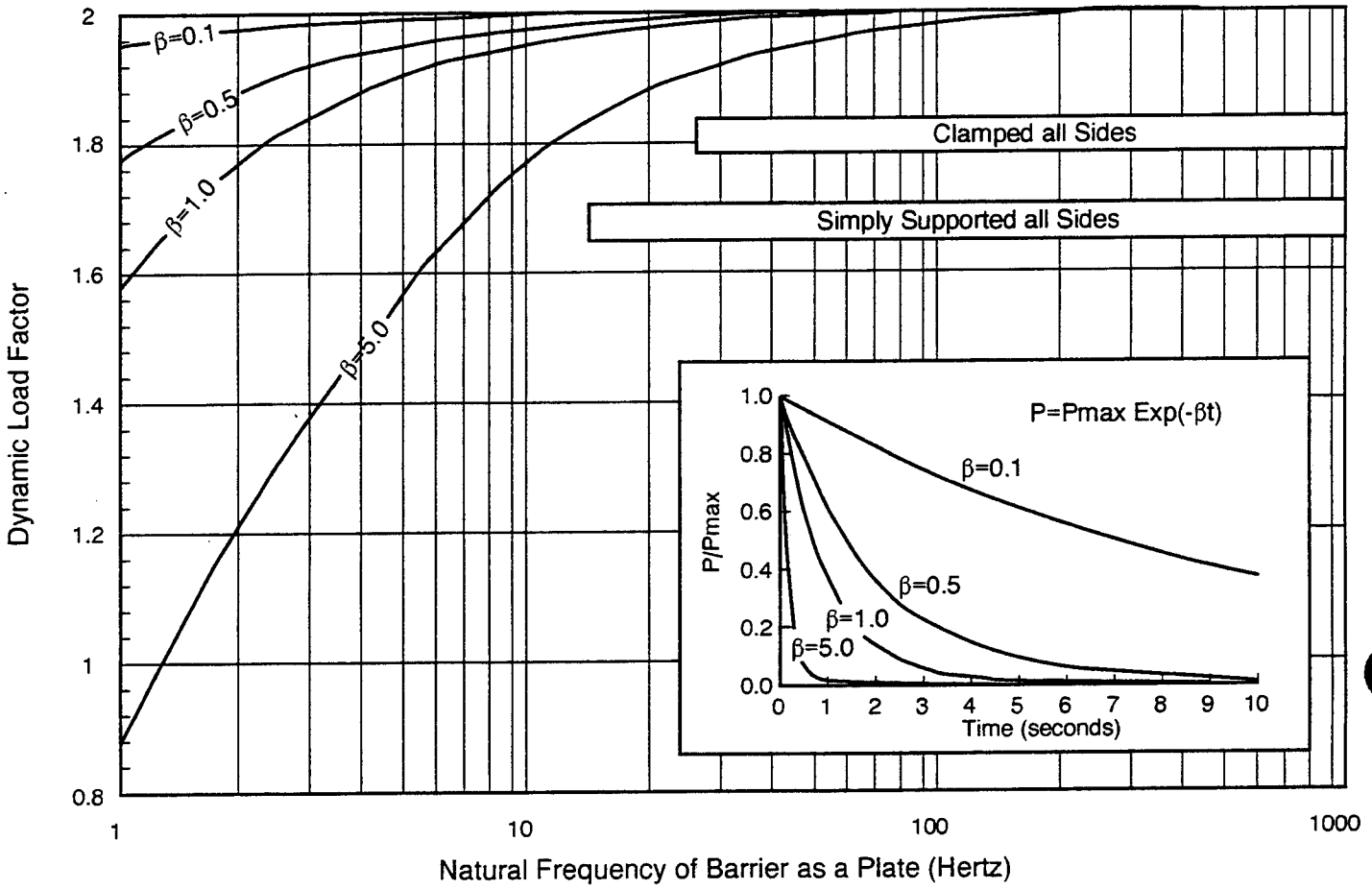
The explosion-isolation wall was designed for a peak deflagration pressure of 240 psi (1.7 MPa) under pseudostatic conditions, with a dynamic load factor of 2.0. Because the explosion-isolation wall is designed to resist creep deformation, temperature gradients will not significantly affect the stability at the wall.

2.2.4 Fracture-Propagation Studies

The fracture-propagation studies evaluated the potential for fracture propagation, using the results of previous analyses. These analyses included a stress analysis and explosion evaluations.

2.2.4.1 Evaluation Procedure

The results of the thermal analysis suggest that elevated temperatures within an explosion-isolation wall and salt will be a localized phenomenon. During an explosion, which may potentially occur 20 years after closure of the first panel, two phenomena could affect the potential fracturing of the salt: (1) the expansion of the explosion products into existing fractures and (2) the potential reflection of sonic waves off free surfaces around the barrier. These effects were evaluated.



Range of Natural Frequencies as a plate

β Shape factor for experimental curve

Figure 2-16
Dynamic Load Factor Versus Frequency of the Concrete Wall as a Plate

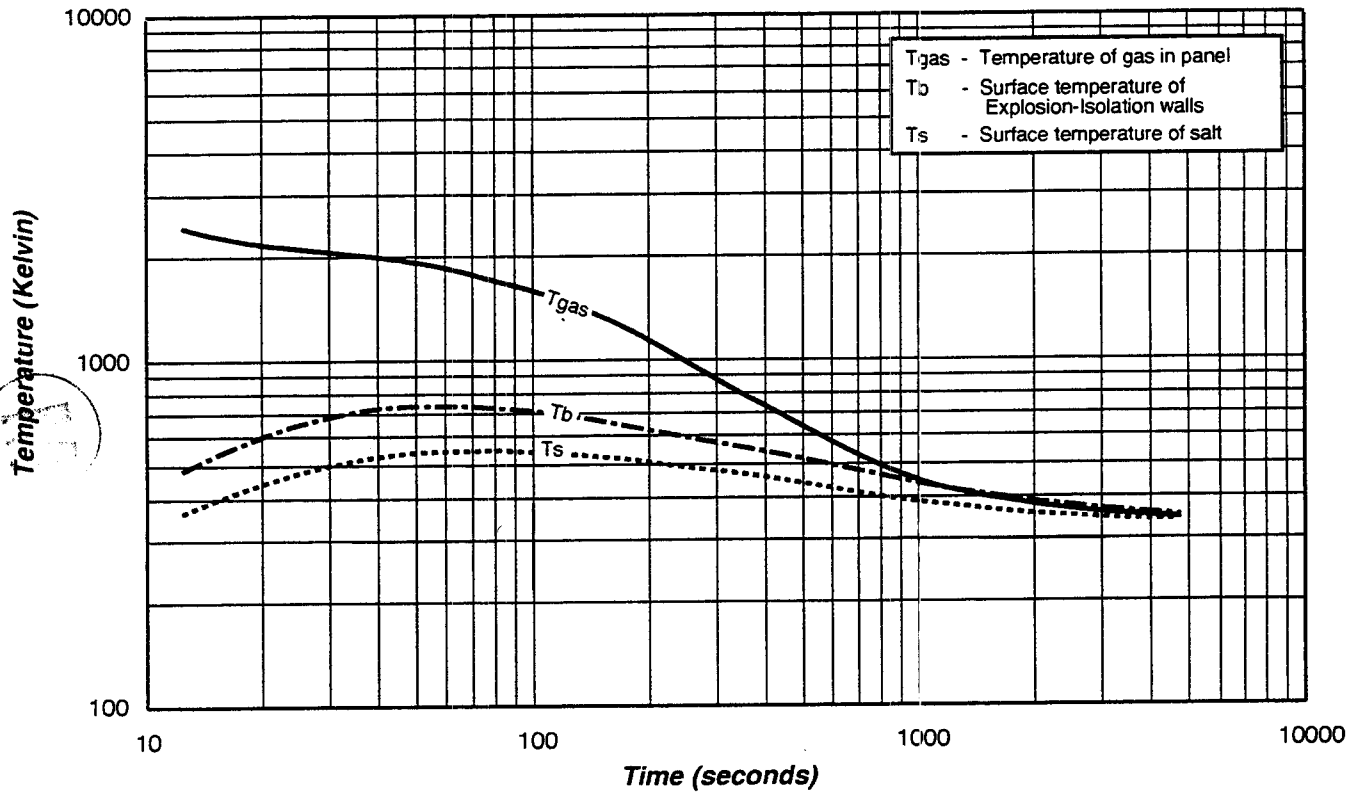


Figure 2-17
Temperature Variation with Time for Gas, Salt, and Explosion-Isolation Walls

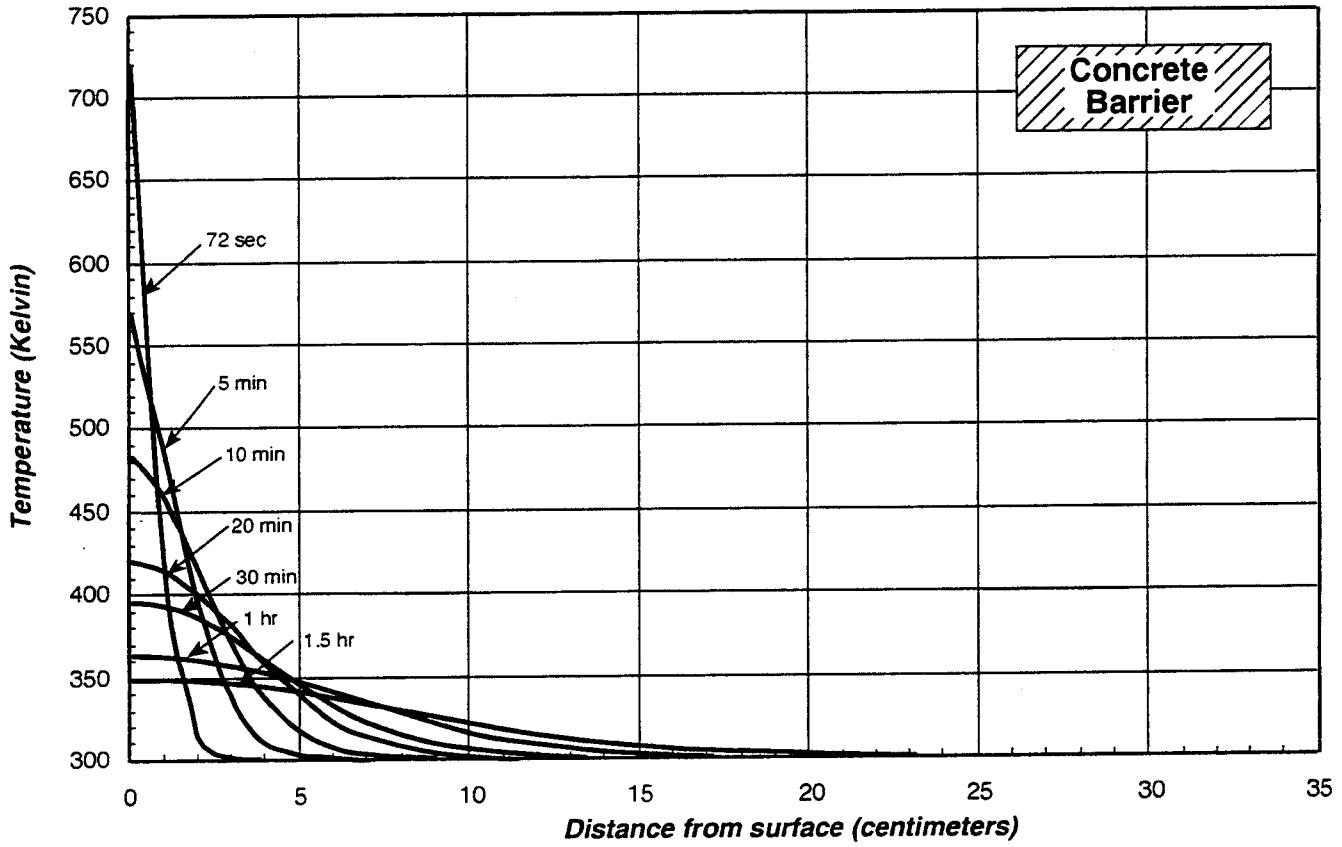


Figure 2-18
Temperature Distribution with Time for Concrete Barrier

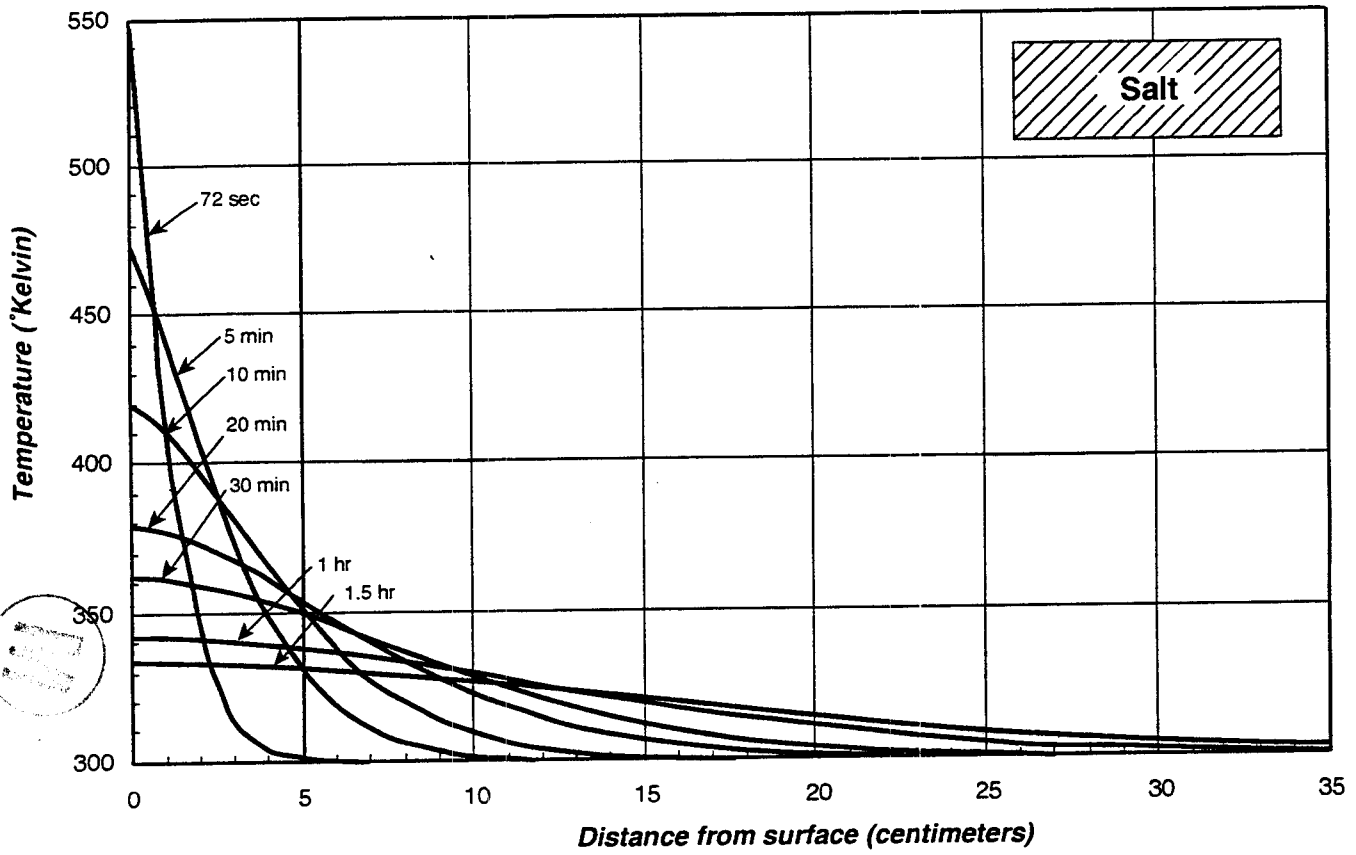


Figure 2-19
Temperature Distribution with Time for Salt

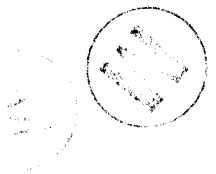
2.2.4.2 Evaluation Results

The fractures in the roof and floor could be affected by the expansion of the gas products on the order of 240 psi (1.7 MPa), which decay rapidly with time and attenuate with distance. Around the wall, the confining stress on the order of 1,450 psi (10 MPa) could develop after 20 years, as presented in Section 2.1.3. Horizontal fracture propagation could occur around the concrete barrier only if the internal gas pressure exceeded the confining pressure. Because the peak internal pressure from the deflagration is only about one-fifth of the confining pressure, fractures would not propagate through or around the main wall.

Following an explosion, the wall would be subject to sonic waves that would impinge on the wall. As the sonic wave encountered a contrast in wall stiffness, a portion of the sonic wave would be refracted, and a portion would be reflected (Jaeger and Cook, 1972). This would result in minor tensile spalling of the isolation wall.

2.2.4.3 Conclusions

At the time of a potential explosion, the development of confining stress relative to the explosion pressure would prevent fracturing around the main concrete barrier. With the selection of a thick enough wall, the effects of a postulated methane explosion can be isolated from the main concrete barrier.



3.0 Design Description

This chapter presents the final design selected from the evaluations performed in the previous chapter. It presents design modifications to cover a range of conditions that may be encountered in the underground and describes the design components for the panel-closure system. Finally, information is presented on the proposed construction for the panel-closure system.

3.1 Design Concept

The composite panel-closure system selected is (1) a standard concrete barrier, rectangular in shape, or (2) an enlarged tapered concrete barrier. Options (1) and (2) will be grouted along the interface and may contain explosion- or construction-isolation walls. Figure 3-1 illustrates these design components. The construction methods and materials to be used to implement the design have been proven in previous mining and construction projects. The standard concrete barrier without DRZ removal will most likely apply to future panel air-intake and air-exhaust drifts where the time duration between excavation and barrier emplacement is short. The enlarged concrete barrier with DRZ removal would apply to Panel 1 where a significant time lapse will occur between excavation and barrier emplacement. The design concept for the enlarged concrete barrier incorporates:

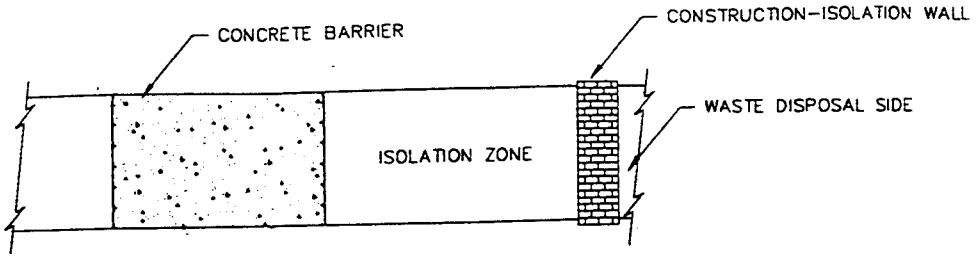
- A concrete barrier that is tapered to promote the rapid stress buildup on the host rock. The stiffness was selected to provide rapid buildup of compressive stress and reduction in shear stress in the host rock.

- The enlarged barrier requires DRZ removal just beyond Clay G and MB 139, and to a corresponding distance in the ribs to keep the tapered shape approximately spherical. The design includes DRZ removal and thereby limits VOC flow through the panel-closure system.

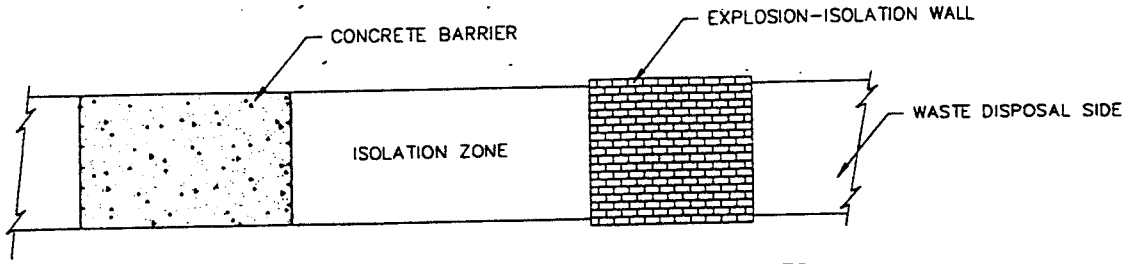
- The design of the panel-closure system includes either a construction- or an explosion-isolation wall designed to provide strength and deformational serviceability during the operational period. The length was selected to assure that uniform compression develops over a substantial portion of the structure and that end-shear loading that might result in fracturing of salt into the back is reduced.

3.2 Design Options

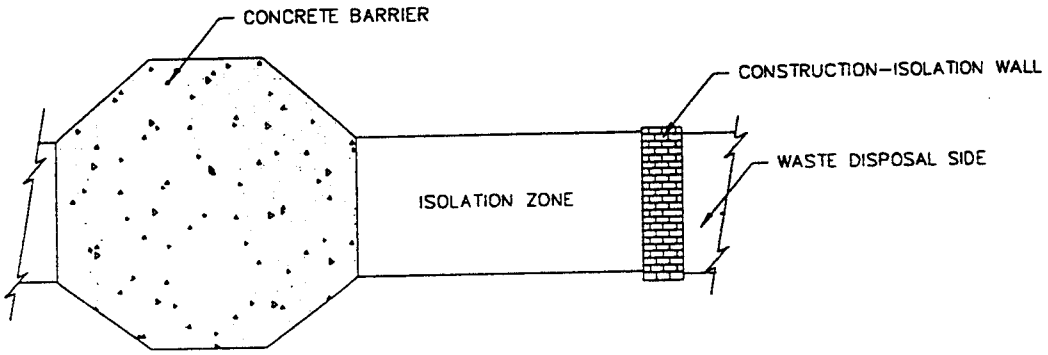
The design options consist of the following:



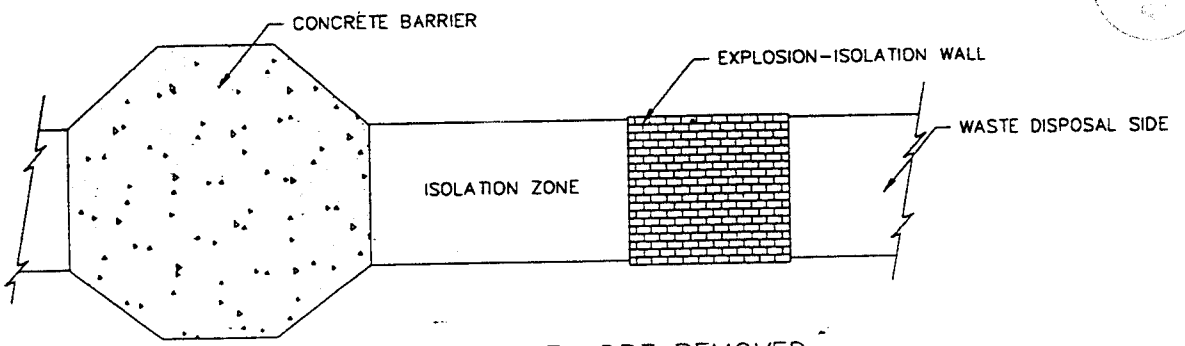
A. CONCRETE BARRIER WITHOUT DRZ REMOVED AND CONSTRUCTION ISOLATION WALL



B. CONCRETE BARRIER WITHOUT DRZ REMOVED AND EXPLOSION ISOLATION WALL



C. CONCRETE BARRIER WITH DRZ REMOVED AND CONSTRUCTION ISOLATION WALL



D. CONCRETE BARRIER WITH DRZ REMOVED AND EXPLOSION ISOLATION WALL

Figure 3-1

Main Concrete Barrier with Wall Combinations

- An enlarged concrete barrier with the DRZ removed and a construction-isolation wall
- An enlarged concrete barrier with the DRZ removed and an explosion-isolation wall
- A rectangular concrete barrier without the DRZ removed and a construction-isolation wall
- A rectangular concrete barrier without the DRZ removed and an explosion-isolation wall.

In each case, interface grouting will be used for the upper barrier/salt interface. The process for selecting these options would depend on the subsurface conditions at the panel-closure system locations described in the following subsections.

3.2.1 Selection of the Concrete Barrier

The design provides flexibility to satisfy the design migration limit for the flow of VOCs out of the panel. An enlarged concrete barrier will be selected where air-intake and air-exhaust drifts have fractured with age resulting in significant flow of VOCs. These conditions apply to the most severe ground conditions in the air-intake and air-exhaust drifts of Panel 1. If ground conditions are more favorable such as might be the case for future panel entries, then the panel-closure system can be simplified to a standard concrete barrier, rectangular in shape, with a construction-isolation wall.

Several methods are available for detecting the location and extent of fractures in the DRZ (DOE, 1995). These methods include ground-penetrating radar and observation boreholes, which have already been used for underground fracture detection at the WIPP (DOE, 1995). These methods will be used to determine when conditions are favorable, and the standard concrete barrier can be used to limit/restrict VOC flow.

The GPR methods and other exploratory methods show where fractures are minimal in order to select an optimum location for the panel-closure system. In such areas, the design can be simplified to a standard concrete barrier without DRZ removal. The area with the least number of fractures as determined by these exploratory methods would mean that compressive stresses increase on the standard concrete barrier. The effective concrete barrier permeability will be reduced with time as stresses increase on the standard concrete barrier.

GPR is a nondestructive electromagnetic reflection technique that is sensitive to variations in the dielectrical constant of rock salt. The use of GPR is a proven technology for detecting shallow fracture zones in the underground and will have practical value in determining the location of a panel-closure system (IT, 1993). GPR surveys perpendicular to the long axis and axial surveys of the drift would provide data to determine the optimum location for the main concrete barrier. Fractured rock will be removed as necessary for installation of the concrete barrier.

For future waste-emplacement panels, GPR will be used to monitor fracture development. Radar surveys could be conducted shortly after excavation to provide a baseline with which to compare future radar surveys. GPR will be used periodically to monitor the development of brittle deformation occurring in the new air-intake and air-exhaust drifts.

Observation boreholes will be drilled into the roof or floor of the new air-intake and air-exhaust drifts and will be used for observation of fractures and bed separation. Observations can be made in the boreholes using a small video camera, or a scratch rod. A scratch rod survey will be performed in accordance with the current Excavation Effects Program (EEP) procedure.

The EEP was initiated in 1986 with the occurrence of fractures in Site and Preliminary Design Validation Room 3. The purpose of the EEP is to study fractures that develop as a result of underground excavation at the WIPP and to monitor those fractures. Borehole inspections have been successful for determining the fracturing and bed separation in the host rock. These inspections have been performed since 1983 (Francke and Terrill, 1993). This technique in addition to the above will be used to determine the optimum location for the panel-closure system.

3.2.2 Selection of an Explosion- or Construction-Isolation Wall

While no requirements for barricading waste areas exist under the MSHA, the intent of the regulations is to safely isolate abandoned areas from active workings using barricades of "substantial construction." The previous analysis (DOE, 1995) examined the issue of methane gas generation from TRU waste and its potential consequence in closed areas. The principal concern is the occurrence of an explosive mixture of methane and an ignition source, which would result in deflagration. If a methane explosion is considered possible, an explosion-isolation wall of sufficient thickness will be used to resist dynamic and creep loads. In the absence of explosive conditions, a construction-isolation wall will be used.

3.3 Design Components

The following subsections present system and components design features.

3.3.1 Concrete Barrier

The enlarged concrete barrier consists of plain concrete, with sufficient unconfined compressive strength and with an approximately circular cross-section excavated into the salt over the central portion of the barrier (Figure 3-2). The enlarged concrete barrier will be located at the optimum locations in the air-intake and air-exhaust drifts with the central portion extending just beyond Clay G and MB 139.

The enlarged concrete barrier will be placed in four cells, with construction joints perpendicular to the direction of potential air flow. The concrete strength will be selected according to the standards specified by the latest edition of the ACI code for plain concrete. The concrete will be placed through 6-inch- (15-cm)-diameter steel pipes and vibrated from outside the formwork. The formwork is designed to withstand the hydrostatic loads during construction, with minimal bracing onto exposed salt surfaces. This will be accomplished by placing a series of steel plates that are stiffened by angle iron, with load reactions carried by spacer rods. The spacer rods will be staggered to reduce potential flow along the rod surfaces through the barrier. Some exterior bracing will be required when the first cell is poured. All structural steel will be ASTM A36, with detailing, fabrication, and erection of structural steel in conformance with the latest edition of the AISC steel manual (AISC, 1989). After concrete placement, the formwork will be left in place.

The above design is for the most severe conditions expected to be encountered at the WIPP. If actual conditions are found to be more favorable (i.e., if the age of the entries at the time of emplacement is less, and if the fractured DRZ does not develop, or there is adequate design margin for the flow of VOCs), the design can be simplified to a rectangular barrier without DRZ removal (Figure 3-3).

3.3.2 Explosion- and Construction-Isolation Walls

An explosion-isolation wall, consisting of concrete-blocks, will mitigate the effects of a postulated methane explosion. The explosion-isolation wall consists of 3,500-psi (24-MPa) concrete blocks mortared together with cement (Figure 3-4).

The concrete block wall design complies with MSHA requirements (MSHA, 1987) because it uses incombustible materials of substantial construction. The explosion-isolation wall will be

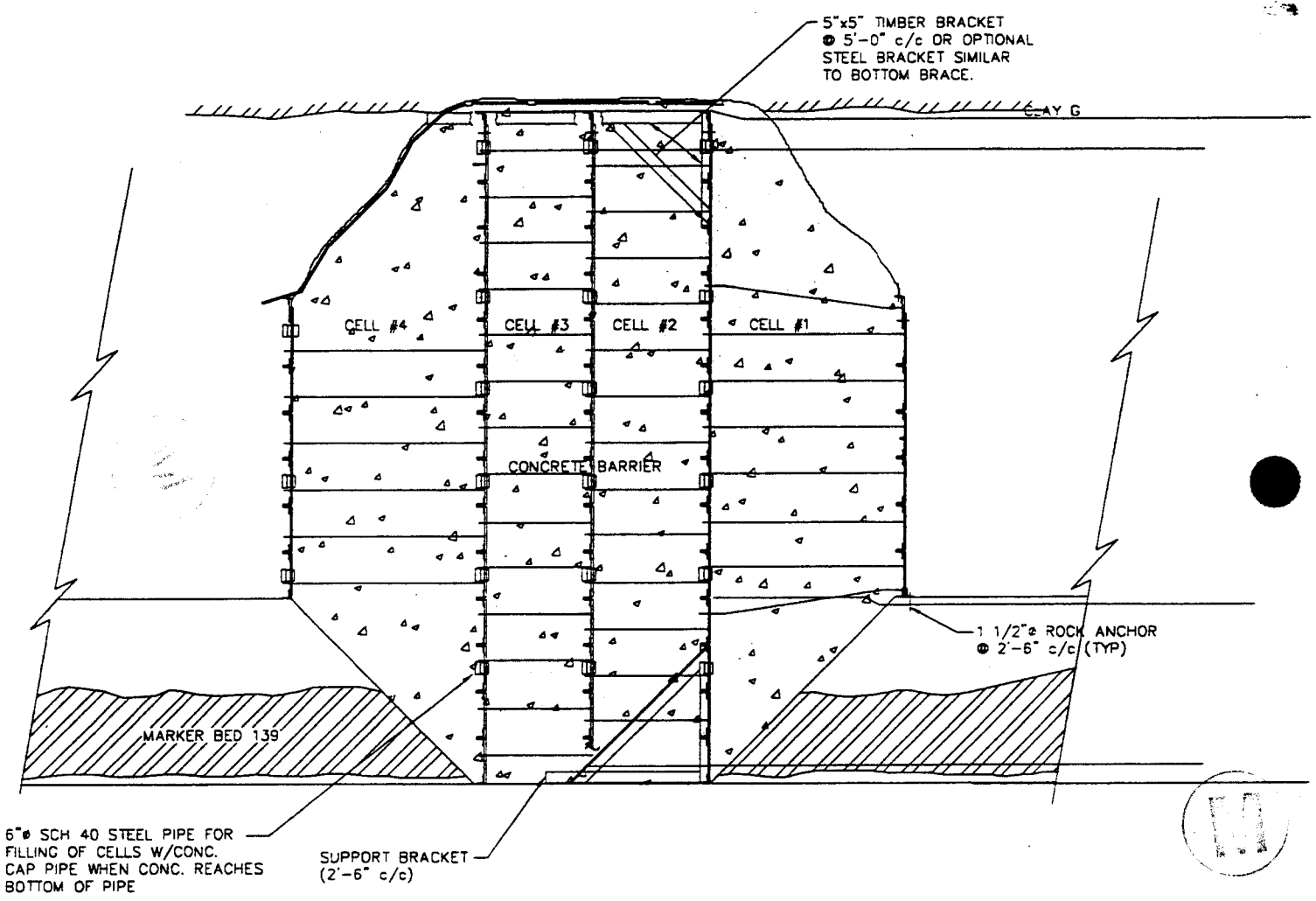


Figure 3-2
Concrete Barrier with DRZ Removal

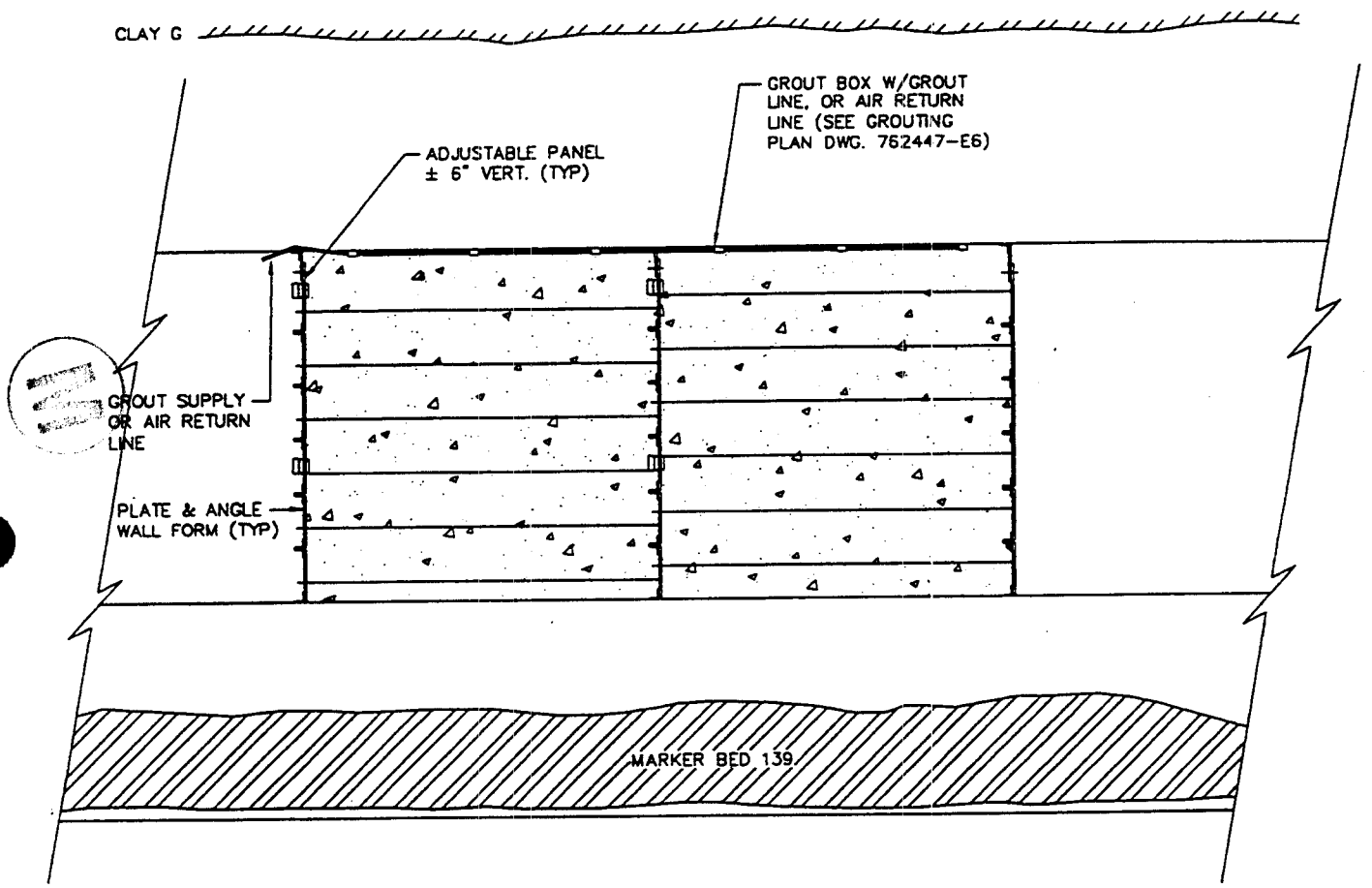


Figure 3-3
Concrete Barrier Without DRZ Removal

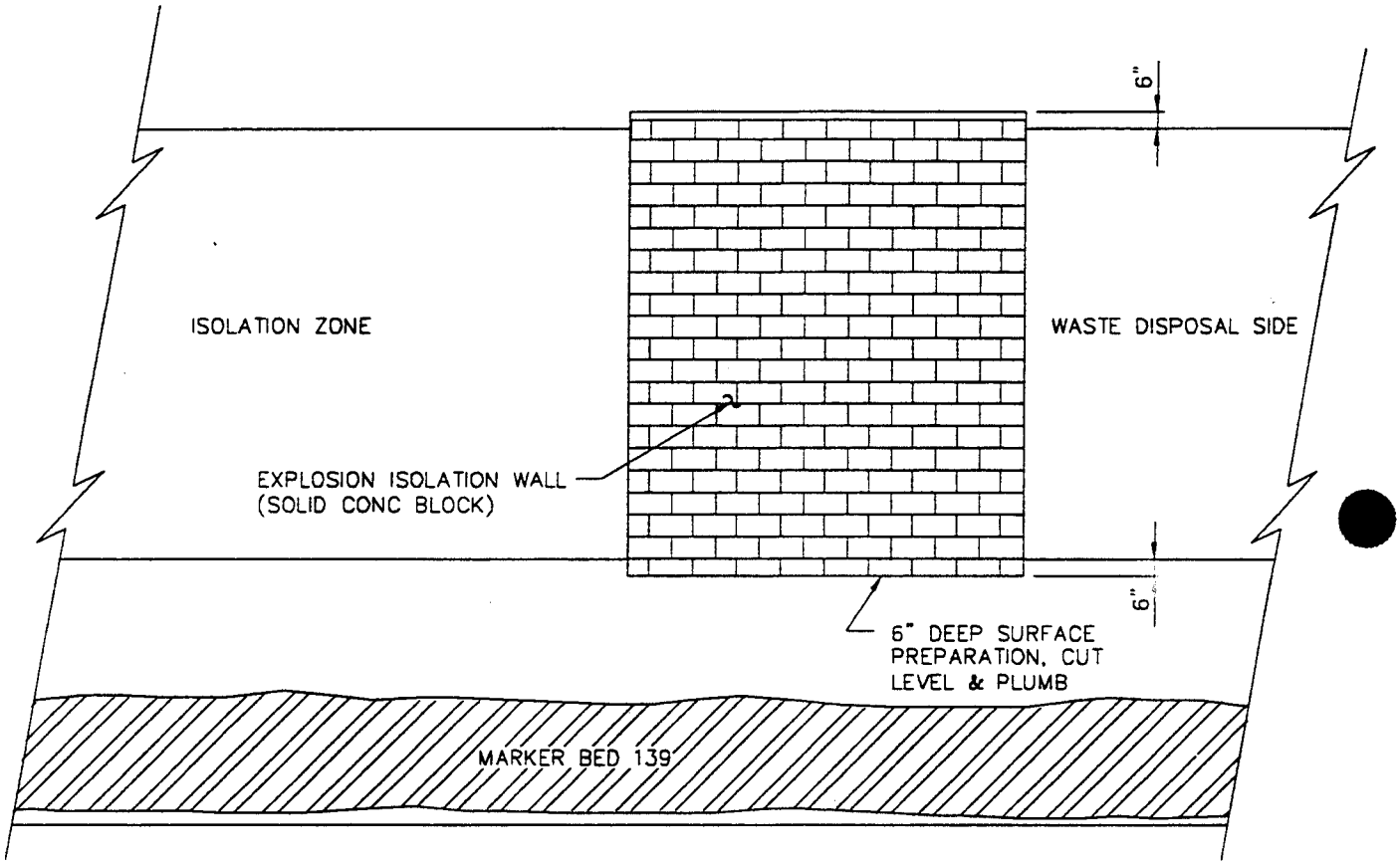


Figure 3-4
Explosion-Isolation Wall

placed into the salt for support. The explosion-isolation walls are designed to resist creep loading from salt deformation. In the absence of the postulated methane explosion, the design will be simplified to a construction-isolation wall. The construction-isolation wall design provides temporary isolation during the time the main concrete barrier is being constructed.

3.3.3 Interface Grouting

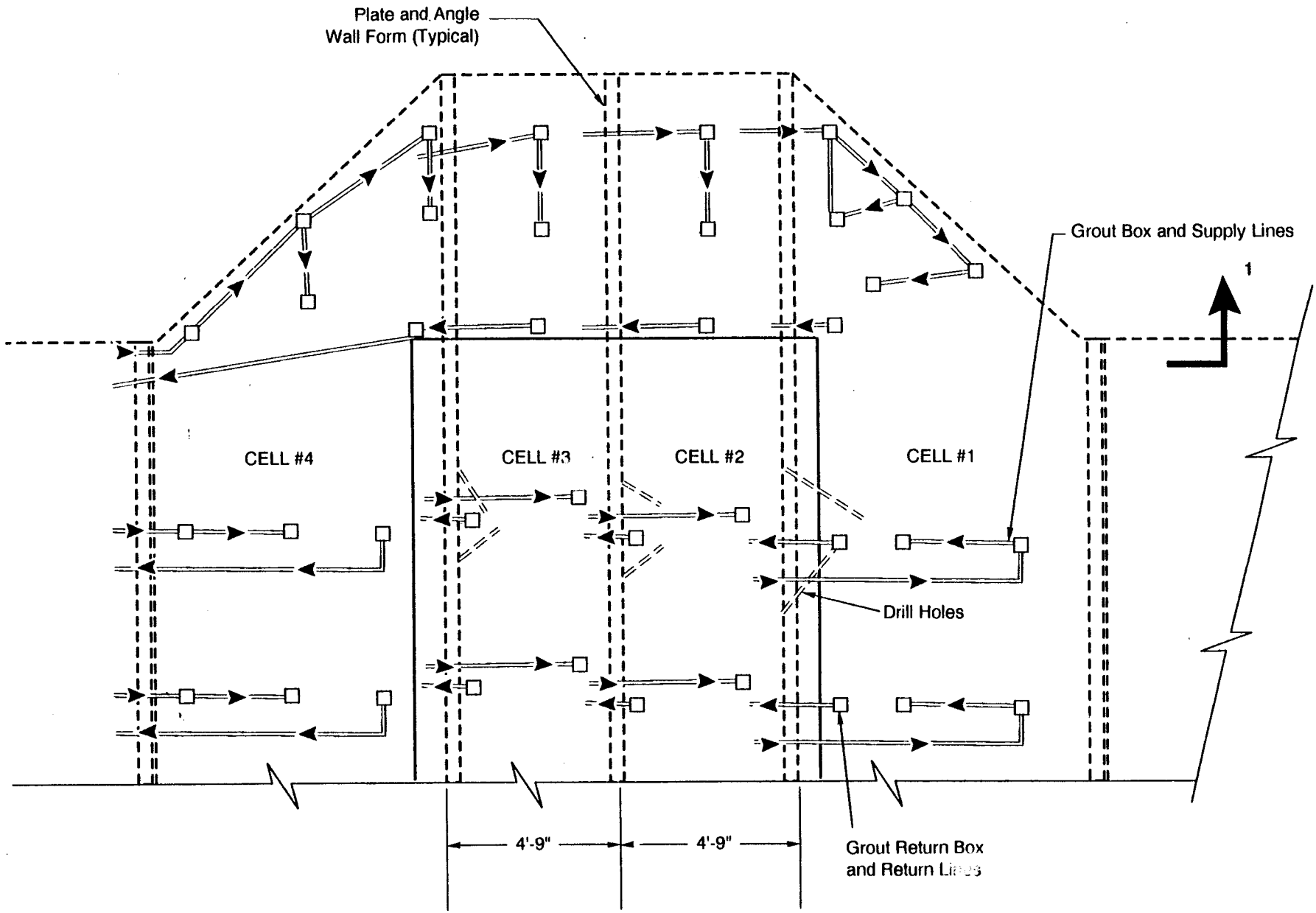
After construction of the main concrete barrier, the interface between the main concrete barrier and the salt will be grouted through a series of grout-supply and air-return lines that will terminate in grout distribution collection boxes. The openings in these boxes will be protected during concrete placement (Figure 3-5). The grout boxes will be mounted near the top of the barrier. The grout will be injected through one distribution system, with air and return grout flowing through a second distribution system.

3.4 Panel-Closure System Construction

The construction methods and materials to be used to implement the design have been proven in previous mining and construction projects. The design uses common construction practices according to existing standards. The proposed construction sequence follows completion of the waste-emplacement activities in each panel: (1) Perform subsurface exploration to determine the optimum location for the panel closure system, (2) select the appropriate design option for the location, (3) prepare surfaces for the construction- or explosion-isolation walls (if required), (4) install these walls, (5) excavate for the enlarged concrete barrier (if required), (6) install concrete formwork, (7) emplace concrete for the first cell, (8) grout the completed cell, and (9) install subsequent formwork, concrete and grout until completion of the enlarged concrete barrier.

The explosion-isolation or construction-isolation walls will be located at some distance from the main concrete barrier. The host rock will be excavated 6 inches (15 cms) around the entire perimeter prior to installing the explosion-isolation wall. The surface preparation will produce a level surface for placing the first layer of concrete blocks. Excavation may be performed by either mechanical or manual means.

Excavation for the enlarged concrete barrier will be performed using mechanical means, such as a cutting head on a suitable boom. The existing roadheader at the main barrier location in each drift is capable of excavating the back and the portions of the ribs above the floor level. Some manual excavation may be required in this situation as well. If mechanical means are not available, drilling boreholes and an expansive agent can be used to fragment the rock



Plan View of an Enlarged Bulkhead

Figure 3-5
Grouting Details

(Fernandez et al., 1989). Excavation will follow the lines and grades established for the design. The roof will be excavated to just above Clay G and then the floor to just below MB 139 to remove the DRZ. The tolerances for the enlarged concrete-barrier excavation are +6 to 0 inches (+15 to 0 cm). In addition, loose or spalling rock from the excavation surface will be removed to provide an appropriate surface abutting the enlarged concrete barrier. The excavations will be performed according to approved ground control plans.

Following completion of the roof excavation for the enlarged barrier, the floor will be excavated. If mechanical means are not available, drilling boreholes and using an expansive agent to fragment the rock (Fernandez et al., 1989) is a method that can be used. Expansive agents would load the rock salt and anhydrite, producing localized tensile fracturing in a controlled manner, to produce a sound surface.

A batch plant at the surface or underground will be prepared for batching, mixing, and delivering the concrete to the underground in sufficient quantity to complete placement of the concrete within one form cell. The placement of concrete will be continuous until completion, with a target time for completing one section of 8 to 10 hours, allowing an additional 2 hours for cleanup of equipment.

Pumping equipment suitable for placing the concrete into the forms will be provided at the main concrete barrier location. After transporting, and prior to pumping, the concrete will be remixed to compensate for segregation of aggregate during transport. Batch concrete will be checked at the surface at the time of mixing and again at the point of transfer to the pump for slump and temperature. Admixtures may be added at the remix stage in accordance with the batch design.

4.0 Design Calculations

Table 4-1 summarizes calculations to support the construction details for an explosion-isolation wall, construction-isolation wall, and structural steel formwork for concrete barriers up to a 29-ft high. The codes for the explosion-isolation and construction-isolation wall are specified by the Uniform Building Code (International Conference of Building Officials, 1994), with related seismic design requirements. The external loads for the solid block wall are as developed in the methane-explosion and fracture propagation design evaluations.

Table 4-1
Constructability Design Calculations Index

Section	Design Area	Category
1.0	Explosion-isolation wall	W
2.0	Explosion-isolation wall seismic check	S
3.0	Formwork design	F

The structural formwork for all cells is designed in accordance with the AISC guidelines on allowable stress (AISC, 1989). Lateral pressures are developed using ACI 347R-88, using a standard concrete weighing 150 pounds per cubic foot (2,410 kg/m^3) with a slump of 8 inches (20 cm) or less. Design loadings reflect full hydrostatic head of concrete, with lifts spaced at 4 ft (1.2 m) intervals from bottom to top through portals, with no external vibration. All forms will remain in place.

5.0 Technical Specifications

The specifications are in the engineering file room at the WIPP and are the property of Westinghouse WID. These specifications are included as an attachment in Appendix G and summarized in Table 5-1.

Table 5-1
Technical Specifications for the WIPP Panel-Closure System

Division 1 - General Requirements	
Section 01010	Summary of Work
Section 01090	Reference Standards
Section 01400	Contractor Quality Control
Section 01600	Material and Equipment
Division 2 - Site Work	
Section 02010	Mobilization and Demobilization
Section 02222	Excavation
Section 02722	Grouting
Division 3 - Concrete	
Section 03100	Concrete Formwork
Section 03300	Cast-in-Place Concrete
Division 4 - Masonry	
Section 04100	Mortar
Section 04300	Unit Masonry System

6.0 Drawings

The drawings (Appendix H) are in the engineering file room at the WIPP and are the property of the Westinghouse WID and summarized in Table 6-1.

Table 6-1
Panel-Closure System Drawings

Drawing Number	Title
762447-E1	Title Sheet
762447-E2	Underground Waste Disposal Plan
762447-E3	Air Intake Drift Construction Details
762447-E4	Air Exhaust Drift Construction Details
762447-E5	Construction and Explosion Barrier Construction Details
762447-E6	Grouting and Miscellaneous Details

7.0 Conclusions

This chapter presents the conclusions for the detailed design activities of the panel-closure system. A design basis, including the operational requirements, the structural and material requirements, and the construction requirements, was developed that addresses the governing regulations for the panel-closure system. Table 7-1 summarizes the design basis for the panel-closure system and the compliance with the design basis. The panel-closure system design incorporates mitigative measures to address the treatment of fractures and therefore counter the potential migration of VOCs. Several alternatives were evaluated for the treatment of fractures. These included excavation and emplacement of a fully enlarged barrier with removal of the DRZ, excavation of the roof and emplacement of a partially enlarged barrier, and emplacement of a standard barrier with formation grouting.

To investigate several key design issues and to implement the design, design evaluations were performed. These design evaluations can be divided into evaluations satisfying the operational requirements of the system and evaluations satisfying the structural and materials requirements of the system. The conclusions reached from the evaluations addressing the operational requirements are as follows:

- Based on an air-flow model used to predict the mass flow rate of carbon tetrachloride through the panel-closure system for the alternatives, the air-flow analysis suggests that the fully enlarged barrier is the most protective for restricting VOCs during the operational period of 35 years.

- Results of the FLAC analyses show that the recommended enlarged configuration is a circular rib-segment excavated to Clay G and under MB 139. Interface grouting would be performed at the upper boundary of the concrete barrier.

- The results of the transverse plane-strain models show that high stresses would form in MB 139 following excavation, but that after installation of the panel-closure system, an increase in barrier-confining stress and a reduction in shear stress would result. The concrete barrier would provide substantial uniform confining stresses as the barrier is subjected to secondary salt creep.

- The removal of the fractured salt prior to installation of the main concrete barrier would reduce the potential for flexure. With the removal of MB 139, the fractured salt stiffens the surrounding rock and results in the development of more uniform compression.

Table 7-1
Compliance of the Design with the Design Requirements

Type of Requirement	Requirement	Section	Compliance with Requirement	Notes on Compliance
Operational	Individual panels shall be closed in accordance with the schedule of actual waste emplacement.	2.1.1	Complies	Gas-flow models used for design are based on the waste-emplacement operational schedule.
	The panel-closure system shall provide assurance that the limit for the migration of volatile organic compounds (VOC) of concern will be met at the point of compliance. To achieve this assurance, the design shall consider the potential flow of VOCs through the several components of the disturbed rock zone and the panel-closure system.	2.1.1, 2.1.2	Complies	Gas-flow modeling shows that the VOC flow is less than the design migration limit.
	The panel-closure system shall comply with its intended functional requirements under loads generated from creep closure and any internal pressure that might develop in the disposal panel under reasonably anticipated conditions.	2.1.2, 4.0	Complies	Stress analyses and design calculations show that the panel-closure system performs as intended.
	The panel-closure system shall comply with its intended functional requirements under a postulated methane explosion.	2.2.3, 2.2.4, 4.0	Complies	The methane explosion studies, fracture propagation studies, and supporting design calculations show that the panel-closure system performs as intended.
	The operational life of the panel-closure system shall be at least 35 years.	2.1.1	Complies	Gas-flow modeling and analyses shows satisfactory performance for at least 35 years.
	The panel-closure system for each individual panel shall not require routine maintenance during its operational life.	3.2	Complies	Passive design components require no routine maintenance.
	The panel-closure system shall address the most severe ground conditions expected in the panel entries. If actual conditions are found to be more favorable, this design can be simplified and still satisfy the operational requirements of the system.	2.1.1 2.1.3 3.2	Complies	Design is based upon flow and structural analyses for the most severe expected ground conditions. If conditions are less severe, simpler design options are used. The various design options accommodate all expected conditions.

Table 7-1 *(Continued)*
Compliance of Design with the Design Requirements

Type of Requirement	Requirement	Section	Compliance with Requirement	Notes on Compliance
Design configuration and essential features	The panel-closure system shall be emplaced in the air-intake and air-exhaust drifts identified by Westinghouse (1995c)	3.2	Complies	The design shows placement in the designated areas for panel closure.
	The panel-closure system shall consist of a concrete barrier and construction-isolation and explosion-isolation walls with dimensions to satisfy the operational requirements of the system.	3.2, 3.3	Complies	The panel-closure system design uses the identified components with dimensions to satisfy the operational requirements of the system.
Safety	The design class for the panel-closure system shall be IIIb. Design and construction shall follow conventional mining and construction practices.	3.4	Complies	Components are designed according to Class IIIb. The construction sequence for the design followed conventional mining practices.
	The structural analysis for the underground shall use the empirical data acquired from the WIPP Excavation Effects Program.	2.1.2	Complies	The structural analysis uses properties that model creep closure for stress analyses from data acquired in the WIPP Excavation Effects Program.
Structural and material	The panel-closure system materials shall be compatible with their emplacement environment and function. Surface treatment between the host rock and the panel-closure system shall be considered in the design.	2.2.1	Complies	The material compatibility studies showed no degradation of materials and no need for surface treatment.
	The selection and placement of concrete in the concrete barrier shall address potential thermal cracking due to the heat of hydration.	2.2.2	Complies	The heat generation studies show that hydration temperatures are controlled by appropriate selection of cement type and placement temperature.
	The panel-closure system shall sustain the dynamic pressure and subsequent temperature generated by a postulated methane explosion.	2.2.3, 2.2.4, 4.0	Complies	The methane explosion study shows that the explosion-isolation wall protects the concrete barrier from pressure loading and thermal loading. The fracture propagation study shows that the system performs as intended.

Table 7-1 *(Continued)*
Compliance of Design with the Design Requirements

Type of Requirement	Requirement	Section	Compliance with Requirement	Notes on Compliance
Construction	The panel-closure system shall use to the extent possible normal construction practices according to existing standards.	3.4	Complies	The specifications include normal construction practices used in the underground at WIPP and according to the most current steel and concrete specifications.
	During construction of the panel-closure system, a quality assurance/quality control program shall be established to verify material properties and construction practices.	3.4	Complies	The specifications include materials testing to verify material properties and construction practices.
	The construction specification shall take into account the shaft and underground access capacities and services for materials handling.	3.4	Complies	The specifications allow construction within the capacities of underground access.

- The trade-off study also showed that a panel-closure system with an enlarged concrete barrier with the removal of the fractured salt roof and anhydrite in the floor was found to be the most protective.

The conclusions reached from the design evaluations addressing the structural and material requirements of the panel-closure system are as follows:

- Existing information on the heat of hydration of the concrete supports placing concrete with a low cement content to reduce the temperature rise associated with hydration. The slump at the required strength would be achieved through the use of plasticizers. A thermal analysis coupled with a salt creep analysis suggest installation of the enlarged barrier at or below ambient temperatures to adequately control hydration temperatures.

- In addition to installation at or below ambient temperatures, the concrete used in the main concrete barrier would exhibit the following:

  - An 8 inch (0.2 meter) slump after 3 hours of intermittent mixing
  - A less-than-25-degree Fahrenheit heat rise prior to installation
  - An unconfined compressive strength of 4,000 psi (28 MPa) after 28 days
  - Volume stability
  - Minimal entrained air.

- The trace amounts of brine from the salt at the repository horizon should not degrade the main concrete barrier for at least 35 years.

- In 20 years, the open passage above the waste stack would be reduced in size. Further, rooms with bulkheads at each end would be isolated in the panel. It is unlikely that a long passage with an open geometry would exist; therefore, the dynamic analysis considered a deflagration with a peak explosive pressure of 240 psi (1.7 MPa).

- The heat-transfer analysis shows that elevated temperatures would occur within the salt and the explosion-isolation wall; however, the elevated temperatures will be isolated by the panel-closure system. Temperature gradients will not significantly affect the stability of the wall.

- The fractures in the roof and floor could be affected by expanding gas products reaching pressures of the order of 240 psi (1.7 MPa). Because the peak internal pressure from the deflagration is only one fifth of the pressure, fractures could not propagate beyond the wall.

The design options to satisfy the design requirements for the panel-closure system include (1) a standard barrier, rectangular in shape, or (2) an enlarged concrete barrier, approximately

spherical in shape. Options (1) and (2) will be grouted at the interface and may contain explosion- or construction-isolation walls.

The design provides flexibility to satisfy the design migration limit for the flow of VOCs out of the panels. An enlarged concrete barrier would be selected where the air-intake and air-exhaust drifts have aged and where there is fracturing resulting in significant flow of VOCs. These conditions apply to the most severe ground conditions in the air-intake and air-exhaust drifts of Panel 1. If ground conditions are more favorable, such as might be the case for future panel entries, the design can be simplified to a standard concrete barrier rectangular in shape, with a construction isolation wall. GPR and observation boreholes are available for detecting the location and extent of fractures in the DRZ. These methods will be used to select the optimum location and appropriate panel-closure system.

The design is presented in this report as a series of calculations, engineering drawings, and technical performance specifications. The drawings illustrate the construction details for the system. The technical performance specifications cover the general requirements of the system, site work, concrete, and masonry. Information on the proposed construction method is also presented.

The design complies with all aspects of the design basis established for the WIPP panel-closure system. The design can be constructed in the underground environment with no special requirements at the WIPP.

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DOE/CAO-96-2160

Final
No-Migration
Variance Petition

June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

APPENDIX A
DERIVATION OF RELATIONSHIPS FOR THE AIR-FLOW MODELS

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A1.0 Introduction

This appendix shows the unrestricted and restricted air-flow models used to determine the performance of the panel closure system alternatives. These analyses are order-of-magnitude estimates of the volume of gas that might flow through the panel seal systems at the Waste Isolation Pilot Plant (WIPP).

A2.0 Model for Unrestricted Flow of VOCs

A model for the unrestricted flow of volatile organic compounds (VOC) was developed to predict the mass flow rates of VOCs and to compare this mass flow rate to the design migration limit for VOCs. As gas generation and panel volumetric creep closure proceed, a mixture of gases containing the VOC concentrations flows from each waste container. It is assumed for the unrestricted flow model that the headspace concentrations serve as a constant source of VOCs. This assumption is highly conservative, because most containers only have trace quantities of VOCs either trapped in the headspace or adsorbed on the surfaces of the various waste forms. It is believed that only a small number of waste containers have significantly greater sources of VOCs, such as a solvent-soaked rag or a can containing residual partially dried paint. Only these waste containers have a likelihood of maintaining a constant headspace VOC concentration as gas generation proceeds. However, the exact proportion of waste containers with higher VOC concentrations versus those with trace quantities is currently unknown. These data are based on results of the characterization of approximately 500 transuranic (TRU) mixed waste drums at the Idaho National Engineering Laboratory (INEL) and Rocky Flats.

The VOCs migrate due to advection from volumetric closure of the panel void space at a rate of about 28,250 ft^3 (800 m^3) per year. Gas generation for the waste inventory at a rate of 0.1 mole per drum per year (8,200 moles per panel per year) results in a volumetric flow rate of 7,060 ft^3 (200 m^3) per year. Because flow is unrestricted, the VOCs migrate under a pressure of one atmosphere. Other assumptions in the unrestricted model are as follows:

- Any gases released into the mine atmosphere would be reduced in concentration by 460,000[1] cfm of uncontaminated air. The mass flow rate of individual VOCs from individual panels following their closure is summed to determine the mass flow rate of VOCs through the exhaust shaft.

- This calculation considers the schedule for closure of individual panels as illustrated in Figure A-1 during the operational life of the WIPP. The VOC mass flow rate changes with time, with the maximum mass flow release occurring after 10 panel equivalents have been closed, about 25 years.

- Each VOC is analyzed in the calculations. Carbon tetrachloride is the most restrictive VOC in terms of satisfying the health-based levels for individual VOCs.

- Open panels of waste will not be considered as a source contributing to the emissions for a no-migration demonstration.

Considering only advection to result in the migration of VOCs, the mass-balance relationship is:

$$C_p * Q_p = C_{es} * Q_{es}$$

where

C_p = Head space concentration for an individual VOC
Q_p = Flow rate of VOCs from the panel that may vary with time
C_{es} = Concentration of VOCs at the exhaust shaft.
Q_{es} = Underground ventilation flow rate for the exhaust shaft

Air dispersion modeling is used for evaluating the receptor concentrations at the WIPP site boundary based upon the exhaust shaft source term. The air dispersion modeling considers such factors as meteorological data, release velocity, release temperature, and proximity of the WIPP site boundary to the exhaust shaft. The results of the modeling are expressed as a ratio R of the concentration at the exhaust shaft to the concentration at at the WIPP site boundary:

$$C_{es} \leq RC_{hbl}$$

This inequality can be expressed in terms of mass flow rate:

---

[1]The design ventilation rate for the WIPP underground is 425,000 standard cfm (12,000 standard m^3 per minute) under standard temperature and pressure conditions of 25 degrees Celsius and 1 atmosphere. The ventilation flow rate of 460,000 cfm (13,025 m^3 per minute) is the observed ventilation rate at the repository horizon under actual temperature and pressure conditions.

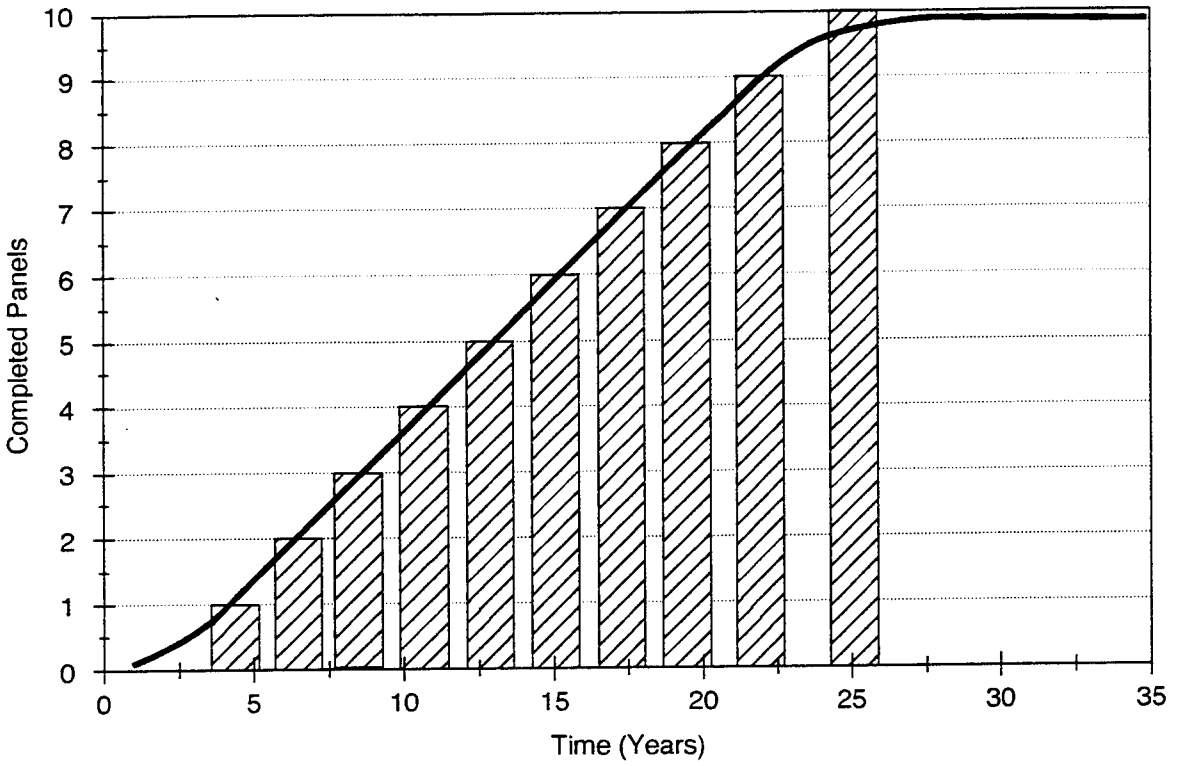

Figure A-1
Schedule for Panel Completion

$$\frac{C_p * Q_p}{Q_{es}} * \frac{1}{R} \leq C_{hbl}$$

where

R = Ratio of the concentrations at the exhaust shaft to the concentrations at the WIPP site boundary

C_{hbl} = Concentration to satisfy the health-based level for the individual VOC.

The ratio of the concentrations at the WIPP site boundary, R equals 10,753, reflecting the substantial atmospheric dispersion in reducing the concentration of VOCs.

The flow rates of VOCs from the panels are calculated for two mechanisms, gas generation and volumetric closure, using the following:

$$Q_p = Q_{gr} + Q_c$$

where

Q_{gr} = Volumetric flow rate due to gas generation[2] (200 m^3 per year per panel)

Q_c = Volumetric flow rate due to panel volumetric closure (800 m^3 per year per panel).

Table A-1 presents the closed panel release limits (migration limits) for VOCs based upon the health-based concentrations of individual VOCs. This inequality can be rewritten as:

$$C_p \cdot Q_p \leq C_{hbl} \cdot Q_{es} \cdot R$$

Table A-2 presents for a single closed panel and ten equivalent closed panels, the release rate for individual VOCs at the end of the 35-year operating period.

For the WIPP site boundary, the VOC concentrations are reduced substantially in the atmosphere. The above analysis shows that the concentration at the WIPP site boundary would be approximately 4 orders of magnitude lower than the concentration at the exhaust shaft. The predicted VOC mass flow rates due to unrestricted flow suffice to comply with the

[2]The volumetric flow due to gas generation is calculated as the gas generation rate (0.1 moles per drum per year) times the number of drums within a panel times the specific volume under atmospheric pressure.

Table A-1
Closed Panel Release Limits for VOCs

Compound	WIPP Site Boundary Health-Based Exposure Level[a] (micrograms per cubic meter)	Exhaust Shaft Concentration Migration Limit (micrograms per cubic meter)	Closed Ten Panel Migration Limit (grams per minute)
Carbon disulfide	10.00	107,530	1,400
Carbon tetrachloride	0.13	1,398	18
Chlorobenzene	20.00	215,060	2,801
Chloroform	0.09	968	13
1,1-dichloroethylene	0.40	4,301	56
Methyl ethyl ketone	1000.00	10,753,000	140,045
Methylene chloride	4.26	45,808	597
1,1,2,2-tetrachoroethane	0.35	3,764	49
Toluene	400.00	4,301,200	56,018

Table A-2
Closed Panel Release Rates for VOCs

Compound	Average Headspace Concentration (milligrams per cubic meter)[a]	Single-Panel Volumetric-Release Rate (cubic meters per minute)	Ten-Panel Volumetric-Release Rate (cubic meters per minute)	Single-Panel Mass-Release Rate (grams per minute)	Ten-Panel Mass-Release Rate (grams per minute)
Carbon disulfide	0.41	0.0019	0.019	7.80×10^{-7}	7.80×10^{-6}
Carbon tetrachloride	3625.77	0.0019	0.019	6.90×10^{-3}	6.90×10^{-2}
Chlorobenzene	63.99	0.0019	0.019	1.22×10^{-4}	1.22×10^{-3}
Chloroform	76.79	0.0019	0.019	1.46×10^{-4}	1.46×10^{-3}
1,1-dichloroethylene	48.68	0.0019	0.019	9.26×10^{-5}	9.26×10^{-4}
Methyl ethyl ketone	241.73	0.0019	0.019	4.60×10^{-4}	4.60×10^{-3}
Methylene chloride	3387.03	0.0019	0.019	6.45×10^{-3}	6.45×10^{-2}
1,1,2,2-tetrachloroethane	69.65	0.0019	0.019	1.33×10^{-4}	1.33×10^{-3}
Toluene	105.51	0.0019	0.019	2.01×10^{-4}	2.01×10^{-3}

[a]Westinghouse Electric Corporation, 1995, "Underground Hazardous Waste Management Unit Closure Criteria for the Waste Isolation Pilot Plant Operational Phase," *WID/WIPP-2038*, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, New Mexico.

closed ten-panel migration limit based upon the health-based levels at the WIPP site boundary over the operational life of the repository.

A3.0 Air Model

The modeling assumptions for the restricted air-flow model are as follows:

- The gases are generated at a specified rate (0.10 moles per drum per year).
- The gases flow out of the panel entries according to Darcy's law under quasi-steady state conditions.
- The gases within the pore space obey the ideal gas law
- The rates of gas generation, gas outflow, and change in compressive storage must balance.
- Hydrodynamic dispersion is neglected in the analysis.

After panel closure, the volume, moles of gas, and pressure are changing as functions of time. The ideal gas law (Hiller and Herber, 1960) is written as:

$$p = \frac{n * R * T}{V}$$

where

p = Pressure
n = Moles of gas in the panel
R = Universal gas constant
T = Absolute temperature
V = Volume

Differentiating with respect to t and using the chain rule, we obtain the following relationship:

$$\frac{dp}{dt} = R * T * \frac{\frac{dn}{dt} * V - n * \frac{dV}{dt}}{V^2}$$

The volumetric closure rate is negative and constant as discussed below. The rate at which gas enters the panel minus the rate that gas leaves the panel must equal the change in moles stored. We obtain the mass-balance relationship:

$$\frac{dn}{dt} = g_r - \frac{p}{R*T} * K_s * \frac{A}{L} * \frac{p - p_{atm}}{\gamma}$$

where

g_r	=	Panel gas generation rate
p_{atm}	=	Atmospheric pressure
γ	=	Air density
K_s	=	Effective panel closure system conductivity
A	=	Cross-sectional area
L	=	Length of flow path

We define the conductance (C) as:

$$C = K_s * \frac{A}{L}$$

and substituting into the ordinary differential equations (ODE), we obtain

$$\frac{dp}{dt} = R*T* \frac{g_r - \frac{p}{R*T} * C * \frac{p - p_{atm}}{\gamma} * V - n * \frac{dV}{dt}}{V^2}$$

$$\frac{dn}{dt} = g_r - \frac{p}{R*T} * C * \frac{p - p_{atm}}{\gamma}$$

These two first-order coupled ODEs can be solved by a simple explicit finite difference technique:

$$p_j = p_{j-1} + R * T * \frac{g_r - \frac{p_{j-1}}{R*T} * C * \frac{p_{j-1} - p_{atm}}{\gamma} * V - n_{j-1} * \frac{dV}{dt}}{V^2} * \Delta t$$

$$n_j = n_{j-1} + g_r - \frac{p_{j-1}}{R*T} * C*\frac{p_{j-1} - p_{atm}}{\gamma}\Delta t$$

where

p_j, n_j = the pressure and moles of gas at the current time step
P_{j-1}, n_{j-1} = the pressure and moles of gas at the previous time step

subject to the boundary condition that the initial pressure equals atmospheric pressure, and the initial moles of gas can be determined by the ideal gas law at initial volume and pressure. Further note that the volume can be expressed as the linear function:

$$V(t) = \alpha * t + \beta$$

where

α = slope of the volume-time relationship
β = intercept of volume-time relationship
t = time

These expressions can be substituted into the above explicit finite difference relationships, and the pressure and molar air flow rates determined as functions of time.

$$\frac{dV}{dt} = \alpha$$

APPENDIX B

CALCULATIONS IN SUPPORT OF PANEL GAS PRESSURIZATION DUE TO CREEP CLOSURE

APPENDIX B
CALCULATIONS IN SUPPORT OF PANEL GAS PRESSURIZATION DUE TO CREEP CLOSURE

B.1.0 Introduction

This appendix presents the closure mechanisms and supporting calculations for panel volumetric closure for the analysis of gas pressurization within a closed panel at the Waste Isolation Pilot Plant (WIPP). The volume reduction is due to the panel volume change from viscoplastic creep closure of the walls, roof, and floor. As the walls, roof, and floor of the excavations converge, the total volume of the panel decreases. The volumetric closure of a panel is the result of several different mechanisms working in tandem. These mechanisms include:

- Viscoplastic creep of the salt toward the excavation
- Fracturing in the roof and floor caused by the deviatoric stresses around the excavation
- Bed separation at the clay seams in the roof and the floor.

The combination of these three mechanisms causes the observed convergence rates in Panel 1. Of these mechanisms, only creep of the salt reduces the total volume of the panel and pore space in the surrounding disturbed rock zone (DRZ). Fracturing in the roof and floor and bed separation transfer the void volume within the excavation to the DRZ. This void volume within the DRZ is assumed to be interconnected with the open excavation. Therefore the total reduction in volume within the panel, based simply on room closure, overestimates the effective reduction in void volume. However, quantifying the amount of interconnected void space within the DRZ would require a much more detailed analysis. The total volume change calculated from the room closure measurements is therefore considered conservative.

Other assumptions made in this calculation are:

- The volumetric closure rates are constant after panel closure.
- The waste in the panel provides no significant resistance to creep closure during the initial 35 years.

- The air volume is the total volume of the excavations minus the solid volume of the waste in drums or other waste packages. This is estimated to equal 138,000 ft^3 (3,908 m^3).

- The closure rate of each room in the panel equals the closure rate at the midpoint of the room.

- The length of each room or drift is constant; to simplify the calculations, only the width and height change with creep closure.

- The panel is comprised of seven rooms and two panel access drifts.

B.2.0 Panel Volume Change Calculation

The panel volume change calculation is performed by first calculating the initial panel volume, then calculating the room and drift closure rates, and finally calculating the panel volumetric closure rate. Following is a detailed description of each part of the calculation.

B.2.1 Initial Panel Volume

The initial panel volume is determined immediately after completion of excavation. The total volume is calculated by summing the individual room and drift volumes within the panel. These volumes are based on the as-built dimensions of the excavated rooms and drifts in Panel 1 (DOE, 1993). Table B-1 presents the room and drift dimensions and the calculated volume of each room and drift. The volume of the air-intake and air-exhaust drifts is not included. The total initial volume of Panel 1 is 1,669,434 ft^3 (47,273 m^3).

The total solid volume of the waste in a filled panel is 138,000 ft^3 (3,908 m^3) (DOE, 1994; Butcher, et al., 1991). Subtracting the waste volume from the total panel volume gives the total initial air volume (1,531,434 ft^3 [43,365 m^3]) in the panel.

B.2.2 Closure Rates

Using convergence data from Panel 1 the average closure rates of the rooms and drifts are determined (DOE, 1993). Closure rates within the rooms and drifts are higher in the first five years after excavation. The roof-to-floor and wall-to-wall closure rates for each of the rooms and drifts are presented in Table B-2.

Because all of the excavations in Panel 1 are approximately 13 x 33 ft (4 x 10 m), the closure rates for each room or drift are the same.

Table B-1
Initial Room and Drift Dimensions and Volume of Panel 1

Room or Drift	Initial Width (ft)	Initial Height (ft)	Initial Length (ft)	Initial Volume (ft^3)
Room 1	33	13	300	128,700
Room 2	33	13	300	128,700
Room 3	33	13	300	128,700
Room 4	33	13	300	128,700
Room 5	33	13	300	128,700
Room 6	33	13	300	128,700
Room 7	33	14	300	138,600
South 1950 panel access drift	33	14	848	391,776
South 1600 from Room 1 to Room 5	33	13	573	245,817
South 1600 from Room 5 to Room 7	33	14	262	121,044
Total Initial Panel Volume				1,669,437

B.2.3 Volumetric Panel Closure Rate

Using the closure rates from Table B-2, the dimensions of the rooms and drifts in Panel 1 can be calculated at the end of each progressive year or for subsequent years using the following equations.

For 0 to 5 years after excavation:

$$V_t = (w_i - R_H t) \times (h_i - R_{VO} t) \times l_i$$

Table B-2
Room and Drift Closure Rates
(DOE, 1993)

Room or Drift	Vertical Closure Rate		Horizontal Closure Rate	
	0 to 5 Years (ft/yr)	> 5 Years (ft/yr)	0 to 5 Years (ft/yr)	> 5 Years (ft/yr)
Room 1	0.3194	0.2109	0.2234	0.1160
Room 2	0.3194	0.2109	0.2234	0.1160
Room 3	0.3194	0.2109	0.2234	0.1160
Room 4	0.3194	0.2109	0.2234	0.1160
Room 5	0.3194	0.2109	0.2234	0.1160
Room 6	0.3194	0.2109	0.2234	0.1160
Room 7	0.3194	0.2109	0.2234	0.1160
South 1950 panel access drift	0.3194	0.2109	0.2234	0.1160
South 1600 from Room 1 to Room 5	0.3194	0.2109	0.2234	0.1160
South 1600 from Room 5 to Room 7	0.3194	0.2109	0.2234	0.1160

For greater than 5 years after excavation:

$$V_t = (w_i - R_H t) \times (h_i - R_{V5}(t-5) - R_{V0}5) \times l_i$$

where

V_t = Volume of the room at time t
t = Time (in years)
w_i = Initial room width
h_i = Initial room height
l_i = Initial room length
R_H = Horizontal closure rate (ft/year)
R_{V0} = Vertical closure rate for first 5 years (ft/year)
R_{V5} = Vertical closure rate after 5 years (ft/year).

We obtain the incremental change in volume:

$$\Delta V = V_1 - V_2$$

where

V_1 = Volume of room at time t_1 (ft^3)
V_2 = Volume of room at time t_2 (ft^3)
ΔV = Change in volume of room between time t_1 and t_2 (ft^3)
t_1, t_2 = Years after excavation

The volume of all the rooms within the panel is calculated at the time of four years after excavation, when the waste is assumed to have been emplaced the amount of time required for waste emplacement (Table B-3). The total volume of the panel after four years is 1,469,112 ft^3 (41,601 m^3). The volume of the panel is then calculated at five years after excavation or one year after panel closure (Table B-3). This volume is 1,420,312 ft^3 (40,219 m^3), and the volume reduction in that year is 48,800 ft^3 (1,382 m^3).

The initial volume in a closed panel after approximately four years is obtained from the total volume at four years (1,469,112 ft^3 [41,601 m^3]) minus the solids volume (138,000 ft^3 [3,908 m^3]), or 1,331,112 ft^3 (37,693 m^3). This volume is used as the initial volume for the restricted air-flow model calculations.

The rate of change for panel volume is assumed to be constant for the first five years after excavation, because the vertical and horizontal closure rates are constant during this period. (Actually, rate of volume change over time decreases slightly with each year due to "corner effects," but this error is less than 2 percent and is considered insignificant.) Table B-3 also shows the panel volumes at 15 and 16 years after excavation and the change in volume between those years. The volumetric panel closure rate is 28,673 ft^3 per year (812 m^3 per year). This is the rate in volume change per year in the panel from five to approximately 35 years after excavation.

At approximately 16 years after excavation, the roof comes in contact with the waste stack. Only 35 years after excavation does the waste stack begin to provide significant resistance to creep (approximately 2 MPa). This resistance is expected to slow the vertical convergence rate by some amount.

Table B-3
Panel Volume at Various Times

Room or Drift	Volume of Room (ft^3)			
	At 4 Years	At 5 Years	At 15 Years	At 16 Years
Room 1	112,914	109,069	85,662	83,401
Room 2	112,914	109,069	85,662	83,401
Room 3	112,914	109,069	85,662	83,401
Room 4	112,914	109,069	85,662	83,401
Room 5	112,914	109,069	85,662	83,401
Room 6	112,914	109,069	85,662	83,401
Room 7	122,545	118,633	94,879	92,583
South 1950 panel access drift	346,395	335,337	268,191	261,702
South 1600 from Room 1 to Room 5	215,665	208,321	163,614	159,296
South 1600 from Room 5 to Room 7	107,023	103,607	82,861	80,856
Total Volume of Panel 1	1,469,112	1,420,312	1,123,529	1,094,856
Change in Volume		48,800		28,673

B.3.0 References

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APPENDIX C
FLAC MODELING OF THE PANEL CLOSURE SYSTEM

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FLAC MODELING OF THE PANEL CLOSURE SYSTEM

Numerical modeling is considered one of the better methods available for quantifying the interaction of concrete barriers with the surrounding media. Therefore, a series of models have been developed for this report to evaluate the interaction of the main concrete barrier of the panel closure system with the surrounding salt for different alternatives and concrete barrier geometries. This appendix discusses the code used and describes the material constitutive models used in the stress analysis.

C.1.0 The FLAC Code

FLAC software has been used for numerical modeling of the underground excavations at the WIPP since 1991. FLAC is a two-dimensional explicit finite difference code that simulates the behavior of rock and soil-like structures. The WIPP Reference Creep Law is built into FLAC and has been verified to Nuclear Regulatory Commission standards (Itasca, 1995). In addition, all versions of FLAC used by the Westinghouse Waste Isolation Division have been verified against the WIPP Second Benchmark Problem (Krieg, 1984).

C.2.0 Material Constitutive Models

The material properties associated with the material constitutive models are given in Tables C-1 through C-3. These properties are the standard properties which have been used in previous WIPP geotechnical FLAC modeling such as the Backfill Engineering Analysis Report (BEAR) (IT, 1994). Note that the stress analysis of the concrete barrier also uses the same stress-strain relationship for the uncompacted crushed salt as was used in the BEAR. The stress analysis in Figure 4-4 used uncompacted crushed salt on one side of the enlarged concrete barrier and open void space on the other side. The crushed salt has subsequently been eliminated from the panel closure system final design. The symmetry in the principal stress plots for the enlarged concrete barrier analysis indicated that the presence or absence of the crushed salt does not significantly affect the stresses within the enlarged concrete barrier. Therefore, the FLAC analysis results presented in Figure 4-4 apply to the panel closure system final design.

Table C-1[a]

FLAC[b] Model Time-Dependent Material Properties

Property	Halite	Argillaceous Halite	Halite, 10% Polyhalite
Bulk modulus (GPa)	20.7	20.7	22.1
Shear modulus (GPa)	12.4	12.4	13.2
Density (kg/m^3)	2,300	2,300	2,300
Activation energy (cal/mol)	12,000	12,000	12,000
A	4.56	4.56	
B	127	127	
D (Pa$^{-4.9}$/s)	5.79×10^{-36}	1.74×10^{-35}	5.21×10^{-36}
n	4.9	4.9	4.9
Gas constant (cal/mol K)	1.987	1.987	1.987
Critical strain rate	5.39×10^{-8}	5.39×10^{-8}	5.39×10^{-8}

Table C-2[a]

FLAC[b] Elastic Material Properties

Property	Anhydrite	Polyhalite	Concrete
Bulk modulus (GPa)	83.4	65.8	11.6
Shear modulus (GPa)	27.8	20.3	9.0
Density (kg/m^3)	2,300	2,300	2320
Cohesion (MPa)	27	17.2	–
Friction (degrees)	29	46.5	–

Table C-3[a]

FLAC[b] Clay Seam Material Properties

Property	Value
Normal stiffness (Pa/m)	1.0×10^{12}
Shear stiffness (Pa/m)	5.0×10^{10}
Cohesion (Pa)	0.0
Friction (degrees)	5

[a]IT, 1994

[b]FLAC = Fast Lagrangian Analysis of Continua
GPa = Gigapascal(s)
kg/m^3 = Kilogram(s) per cubic meter
cal/mol = Calorie(s) per mole
Pa$^{-4.9}$/s = Pascal(s) to the negative 4.9 per second
cal/mol K = Calorie(s) per mole Kelvin
A,B,n = unitless model factors
D = model factor
Pa/m = Pascal(s) per meter
MPa = Megapascal(s)

C.3.0 References

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APPENDIX D
BRINE/CEMENT INTERACTIONS

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BRINE/CEMENT INTERACTIONS

Concern about potentially deleterious constituents in the Waste Isolation Pilot Plant (WIPP) brines were initially raised when evidence of some minor concrete deterioration in the waste shaft key was noted. The cause is geochemical alteration of the concrete shaft liner and shaft grout by the brine present at the Rustler-Salado contact. Chemical constituents detected in brine samples included both organic and inorganic compounds that probably originated from dissolution of the concrete liner and grout materials used in the shaft construction. The presence of large amounts of organics that likely originated from the chemical grout appeared to have complexed the calcium present in the brine, interfering with the inorganic chemistry of the naturally occurring brine. The brines in contact with the waste shaft key were also found to be significantly higher in both chlorides and magnesium than the Salado Formation brine. These factors probably resulted in a Rustler/Salado brine chemistry more aggressive than that of the naturally occurring Salado brines that may contact the panel barrier.

Lankard Materials Laboratory (LML) (1992) concluded that there has been both a "physical attack" component and a "chemical attack" component acting upon the waste shaft key by brines. A "worst-case" scenario proposed by LML indicated that deterioration from both chemical and physical factors could result in a loss of material on the shaft side of the concrete liner at a rate of approximately 12 centimeters (5 inches) over a 50-year period.

The very local deterioration of the waste shaft key concrete resulted in some reduction in its load-bearing capacity and some increase in its permeability to brine infiltration. In addition, exposure of chemical residue deposits to the air within the shaft may have created a spalling effect that also facilitated local concrete deterioration on the interior (shaft opening) side of the liner.

Sandia National Laboratories/New Mexico (SNL/NM) studied the effect of high-magnesium brine interactions on various candidate barrier materials (SNL/NM, 1994). High-magnesium brines are characteristic of the Rustler-Salado contact, which is the location of the waste shaft key. The study was intended to evaluate chemical impacts to mass-concrete barriers in the WIPP panels and to the Salado Formation. However, the results of the study were also used to evaluate the cause of the deterioration of the waste shaft key. IT Corporation (IT) (1994),

in a separate study, also evaluated the geochemistry of brines associated with the waste shaft key near the Rustler-Salado Formation contact.

Both studies concluded that the brines have chemically reacted with the constituents in the concrete and grouts used in the waste shaft key liner. The SNL/NM (SNL/NM, 1994) study theorized that the loss of the liner's strength was facilitated by the loss of calcium from the concrete liner. SNL/NM noted that the magnesium present in the brine replaced calcium in the concrete, but the replacement process occurred as a delayed reaction. Magnesium replacement did not occur until after the structural integrity of the waste shaft key liner was already impacted negatively by the loss of calcium, which increased the porosity of the liner. This resulted in a more open and permeable microstructure not attributable solely to a weakening effect from magnesium replacement. Both the IT and SNL/NM studies supported the conclusion that the waste shaft key liner deterioration occurred only locally and in the outermost reaction zone of the liner, so that the structural integrity of the liner as a whole was not significantly impacted. SNL/NM proposed that further deterioration of the liner may be limited only to areas of the concrete liner that develop stress fractures.

Wakeley et al. (1993) studied salt-saturated concrete and grout emplaced in the floor of the WIPP repository six years before its retrieval. The concrete and grout used in the study were cementitious, rather than organic. In retrieving the concrete and grout plugs, the plugs were overcored to also retrieve some host rock.

The study concluded that little to no deterioration occurred to the concrete or grout and that general compressive strengths of the concrete and grout increased over time. The lowest compressive strength values were observed in samples taken from the disturbed rock zone. Reaction rims with increased permeability were noted on anhydrite surrounding the plugs, suggesting interaction between the grout or concrete and host rock. However, comparable evidence of a reaction with the concrete or grout was not seen. There was also evidence of dissolution of halite in the anhydrite zone near the plugs; however, the evidence also indicates that the presence of the halite facilitated better bonding between the grout or concrete and the host rock. Crystallization of new phases was also noted on free surfaces, indicating that strongly ionic magnesium-bearing fluids were present and moving. The fluid movement appeared to have no effect on the host rock other than to improve bonding.

The differences in the appearances, strengths, and phase assemblages between the grout/concrete plugs in the study discussed above and the waste shaft key liner concrete are

different enough that two extremely different service environments can be inferred. The magnesium level and fluid transport are apparently much greater in the waste shaft key location, facilitating a greater degree of deterioration of the waste shaft key concrete than was noted in the plugs studied by Wakeley et al. (1993). The waste shaft key concrete liner was also composed of organic constituents, which appeared to be more reactive with the brine chemistry. The main concrete barrier will be located in a service environment similar to that studied by Wakeley et al. (1993), where very minor amounts of brine would contact the main concrete barrier.

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APPENDIX E

PREVIOUS STUDIES OF PANEL-CLOSURE SYSTEM MATERIALS

APPENDIX E
PREVIOUS STUDIES OF PANEL-CLOSURE SYSTEM MATERIALS

In researching the available literature relating to panel-closure system designs and materials, studies on both long-term and short-term barrier performance were evaluated. The intended function of the main concrete barrier described in this report is to provide short-term (35 years) barrier capability until the repository host rock reconsolidates around the barrier. However, studies on long-term barrier performance were found useful for the panel-closure system material compatibility evaluation performed for this document. The results of these studies provided insight into the complex issues to be considered for selecting an appropriate concrete and grout for the panel-closure system.

Stormont (1987) studied small-scale seal performance tests (SSSPT). The SSSPTs were designed as in situ experiments to evaluate the performance of candidate seal materials. Barrier systems consisted of the barrier itself, the barrier-rock interface, and the surrounding rock. The system performance was evaluated using thermal/mechanical and fluid flow (both gas and brine) data generated by testing under expected repository conditions. Thermal, mechanical, and hydrologic performance of the barriers was evaluated. Test Series A consisted of a bulkhead constructed of salt-based concrete. Regarding hydration of the concrete, stresses and strains induced in the rock and the barrier were a result of hydration. Stresses and strains also resulted from the salt creep and from the panel-closure system material. Evaluation of these stresses and strains yielded information about the stability of the barrier system and the structural/fluid flow relationship. The permeabilities of the barrier material with respect to gas and brine were important for evaluating the potential for a repository breach scenario. Test Series A was conducted in geologic horizons that included bedded halite and interbeds of clay and anhydrite.

Three types of concrete were evaluated for the Test Series A study: salt-free concrete, salt concrete, and expansive salt-based concrete. The latter proved to yield the most favorable results due to its significant expansive properties, which create a tight interface; its workability (about 4 hours); and for its ability to inhibit dissolution of surrounding salt during cement hydration.

Stormont (1988) also studied the performance of grout and concretes as constituents of main concrete barriers for the panel-closure system. The use of cementitious grouts within the disturbed rock zone adjacent to the main barrier was determined to be detrimental at times, as it could facilitate fracture propagation. To prevent the load reaction causing the fracture propagation, Stormont proposed the emplacement of rigid concrete at the main barrier location. Stormont's investigations of concrete to form the actual main barrier indicated that concrete is impermeable, and any associated leakage across the barrier would occur at the concrete/rock interface zone. Leakage could be attributed to concrete shrinkage and the integrity of the rock itself. However, Stormont noted that the presence of halite in the host rock would result in compressional forces exerted on the concrete barrier over time, with little or no leakage occurring.

SSSPT performed by Stormont (1988) and Finley and Tillerson (1992) evaluated salt-based concrete, bentonite, and salt blocks for barrier performance. In the salt-based concrete barriers, both brine and gas migration across the barrier-rock interface were retarded by salt creep adjacent to the barrier and the expansive properties of the salt-based concrete. The salt-based concrete barriers also withstood significant back-pressure forces. Bentonite and salt blocks did not perform as satisfactorily with respect to their load-bearing capacities or fluid permeabilities.

Hansen et al. (1994) discussed barrier materials for vertical shaft environments in terms of the barriers' long- and short-term components. The single long-term component envisaged in their studies was reconsolidated salt, especially engineered to achieve a barrier function in approximately 100 years. However, short-term materials included concrete, bentonite, grout, chemical seal rings, and potential alternatives, although the alternatives were not included in a reference barrier design. Each barrier component had a functional requirement to prevent the passageways from becoming the preferred passageways for transport of brines or gases to or from the repository. Short-term components provided barriers to brine and groundwater inflow to the consolidating and long-term members and to the repository. The composition of each selected barrier was based on experience in the mining industry, assurance of function through test results, and compatibility with the stratigraphy in which the barrier was placed. The authors looked at specific geologic horizons with respect to their ability to prevent brine and gas flow.

Test Series B (Peterson et al., 1987) more likely approximated the configuration of the proposed panel barrier, which will be emplaced in a horizontal drift leading to the waste-

emplacement panels. The type of material used in the testing was a salt-saturated expansive concrete, as was used in Test Series A.

In both the A and B test series, the parameter of primary interest was the barrier permeability. For calculational purposes, it was assumed that all flow goes through the barrier. However, some flow may enter the surrounding formation as well, although it is difficult to determine and quantify. Factors affecting measured flow rates through the barrier would include the pressure under which the brine was flowing. If a brine was saturated with respect to its liquid phase at ambient conditions, added pressures may decrease its saturation and encourage dissolution of the surrounding halite.

In one test, barrier brine flow rate decreased slowly with time; this is an important consideration when modeling long-term response. Possible mechanisms causing this decrease include precipitation, healing, or creep closure of open pore spaces. Estimates of brine and gas permeabilities depend strongly on the degree of pore saturation.

Only gas-flow tests were performed in the B Series. All of the barriers leaked (though at slow rates) in the B Series tests. No leakage occurred at the barrier/formation interface. Leaks were associated with a small formation fracture and with an instrumentation bundle. Gas-flow tests performed approximately one year later indicated no leakage associated with the barriers.

Test Series C (Stormont et al., 1987) consisted of salt and salt-bentonite block barrier material emplaced in a horizontal drift within almost pure halite. Four barriers were composed of salt blocks, and four barriers consisted of salt-bentonite blocks. Four of the barriers, two representing each type of material described above, were evaluated without instrumentation, for fluid flow and permeability testing. Instrumentation and cabling are often leak paths for such testing. The instrumentation used in the other barriers measured deformations and pressures and provided other important data. The data suggest that crushed salt provides very little resistance to closure until the crushed salt is very dense. Deformation experiments were designed to verify or refute this evidence.

Principal advantages to salt-block emplacements as opposed to mechanical or pneumatic backfilling were that initial porosity of the crushed or granular salt was minimized, reducing the time required for effective or complete salt consolidation. This in turn reduced the likelihood of brine influx from the surrounding strata that could impede the consolidation

process. Block emplacements also allowed considerable control over production and emplacement. Blocks could be tailored to achieve certain properties, such as addition of bentonite or moisture.

Experiments with different types of blocks indicated that the relative density of the blocks increased with the maximum particle size used. Further, blocks cured in humid environments became extremely friable and unviable. Within the Waste Isolation Pilot Plant (WIPP) facility, the humidity of the ventilation air is below the critical humidity of 75 percent (the air will take moisture from the salt).

Blocks cured at ambient conditions were the most resilient in that they resisted chipping and shattering. Their "toughness" was a result of the development of an indurated "skin" from particle caking. Caking occurs when moisture at particle contacts is evaporated, resulting in bridging and microcrystalline growth that essentially cements the particles together. However, an indurated skin may also hinder consolidation at the interfaces between blocks from a lack of available water believed necessary for rapid consolidation.

The purpose of adding bentonite to salt blocks was to reduce the permeability without requiring extensive consolidation. Data collected indicated that permeabilities to brines and water fell off to microdarcy values somewhere between 25 and 50 percent bentonite by weight. For this experiment, a 1:1 ratio of salt to bentonite was used. Over 90 percent of the bentonite was composed of the clay mineral montmorillonite. Water was also introduced into the mixture.

Salt/bentonite blocks cured in the humid environment took sufficient moisture from the air to become extremely friable, and therefore, unviable. Under covered conditions, less moisture was lost. Salt/bentonite blocks were also tougher than salt-only blocks. Also, greater amounts of moisture contributed to a tougher block than the addition of less moisture.

The use of mortars was necessary to fill the voids between the blocks and the borehole wall. Mortar was generally only emplaced into the interface and not between blocks. The mortars were composed of the same materials as the blocks.

In summary, both types of blocks were found to lose excessive moisture to the dry mine atmosphere unless they were covered between the time of production and the time of emplacement. Initial fluid flow testing of the salt/bentonite barriers revealed that erosion

along the block/rock interface occurred when the brine was introduced too rapidly to allow the bentonite to take up the water and swell to shut down flow paths. Subsequent testing with slower introduction of brine confirmed this result, that is, salt/bentonite blocks could be effective barriers to brine flow. Structural measurements provided data to test laboratory models of salt consolidation. To date, the measurements do not contradict model predictions of the barriers providing little resistance to hole closure until they become very dense.

The concrete and grout used in the above-referenced study were developed by Gulick and Wakeley (1989). They proposed expansive salt-saturated concrete (ESC) and grout mixtures that yielded favorable results for suitability as panel barrier and grout materials during the in-place testing at the WIPP repository. The grout composition was summarized in the text of this report in Section 2.2.1. The formulation for the ESC is shown in Table E-1.

Table E-1
Expansive Salt-Saturated Concrete

Component	Percent of Total Mass
Class H cement	9.03
Chem comp III	6.03
Cal seal (plaster)	1.80
Class C fly ash	5.10
Fine aggregate	34.11
Coarse aggregate	34.58
Sodium chloride	2.50
Defoaming agent	0.21
Sodium citrate	0.11
Water (iced)	6.60

Class H cement is a standard oil-well cement. It has been used extensively in grouts and concretes in underground applications. Class C fly ash contributes expansive properties to the concrete. Cal Seal (a plaster of paris manufactured by Haliburton) also develops expansive properties in mixtures containing Class H cement. Expansive components that are added to the concrete or grout mixtures enhance bonding between the concrete or grout and the host rock. The addition of sodium chloride to the mixture is necessary to assure that the water

content of the concrete or grout is in equilibrium with the host rock. This prevents dissolutioning, and also inhibits or reduces deterioration of the concrete or grout. Defoaming agents inhibit air entrainment in the concrete or grout mixture.

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APPENDIX F

HEAT TRANSFER MODEL DERIVATION METHANE EXPLOSION

APPENDIX F
HEAT TRANSFER MODEL DERIVATION
METHANE EXPLOSION

Under the conditions of a postulated methane explosion within the panel, the temperature of the gas is raised by the combustion process to an initial value $T_{g\ init}$ with time t = 0 corresponding to initial conditions in the panel. Subsequently, the gas temperature in the panel decreases as heat is transferred to the surrounding salt and to the two explosion-isolation walls in the air-intake and air-exhaust drifts of each panel.

At time t = 0 the pressure in the panel is P_{init} based on panel closure due to creep and the elevation in pressure resulting from the explosion. Thus, the rise time of the temperature is not considered in the model.

At time t = 0, the volume of the panel is V_{init} and is assumed to remain constant throughout the cooling of the gas in the panel because of the short duration of the explosion. This means that the effect of creep on the panel volume is assumed negligible during the postulated explosion. The initial volume is given by:

$$V_{init} = V_{panel} - V_{waste} - V_{creep}$$

where

V_{init} = Initial volume
V_{panel} = Volume of the panel
V_{waste} = Volume of the waste
V_{creep} = Volume reduction due to creep

and is taken as given at the start of the heat transfer analysis and assumed to remain constant during the transfer of heat to the panel walls, roof, and floor.

F.1.0 Heat Balance

Assuming a constant volume is equivalent to stating that any creep closure of the panel volume during the explosion and subsequent cooling can be neglected.

$$\frac{dQ_{volume\ of\ gas}}{dt} = qA_{walls,\ floor,\ roof}$$

where $Q_{volume\ of\ gas}$ represents the heat contained in the hot gases subsequent to an explosion, q is the heat flux rate at the boundaries of the panel volume, and $A_{walls,\ floor,\ roof}$ is the surface area of the panel volume.

Following D'Appolonia (1978) it is conservatively assumed that the heat transfer to the surrounding walls, floor, roof, is related to the rate of change of enthalpy of the reaction products gas. Thus, the heat content of the room is given by:

$$\frac{dQ_{volume\ of\ gas}}{dt} = nC_p\frac{dT_g}{dt}$$

where n is the number of moles of gas in the room subsequent to the explosion, T_g is the gas temperature, and C_p is the heat content of the gas at constant pressure.[1] Thus,

$$nC_p\frac{dT_g}{dt} = qA_{walls,\ floor,\ roof} \qquad (1)$$

F.2.0 Moles of Gas

The gas in the panel subsequent to the explosion is a mixture of the combustion products of the explosive gas which is taken to be a mixture of methane, CH_4 and air. Because methane can explode with other than a stoichiometric air/methane mixture (i.e., the methane concentration in air for an explosion to occur is a range as opposed to a single value), it is impossible to determine the number of moles of combustion product gas precisely. Thus, it is assumed that the explosion occurs with a stoichiometric air/methane mixture.

[1]The specific heat at constant volume is used even though the explosion or rapid combustion of the methane-air mixture occurs at constant volume because the rate of change of enthalpy as opposed to internal energy has been used.

F.2.1 Mixture

The stoichiometric reaction for methane is (Bodartha, 1980):

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

with the moles of air given by:

$$n_{air} = 4.77(2) = 9.54 \ mole\ air/mole\ methane$$

or 9.54 moles of air are required to provide 2 moles of oxygen. Using a ratio of 9.54 moles of air per mole of methane, the total moles of gas at the time of the explosion would be:

$$n = (9.54 + 1)n_{CH4}$$

The number of moles of nitrogen in the air and in the combustion products gas is 3.77(2) = 7.54 moles/mole of methane (Bodartha, 1980). Thus,

$$7.54 \text{ moles } N_2 + 2 \text{ moles } O_2 + 1 \text{ mole } CH_4 =$$
$$7.54 \text{ moles } N_2 + 1 \text{ mole } CO_2 + 2 \text{ moles } H_2O$$

On a molar basis the reaction products are 71.5% nitrogen, 9.5% carbon dioxide, and 19% water vapor. This compares with a reaction product that is 72.9% nitrogen, 11.6% carbon dioxide and 15.5% water vapor when propane is burned at a stoichiometric ratio (D'Appolonia, 1978). Also, 10.54 moles of the methane-air mixture produces 10.54 moles of reaction products. Thus, the number of moles of air/methane prior to the explosion is the same as the number of moles of the product gas and the above relation for n will be used to compute the heat content in a panel prior to cooling.

$$n_{gas} = 10.54\ n_{CH4} \tag{2}$$

Substituting (2) into (1),

$$10.54\ n_{CH4}\ C_p\ \frac{dT_g}{dt} = qA_{walls,\ floor,\ roof}$$

or

$$\frac{dT_g}{dt} = \frac{qA_{walls,\ floor,\ roof}}{10.54\ n_{CH4}\ C_p} \qquad (3)$$

is the differential equation for the time rate of change of the gas temperature in the panel following an explosion.

F.2.2 Specific Heat

The specific heat, Cp, of the combustion products of the explosion is required by equation (3). In general, the specific heat is a function of temperature over large temperature ranges. Figure C-1 shows plots of specific heats of the combustion products of stoichiometric propane-air mixtures and methane-air mixtures based on data from D'Appolonia (1978) and Reid, et al., (1977). The curves for propane-air mixtures are shown for comparison between the Reid, et al. data and the D'Appolonia data.

For an explosion temperature on the order of 2400 degrees kelvin (°K), and using an average of the wall temperature and gas temperature to evaluate the specific heat, the temperature dependence curve will be evaluated in the region of 1400 °K which is about the maximum useful temperature for the Reid, et al. data.

As shown on Figure F-1, the Reid et al. (1977) and D'Appolonia (1978) data agree well up to a temperature of approximately 1400 °K. At the greater temperatures Reid et al. (1977), and other data indicate a decrease in specific heat with greater temperatures which is not consistent with expectation.

Figure F-2 shows a comparison of Reid et al. (1977) and the D'Appolonia (1978) data multiplied by 0.961, the ratio of specific heats for a methane-air mixture to a propane-air mixture at 300 °K. Below 1400 °K the agreement is very good. Above 1400 °K the curve based on the D'Appolonia data remains valid. Therefore, the specific heat of the combustion products formed from a stoichiometric methane air mixture as a function of temperature is[2]

$$C_p = 1.29\ x\ 10^{-3}\ T + 7.3353 - \frac{32682}{T^2} \qquad (4)$$

[2]Equation (4) was obtained by multiplying Equation (9) of Appendix B of D'Appolonia [1978] by 0.961.

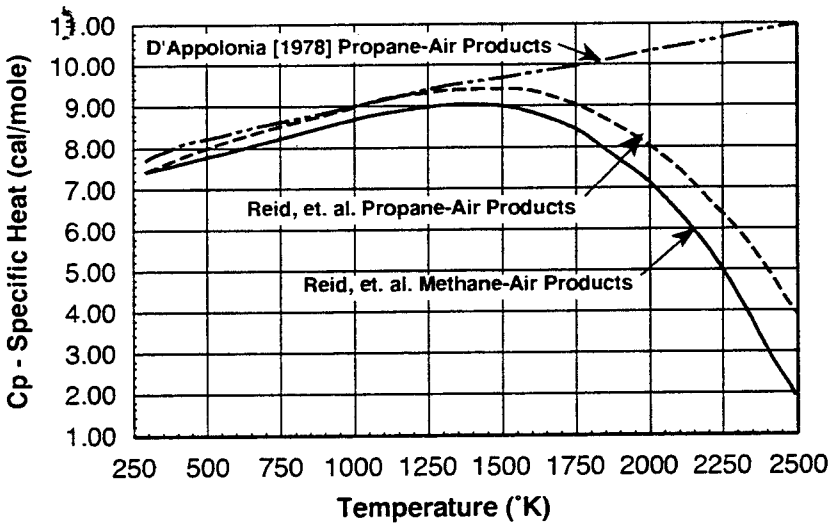

Figure F-1
Specific Heat as a Function of Temperature

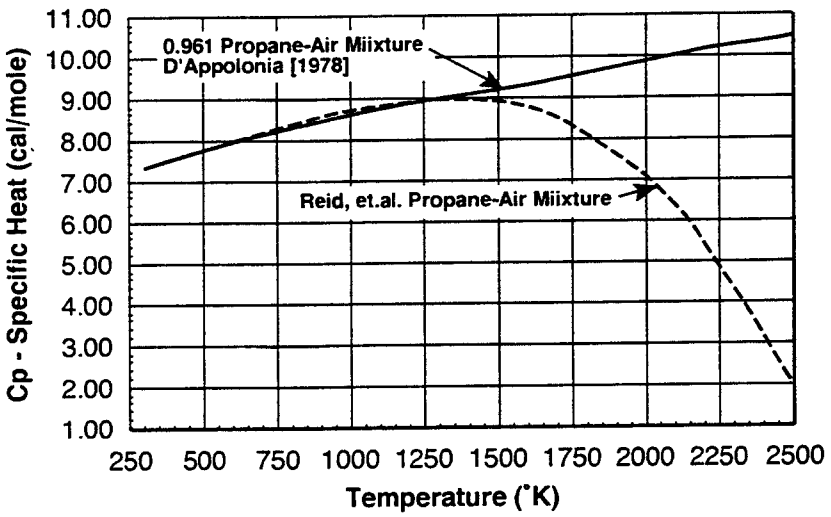

Figure F-2
Specific Heat for Methane-Air Stochiometric Mixture

F.3.0 Heat Transfer to the Walls, Floor, Etc.

Heat is transferred from the gas to the surrounding walls, floor and roof of the panel rooms by both convection and radiation. Heat is then transferred into the walls, floor, roof, via conduction. Thus, the rate of heat conduction into the salt or the wall is governed by the rate at which heat can be conducted into the solids.

F.3.1 Radiation Heat Transfer

Heat transferred from the gas to the walls, floor, roof, is given by:

$$q_{rs} = \sigma\left(T_g^4 - T_w^4\right)$$

where q_{rs} is the heat flux to the walls, floor, roof, σ is the Stefan-Boltzmann constant (1.35×10^{-12} cal/cm^2-sec-°K), and T_w is the temperature of the walls, floor, and roof.

The majority of the surface area of the panel available for heat transfer via both radiation and convection is salt. However, a small portion of the total area will be the inner face of the explosion-isolation wall (or construction-isolation well). Because the wall, floor, roof temperature is controlled by the time dependent conduction of heat into either the walls, floor, roof or the wall faces, and the diffusivities and conductivities of the salt and wall, floor, roof material may be different, the radiation heat transfer is divided into two components.

The radiative heat transfer to the salt (T_{ws}) is:

$$q_{rs} = \sigma\left(T_g^4 - T_{ws}^4\right)$$

and the radiative heat transfer to the explosion-isolation wall (T_{wb}) is:

$$q_{rb} = \sigma\left(T_g^4 - T_{wb}^4\right)$$

The combined radiative heat transfer to the walls, floors, roof is:

$$Q_r = q_{rs}A_s + q_{rb}A_b$$

or

$$Q_r = \sigma\left(A_s\left[T_g^4 - T_{ws}^4\right] + A_b\left[T_g^4 - T_{wb}^4\right]\right) \quad (5)$$

where A_b = Area of the walls, and A_s = area of the salt.

Equation (5) comprises the radiation portion of the right hand side of the differential equation, (3), for the rate of gas temperature in the panel.

F.3.2 Convection Heat Transfer

In addition to radiation, heat is transferred to the walls, floor, roof, and explosion-isolation walls by natural convection. In subsequent discussion, walls denote all exposed surface area of salt within a panel. Explosion-isolation walls denote the surface area of the expendable walls placed in the sealed air-intake and air-exhaust drifts of the panel.

F.3.2.1 Heat Transfer from Gas to the Walls

In addition to radiation, heat is transferred to the walls, floor, roof, and explosion-isolation walls via natural convection. The heat flux due to convection (q_c) is given by:

$$q_c = h\left(T_b - T_w\right)$$

where h = Film coefficient.

As for the case of radiation, the majority of heat transfer by convection will occur to the surrounding salt. However, a portion will be transferred to the explosion-isolation wall. Because the temperature of the explosion-isolation wall may be different from the temperature of the salt, the convective heat transfer is divided into the two components analogous to the radiation heat transfer. For the salt, the convection heat transfer is:

$$q_{cs} = h\left(T_g - T_{ws}\right)$$

and for the explosion-isolation walls:

$$q_{cb} = h\left(T_g - T_{wb}\right)$$

The combined radiative heat transfer (Q_c) to the walls, floors, roof, and explosion-isolation walls is:

$$q_{cb} = h\left(T_g - T_{wb}\right)$$

The combined radiative heat transfer (Q_c) to the walls, floors, roof, and explosion-isolation walls is:
assuming that the heat transfer coefficient does not change with location or material.

$$Q_c = q_{c\ NaCl}\ A_s + q_{cb} A_b$$

Theoretically the convective heat transfer coefficient is different for the face of the explosion-isolation walls, which are vertical compared with the heat transfer coefficient for the roof and floor faces of the panel which are horizontal. Neglecting the difference in heat transfer coefficient due to geometric differences, the above two equations for the heat flow to the walls, floor, roof, and explosion-isolation walls can be combined to give

$$Q_c = h\left(A_s\left[T_g - T_{ws}\right] + A_b\left[T_g - T_{wb}\right]\right) \tag{6}$$

Equation (6) gives the convective heat transfer portion of the right hand side of Equation (3). Combining (3), (5) and (6),

$$\frac{dT_g}{dt} = -\frac{Q_c + Q_r}{10.54\ n_{CH4}\ C_p} \tag{7}$$

where the negative sign indicates that Q_c and Q_r represent heat transferred out of the system consisting of the gas in the room. These same quantities then represent heat transferred into the surrounding salt and explosion-isolation wall.

F.3.2.2 Convection Coefficient

Assuming the convection coefficient is the same at all surfaces and following the methods developed in D'Appolonia (1978), with all units in the centimeter-gram-second (cm-g-sec) system of units,

$$N_u = 0.13[P_r G_r]^{1/3}$$

where P_r is the Prandtl number and G_r is the Grashof number. The Prandtl number is essentially constant and is taken as 0.71 regardless of pressure and temperature. The Grashof number is given by

$$G_r = \frac{g\beta L^3(T_g - T_w)}{\nu^2}$$

where g is the acceleration of gravity, β is the volume coefficient of thermal expansion and ν is the kinematic viscosity of the gas. For ideal gases,

$$\beta = \frac{1}{T_g}$$

and the kinematic viscosity is given by

$$\nu = \frac{\mu}{\rho}$$

where μ is the absolute viscosity ρ = mass density. Substituting for n and β in the expression for the Grashof number,

$$G_r = \frac{g\rho^2 L^3(T_g - T_w)}{T_m \mu^2}$$

where

$$T_m = \frac{T_g + T_w}{2}$$

is the average of the gas and surface temperature.

Substituting for the Grashof number and Prandtl number in the expression for the Nusselt number,

$$N_u = 0.13\left(0.71\frac{g\rho^2 L^3[Tg - T_w]}{T_m\mu^2}\right)^{1/3}$$

$$N_u = 0.146L\left(\frac{g\rho^2}{\mu^2}\left[\frac{T_g - T_w}{T_g + T_w}\right]\right)^{1/3}$$

and substituting for the Nusselt number in the expression for the convection coefficient,

$$h = 0.146k_g\left(\frac{g\rho^2}{\mu^2}\left[\frac{T_g - T_w}{T_g + T_w}\right]\right)^{1/3}$$

Since the thermal conductivity of the gas is given by[3]

$$k_g = 6.4 \times 10^{-5}\left(\frac{T_m}{300}\right)^{.75}$$

$$h = 9.34 \times 10^{-6}\left(\frac{T_g + T_w}{600}\right)^{.75}\left(\frac{g\rho^2}{\mu^2}\left[\frac{T_g - T_w}{T_g + T_w}\right]\right)^{1/3} \quad (8)$$

Figure F-3 shows h as a function of surface temperature based on a gas temperature of 2400°K and density and viscosity consistent with conditions at the time of an explosion.

Assuming that no additional gas is generated subsequent to the explosion, the density of the gas after the explosion is the same as before the explosion since mass is conserved. Thus, the gas density after the explosion is the molecular weight of n moles of methane plus 9.54n moles of air divided by the initial volume,

[3]D'Appolonia [1978].

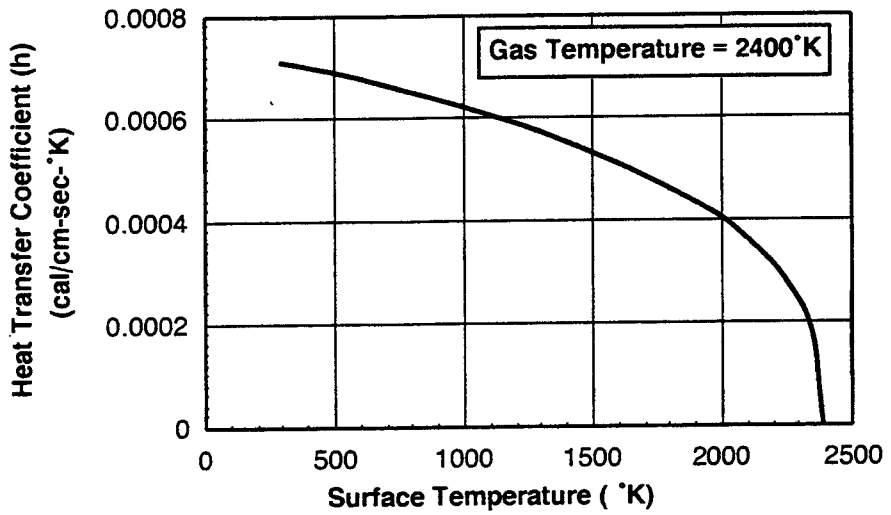

Figure F-3
Convection Heat Transfer Coefficient Versus Temperature

$$\rho = n\left(\frac{M_{w\,CH4} + 9.54M_{w\,air}}{V_{init}}\right)$$

$$\rho = n\left(\frac{16 + 9.54(29)}{V_{init}}\right)$$

$$\rho = \frac{292.66n}{V_{init}} \tag{9}$$

$$\mu = 1.85\ x\ 10^{-4}\left(\frac{T_m}{300}\right)^{0.67} \tag{10}$$

and the viscosity is given by (D'Appolonia, 1978), where the viscosity is evaluated at the average of the surface and gas temperatures.

Because there will be two different surface temperatures, one corresponding to the salt, and one for the explosion-isolation wall, there will be different convective heat transfer coefficients as well.

F.3.3 Conduction Into the Walls, Floor, Roof, and Explosion-Isolation Walls

The temperature which controls the heat transfer from the gas via radiation and convection is controlled by the rate at which heat is conducted into the walls, roof, floor, and explosion-isolation walls. The diffusion of heat into the walls, floor, roof, and explosion-isolation walls is assumed to be governed by a one-dimensional, semi-infinite thermal diffusion model. If the temperature penetrates the explosion-isolation walls, the model is changed to be thermal diffusion across a slab of finite thickness with an ambient gas temperature on the side in the isolation zone.

Thermal diffusion into the walls, floor, roof, and explosion-isolation walls is governed by the partial differential equation,

$$\alpha \frac{\partial^2 T}{\partial x^2} = \frac{\partial T}{\partial t}$$

where α is the thermal diffusivity, T is the temperature, x is the distance into the wall, floors, roof, or explosion-isolation walls, and t is time. At x = 0 the flow of heat into the walls, floor, roof, or explosion-isolation walls is governed by the boundary condition,

$$-k \frac{\partial T}{\partial x} = q_{in}$$

where q_{in} is the heat flux into the walls, etc. from the gas via convection and radiation and k is the thermal conductivity. Because the thermal diffusivity and conductivity for salt is different from that of the explosion-isolation wall, two conduction models are required.

F.3.3.1 Heat Conduction to the Salt

The first involves the heat transferred from the gas to the salt and is governed by the partial differential equation,

$$\alpha_s \frac{\partial^2 T_s}{\partial x^2} = \frac{\partial T_s}{\partial t} \qquad (11i)$$

where α_s is the thermal diffusivity of salt which is a function of temperature. Figure F-3 shows plots of thermal diffusivity for halite, anhydrite, argillaceous halite and polyhalite (Krieg, 1983). Figure F-4 also shows data from D'Appolonia (1978) that used the relation

$$\alpha_s = \frac{10}{T_s}$$

for salt. The D'Appolonia temperature dependence yields slightly higher values compared with the Waste Isolation Pilot Plant (WIPP) data, but indicates a consistency in the data. For purposes of the post-explosion heat transfer analysis the temperature dependent data for salt has been used.

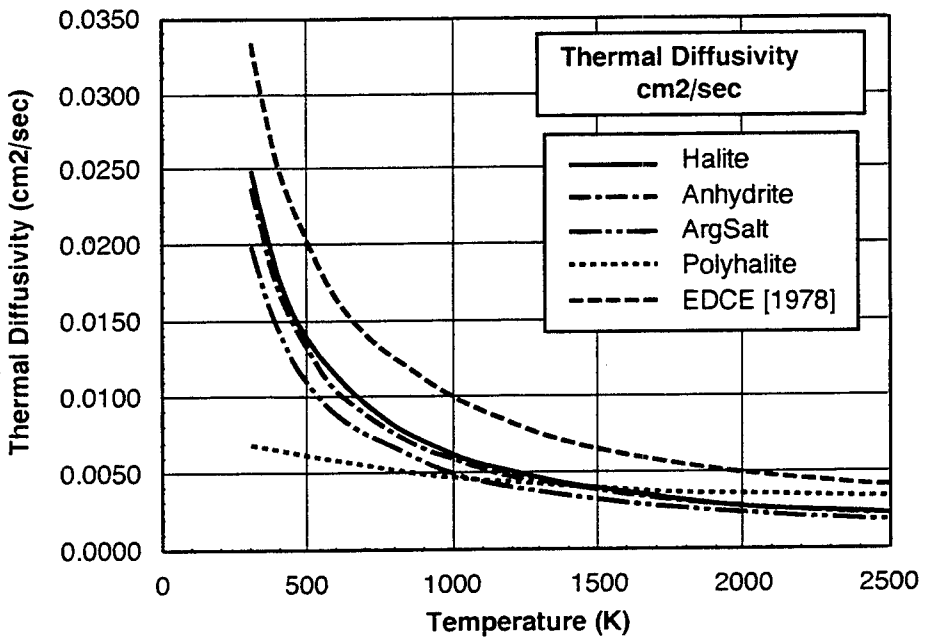

Figure F-4
Thermal Diffusivity of WIPP Geologic Materials

$$\alpha_s = 0.025\left[\frac{300}{T_s}\right]^{1.14} \tag{12i}$$

The boundary condition at the surface of the salt is:

$$-k_s\frac{\partial T_s}{\partial x} = q_{sr}+q_{sc} \tag{13i}$$

where k_s is the thermal conductivity of the salt. Figure F-4 shows plots of thermal conductivities for the same materials as a function of temperature. Again, the thermal conductivity from D'Appolonia (1978):

$$k_s = \frac{4.5}{T_s}$$

is also shown on Figure F-5 to check the consistency of the WIPP data. Again, the thermal conductivity for halite was used for the post-explosion heat transfer analysis.

$$k_s = 0.012\left[\frac{300}{T_s}\right]^{1.14} \tag{14i}$$

The terms q_{sr} and q_{sc} in (13i) couple the heat conduction into the salt with the rate of cooling of the gas via equations (7) through (10). In addition to the boundary conditions given by (12i), initial conditions at time t = 0 are required. It is assumed that at t = 0 the salt is at the ambient temperature in the panel, T_{amb}. Equations (11i) through (14i) with the initial conditions form the complete problem for the temperature in the salt as a function of time as the gas cools following the explosion.

F.3.3.2 Heat Conduction to the Explosion-Isolation Walls

The second model involves the heat transferred from the gas to the explosion-isolation walls and is governed by the partial differential equation,

$$\alpha_b\frac{\partial^2 T_b}{\partial x^2} = \frac{\partial T_b}{\partial t} \tag{11ii}$$

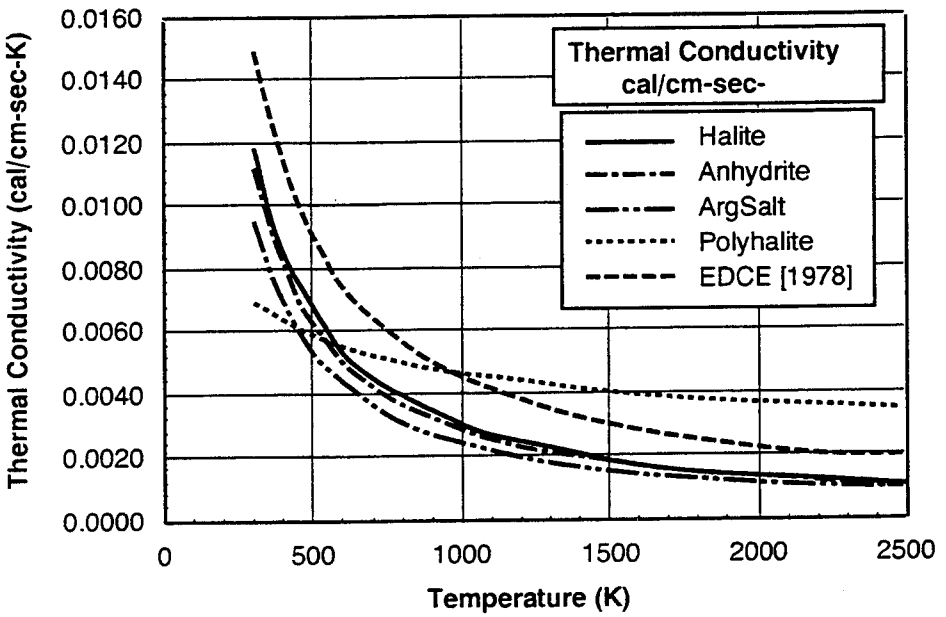

Figure F-5
Thermal Conductivity of WIPP Geologic Materials

where α_b is the thermal diffusivity of explosion-isolation walls. If the explosion-isolation walls are concrete, the thermal diffusivity does not vary with temperature (D'Appolonia, 1978),

$$\alpha_s = 0.005 \tag{12ii}$$

The boundary condition is:

$$-k_b \frac{\partial T_b}{\partial x} = q_{br} + q_{bc} \tag{13ii}$$

where q_{br} = heat flux for the salt, q_{bc} = heat flux for explosion-isolation walls, and k_b is the thermal conductivity of the walls. Again, if the explosion-isolation walls are concrete, the thermal conductivity is constant (D'appolonia, 1978).

$$k_b = 0.002 \tag{14ii}$$

Analogous to the case for salt, the terms q_{br} and q_{bc} in (13ii) couple the heat conduction into the salt with the rate of cooling of the gas via equations (7) through (10). At t = 0 the explosion-isolation walls are at the ambient temperature at the panel level, T_{amb}.

F.4.0 Numerical Model

Equations (1) through (14) were solved using a computer program based on an explicit finite difference representation of the equations. In subsequent discussion the following symbols are used,

τ	=	time step Δt
ε	=	distance between mesh points, Δx, in finite difference representation of semi-infinite solid used to model the explosion-isolation walls.
n	=	subscript denoting the value of a variable at time t.
n+1	=	subscript denoting the value of a variable at time t+τ.
m	=	subscript denoting the value of a variable at mesh point m in a finite difference representation of a semi-infinite solid. m = 0 corresponds to the boundary x = 0.
$T_{g\,n}$	=	gas temperature at time t.
T_{s0}	=	temperature at x = 0 in salt.
T_{b0}	=	temperature at x = 0 in an explosion-isolation wall.
T_{smn}	=	temperature in salt at mesh point m and time n.
T_{bmn}	=	temperature in explosion-isolation walls at mesh point m and time n.
α_{sm}	=	thermal diffusivity in salt at mesh point m (function of temperature).

α_{bm} = thermal diffusivity of explosion-isolation wall material at mesh point m (may be constant or a function of temperature).
q_{rsn} = heat flux to wall (salt) via radiation at time point n.
q_{rbn} = heat flux to explosion-isolation wall via radiation at time point n.
q_{csn} = heat flux to wall (salt) via convection at time point n.
q_{cbn} = heat flux to explosion-isolation wall via convection at time point n.

Where symbols are used for parameters that are a function of temperature and consequently also a function of time, the subscripts n and n+1 refer to whether the parameter is evaluated at t or t + Δt.

F.4.1 Overview of Computer Program

Figure F-6 provides a simplified flow chart of the computer program used to solve the equations in the model in explicit finite difference form.

F.4.2 Finite Difference Formulation

For the first past through the calculational loop n = 0 and the gas temperature is set to T_{g0}, the initial temperature. Based on the assumption of constant volume during the explosion, the temperature is related to the pressure by,

$$T_{g0} = T_{gamb}\left(\frac{P_0}{P_{amb}}\right) = 8T_{gamb} \qquad (15)$$

where

T_{gamb} = the gas temperature prior to the explosion
P^{amb} = the gas pressure prior to the explosion (taken as 2 atm)
P_0 = the gas pressure caused by the explosion (taken as 16 atm)
T_{g0} = the gas temperature caused by the explosion which is the initial gas temperature for the cooling analysis.

The initial temperature of the salt (T_{smo}) and explosion-isolation walls (T_{bmo}) for the heat conduction calculations are set to the ambient temperature at all mesh points.

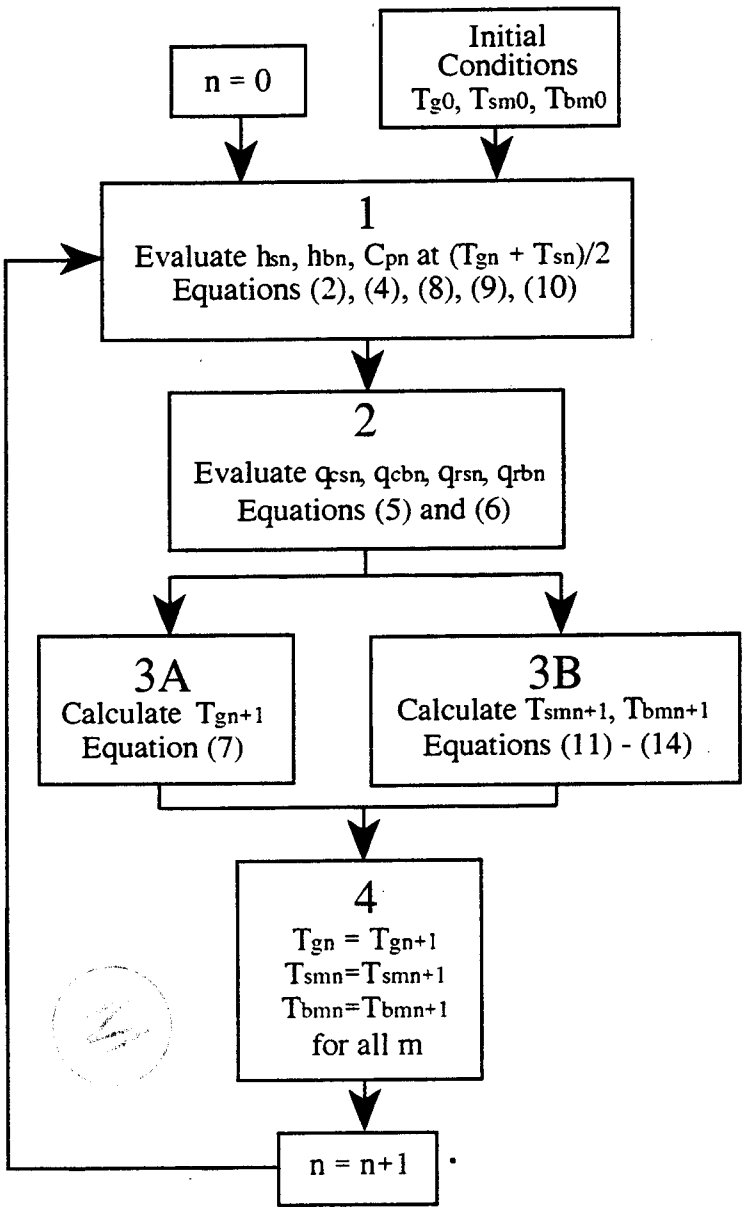

Figure F-6
Program Flow Chart

$$T_{sm0} = T_{amb} \quad m = 1 \ldots M$$
$$T_{bm0} = T_{amb} \quad m = 1 \ldots M \tag{16}$$

where M is the maximum mesh point number used in the finite difference representation of the semi-infinite solid. T_{amb} is the ambient temperature of the salt and explosion-isolation wall at the time of the explosion.

F.4.2.1 Program Section 1

Section 1 of the program (Figure F-3) calculated the parameters required for the determination of the heat fluxes from the hot gas to the cooler walls. These calculations are performed initially based on values for n = 0, initial conditions. Subsequently, they are evaluated based on the temperature values at time point n.

Thus,

$$\mu_{sn} = 1.85 \times 10^{-4} \left(\frac{T_{gn} + T_{s0n}}{600} \right)^{0.67}$$
$$\mu_{bn} = 1.85 \times 10^{-4} \left(\frac{T_{gn} + T_{b0n}}{600} \right)^{0.67} \tag{17}$$

where

μ_{sn} = viscosity of the salt

μ_{bn} = viscosity of the explosion-isolation wall

T_{gn} = gas temperature at time point n

T_{s0n} = wall temperature of the salt at time point n, which is the m = 0 mesh point of the finite difference representation of the semi-infinite solid used to model heat conduction into the salt

T_{b0n} = surface temperature of the explosion-isolation wall.

Since the initial surface temperatures of the salt and the walls are the same, the initial value of μ will be the same at both the salt and the walls. However, with time as the surface temperature of the explosion-isolation walls varies from the surface temperature of the salt, the values of μ will be different for the salt compared with the walls. This plays a role in

having different convection heat transfer coefficients at the salt compared with the explosion-isolation walls.

The convection heat transfer coefficients are given by (8) below.

$$h_{sn} = 9.34 \times 10^{-6}\left(\frac{T_{gn} + T_{s0n}}{600}\right)^{.75}\left(\frac{g\rho^2}{\mu_{sn}^2}\left[\frac{T_{gn} - T_{s0n}}{T_{gn} + T_{s0n}}\right]\right)^{1/3}$$

$$h_{bn} = 9.34 \times 10^{-6}\left(\frac{T_{gn} + T_{b0n}}{600}\right)^{.75}\left(\frac{g\rho^2}{\mu_{bn}^2}\left[\frac{T_{gn} - T_{b0n}}{T_{gn} + T_{b0n}}\right]\right)^{1/3} \qquad (18)$$

The density, ρ, remains constant by virtue of the constant volume and constant number of moles. The acceleration of gravity, g, also remains constant for all time points.

The specific heat of the gas which is required for Section 3A of the program is given by (4) below.

$$C_{pn} = 6.45 \times 10^{-4}\left(T_{gn} + T_{s0n}\right) + 7.3353 - \frac{130728}{\left(T_{gn} + T_{s0n}\right)^2} \qquad (19)$$

Because the specific heat is a bulk property of all of the gas in the panel, it is affected by all of the surface area in the panel. Because the surface area of the salt is orders of magniture larger than the surface area of the explosion-isolation walls, the specific heat at each time is based solely on the surface temperature of the salt.

F.4.2.2 Program Section 2

The heat flux rates to the walls as well as the total heat transfer rates to the walls via convection and radiation are calculated in Section 2 of the program. Flux is required for the boundary condition for the heat conduction analysis of Section 3B and total heat flow is required for the change in gas temperature calculation in Section 3A.

The total heat flow values are given by (5) and (6) which for time step n become where h_{sn} and h_{bn} are given by (18). The total heat flows are used in Section 3A of the program evaluates the time rate of change of the gas temperature using equation (7).

$$Q_{rn} + \sigma\left(A_s\left[T_{gn}^4 - T_{s0n}^4\right] + A_b\left[T_{bn}^4 - T_{b0n}^4\right]\right) \tag{20}$$

$$Q_{cn} = A_s h_{sn}\left(T_{gn} - T_{s0n}\right) + A_b h_{bn}\left(T_{gn} - T_{bn}\right)$$

The total heat flows at time step n given by (20) are heat flow out of the gas occupying the panel volume and into the explosion-isolation walls. For the heat flow into the explosion-isolation walls, the areas, A_s and A_b cancel from the equations representing the boundary conditions at x = 0 for the transient heat conduction problems solved in Section 3B of the program. Thus, for Section 3B, the heat flux values are required. These are the same as (20) without the areas.

$$q_{rn} = \sigma\left(\left[T_{gn}^4 - T_{s0n}^4\right] + \left[T_{gn}^4 - T_{b0n}^4\right]\right) \tag{21}$$

$$q_{cn} = h_{sn}\left(T_{gn} - T_{s0n}\right) + h_{bn}\left(T_{bn} - T_{bn}\right)$$

where q_{rn} and q_{cn} are the heat fluxes due to radiation and convection.

For the total heat flow and heat flux due to radiation, the Stefan-Boltzmann constant is taken to be constand for all values of temperature and hence time.

$$\sigma = 1.355 \times 10^{-12} \tag{22}$$

F.4.2.3 Program Section 3

Section 3 comprises the main body of the program.

F.4.2.3.1 Program Section 3A

Equation (7) governs the rate of change of gas temperature in the panel volume. Using the explicit finite difference approximation,

$$\frac{dT_g}{dt} = \frac{1}{\tau}\left(T_{gn+1} - T_{bn}\right)$$

where $\tau = \Delta t$ is the time increment, Equation (7) becomes

$$T_{gn+1} = T_{gn} - \tau \left(\frac{Q_{cn} + Q_{rn}}{10.54\ n_{CH4}\ C_{pn}} \right) \tag{23}$$

where Q_{cn}, Q_{rn}, and C_{pn} are given by (20) and (19) and n_{CH4} is an input representing the moles of methane in the panel volume at the time of the explosion. Equation (23) gives the gas temperature in the panel at time $t + \Delta t$ in terms of the gas temperature at time t and the total heat flow values at time t.

F.4.2.3.2 Program Section 3B

Section 3B of the program is the most complex. It solves two transient heat conduction problems assuming that the walls, floor, roof, and explosion-isolation walls are semi-infinite solids having thermal conductivities and diffusivities that may or may not be temperature dependent. In the case of the walls, floor and roof, the panel volume the conductivity and diffusivity of salt is dependent on temperature. Assuming that the explosion-isolation wall material is concrete, the conductivity and diffusivity of the explosion-isolation wall are independent of temperature.

Because of the temperature dependence of the conductivity and diffusivity of the salt, and the time-dependent spatial temperature distribution into the walls, floor and roof, the conductivity that is required for the boundary condition at $x = 0$ varies with time and the thermal diffusivity varies in both time and space. The partial differential equation for transient heat conduction when the diffusivity varies spatially is given by:

$$\frac{\partial}{\partial x}\left(\alpha \frac{\partial T}{\partial x} \right) = \frac{\partial T}{\partial t} \tag{a}$$

which can be expanded as:

$$\left(\frac{\partial \alpha}{\partial x} \right)\left(\frac{\partial T}{\partial x} \right) + \alpha \frac{\partial^2 T}{\partial x^2} = \frac{\partial T}{\partial t} \tag{b}$$

Using the finite difference approximations,

$$\frac{\partial \alpha}{\partial x} = \frac{1}{2\varepsilon}(\alpha_{m+1} - \alpha_{m-1}) \tag{ci}$$

$$\alpha\frac{\partial^2 T}{\partial x^2} = \frac{\alpha_m}{\varepsilon^2}(T_{m-1} - 2T_m + T_{m+1}) \tag{cii}$$

$$\frac{\partial T}{\partial x} = \frac{1}{2\varepsilon}(T_{m+1} - T_{m-1}) \tag{cii}$$

where e = Δx, the left hand side of equation (b) becomes

$$\left(\frac{\partial T}{\partial x}\right)\left(\frac{\partial T}{\partial x}\right) + \alpha\frac{\partial^2 T}{\partial x^2} = \frac{1}{4\varepsilon^2}\left([\alpha_{m+1}-\alpha_{m-1}][T_{m+1}-T_{m-1}]+4\alpha_m T_{m-1}-8\alpha_m T_m+4\alpha_m T_{m+1}\right) \tag{d}$$

or

$$=\frac{1}{4\varepsilon^2}(\alpha_{m+1}T_{m+1}-\alpha_{m+1}T_{m-1}-\alpha_{m-1}T_{m+1}+\alpha_{m-1}T_{m-1})+\frac{1}{4\varepsilon^2}(4\alpha_m T_{m-1}-8\alpha_m T_m+4\alpha_m T_{m+1}) \tag{e}$$

$$4\varepsilon^2\left(\left[\frac{\partial \alpha}{\partial x}\right]\left[\frac{\partial T}{\partial x}\right]+\alpha\frac{\partial^2 T}{\partial x^2}\right)= v_{m-1}(\alpha_{m-1}+4\alpha_m-\alpha_{m+1})-8\alpha_m T_m+T_{m+1}(\alpha_{m+1}+4\alpha_m-\alpha_{m-1}) \tag{f}$$

Using an explicit finite difference representation of the time derivative as used in Section 3A.

$$\frac{\partial T_m}{\partial t} = \frac{1}{\Delta t}(T_{m\,n+1}-T_{m\,n}) \tag{g}$$

Substituting (f) and (g) into the partial differential equation (a),

$$T_{m-1\ n}(\alpha_{m-1}+4\alpha_m-\alpha_{m+1})-8\alpha_m T_{m\ n}+T_{m+1\ n}(\alpha_{m+1}+4\alpha_m-\alpha_{m-1}) = \frac{1}{N}(T_{m\ n+1}-T_{m\ n}) \tag{h}$$

where

$$N = \frac{\Delta t}{4\varepsilon^2} \tag{i}$$

is analogous to the modulus for the case of constant diffusion. Solving (h) for $T_{m\ n+1}$

$$T_{m\ n+1} = T_{m-1\ n}N(\alpha_{m-1} + 4\alpha_m-\alpha_{m+1})-(8N-1)\alpha_m T_{m\ n}+T_{m+1\ n}N(\alpha_{m+1}+4\alpha_m-\alpha_{m-1}) \tag{j}$$

For the case of constant diffusivity,

$$\alpha_{m-1} = \alpha_m = \alpha_{m+1} = \alpha$$

with

$$M = \frac{\alpha\Delta t}{\varepsilon^2} = 4\alpha N \tag{k}$$

equation (j) becomes

$$T_{m\ n+1} = M\ (T_{m+1\ n} + T_{m-1\ n}) - (2M-1)T_{m\ n} \tag{l}$$

which is the finite difference equation for the case of constant diffusivity (Carslaw and Jaeger, 1959). Thus, equation (j) reduces to the correct equation when the diffusivity is constant and is the finite difference equation for the case of variable diffusivity.

For a numerical stability criteria,

$$M<0.5 \tag{m}$$

the corresponding relation for the case of variable diffusivity becomes equation (n) for all m.

$$MAX(\alpha_m N)<0.125 \tag{n}$$

The thermal conductivity and thermal diffusivity at each time point are evaluated from the temperature at that time and space as given previously for the temperature variation of the conductivity and diffusivity.

The boundary condition at x = 0, is the same as for the case of constant diffusivity,

$$-k_n \frac{\partial T_n}{\partial x} = q_{rn} + q_{cn} \tag{o}$$

where q_{rn} and q_{rn} are determined in Section 2. Using the finite difference relationship (Carslaw and Jaeger, 1959),

$$\frac{\partial T_n}{\partial x} = \frac{1}{2e}\left(-3T_{0\,n} + 4T_{1\,n} - T_{2\,n}\right) \tag{p}$$

equation (o) becomes:

$$-\frac{k_n}{2\varepsilon}\left(-3T_{0\,n} + 4T_{1\,n} - T_{2\,n}\right) = q_{rn} + q_{cn}$$

$$3T_{0\,n} - 4T_{1\,n} + T_{2\,n} = \frac{2\varepsilon}{k_n}\left(q_{rn} + q_{cn}\right) \tag{q}$$

Substituting for q_{rn} and q_{cn}:

$$3T_{0\,n} - 4T_{1\,n} + T_{2\,n} = \eta_n\left(T_{gn} - T_{0n}\right) + \gamma_n\left(T_{gn}^4 - T_{0n}^4\right)$$

where

$$\eta_n = \frac{2\varepsilon h_n}{-k_n} \tag{r}$$

and

Using the identity

and defining

$$\gamma_n = \frac{2\varepsilon\sigma}{k_n} \qquad (s)$$

$$T_{gn}^4 - T_{0n}^4 = (T_{gn} - T_{0n})(T_{gn} + T_{0n})\left(T_{gn}^2 + T_{0n}^2\right)$$

$$f_n = (T_{gn} + T_{0n})\left(T_{gn}^2 + T_{0n}^2\right) \qquad (t)$$

$$3T_{0n} - 4T_{1n} + T_{2n} = (\eta_n + \gamma_n f_n)(T_{gn} - T_{0n}) \qquad (u)$$

For the case of both convection and radiation equation (u) is a fourth order equation in T_{0n} and has to be solved using a numerical technique such as Newton-Raphson iteration. Since the effect of radiation heating of the walls, floor, roof, and explosion-isolation walls leads to a more rapid cooling of the combustion gas following the explosion, and temperatures effects on the salt or explosion-isolation material is worse for longer durations, it is conservative to neglect radiation heat transfer. In this case, equation (u) becomes linear:

$$3T_{0n} - 4T_{1n} + T_{2n} = \eta_n (T_{gn} - T_{0n}) \qquad (v)$$

which can be solved directly for T_{0n}:

$$T_{0n} = \frac{4T_{1n} - T_{2n} + \eta_n T_{gn}}{3 + \eta_n} \qquad (w)$$

At each time the field equations are solved based on the previous time. The boundary condition (w) is then applied.

Equations (j) and (u) are formulated for both the salt comprising the walls, floor, and roof and for the explosion-isolation walls. As noted, the field equations for variable diffusivity reduce appropriately to the special case of a constant diffusivity so the above equations are sufficiently general to handle both the material of the explosion-isolation wall and the salt.

F.4.2.4 Program Section 4

In Section 4 of the program, the temperature values at time t+Δt (n+1) become the new values at time t (n). The time counter, n, is incremented by 1 and the program returns to Section 1 to compute the solution at the subsequent time step.

F.4.3 Initial Volume, Surface Area and Number of Moles

The volume of gas to be cooled via heat transfer to the walls, roof, floor, and explosion-isolation walls following an explosion is taken to correspond to the effective panel volume at the time when the air-methane mixture in the panel enters the explosive range. The effective volume is defined as:

$$V_{eff} = \phi V$$

where V is the panel volume considering closure of the panel and Φ is the porosity which accounts for the waste emplaced in the panel. Figure F-7 shows a plot of the effective volume as a function of time.

Based on Figure 4.2 of the Conceptual Design Report (DOE, 1995), the methane-air mixture in the panel volume enters the explosive range at 25 years. From Figure F-7 this corresponds to a panel volume of 1.6×10^{10} cm^3 at the time the postulated explosion occurs.

The surface area at the time of the postulated explosion was obtained from the volume at the time the methane air mixture enters the explosive range at 25 years and the initial ratio of surface area to volume.

$$A_s = \left(\frac{A_{sinit}}{V_{init}} \right) V$$

Figure F-8 shows a plot of panel surface area as a function of time.

Based on the air-methane mixture entering the explosive range at 25 years, the surface area at the time of the explosion is 1.6×10^8 cm^2. The area of two 14 foot x 14 foot explosion-isolation walls is 1.82×10^5 cm^2. Thus the area of the explosion-isolation walls is

$$\frac{1.82 \; x \; 10^5}{1.6 \; x \; 10^8} = 0.0014 = 0.14\%$$

of the total surface area.

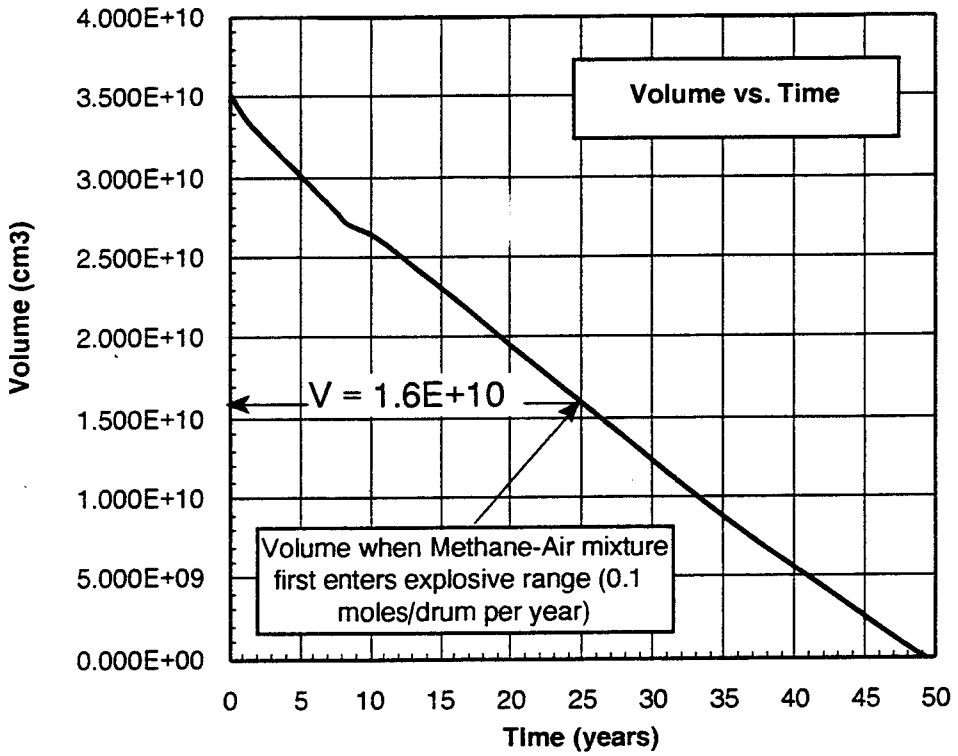

Figure F-7
Effective Panel Volume vs Time

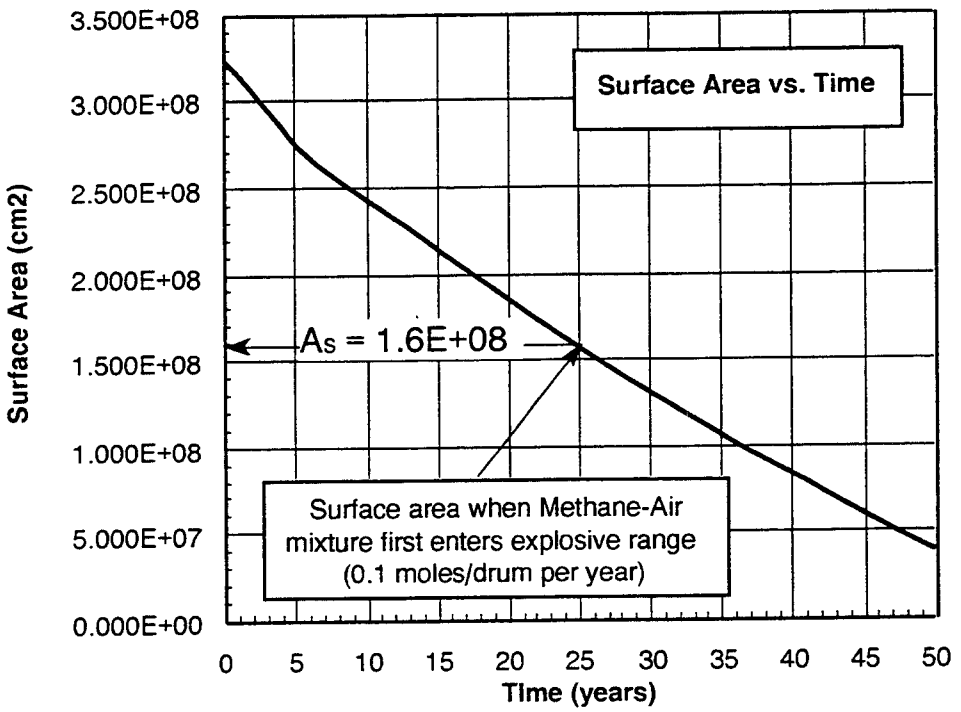

Figure F-8
Surface Area Rooms, Floor and Roof vs Time

The number of moles of combustion gas is found using the ideal gas law based on an initial pressure of 16 atmospheres (atm) and an initial temperature of 2,400 °K.

$$n = \frac{pV}{RT} \tag{24}$$

with

R = 82.06 cm^3-atm/mol-°K (ideal gas law constant)
p = 16 atm
V = 1.6×10^{10}
T = 2400 °K

$$n = \frac{16 \; x \; (1.6 \; x \; 10^{10})}{82.06 \; x \; 2400}$$

$$n = 1.3 \; x \; 10^6 \; moles$$

The program uses the number of moles of methane and air independently to calculate the density. Thus,

$$10.54 \; n_{CH4} = 1.3 \; x \; 10^6 \tag{25}$$

$$n_{CH4} = 1.233 \; x \; 10^5$$

$$n_{air} = 9.54 \; x \; n_{CH4} = 1.176 \; x \; 10^6$$

The density is given by

$$\frac{(1.233 \; x \; 10^5)(16) \; + \; (1.176 \; x \; 10^6)(29)}{1.6 \; x \; 10^{10}} = 0.002255$$

F.5.0 Results

The numerical formulation discussed in Section 4.0 was executed using a spatial grid size, ε - 1 cm and a time increment, τ = 10 seconds. No problems with numerical stability were encountered using these values.

At time t = 0, the initial heat transfer from the combustion gas to the salt and explosion-isolation walls results is a large temperature gradient at the surface. To represent this gradient accurately using a finite difference formulation would require an extremely small grid spacing as the initial temperature gradient extends only an infinitesimal distance into the surface. Using a grid spacing sufficiently small to accurately characterize the initial gradient would be prohibitive, relative to the number of mesh points and time steps required.

The initial conditions for the finite difference calculations were determined by using an exact solution for the case of constant convective heat transfer coefficient and constant gas temperature. The use of the closed form solution to determine the initial conditions assumes that the change in gas temperature over small initial times is small and that the heat transfer coefficient is weakly dependent on the temperature difference between the gas and the surfaces of the salt and explosion-isolation walls. Based on the closed form solution, the initial conditions for the finite difference model were taken at a time of 12.7 seconds following the explosion. For shorter initial times, the gradient had not propagated sufficiently far into the surfaces to be represented with a 1 cm. grid spacing. Thus, the initial time for the finite difference calculations was 12.7 seconds with initial temperatures based on the closed form solution.

Figure F-9 shows the gas temperature, salt temperature (walls, floor, and roof) and explosion-isolation wall temperature as a function of time following the explosion. Figure F-10 shows the temperature distribution into the explosion-isolation walls at various times following the explosion. Figure F-11 shows the temperature distribution into the salt at various times following the explosion.

Figure F-9 shows that the temperature of the gas has nearly reached the initial ambient conditions after about 2 hours. Over that span of time, elevated temperature in the explosion-isolation wall has a maximum extent of 15 cm (about 6 inches) into the explosion-isolation wall. Since the explosion-isolation wall is at least 36 inches (91.4 cm) thick, the elevated temperature will not reach the opposite side of the wall. Thus, the assumption of a semi-infinite body in the numerical model is not violated.

A comparison of the results shown on Figure F-9 with the results given in D'Appolonia (1978) is favorable. The ratios of surface area and volume used in D'Appolonia (1978) as well as the initial pressures are not the same as used for this analysis. The temperatures shown on Figure F-9 are slightly higher than those predicted for a pressure of 9 atm as shown

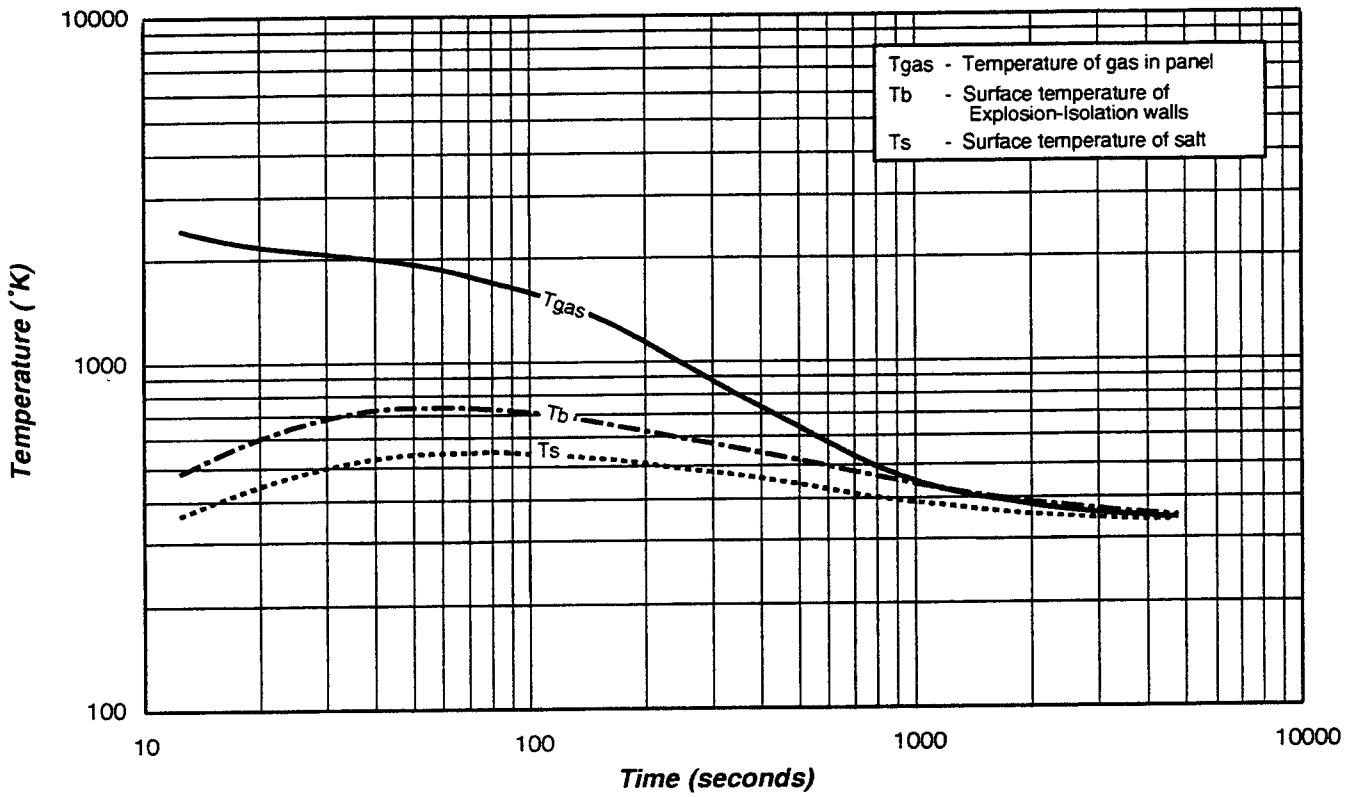

Figure F-9

Temperature Variation with Time for Gas, Salt, and Explosion-Isolation Walls

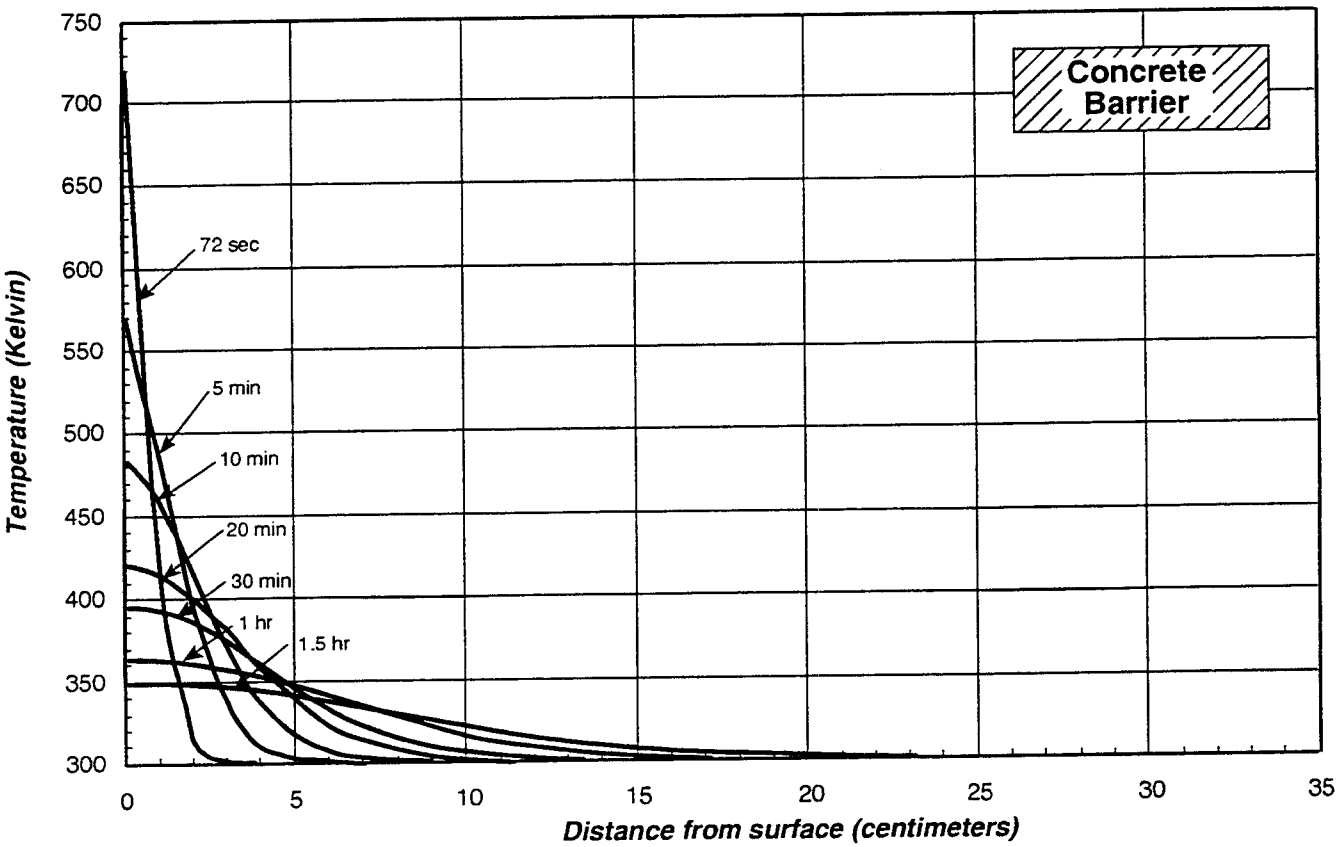

Figure F-10
Temperature Distribution with Time for Concrete Barrier

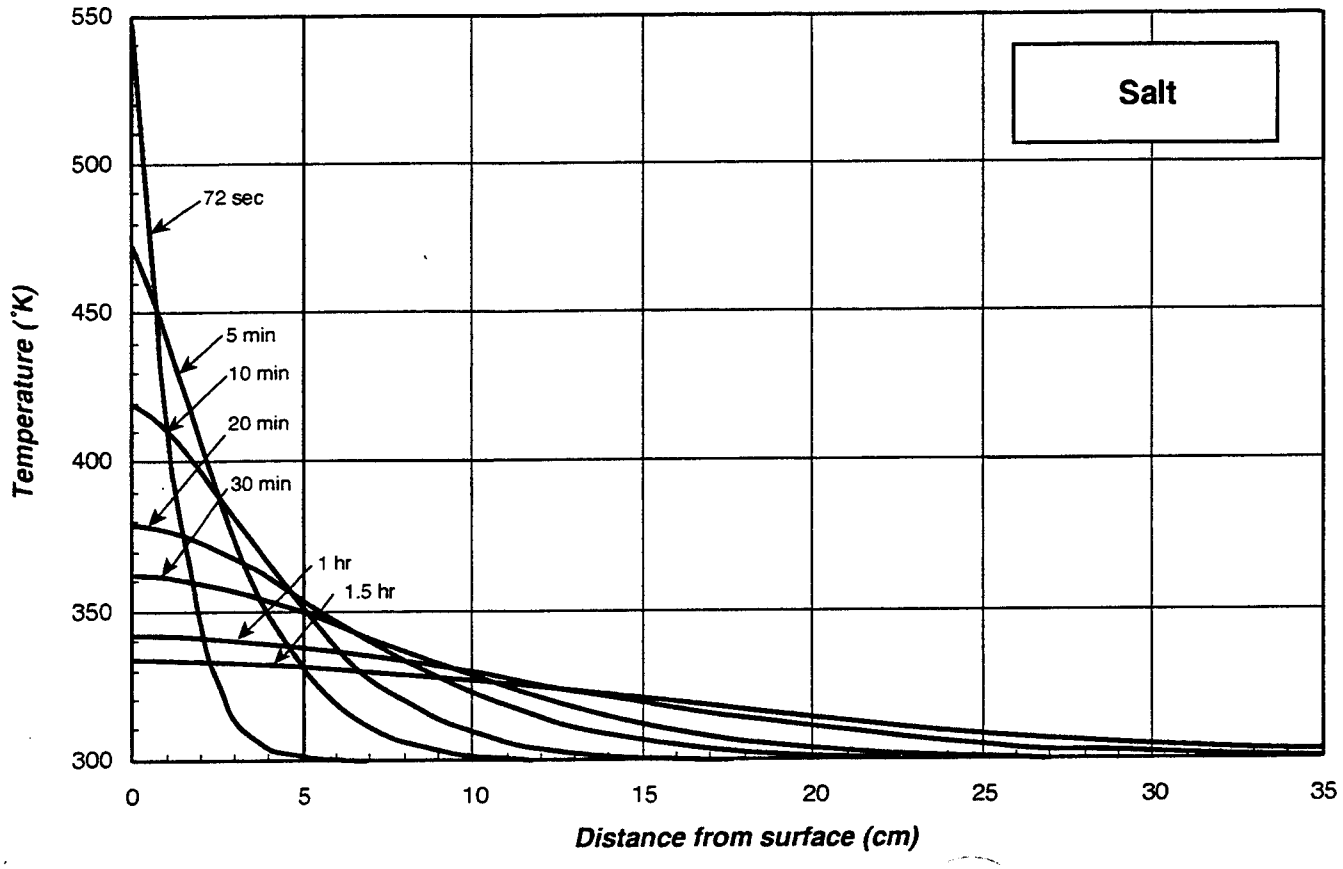

Figure F-11
Temperature Distribution with Time for Salt

in D'Appolonia [1978]. This is as expected since the initial pressure affects the number of moles which determines the rate of temperature decay in the gas. This is illustrated by comparison of the results for 9 atm with those for 27 atm shown in D'Appolonia (1978). The favorable comparison of the results shown on Figure F-9 with those of D'Appolonia (1978) provides verification of the numerical model used in these analyses.

F.6.0 References

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APPENDIX G
TECHNICAL SPECIFICATIONS

SECTION 01010

SUMMARY OF WORK

SECTION 01010

SUMMARY OF WORK

PART 1 - GENERAL

1.1 Scope

This section includes:

- Scope of Work
- Definitions and Abbreviations
- Drawings
- Work by Others
- Contractors Use of Site
- Contractors Use of Facilities
- Work Sequence
- Work Plan
- Submittals

1.2 Scope of Work

The Contractor shall furnish all labor, materials, equipment and tools to perform operations in connection with the construction of two (2) panel closure systems for each panel, one of each to be installed in the air intake drift and the air exhaust drift of a waste-emplacement panel, as shown on the drawings and called for in these specifications.

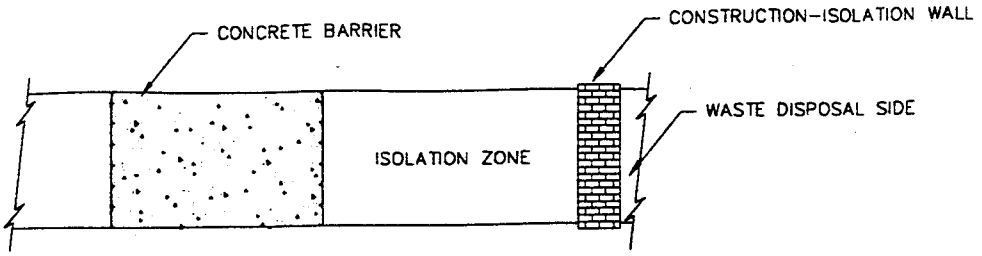
Four (4) possible arrangements of the concrete barrier and isolation walls are shown on the attached Figure 1 "Plan Variations." The specific requirements for the panel closure system will be determined by the Westinghouse WID prior to the time of installation and will be defined in the contract documents.

- Concrete barrier with disturbed rock zone (DRZ) removal up through clay seam G and down through marker bed 139 (MB 139) in combination with a construction isolation wall (Sketch A).

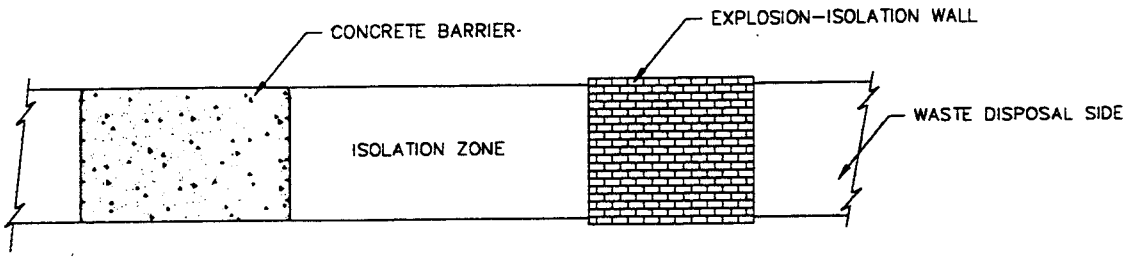
- Concrete barrier with DRZ removal in combination with an explosion isolation wall (Sketch B.)

- Concrete barrier without DRZ removal in combination with construction isolation wall (Sketch C).

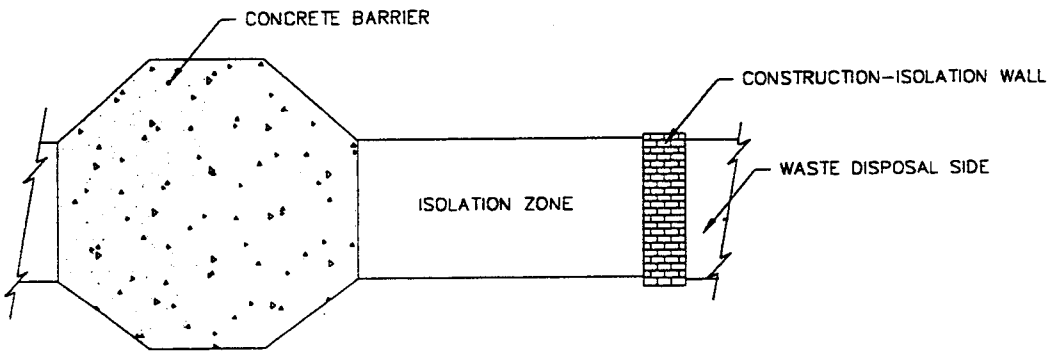
- Concrete barrier without DRZ removal in combination with an explosion isolation wall (Sketch D).



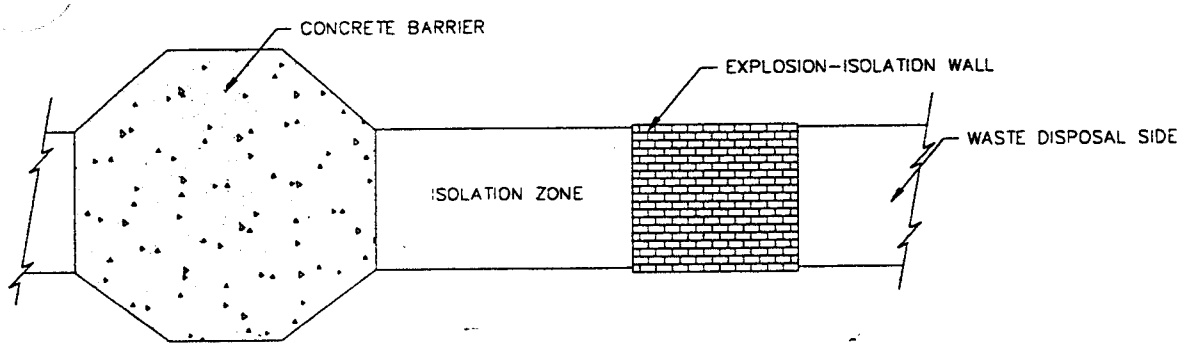
A. CONCRETE BARRIER WITHOUT DRZ REMOVED AND CONSTRUCTION ISOLATION WALL



B. CONCRETE BARRIER WITHOUT DRZ REMOVED AND EXPLOSION ISOLATION WALL



C. CONCRETE BARRIER WITH DRZ REMOVED AND CONSTRUCTION ISOLATION WALL



D. CONCRETE BARRIER WITH DRZ REMOVED AND EXPLOSION ISOLATION WALL

Figure 1
Plan Variations

The scope of work shall include but not be limited to the following units of work:

- Develop work plan, health and safety plan (HASP) and contractors quality control plan (CQCP)
- Prepare and submit all plans requiring approval
- Mobilize to site
- Coordinate construction with operations
- Perform the following for the air intake entry and the air exhaust entry.
  - Excavate the surface preparation for the explosion (or construction) isolation wall
  - Construct the explosion (or construction) isolation wall
  - Excavate the DRZ if required by contract
  - Install the form work for the concrete barrier
  - Place concrete for the concrete barrier
  - Grout the interface of concrete barrier/back wall
  - Provide contact grouting along the contact surface (if required by the engineer)
- Clean up construction areas in underground and above ground
- Submit all required record documents
- Demobilize from site

1.3 Definitions and Abbreviations

Definitions

Contact-handled waste—Contact-handled defense transuranic (TRU) waste with a surface dose rate not to exceed 200 millirem per hour.

Concrete barrier—A barrier placed in the access drifts of a panel to restrict the mass flow rate of volatile organic compounds (VOC).

Concrete block—Concrete used for construction of either an explosion-isolation wall or a construction-isolation wall.

Construction-isolation wall—A wall immediately adjacent to the panel waste-emplacement area that is made of concrete block, with mortar or of steel to isolate construction personnel from coming into contact with the waste.

Creep—Plastic deformation of salt under deviatoric stress.

Design migration limit—A mass flow rate that results in an exposure of the affected individual that is at least 1 order of magnitude below the health-based exposure levels for VOCs during the Waste Isolation Pilot Plant (WIPP) operational period.

Disturbed rock zone (DRZ)—A zone surrounding underground excavations where stress redistribution occurs with attendant dilation and fracturing.

Explosion-isolation wall—A concrete-block wall adjacent to the panel waste-emplacement area with mortar that can sustain the pressure and temperature transients of a methane explosion.

Health-based concentration level—The annual average concentration level for a VOC in air that must not be exceeded at the point of compliance.

Health-based migration limit—The mass flow rate of a VOC from all closed panels that results in the health-based concentration level at the point of compliance.

Hydration temperature—The transient temperature developed by a cementitious material due to the hydration of the cement.

Interface grouting—Grouting performed through grout boxes and pipe lines to fill the void at the concrete barrier/back-wall interface.

Methane explosion—A postulated deflagration caused by the buildup of methane gas to explosive levels.

Partial closure—The process of rendering a part of the hazardous waste management unit in the underground repository inactive and closed according to approved facility closure plans. The partial-closure process is considered complete after partial-closure activities are performed in accordance with approved Resource Conservation and Recovery Act (RCRA) partial closure plans.

Point of compliance—The operating point of compliance for VOC health-based exposure levels at the WIPP, which is the WIPP site boundary.

Remote-handled waste—Any of the various forms of high beta-gamma defense TRU waste requiring remote-handling due to a surface dose rate exceeding 200 millirem per hour.

Standard barrier—A concrete barrier emplaced into the panel-access drifts without major excavation of the surrounding rock.

Volatile Organic Compound (VOC)—Any VOC comprising the land-disposal-restricted indicator VOC constituents in the WIPP waste inventory.

Westinghouse—Westinghouse Electric Corporation, Waste Isolation Division (WID) as the construction management authority.

Abbreviations/Acronyms

ACI	American Concrete Institute
AISC	American Institute for Steel Construction
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DRZ	disturbed rock zone
EPA	U.S. Environmental Protection Agency
MB 139	Marker Bed 139
MSHA	U.S. Mining Safety and Health Administration
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
RCRA	Resource Conservation and Recovery Act
SMC	Salado Mass Concrete
USACE	U.S. Army Corps of Engineers
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

1.4 List of Drawings

The following drawings are made apart of this specification:

762447-E1	Panel closure system, air intake and exhaust drifts, title sheet
762447-E2	Panel closure system, underground waste-emplacement panel plan
762447-E3	Panel closure system, air intake drift, construction details
762447-E4	Panel closure system, air exhaust drift, construction details
762447-E5	Panel closure system, construction and explosion walls, construction details
762447-E6	Panel closure system, air intake and exhaust drifts, grouting and miscellaneous details

1.5 Work by Others

Survey

All survey work to locate the barriers and walls, control and confirm excavation, and complete the work will be supplied by Westinghouse. All survey measurements for record purposes will also be performed by Westinghouse. The Contractor shall be responsible for verifying the excavation dimensions to develop the form work to fit the excavation.

Excavation

The Westinghouse WID may elect to perform certain portions of the work, notably the excavation. The work performed by the Westinghouse will be defined prior to the contract.

1.6 Contractor's Use of Site

Site Conditions

The site is located near Carlsbad, New Mexico, as shown on the site location maps and the title sheet drawing. The underground arrangements and location of the WIPP waste-emplacement panels are shown on the plan view drawing. The work described above is to construct the concrete barriers in the air intake and exhaust drifts of one of the panels upon completion of the disposal phase of that panel. The waste-emplacement panels are located approximately 2,150 feet below the ground surface. The Contractor shall visit the site and become familiar with the site and site conditions prior to preparing his bid proposal.

Contractor's Use of Site

Areas at the ground surface will be designated for the Contractor's use in assembling and storing his equipment and materials. The Contractor shall utilize only those areas designated.

Limited space within the underground area will be designated for the Contractor's use for storage of material and setup of equipment.

Coordination of Contractor's Work

The Contractor is advised that on-going waste emplacement and excavation operations are being conducted throughout the period of construction of the panel barrier system. The Contractor shall coordinate his construction operations with that of the waste emplacement and mining operations. All coordination shall be through Westinghouse WID.

1.7 Contractor's Use of Facilities

Existing facilities at the site which are available for use by the Contractor are:

- WIPP roadheader
- Waste shaft conveyance
- Salt skip hoist
- (1) 20 ton forklift

- (1) 40 ton forklift
- 460 volt AC, 3 phase power
- Water (underground, at waste shaft only) (above ground, at location designated by Engineer)

Additional information on these facilities is presented in Section 02010.

1.8 Work Sequence
Work Sequence shall be as shown on the drawings and directed by Westinghouse WID .

1.9 Work Plan
The Contractor shall prepare and submit for approval by Westinghouse WID a Work Plan fully describing his proposed construction operation. The work plan shall define all proposed equipment. The work plan shall also include the method of excavation, grouting, and pumping concrete. The work plan shall also contain such items as control of surface dust emissions. No work shall be performed prior to approval of the Work Plan.

1.10 Health and Safety Plan (HASP)
The Contractor shall obtain, review, and agree to applicable portions of the existing WIPP Safety Manual, WP 12-1. The Contractor shall prepare and submit for approval to Westinghouse, a project-specific HASP taking into account all applicable sections of the WIPP Safety Manual. The Contractor shall also perform a Job Hazard Analysis in accordance with WP 12-111.

1.11 Contractor Quality Control Plan (CQCP)
The Contractor shall prepare and submit for approval to Westinghouse a CQCP identifying all personnel and procedures to produce an end product which complies with the contract requirements. The CQCP shall comply with all Westinghouse WID requirements and Section 01400, Contractor Quality Control, of this specification.

1.12 Submittals
Submittals shall be in accordance with Westinghouse WID Submittal Procedures and as required by the individual specifications.

PART 2 - PRODUCTS

(Not used)

PART 3 - EXECUTION

(Not Used)

SECTION 01090

REFERENCE STANDARDS

SECTION 01090

REFERENCE STANDARDS

PART 1 - GENERAL

1.1 Scope

This section includes:

- Provision of Reference Standards at Site.
- Acronyms used in Contract Documents for Reference Standards. Source of Reference Standards.

1.2 Quality Assurance

For products or workmanship specified by association, trade, or Federal Standards, comply with requirements of the standard, except when more rigid requirements are specified or are required by applicable codes.

Conform to reference by date of issue current on the date of the owner-contractor agreement.

The Contractor shall obtain copy of the standards referenced in the individual specification sections. Maintain a copy at jobsite during submittals, planning, and progress of the specific work, until completion of work.

Should specified reference standards conflict with the contract documents, request clarification from the Engineer before proceeding.

1.3 Schedule of References

Various publications are referenced in other sections of the specifications to establish requirements for the work. These referenced are identified by documents number and title. The addresses of the organizations whose publications are referenced are listed below.

ACI	ACI International P.O. Box 19150 Detroit,MI 48219-0150 Ph: 313-532-2600 Fax: 313-533-4747

AITC	American Institute of Timber Construction 7012 So. Revere Parkway, Suite 140 Englewood, CO 80112 Ph: 303-792-9559 Fax: 303-792-0669
AISC	American Institute of Steel Construction One E. Wacker Dr., Suite 3100 Chicago, IL 60601-2001 Ph: 312-670-2400 Fax: 312-670-5403
ANSI	American National Standards Institute 11 West 42nd St. New York NY 10036 pH: 212-642-4900 Fax: 212-302-1286
API	American Petroleum Institute 1220 L. St., NW Washington, DC 20005 Ph: 202-682-8375 Fax: 202-962-4776
ASTM	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103 Ph: 610-832-9585 Fax: 215-977-9679
AWS	American Welding Society 550 LeJeune Road Miami, FL 33135 Ph: 800-443-9353 Fax: 305-443-7559
CFR	Code of Federal Regulations Government Printing Office Washington, DC 20402 Ph: 202-783-3238 Fax: 202-223-7703

EPA	Environmental Protection Agency Public Information Center 401 M St., SW Washington, DC 20460 Ph: 202-260-2080
FTM-STO	Federal Test Method Standards Standardization Documents Order Desk Bldg. 4D 700 Robbins Ave. Philadelphia, PA 19111-5094 Ph: 215-697-2179 Fax: 215-697-2978
NRMCA	National Ready-Mixed Concrete Association 900 Spring St. Silver Spring, MD 20910 Ph: 301-587-1400 Fax: 301-585-4219
NTIS	National Technical Information Service U.S. Department of Commerce Springfield, VA 22161 (703) 487-4650
PCA	Portland Cement Association 5420 Old Orchard Road Skokie, IL 60077
USACE	U.S. Army Corps of Engineers U.S. Army Engineer Waterway Experiment Station ATTN: Technical Report Distribution Section, Services Branch, TIC 3909 Halls Ferry Rd. Vicksburg, MS 39180-6199 Ph: 601-634-2355 Fax: 601-634-2506
WID	Westinghouse Electric Corporation Waste Isolation Division Carlsbad, New Mexico 88221

-- End of Section

SECTION 01400
CONTRACTOR QUALITY CONTROL

SECTION 01400

CONTRACTOR QUALITY CONTROL

PART 1 - GENERAL

1.1 Scope

This section includes:

- Contractor Quality Control Plan (CQCP)
- Reference Standards
- Quality Assurance
- Tolerances
- Testing Services
- Inspection Services
- Submittals

1.2 Related Sections

- 01090 - Reference Standards
- 01600 - Material and Equipment
- 02222 - Excavation
- 02722 - Grouting
- 03100 - Concrete Formwork
- 03300 - Cast-in-Place Concrete
- 04100 - Mortar
- 04300 - Unit Masonry System

1.3 Contractor Quality Control Plan

The Contractor shall prepare and submit for approval by Westinghouse WID, a Quality Control Plan, as described in Section 3.2. No work shall be performed prior to approval of the Contractor's Quality Control Plan.

1.4 References and Standards

Refer to individual specification sections for standards referenced therein, and to Section 01090 - Reference Standards for general listing.

Standards referenced in this section are as follows:

ASTM C1077-95a	Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

ASTM C1093-88	Practice for Accreditation of Testing Agencies for Unit Masonry
ASTM E329-95	Practice for Use in the Evaluation of Inspection and Testing Agencies as Used in Construction
ASTM E543-95	Practice for Determining the Qualification of Nondestructive Testing Agencies
ASTM E548-94	Practice for Preparation of Criteria for Use in the Evaluation of Testing Laboratories and Inspection Bodies

1.5 Quality Assurance

- Monitor quality control over suppliers, manufacturers, products, services, site conditions, and workmanship, to produce work of specified quality
- Comply with specified standards as minimum quality for the work except where more stringent tolerances, codes, or specified requirements indicate higher standards or more precise workmanship
- Perform work by persons qualified to produce required and specified quality
- Verify that field measurements are as indicated on shop drawings
- Secure products in place with positive anchorage devices designed and sized to withstand stresses, vibration, physical distortion, or disfigurement.

1.6 Tolerances

Monitor excavation fabrication and installation tolerance control of work and products to produce acceptable work. Do not permit tolerances to accumulate.

Adjust products to appropriate dimensions; position before securing products in place.

1.7 Testing Services

Unless otherwise indicated by Westinghouse WID, the Contractor shall employ an independent firm to perform the testing services and other services specified in the individual specification sections, and as required by Westinghouse WID. Testing and source quality control may occur on or off the project site.

The testing laboratory shall comply with applicable sections of the reference standards and shall be authorized to operate in the state in which the project is located.

Testing equipment shall be calibrated at reasonable intervals with devices of an accuracy traceable to either the National Bureau of Standards or accepted values of natural physical constants.

1.8 Inspection Services

The Contractor shall employ an independent firm to perform inspection services as a supplement to the Contractor's quality control as specified in the individual specification sections, and as required by Westinghouse WID. Inspection may occur on or off the project site.

The inspection firm shall comply with applicable sections of the reference standards.

1.9 Submittals

The Contractor shall submit a Contractors' Quality Control Plan as described herein.

Prior to start of work, the Contractor shall submit for approval, the testing laboratory name, address, telephone number and name of responsible officer of the firm. He shall also submit a copy of the testing laboratory compliance with the reference ASTM standards, and a copy of report of laboratory facilities inspection made by Materials Reference Laboratory of National Bureau of Standards with memorandum of remedies of any deficiencies reported by the inspection.

Prior to start of work, the Contractor shall submit for approval the inspection firm name, address, telephone number and name of responsible officer of the firm. He shall also submit the personnel proposed to perform the required inspection, along with their individual qualifications and certifications (Example: Certified AWS Welding Inspector.)

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

3.1 General

The Contractor is responsible for quality control and shall establish and maintain an effective quality control system. The quality control system shall consist of plans, procedures, and organization necessary to produce an end product which complies with the contract requirements. The system shall cover all construction operations, both on site and off site, and shall be keyed to the proposed construction sequence. The project superintendent will be held responsible for the quality of work on the job. The project superintendent in this context shall mean the individual with the responsibility for the overall management of the project including quality and production.

3.2 Quality Control Plan

3.2.1 General

The Contractor shall furnish for review and approval by Westinghouse WID, not later than 30 days after receipt of notice to proceed, the Contractor Quality Control (CQC) Plan proposed to implement the requirements of the Contract. The plan shall identify personnel, procedures, control, instructions, test, records, and forms to be used. Construction will be permitted to begin only after acceptance of the CQC Plan.

3.2.2 Content of the CQC Plan

The CQC Plan shall include, as a minimum, the following to cover all construction operations, both on site and off site, including work by subcontractors, fabricators, suppliers, and purchasing agents:

- A description of the quality control organization, including a chart showing lines of authority and acknowledgment that the CQC staff shall implement the control system for all aspects of the work specified. The staff shall include a CQC System Manager who shall report to the project superintendent.

- The name, qualifications (in resume format), duties, responsibilities, and authorities of each person assigned a CQC function.

- Description of the CQC System Manager's responsibilities and delegation of authority to adequately perform the functions of the CQC System Manager, including authority to stop work which is not in compliance with the contract. The CQC System Manager shall issue letters of direction to all other various quality control representatives outlining duties, authorities, and responsibilities.

- Procedures for scheduling, reviewing, certifying, and managing submittals, including those of subcontractors, off site fabricators, suppliers, and purchasing agents. These procedures shall be in accordance with Westinghouse WID Submittal Procedures.

- Control, verification, and acceptance testing procedures for each specific test to include the test name, specification paragraph requiring test, feature of work to be tested, test frequency, and person responsible for each test. (Laboratory facilities will be subject to approval by Westinghouse WID.)

- Procedures for tracking construction deficiencies from identification through acceptable corrective action. These procedures will establish verification that identified deficiencies have been corrected.

- Reporting procedures, including proposed reporting formats.

- A list of the definable features of work. A definable feature of work is a task which is separate and distinct from other tasks and has separate control requirements. It could be identified by different trades or disciplines, or it could be work by the same trade in a different environment. Although each section of the specifications may generally be considered as a definable feature of work, there are frequently more than one definable feature under a particular section. This list will be submitted to Westinghouse WID for approval.

3.2.3 Acceptance of Plan

Acceptance of the Contractor's plan is required prior to the start of construction. Acceptance is conditional and will be predicated on satisfactory performance during the construction. The Owner reserves the right to require the Contractor to make changes in his CQC Plan and operations including removal of personnel, as necessary, to obtain the quality specified.

3.2.4 Notification of Changes

After acceptance of the CQC Plan, the Contractor shall notify Westinghouse WID in writing of any proposed change. Proposed changes are subject to acceptance by Westinghouse WID.

3.3 Quality Control Organization

3.3.1 General

The requirements for the CQC organization are a CQC System Manager and sufficient number of additional qualified personnel supplemented by independent testing and inspection firms as required by the specifications, to ensure contract compliance. The Contractor shall provide a CQC organization which shall be at the site at all times during progress of the work and with complete authority to take any action necessary to ensure compliance with the contract. All CQC staff members shall be subject to acceptance by Westinghouse WID.

3.3.2 CQC System Manager

The Contractor shall identify as CQC System Manager an individual within his organization at the site of the work who shall be responsible for overall management of CQC and have the authority to act in all CQC matters for the Contractor. The CQC System Manager shall be a graduate engineer, with a minimum of five years construction experience on construction similar to this contract. This CQC System Manager will be employed by the prime Contractor. The CQC System Manager shall be assigned no other duties. An alternate for the CQC System Manager will be identified in the plan to serve in the event of the System Manager's absence. The requirements for the alternate will be the same as for the designated CQC System Manager.

3.3.3 CQC Personnel

In addition to CQC personnel specified elsewhere in the contract, the Contractor shall provide as part of the CQC organization specialized personnel or third party inspectors to assist the CQC System Manager. These individuals shall be employed by the prime Contractor; be

responsible to the CQC System Manager; have the necessary education and/or experience. These individuals shall have no other duties other than quality control.

3.3.4 Organizational Changes

The Contractor shall maintain his CQC staff at full strength at all times. When it is necessary to make changes to the CQC staff the Contractor shall revise the CQC Plan to reflect the changes and submit the changes to Westinghouse WID for acceptance at the Contractors' expense.

3.4 Tests

3.4.1 Testing Procedure

The Contractor shall perform specified or required tests to verify that control measures are adequate to provide a product which conforms to contract requirements. Upon request, the Contractor shall furnish to Westinghouse WID duplicate samples of test specimens for possible testing by Westinghouse WID. Testing includes operation and/or acceptance tests when specified. The Contractor shall procure the services of an approved testing laboratory. The Contractor shall perform the following activities and record and provide the following data:

- Verify that testing procedures comply with contract requirements.
- Verify that facilities and testing equipment are available and comply with testing standards.
- Check test instrument calibration data against certified standards.
- Verify that recording forms and test identification control number system, including all of the test documentation requirements, have been prepared.
- Results of all tests taken, both passing and failing tests, will be recorded on the CQC report for the date taken. Specification paragraph reference, location where tests were taken, and the sequential control number identifying the test will be given. If approved by Westinghouse WID, actual test reports may be submitted later with a reference to the test number and date taken. An information copy of tests performed by an off site or commercial test facility will be provided directly to Westinghouse WID. Failure to submit timely test reports as stated may result in nonpayment for related work performed and disapproval of the test facility for this contract.

3.5 Testing Laboratory

The testing laboratory shall provide qualified personnel to perform specified sampling and testing of products in accordance with specified standards, and ascertain compliance of materials and mixes with requirements of Contract Documents. The testing laboratory shall promptly notify Westinghouse WID and Contractor of any observed irregularities or non-conformance of Work or Products.

Reports indicating results of tests, and compliance (or noncompliance) with the contract documents will be submitted in accordance with Westinghouse WID submittal procedures.

The Contractor shall cooperate with the independent testing firm, furnish samples, storage, safe access, and assistance by incidental labor as required. Testing by the independent firm does not relieve the contractor of the responsibility to perform the work to the contract requirements.

The laboratory may not:

- Release, revoke, alter, or enlarge on requirements of the contract
- Approve or accept any portion of the work
- Assume any duties of the Contractor.

The laboratory has no authority to stop the work.

3.6 Inspection Services

The inspection firm shall provide qualified personnel at site to supplement the Contractor's Quality Control Program to perform specified inspection of Products in accordance with specified standards. He shall ascertain compliance of materials and mixes with requirements of Contract Documents, and promptly notify the CQC System Manager, Westinghouse WID and the Contractor of observed irregularities or non-conformance of Work or Products. The inspector does not have the authority to stop the work. The inspector shall refer such cases to the CQC System Manager who has the authority to stop work (see Section 3.2.2).

Reports indicating results of the inspection and compliance (or noncompliance) with the contract documents will be submitted in accordance with Westinghouse WID submittal procedures.

The Contractor shall cooperate with the independent inspection firm, furnish samples, storage, safe access and assistance by incidental labor, as requested.

Inspection by the independent firm does not relieve the Contractor of the responsibility to perform the work to the contract requirements.

3.7 Completion Inspection

3.7.1 Pre-Final Inspection

At the completion of all work the CQC System Manager shall conduct an inspection of the work and develop a "punch list" of items which do not conform to the approved drawings and specifications. Once this is accomplished the Contractor shall notify Westinghouse WID that the facility is complete and is ready for the "Prefinal" inspection. Westinghouse WID will perform this inspection to verify that the facility is complete. A "Final Punch List" will be developed as a result of this inspection. The Contractor's CQC System Manager shall ensure

that all items on this list have been corrected and notify Westinghouse WID so that a "Final" inspection can be scheduled. Any items noted on the "Final" inspection shall be corrected in a timely manner. These inspections and any deficiency corrections required by this paragraph will be accomplished within the time slated for completion of the entire work.

3.7.2 Final Acceptance Inspection

The final acceptance inspection will be formally scheduled by Westinghouse WID based upon notice from the Contractor. This notice will be given to Westinghouse WID at least 14 days prior to the final acceptance inspection and must include the Contractor's assurance that all specific items previously identified to the Contractor as being unacceptable, along with all remaining work performed under the contract, will be complete and acceptable by the date scheduled for the final acceptance inspection.

3.8 Documentation

The Contractor shall maintain current records providing factual evidence that required quality control activities and/or tests have been performed. These records shall include the work of subcontractors and suppliers and shall be on an acceptable form that includes, as a minimum, the following information:

- Contractor/subcontractor and their area of responsibility.
- Operating plant/equipment with hours worked, idle, or down for repair.
- Work performed each day, giving location, description, and by whom.
- Test and/or quality control activities performed with results and references to specifications/drawings requirements. List deficiencies noted along with corrective action.
- Quantity of materials received at the site with statement as to acceptability, storage, and reference to specifications/drawings requirements.
- Submittals reviewed, with contract reference, by whom, and action taken.
- Off-site surveillance activities, including actions taken.
- Instructions given/received and conflicts in plans and/or specifications.
- Contractor's verification statement.

These records shall indicate a description of trades working on the project; the number of personnel working; weather conditions encountered; and any delays encountered. These records shall cover both conforming and deficient features and shall include a statement that equipment and materials incorporated in the work and workmanship comply with the contract. The original and one copy of these records in report form shall be furnished to Westinghouse

WID daily. Reports shall be signed and dated by the CQC System Manager. The report from the CQC System Manager shall include copies of test reports and copies of reports prepared by all subordinate quality control personnel.

3.9 Notification of Noncompliance

Westinghouse WID will notify the Contractor of any detected noncompliance with the foregoing requirements. The Contractor shall take immediate corrective action after receipt of such notice. Such notice, when delivered to the Contractor at the worksite, shall be deemed sufficient for the purpose of notification. If the Contractor fails or refuses to comply promptly, Westinghouse WID may issue an order stopping all or part of the work until satisfactory corrective action has been taken. No part of the time lost due to such stop orders shall be made the subject of claim for extension of time or for excess costs or damages by the Contractor.

End of section.

SECTION 01600
MATERIAL AND EQUIPMENT

SECTION 01600

MATERIAL AND EQUIPMENT

PART 1 - GENERAL

1.1 Scope

This section includes:

- Equipment
- Products
- Transportation and handling
- Storage and protection
- Substitutions

1.2 Related Sections

- 01010 - Summary of Work
- 01400 - Contractor Quality Control
- 02010 - Mobilization and Demobilization
- 02222 - Excavation
- 02722 - Grouting
- 03100 - Concrete Formwork
- 03300 - Cast-in-Place Concrete
- 04100 - Mortar
- 04300 - Unit Masonry System

1.3 Equipment

The Contractor shall specify his proposed equipment in the Work Plan. Power equipment for use underground shall be either electrical or diesel engine driven. All diesel engine equipment shall be certified for use underground.

1.4 Products

The Contractor shall specify in the Work Plan, or in subsequently required submittals the proposed products including, but not limited to the grout mix and its components, concrete mix and its components, mortar mix and its components, formwork, and masonry. The proposed products shall be supported by laboratory test results as required by the specifications. All products shall be subject to approval by Westinghouse WID.

1.5 Transportation and Handling

- Transport and handle products in accordance with manufacturer's instructions.
- Promptly inspect shipments to ensure that products comply with requirements, quantities are correct, and products are undamaged.
- Provide equipment and personnel to handle products by methods to prevent soiling, disfigurement, or damage.

1.6 Storage and Protection

- Store and protect products in accordance with manufacturers' instructions.
- Store with seals and labels intact and legible.
- Store sensitive products in weather tight, climate controlled, enclosures in an environment favorable to product.
- For exterior storage of fabricated products, place on sloped supports above ground.
- Cover products subject to deterioration with impervious sheet covering. Provide ventilation to prevent condensation and degradation of products.
- Store loose granular materials on solid flat surfaces in a well-drained area. Prevent mixing with foreign matter.
- Provide equipment and personnel to store products by methods to prevent soiling, disfigurement, or damage.
- Arrange storage of products to permit access for inspection. Periodically inspect to verify products are undamaged and are maintained in acceptable condition.

1.7 Substitutions

1.7.1 Equipment Substitutions

The Contractor may substitute equipment for that proposed in the Work Plan subject to Westinghouse WID's approval. The Contractor shall demonstrate the need for the substitution, and the applicability of the proposed substitute equipment.

1.7.2 Product Substitutions

The Contractor may not substitute products after the proposed products have been approved by Westinghouse WID unless he can demonstrate that the supplier/source of that product no longer exists in which case he shall submit alternate products with lab test results to

Westinghouse WID for approval. In the case that product is a component in a mix, the Contractor shall perform mix testing using that component and submit laboratory test results.

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

Not used.

End of section.

SECTION 02010
MOBILIZATION AND DEMOBILIZATION

SECTION 02010

MOBILIZATION AND DEMOBILIZATION

PART 1 - GENERAL

1.1 Scope

This section includes:

- Mobilization of equipment and facilities to site
- Contractor use of site
- Use of existing facilities
- Demobilization of equipment and facilities
- Site cleanup

1.2 Related Sections

- 01010 - Summary of Work
- 01600 - Material and Equipment

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

3.1 Mobilization of Equipment and Facilities to Site

Upon authorization to proceed, the Contractor shall mobilize his equipment and facilities to the jobsite. Equipment and facilities shall be as specified, and as defined in the Contractor's Work Plan. The Contractor shall erect the batch plant and assemble his equipment and materials in the areas designated by Westinghouse WID. Facilities shall be located as near as practical to the existing utilities.

Westinghouse WID will provide utilities (460 volt AC, 3 phase, and water) at designated locations. The Contractor shall be responsible for all hookups and tie-ins required for his operations.

The Contractor shall be responsible for providing his own office, storage, and sanitary facilities.

Areas will be designated for the Contractor's use in the underground area in the vicinity of the panel closure system installation. These areas are limited.

3.2 Use of Site

The Contractor shall use only those areas specifically designated for his use by Westinghouse WID. The Contractor shall limit his on-site travel to the specific routes required for performance of his work, and designated by Westinghouse WID.

3.3 Use of Existing Facilities

Existing facilities at the site which are available for use by the Contractor are:

- WIPP roadheader
- Waste shaft conveyance
- Salt skip hoist
- (1) 20 ton forklift
- (1) 40-ton forklift
- 460 Volt AC, 3 phase power
- Water (in mine, at waste shaft only-above ground at location designated by Westinghouse WID).

The Contractor shall arrange for use of the facilities with Westinghouse WID and coordinate his actions/requirements with that of the ongoing operations.

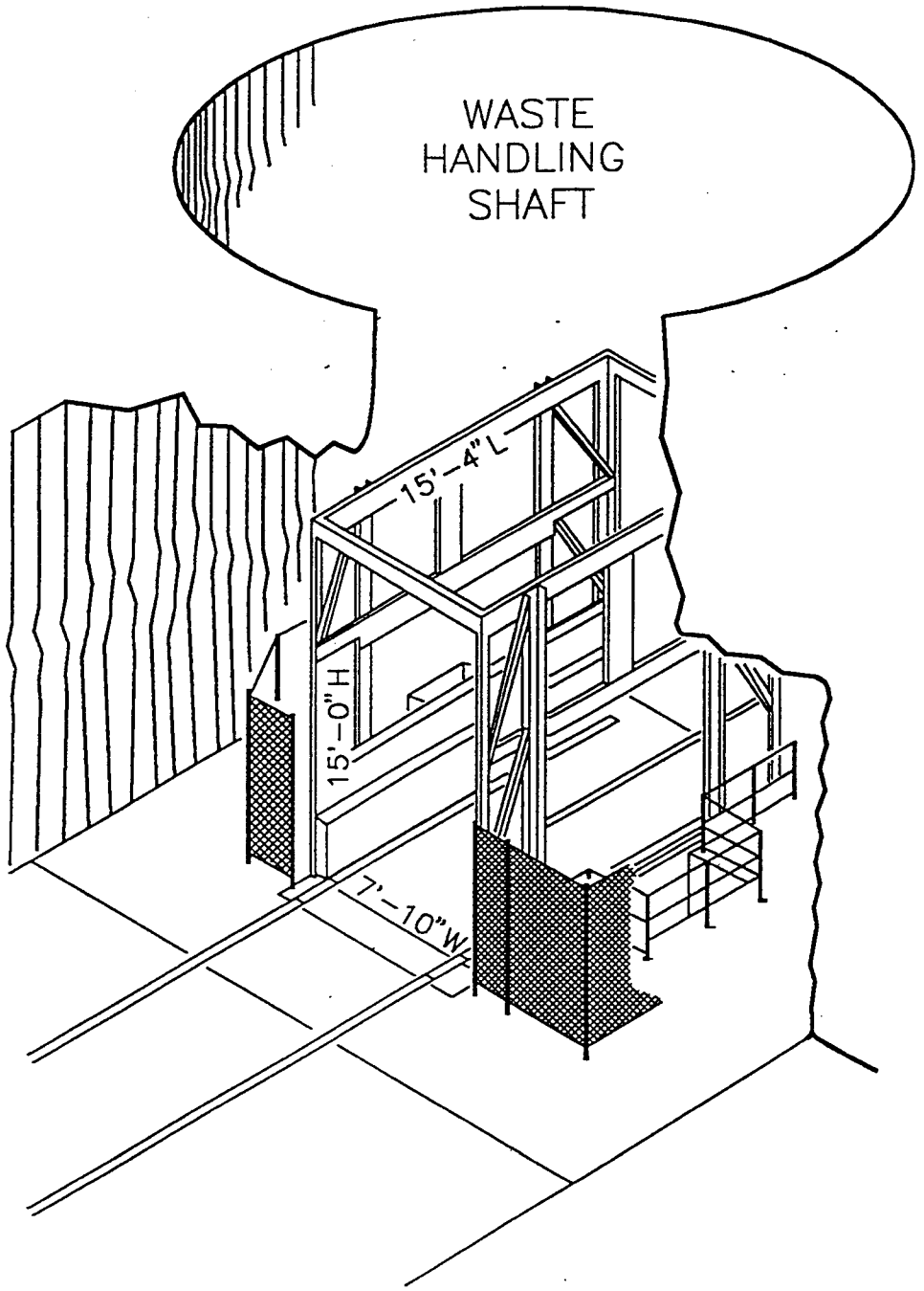
Use of water in the underground will be restricted. No washout or cleanup will be permitted in the underground. Above ground washout/cleanup or equipment will be allowed in the areas designated by Westinghouse WID.

The Contractor is cautioned to be aware of the physical dimensions of the waste conveyance and the air lock (see Figures 2 and 3, attached).

The Contractor shall be responsible for any damage incurred by the existing site facilities as a result of his operations. Any damage shall be reported immediately to Westinghouse WID and repaired at the Contractor's cost.

3.4 Demobilization of Equipment and Facilities

At completion of this work, the Contractor shall demobilize his equipment and facilities from the job site. The batch plant shall be disassembled and removed along with any unused material. All Contractor's equipment and materials shall be removed from the mine and all disturbed areas restored. Utilities shall be removed to their connection points unless otherwise directed by Westinghouse WID.



NOTES

(1) CAGE DIMENSIONS SHOWN ARE INSIDE.

(2) WASTE HOIST DESIGN CAPACITY IS 80,000 LBS.

Figure 2

Waste Handling Shaft Cage Dimensions

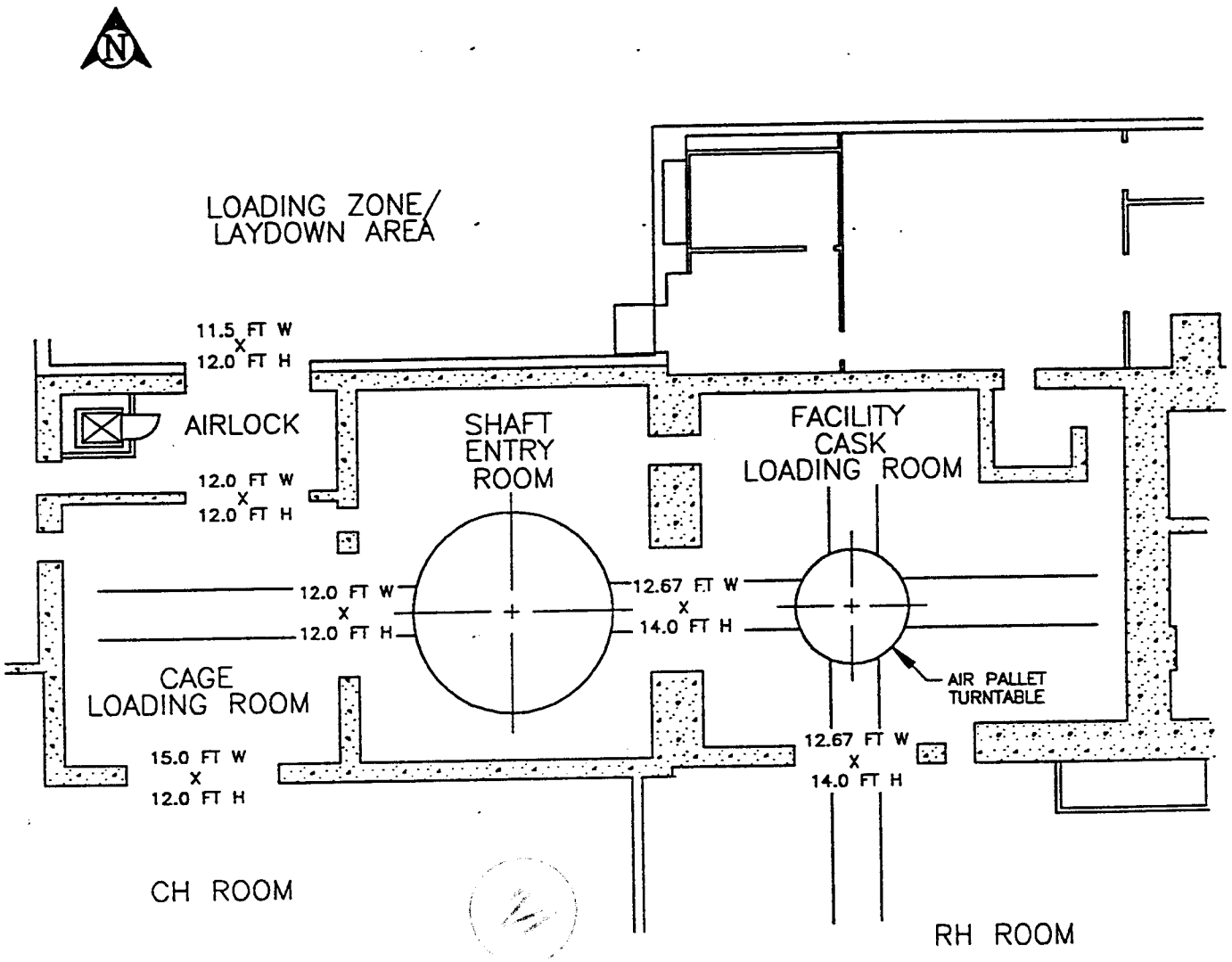


Figure 3

Waste Shaft Collar and Airlock Arrangement

3.5 Site Cleanup

At conclusion of the work, the Contractor shall remove all trash, waste, debris, excess construction materials, and restore the affected areas to its prior condition, to the satisfaction of Westinghouse WID. A final inspection of the areas will be conducted by Westinghouse WID and the Contractor before final payment is approved.

End of section.

SECTION 02222
EXCAVATION

SECTION 02222

EXCAVATION

PART 1 - GENERAL

1.1 Scope
This section includes:

- Excavation for main concrete barrier
- Excavation for surface preparation and levelling of base areas for isolation walls
- Disposition of excavated materials.

1.2 Related Sections

- 01010 - Summary of Work
- 01600 - Material and Equipment
- 03100 - Concrete Form Work
- 04300 - Unit Masonry System.

1.3 Reference Documents
"Reference Stratigraphy and Rock Properties for the Waste Isolation Pilot Plant (WIPP) Project" by R.D. Krieg-Sandia National Laboratory Document Sand 83-1908. [Available through National Technical Information Service (NTIS).]

1.4 Field Measurements and Survey
All survey required for performance of the work will be provided by Westinghouse WID. To develop the concrete formwork to fit the excavation, the Contractor shall be responsible for verifying the excavation dimensions.

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

3.1 Excavating for Concrete Barrier
Excavation for the main concrete barrier shall be performed to the lines and grades shown on the drawings. Excavate the back a minimum of 1 inch to 3 inches beyond clay seam G, and the floor a minimum of 1 inch to 3 inches below the anhydride marker bed 139 (MB-139) to

assure removal of the disturbed rock zone (DRZ). Excavation shall be performed utilizing mechanical means such as a cutting head on a suitable boom, by drilling boreholes and using an expansive agent to fragment the rock or other competent equipment or methods submitted to Westinghouse WID for review and approval. The use of explosives is prohibited. The existing WIPP roadheader mining machine may also be available for use. The Contractor is to determine availability and coordinate proposed use of the roadheader with Westinghouse WID. The existing roadheader is capable of excavating the back and the portions of the ribs above the floor level. However, it is not capable of excavating the portion below floor level.

The tolerances for the concrete barrier excavation shall be +6 inches, to 0 inch. In addition, the Contractor is to remove all loose or spalling rock from the excavation surface to provide a sound surface abutting the concrete barrier. The Contractor shall provide and install roof bolts for support as required for personnel protection and approved ground control plans.

3.2 Excavating for Surface Preparation and leveling of Base Areas for Isolation Walls

The Contractor shall excavate a 6-inch surface preparation around the entire perimeter of the isolation walls. The surface preparation in the floor shall be made level to produce a surface for placing the first course of block in the isolation walls. Tolerances for the leveled portion of the surface preparation are ±1 inch. Excavation may be performed by either mechanical or manual means. Use of explosives is prohibited.

3.3 Disposition of Excavated Materials

The Contractor shall remove all excavated materials from the panel-access drift where they are excavated. Excavated materials shall be removed from the mine via the salt skip to the surface, where they will be disposed on site at a location as directed by Westinghouse WID.

3.4 Field Measurements and Survey

All survey required for performance of the work will be provided by Westinghouse WID. The Contractor shall protect all survey control points, bench marks, etc., from damage by his operations. WID will verify by survey that the Contractor has excavated to the required lines and grades. The Contractor shall be responsible for verifying the excavation dimensions to develop concrete formwork to fit the excavation. No form work or block work is to be erected until this survey is completed. The Contractor is to coordinate the survey work with his operations to assure against lost time. The Contractor shall notify Westinghouse WID at least 24 hours prior to the time surveying is required

End of section.

SECTION 02722
GROUTING

SECTION 02722

GROUTING

PART 1 - GENERAL

1.1 Scope

This section includes:

- Grouting of concrete barrier.

1.2 Related Sections

- 01010 - Summary of Work
- 01400 - Contractor Quality Control
- 01600 - Material and Equipment
- 03100 - Concrete Form Work
- 03300 - Cast-in-Place Concrete

1.3 References

ASTM C1107-91a Standard Specification for Dry, Hydraulic Cement Grout (Nonshrink)

ASTM C109/ C109M-95 Test Method for Compressive Strength of Hydraulic Cement Mortars

1.4 Submittals for Review and Approval

Thirty days prior to the initiation of grouting, the Contractor shall submit to Westinghouse WID for review and approval, the following:

- Type of grout proposed
- Product data:
  - Manufacturer's specification and certified laboratory tests for the manufactured grout, if proposed
  - Certified laboratory tests for the salt-saturated grout, if proposed, using project-specific materials

- Proposed grouting method, including equipment and materials and construction sequence in Work Plan.

1.5 Submittals for Construction

Daily grouting report indicating the day, date, time of mixing and delivery, quantity of grout placed, water used, pressure required, problems encountered, action taken, quality control data, testing results, etc., no later than 24 hours following construction.

PART 2 - PRODUCTS

2.1 Grout Materials

Grout used for grouting in connection with fresh water/plain cement concrete shall be nonshrink, cement-based grout, Five Star 110 as manufactured by Five Star Products Inc., 425 Stillson Road, Fairfield, Connecticut 06430 or approved equal. Mixing and installation shall be in accordance with the manufacturer's recommendations.

As an alternate to the above grout, in connection with the Salado Mass concrete mix, the Contractor shall use, subject to the approval of Westinghouse WID, a salt saturated grout. The following formulation is suggested to the Contractor as an initiation point for selection of the grout mix. Salt saturated grout strength shall be 4500 psi at 28 days.

Salt-Saturated Grout (BCT-1F)

Component	Percent of total Mass (wt.)
Class H cement	48.3
Class C fly ash	16.2
Cal Seal (plaster - from Halliburton)	5.7
Sodium chloride	7.9
Dispersant	0.78
Defoamer	0.02
Water	21.1

Water for mixing shall be of potable quality, free from injurious amounts of oil, acid, alkali, salt, or organic matter, sediments, or other deleterious substances, as specified for concrete, Section 03300-2.3.

2.2 Product Data

If the Contractor proposes to utilize a manufactured nonshrink cement-based grout, he shall submit complete manufacturer's specifications for the product, along with certified laboratory test results of the material.

If the Contractor proposes to utilize the salt-saturated grout in connection with the Salado Mass concrete mix, he shall submit manufacturer's/supplier's specifications for the component materials, and certified laboratory test results for the resultant mix.

PART 3 - EXECUTION

3.1 General

The Contractor shall furnish all labor material, equipment, and tools to perform all operations in connection with the grouting.

Grout delivery and return lines for interface grouting shall be installed in the form work or in the area to be grouted to provide uniform distribution of the grout as shown on the drawings. The exact location of the boxes and lines shall be determined in the field. Additional grout delivery and return lines and boxes may be required by Westinghouse WID.

Pumps shall be positive displacement piston type pump designed for grouting service capable of operating at a discharge pressure of 100 psi. The Contractor shall supply a standby pump to be utilized in the event of a breakdown of the primary unit.

Mixers shall be high velocity "colloidal" type with a rotary speed of 1,200 to 1,500 rpm. Grout shall be mixed to a pumpable mix as per the manufacturer's recommendations.

Mixing water shall be accurately metered to control the consistency of the grout.

The Contractor shall provide all necessary valves, gages, and pressure hoses.

Water for mixing is available at the waste shaft. The Contractor is cautioned that no free water discharges or spills are permitted in the mine. All cleanup and washout operations shall be performed at the ground surface.

Potential spill areas in the underground shall be identified by the Contractor in the work plan. The Contractor shall provide measures to contain suitable containment. Isolation measures shall include, but are not limited to, lining with a membrane material (PVC, hypalon, HDPE), draped curtains (polyethylene,PVC, etc.), corrugated sheet metal protective walls or a combination of these and other measures.

If salt-saturated grout is selected for use, the Contractor shall make provisions to accurately proportion the components. Proportioning shall be by weighing. Sufficient quantities of dry

components shall be developed prior to initiation of the grouting to perform the work so as not to incur delays during the mixing/placing sequence.

3.2 Interface Grouting of Concrete Barrier

After each cell of the concrete barrier has been allowed to cure for a period of seven days, or as directed by Westinghouse WID, the Contractor shall interface grout the remaining space between the back wall and the top surface of the concrete barrier.

Each cell of the concrete barrier shall be grouted before the next adjacent cell is formed and concrete placed. Grout delivery and return lines shall be installed with the form work as shown and called for on the drawings, or as directed by Westinghouse WID.

The placing of grout, unless otherwise directed by Westinghouse WID shall be continuous until completed. Grouting shall progress from lower to higher grout pipes. Grouting shall proceed through a single delivery line until grout escapes from the adjacent return line. The Contractor shall then secure these lines and move to the next adjacent set of delivery and return lines. Pressure shall be adjusted to adequately deliver the grout to the forms, as witnessed by grout in the return line.

The grouting operation shall be conducted in a manner such that it does not affect the stability of the concrete barrier structure.

3.3 Contact Grouting

After completion of interface grouting if directed by Westinghouse WID, the Contractor shall contact grout to fill any remaining voids at the concrete barrier/back wall interface. Contact grouting includes all operations to drill, clean, and grout holes installed in the concrete barrier.

The Contractor shall drill and grout the interface zone to the main concrete barrier as directed by Westinghouse WID.

The location, direction, and depth of each grout hole shall be as directed by Westinghouse WID. The order in which the holes are drilled and the manner in which each hole is drilled and grouted, the proportions of the water used in the grout, the time of grouting, the pressures used in grouting, and all other details of the grouting operations shall be as directed by Westinghouse WID.

Wherever required, contact grouting will entail drilling the hole to a limited depth, installing a packer, and performing grouting.

3.3.1 Drilling

The holes shall be drilled with rotary-type drills. Drilling grout holes with percussion-type drills will not be permitted except as approved by Westinghouse WID.

The requirements as to location, depth, spacing, and direction of the holes shall be as directed by Westinghouse WID.

The minimum diameter shall be approximately 11/2 inches.

When the drilling of each hole or stage of has been completed, compressed air will be used to flush out drill cuttings. The hole shall then be temporarily capped or otherwise suitably protected to prevent the hole from becoming clogged or obstructed until it is grouted.

3.3.2 Materials for Contact Grouting

Standard weight black steel pipe conforming to ASTM A-53 shall be set in the concrete in the locations as directed by Westinghouse WID. All pipe and fittings shall be furnished by the Contractor.

The size of the grout pipe for each hole and the depth of the holes for setting pipe for grouting shall be as directed by Westinghouse WID. Care shall be taken to avoid clogging or obstructing the pipes before being grouted, and any pipe that becomes clogged or obstructed from any cause shall be cleaned satisfactorily or replaced.

The packers shall be furnished by the Contractor and shall consist of expansible tubes or rings of rubber, leather, or other suitable material attached to the end of the grout supply pipe. The packers shall be designed so that they can be expanded to seal the drill hole at the specified locations and when expanded shall be capable of withstanding without leakage, for a period of 5 minutes, air pressure equal to the maximum grout pressures to be used.

3.3.3 Grouting Procedures

Different grouting pressures will be required for grouting different sections of the grout holes. Pressures as high as necessary to deliver the grout but which, as determined by trial, are safe against concrete displacement shall be used in the grouting.

If, during the grouting of any hole, grout is found to flow from adjacent grout holes or connections in sufficient quantity to interfere seriously with the grouting operation or to cause appreciable loss of grout, such grout holes and connections shall be capped temporarily. Where such capping is not essential, holes shall be left open to facilitate the escape of air as the grout is forced into other holes. Before the grout has set, the grout pump shall be connected to adjacent capped holes and to other holes from which grout flow was observed, and grouting of all holes shall be completed. If during the grouting of any hole, grout is found to flow from points in the barrier, any parts of the concrete structure, or other locations, such flows or leaks shall be plugged or caulked by the Contractor as directed by Westinghouse WID.

As a safeguard against concrete displacement, excessive grout travel, or while grout leaks are being caulked, Westinghouse WID may require the reduction of the pumping pressure, intermittent pumping, or the discontinuance of pumping.

The consistency of the grout mix shall be varied, as directed by Westinghouse WID, depending on the conditions encountered. Where the grout hole or connection continues to take a large amount of grout after the mix has been thickened, Westinghouse WID may require that pumping be done intermittently, waiting up to 8 hours between pumping periods to allow grout in the barrier to set. After the grouting is complete, the pressure shall be maintained by means of stopcocks, or other suitable valve that it will be retained in the holes or connections being grouted.

3.4 Cleanup

No clean-up or washing of equipment with water is allowed in the underground. No free water spills are permitted. All clean out or wash out requiring water will be performed above ground at the location approved by Westinghouse WID. See note above regarding potential spill areas in Section 3.1 - General.

3.5 Quality Control

The Contractor shall provide a third-party quality control inspector at the site throughout the grout placement operations. The inspector shall determine that the grout mix is properly proportioned and properly mixed to the approved consistency. The inspector shall sample and make one set of grout cubes for compression testing for every 50 cubic feet of grout placed, or fraction thereof, for each day of grout placement.

End of section.

SECTION 03100
CONCRETE FORMWORK

SECTION 03100

CONCRETE FORMWORK

PART 1 - GENERAL

1.1 Scope

This section includes:

- Formwork for cast-in-place concrete with shoring, bracing, and anchorage
- Accessory items, grout pipes, concrete delivery pipes.

1.2 Related Sections

- 01010 - Summary of Work
- 01400 - Contractor Quality Control
- 01600 - Material and Equipment
- 02722 - Grouting
- 03300 - Cast-in-Place Concrete
- 04300 - Unit Masonry System

1.3 References

ACI 301-89	Specifications for Structural Concrete for Buildings
ACI 318-89(92)	Building Code Requirements for Reinforced Concrete
ACI 347-94	Recommended Practice for Concrete Formwork
ASTM A-36/ A36M-91	Standard Specification for Structural Steel
ASTM A-53-90b	Standard Specification for Pipe, Steel, Black, and Hot-Dipped Zinc Coated Welded and Seamless
ASTM A-325-91c	Standard Specification for Structural Bolts, Steel, Heat-Treated 120/105 ksi Minimum Tensile Strength
ASTM A-615-95b	Standard Specifications for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
AWS A3.0-94	Welding Terms and Definitions

AWS A5.1-91	Specification for Mild Steel Covered Arc Welding Electrodes
AWS D1.1-94	Structural Welding Code-Steel
AISC	Manual of Steel Construction Latest Edition

1.4 Submittals

The Contractor shall submit the following supporting documentation for the adequacy of the formwork 30 days prior to initiation of work at site:

- Shop detail drawings with appropriate calculations to support the adequacy of the formwork.
- Mill test certification of materials utilized in construction of the forms.
- Details of installation contained in the Contractor's Work Plan.

1.5 Quality Assurance

The design and detail of the formwork shall be conducted under direct supervision of a professional structural Engineer experienced in design of this work. Responsibilities include:

- Fabricating formwork in accordance with AISC manual of steel construction.
- Performing all welding in accordance with AWS D1.1 structural welding code.
- Performing all bolting in accordance with AISC specification for structural joints using ASTM A325 or A490 bolts.
- Performing work in accordance with ACI 301, 318, and 347, AISC and AWS standards. Maintain one copy of all standards at site.

PART 2 - PRODUCTS

2.1 Form Materials

Forms for the concrete barrier shall be constructed of ASTM A-36 steel.

Pipe inserts shall be ASTM A-53 black standard weight pipe.

Form spacers shall be ASTM A-36 round stock.

Bolts shall be ASTM A325 high strength structural bolts.

Grout pipes shall be ASTM A-53 standard weight pipe or flex conduit as shown on the drawings.

Rock anchors shall develop strength equal to or greater than ASTM A-36 round stock.

Welding electrodes shall conform to AWS A5.1.

PART 3 - EXECUTION

3.1 General

The Contractor shall furnish all labor material equipment and tools to perform all operations in connection with the design, detail, fabrication and erection of the formwork and the fabrication and installation of grout pipes for the main concrete barrier. All work shall be performed according to standards referred to in Paragraph 1.3.

The Contractor may, at his option submit an alternate design or modify the design shown on the drawings, subject to the approval of Westinghouse WID. All designs must be supported by design calculations stamped and sealed by a registered professional engineer.

The Contractor shall furnish, fabricate and install all grout pipes and grout boxes for both the concrete barrier and the isolation walls.

3.2 Shop Drawings

The Contractor shall design and detail all formwork for the concrete barrier, complete with any required bracing and shoring for the concrete barrier as shown on the drawings, in accordance with ACI 318 and 347 and the AISC manual of steel construction.

The details shall incorporate provision for adjusting and modifying the formwork to suit the excavation. Excavation tolerances are given in Section 02222 Excavation.

The Contractor shall be responsible for verifying the excavation dimensions to develop the concrete formwork to fit the excavation.

Prior to fabrication, the Contractor shall submit shop drawings complete with supporting calculations for review/approval by Westinghouse WID 30 days prior to initiating work. The contractor shall incorporate all Westinghouse WID's comments, revisions, resolve all questions and resubmit drawings for final approval prior to proceeding with fabrication.

3.3 Fabrication

The Contractor shall fabricate all formwork and ancillary items in accordance with the latest edition of the AISC Manual of Steel Construction and the approved detail drawings.

Formwork shall contain all inserts for grouting and pumping concrete. Sufficient valving shall be provided on inserts to allow shut off of concrete and grout to prevent back flow through the form work.

All welding shall be in accordance with AWS D1.1 structural welding code including operator and procedure certifications. Elements shall be welded using E-7018 low hydrogen electrodes. Panels shall be piece marked to correspond to the erection drawing(s) and sequence at fabrication.

3.4 Installation

3.4.1 Grout Pipes

The Contractor shall furnish, fabricate, and install all grout pipes and boxes as approved by Westinghouse WID. Grout pipes and boxes shall be attached to the back surface using masonry anchors as shown on the drawings or other approved methods. Grout pipes shall be connected to the inserts installed in the permanent forms and securely fastened to the formwork. All grout pipes will be blown out with compressed air after installation and prior to closure of the formwork to assure they are clean and free from debris or obstructions. Grout pipes shall then be temporarily capped to prevent entry of foreign matter until ready for grouting. The Contractor shall apply masking tape to the grout box openings to prevent concrete infiltration during concrete placement.

3.4.2 Formwork

The steel formwork for the concrete barrier is to remain in place at completion of each segment of the barrier, therefore all formwork shall be free from oil, grease, rust, dirt, mud or other material that would prevent bonding by the concrete. Forms will not be oiled or receive application of release agent.

The Contractor shall install formwork at the locations shown on the drawings to the lines and grades shown. Forms are to be mortar tight. The Contractor shall adjust the formwork to suit the contour of the excavation. Rock may be trimmed or chipped to suit where interferences are encountered. Where overexcavation has occurred in excess of the designed-in adjustability of the formwork, modifications shall be proposed to Westinghouse WID for his approval prior to installation. Installation of the formwork shall be reviewed and approved by Westinghouse WID prior to proceeding with concrete installation.

The Contractor shall provide a sealant or gasket material subject to the approval of Westinghouse WID.

3.5 Quality Control

The Contractor shall arrange for and contract with an approved third party inspector to provide inspection/testing services for the fabrication and installation of the formwork and ancillary items, as required by the QA/QC plan.

The Contractor shall furnish certified mill test reports for all materials utilized in the fabrication.

All welding shall be in accordance with AWS D1.1 structural welding code. The Contractor shall furnish welding operator and procedure certifications for all operators and procedures utilized.

Fabricated components shall be inspected for dimension and overall quality. Welds shall be inspected by an AWS certified welding inspector.

The inspector shall visually inspect the installation for fit-up and dimensionally for location.

3.6 Handling, Shipping, Storage

The Contractor shall handle, ship, and store fabricated components with care to avoid damage. Stored components shall be placed on timbers or pallets off the ground to keep the units clean. Components shall be tarped while in outdoor storage. Components that become spattered or contaminated with mud will be thoroughly cleaned during erection, and prior to concrete emplacement. Damaged components will be rejected by the inspector and replaced by the contractor at his cost.

End of section.

SECTION 03300
CAST-IN-PLACE CONCRETE

SECTION 03300

CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.1 Scope

This section includes:

- Cast-in-place concrete for concrete barrier
- Concrete mix design.

1.2 Related Sections

- 01010 - Summary of Work
- 01400 - Contractor Quality Control
- 01600 - Material and Equipment
- 02222 - Excavation
- 02722 - Grouting
- 03100 - Concrete Formwork

1.3 References

ACI 211.1-91	Standard Practice for Selecting Proportions for Normal, Heavy Weight, and Mass Concrete
ACI 318.1-89(92)	Building Code Requirements for Structural Plain Concrete
ACI 304R-89	Guide for Measuring, Mixing, Transporting, and Placing Concrete
ASTM C 33-93	Standard Specification for Concrete Aggregates
ASTM C 39-94	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 94-94	Standard Specification for Ready-Mixed Concrete
ASTM C 136-95a	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 143-90a	Standard Specification for Slump of Hydraulic Cement Concrete

ASTM C 150-95	Standard Specification for Portland Cement
ASTM C 186-94	Standard Test Method for Heat of Hydration of Hydraulic Cement
ASTM C 403/ C 403M-95	Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
ASTM C 494-95	Standard Specification for Chemical Admixtures for Concrete
ASTM C 618-94a	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolam for Use as an Admixutre in Portland Cement Concrete
ASTM C 845-90	Standard Specification for Expansivce Hydraulic Cement
ASTM D 2216-92	Standard Test Method for Laboratory Determination of Water (moisture) Content of Soil and Rock
USACE CRD-C 36	Method of Test for Thermal Diffusivity of Concrete
USACE CRD-C 48	Standard Test Method for Water Permeability of Concrete
API 10	Cements
NRMCA	Check List for Certification of Ready Mixed Concrete Production Facilities
NRMCA	Concrete Plant Standards

Westinghouse WID Standards

WIPP-DOE-71	Design Criteria Waste Isolation Pilot Plant, Revised Mission Concept -- IIA (DOE, 1984)
WP 03-1	WIPP Startup and Acceptance Test Program (Westinghouse, 1993b)
WP 09-010	Design Development Testing (Westinghouse, 1991)
WP 09-CN3021	Component Numbering (Westinghouse, 1994a)
WP 09-024	Configuration Management Board/Engineering Change Proposal (ECP) (Westinghouse, 1994b)

1.4 Submittals for Review/Approval

The Contractor shall submit the following for approval 30 days prior to initiating any work at the site:

Type of concrete proposed

Product Data - Laboratory test data and trial mix data for the proposed concrete to be utilized for the concrete barrier.

Proposed method of installation, including equipment and materials in work plan.

1.5 Submittals at Completion

Laboratory test data developed during the installation of the concrete barrier.

1.6 Quality Assurance

Perform work in accordance with the Contractor's Quality Control Plan and referenced ACI and ASTM standards.

Acquire cement, aggregate and component materials from the same source throughout the work.

PART 2 - PRODUCTS

2.1 Cement

Portland cement shall conform to ASTM C150 Type II modified with Pozzolan or IV for plain cement concrete or API 10 Class H oil well cements. Cement utilized in the mix shall be Portland cement, Type II modified with pozzolan or type IV, to limit the heat of hydration of the resultant mix. The source of the cement to be used shall be indicated and manufacturer's certification that the cement complies to the applicable standard shall be provided with each shipment.

2.2 Aggregates

Aggregates shall be quartz aggregates conforming to the requirements of ASTM C33.

Fine aggregate shall meet the requirements of ASTM C33 having a fineness modulus in the range of 2.80 to 3.00.

Coarse aggregate maximum size shall be 1 1/2 inches and shall be clean, cubical, angular, 100 percent crushed aggregate without flat or elongated particles.

The source of the aggregate is to be indicated and test reports certifying that the aggregate complies with the applicable standard are to be submitted for approval with the trial mix data.

2.3 Water

Water used in mixing concrete shall be of potable quality, free of injurious amounts of oil, acid, alkali, organic matter, or other deleterious substances.

Water shall conform to the provisions in ASTM C94, and in addition, shall conform to the following:

- pH not less 6.0 or greater than 8.0
- Carbonates and/or bicarbonates of sodium and potassium: 1000 ppm maximum
- Chloride ions (C1): 250 ppm maximum
- Sulfate ions (SO_4): 1000 ppm maximum
- Iron content: 0.3 ppm maximum
- Total solids: 2000 ppm maximum

When ice is used in concrete mix, the water used for making ice shall meet all of the above requirements.

The source of water is to be indicated and certified copies of test data from an approved laboratory confirming that the water to be used meets the above requirements shall be submitted for approval with the trial mix data.

2.4 Admixtures

Pozzolan shall conform to ASTM C618. Sampling and testing of pozzolans shall conform to ASTM C311. Approximately 5 percent by weight of pozzolan may be used to replace cement in the mixes when approved.

All admixtures shall conform to ASTM C-494. The source of any admixtures proposed are to be indicated and certified copies of test data from an approved laboratory shall be submitted for approval with the trial mix.

2.5 Target Properties of the Concrete Mix

The Contractor shall develop and proportion a plain cement concrete mix for use in constructing the concrete barrier. The Contractor shall demonstrate by trial mix that the proposed concrete meets the following properties:

Target properties for Barrier Concrete

Property	Comment
4-hr working time	Indicated by 8-inch slump (ASTM C 142) after 3-hr intermittent mixing. Max 10-inch slump at mixing.
Less than 25 °F heat rise prior to placement	Difference between initial condition and temperature after 4 hr.
4,000 psi compressive strength (f'_c)	At 28 days after casting (ASTM C 39)
Volume stability	Length change between +0.05 percent and -0.02 percent (ASTM C 490)
Minimal entrained air	2 percent to 3 percent air

The Contractor shall use water reducing agents, plasticizers and other admixtures to achieve the slump and workability of the mix without adding excessive mixing water or excessive water-cement ratio. All admixtures shall conform to ASTM C-294.

The Contractor shall provide certified copies of test data from an approved laboratory demonstrating compliance with the above target properties.

In addition to the target properties the Contractor shall provide certified test data for the trial mix for the following properties:

- Heat of hydration ASTM C-186
- Concrete Set ASTM C-403
- Thermal Diffusivity USACE CRD-C36
- Water Permeability USACE CRD-C43

2.6 Salado Mass Concrete

The Contractor may elect to utilize the Salado Mass concrete in preference to developing a plain cement concrete. If Salado Mass concrete is selected, the Contractor shall demonstrate that the Salado Mass concrete meets the target properties shown above. Recommended initial proportioning of the Salado Mass concrete is as follows:

Component	Percent of Total Mass
Class H cement (API 10)	4.93
Chem Comp III (ASTM C-845 Type K)	2.85
Class F fly ash (ASTM C-618)	6.82
Fine aggregate	33.58
Coarse aggregate	43.02
Sodium chloride	2.18
Defoaming agent	0.15
Sodium citrate	0.09
Water	6.38

The Contractor shall prepare a trial mix and provide certified test data from an approved testing laboratory for slump, compressive strength, heat rise, heat of hydration, concrete set time, thermal diffusivity, and water permeability as indicated above for the plain concrete mix.

PART 3 - EXECUTION

3.1 General

The Contractor shall provide all labor material, equipment and tools necessary to develop, supply, mix, transport and place mass concrete in the forms as shown on the drawings and called for in these specifications. All work shall be according to the standard references in paragraph 1.3.

The Contractor will be required to provide and erect on the site a batch plant, suitable to store, handle, weight and deliver the proposed concrete mix. The batch plant shall be certified to NRMCA standards. The batch plant shall be erected on site in the location as directed by Westinghouse WID.

The Contractor shall batch, mix, and deliver to the underground, sufficient quantity of concrete to complete placement of concrete within one form section, as shown on the drawings. Once begun, placement of concrete in a section shall be continuous until completed. Target time for concreting one section is eight to ten hours allowing an additional two hours for clean up of equipment, for a total 10- to 12-hour shift.

It is expected that addition of water to the dry materials and mixing of the concrete will occur at the ground surface with transport of wet concrete to a pump at the underground level where it will be pumped into the forms.

The Contractor is to provide all transport vehicles or means to transfer the wet concrete from the mixer truck to the pump. It is expected that the Contractor will use the waste conveyance hoist to transfer from the ground surface to the mine level. The Contractor is to familiarize himself with the dimensions of the waste conveyance and the airlock in order to provide suitable transport vehicles. The Contractor is also to familiarize himself with the capacity and speed of the conveyance to allow transfer of sufficient concrete to sustain the continuing placement of concrete. (See Figures 2 and 3 attached to Section 02010 - Mobilization and Demobilization).

The Contractor shall determine the horizontal distance to the entry where placement of the concrete barrier is to occur, and develop a route, with the approval of Westinghouse WID for traffic flow within the underground.

Details of the logistics for handling the concrete shall be included in the Contractors' Work Plan, and submitted to Westinghouse WID for approval prior to start of work at the site.

Potential spill areas in the underground shall be identified by the Contractor in the Work Plan. The Contractor shall provide measures to contain and isolate any water from contact with the halite in these areas. Suitable containment isolation measures shall include but are not limited to, lining with a membrane material (PVC, hypalon, HDPE), draped curtains (polyethylene, PVC, etc.), corrugated sheet metal protective walls or a combination of these and other measures.

3.2 Pumping Concrete

The Contractor shall provide pumping equipment suitable for placing the concrete into the forms. The Contractor at a minimum, shall provide an operating and a spare pump, to be used in the event of breakdown of the primary unit. After transporting and prior to pumping the concrete shall be remixed to compensate for segregation of aggregate during transport. The Contractor shall indicate the equipment proposed for pumping (manufacturer, model, type, capacity, pressure and remixing at the point of delivery in the Work Plan).

Each batch of concrete shall be checked at the surface at the time of mixing and again at the point of transfer to the pump for slump and temperature, and shall conform to the following:

- Max. slump at mixing - 10 inches
- Max. slump at delivery to pump - 8 inches
- Max. temperature at placement = 70°F

Note: No water is to be added to the mix after the initial mixing and slump are determined.

The Contractor shall connect to the pipe ports fabricated into the forms for delivery of the concrete, beginning with the lowest ports first. Pumping shall continue until concrete is seen in the adjacent port at which time the delivery hose will be transferred to that port and the first port capped.

Pumping shall continue moving laterally then upward until the entire form is filled and the pour is completed.

3.4 Coordination of Work

The Contractor is to coordinate his work mixing, transporting, and placing the mass concrete with the on-going operations in the underground. Coordination of use of the facilities and existing equipment shall be through Westinghouse WID.

3.5 Clean-Up

No clean up or washing of equipment with water will be allowed in the underground. No free water spills are permitted in the underground. All clean-out or wash-out requiring water will be performed above ground at the location approved by Westinghouse WID.

3.6 Quality Control

The Contractor shall provide a third-party quality control inspector at the site throughout the concrete placement. The inspector shall be responsible for determining that the batch plant is proportioning the mix according to the approved proportions. The batch plant shall provide a print out of batch quantities for each truck delivered to the mine. The inspector shall also determine the slump for each batch as it is mixed and allow additional water to be added until the initial slump is achieved. No additional water is to be added after this time. Temperature will also be recorded at this time.

The inspector shall also determine the slump and temperature following the remixing when concrete is transferred to the pump. Concrete not meeting or exceeding the specification is to be rejected and removed from the underground.

Concrete test cylinders to determine unconfined compression strength shall be taken by the inspection at the delivery from remixer to the pump in the underground. Four (4) cylinders shall be made for each 50 cubic yards of concrete placed. Cylinders shall be sealed with polyethylene and taped and field cured at ambient temperatures in the mine adjacent to the concrete barrier area. Two (2) samples shall be tested at 7 days and the remaining two (2) at 28 days.

End of section.

SECTION 04100
MORTAR

SECTION 04100

MORTAR

PART 1 - GENERAL

1.1 Scope
This section includes:

- Mortar for Isolation Wall Construction.

1.2 Related Sections

- 01010 - Summary of Work
- 01400 - Contractor Quality Control
- 01600 - Material and Equipment
- 04300 - Unit Masonry System

1.3 References

ASTM C91-95	Standard Specification for Masonry Cement
ASTM C144-93	Standard Specification for Aggregate for Masonry Mortar
ASTM C150-95	Standard Specification for Portland Cement
ASTM C207-91	Standard Specification for Hydrated Lime for Masonry Purposes
ASTM C270-94	Standard Specification for Mortar for Unit Masonry
ASTM C780-94	Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry
ASTM C1142-94	Ready-Mixed Mortar for Unit Masonry
ASTM E447-92	Test Methods for Compressive Strength of Masonry Prisms

1.4 Submittals for Review and Approval
The Contractor shall submit for approval the following 30 days prior to the initiation of work at the site.

Design mix.

Certified laboratory tests for the proposed design mix, indicating conformance of mortar to property requirements of ASTM C270, and test and evaluation reports to ASTM C780.

1.5 Submittals at Completion
Certified laboratory test results for the construction testing of mortar mix.

1.6 Quality Assurance
Perform work in accordance with the Contractor's Quality Control Plan and referenced ASTM standards. Acquire cement, aggregate, and component materials from the same source throughout the work.

1.7 Delivery Storage Handling
Maintain packaged materials clean, dry and protected against dampness, freezing and foreign matter.

PART 2 - PRODUCTS

2.1 Mortar Mix
The Contractor shall provide mortar for Isolation Walls, which shall be in conformance with ASTM C270 type M, using the property specification (3,000 psi at 28 days).

Sand for mortar shall conform to ASTM C144.

Water used for mixing mortar shall be of potable quality, free of injurious amounts of oil, acid alkali, organic matter, sediments, or other deleterious substances, as specified for Concrete, Section 03300 2.3.

The supply of materials as defined in the design mix shall remain the same throughout the job.

PART 3 - EXECUTION

3.1 General
The Contractor shall furnish all labor material equipment and tools to perform all operations in connection with supplying and mixing mortar for constructing the isolation walls.

The Contractor shall fully describe his proposed mortar mixing operation, including proposed equipment and materials in the Work Plan.

3.2 Mortar Mixing

Mortar shall be machine-mixed with sufficient water to achieve satisfactory workability. Maintain sand uniformly damp immediately before the mixing process. If water is lost by evaporation, retemper only within one and one half hours of mixing. Use mortar within two hours of mixing at ambient temperature of 85° in the mine.

3.3 Installation

The Contractor shall install mortar to the requirements of Section 04300 Unit Masonry System.

3.4 Field Quality Control

The Contractor shall provide a third party Quality Control Inspector to perform all sampling and testing to confirm that the mortar mix conforms to the proposed mix properties developed in the design mix.

Construction testing of mortar mix shall be in accordance with ASTM C780 for compression strength. Four (4) prism specimens shall be taken for each 50 cu. ft. of mortar or fraction thereof placed each day.

End of Section.

SECTION 04300
UNIT MASONRY SYSTEM

SECTION 04300

UNIT MASONRY SYSTEM

PART 1 - GENERAL

1.1 Scope
This section includes:

- Concrete Masonry Units

1.2 Related Sections

- 01010 Summary of Work
- 01400 Contractor Quality Control
- 01600 Material and Equipment
- 02722 Grouting
- 03100 Concrete Formwork
- 04100 Mortar

1.3 References

ASTM C55-94a Standard Specification for Concrete Building Brick

ASTM C140-94a Standard Method of Sampling and Testing Concrete Masonry Units

1.4 Submittals for Revision and Approval
The Contractor shall submit for approval the following 30 days prior to initiation of the work at the site.

Certified laboratory test results for the proposed solid masonry units.

1.5 Quality Assurance
Perform the work in accordance with the Contractor's Quality Control Plan.

PART 2 - PRODUCTS

2.1 Concrete Masonry Units
Concrete masonry units shall be solid (no cavities or cores), load bearing high-strength units having a minimum compressive strength of 3500 psi. Concrete masonry units shall be tested

in accordance with ASTM C140. All other aspects of the concrete masonry units shall comply with ASTM C55, Type I Moisture Controlled.

Nominal modular size shall be 8 x 8 x 16 inches, or as otherwise approved by Westinghouse WID.

Concrete brick shall comply with ASTM C55, Grade N, Type I (moisture controlled) having a minimum compressive strength of 3500 psi (Avg. 3 units) or 3000 psi for individual unit.

2.2 Mortar

Mortar shall be as specified in Section 04100 Mortar.

PART 3 - EXECUTION

3.1 General

The Contractor shall furnish all labor, material, equipment and tools to perform all operations of installing Unit Masonry Isolation Walls to the lines and grades shown on the drawings.

The Contractor shall examine the excavation of the entry to affirm that the keys have been properly leveled and cut to the appropriate depths, at the proper locations prior to any to any work.

3.2 Installation

The Contractor shall install the isolation walls using concrete masonry units as specified above. Masonry units shall be installed with 3/8-inch mortar joints with full mortar bedding and full head joints. Masonry units shall be installed in running bond with headers every third course. Masonry units shall be mortared tight to the ribs and the back wall to provide a seal all around the isolation wall.

Concrete brick may be used as required for fit-up around grout pipes, or minimizing the dimensional fit-up at the top or sides of the isolation walls as approved by Westinghouse WID. The interface between the top of the isolation wall and the back wall shall be completely mortared to provide full contact between the back and the block wall.

3.3 Field Quality Control

The Contractor shall provide a third-party Quality Control Inspector to inspect the installation of the Concrete Masonry Unit Isolation Walls. Inspection and testing of the mortar shall be in accordance with Section 04100 Mortar.

End of Section

APPENDIX H
DESIGN DRAWINGS

The information contained in this box is oversized or unacceptable quality and cannot be accurately digitized. To view the original please contact the DOE Carlsbad Field Office Chief Information Officer at 234-7200.

APPENDIX I2

WASTE ISOLATION PILOT PLANT
SEALING SYSTEM DESIGN REPORT

DOE/WIPP-95-3117

Waste Isolation Pilot Plant Sealing System Design Report

October 1995

Waste Isolation Pilot Plant

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Certification

I certify under penalty of law that the document DOE/WIPP-95-3117 entitled "Sealing System Design Report," was prepared under my supervision for Sandia National Laboratories according to the Sandia National Laboratories Waste Isolation Pilot Plant Quality Assurance Program Description, Revision P. This quality assurance program is designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

Albert W. Dennis, P.E.
New Mexico
Certificate No. 5971
Expires December 31, 1995

ABSTRACT

This report documents the Waste Isolation Pilot Plant shaft sealing system design. The seals are designed to limit the release of radionuclides and hazardous constituents from an underground nuclear waste repository in salt. Design concepts documented in this report will form the basis for no-migration variance petition modeling. In addition, these concepts are the basis for detailed sealing system design development and evaluations that will be completed in 1996 in support of the planned Compliance Certification Application. The report describes the geologic and hydrologic setting for the seals, presents qualitative and quantitative design guidance, describes the design, documents the sealing materials and their properties, and discusses evaluations of sealing system performance. The design uses a variety of common materials that have very low permeability, demonstrated technologies for construction processes, multiple components to perform each intended function, and the entire length of the shafts to effect a seal system that will meet the performance requirements. For the permanent or long-term seal that resists both gas and brine flow, more then 500 ft of highly compacted crushed salt is used in series with more than 400 ft of clay barriers. The design retards gas flow in the short term using a combination or a rigid concrete barrier (enhanced by an asphalt waterstop) and a compacted clay barrier approximately 100 ft high. Short-term brine flow down the shaft is limited by a clay barrier within the overlying formation and by a combination of more than 500 ft of asphalt, clay, and concrete barriers within the salt.

WASTE ISOLATION PILOT PLANT
SEALING SYSTEM DESIGN REPORT

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WASTE ISOLATION PILOT PLANT
SEALING SYSTEM DESIGN REPORT

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Introduction

Purpose of this Report

This shaft seal report documents the Waste Isolation Pilot Plant (WIPP) shaft sealing system design. Panel closure systems and borehole seal designs will be documented separately. It is intended that the design concepts documented in this report form the basis for no-migration variance petition modeling and detailed design development and evaluations that will be completed in 1996. The detailed design will be documented in a topical report and included as appropriate in the Compliance Certification Application to the Environmental Protection Agency (EPA).

Report Organization

The remainder of this report comprises 6 sections and 4 appendices. The body of the design report does not generally contain detailed backup information; this information is incorporated by reference or in the appendices. This introduction identifies the purpose of the report, explains how the report is organized, and briefly describes the design development process.

Site characteristics that provide the setting into which the seals would be placed are documented in Section 1; these characteristics include the WIPP geology and stratigraphy for both the region and the shafts along with the hydrologic setting for the seals.

Section 2 presents the design guidance used for the shaft seal program. Both qualitative and quantitative guidance are described; the quantitative guidance related to the desired effective permeability of the sealing system is described based on the more detailed discussions presented in Appendix C. Seal-related guidance from applicable regulations is briefly described. The time frame is identified for the performance of various components since some components meet short-term needs while other components are specifically intended to meet long-term (permanent) considerations.

The shaft sealing system is documented in Section 3; somewhat more detail is provided for these design concepts in the drawings provided in Appendix B. The basis for the current concepts is briefly described along with why the Air Intake Shaft (AIS) is used as the model shaft for the sealing system design discussions. For each of the elements of the design guidance identified in Section 2, the approach taken in the design and the related design uncertainties are described. Finally, design alternatives considered during the course of the development of this design are briefly discussed.

Section 4 discusses the materials used in the various seal components and explains why they are expected to function as intended. The material used to seal the shaft cross section is described along with discussions of both interface considerations between the material and the host rock and seal-related considerations in the disturbed rock near the shaft. Material properties including permeability, strength, and mechanical constitutive response are given for each material. Brief discussions of expected performance, construction techniques, longevity, and other characteristics relevant to the WIPP setting are also given.

The performance of the shaft sealing system design is evaluated in Section 5. Performance measures for the shaft sealing system are discussed along with preliminary analyses

of the sealing system. Both brine and gas flow considerations are described briefly while more details of some of the analyses are provided in Appendix D.

The sealing system discussions are concluded in Section 6 by summarizing the basis for the conclusion that an effective, implementable design concept has been presented. A section is then provided that documents principal references used in developing this design; the references provide additional information related to discussions contained in the report.

Seal Design Development Process

This report presents a conservative approach to shaft sealing system design. Shaft sealing system performance plays a crucial role in meeting regulatory radionuclide and hazardous constituents release requirements. Although all engineering materials have uncertainties in properties, a combination of available, low-permeability materials can provide an effective sealing system. To reduce system uncertainties and to provide additional assurance of compliance, additional components have been added to this sealing system. Components in this design include long columns of clay, densely compacted crushed salt, a water stop of asphaltic material sandwiched between massive low-permeability concrete plugs, and a column of asphalt. Different materials perform identical functions within the design, thereby adding confidence in system performance.

The design is based on common materials and construction technologies available today. In choosing materials, emphasis was given to permeability characteristics and mechanical properties of seal materials. However, the system is also chemically and physically compatible with the host formations, enhancing long-term performance. Advancements on several fronts have demonstrated that the specified materials can be engineered to create a very low permeability seal while enabling healing of disturbed rock zones (DRZs) within the host Salado Formation. Dense, compacted seal components and rigid concrete components are particularly effective in rapidly enhancing healing of the DRZ in the Salado Formation.

Recent laboratory experiments, construction demonstrations, and field test results have added to the broad and credible database and have supported advances in modeling capability. Results from a series of multi-year, in situ, small-scale seal performance tests show that bentonite and concrete seals maintain very low permeabilities and show no evidence of deterioration in the WIPP environment. A large-scale dynamic compaction demonstration established that crushed salt can be successfully compacted. Laboratory tests show that compacted crushed salt consolidates through creep closure of the shaft from initial conditions achieved in dynamic compaction to a dense salt mass with nearly the same permeability as in situ salt. These technological advancements now allow more credible analysis of the shaft sealing system.

The design was developed through an interactive process involving a design team consisting of technical specialists in the design and construction of underground facilities, materials behavior, rock mechanics analysis, and fluid flow analysis. The design team included specialists drawn from the staff of Sandia National Laboratories, Parsons Brinckerhoff Quade and Douglas, Inc., RE/SPEC Inc., and INTERA Inc. The three contractors were managed by Sandia National Laboratories through a single point of contact. The contractors were required to develop a quality assurance program consistent with the Sandia National Laboratories Quality Assurance Program Description, Revision P and Quality Assurance Procedure 19-1, Computer Software Requirements. All three contractor received quality assurance support visits and were

audited through the Sandia National Laboratories audit and assessment program. Quality assurance documentation is maintained in the Sandia National Laboratories WIPP Central Files. In addition to the contractor support, technical input was obtained from consultants in various technical specialty areas.

Technical, management, and QA reviews have been performed on this report under the auspices of the DOE Carlsbad Area Office Management Procedures for Document Review (MP4.2, Rev. 0). Staff from DOE (compliance; operational and experimental program), Westinghouse Waste Isolation Division, the WIPP Technical Assistance Contractor, and Sandia National Laboratories conducted this review. Documentation is in the WIPP Central File.

NOTE

Both English and Standard International (SI) units are used in this report. The construction industry uses English units during preliminary considerations and design, whereas the scientific community uses SI. In general the engineering information is retained in English units consistent with available drawings for WIPP shafts, and SI units are used in the text where the conversion makes sense. Laboratory and field measurements of density, permeability, water content, and discussion of technical results are all in SI units.

1.0 Site Geologic and Hydrologic Setting

1.1 Regional WIPP Geology and Stratigraphy

Geologically, the WIPP is located in the Delaware Basin, which began forming approximately 300 million years ago. Rapid subsidence in the early Permian Period resulted in deposition of a sequence of deep-water sandstones, shales, and limestones rimmed by shallow-water limestone reefs. Subsidence slowed during the late Permian Period. Evaporite deposits of the Salado Formation (which hosts the WIPP underground workings) filled the basin and extended over the reef margins. The evaporites, carbonates, and clastic rocks of the Rustler Formation and the Dewey Lake Red Beds were deposited above the Salado Formation near the end of the Permian Period. The Santa Rosa and Gatuña Formations were deposited after the close of the Permian Period.

From the surface downward, the stratigraphic units in the WIPP vicinity above the repository are the Quaternary surface sand sediments, Gatuña Formation, Santa Rosa Formation, Dewey Lake Red Beds, the Rustler Formation, and the Salado Formation. Detailed stratigraphic information on these formations is provided in Holt and Powers (1990). The stratigraphic profile for the Air Intake Shaft (AIS) from the surface to the repository horizon is illustrated in Figures 1-1 and 1-2. The principal stratigraphic units, the Dewey Lake Red Beds, the Rustler Formation and the Salado Formation comprise all but the upper 56 ft (17m) of the geologic section above the WIPP facility.

The Dewey Lake Red Beds, which extend from a mean sea level (MSL) elevation of approximately 3353 ft MSL to 2879 ft MSL, a distance of 474 ft (144 m), consist of alternating layers of reddish-brown, fine-grained sandstone and siltstone cemented with calcite and gypsum (Vine, 1963). The Rustler Formation lies below the Dewey Lake Red Beds and extends from approximately 2879 ft MSL to about 2569 ft MSL, a distance of 310 ft (94 m). This formation, the youngest of the Late Permian evaporite sequence, includes units that provide potential pathways for radionuclide migration from the WIPP. Five units of the Rustler have been described (from youngest to oldest): (1) the Forty-niner Member, (2) the Magenta Dolomite Member, (3) the Tamarisk Member, (4) the Culebra Dolomite member, and (5) an unnamed lower member.

The 250-million-year-old Salado Formation lies below the Rustler Formation. It is about 2000 ft (600 m) thick and consists of three informal members (from youngest to oldest): (1) an upper member (unnamed) composed of reddish-orange to brown halite interbedded with polyhalite, anhydrite, and sandstone, (2) a middle member (the McNutt Potash Zone) composed of reddish-orange and brown halite with deposits of sylvite and langbeinite; and (3) a lower member (unnamed) composed of mostly halite with lesser amounts of anhydrite, polyhalite, and glauberite, with some layers of fine clastic material. These lithologic layers are nearly horizontal at the WIPP, with a regional dip of less than one degree. The WIPP repository is located in the unnamed lower member of the Salado Formation. The facility station level varies between the shafts; however, it is located between 1306 and 1316 feet (398 and 401 m) below the top of the Salado Formation.

1.2 Local WIPP Stratigraphy and Groundwater / Brine Occurrence

To establish the geologic framework required for the design of the WIPP facility shaft sealing system, an evaluation was performed to assess the geologic conditions existing in and between the shafts, where the individual shaft sealing systems will eventually be emplaced. The study evaluated shaft stratigraphy, regional groundwater occurrence, brine occurrence in the exposed Salado Formation section, and the consistency between data recorded on shaft as-built drawings and the actual field data. The following sections discuss shaft stratigraphy, regional groundwater occurrence, and brine occurrence in the exposed Salado Formation section. The complete report of the stratigraphic evaluation results is included in Appendix A.

1.2.1 Shaft Stratigraphy

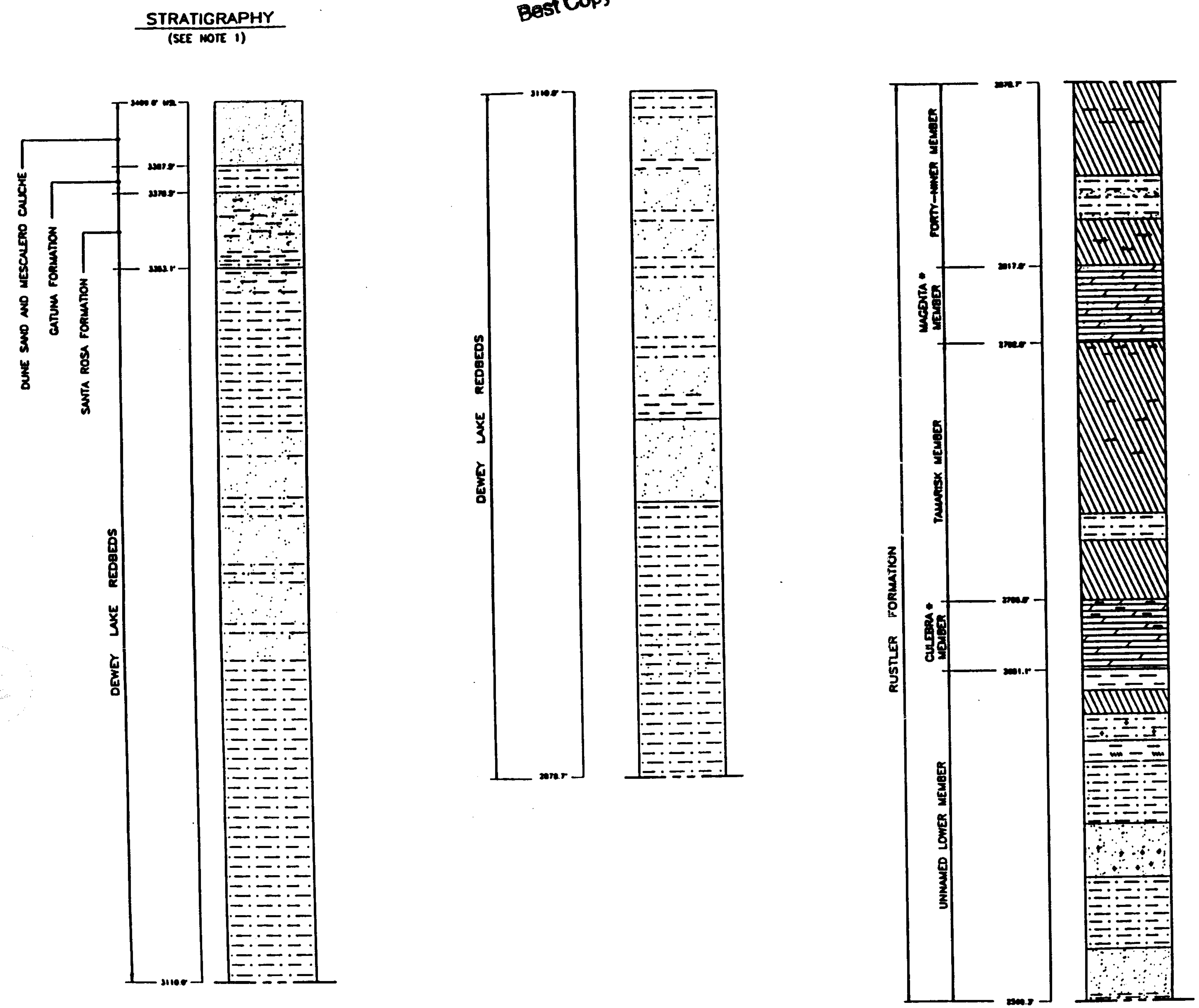
Four shafts connect the WIPP underground workings to the surface. These shafts are currently identified as the

- Air Intake Shaft (AIS),
- Exhaust Shaft,
- Salt Handling Shaft (formerly referred to as the Exploratory Shaft or the Construction and Salt Handling Shaft), and
- Waste Shaft (formerly referred to as the Ventilation Shaft).

Stratigraphic correlation and evaluation of the unit contacts present in the four shafts indicates that the lithologic units mapped within each shaft during the geologic mapping of the shafts typically have vertical consistency and horizontal continuity, which is demonstrated by the occurrence of lithologic units at approximately the same level in all four shaft locations. Some stratigraphic contact elevations vary because of regional structure and the stratigraphic thinning and thickening of units. However, the majority of the stratigraphic contacts used to date are suitable for engineering design reference because they intersect all four shafts. This stratigraphic consistency is beneficial because it will allow the shaft sealing system to be designed based on the AIS and then applied to the other three shafts with minor adjustments for stratigraphic variations. The ten stratigraphic contacts unsuitable for design reference, because they are not present in all four shafts, are listed in Table 1-1.

Table 1-1. Stratigraphic Contacts Unsuitable for Engineering Design Reference

Stratigraphic Contact	Comment
Mescalero Caliche	Not mapped in air intake and waste shafts.
Gatuña Formation	Not mapped in waste shaft.
Dewey Lake Red Beds	Erosional contact - highly irregular upper surface.
Marker Bed 100	Not present in all four shafts.
Marker Bed 119	Not present in all four shafts.
Marker Bed 120	Not present in all four shafts.
Marker Bed 125	Not present in all four shafts.
Marker Bed 133	Not present in all four shafts.
Marker Bed 137	Not present in all four shafts.
Anhydrite "b"	Not present in all four shafts.
Marker Bed 139	Not present in all four shafts.



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LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES	SECONDARY CONSTITUENTS
MUDSTONE/CLAYSTONE	ARGILLACEOUS
CLAYSTONE BED	SILTY
SILTSTONE	SANDY
SANDSTONE	SULFATIC
ANHYDRITE/GYPSUM	DOLOMITIC
DOLOMITE	CALCAREOUS
HALITE	HALITIC
POLYHALITE	POLYHALITIC
	LANGBEINITE

NOTE:

1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT WALLS, DOE/WIPP-90-051, "GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WASTE ISOLATION PILOT PLANT", 1990, AND "LETTER REPORT ON THE RESULTS OF THE WASTE ISOLATION PILOT PLANT SHAFT STRATIGRAPHY CORRELATION PROJECT", 1994.

   ASTERISK(*) INDICATES GROUNDWATER (RUSTLER/SUPRA RUSTLER FORMATIONS) OR BRINE SEEPAGE/WEEPS (SALADO FORMATION) OBSERVED DURING THE MAPPING OF THE AIR INTAKE SHAFT. AS OF 1994, ONLY MB103 SHOWED VISIBLE MOISTURE ON THE SALADO FORMATION SURFACE EXPOSED WITHIN THE AIR INTAKE SHAFT, "BRINE SAMPLING EVALUATION PROGRAM 1992-1993 REPORT," 1994, DOE-WIPP 94-011.

ABBREVIATION:

ANH.	ANHYDRITE
COL.	COLUMN
CONC.	CONCRETE
D	DIAMETER
DET.	DETAIL
DOE	DEPARTMENT OF ENERGY
DWG.	DRAWING
EL.	ELEVATION
EXIST.	EXISTING
MSL	MEAN SEA LEVEL
TYP.	TYPICAL
VACA TR.	VACA TRISTE
WID	WESTINGHOUSE WASTE ISOLATION DIVISION
WIPP	WASTE ISOLATION PILOT PLANT

SCALE IN FEET 0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO. AC-4000

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS

AIR INTAKE SHAFT
STRATIGRAPHIC PROFILE

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-003	SHEET NO. 1 OF 2

Figure 1-1.

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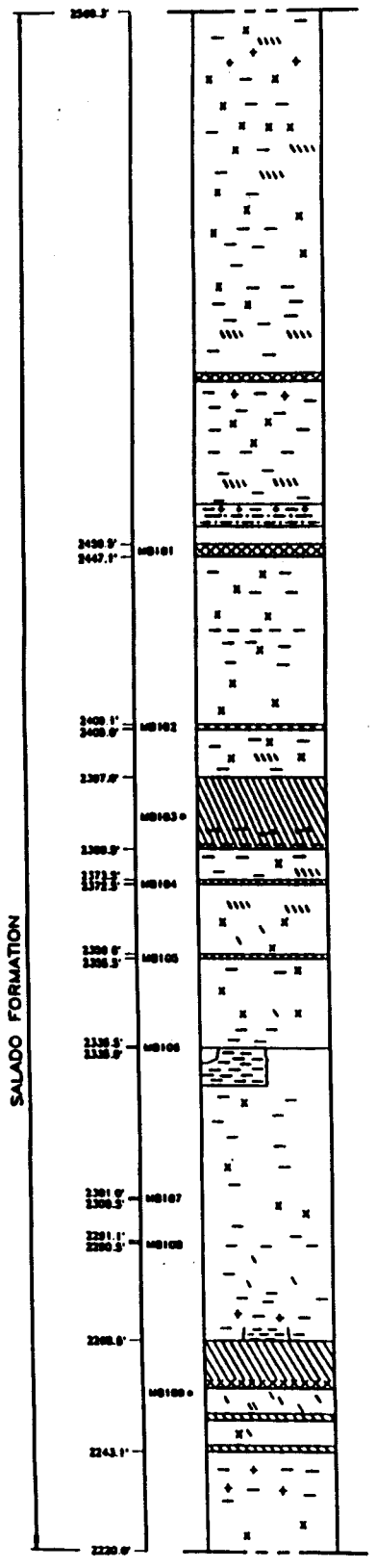
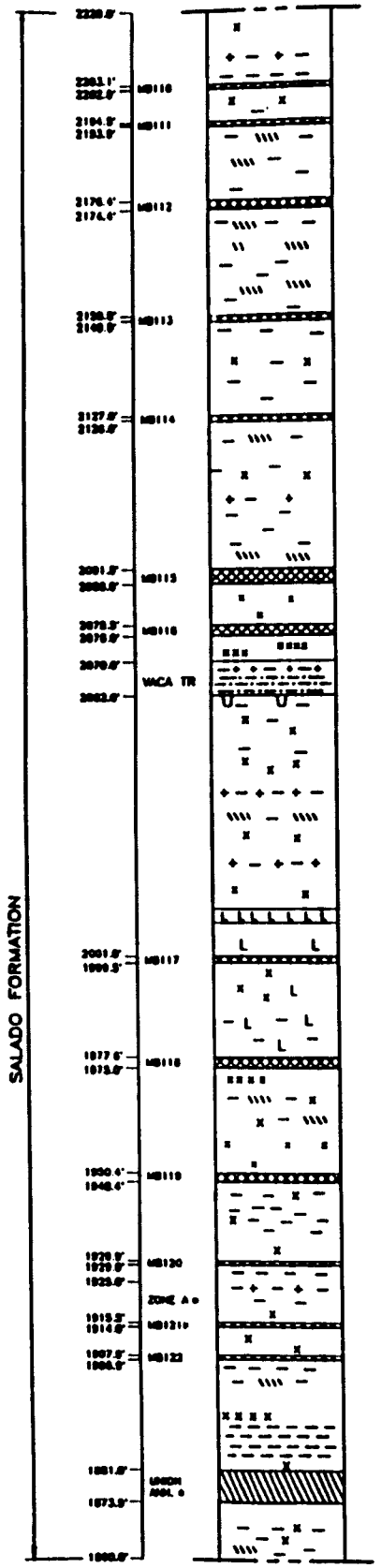
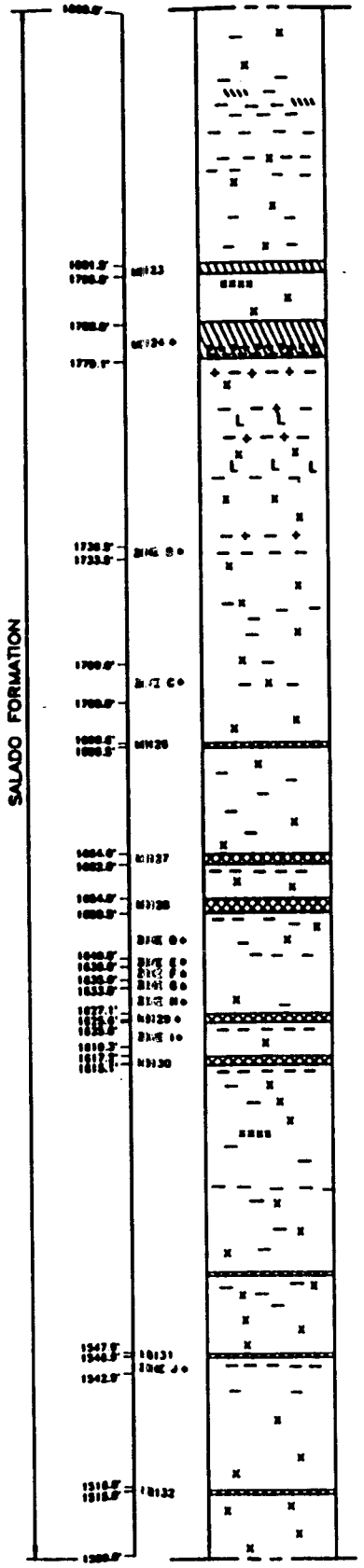
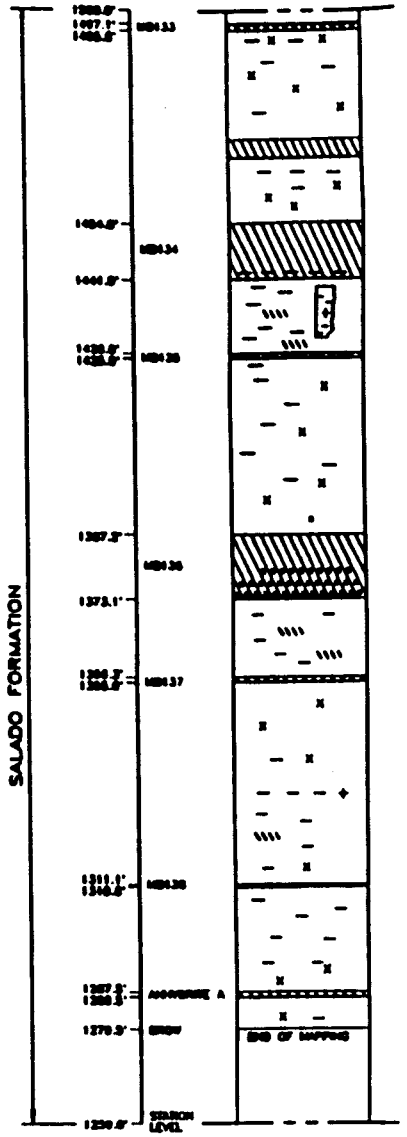
STRATIGRAPHY

(SEE NOTE 1 OF SHEET NO. 1)









LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES

- MUDSTONE/CLAYSTONE
- CLAYSTONE BED
- SILTSTONE
- SANDSTONE
- ANHYDRITE/GYPSUM
- DOLOMITE
- HALITE
- POLYHALITE

SECONDARY CONSTITUENTS

- ARGILLACEOUS
- SILTY
- SANDY
- SULFATIC
- DOLOMITIC
- CALCAREOUS
- HALITIC
- POLYHALITIC
- LANGBEINITE

SCALE IN FEET

0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4000

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION

AIR INTAKE SHAFT
STRATIGRAPHIC PROFILE

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SHL-003	SHEET NO. 2 OF 2

Figure 1-2.

Figures 1-3 and 1-4 are structural cross sections based on MSL elevations that illustrate the typical consistency of stratigraphic unit contacts both vertically and horizontally among the four shafts. With the exception of the 11 lithologic units listed above in Table 1-1, all of the unit contacts and marker beds shown in Figures 1-3 and 1-4 are suitable for reference for the shaft sealing system design. It should be noted that there is a 440-ft (122-m) north-south offset between the Salt Handling Shaft and the Waste Shaft, as indicated on the figure legends.

1.2.2 Regional and Local Groundwater Occurrence in the Rustler Formation and Shallower Units

Geohydrological surveys of the WIPP site have identified six regional intervals of groundwater occurrence (Beauheim and Holt, 1990). These intervals are listed in Table 1-2.

Table 1-2. Regional Intervals of Groundwater Occurrence

Stratigraphic Unit	Remarks
Rustler Formation	
Forty-niner Member	Aquitard; water producing unit is a claystone interbedded with anhydrite and or gypsum units.
Magenta Dolomite Member	Regional aquifer; consists of fine grained gypsiferous arenaceous dolomite.
Tamarisk Member	Aquitard; consists of claystone sandwiched between two anhydrites.
Culebra Dolomite Member	Regional aquifer; consists of a finely crystalline, locally argillaceous and arenaceous, vuggy dolomite.
Unnamed Lower Member	Aquitard; consists of interbedded siltstone, sandstone, halite, and anhydrite. Regionally has two water producing units; however only one is present at the WIPP site. It is characterized by low permeability.
Rustler/Salado Formation Contact	Groundwater seeps at formation contact; general area of "brine aquifer" at Nash Draw

The Dewey Lake Red Beds geologic unit is not a regionally productive source of water. Drilling has identified only a few localized zones of relatively high permeability (Mercer, 1983; Beauheim, 1987). In the Rustler Formation most groundwater flow occurs in the Culebra Dolomite and Magenta Dolomite members, as well as in the Rustler-Salado contact residuum or "brine aquifer" in the vicinity of Nash Draw (Beauheim and Holt, 1990). The other units (the Forty-niner Member, Tamarisk Member, and Unnamed Lower Member) are considered aquitards (a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer) because of their low permeability throughout the area. Groundwater near the WIPP usually contains large concentrations of total dissolved solids. Moisture at the Rustler-Salado contact was observed in the Salt Handling Shaft but not the other three shafts. The only discussion of seepage rates in the references used for the stratigraphic evaluation was related to the Rustler Formation.

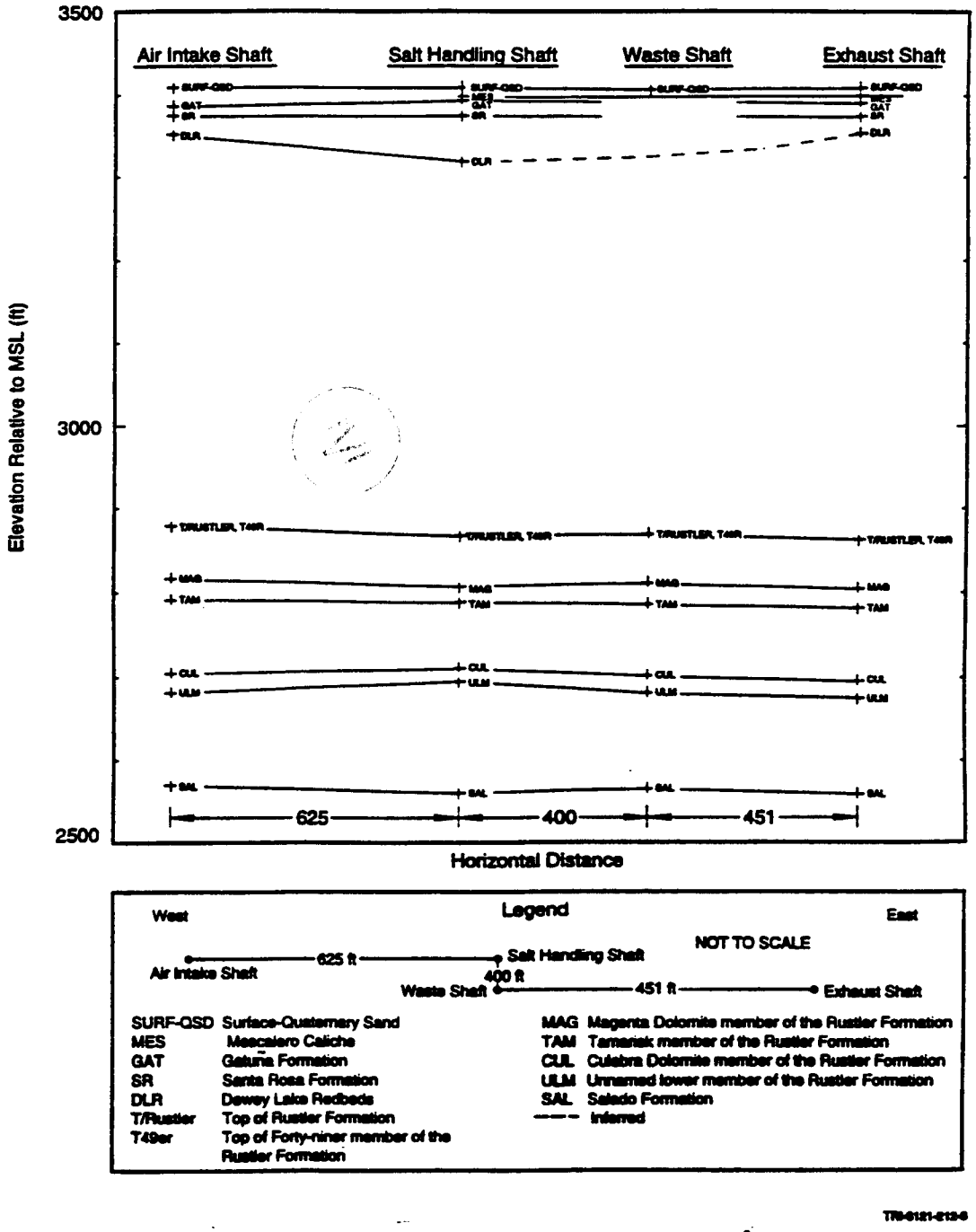


Figure 1-3. Structural cross section through excavated shafts (based on stratagraphic unit top), ground surface to top of Salado Formation.

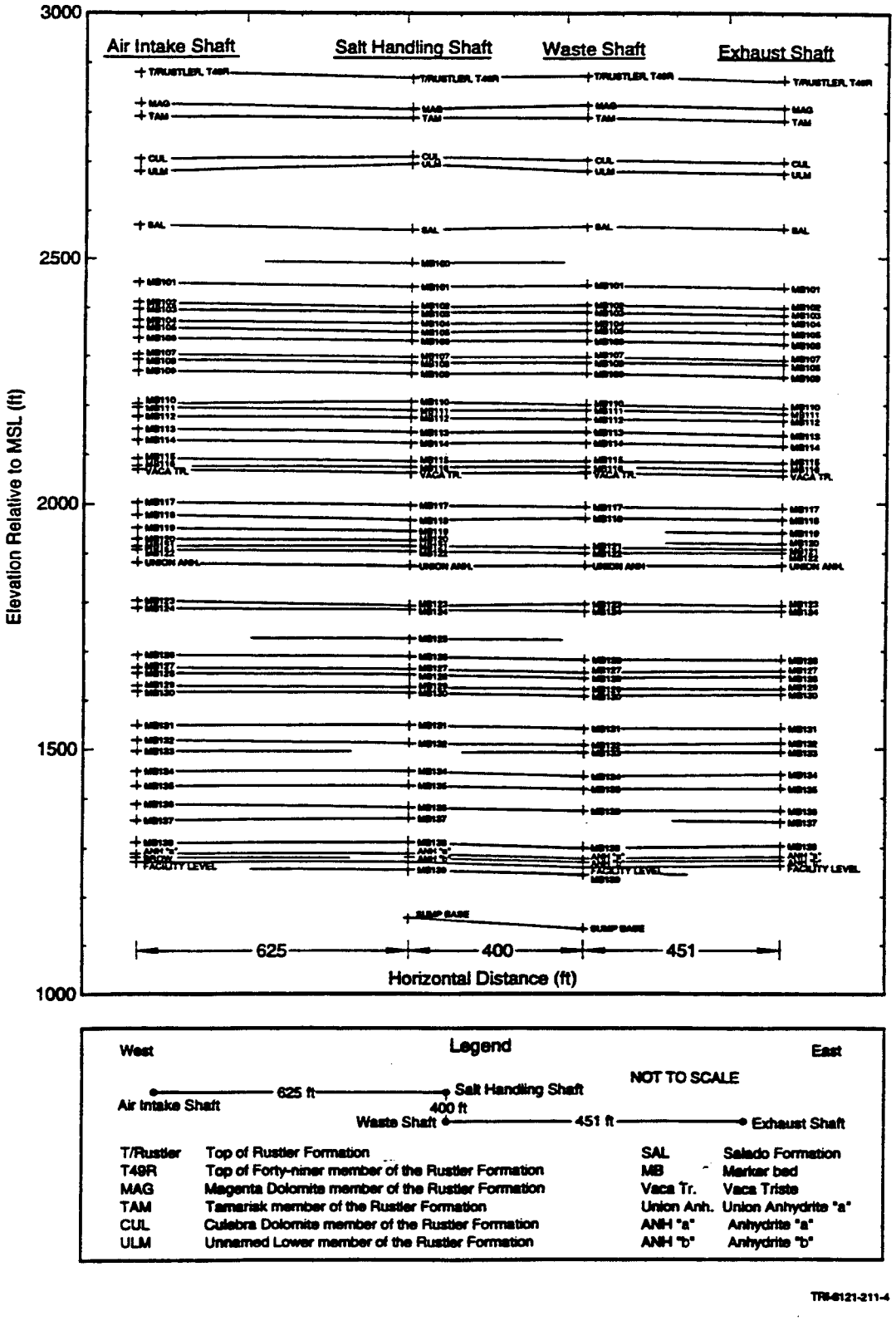


Figure 1-4. Structural cross section through excavated shafts (based on stratagraphicunit top), top of Rustler Formation to total depth.

1.2.3 Regional and Local Groundwater and Brine Occurrence in the Salado Formation

The Salado Formation has not been disturbed by post-depositional processes such as structural deformation and dissolution in the WIPP area. The formation is assumed to be brine-saturated throughout the WIPP area because of the presence of a regional hydrostatic pressure gradient (Mercer, 1983). Groundwater (brine) flow within it is extremely low because primary porosity and open fractures are lacking in the salt (Mercer, 1983) and low permeability, averaging 5.0×10^{-20} m², allows for little groundwater movement (Powers et al., 1978). Groundwater found in the Salado Formation appears in the form of seeps and weeps and is salt saturated.

The shafts were evaluated for intervals of brine seepage occurrence below the Rustler-Salado Formation contact within the exposed Salado Formation section. Of the four shafts, brine seepage in this interval was observed and noted only in the AIS during shaft mapping. However, the identified brine seepage intervals in the AIS have been projected to the other shafts—for shaft sealing system design purposes—in anticipation that these seepage intervals may be present in all four of the shafts (see Appendix A). There were no notations indicating volume quantities of brine seepage in the references used for the stratigraphic evaluation. Four of the seventeen intervals observed in the AIS (MB 103, MB 124, Vaca Triste siltstone, and Union Anhydrite) were identified during the AIS mapping as primary brine-producing intervals in the Salado Formation (Holt and Powers, 1990). Ten of the seventeen seepage intervals were not named when the shaft was mapped. These intervals have subsequently been designated as zones A through J (see Appendix A). Seepage (i.e., seeps and weeps) observed in the exposed Salado Formation AIS has not been quantified but can be contrasted with recorded water-inflow data from the Rustler Formation water bearing units, which flowed less than a total of 1.5 gallons per minute into the shaft prior to liner installation. After liner installation, the inflow rate dropped to less than 0.1 gallon per minute (Jarolimek et al., 1983). The terms *weeps* and *seeps*, which refer to low volume fluid flow, such as water oozing from the rock, are used to describe brine occurrence in the Salado Formation exposed in the AIS. The unquantified seepage in the Salado Formation is minor in comparison to the Rustler Formation flow rates after liner installation.

The identified intervals from the AIS lithologic log are presented in Table 1-3. A recent observation (July 1994) of seepage intervals within the AIS was conducted as part of the Brine Sampling and Evaluation Program (BSEP). These recent observations indicated the presence of salt encrustations in 73 locations, including the surfaces of the brine seepage intervals identified during shaft mapping; however, only the salt encrustations on the surface of Marker Bed 103 were observed to be wet (Deal et al., 1995).

Table 1-3. Observed Brine Seepage Intervals (Salado Formation) Logged during the Mapping of the Air Intake Shaft

Stratigraphic Unit/ Engineering Feature	Unit/Feature Top (ft-MSL)	Unit/Feature Bottom (ft-MSL)	Comments
Salado Formation	2569.3	Did not penetrate	Regional potential for groundwater (brine) occurrence at the Rustler/Salado Formation contact; (Holt & Powers, 1990). No groundwater at contact noted on lithologic log. Shaft did not penetrate base of unit.
Marker Bed 103	2397.0	2380.5	Brine; Weeps - moist surface in lower 4 ft; Anhydridic dolomite overlying claystone where weeps occur (Holt & Powers, 1990).
Marker Bed 109	2268.5	2243.1	Brine; Weeps: weep symbol on log with no weep description. Weeps occur in mudstone with anhydrite nodules (Holt & Powers, 1990).
Vaca Triste	2070.0	2062.0	Brine (Holt & Powers, 1990). Composed of halitic siltstone and mudstone.
Zone A	1925.0	1915.5	Brine; Some weeps, halite with a trace of polyhalite: AIS log (Holt & Powers, 1990).
Marker Bed 121	1915.5	1914.0	Brine; Weeps: AIS log. Weep symbol on log near base of unit (polyhalite) - no description. 2-3" clay at base (Holt & Powers, 1990).
Union Anhydrite	1881.0	1873.5	Brine; Unit as a whole bears fluid. Weeps parallel to strata are very common around zones with clastic halite. Weeps occur also around fractures and contacts. AIS log (Holt & Powers, 1990).
Marker Bed 124	1788.0	1779.1	Brine; Recent weeps parallel to fractures and bedding planes in anhydrite: AIS log (Holt & Powers, 1990).
Zone B	1736.5	1733.5	Brine; Abundant weeps, halite argillaceous to trace clay: AIS log (Holt & Powers, 1990).
Zone C	1709.0	1700.0	Brine; Modest amount of weeps, halite, trace clay and polyhalite: AIS log (Holt & Powers, 1990).
Zone D	1650.5	1640.0	Brine; Weeps in lower most part, interbedded polyhalite and argillaceous halite: AIS log (Holt & Powers, 1990).
Zone E	1640.0	1638.0	Brine: Weeps in pits, argillaceous halite: DOE-AIS log (Holt & Powers, 1990).
Zone F	1638.0	1635.0	Brine; Moderate weeps in unit, halite with trace polyhalite and clay: AIS log (Holt & Powers, 1990).
Zone G	1635.0	1633.0	Brine; Abundant weeps from pits, argillaceous halite and halitic claystone: AIS log (Holt & Powers, 1990).
Zone H	1633.0	1627.1	Brine; Moderate weeps, halite and polyhalite: AIS log (Holt & Powers, 1990).
Marker Bed 129	1627.1	1625.6	Brine; Abundant weeps: AIS log (Holt & Powers, 1990).
Zone I	1625.0	1619.3	Brine; Weeps, halite with polyhalite and claystone interbeds: AIS log (Holt & Powers, 1990).
Zone J	1546.9	1542.9	Brine; Abundant weeps, halite trace to some clay and polyhalite: AIS log (Holt & Powers, 1990).

2.0 Design Guidance

The WIPP is subject to numerous regulatory requirements. The use of both engineered and natural barriers to isolate wastes from the accessible environment is required by 40 CFR 191.14(d). Quantitative requirements for potential releases of radioactive and other hazardous materials from the repository system are specified in 40 CFR 191 and 40 CFR 268. The regulations do not impose quantitative requirements on individual components of the repository sealing system.

The absence of regulatory requirements at the component level allows repository designers to identify and assess the components and component parameters that have the greatest impact on potential releases from the repository. For example, a preliminary assessment of the "undisturbed performance" of the WIPP (WIPP PA Department, 1993) identified four parameters associated with the waste form, one parameter associated with the site, and the shaft sealing system permeability as *"very important"* when repository performance is compared to the regulatory requirements.

The guidance described for the design of the shaft sealing system in this section addresses the need for the WIPP to comply with system requirements noted above and to follow accepted engineering practices using demonstrated technology. The design guidance addresses the need to limit:

1. radiological or other hazardous constituents reaching the regulatory boundaries,
2. groundwater flow into and through the sealing system,
3. chemical and mechanical incompatibility,
4. structural failure of system components,
5. subsidence and accidental entry,
6. development of new construction technologies and/or materials.

Qualitative design guidance and design approach for the shaft sealing system are presented in Section 2.1. Quantitative design guidance for fluid flow is presented in Section 2.2. Qualitative as well as quantitative guidance is applicable to the design described in Section 3.0, but quantitative guidance serves as the basis for the evaluation of the sealing system presented in Section 5.0. Because the shaft sealing system depends in part on assumptions made in other parts of the repository system, the quantitative design guidance for the shaft sealing system may change as the evaluation of the total repository system performance progresses. For example, the need to retard gas flow is dependent on assumptions related to waste form, brine availability, etc.

2.1 Qualitative Design Guidance and Design Approach

Table 2-1 contains qualitative design guidance and the design approach used to implement it.

Table 2-1. Shaft Sealing System Design Guidance

Qualitative Design Guidance	Design Approach
The shaft sealing system shall limit:	The shaft sealing system shall be designed to meet the qualitative design guidance in the following ways:
1. the migration of radiological or other hazardous constituents from the repository horizon to the regulatory boundary during the 10,000-year regulatory period following closure;	1. brine migrating from the repository horizon to the Rustler Formation must pass through a low permeability sealing system;
2. groundwater flowing into and through the shaft sealing system;	2. groundwater migrating from the Rustler Formation to the repository horizon must pass through a low permeability sealing system ;
3. chemical and mechanical incompatibility of seal materials with the seal environment;	3. the sealing system materials are chemically and mechanically compatible with the seal environment or can be protected;
4. the possibility for structural failure of individual components of the sealing system;	4. structural analysis shows that each component is adequate to withstand the forces expected from rock creep and hydraulic pressure;
5. the possibility for subsidence of the ground surface in the vicinity of the shafts and accidental entry after sealing;	5. the shaft is completely filled with low porosity materials, and construction equipment would be needed to gain entry;
6. the need to develop new technologies or materials for construction of the shaft sealing system.	6. construction of the shaft sealing system is feasible using available technologies and materials.

2.2 Quantitative Design Guidance for Fluid Flow

Quantitative guidance is derived from 40 CFR 191 and 40 CFR 268. These design concerns involving fluid flow are design-specific. The shaft sealing system has been designed to control migration of radionuclides and other hazardous materials from the time of repository closure. The shaft sealing system is depicted in Figure 2-1. Control is achieved by utilizing shaft sealing system components constructed of asphalt, clay, and concrete that will be effective upon emplacement and a compacted salt component that will become effective during the 100 years following emplacement. The upper clay component and the consolidated salt component constitute long-term barriers (lasting through the 10,000-year regulatory period and beyond) to fluid flow for the sealing system. (The 100 years following repository closure are referred to as the "short term"; the 100 to 10,000-year period is referred to as the "long term.") The asphalt and concrete components provide additional assurance that the sealing system will be effective during the consolidation period for the salt component (the 100 years following closure).

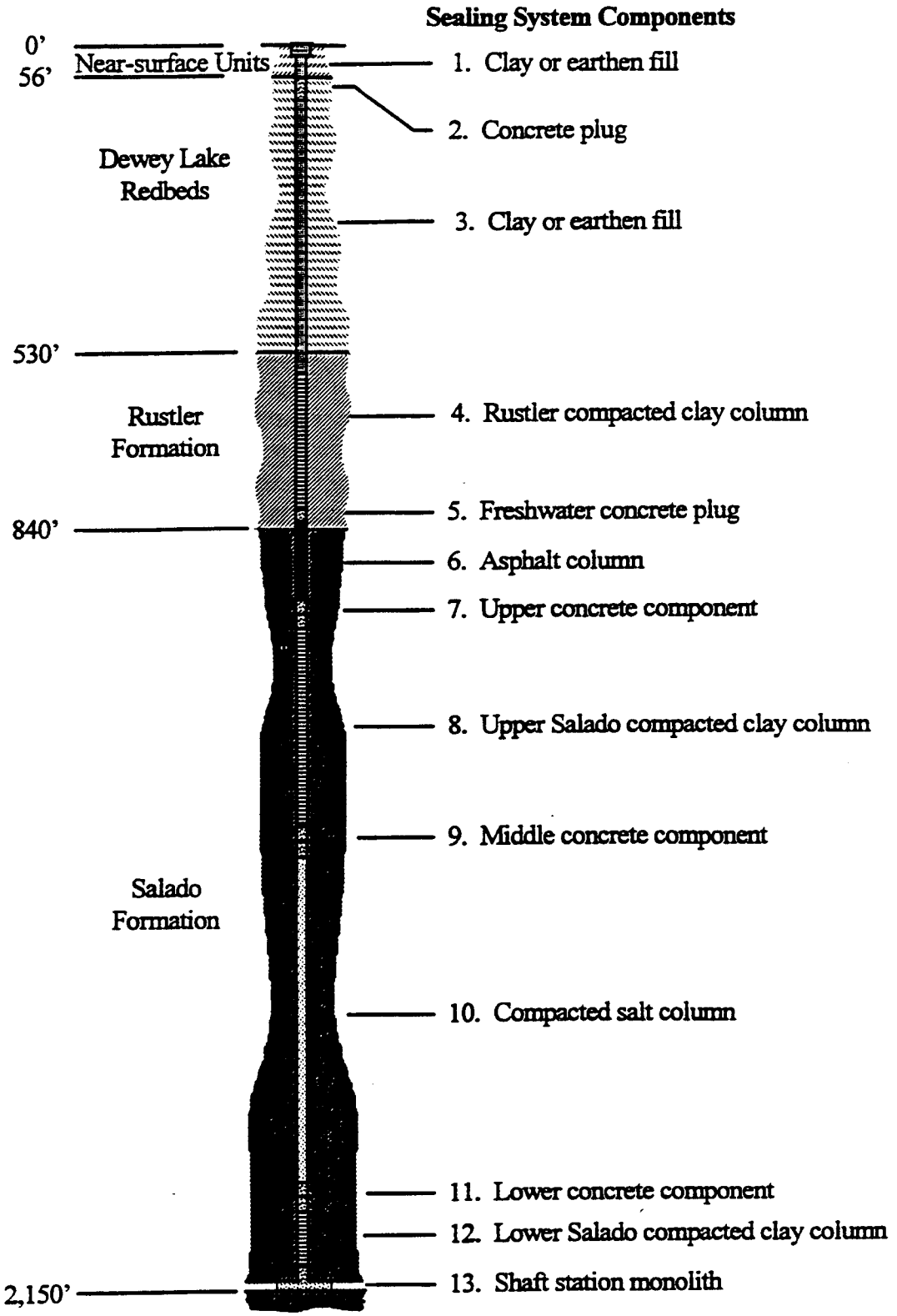


Figure 2-1. Arrangement of the Air Intake Shaft Sealing System.

Fluid flow provides the principal mechanism for radiological or other hazardous constituents to be transported from the repository to the regulatory boundaries. As a consequence, the approach taken to isolate these materials is limiting fluid flow through the sealing system.

The Rustler Subsystem consists of Components 4 and 5. It extends from the base of the Near-Surface Subsystem to within 16 ft (5 m) of the Rustler-Salado Contact, a distance of 255 ft (79 m). In both the short term and long term, this subsystem shall limit the flow of groundwater from the Rustler Formation into and through the shaft and assist in limiting accidental entry and subsidence. The Rustler compacted clay column (Component 4) shall provide short-term and long-term separation of water bearing zones in the Rustler.

The Salado Formation Subsystem is divided into two elements, hereafter referred to as the upper seal system and the lower seal system. The upper seal system consists of Components 6 through 9 and extends from the bottom of the Rustler Subsystem to the bottom of the middle concrete component, a distance of 582 ft (177 m). In the short term, the upper seal system shall limit the flow of Rustler-Salado Contact groundwater into and through the shaft. In the long term, the upper Salado clay column (Component 8) shall act as a permanent barrier to the flow of brine and gas. The lower seal system consists of Components 10, 11, and 12. It extends from the bottom of the upper seal system to the shaft station monolith (Component 13), a distance of 707 ft (215 m). The monolith is the structural component that stabilizes and limits deformation of the shaft station area. In the short term, the lower concrete component (Component 11) and the lower Salado compacted clay column (Component 12) shall retard the flow of brine and gas from the repository into the compacted salt column. The compacted salt column will consolidate during the short term and shall serve as a permanent (long-term) barrier to the flow of brine and gas. The lower Salado compacted clay column shall also act as a barrier to the flow of brine and gas during the long term.

Modeling studies have provided quantitative design guidance for limits of brine or gas flow through the total sealing system. These studies (presented in Appendix C) have shown for a shaft sealing system having the equivalent of 100 m in length:

- a permeability of 10^{-16} m^2 limits brine flow, and
- permeabilities of less than 10^{-18} m^2 reduce gas flow.

In addition, a design assumption has been made that gas generation in the waste region during the 100 years following seal construction will not result in pressure differences in excess of 2 MPa through the shaft sealing systems.

3.0 Design Description

The design presented in this section was developed to limit the release of radioactive materials and hazardous constituents to levels that are below regulatory limits. This design is based on the design guidance outlined in Section 2.0, past designs, the desire to reduce the uncertainties associated with the performance of sealing system, and the need to effectively seal the shaft wall disturbed rock zone (DRZ) at the time the sealing system is installed. Knowledge related to the ability to compact salt to high densities, which was gained from recent experimental results, has also been used in the design.

The past designs are:

- the initial reference seal system design (Nowak et al., 1990),
- the seal design alternative study (Van Sambeek et al., 1993), and
- the sealing system for a representative WIPP shaft (Hansen et al., 1995).

The sealing system design has progressed over the past five years from the initial concepts presented by Nowak (1990) to the concepts presented in this document. The design changes were implemented to take advantage of knowledge gained from small scale seals tests conducted at the WIPP, salt compaction tests and laboratory determination of the permeability of compacted salt samples conducted by Sandia National Laboratories, advances in the ability to predict the time-dependent mechanical behavior of the intact salt rock, and technical studies.

Reduction of the uncertainty associated with long-term performance is addressed by replacing the upper and lower Salado Formation salt columns used in the earlier designs with compacted clay columns and by adding an asphalt sealing component in the Salado Formation. Use of different materials for sealing system components reduces the uncertainty associated with a common-mode failure. The compacted salt column provides a seal with an initial permeability several orders of magnitude higher than the clay or asphalt columns but with long-term properties approaching those of the host rock. The use of clay also allows testing of the "as-emplaced" material to verify that the values for permeability used in design are achieved in the field. Asphalt provides an assured seal of the shaft cross section and the interface at the time of installation. Sealing of the DRZ at the time of installation is addressed by grouting in the Rustler Formation and including an asphalt waterstop in each of the concrete components in the Salado Formation. Recent experimental results (Ahrens and Hansen, 1995) established that crushed salt can be compacted to an initial density that is at or near 90 percent of the density of undisturbed salt. These materials are used in concert to reduce overall uncertainty of the seal system.

3.1 Use of the Air Intake Shaft Sealing System Design as a Representative Design for all Shaft Sealing Systems

The stratigraphy at the WIPP site is uniform from shaft to shaft. As noted in Section 1.1, a few of the marker beds are not present in all shafts, and some thinning and thickening of lithologic units exist, but typically the units have vertical consistency and horizontal continuity. Vertical consistency is demonstrated by the fact that shaft mapping shows relatively little change in the elevation of marker beds and thickness of units when all four shafts are considered, and horizontal continuity is demonstrated by the fact that the shaft mapping reports show all major geologic formations and almost all marker beds to be present at all four shaft locations. The sources for potential groundwater (Appendix A, Sect. 3) are the same for all four WIPP shafts, as is the source for gas and brine. Groundwater sources are the Culebra and Magenta Members of

the Rustler Formation, the Rustler-Salado Contact Zone, and several Marker Beds in the Salado Formation. The waste emplacement area of the repository is the source for gas and brine. The waste emplacement area is connected to the shafts by the access drifts, marker beds, and the DRZ. Because the stratigraphy is consistent and the sources for groundwaters, gas, and brine are the same; a sealing system developed for the Air Intake Shaft (AIS) can be used to seal the remaining WIPP shafts. Adjustments in the diameter of components and minor adjustments in component locations, to suit shaft-specific variations in the stratigraphy, will be required in each of the remaining shafts. The AIS was selected as the model shaft for design of the sealing system because the shaft mapping report (Holt and Powers, 1990) describes the stratigraphy in greater detail than the mapping reports for the other shafts.

The Waste Shaft and Salt Handling Shaft have sumps, while the AIS and Exhaust Shaft do not have sumps. The sumps will be backfilled at closure to provide a base for construction of the shaft sealing system. This backfill is not relied on to perform a sealing function. Therefore, the absence of a sump in the AIS does not adversely impact the design of the shaft sealing system.

3.2 Air Intake Shaft Sealing System

The general arrangement of the shaft sealing system is shown in Figures 3-1 and 3-2. A complete set of design drawings is included in Appendix B. The AIS sealing system design was developed to meet the design guidance presented in Section 2.0 of this document. This section discusses, qualitatively, how each of the elements of design guidance is addressed by the design. In Section 5.0 an evaluation of the design's ability to meet the objectives is presented. To facilitate discussion, each of the sealing system components has been assigned a unique number and a descriptive name. The component numbers and names are presented in Figure 2-1.

Each of the elements of the design guidance is addressed in this discussion. The migration of groundwater into and through the sealing system is discussed first because it offers an opportunity to introduce each of the sealing system components in order from the surface to the repository horizon. The guidance on brine reaching the accessible environment is discussed next, and the remaining guidance elements are discussed in the same order as they are listed above in Table 2-1.

3.2.1 Groundwater Migration into the Sealing System

a. **Design Guidance.** The shaft sealing system shall limit groundwater flowing into and through the shaft sealing system.

b. **Source of Groundwater.** During the mapping of the AIS, brine was observed entering the shaft from the Magenta and Culebra members of the Rustler Formation, the Rustler-Salado Formation contact zone, and 17 brine seepage intervals in the Salado Formation (Section 1.2). The region between the surface and the upper Salado Formation was mapped in the fall of 1988, and the remainder of the Salado Formation was mapped in the fall of 1989. The quantity of brine migrating into the shaft was small: the Rustler Formation water bearing zones were estimated to have an inflow rate of 1.5 gpm before the shaft lining was installed and 0.1 gpm after liner installation. Only one of the 17 brine seepage intervals in

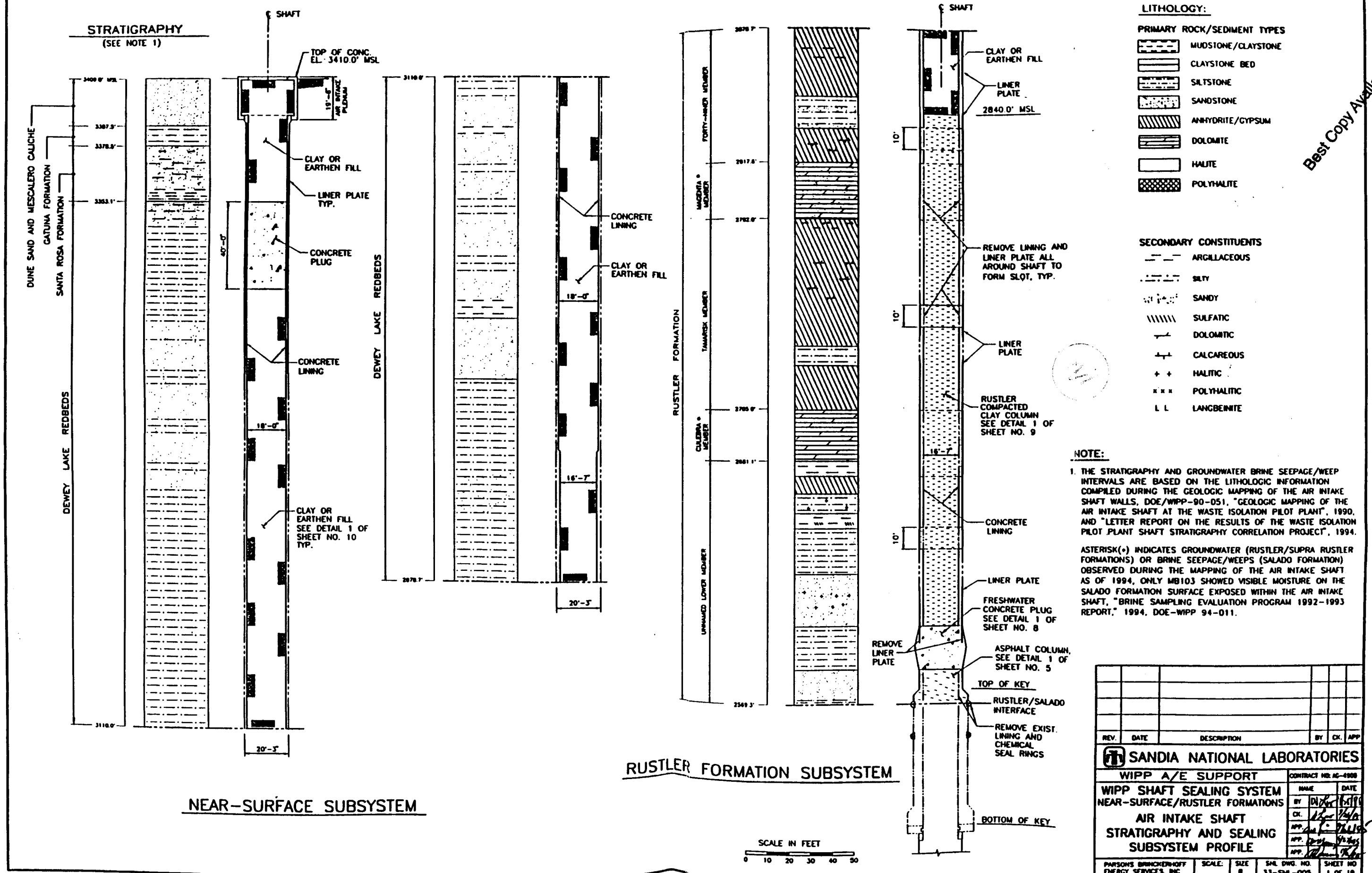


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Figure 3-1.

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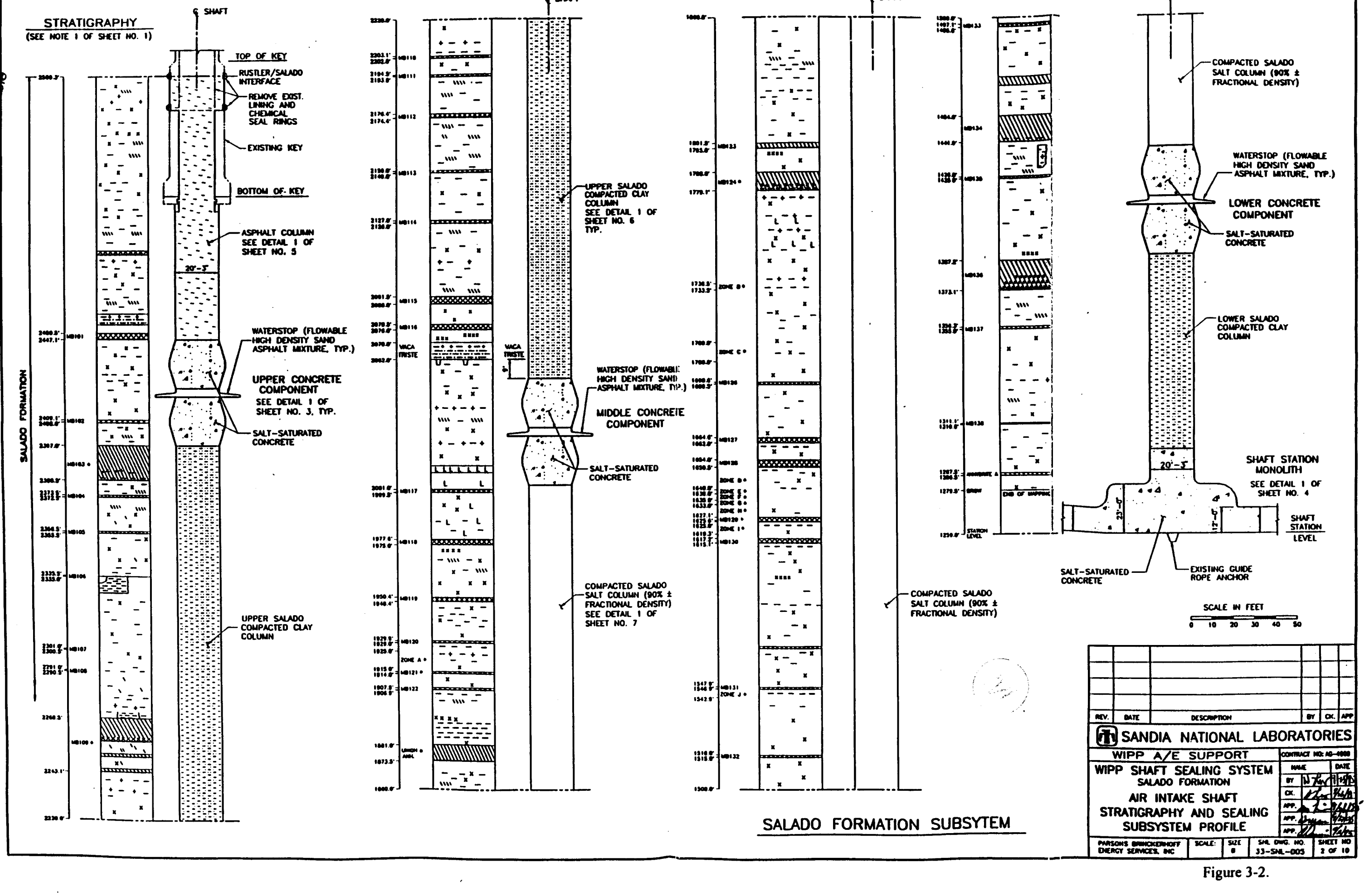

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4000

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
AIR INTAKE SHAFT
STRATIGRAPHY AND SEALING SUBSYSTEM PROFILE

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PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-005	SHEET NO 2 OF 10

Figure 3-2.

the Salado Formation, Marker Bed 103, was found to be moist during a July 1994 inspection. Moisture was observed in the uppermost section of the Dewey Lake Red Beds. For design purposes the following assumptions were used:

- migration of brine into the shaft occurs only at the locations identified in the AIS mapping report, and
- MB 121, 124, and 129; Zones A through J; and the Union Anhydrite will not produce sufficient inflow to affect the consolidation of the compacted salt column.

c. **Potential Pathways for Groundwater Infiltration.** Three potential pathways for groundwater infiltration are addressed by the sealing system design:

1. the material sealing the shaft,
2. the interface between materials sealing the shaft and the surrounding rock, and
3. the DRZ surrounding the shaft.

d. **Design Approach.** Infiltration of groundwater is limited in the following ways:

- Rustler Brines. The shaft through the Rustler Formation will be sealed with compacted clay (Component 4 shown in Appendix B Dwg. 33-SNL-005, Sh. 9 of 10). This component is 235 ft long. The clay will be compacted using conventional methods. The existing shaft liner and shaft liner plate will be removed over the length of the Magenta and Culebra Members and over a portion of the aquitards above, between, and below these water bearing zones. Removal of the shaft liner in these regions permits the clay to seal the interface and interrupts pathways along or through the existing liner. The DRZ will be grouted in areas scheduled for liner removal before the existing liner and liner plate are removed to assure shaft wall stability. A concrete plug (Component 5 shown in Appendix B Dwg. 33-SNL-005, Sh. 8 of 10) will be installed below the compacted clay column to serve as a base for compaction of the clay. The concrete plug will be placed using standard construction methods, and the interface and DRZ will be grouted, if necessary.

  Brines passing through the compacted clay column and concrete plug will be intercepted by the sealing system located at and just below the Rustler-Salado Contact zone.

- Rustler-Salado Interface Brines. The shaft through the Rustler-Salado Contact and immediately below this contact will be filled with asphalt (Component 6 shown in Appendix B Dwg. 33-SNL-005, Sh. 5 of 10). To assure an interface seal through this zone, a portion of the existing shaft key (shown in Figure 3-2) will be removed. The asphalt column is 138 ft long. The asphalt is discussed in Section 4.5. The asphalt will provide a complete seal across the shaft and along the shaft interface. The shaft walls are unlined in the Salado Formation below the existing shaft key. Brines passing the asphalt column will be confined to the Salado DRZ.

  The shaft will be sealed by the upper concrete component (Component 7 shown in Appendix B Dwg. 33-SNL-005, Sh. 3 of 10), which will be located immediately below the asphalt column. This component is 50 ft long and will be composed of upper and lower salt-saturated concrete plugs and an asphalt waterstop located at its midpoint. This component will effect a DRZ seal through two mechanisms:

  1. Healing of the DRZ. The DRZ in the salt surrounding the concrete plugs will heal as its stress state approaches that of undisturbed salt. By resisting inward creep of the salt, the concrete plugs will help reestablish a more uniform stress field. As the deviatoric

portion of the stress tensor diminishes and the mean stress increases, damaged salt will begin to heal. The concrete plugs will promote rapid healing of the DRZ.

2. Asphalt. The asphalt waterstop (shown in Figure 3-3 and Appendix B, Drawing 33-SNL-005, Sh. 3 of 10) will effect a seal in the DRZ by interrupting the flow path through the DRZ. The waterstop consists of a tapered slot cut 10 ft beyond the existing shaft wall and filled with a flowable high density sand-asphalt mixture. The slot is 2-ft high at the shaft wall and tapers to 1-ft high at its tip. The slot will be cut using equipment similar to that used in coal mining to undercut coal seams. Upon excavation of the slot a DRZ will form around the slot. The DRZ beyond the tip of the slot will heal shortly after the slot is filled with the flowable sand-asphalt mixture and the upper element of the concrete plug is placed.

The sand-asphalt mixture will be continuous across the shaft cross section, the interface, and the slot. Thus, this component will effectively seal all brine migration pathways. The upper element of this concrete component also provides a base for the asphalt column.

Any brine passing this seal from above will encounter the upper Salado compacted clay column (Component 8) and the middle concrete component (Component 9) before it reaches the compacted salt column (Component 10).

- Marker Beds 103 and 109 and the Vaca Triste. The shaft through this region will be sealed by the upper Salado compacted clay column (Component 8 shown in Appendix B Dwg. 33-SNL-005, Sh. 6 of 10) and the middle concrete component (Component 9 shown in Appendix B Dwg. 33-SNL-005, Sh. 3 of 10). The clay column will be 344 ft long. The middle concrete component is identical to the upper concrete component (Component 7).

  MB 103 is the only unit within the Salado that is currently moist and therefore a potential source of groundwater within the Salado Formation. MB 109 and the Vaca Triste also intersect this component. These units were moist when the AIS was mapped, but did not appear moist when the shaft was inspected in 1994. The upper Salado compacted clay column will control inflow (if any) from these units. The upper Salado compacted clay column will be constructed in the same manner as the Rustler compacted clay column (Component 4). Because the shaft is not lined in the Salado, this component will seal both the shaft and the interface.

  Moisture in this location migrating downward through the DRZ will be controlled by the middle concrete component (Component 9).

- Marker Beds 121, 124, and 129; Zones A through J; and the Union Anhydrite. The shaft through this region will be sealed by the compacted salt column (Component 10 shown in Appendix B Dwg. 33-SNL-005, Sh. 7 of 10). The compacted salt column will be constructed to obtain approximately 90 percent of the density of the intact WIPP salt. The salt column will be approximately 564 ft long.

  Moisture was observed on the shaft wall at MB 121, 124, and 129; Zones A through J; and the Union Anhydrite when the shaft was mapped in 1989. Only salt encrustations were observed at these locations when the shaft was inspected in 1994. The absence of observable moisture indicates that either: (1) the moisture observed during shaft mapping resulted from limited area drainage of these units, which has ceased, or (2) the inflow is very low and evaporation prevents visible brine accumulation.

  The salt column will offer limited resistance to brine migration immediately after

emplacement, and become less permeable as creep closure further compacts the salt and induces healing. Because the shaft is not lined in the Salado, this component will seal both the shaft and the interface. The compacted salt does not provide sufficient initial stiffness to bring about early healing of the DRZ.

- Groundwaters Between the Compacted Salt Column and the Repository. No sources of groundwater were identified below Zone J in the AIS. Groundwater reaching this region must pass the lower concrete component (Component 11 shown in Appendix B Dwg. 33-SNL-005, Sh. 3 of 10) and the lower Salado clay column (Component 12 shown in Appendix B Dwg. 33-SNL-005, Sh. 6 of 10) before gaining access to the repository horizon.

  The lower concrete component is identical to the upper concrete component (Component 7). The lower concrete component provides a base for compaction of the compacted salt column.

  The lower Salado clay column is approximately 94 ft long. Because the shaft is not lined in the Salado, this component will seal both the shaft and the interface.

- Shaft Station Monolith. The shaft station monolith (Component 13 shown in Appendix B Dwg. 33-SNL-005, Sh. 4 of 10) is the bottom component of the AIS sealing system. Its function is to stabilize the shaft station area. The shaft station monolith also provides a base for compaction of the lower clay column. The shaft station monolith will completely fill the station area. The interface between the monolith and the surrounding rock will be grouted.

- Sumps. The Waste Shaft and Salt Handling Shaft have sumps that extend 126 ft. and 114 ft., respectively, below the shaft station level. The sumps will be filled prior to construction of the shaft station monoliths in these shafts. Seepage has been observed at MB 139 and MB 140 in the sumps of the Waste Shaft and Salt Handling Shaft.

e. **Design Uncertainties.** The design uncertainties fall into three categories:

1. Uncertainties associated with present conditions in the Salado Formation, for example: the current availability of groundwater for infiltration and the extent and permeability of the DRZ in the various units and marker beds penetrated by the shaft.
2. Uncertainties associated with future conditions, for example: the future availability of groundwater for infiltration and changes in the extent and permeability of the DRZ with time.
3. Uncertainties associated with the long-term properties of certain sealing materials, for example: the useful life of the concrete components and the permeability of compacted crushed salt as a function of time.

These design uncertainties are addressed in the design by:

1. using all available space in the shafts for sealing;
2. using multiple components so poor performance of a single component will not lead to system failure;
3. using different materials so poor performance of one material does not lead to system failure.

The performance of the shaft sealing system is discussed in Section 5, Evaluation of Shaft Sealing System Design.

3.2.2 Brine Reaching the Regulatory Boundaries

a. **Design Guidance.** The shaft sealing system shall limit the migration of radiological or other hazardous constituents from the repository horizon to the regulatory boundary during the 10,000-year regulatory period following closure.

b. **Source of Brine.** After brine has migrated into the repository disposal areas, they are then modeled as the source of the brine for regulatory concerns.

c. **Potential Pathways for Brine.** The pathways for brine forced upward from the repository level upward to the Culebra level (a vertical distance of approximately 1,370 ft) are the same as those for groundwater migration downward to the repository (i.e., the shaft, interface zone, and DRZ).

d. **Design Approach.** Migration of brine is limited in the following ways:

- MB 138. Brine entering the sealing system at and below MB 138 must pass through the lower clay column (Component 12). The lower clay column serves to limit migration of brine into the shaft and interface zone. The clay will be placed and compacted in a moist condition to assure good contact along the shaft walls and thus seal the interface zone. Brine migrating upward through this clay column, along the interface , and/or through the DRZ will be controlled by the lower concrete component (Component 11) during the first 100 years following closure.

- The Lower Concrete Component and Subsequent Components. The lower concrete component and the remaining components between this component and the Culebra Member will limit the upward flow of brine in the same manner that they limit the downward flow of groundwater.

e. **Design Uncertainties.** In addition to the design uncertainties identified in Section 3.3.1, uncertainties associated with the location of the entry point(s) and pressure history for brine into the sealing system have been identified.

This design uncertainty is addressed by placing sealing components with properties sufficient to resist fluid flow under WIPP conditions at and above MB 138.

3.2.3 Design Life

a. **Design Guidance.** The shaft sealing system shall limit chemical and mechanical incompatibility of sealing materials with the seal environment.

b. **Design Approach.** The design is composed of clay and salt components that will be stable throughout and beyond the 10,000-year regulatory period, asphalt components that may be stable throughout this period, and concrete components that are expected to degrade during this period. The design initially relies on the concrete, asphalt, and clay components to seal the shafts. After the first 100 years, the design relies on the clay and salt components to seal the shafts. The clay and salt shaft sealing system components are constructed of materials that are chemically compatible with the host rock and brine that may come in contact with them.

c. **Design Uncertainties.** The permeability-density relationship used to predict the permeability of the compacted salt column as a function of time is a major uncertainty associated with meeting this design guidance item. Other, lessor uncertainties are

associated with the prediction of the useful life of the concrete and asphalt components. These design uncertainties have been addressed by (1) replacing the upper and lower compacted salt columns used in previous designs with compacted clay columns and (2) restricting the design (required) life of the concrete and asphalt components to 100 years.

3.2.4 Structural Adequacy

a. **Design Guidance.** The shaft sealing system shall limit the possibility for structural failure of individual components of the sealing system.

b. **Design Approach.** The structural adequacy of the components will be demonstrated using standard approaches and techniques. Structural analysis of the upper, middle, and lower concrete components was performed. The analysis showed that these components are primarily subjected to compressive loads. The analysis of these concrete components included analysis of the surrounding salt and predicted both the initial increase in the extent of the DRZ surrounding the concrete components and waterstops, and the subsequent healing of this DRZ. These concrete components are structurally adequate. Analyses have also been performed to predict the consolidation of the compacted salt column and clay columns. These analyses show that the compacted salt column will consolidate sufficiently during the 100 years following closure to form a low permeability seal. Healing of the DRZ surrounding the lower portion of the compacted salt column and the lower clay column will also be accomplished during the 100 years following closure. Healing of the upper portion of the DRZ surrounding the compacted salt column and the upper clay column may not be completed during the 100 years following closure. A discussion of the mechanical response of the sealing system is presented in Section 5.2.2.

c. **Design Uncertainties.** The method used to address this design guidance item is the accepted approach where applicable codes and standards are not available. When uncertainties are identified by either design reviews or analyses, the design will be modified to reduce the uncertainties and to resolve issues of structural adequacy.

3.2.5 Subsidence and Accidental Entry

a. **Design Guidance.** The shaft sealing system shall limit the possibility for subsidence of the ground surface in the vicinity of the shafts and accidental entry after sealing.

b. **Design Approach.** The potential for subsidence is limited by complete filling of the shafts with low porosity materials. The potential for accidental entry is limited by installation of sealing system components whose removal would require construction activities similar to those used to sink the shaft.

c. **Design Uncertainties.** None identified.

3.2.6 Development of New Construction Technologies and/or Materials

a. **Design Guidance.** The shaft sealing system shall limit the need to develop new technologies or materials for construction of the shaft sealing system.

b. **Design Approach.** The sealing system can be constructed using currently available technologies and materials. Obviously, adapting these available technologies for use at the WIPP will require development of construction procedures specific to the WIPP shafts. Current construction practices will be employed to:

- prepare the shaft walls prior to emplacement of sealing components. For example, the shaft walls will be cleaned, scaled back to sound surfaces, and all loose materials and shaft fittings will be removed prior to emplacement of sealing components in the Salado Formation;
- grout the Rustler Formation and units above the Rustler to limit groundwater inflow and to assure shaft stability in those regions where the existing shaft liner will be removed prior to emplacing sealing materials;
- grout the interface between concrete components and surrounding rock;
- emplace asphalt and concrete and both compact clay and salt components.

c. **Design Uncertainties.** The following design uncertainty has been identified: The asphalt column may be subject to intrusion of brine from the Rustler-Salado contact zone.

When asphalt was used to seal the annulus between old leaking shaft linings and new shaft linings in Germany, the hydraulic head in the asphalt column was maintained at a higher level than the hydraulic head in the surrounding formation to prevent the displacement of asphalt by groundwater. The hydraulic head in the Rustler-Salado Interface is higher than that in the asphalt column. The higher hydraulic head in the Rustler-Salado brine may initially result in brine intrusion into the asphalt column. However, the asphalt column is completely contained and the asphalt is not free to displace either vertically or horizontally. Therefore, the asphalt in the column would quickly reach an equilibrium pressure with the brine if brine intrusion occurs.

This design uncertainty will be addressed by assessing the potential effect of brine intrusion into the asphalt column. If this uncertainty cannot be satisfactorily resolved, the design will be revised to place the top of the asphalt column below the Rustler-Salado contact zone.

3.3 Design Alternatives

During the course of the development of this design, a number of alternatives were considered. In this section a number of these design alternatives are presented and discussed. During final design, detailed analyses of the system and its components may identify the need to incorporate some of the alternatives presented below. The alternatives are presented for the components starting at the surface and proceeding downward. In each case the current component is identified and then alternatives are identified which could be used in place of the current component.

Component 1. Clay or earthen fill is used for Component 1. Alternatives considered were:

a. A concrete plug could be installed at the surface (e.g., in the AIS plenum) and the shaft could be filled below the plug. The plug design would be different for each shaft because each of the four shafts terminate differently at the surface.

b. The plenum could be dismantled and a cap could be placed over the shaft collar or a plug could be placed in the shaft collar area. For the purpose of this discussion, a cap is slab of concrete capable of supporting a specified superimposed load, and a plug is a mass of concrete that fills the shaft and whose thickness is equal to or greater than the shaft diameter. The collars of the Waste Shaft and AIS are located approximately 20 ft below the

ground surface, while the collars of the Salt Handling Shaft and Exhaust Shaft are located at the surface.

c. The clay or earthen fill could be replaced with compacted clay. This alternative would provide fill with higher density and lower permeability than that provided by clay or earthen fill.

d. The existing concrete shaft liner could be removed. (Note: This alternative applies to all components located in the lined portion of the shaft.) This alternative would eliminate any compromise of the sealing system integrity by liner condition.

Component 2. A concrete plug is used for Component 2. Alternatives considered were:

a. The existing shaft liner could be removed and the plug could be keyed into the surrounding rock. This alternative could be chosen at the time of shaft closure if the concrete shaft liner in this region is not sufficiently sound.

b. Compacted clay or earthen fill could be used instead of concrete. This alternative would be used if a concrete cap or plug is placed at or near the ground surface.

Component 3. Clay or earthen fill is used for Component 3. Alternatives considered were:

a. Compacted clay could be used instead of clay or earthen fill.

b. Asphalt could be used instead of compacted clay or earthen fill. In Germany, asphalt has been used to seal leaking shaft liners (Valk, 1989; Stoss and Braum, 1983). New steel liners were installed in the German shafts and asphalt was placed in the void between the new liners and the leaking liners. The asphalt effectively sealed the leaking liner and permitted continued use of the shaft. The hydrostatic pressure in the asphalt must exceed that of the groundwater to effectively exclude groundwater from a shaft. The specific density of the asphalt fill and the height of the asphalt column would be chosen so that the hydrostatic pressure in the asphalt is higher than that in the water bearing units of the Rustler Formation and the Rustler-Salado contact zone.

c. The existing concrete shaft liner could be removed. (See Component 1, Item d for discussion.)

Component 4. A compacted clay column is used for Component 4. Alternatives considered were:

a. Asphalt could be used instead of a compacted clay. (See Component 3, Item b for discussion.)

b. The existing concrete shaft liner could be removed. (See Component 1, Item d for discussion.)

Component 5. A freshwater concrete plug is used for Component 5. Alternatives considered were:

a. If asphalt is used for Component 4, the freshwater concrete plug would be deleted and replaced by asphalt.

b. The plug design could be modified so excavation is not required. The DRZ and interface would be grouted. The plug would develop resistance to displacement through mechanical

interlock with the surrounding rock. A longer plug may be required to assure adequate support, but there would be no need for excavation after removal of the existing shaft liner.

Component 6. An asphalt column is used for Component 6. Alternatives considered were:

a. A compacted clay column could be used instead of the asphalt column. Compacted clay would provide a shaft fill with low permeability. This low permeability material would limit migration of groundwater from the Rustler-Salado Interface into the shaft. If Component 5 were retained and a sodium bentonite clay (for example, American Colloid Co., type MX-80) was emplaced in this location the clay would be completely contained. If brine entered this region local swelling of the bentonite would occur, developing pressures that would seal the interface between the clay and the surrounding rock and force the clay into fissures in the surrounding rock (Pusch, 1982).

b. Pelletized dry bentonite could be placed in this region. The bentonite would be confined by the concrete plugs above and below the surrounding shaft wall. If brine entered this region local swelling of the bentonite would occur, sealing the region.

c. The freshwater concrete plug (Component 5) could be relocated below the existing key (a movement of approximately 80 ft downward) and the Rustler compacted clay column (Component 4) extended through the key. This would reduce the length of the asphalt column (Component 6) from 138 ft to 38 ft. An asphalt column 38 ft long would also effectively seal the shaft and interface.

Component 7. A concrete plug with an asphalt waterstop is used for Component 7. Alternatives considered were:

a. This component could be removed and replaced by either of the adjacent components. If a rigid plug is not emplaced, healing of the DRZ would take longer. The transition between the asphalt column and the clay column could be maintained by a concrete cap over the clay.

b. The plug design could be modified so excavation is not required. The plug would develop resistance to displacement through mechanical interlock with the surrounding salt rock. A longer plug may be required to assure adequate support, but there would be no need for additional excavation.

c. The waterstop could be eliminated or modified by not extending it into the surrounding salt rock. Upon installation, the asphalt provides assured sealing of the shaft cross section and interface. Sealing of the DRZ would be through creep closure and additional time would be required to achieve sealing of the DRZ.

Component 8. A compacted clay column is used for Component 8. The alternative considered was a compacted salt column.

Previous designs used a salt column in this region. The salt column was replaced by a clay column to (1) provide a medium that is less permeable during the 100 years following closure and (2) reduce the uncertainty associated with using the same material in each of the long-term seal components.

Component 9. A concrete plug with an asphalt waterstop is used for Component 9. The alternatives considered for this component are discussed under Component 7.

Component 10. A salt column is used for Component 10. Alternatives considered were:

a. This component could be replaced with a compacted clay column. Initially the compacted clay column would have a permeability lower than a compacted salt column. However, during the 100 years following closure, the salt column permeability is reduced by creep closure and by the end of the period the permeability of the salt column would be less than that of the clay column.

b. Compressed salt blocks or quarried salt blocks with salt-mortared joints could be used. The use of either of these materials would assure a salt column with a high value for its initial average density. Uncertainties exist with regard to the ability of the mortar joints to consolidate in a uniform manner.

Component 11. A concrete plug with an asphalt waterstop is used for Component 11. The alternatives considered for this component are discussed under Component 7.

Component 12. A compacted clay column is used for Component 12. The alternative for this component is discussed under Component 8.

Component 13. Shaft Station Monolith

This Component could be replaced by compacted crushed salt. Compacted crushed salt would be less rigid than the concrete and would therefore allow greater rock mass movement into the station area.

4.0 Materials

The basic design guidance for WIPP shaft seals is: prevent the shafts from becoming a pathway that compromises the repository's ability to meet performance objectives. Implicit in the fundamental design criteria is the assumption that if seal components are less permeable than the host rock, the sealing system will be adequate. This section discusses the materials used in the various seal components and explains why they are expected to function as intended. To return an open shaft to a state of low permeability, the seal design must account for three cross sectional elements:

1. the massive plug material that fills the opening,
2. the interface between the plug and the host rock, and
3. the disturbed rock around the shaft.

In this section pertinent material properties of the several seal elements are described. In general, the materials were selected for seal design elements because they are compatible with the stratigraphy, available, constructable, and have desired performance characteristics. The materials have been used widely or studied in detail to provide the basis for use within the WIPP sealing system. Material properties including permeability, strength, and mechanical constitutive response are given for each material as well as brief discussions of expected performance, construction techniques, longevity, and other characteristics relevant to the WIPP setting.

The terms "short-term" and "long-term" in this design report refer to the first 100 years after closure and from 100 to 10,000 years, respectively. The functional periods for some components such as concrete plugs, clay columns, and asphalt begin immediately upon construction. Each of these materials is expected not to degrade for very long periods; clay and asphalt are likely to be geochemically stable beyond the regulatory period of 10,000 years. Salt-saturated concrete within the Salado is likely to remain intact for hundreds of years, but guarantee of survival is more problematic. Nonetheless, design guidance for longevity of concrete, grout, and asphalt is for the first 100 years after closure. The crushed salt long-term component will become functional well within that period and will function in tandem with the clay column.

The seal materials include:

- Freshwater Portland cement concrete
- Salt-saturated concrete (Salado Mass Concrete)
- Compacted salt
- Compacted clay
- Asphalt
- Cementitious grout
- Clay or earthen fill.

Each material possesses particular favorable attributes. In the following discussion, all these materials except earthen fill, an optional material, will be examined with respect to their intended functions.

4.1 Freshwater Concrete

Concrete is perhaps the most common structural material used in the United States. For this seal design, freshwater concrete is differentiated from salt-saturated concrete. All good quality concrete possesses the highly desirable attributes of strength, ease of construction, rigidity, and a wide range of properties that can be tailored to specific functions. Concrete also has a very low permeability if it remains uncracked. These properties combine to make concrete the material of choice for hydraulic applications such as water storage tanks, water and sewer pipes, tunnel and shaft linings, massive dams, and countless other applications.

Use of concrete as a shaft seal component takes advantage of the exceptional performance of concrete in compressional states of stress. Reinforced concrete design is based on compressional volumes of concrete balanced by tensile stresses within reinforcing steel. Within the shaft setting, no tensile states of stress will exist, allowing use of unreinforced concrete. Vertical placement has the obvious advantage of no formwork and ready access during placement. In addition, concrete within the sealing system will not experience freeze-thaw cycles, which give rise to cracking in normal surface structural elements.

Freshwater concrete will be used within the non-Salado formations as a plug above the asphalt column straddling the Rustler/Salado contact (Component 5) and as a concrete plug near the top of the shaft (Component 2). These concrete plugs are designed to function as structural members possessing low permeability. Construction conditions are very favorable for a full face plug because hydration will be completed at 100% relative humidity. Preservation of water for hydration ensures a dense cementing paste. Well designed and properly cured mass concrete, as used in dams, typically will not achieve equilibrium pore pressure in its usual life (Neville, 1975), which is qualitative affirmation of extremely low permeability. The concrete elements of the seal design are expected to be structurally competent and much less permeable than the host rock.

4.2 Salt-Saturated Concrete

Salt-saturated concrete contains a sufficient amount of salt as an aggregate to saturate the water for hydration with respect to NaCl. Salt-saturated concrete will be used within the Salado Formation (Components 7, 9, 11, and 13) because freshwater concrete would dissolve part of the host rock. Dissolution would result in a poor bond or perhaps a more porous interface. Salt-saturated concrete, on the other hand, will bond tightly with the Salado host rock as it cures (Wakeley et al., 1993). Salt-saturated concrete has been used since the 1940s for completion of oil wells in salt domes and for decades in salt and potash mines. Use within these industries is quite wide but performance measures and properties of the salt-saturated concretes are not well published or documented. The salt-saturated concrete proposed for the WIPP sealing system (called Salado Mass Concrete, or SMC) is the result of several years of optimization and characterization of a preferred mix design. In addition, salt-saturated concrete has been used in experimental investigations at the WIPP. Therefore, the specification of SMC for WIPP seal components is well founded in experience and recent technical experimental results.

The Waterways Experiment Station (WES), operated by the US Army Corps of Engineers, has served the WIPP in concrete and grout development for about 20 years. Experience includes grout development and the grouting of a deep borehole in the Bell Canyon Formation (Gulick et al., 1980), a series of small-scale tests underground at the WIPP (Wakeley

et al., 1993; Finley and Tillerson, 1992) and recent optimization studies and mass concrete trial batches of SMC (Wakeley et al., 1995). In addition, the WES performed chemical degradation studies of cementitious materials including grouts, salt-saturated samples extracted from the WIPP horizon after several years in situ, and SMC. Some of the basic applicable results of these studies are given here.

Concrete permeability is an important design parameter. Studies show that the intrinsic permeability of SMC is extremely low, approaching 1×10^{-21} m^2 when 100-mm-diameter samples are tested with nitrogen and permeability decreases as a function of time. This measurement corroborates the results of the Small Scale Seal Performance Tests (SSSPTs), which used another mixture of salt-saturated concrete. The salt-saturated concrete plugs in the SSSPTs were situated horizontally in a pillar and vertically in the WIPP horizon floor. They were subjected to stress and associated deformation, including floor heave, for about 9 years between performance tests. The SSSPT permeabilities measured on 1-m concrete plugs ranged from 4×10^{-19} m^2 when initially tested in 1986 to less than 4×10^{-19} m^2 when retested in 1995. The permeabilities measured during the SSSPT are system values that include transmissivity of the concrete, the interface, and any DRZ around the seal.

A smaller database of structural material properties exists for salt-saturated concrete than for the well-documented normal freshwater concrete. However, SMC concrete is expected to perform (based on laboratory measurements) as well or better than freshwater concrete in the Salado section of the shaft seals. Strength and deformational characteristics of SMC are equivalent to a very good quality freshwater concrete, and the stress state is compression. When batched in bulk volumes, SMC has a strength around 6000 psi (40 MPa) and a modulus of elasticity of over 5×10^6 psi (35 GPa) (Wakeley et al., 1995). Volume stability was found to be excellent: -0.0002 to -0.0004 after about a year of testing at 50% relative humidity, following ASTM standard procedures. It is expected that SMC used in situ will not shrink because curing conditions will eliminate moisture loss (i.e., concrete hydration will occur at 100% relative humidity).

The constitutive model for concrete is integral to analysis of the shaft sealing system. It is expected that a rigid inclusion such as a massive plug of SMC will exert a backstress against the host salt formation. In turn, the reestablished state of stress will tightly compress the interface and close fractures and promote healing within the DRZ. For modeling purposes, SMC is assigned an isothermal creep law fit to long-term creep test data. The elastic modulus is time (age) dependent, but reaches a constant value after about a year.

Another consideration with respect to the use of concrete within the Salado Formation is the potential of degradation if the concrete is exposed to replenished supplies of caustic brines. Salt-saturated concretes have been shown to resist brine attack better than ordinary Portland cement concrete (Wakeley et al., 1994). Based on the most representative field examples to date (Wakeley et al., 1993), degradation of salt-saturated concrete exposed to natural WIPP brines for over six years was found to be insignificant. After six years in situ, the bond between the salt-saturated concrete and the host rock was excellent and the phase assemblages were unaffected by the brine. The specified SMC for seal components in the Salado Formation is also more resistant to degradation by brine than is freshwater concrete. In addition, sources of brine within the Salado are limited and exposure of massive concrete structures to brine would be limited. Degradation of cementitious materials and concrete structures in the Salado portion of the shaft seal design is most unlikely.

4.3 Compacted Salt

Reconstituted salt comprises a major seal element (Component 10) located between MSL 2002 and 1440 ft (170 m in length). The concept of using crushed salt as a seal material originated in the 1950s when the National Academy of Sciences originally proposed storage of nuclear waste material in salt formations. It was assumed that the shafts could be filled with crushed salt, which would then consolidate naturally into a nearly impermeable seal by creep of the host rock. Chemical, physical, and mechanical compatibility was intrinsically assured. Laboratory testing over the last decade has shown that pulverized salt can be compressed into very dense blocks possessing very low permeability. Demonstrations of large-scale dynamic compaction and associated laboratory testing have established construction feasibility and measured several crucial performance parameters. Recent data establish that compacted crushed salt is a viable seal material.

Crushed salt will provide a seal that will function essentially forever once it has consolidated. This is demonstrated by establishing initial conditions, a constitutive response of the crushed salt as it consolidates, and a permeability/density function for the consolidating salt. Initial characteristics of dynamically compacted salt have now been measured (Ahrens and Hansen, 1995). A full-scale demonstration successfully compacted mine-run WIPP salt to a uniform density of 90% of intact salt. Compaction was relatively simple and involved dropping a 9000-kg weight into a structural steel test chamber containing mine-run salt. The demonstration did not attempt to optimize control parameters by grinding or sizing the salt and/or by optimizing the initial moisture content. The compacted mass (40 m^3) was permeability tested using a borehole gas flow tool. The mass was determined to have an average nitrogen permeability of 9×10^{-14} m^2. This unique application of construction practices provides a baseline for predictions involving the shaft seal element comprising 170 m of compacted salt.

A significant effort has been made to establish a constitutive model for crushed salt because modeling of the sealing system is one means of evaluating performance through time. The model is used to predict performance of the salt after it is compacted in the open shaft. Initial technical evaluation of potential crushed salt constitutive models has been completed (Callahan et al., 1995). In this study, ten models with the potential to describe phenomenological and micromechanical processes of crushed salt were selected from a literature search. Three of the ten candidate models were screened for rigorous comparisons to a specially developed but somewhat limited database. The database contained hydrostatic consolidation tests, shear consolidation tests, and a combination of shear and hydrostatic tests. Based on the fitting statistics and the ability of the models to predict the test data, a model proposed by Spiers and coworkers (Spiers and Brzesowsky, 1993; Spiers and Schutjens, 1990; Spiers et al., 1989) was judged superior to other candidate models. The constitutive model work is fundamental to performance calculations of a crushed salt seal.

The constitutive model for consolidating crushed salt will be used in future calculations as part of seal design and system performance analysis. Conceptually, computer models will simulate the shaft after it has been filled with compacted salt. Constitutive relationships dictate how the host salt material creeps into the former shaft volume and how the crushed salt responds (i.e., by volume reduction and by change in the stress state). Volume reduction is accompanied by decreasing permeability within the salt component.

Other advancements in the basic understanding of crushed salt consolidation have occurred in the laboratory. This ongoing testing will develop a relationship between density and permeability as well as measure elastic constants. An initial test shows that permeability is reduced substantially and quickly at pressures ≤ 5 MPa. The experimental response of a sample of dynamically compacted salt is shown in Figure 4-1. A hydrostatic pressure of 2 MPa reduced permeability of the compacted salt sample by an order of magnitude. Further compression to 5 MPa reduced permeability to 3×10^{-18} m^2 and increased sample density to approximately 0.97 of the density of intact salt. Using these data to formulate a preliminary permeability/density function, together with the appropriate constitutive relationship, allow an estimation of the permeability of the compacted salt column as a function of time.

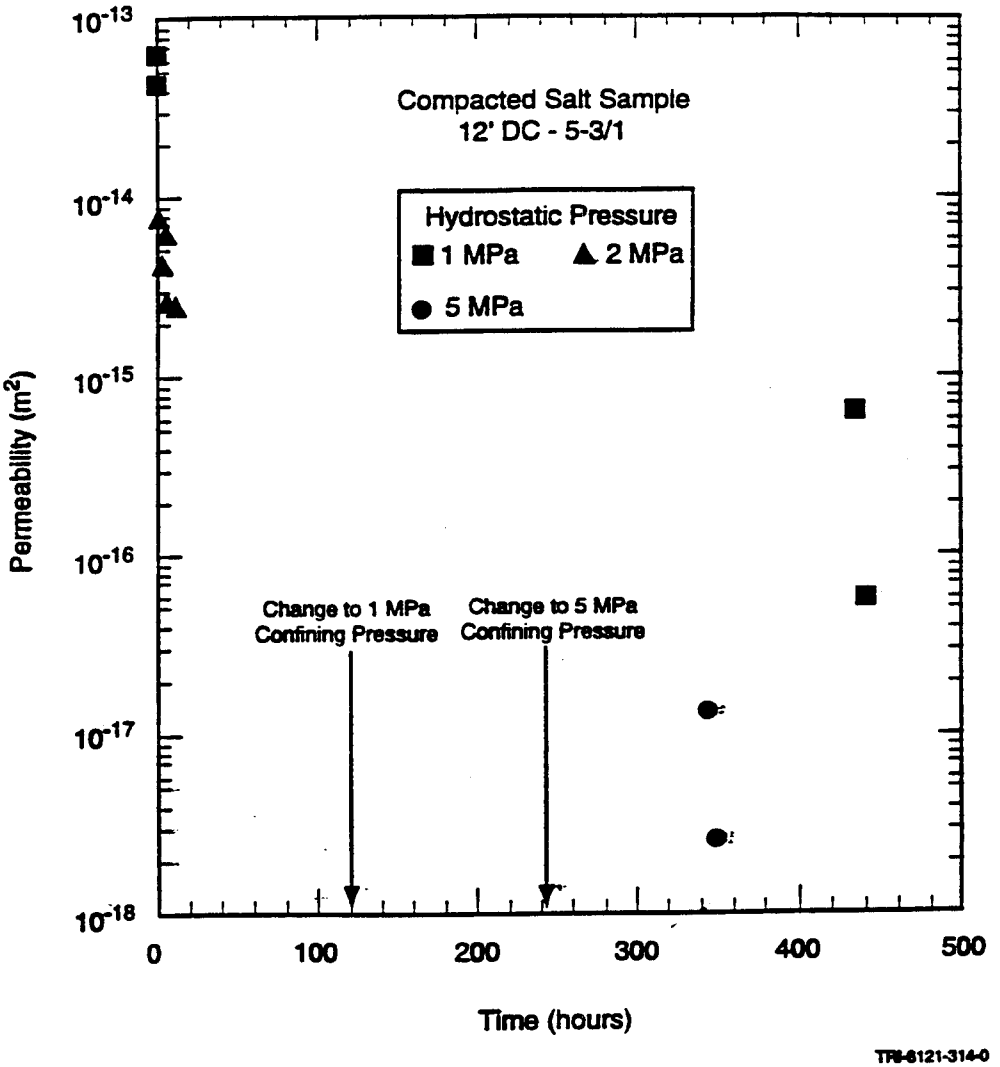

Figure 4-1. Permeability of compacted salt at low hydrostatic stresses.

Figure 4-2 plots the expected permeability range of the Salado salt column 100 years after placement at an initial density of 0.9 of intact salt. A range of values reflects differences between parameters for clean and argillaceous salt. This particular calculation includes the effect of backstress on the crushed salt. Under these modeling assumptions it is shown that 70 m of the salt column is tighter than 1×10^{-18} m^2 at 100 years. These magnitudes of permeability and effective lengths of salt column are consistent with those used for design evaluation (Appendix D). Tests currently being conducted will generate additional permeability data with stress path deviation to characterize elastic properties as a function of density. These additional calculations will refine the information plotted in Figure 4-2.

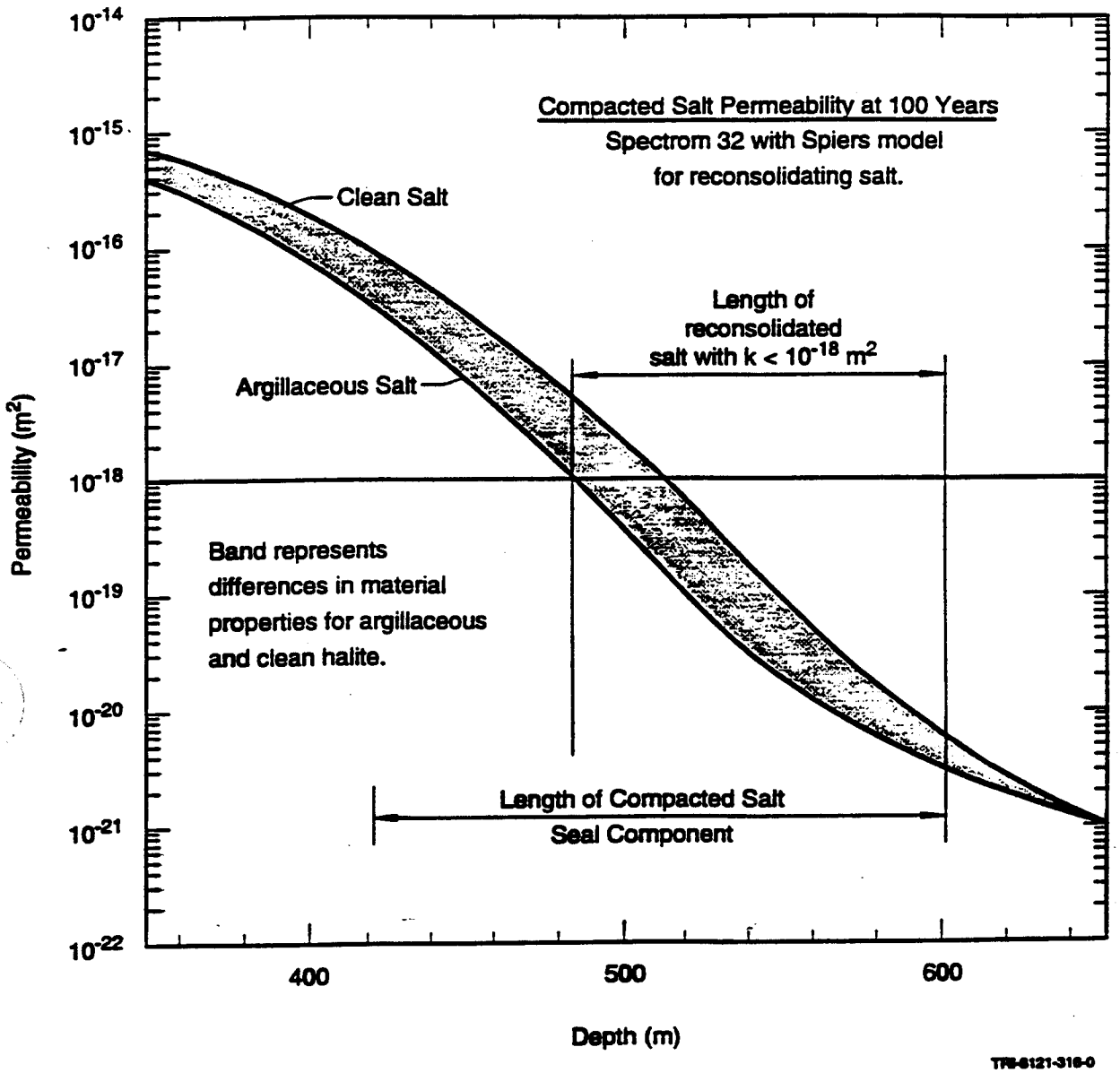

Figure 4-2. Estimated permeability of the Salado salt column at 100 years.

4.4 Compacted Clay

Clay comprises major components of the shaft sealing system at five locations: (1) near the surface between 3410 ft and 3353 ft MSL, (2) in the Dewey Lake between 3313 ft and 2840 ft MSL, (3) between 2840 ft and 2605 ft MSL in the Rustler, (4) between 2397 ft and 2053 ft MSL in the Salado Formation (Component 8), and (5) near the bottom of the shaft between 1340 ft and 1296 ft MSL (Component 12). Bentonite clay is chosen here because of its overwhelmingly positive sealing characteristics. Relative to other clay minerals, such as illite or kaolinite, bentonite is perhaps two orders of magnitude less permeable (see Section 4.5). Bentonite is widely used as a sealing component in a variety of geotechnical applications. In particular, bentonite is considered a primary sealing material in several international nuclear waste repository programs. Studies on sealing with bentonite have been conducted in Canada, England, France, Germany, Sweden, Switzerland, and the United States.

Bentonite is an excellent seal material because of its many positive attributes for the WIPP environment: low permeability, swelling potential, strength and mechanical properties, compatibility and longevity, as well as reasonable construction requirements. Generation of significant gas pressure (as much as 2 MPa) is not expected for the first several hundred years after waste emplacement. Nonetheless, the proposed design will quickly and effectively minimize gas migration. Compacted bentonite is an effective gas barrier because of a threshold pressure that is required to displace water in the larger pores. This performance characteristic coupled with the low permeability of the lower concrete component is sufficient to protect the consolidating salt column from gases generated by the repository.

In situ tests of bentonite at the WIPP, involving about a cubic meter of material, corroborate the expected sealing function. Blocks of bentonite were stacked in vertical and horizontal 1-m-diameter boreholes. Microdarcy permeability (1×10^{-18} m^2) was measured after about two months of brine testing. Subsequently, permeability continued to decrease. After 6 years of brine flow testing at 0.67 MPa (100 psi), no brine has been observed to have passed through the 1-m seal. A test of threshold pressure using gas and the same bentonite seal was completed in 1995. A pressure over 500 psi (>3 MPa) was required to initiate flow.

In addition to its inherent low permeability, clay can also be expected to resist creep of the host Salado Formation salt into the shaft. By resisting inward creep of the salt, the clay component will help reestablish a more uniform stress field. As the deviatoric portion of the stress tensor diminishes and the mean stress increases, damaged salt will begin to heal. The clay component near the bottom of the shaft will promote rapid healing of the DRZ. Compaction data from Lambe and Whitman (1969) was used to develop a density-dependent bulk modulus. When this material model is used to represent clay placed in the lower Salado compacted clay column, the DRZ over the length of the clay component is eliminated in less than 25 years after construction. Figure 4-3 is a plot of DRZ healing as a function of time for the shaft column filled with compacted clay. Based on the most recent creep and fracture finite-element model (Chan et al., 1995), if 50 years are assumed to elapse before construction of the shaft seals, the potential exists for a DRZ to develop up to 0.8 shaft radii into the rock mass. Rigidity of the clay is sufficient to heal the DRZ in salt between 10 and 25 years after construction of the seal component. Any stiff seal material, such as concrete, would likewise heal a DRZ in salt within the same period of time.

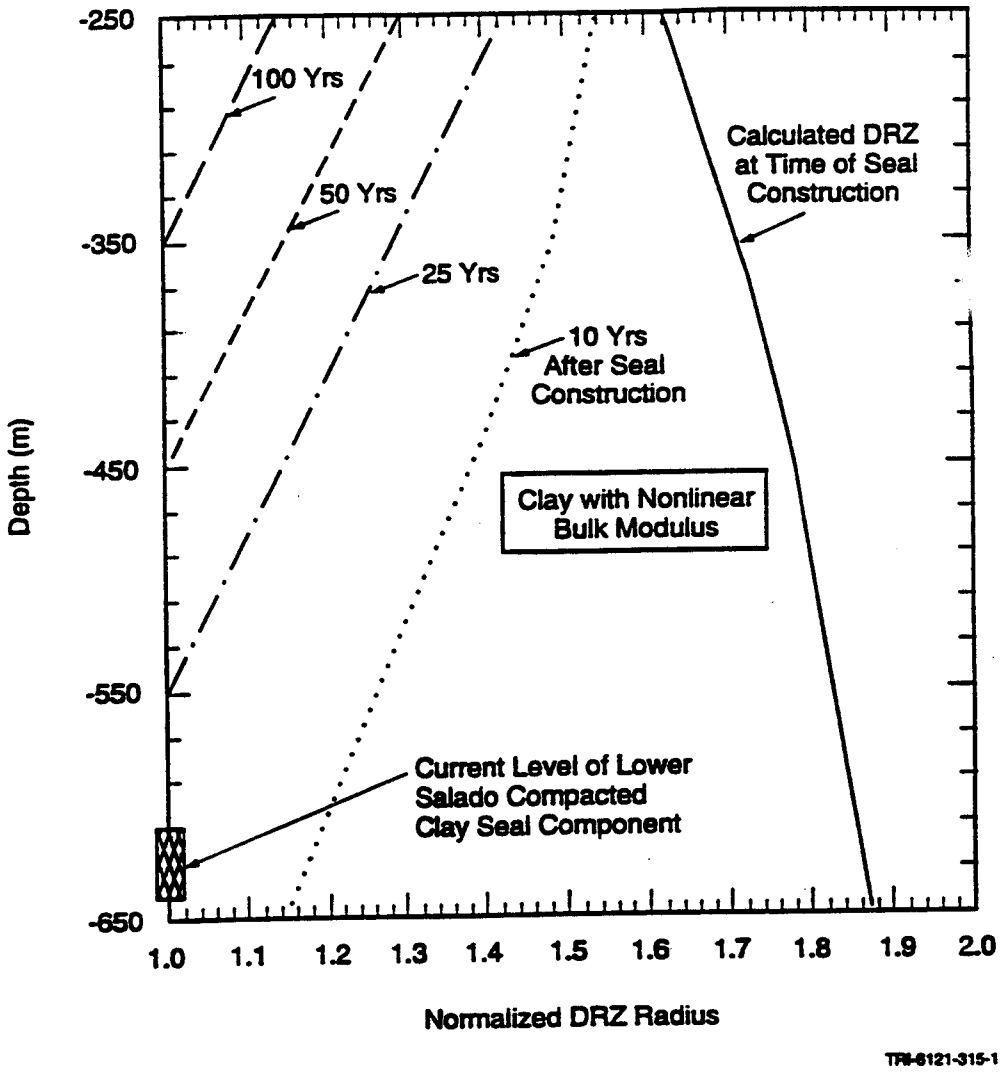

Figure 4-3. Extent of DRZ at various depths within the shaft.

Elsewhere in the seal column, clay can be expected to possess equally low permeability. Within the Rustler, the clay seal component will be less permeable than most of the surrounding rock no matter which clay mineralogy is selected. The anhydrite layers in the Rustler have very low permeabilities. The overall permeability of the Rustler is about 1×10^{-14} to 10^{-15} m^2 (Beauheim, 1987). As illustrated in Figure 4-4, clays can readily achieve permeabilities lower than 10^{-14} to 10^{-15} m^2. The compacted clay component within the upper Salado will inhibit fluid flow just like other clay components would, but the DRZ within the salt would not heal as quickly as around components at greater depth because of smaller stress magnitudes. Bentonite and other clays act as aquitards in the geologic setting. This means clay remains relatively impermeable over time periods far exceeding the regulatory period for the WIPP.

4.5 Asphalt

An asphalt column is proposed as an extensive seal component from MSL 2585 to 2447 ft (Component 6). In addition, asphalt is proposed to act as a waterstop between concrete members at three locations within the Salado Formation. Asphalt or bitumen is commonly used in Europe as a seal component around concrete shaft liners and is considered a viable seal material for radioactive waste programs in England and Germany. Asphalt has been considered as an alternative seal material within the WIPP seals program for several years. Asphalt has been added to the present shaft seal design to increase redundancy and confidence in performance of the system and to add assurance that transport of brine down the sealed shaft is precluded.

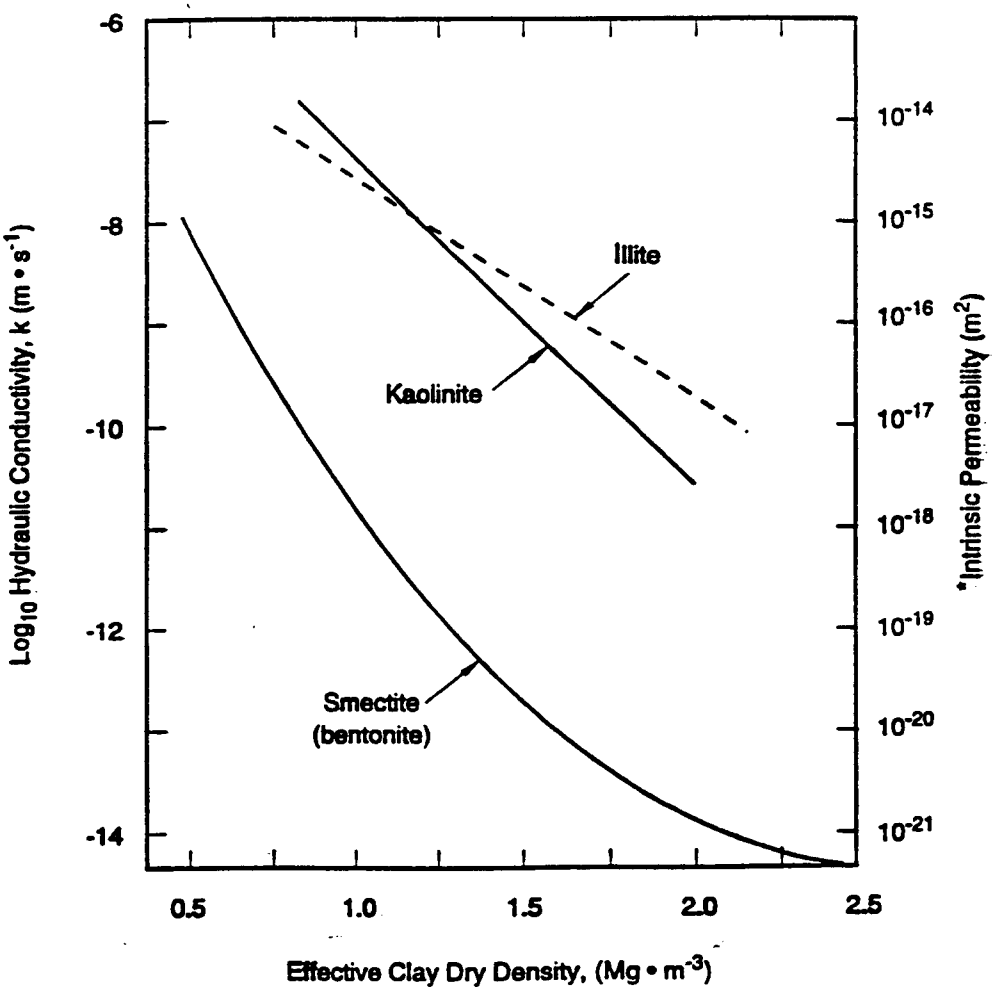

Figure 4-4. Relationship between hydraulic conductivity, intrinsic permeability, and effective clay dry density for selected clay minerals (from Johnson et al., 1994).

Technical specifications for asphaltic components have not yet been completed, but considerations center on use of an asphalt mastic mix (AMM) in contrast to hot-mix asphalt concrete or liquid asphalt options. AMMs for hydraulic structures are mixtures of asphalt, sand, and mineral filler. The asphalt content of AMM is much higher than that used in typical hot-mix asphalt concretes such as pavements.

High asphalt contents (10-20% by weight) and fine, well graded aggregate comprising sand and mineral fillers are used to minimize interconnected porosity. Equipment available from vertical barrier-construction and well-drilling technologies can be adopted to build an AMM seal successfully under WIPP construction conditions. In place densities should approach 98% of maximum theoretical density with a permeability of 1×10^{-21} m^2.

The viscosity of the AMM is an important physical property of the design specification. The AMM must be pourable at application temperatures, able to penetrate into voids or fractures, and viscous enough to control long-term flow. Hydrated lime is a possible additive to decrease moisture susceptibility and to act as an antimicrobial agent.

For calculations, asphalt in the shaft is assumed to behave elastically. Elastic properties of asphalt are sensitive to temperature, which is held constant at 27° C. Elastic properties for current analysis are taken from Yoder and Witczak (1975).

4.6 Cementitious Grout

Grouting is an option for sealing interfaces and the DRZs of nonsalt units within the Salado Formation. Portland cement is the most widely used grouting material because of its low cost, availability, engineering properties, and long history of use. Neat (without aggregate) cement grout consists of Portland cement and water, but admixtures are commonly employed to alter its characteristics. There are five types of Portland cement, and any may be used for grout. The choice of cement type depends on the application. Grout can be formulated to attain certain specific properties, such as low heat of hydration, chemical resistance, and high early strength.

Within the shaft sealing system, grout is proposed to seal interfaces and penetrate microfractures within the DRZ of nonsalt lithologies or other zones where microfractures are not expected to heal naturally. All cementitious grouts contain particles, so the maximum particle dimension should be no larger than one-third of the aperture of the microcracks. A cementitious grout has been developed at Sandia National Laboratories (Ahrens, 1995) and demonstrated to be suited for producing, mixing, and injecting at the WIPP. The grout, called "ultrafine," has 90% of its particles smaller than 6 microns. Ultrafine consists of Type V sulfate-resistant Portland cement, a pozzolan of amorphous silica, and superplasticizer. Pozzolan replaces much of the Portland cement, reducing heat of hydration. Ultrafine is the specified grout for the sealing system.

4.7 Materials Summary

A recap of the materials used in the seal design, the potential zones they treat, and their performance period are given in Table 4-1. The primary design function expected of the materials is to prevent the sealed shaft and the surrounding DRZ from becoming a preferred pathway for the transmission of fluids; therefore, Table 4-2 summarizes the permeabilities of the components.

Table 4-1. Seal Materials for the Salado Formation

Material	Short-term Period			Long-term Period		
	Cross Section	Interface	DRZ	Cross Section	Interface	DRZ
Concrete	X	X	X			X
Compacted Salt				X	X	X
Compacted Clay	X	X		X	X	X
Asphalt Column	X	X		X	X	
Asphalt Water Stop	X	X	X	X	X	X

Table 4-2. Material Permeabilities

Seal Material	Permeability (m^2)
Freshwater/Salt-Saturated Concrete 0 to 100 years 100 to 10,000 years	 5.0×10^{-19} 1.0×10^{-14}
Consolidated Salt 0 years 100 years 100 to 10,000 years	 9.0×10^{-14} 1.0×10^{-18} $<1.0 \times 10^{-18}$
Clay/Compacted Clay	1.0×10^{-18}
Asphalt	1.0×10^{-21}
Cementitious Grout	3.0×10^{-17}
Earthen Fill	1.0×10^{-14}
Salado Halite	1.0×10^{-21}
Salado DRZ	1.0×10^{-16} to 1.0×10^{-21}

5.0 Evaluation of Shaft Sealing System Design

In this section, the performance of the shaft sealing system is compared to the design guidance presented in Section 2. The design is evaluated with respect to this comparison and also with respect to the functions of the shaft sealing system. The performance expectations for the shaft sealing system are discussed, as well as analyses conducted to evaluate the sealing system. This section presents a summary of the analyses which demonstrate that the sealing system meets the design guidance and performance expectations. Further evaluation of the sealing system with respect to fluid flow is currently under way using two-phase flow models. These analyses will be available for the compliance certification package.

In general, the sealing system is divided into two functional regions: the upper seal system and the lower seal system. The compacted salt column comprises a member of the lower seal system. Performance expectations of the upper seal system are to separate water bearing zones and to retard the downward migration of brine into the compacted salt column. Design performance of the lower seal system is divided into short-term and long-term functions. In the short-term, the lower concrete component (Component 11) and the lower Salado compacted clay column (Component 12) are expected to retard the flow of brine and gas from the repository into the compacted salt column. The compacted salt column will consolidate during the short-term and will act as a permanent barrier to the flow of brine or gas through the sealing system to the regulatory boundary during the long-term.

There are two major long-term seal materials for the WIPP shaft sealing system: the upper and lower clay columns (Components 8 and 12), and the compacted salt column (Component 10). Redundancy of function is incorporated into the system to assure the salt is adequately protected while it consolidates. From above, asphalt, concrete, and clay protect the salt column. From below, clay and concrete with an asphalt waterstop protect the salt. After the salt column consolidates, the clay and perhaps the asphalt will also continue to provide long-term performance redundancy.

5.1 Structural Performance

Analyses were performed to evaluate structural considerations for seal components in the Salado formation. Components comprising the WIPP sealing system will be subjected to favorable, compressive stress conditions. Uniform compressive stresses will decrease void space, tighten any interfaces, heal microfractures in salt, and reduce permeability of the entire seal system. At this point in the design process, structural properties are available for materials that will be used for evaluating the configuration and locations of each sealing component. The materials are discussed in Section 4.0, and the configurations are shown in Drawing 33-SNL-005, Sheets 1 through 10 (Appendix B). During the next phase of design, additional component analyses will be conducted to verify that they are adequate to withstand the forces expected from rock creep and hydraulic pressure. Analyses used in the design of components are discussed below.

The principal structural considerations associated with the compacted salt column are:

- the rate at which the compacted salt consolidates, and
- the ability of the consolidating salt to create a compressive load (backstress) on the shaft walls.

Both the consolidation rate and the backstress are dependent on the initial density of the compacted salt, depth of emplacement, and elapsed time after emplacement. As the density of the emplaced salt increases, the consolidation rate decreases and backstress increases. Increase in backstress is desirable because it promotes healing of the DRZ. Analysis showed that compacted salt emplaced at a density approaching 90 percent of intact salt would consolidate sufficiently to meet the quantitative design guidance for long-term seals. Examples of results from these analyses are presented in Appendix D and Section 4.

The principal structural consideration associated with the clay and asphalt components was the determination of the time necessary to heal a portion of the DRZ adjacent to the components. Figure 4-3 shows the extent of the DRZ as a function of depth and time when compacted clay is used as the sealing material. This particular analysis demonstrates that the DRZ is healed near the lower Salado clay component in less than 25 years. Similar rapid healing of the DRZ is expected for other rigid or relatively incompressible seal materials used in this design.

The principal structural considerations associated with the concrete components are:

- determination of the effects that notches excavated in the shaft wall have on DRZ,
- time (after installation) required to heal the DRZ around the waterstop,
- time (after installation) required to heal the DRZ around the concrete plugs, and
- ability of the concrete plugs and host rock to accommodate shear and bearing stress imposed by overlying fill materials and/or pressure that may be imposed by brine or gas.

These analyses were used to choose the sizes and shapes of the asphalt waterstop and the concrete plugs. The analyses also identified stress levels in the concrete plugs as a function of time.

5.2 Fluid Flow Evaluation

Qualitative guidance on the performance of the system indicates the need to limit brine flow down the shaft and limit brine or gas flow up the shaft. Both considerations have impact on the time necessary for consolidation of the compacted salt column (Component 10). This component is therefore used to evaluate the performance of the remaining components during the first 100 years. If the compacted salt column is protected from the flow of brine from above, then the repository will be isolated from that brine flow as well. Similarly, the consolidating salt must be protected from upward flow of brine or gas during that period. Limitation of fluid flow into the salt column inherently limits upward migration of brine or gas through those components that overlie the salt column and, consequently, to the regulatory boundary. Quantitative design guidance (Section 2) has provided estimates of seal properties required to limit the flow of fluids in the shaft sealing system, and Section 3 gives specific purposes of each design component.

A comparative analysis of flow potential is described in Appendix D. This analysis compares flow potential, as defined by hydraulic conductance for both the cross-sectional seal material and the expected disturbed rock zone (DRZ), to the quantitative design guidance. Details of the single-phase fluid flow analysis are described in section D.3 along with the analysis assumptions and the associated parameters. Tables D-1 and D-2 provide both the absolute and normalized hydraulic conductance values for the lower and upper seal system

components. Results in these tables allow an evaluation of the degree to which the sealing system meets the design guidance; the quantitative guidance is met if the sum of the normalized conductances for the components of a system exceed unity. The degree to which an individual component can meet the quantitative system requirement for that function by itself can also be evaluated. Readers should not necessarily draw the conclusion (based solely on a low normalized conductance) that a particular component/material is ineffective because component length and the extent of the DRZ are both included in the conductance values, as discussed in Appendix D.

5.2.1 Upper Seal System

This section summarizes an evaluation of the upper seal system as compared to the design guidance for flow. A scoping analysis will also be provided in this section on the expected brine flow into the compacted salt column from the Rustler formation.

Both the qualitative and the quantitative design guidance for the upper seal system given in Section 2 are met at all times. Additionally, system confidence is very high because, at emplacement, two components meet the design guidance for the system and, within 50 years after emplacement, all components meet the design guidance by themselves. The total normalized conductance for the upper seal system is greater than 4.0 immediately after installation and improves with time because of DRZ healing. This result is not surprising because extensive lengths of very low permeability materials are used, and the permeability of the DRZ is not much higher than the needed system permeability. The upper seal system therefore meets the design guidance and offers redundancy for the regulatory period.

The following discussion presents a conservative approximation of brine flow down to the compacted salt column. Using Darcy's Law and assuming that the shaft above the upper compacted clay (Component 8) is filled with water, the predicted flow is:

$$\text{flow} = (\text{conductance}) \times (\text{height of water column}) \qquad (5\text{-}1)$$

The conductance for the clay seal material and surrounding DRZ is, from Table D-1, time-dependent for the first 100 years. Using the appropriate conductance at times 0, 10, and 50 years, a conservative calculation predicts a maximum of 30 m^3 of brine can flow through the clay column in 100 years (it is assumed that the conductance remains constant for the period between 50 and 100 years). The initial pore volume of the compacted salt column is approximately 500 m^3. As the salt consolidates, the pore volume is reduced. Brine saturation of the available pore volume will impede the consolidation rate. From Figure D-3 it is seen that, at 100 years, the fractional density at the midpoint of the salt column is approximately 95% of the density of intact halite. Based on this figure, a first-order approximation of the available pore volume at 100 years is 150 m^3. This pore volume is significantly greater than 30 m^3. This quantity of brine is not sufficient to impede consolidation of the salt column. This analysis takes no credit for seal components that overlie the clay seal material or the concrete component with an asphalt waterstop, which underlies the compacted clay. Therefore, it can be concluded that the upper seal system will meet the performance expectation of limitation of brine flow down into the salt column.

5.2.2 Lower Seal System

This section summarizes an evaluation of the lower seal system as compared to the design guidance for gas flow. Table D-1 identifies the effective conductance of various components that can limit gas or brine flow. With the exception of initial emplacement (t = 0), the system is effective at all times in meeting the quantitative design guidance for this system. The lower seal components comprising concrete with a water stop (Component 11) and compacted clay (Component 12) do not need to immediately meet the quantitative design guidance because gas pressure is expected to be minimal in the first few years after repository closure.

The lower compacted clay column will be capable of providing an effective gas seal. Two-phase flow dynamics are not considered in these calculations. The compacted clay column will be moist when emplaced. The current design specifies a gas threshold pressure of 2 MPa. Three physical characteristics of the sealing system control the flow of gas. These are the difference in fluid pore pressures across the seal (driving force), the gas threshold pressure of the seal, and the relative permeability of the seal (gas permeability). Because the clay column will be emplaced at a brine saturation approaching unity, the gas permeability of the clay seal will approach zero and at most will be one-tenth or one-hundredth of the intrinsic permeability of the clay (intrinsic permeability is used in the analyses presented in Appendix D). Substituting an intrinsic permeability one order of magnitude smaller than the one used for the clay column reveals that the normalized hydraulic conductance for the clay column and DRZ would be greater than 1 and would meet the guidance. For the seal to be an ineffective gas barrier at early times, the gas pressures at the base of the shaft would have to increase to pressures exceeding the pore pressure in the seal plus the gas threshold pressure of the seal material. Gas threshold pressure can be related to permeability (Davies, 1991). For a seal with a permeability of 1×10^{-18} m^2, the gas threshold pressure could be several MPa. Therefore, even though the single-phase calculations show that the lower seal does not meet the quantitative design guidance at closure, two-phase flow dynamics will result in an effective gas seal.

6.0 Conclusions

The WIPP shaft sealing system design documented in this report is an effective, implementable design concept. The design concepts were developed through an interactive process involving technical specialists in the design and construction of underground facilities, materials behavior, rock mechanics analysis, and fluid flow analysis. The design uses (1) a variety of common materials that have very low permeability, (2) demonstrated technologies for construction processes, (3) multiple components to perform each intended function, and (4) the entire length of the shafts to effect a sealing system. In addition, the design incorporates recent developments related to:

- successful demonstrations of compaction technology for salt compaction;
- attainment of high densities and accompanying low permeabilities in consolidating crushed salt;
- development of a constitutive model for crushed salt consolidation;
- design guidance that better quantify performance goals for, and the importance of, seal permeability;
- design guidance on functional requirements for seal components;
- development of improved capabilities for simulating WIPP salt creep behavior and potential DRZ development and healing;
- successful retesting (~10 years after emplacement) of WIPP small-scale concrete seal performance, which shows permeability ~10^{-20} m^2; and
- additional information from WIPP studies, international studies, and construction experience related to the very low permeabilities of salt-saturated concrete, asphalt, and clay.

The designers have provided a shaft sealing system that is an effective barrier to brine and gas flow. For the permanent or long-term seal that resists both gas and brine flow, robustness is achieved by providing more than 500 ft of a highly-compacted crushed salt barrier in series with more than 400 ft of clay barriers. The design retards gas flow in the short-term using a redundant combination of a rigid concrete barrier (enhanced by an asphalt waterstop included as an additional DRZ barrier) and a compacted clay barrier approximately 100 ft in length. Finally, short-term brine flow down the shaft is limited by a clay barrier within the Rustler Formation and by a combined length of more than 500 ft of asphalt, clay, and concrete barriers within the Salado Formation. These design concepts form the basis for No-Migration Variance Petition modeling, initiation of the detailed design development, and evaluations that will be completed in 1996 for incorporation, as appropriate, into the Compliance Certification Application.

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Appendix A:
Results of the Shaft Stratigraphy and Geohydrology Evaluation

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Results of the Shaft Stratigraphy and Geohydrology Evaluation

The purpose of evaluating the shaft stratigraphy and geohydrology at the Waste Isolation Pilot Plant (WIPP) is to establish the geologic and hydrologic information base required for design of the WIPP Facility Shaft Sealing System. The evaluation was completed in two phases. Phase I included:

- Confirmation of previously determined elevations of named stratigraphic unit contacts and marker beds from surface to total depth of the shafts, as ascertained from geotechnical reports on geologic mapping of each shaft during construction.
- Summary of regional groundwater occurrence intervals, as well as intervals of groundwater/ brine seeps logged during the geologic mapping of each shaft.
- Summary of clay presence in marker beds as logged during the geologic mapping of each shaft.
- Compilation of the stratigraphic data into a data base of named stratigraphic unit contacts and their mean sea level (MSL) elevations that intersect all four WIPP shafts.
- Construction of geologic structural cross-sections through the excavated shafts utilizing the compiled stratigraphic data base (SDB).

Phase II focused on further evaluation of brine occurrence within the exposed Salado Formation section and survey control for determining a reference point for use when determining subsurface depths. The Phase II evaluation of each shaft included:

1. Detailed correlation and projection of brine seepage intervals between the shafts, which was accomplished by compiling and evaluating data from available geotechnical shaft inspection reports, shaft geotechnical reports, and recently published groundwater reports to identify additional intervals of brine seepage that were not analyzed in previous shaft design studies.
2. Research of survey information to secure copies of the original survey plats, which document ground surface elevation for each shaft.
3. Review of shaft as-built diagrams to determine
   - a consistent surveyed datum, based on mean sea level (MSL), for reference when computing below-surface depths of named stratigraphic unit contacts and other relevant intervals of engineering design interest and
   - consistency between elevations of engineering and lithologic features in the shafts recorded on as-built drawings and shaft geotechnical reports.

A.1 Stratigraphic Evaluation

A.1.1 Correlation of Stratigraphic Contacts

Correlated stratigraphic unit contacts presented in the four shafts are expressed in MSL elevations. Figures 1 and 2 are geologic structural cross-sections based on MSL elevations. It

should be noted that there is a 400 ft (122 m) north-south offset between the Salt Handling shaft and the Waste Shaft as indicated on the figure legends. The cross-sections are presented here in a straight line format for ease of comparing stratigraphic consistency between adjacent shafts. These figures illustrate that the stratigraphic unit contacts are consistent both vertically and horizontally between the shafts. Some stratigraphic contact elevations vary because of regional structure and the stratigraphic thinning and thickening of units. However, the majority of the stratigraphic contacts used to date are suitable for the shaft stratigraphy correlation project because they intersect all four shafts. The exceptions are the following marker beds, listed in Table 1, which (1) do not correlate among all four shafts because of localized thinning and pinch-outs, (2) are erosional surfaces, or (3) simply were not recorded during the geologic mapping of the shaft wall.

Table 1. Marker beds unsuitable for correlation

Stratigraphic Contact	Comment
Mescalero Caliche	Not mapped in air intake and waste shafts.
Gatuña Formation	Not mapped in waste shaft.
Dewey Lake Red Beds	Erosional contact - highly irregular upper surface.
MB-100	Not present in all four shafts.
MB-119	Not present in all four shafts.
MB-120	Not present in all four shafts.
MB-125	Not present in all four shafts.
MB-133	Not present in all four shafts.
MB-137	Not present in all four shafts.
Anhydrite b	Not present in all four shafts.
MB-139	Not penetrated by all four shafts.

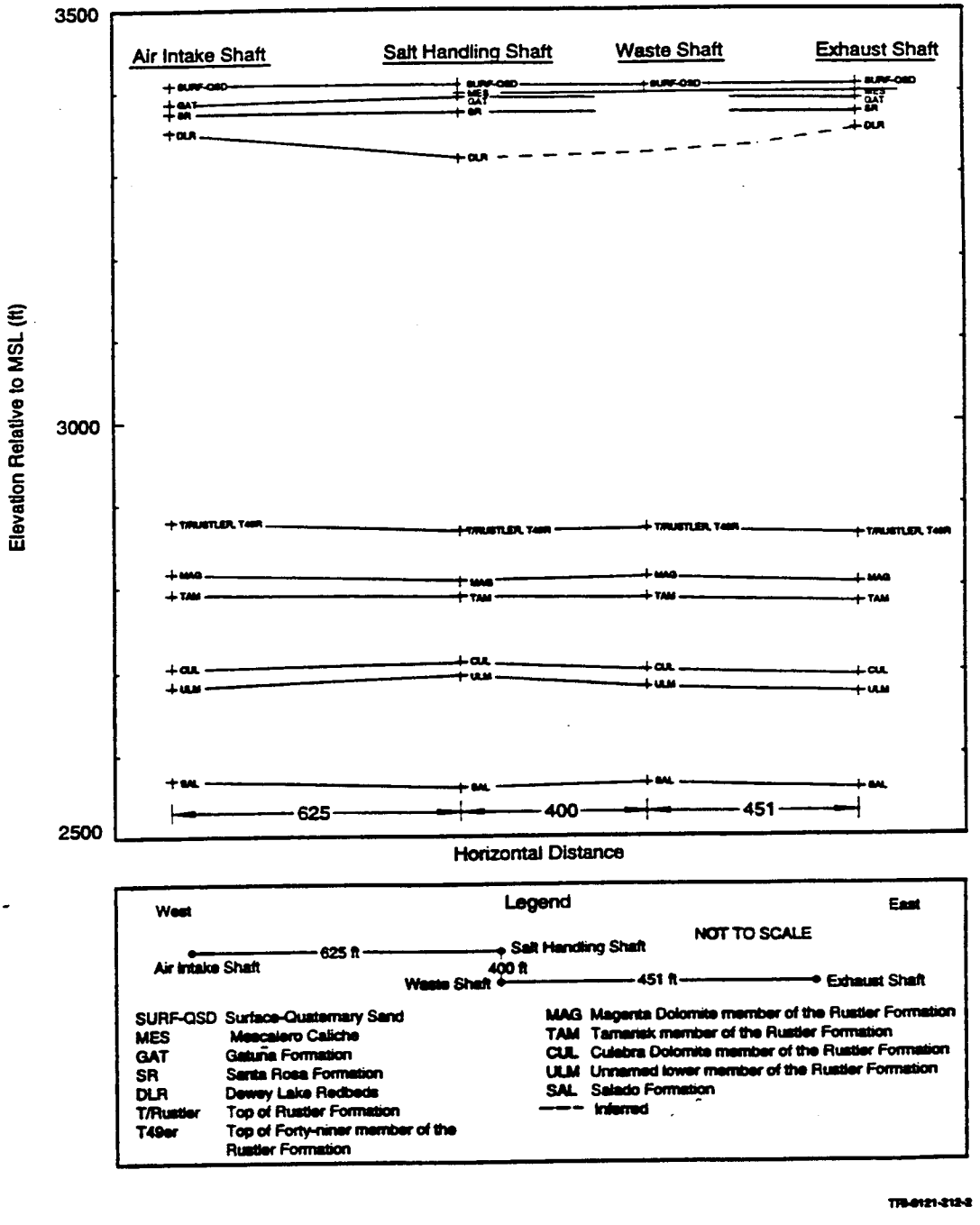

Figure 1. Structural Cross-section through excavated shafts, ground surface to top of Salado Formation.

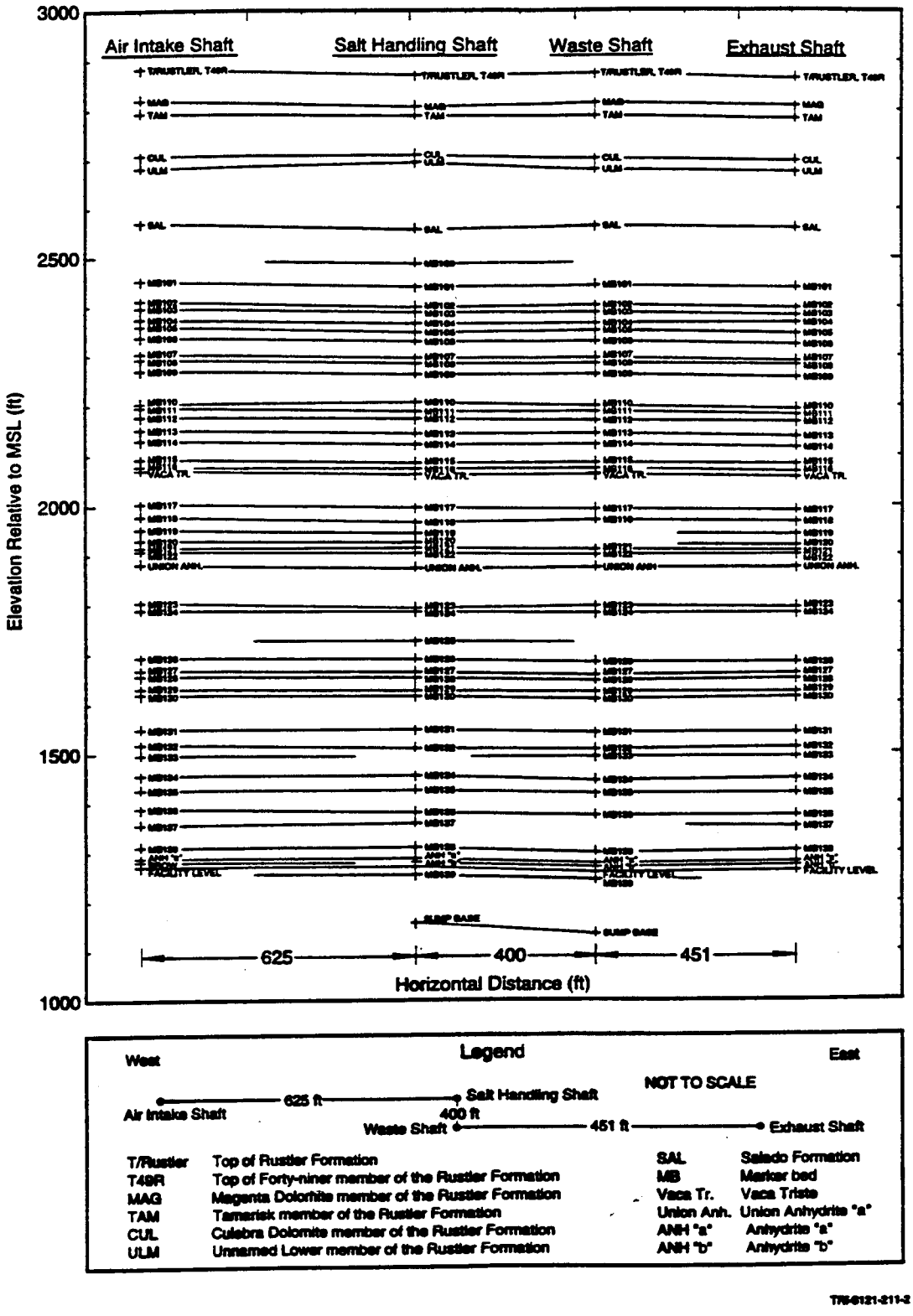

Figure 2. Structural Cross-section through excavated shafts, top of Rustler Formation to total depth.

A.1.2 Sources of Information/Methodology of Stratigraphic Correlations

Lithologic logs, surface elevation references, and previous stratigraphic interpretation were secured from the sources listed in Table 2. It should be noted that, since its construction, the Salt Handling Shaft has had several names. At various times it has been called the *Exploratory Shaft*, the *Construction and Salt Handling Shaft*, and the *Salt Handling Shaft*. Currently, and therefore in this report, it is called the Salt Handling Shaft. Also note that the Waste Shaft was called the *Ventilation Shaft* during the initial phases of its construction.

Table 2. Stratigraphic information sources

Shaft	Document Number (Author)	Document Title
Exhaust	DOE-WIPP-86-008 (Holt and Powers, 1986)	Geotechnical Activities in the Exhaust Shaft
	DACW47-83-B-0010	Contract Drawings-CCP-1F6/1D Underground Experimental Areas/Waste Shaft and Exhaust Shaft (Drawing 35-R-004-O1D)
Waste (formerly called Ventilation Shaft)	WTSD-TME-038(Holt and Powers, 1984)	Geotechnical Activities in the Waste Handling Shaft
	(TSC-D'Appolonia, 1983) GFDR No. 4	Geologic Mapping and Water Inflow Testing in the SPDV Ventilation Shaft
	WTSD-TME-3179 (Jarolimek et al., 1983b)	Correlation of Drillhole and Shaft Logs Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico
Salt Handling (formerly called Exploratory or Construction & Salt Handling)	TME 3178 (Jarolimek, Timmer, and McKinney, 1983a)	Geotechnical Activities in the Exploratory Shaft-Selection of the Facility Interval
	WTSD-TME-3179 (Jarolimek, Timmer, and Powers, 1983b)	Correlation of Drillhole and Shaft Logs Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico
	DOE-WIPP-86-010 (US DOE, 1986)	Waste Isolation Pilot Plant Design Validation Final Report Appendices
Air Intake	DOE-WIPP-90-051 (Holt and Powers, 1990)	Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant
	DACW47-83-B-0010	Contract Drawings - CCP-1F6/1D Underground Experimental Areas/Waste Shaft and Exhaust Shaft (Drawing 35-R-004-01D)

To confirm previous correlations, each shaft lithologic log was enlarged or reduced to a consistent scale of 1 in. = 10 ft. The lithologic log from the Air Intake Shaft (AIS) was used as the control log for correlations because it recorded the vertical occurrence of named stratigraphic unit contacts from ground surface to total depth at the facility level.

Correlation of the shaft logs required a side-by-side comparison with the AIS log. The tops and bases of the stratigraphic units were marked or confirmed and recorded as elevations relative to MSL. Several named stratigraphic unit contacts were not recorded on all four shaft logs during the original mapping program. Unrecorded named stratigraphic units were correlated with adjacent shaft logs. The newly correlated named stratigraphic unit contacts are listed in Table 3.

Table 3. Newly correlated named stratigraphic unit contacts

Shaft	Stratigraphic Unit	Unit Top (ft-MSL)
Exhaust	MB-125	Not Present (Pinched out)
Waste	MB-119	Not Present (Pinched out)
	MB-120	Not Present (Pinched out)
	MB-125	Not Present (Pinched out)
Salt Handling	MB-130	1613.5
	MB-133	Not Present (Pinched out)
Air Intake	MB-106	2335.5
	MB-113	2150.0
	MB-114	2127.0
	MB-125	Not Present (Pinched out)
	Anhydrite a	1287.5

Ground surface (finished grade) MSL elevations and the survey control were recorded and evaluated for reliability. The surveyed ground surface (finished grade) MSL evaluations and reference sources are listed in Table 4.

A.1.3 Clay Associated with Marker Beds

Clay layers, when continuous, often form impermeable seams upon which water will migrate. When shafts are excavated, seeps or increased moisture content are often observed immediately above a clay layer. In some instances, if the clay was buried prior to dewatering, the clay layer can yield some water as it dewaters and consolidates after being exposed subsequent to shaft construction (Deal et al., 1995).

Clay was observed in association with a majority of the designated marker beds; it was located typically at the marker bed base and ranged from thin clay blebs (small, usually rounded inclusions of clay) to thicknesses of 1 ft. Most clay layers fall into a thickness range between 1 and 6 in. Occurrence of clay related to marker beds has been entered into the shaft SDB. Information relating to clay occurrence was secured from the lithologic logs in the following

reports: Holt and Powers, 1986; Holt and Powers, 1984; Jarolimek et al., 1983b; Holt and Powers, 1990.

Table 4. Surveyed ground surface (finished grade) MSL evaluations and reference sources

Shaft	Ground Surface (Elevation: ft-MSL)	Information Source
Exhaust	3410.0	Contract Drawings - CCP-1F6/1D;/ Drawing 35-R-004-01D. Based on USGS Survey Reference.
Waste	3407.5	Construction Survey; Table 1 WTSD-TME-038 (Holt and Powers, 1984) and Waste Shaft 311 General Arrangement Plans and Sections: Bechtel Job No. 12484 Drawing 31-R-013-01D Revision A
Salt Handling	3410.5	Surveyed Elevation tied to CWI Benchmark No. CW-1. DOE-WIPP 86-010 (US DOE, 1986)
Air Intake	3409.0	Contract Drawings CCP-1F6/1D:/ Drawing 35-R-004-01D based on USGS Survey Reference.

Although benchmark references were not noted for each shaft, each survey referenced a USGS Survey Reference.

A.1.4 Shaft Stratigraphic Data Base

The stratigraphic unit top and bottom MSL surface elevation, ground surface elevation (finished grade), and elevations of selected engineering features were recorded in a spreadsheet-based data base, the SDB. The SDB records the following information for each shaft:

- Engineering features (top of concrete, base of key, and station level)
- Ground Surface (finished grade)
- Stratigraphic unit contact name
- Unit top MSL elevation
- Unit bottom MSL elevation
- Groundwater/brine observance
- Clay observance
- Comments relating to the stratigraphic unit or engineering feature.

The MSL elevations were rounded to the nearest 0.10 ft. Values from 0.05 to 0.09 were rounded up, and values less than 0.05 were rounded down. SDB summaries for each shaft are provided in Section A4.0 of this appendix.

A.2 Groundwater / Brine Occurrence

A.2.1 Regional Groundwater Occurrence Intervals within the Shafts

A review of the regional geohydrology of the WIPP site and surrounding area identified six regional intervals of groundwater occurrence (Beauheim and Holt, 1990). These intervals are listed in Table 6.

Table 6. Regional Intervals of Groundwater Occurrence

Stratigraphic Unit	Remarks
Rustler Formation	
Forty-niner Member	Aquitard; water producing unit is a claystone interbedded with andhydrite and or gypsum units.
Magenta Dolomite Member	Regional aquifer; consists of fine grained gypsiferous arenaceous dolomite.
Tamarisk Member	Aquitard; consists of claystone sandwiched between two anhydrites.
Culebra Dolomite Member	Regional aquifer; consists of a finely crystalline, locally argillaceous and arenaceous, vuggy dolomite.
Unnamed Lower Member	Aquitard; consists of interbedded siltstone, sandstone, halite, and anhydrite. Regionally has two water producing units; however only one is present at the WIPP site. It is characterized by low permeability.
Rustler/Salado Formation Contact	Groundwater seeps at formation contact; general area of "brine aquifer" at Nash Draw

A.2.2 Groundwater / Brine Occurrence in the Salado Formation

A literature and data search was performed to identify groundwater/brine occurrence intervals in the Salado Formation. This search included review of geotechnical shaft reports, geotechnical shaft inspection reports, and WIPP site-specific published hydrologic/groundwater reports. Groundwater encountered in the Salado Formation appears in the form of seeps and weeps (i.e. small volumes of water oozing from the rock that produce a damp, moist, or wet surface). There has been no quantification of fluid flow associated with weeps or seeps. The groundwater is salt saturated and is identified in the literature as brine.

The geotechnical reports and associated lithologic logs for the Salt Handling, Waste, and Exhaust shafts did not include notations of observed brine seepage intervals within the Salado Formation section. The AIS geotechnical report (Holt and Powers, 1990), documenting the geologic mapping of the shaft, provided excellent data for identifying brine seepage intervals occurring within the Salado Formation section.

Within the AIS, seventeen intervals (excluding the potential seepage interval at the Rustler/Salado interface) are identified as producing brine seepage. The extent of seepage varied from the mention of recent weeps to abundant weeps. Two other zones of seepage below the repository (MB 139 and MB 140) that intersect shaft sumps in the waste and salt handling shafts were identified through personal communications with experimenters at Sandia National Laboratories for a total of 19 seepage intervals within the Salado Formation. The intervals located above the repository are listed in Table 7. Seepage intervals that did not correspond to a previously named lithologic unit were assigned zone designations for the purpose of conveying information in this report.

There were no notations indicating volume quantities of brine seepage from the identified seepage intervals. Four of the seventeen intervals observed in the AIS (MB 103, MB 124, Vaca

Triste siltstone, and Union Anhydrite) were identified during the AIS mapping as primary brine-producing intervals in the Salado Formation (Holt and Powers, 1990). Quantities of seepage observed in the AIS can be placed into perspective by contrasting the Salado Formation seepage notations with the recorded water-inflow data from the Rustler Formation aquifers in the Salt Handling Shaft. The Rustler Formation aquifers flowed less than a total of 1.5 gallons per minute into the shaft prior to liner installation. After liner installation, the inflow rate dropped to less than 0.1 gallons per minute (Jarolimek et al., 1983a). The Geotechnical Shaft reports for the Exhaust, Waste, and Salt Handling shafts did not indicate intervals of brine seepage deeper than the Rustler/Salado Formation interface; however, Saulnier and Avis (1988) conducted pulse injection tests using a multipacker tool at the 850 ft and the 1320 ft intervals within the Waste Handling Shaft. Within these intervals hydraulic conductivity values for halite, polyhalite, and anhydrite were determined. The hydraulic conductivities and associated derived intrinsic permeabilities (in parentheses) are recorded as follows:

- Halite: 1.0E-13 to 3.0E-14 m/s (1×10^{-20} m^2 to 4×10^{-21} m^2)
- Polyhalite: 2.0E-14 m/s (3×10^{-21} m^2)
- Anhydrite: 3.0E-14 m/s (4×10^{-21} m^2).

To anticipate that the brine seepage intervals documented in the AIS have lateral extent and potentially intersect all four shafts, these intervals were projected through correlation of the shaft lithologic logs, from the AIS to the other four shafts, as illustrated in Figure 3. The cross-sections in Figures 4 through 7 illustrate the relationship of the newly designated brine seepage intervals (seepage zones) to the identified marker beds. These identified brine seepage intervals are recorded in the SDB for each shaft which is presented in Section A4.0 of this appendix.

Table 7. Brine seepage intervals occurring within the Salado Formation section

Marker Bed/Zone	Unit Top (ft-MSL)	Unit Bottom (ft-MSL)
MB103	2397.0	2380.5
MB109	2268.5	2243.1
Vaca Triste	2070.0	2062.0
Zone A	1925.0	1915.5
MB121	1915.5	1914.0
Union Anhydrite	1881.0	1873.5
MB124	1788.0	1779.1
Zone B	1736.5	1733.5
Zone C	1709.0	1700.0
Zone D	1650.5	1640.0
Zone E	1640.0	1638.0
Zone F	1638.0	1635.0
Zone G	1635.0	1633.0
Zone H	1633.0	1627.1
MB129	1627.1	1625.6
Zone I	1625.0	1619.3
Zone J	1546.9	1542.9

Note: Zones E through H are identified separately because of variable lithologies within that section of the AIS.

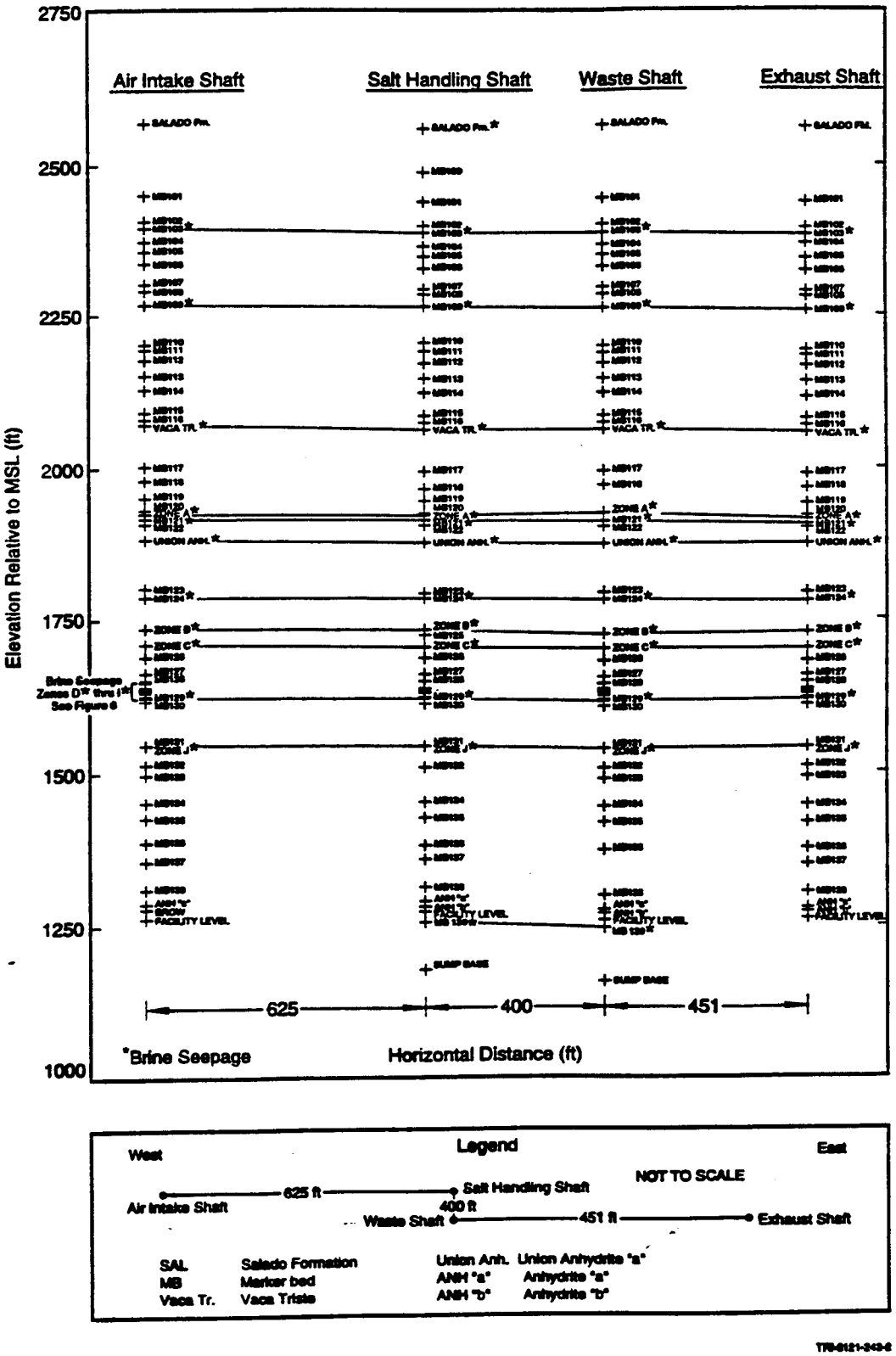

Figure 3. Structural Cross-section through excavated shafts, showing correlation of mapped brine seepage intervals, top of Salado Formation to total depth.

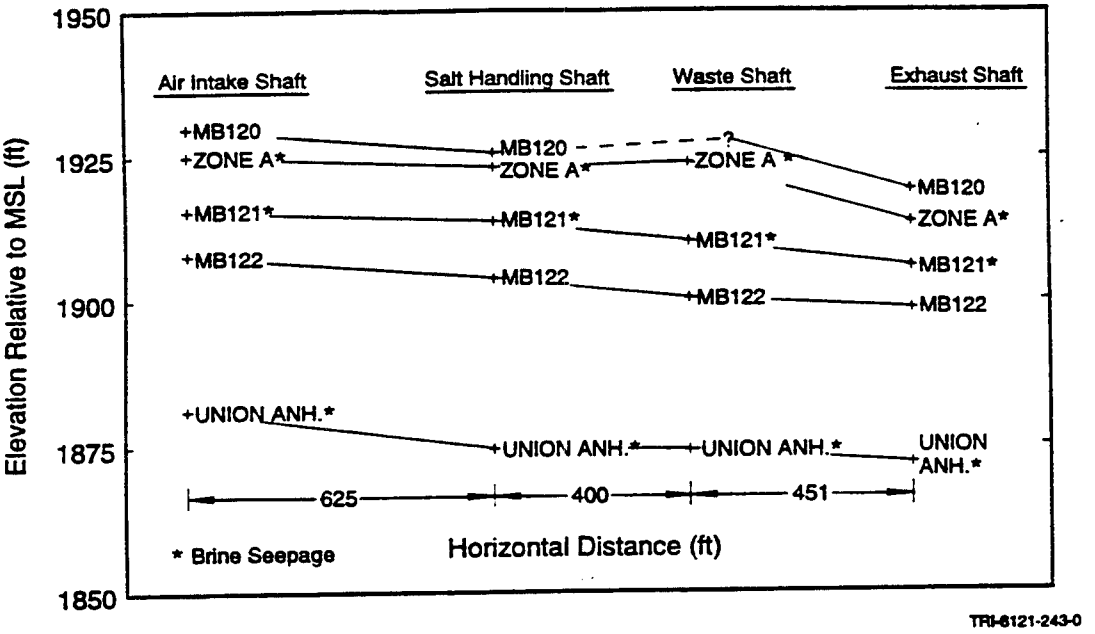

Figure 4. Brine seepage zone A.

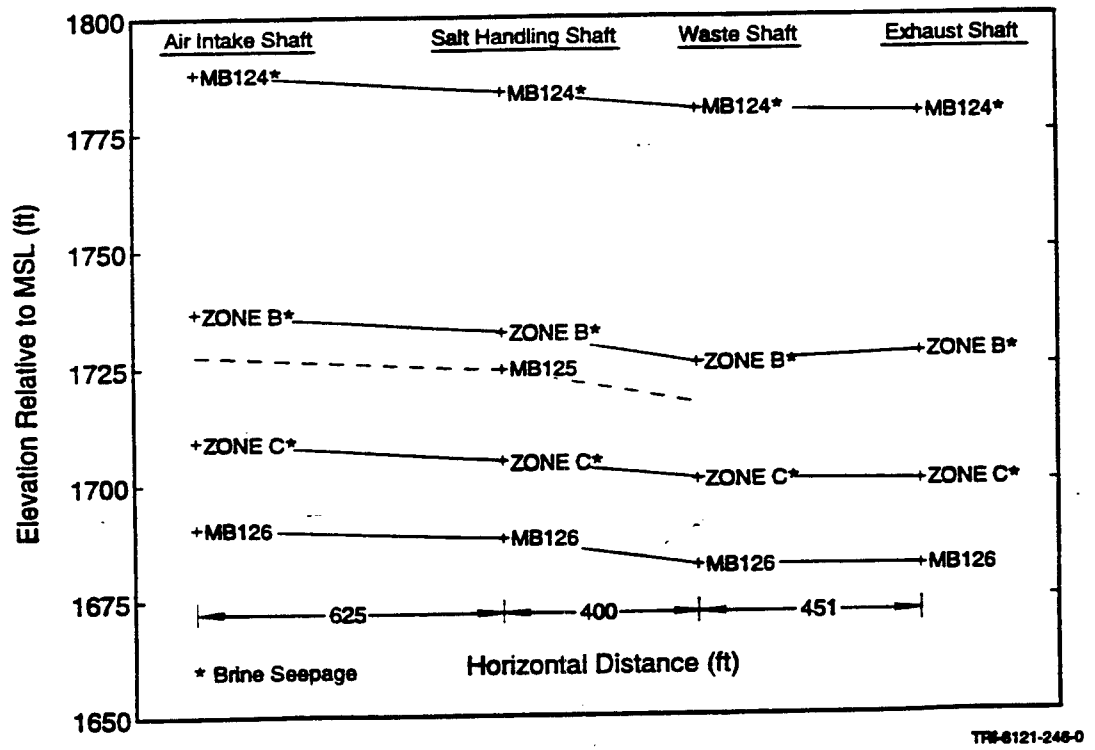

Figure 5. Brine seepage zones B and C.

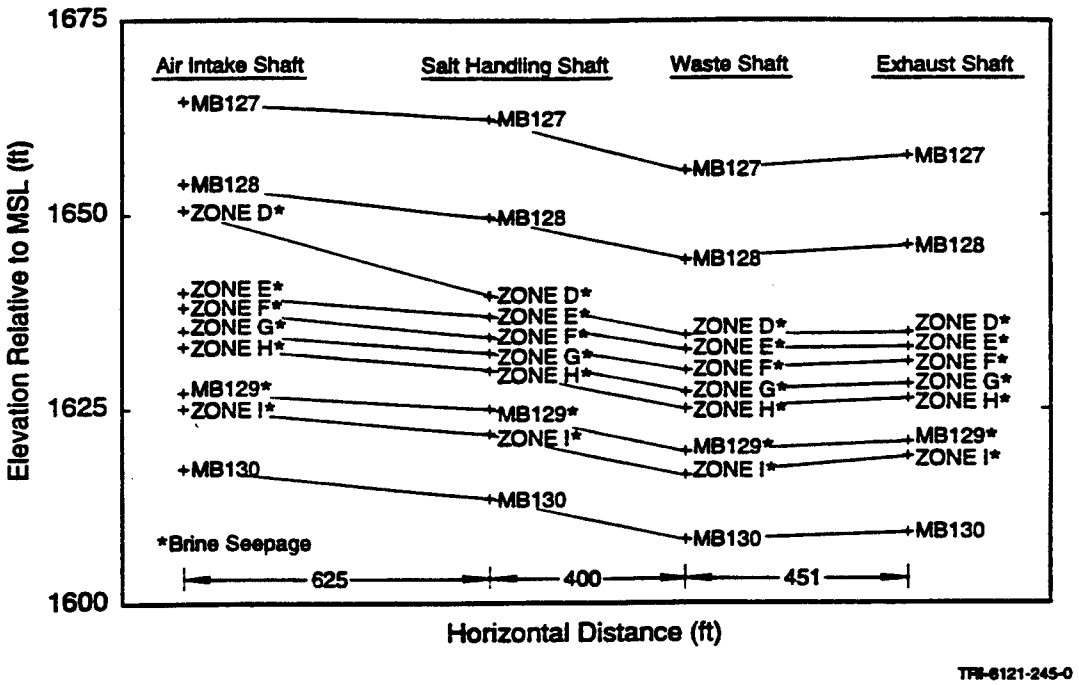

Figure 6. Brine seepage zones D through I.

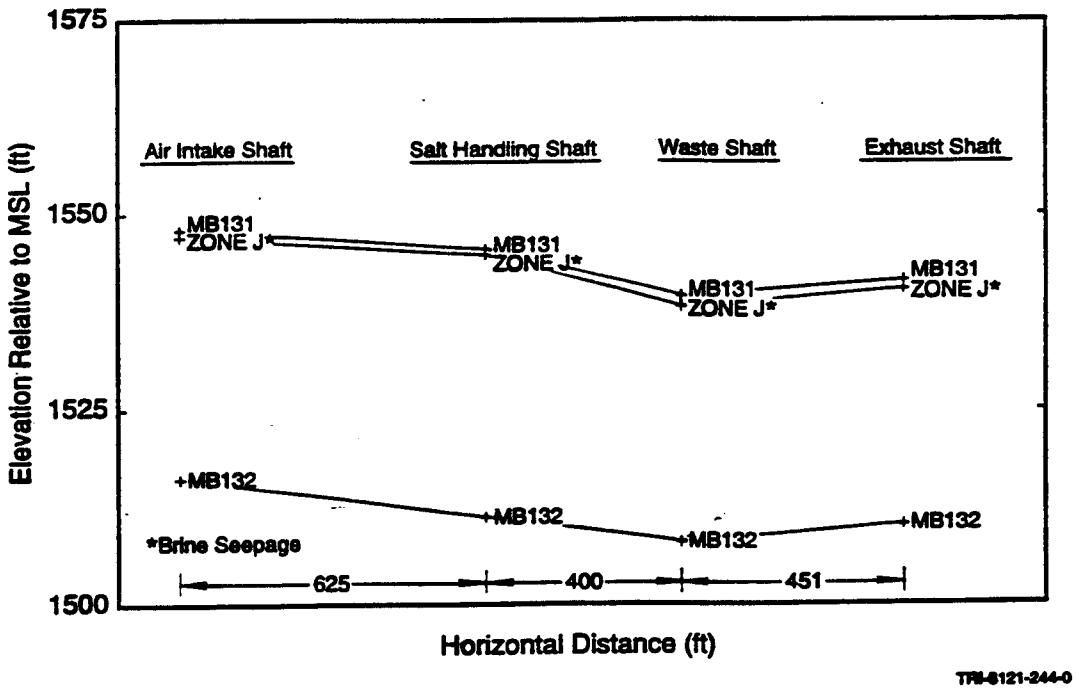

Figure 7. Brine seepage zone J.

To evaluate current brine seepage conditions, Westinghouse Waste Isolation Division staff were contacted in January of 1994 concerning the availability of the shaft geotechnical inspection reports for each shaft. Staff members indicated that the reports are available for review; however, these inspection reports concentrate on groundwater conditions within the Rustler Formation (Lower Seal System) and that the reports do not denote brine seepage intervals in the Salado Formation (Salado Salt Column). During trips in and out of the shafts, some damp clay seams within the Salado Formation have been observed (conversation with Westinghouse engineering staff; January 1994). These intervals have not been logged in the shaft inspection reports. Westinghouse staff mentioned that the best records of brine seepage intervals in the Salado Formation are the lithologic logs that were assembled during the lithologic mapping of each shaft (Jarolimek et al., 1983b; Holt and Powers, 1984; Holt and Powers, 1990; Holt and Powers, 1986). These reports were obtained and used to assemble the SDB. Copies of the shaft inspection records were not requested because they do not note the brine seepage intervals in the Salado Formation penetrated by the shafts.

Subsequent to contacting Westinghouse Waste Isolation Division staff concerning availability of recent geotechnical inspection reports, an inspection— which emphasized observance of brine seepage and associated salt encrustations— was performed in the AIS (Deal et al., 1995). This inspection was conducted during July 1994 as part of the Brine Sampling and Evaluation Program (BSEP). As reported in Deal et al. (1995), the AIS observations were made from the shaft man cage which moves vertically approximately 9 feet from the shaft wall. The Salado section was initially observed on the way down to the repository level. A more detailed inspection was conducted during the ascent. On the ascent salt encrustations, indicating seepage when moist or previous seepage when dry, were marked according to their location on the lithologic log developed during shaft mapping (Holt and Powers, 1990). Seventy-three salt encrustations were logged during the observation. The encrustations observed were related to rock bolts, thin localized argillaceous (clayey) intervals and previously identified seepage intervals. Pictures taken of significant salt encrustations during the observations indicate that seepage associated with the encrustations was primarily localized (i.e. point source) with the exception being encrustations located in zones that were originally mapped as producing brine. MB 103 was the only encrustation interval that was observed to be wet indicating active brine seepage. From the man cage it was not possible to determine if there was moisture present beneath encrustations observed to be dry at the exposed surface. Most of the sulfate beds (anhydrite and polyhalite) and especially the polyhalite units showed no weeps or encrustations (Deal et al., 1995).

Observations were also conducted in the Waste and Salt Handling shafts (Deal et al., 1995). In these shafts the Salado section above the shaft sump was obscured primarily by grout spillage from shaft key and liner installation. Observations in the sump of the Waste and Salt Handling Shafts did not show moisture at the surface or in the open fractures of Marker Bed 139 (Deal et al., 1995).

A.2.3 Typical Rustler and Salado Formation Hydraulic Conductivity/Transmissivity Values

The literature was searched for hydraulic conductivity values associated with different lithologies encountered within the Salado Formation (Salado Salt Column Interval), as well as transmissivity data for water bearing units of the Rustler Formation. Such values will assist in relating the documented occurrences of brine seepage to potential fluid (brine) inflow to the

Salado Formation Subsystem. The hydraulic conductivity data for various lithologies encountered within the Salado Formation, and the transmissivity data for water bearing units encountered in the Rustler Formation (Forty-niner Member, Magenta Dolomite Member, Tamarisk Member, Culebra Dolomite Member, and the unnamed lower member), are profiled in Table 8.

Table 8. Typical Rustler and Salado Formation hydraulic conductivity/transmissivity values

Stratigraphic Unit	Lithology	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)	Relevant Reports/ Comments
Forty-niner Member	Claystone Clay		1.73E-05 to 3.46E-04	SAND87-0039 (Beauheim, 1987)
Magenta Dolomite Member	dolomite		9.23E-03 or less up to 9.29E-02	SAND90-2035J (Beauheim and Holt, 1990)
Tamarisk Member	claystone		9.29E-05 or less	SAND90-2035J (Beauheim and Holt, 1990)
Culebra Dolomite Member	dolomite		Less than 3.72E-04 to 1.16E+02	SAND90-2035J (Beauheim and Holt, 1990)
Unnamed Lower Member	silty claystone		9.29E-06 to 5.75E-05	SAND90-2035J (Beauheim and Holt, 1990); Potential communicator with Culebra. Three zones compose this unit; however, only zone 1 is present within the WIPP boundary.
Salado Formation	halite, argillacious	1.22E-09 to 2.13E-08		SAND90-2035J (Beauheim and Holt, 1990)
	halite	Less than 3.05E-11 10.0E-14 to 2.59E-09		SAND90-2035J (Beauheim and Holt, 1990) SAND88-7001 (Saulnier and Avis, 1988)
	polyhalite	1.82E-09 1.73E-09		SAND89-0462 (Lappin et al., 1989); Table 3-2 Waste Shaft SAND88-7001 (Saulnier and Avis, 1988)
	anhydrite	3.05E-08 to 6.09E-07 2.59E-09		SAND90-2035J (Beauheim and Holt, 1990); MB139, approximately 3 ft thick. Hydraulic conductivity depends on the amount of fracturing present. Pore pressures show distinct gradient towards the underground facility. Pressures as high as 1700 psi have been measured at distances of 35 ft from excavations. SAND88-7001 (Saulnier and Avis, 1988)

*Note: Salado brines which flow into the WIPP Facility are not derived from fluid inclusions, but instead are grain boundary fluids with residence times of at least several million years (Stein and Krumhansl, 1986).

*Note: Permeability increases around the facility within 5 to 10 ft because of fracturing and possible matrix dilation (Beauheim and Holt, 1990).

A.3 Shaft Survey Data

A.3.1 Original Survey Coordinates and Surface Elevations

Westinghouse staff were contacted concerning the availability of the original survey plats that show the coordinates and the surface elevation of each shaft location prior to shaft construction. The original survey plats are not available; however, the shaft coordinates and surface elevations are recorded on the as-builts for each shaft. A comparison was made between the ground surface (finished grade) elevations secured from the Bechtel and Westinghouse as-built drawings for each shaft and those recorded in the SDB. Results of the comparison are presented in Table 9.

Table 9. Comparison between ground surface (finished grade) elevations secured from Bechtel and Westinghouse as-built drawings and those recorded in the SDB

Shaft	Ground Surface Elevation (Finished Grade) SDB (ft-MSL)	Surface Elevation Bechtel/Westinghouse As-Built (ft-MSL)	Difference In Elevation Data (SDB less As-Built) (ft)
Air Intake	3409.0	3409.0	0.0
Exhaust	3410.0	3409.9	0.1
Salt Handling	3410.5	3411.0	-0.5
Waste	3407.5	3407.5	0.0

The comparison of surface elevation data illustrates relative consistency between (1) surface elevations reported in geotechnical reports and working drawings, and (2) the data recorded on the Bechtel/Westinghouse as-built drawings for each shaft. The two minor discrepancies noted are in the Exhaust Shaft and the Salt Handling Shaft, which reflected differences of 0.1 ft and 0.5 ft respectively.

A.3.2 Review of Shaft As-Built Drawings to Determine a Consistent Surveyed Datum

Current shaft as-built drawings were secured from Westinghouse. These drawings were reviewed to determine a consistent surveyed datum, based on MSL, for reference when computing below-surface depths of named stratigraphic unit contacts and other relevant intervals of engineering design interest. The shaft as-built drawings for each of the shafts utilized a surveyed reference datum elevation of 3409.0 ft MSL based on the 1927 USGS North American Datum. For computing below-surface depths in the shafts, the reference datum of 3409.0 ft MSL is equated to a reference level 0'-0" (i.e., reference level 0'-0" = 3409.0 ft-MSL based on the USGS North American Datum). Elevations of selected features and/or objects within each shaft, and the reference drawings used to determine these elevations, are incorporated into the SDB (Attachment 1). The as-built drawings reviewed for each shaft and general survey information are marked "Info Only" and are current to February 18, 1994. The survey information and shaft as-built drawings reviewed are outlined in Tables 10 through 14.

Table 10. Site Work/Site development overall plans

Drawing Number	Title
24-C-053-005 Rev. B Sheet 1/2 and 2/2	Site Work, Site Development Overall Plan. (Inactivated per ECO#5667)
24-C-060-005 Rev. A Sheet 1/2 and 2/2	Site Work – Rough Grading Plan. (Inactivated per ECO#5567)
24-C-075-005 Rev. B. Sheet 1/2 and 2/2	Site Work – Rough Grading Plan and Sections. (Inactivated per ECO#5567)
24-C-078-005 Rev. B Sheet 1/2 and 2/2	Site Work – Rough Grading Sections.
21-C-011-SF9 Rev. 10	Base Line Monuments Plans & Sections.
21-V-002-W Rev. B	WIPP Site Surveys and Subsidence Monuments.
21-C-0012-SF9 Rev. 6	Subsidence Monuments Plans and Details.

Table 11. Air Intake Shaft as-builts reviewed

Drawing Number	Title
33-R-001-34A Rev. 4	Air Intake Shaft 331 General Arrangement Plans and Sections.
33-D-002-W	Air Intake Shaft 331 Shaft Collar/Air Intake Platform Plan, Sections and Details (new).
33-C-001-W	Air Intake Shaft 331 Shaft Collar/Air Intake Platform Plan, Sections and Details (new).
33-C-004-W1 and W2	Air Intake Shaft 331 Shaft Key Plan, Sections and Details (new).
33-D-008-W	Air Intake Shaft 331 General Arrangement (new).
51-W-212-W	Air Intake Shaft 331 Shaft Station Plans, Sections and Details.

Table 12. Salt Handling (Exploratory Shaft) as-builts reviewed

Drawing Number	Title
37-R-010 Rev. A	Key and Shaft Station Location Section.
37-R-023 Rev. A	General Arrangement at Surface Plan and Section.
37-R-012 Rev. A	Key Sections and Details.
24-C-202-05A Rev. A	C&SH Shaft Collar Modification Plan Sections & Details.
24-C-202-1Fc-4 Rev. G p.7	C&SH Shaft Collar Area. C&SH Shaft Collar Modification Plan Section & Details.
37-R-019 Rev. A	Station Develop. - Experimental Level Plan and Sections.
37-R-010 Rev. A	Key and Shaft Station Location Section.

Table 13. Waste Shaft as-builts reviewed

Drawing Number	Title
31-R-001-01D Rev. B	Waste Shaft 311 Shaft Development Sections.
31-R-002-01D Rev. A	Waste Shaft 311 Shaft Lining and Key Section and Details.
31-R-013-01D Rev. B	Waste Shaft 311 General Arrangement Plans and Sections.
A-0001	As-Built for Waste Shaft Collar.

Table 14. Exhaust Shaft as-builts reviewed

Drawing Number	Title
S-020	Exhaust Shaft with Collar Layout.
S-024	Detail Exhaust Shaft Layout.
35-R-004-01D Rev. B	Exhaust Shaft 351 General Arrangement Plans and Sections.
35-R-002-01D Rev A.	Exhaust Shaft 351 Shaft Living and Key Section and Details.
35-R-004-01D Rev. A	Exhaust Shaft 351 General Arrangement Plans and Sections.

A.3.3 Designation of Surface Reference Point

A physical surface reference point needs to be designated for the shafts to facilitate completion of the sealing system design drawings and final seal emplacement. It was recommended that the designated surface reference point elevation chosen for the shaft seal design drawings be the "top of concrete" for each shaft. "Top of concrete" is defined as the top of the collar for the Waste and Exhaust shafts, and the top of the existing shaft for the Salt Handling Shaft. "Top of concrete" for the AIS is defined as the top of the plenum. Table 15 identifies the designated surface reference, surface reference elevation (ft-MSL), and the distance above or below the current WIPP reference level 0'-0" (3409.0 ft MSL).

Table 15. Designated surface reference, surface reference elevation (ft-MSL), and distance above or below current WIPP reference level 0'-0" (3409.0 ft MSL).

Shaft	0'-0" Designated Surface Reference	Designated Surface Reference Elevation (ft-MSL)	Distance (ft) Above or Below Current WIPP Reference Level 0'-0" (3409.0 ft-MSL)
AIS	Top of Plenum	3410.0	1.0 Above
Waste	Top of Pad	3408.5	0.5 Below
Exhaust	Top of Collar	3411.5	2.5 Above
Salt Handling	Top of Existing Shaft	3411.5	2.5 Above

Designating the surface references as outlined in Table 15 will:

1. allow shaft seal designs to be developed with depth measurements measured from a consistent reference point that is specific to each shaft,
2. provide an easily identifiable reference that should still be in existence at the time the shafts are sealed, and
3. avoid the confusion created during shaft sealing operations that can arise from taking measurements from a reference level that is not tied to a physical shaft object.

To avoid future confusion when comparing existing shaft as-builts and final shaft seal design drawings, the seal design drawing notes should clearly identify the designated surface reference point and its relationship to the WIPP Standard Reference Level 0'-0" at 3409.0 ft-MSL.

A.3.4 Comparison of Stratigraphic Data Base and As-Built Elevations

Information from the SDB and the shaft as-built drawings were compared to determine discrepancies that may exist between the geologic data secured from the lithologic logs and the geologic data recorded on the shaft as-built drawings.

Elevation comparisons were made for select shaft and geologic features that were identified in both data sources. Features compared are specifically outlined for each shaft in Sections 3.4.1 through 3.4.4 and their associated tables.

In general, elevations were compared for the following geologic/shaft features:

- Ground surface (finished grade)
- Mescalero caliche

- Gatuña Formation
- Magenta Dolomite Member
- Culebra Dolomite Member
- Salado Formation
- Base of Key
- Shaft Station level.

If the feature and associated MSL elevation were identified in both data sources, the feature will be included in the comparison table for that specific shaft. Comparisons of elevations from both data sources showed differences varying from a minimum of 0.0 ft to a maximum of 9.0 ft as outlined in the following sections. The major discrepancies between the two data sources are found in the comparisons of the AIS and the Salt Handling Shaft. None of the data discrepancies in any single shaft was consistent enough to suggest that application of a single correction factor to either data set would reconcile the data.

Identifying lithologic contacts, especially when the contacts are gradational, can be a highly interpretive process. The difference in elevation values between the data sets (approximately ft or less) indicates a general consensus about the locations of the geologic features/objects relative to MSL. The as-built drawings should reflect the lithologic contacts mapped after the construction of each shaft. These differences in elevation indicate that some of the as-built lithologic contact elevations may have been transferred from preconstruction shaft design drawings to the final as-built drawings.

A.3.4.1 Air Intake Shaft

Ground surface (finished grade) elevations are consistent between the two data sources. The as-built elevations for the Magenta Dolomite Member, Salado Formation, and the base of the Shaft Key are consistent to within 0.3 ft relative to elevations secured from the shaft lithologic log. The Culebra Dolomite Member elevation recorded on the as-builts is 9.0 ft low relative to elevations secured from the shaft lithologic log. Conversation with Westinghouse staff revealed that the elevation for the as-built elevation for the Culebra Dolomite member should reference the elevation recorded in Holt & Powers (1990). By referencing this report and placing the unit in its proper scaled position on the drawing this discrepancy is eliminated. Table 16 compares the AIS lithologic log to the as-built elevations.

Table 16. Air Intake Shaft lithologic log versus as-built elevations

Geologic Feature/Object	Lithologic Log Elevation (ft-MSL)	As-built Elevation (ft-MSL)	Difference in Elevation: Lithologic Log less As-built (ft MSL)
Ground surface (finished grade)	3409.0	3409.0	0.0
Magenta Dolomite Member	2817.6	2817.6	0.0
Culebra Dolomite Member	2705.0	2696.0	9.0
Salado Formation	2569.3	2569.0	0.3
Base of Key	2513.0	2513.0	0.0

A.4.4.2 Exhaust Shaft

The ground surface (finished grade) elevation and the elevations of the Magenta Dolomite Member and Culebra Dolomite Member are consistent to within 0.1 ft. The Mescalero Caliche and the Gatuña Member elevations differ by 2.5 ft and 2.0 ft respectively. Table 17 compares the Exhaust Shaft lithologic log to the as-built elevations.

Table 17. Exhaust Shaft lithologic log versus as-built elevations

Geologic Feature/Object	Lithologic Log Elevation (ft-MSL)	As-built Elevation (ft-MSL)	Difference in Elevation: Lithologic Log less As-built (ft-MSL)
Ground surface (finished grade)	3410.0	3409.9	0.1
Mescalero Caliche	3401.5	3399.0	2.5
Gatuña Formation	3391.9	3389.9	2.0
Magenta Dolomite Member	2806.4	2806.5	-0.1
Culebra Dolomite Member	2695.4	2695.5	-0.1
Salado Formation	2558.5	2558.5	0.0

A.3.4.3 Waste Shaft

The ground surface (finished grade) elevation and the elevations of the Magenta Dolomite Member and the Culebra Dolomite Member are consistent. Elevations for the Salado Formation and the Shaft Station Level differ by 0.3 ft and 2.0 ft respectively. Table 18 compares the Waste Shaft lithologic log to the as-built elevations.

Table 18. Waste Shaft lithologic log versus as-built elevations

Geologic Feature/Object	Lithologic Log Elevation (ft-MSL)	As-built Elevation (ft-MSL)	Difference in Elevation: Lithologic Log less As-built (ft MSL)
Ground surface (finished grade)	3407.5	3407.5	0.0
Magenta Dolomite Member	2813.0	2813.0	0.0
Culebra Dolomite Member	2702.5	2702.5	0.0
Salado Formation	2565.3	2565.0	0.3
Shaft Station Level	1247.0	1249.0	-2.0

A.3.4.4 Salt Handling Shaft

Ground surface (finished grade) elevations are consistent to within 6 in. The Magenta Dolomite Member, Culebra Dolomite Member, and the Salado Formation elevations vary from 2 to 8 ft. Discrepancies in data result from recording as-built lithologic data from borehole ERDA-9 (see note on drawing 37-R-010, Rev. 7), which is an offset to the shaft. Table 19 compares the Salt Handling Shaft lithologic log to the as-built elevations.

Table 19. Salt Handling Shaft lithologic log versus as-built elevations

Geologic Feature/Object	Lithologic Log Elevation (ft-MSL)	As-built Elevation (ft-MSL)	Difference in Elevation: Lithologic Log less As-built (ft MSL)
Ground surface (finished grade)	3410.5	3411.0	-0.5
Magenta Dolomite Member	2808.0	2816.0	-8.0
Culebra Dolomite Member	2711.0	2705.0	6.0
Salado Formation	2560.0	2558.0	2.0

A.4 Stratigraphic Database

The Stratigraphic database presents geologic and hydrogeologic information for each individual shaft along with select engineering features (i.e., top of concrete, base of key, and station level). Specifically, information recorded for each shaft includes:

- Engineering features (top of concrete, base of key, and station level)
- Ground Surface (finished grade)
- Stratigraphic unit contact name
- Unit top and bottom MSL elevation
- Groundwater/brine observance
- Clay observance
- Comments relating to stratigraphic unit or engineering features.

A.4.1 Air Intake Shaft Stratigraphic Database

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Top of Concrete	3410.0				Bechtel Drawing 33-R-001-34A Rev. 4, Air Intake Shaft 331 General Arrangement Plans and Sections and 33-R-012-34A Rev. 5, Air Intake Shaft 331 Shaft Development 16'-0" Diameter Shaft Sections
Ground Surface (SURF) /Finished Grade	3409.0				Ground surface (finished grade): 3409.00 ft msl based on USGS survey Marker; Shaft Development Drawing # 33R-012-34A. Stratigraphic contacts are from lithologic log; DOE-WIPP-90-051
Quaternary Sd. (QSD)	3409.0	Not mapped			
Mescalero Caliche (MES)	Not mapped	Not mapped			
Gatuna Fm. (GAT)	3387.5	3378.5			
Santa Rosa Fm. (SR)	3378.5	3353.1			
Dewey Lk Rb. (DLR)	3353.1	2878.7			Top contact is an erosional surface
Rustler Fm. (RUS)	2878.7	2569.3			
49-er mbr (49R)	2878.7	2817.6	x		Groundwater, regional aquitard; at some locations a thin claystone has a transmissivity comparable to the Magenta. SAND90-2035J
Magenta D. mbr (MAG)	2817.6	2792.0	x		Groundwater, regional; SAND90-2035J & DOE-WIPP 90-051
Tamarisk mbr (TAM)	2792.0	2705.0	x		Groundwater, regional aquitard; SAND90-2035J
Culebra D. mbr (CUL)	2705.0	2681.1	x		Groundwater, regional; SAND90-2035J & DOE-WIPP 90-051
Unnamed L. mbr (ULM)	2681.1	2569.3	x		Groundwater, regional aquitard (siltstone unit at H-16); SAND90-2035J
Salado Fm. (SAL)	2569.3	Did not penetrate	x		Regional potential for Groundwater (brine) occurrence at the Rustler /Salado Fm. contact; SAND90-2035J. No Groundwater at Fm. contact noted on lithologic log. Shaft did not penetrate base of unit.

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Key (See Comments)		2513.0			Elevation 2513.0 ft.-msl from Westinghouse Isolation Division (WID) Drawing 33-C-004-W1, Air Intake Shaft 331 Shaft Key Plan, Sections and Details. This elevation is seven (7) feet higher than the base of Key concrete reported on the AIS lithologic log.
MB 100	*	*			Not marked on log
MB 101	2450.5	2447.1			
MB 102	2409.1	2408.0			
MB 103	2397.0	2380.5	x		Brine; Weeps - moist surface in lower 4ft; DOE-WIPP-90-051; Anhydridic dolomite overlying claystone where weeps occur.
MB 104	2373.5	2372.5			
MB 105	2356.6	2355.5			
MB 106	2335.5	2335.0			Correlated with exploration shaft.
MB 107	2301.0	2300.5			
MB 108	2291.1	2290.5			
MB 109	2268.5	2243.1	x		Brine; Weeps: DOE-WIPP-90-051, weep symbol on log with no weep description. Weeps occur in mudstone with anhydrite nodules.
MB 110	2203.1	2202.0			
MB 111	2194.5	2193.9			
MB 112	2176.4	2174.4		x	Thin laminae.
MB 113	2150.0	2149.0			Correlated with exploration shaft.
MB 114	2127.0	2126.0			Correlated with exploration shaft.
MB 115	2091.5	2088.0			
MB 116	2078.5	2076.0			
Vaca Triste (VACA TR)	2070.0	2062.0	x		Brine; DOE-WIPP-90-051. Composed of halitic siltstone and mudstone.
MB 117	2001.0	1999.5			
MB 118	1977.6	1975.0			
MB 119	1950.4	1948.4			
MB 120	1929.9	1929.0		x	Thin clay layers/blebs.
Zone A	1925.0	1915.5	x		Brine; Some weeps, halite with a trace of polyhalite: DOE-WIPP-90-051 - AIS log

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
MB 121	1915.5	1914.0	x	x	Brine; Weeps: DOE-WIPP-90-051 - AIS log. Weep symbol on log near base of unit (polyhalite) - no description. 2-3" clay at base.
MB 122	1907.9	1906.9			
Union Ahh.	1881.0	1873.5	x		Brine; Unit as a whole bears fluid. Weeps parallel to strata are very common around zones with clastic halite. Weeps occur also around fractures and contacts. DOE-WIPP-90-051 - AIS log
MB 123	1801.5	1795.0			
MB 124	1788.0	1779.1	x		Brine; Recent weeps parallel to fractures and bedding planes in anhydrite: DOE-WIPP-90-051 - AIS log
Zone B	1736.5	1733.5	x		Brine; Abundant weeps, halite argillaceous to trace clay: DOE-WIPP-90-051 - AIS log
Zone C	1709.0	1700.0	x		Brine; Modest amount of weeps, halite, trace clay and polyhalite: DOE-WIPP-90-051 - AIS log
MB 125	Absent	Absent			Section absent (Pinched out).
MB 126	1690.6	1689.5			
MB 127	1664.6	1662.0		x	Thin clay layers/blebs in upper 1 ft.
MB 128	1654.0	1650.5		x	Thin clay layers at base.
Zone D	1650.5	1640.0	x		Brine; Weeps in lower most part, interbedded polyhalite and argillaceous halite: DOE-WIPP-90-051 - AIS log
Zone E	1640.0	1638.0	x		Brine: Weeps in pits, argillaceous halite: DOE-WIPP-90-051 - AIS log
Zone F	1638.0	1635.0	x		Brine; Moderate weeps in unit, halite with trace polyhalite and clay: DOE-WIPP-90-051 - AIS log
Zone G	1635.0	1633.0	x	x	Brine; Abundant weeps from pits, argillaceous halite and halitic claystone: DOE-WIPP-90-051 - AIS log
Zone H	1633.0	1627.1	x		Brine; Moderate weeps, halite and polyhalite: DOE-WIPP-90-051 - AIS log
MB 129	1627.1	1625.6	x		Brine; Abundant weeps: DOE-WIPP-90-051 - AIS log
Zone I	1625.0	1619.3	x	x	Brine; Weeps, halite with polyhalite and claystone interbeds: DOE-WIPP-90-051 - AIS log

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
MB 130	1617.2	1615.1		x	Thin clay layers/blebs at base.
MB 131	1547.9	1546.9			
Zone J	1546.9	1542.9	x		Brine; Abundant weeps, halite trace to some clay and polyhalite: DOE-WIPP-90-051 - AIS log
MB 132	1516.0	1515.0			
MB 133	1497.1	1495.6			
MB 134	1454.0	1441.9			
MB 135	1426.0	1425.0			
MB 136	1387.2	1373.1			
MB 137	1356.3	1355.0			
MB 138	1311.1	1310.6			
Anhydrite "a" (ANH "a")	1287.5	1286.5			
Anhydrite "b" (ANH "b")	Not mapped	Not mapped			
Brow	1279.5				Excavated brow at facility level. MB-139 thru 142 were not penetrated by the shaft.
Station Level		1259.0			Westinghouse Isolation Division (WID) DWG. 33-D-008-W Air Intake Shaft 331 General Arrangement and WID DWG. 51-W-212-W Air Intake Shaft Station Plans, Sections and Details. Station level not on lithologic log.
					MB-139 thru 142 were not penetrated by the Air Intake Shaft.

A.4.2 Exhaust Shaft Stratigraphic Database

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Top of Concrete	3411.5				Bechtel Drawing 35-R-001-01D Rev. B, Exhaust Shaft 351 Development Plan Sections and Detail
Ground Surface (SURF) /Finished Grade	3410.0				Ground Surface (finished grade) 3410 ft. MSL. Based on survey-USGS 1927 North American datum.
					Contract Drawings-CCP1Fb/1D, Underground Experimental Areas/Waste Shaft and Exhaust Shaft. Drawing 35-R-004-01D. Stratigraphic contacts from lithologic log; DOE-WIPP-86-008.
Quaternary Sd (QSD)	3410.0	3401.5			
Mescalero Caliche (MES)	3401.5	3391.9			
Gatuna Fm. (GAT)	3391.9	3375.0			
Santa Rosa Fm. (SR)	3375.0	3355.4			
Dewey Lk. Rb. (DLR)	3355.4	2862.5		x	Top contact is an erosional surface. Occasional thin clay layers (<6" thick)
Rustler FM. (RUS)	2862.5	2558.5			
49-er mbr (49R)	2862.5	2806.4	x		Groundwater, regional aquitard; at some locations a thin claystone has a transmissivity comparable to the Magenta. SAND90-2035J
Magenta mbr (MAG)	2806.4	2782.0	x		Groundwater, regional; Sand90-2035J; DOE-WIPP-86-008
Tamarisk mbr (TAM)	2782.0	2695.4	x	x	Groundwater, regional aquitard; SAND90-2035J. Occasional thin clay layers < 6" thick.
Culebra D mbr (CUL)	2695.4	2673.0	x		Groundwater, regional; SAND90-2035J; DOE-WIPP-86-008
Unnamed L mbr (ULM)	2673.0	2558.5	x	x	Groundwater, regional aquitard (siltstone unit at H-16); SAND90-2035J. Occasional thin clay layers (< 6" thick)
Salado Fm. (SAL)	2558.5	Did not penetrate	x		Regional potential for Groundwater (brine) occurrence at the Rustler /Salado Fm. contact; SAND90-2035J. No Groundwater at Fm. contact noted on lithologic log. Shaft did not penetrate base of unit.

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Key (See Comments)		2502.0			Elevation 2502 ft.-msl (level 907.00) calculated from Bechtel Drawing 35-R-002-01D Rev. A, and Exhaust Shaft 351 Shaft Lining and Key Section and Detail.
MB 100	*	*			Not marked on log
MB 101	2436.5	2433.5			
MB 102	2394.8	2393.6		x	Clay near base (3" thick)
MB 103	2382.0	2367.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 104	2359.0	2358.7			
MB 105	2342.9	2341.8		x	Clay at base
MB 106	2322.5	2321.8		x	Clay at base (1" thick)
MB 107	2289.0	2288.5			
MB 108	2279.7	2277.5		x	Clay at base (2" thick)
MB 109	2256.0	2230.5			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 110	2191.8	2189.6		x	Clay at base
MB 111	2181.8	2181.4			
MB 112	2164.2	2161.9		x	Clay at base (1" - 2.5" thick)
MB 113	2137.8	2136.4		x	Clay at base (2" thick)
MB 114	2114.6	2113.8			
MB 115	2078.9	2075.5		x	Clay at base (1" thick)
MB 116	2066.3	2064.0		x	Clay at base (1" thick)
Vaca Triste (VACA TR)	2055.3	2051.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 117	1988.6	1987.3			
MB 118	1965.0	1962.7		x	Clay (1" - 2" thick)
MB 119	1938.9	1937.0			
MB 120	1919.0	1918.3			
Zone A	1913.5	1905.6			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 121	1913.5	1905.6			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 122	1898.5	1897.0			
Union Anhydrite	1872.0	1866.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 123	1793.0	1786.0			

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
MB 124	1779.3	1770.0		x	Potential brine seepage interval- inferred from AIS brine seepage conditions. Clay (1" - 2" thick)
Zone B	1727.8	1724.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone C	1700.3	1690.8			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 125	Absent	Absent			Section absent (Pinched out).
MB 126	1682.0	1681.5			
MB 127	1657.5	1655.3			
MB 128	1646.0	1644.3			
Zone D	1634.8	1633.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone E	1633.0	1631.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone F	1631.0	1628.3			Potential brine seepage interval–inferred from AIS brine seepage conditions
Zone G	1628.3	1626.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone H	1626.3	1620.8			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 129	1620.8	1619.0		x	Potential brine seepage interval- inferred from AIS seepage conditions. Clay at base (1/4" thick)
Zone I	1619.0	1614.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 130	1609.0	1608.3		x	Clay at base (1" thick)
MB 131	1541.5	1540.3			
Zone J	1540.3	1536.0			Potential brine seepage interval–inferred from AIS brine seepage conditions
MB 132	1510.2	1509.4			
MB 133	1491.9	1488.6			
MB 134	1446.5	1434.7			
MB 135	1419.0	1418.2			
MB 136	1374.3	1363.4			
MB 137	1349.8	1348.9			
MB 138	1302.6	1302.1			
Anhydrite "a" (ANH "a")	1279.6	1278.9			

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Anhydrite "b" (ANH "b")	1272.1	1271.8			
Station Level	1262.5	1252.0			Elevation 1252.00 ft-msl calculated from Bechtel drawings (level 2157.00 ft) Approximate-Bechtel Drawing 35-R-001-01D Rev. B, Exhaust Shaft 351 Development Plan Sections & Detail.
					MB-139 thru 142 were not penetrated by the exhaust shaft.

A.4.3 Salt Handling Shaft Stratigraphic Database

Stratigraphic Unit/Engineering Feature	Unit/ Feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Top of Concrete	3411.5				Bechtel Drawing 37-R-010 Rev. A, Exploratory Shaft Key and Shaft Station Location Section (Top of Existing Shaft)
Ground Surface (SURF)/Finished Grade	3410.5				Ground surface (finished grade) elevation is tied to CWI benchmark No. CW-1 outside the exploratory shaft at an elevation of 3410.080 ft MSL; DOE-WIPP 86-010. Stratigraphic contacts are from lithologic log; TME 3178.
Quaternary Sd (QSD)	3410.5	3399.0			Stratigraphic units behind casing were not mapped. Mapping started in the basal portion of the Santa Rosa Fm. . Unit tops behind casing are secured from gamma ray log interpretation and the Bechtel drill log. DOE- WIPP-86-010.
Mescalero Caliche (MES)	3399.0	3394.5			
Gatuna Fm. (GAT)	3394.5	3374.0			
Santa Rosa Fm. (SR)	3374.0	3319.0			
Dewey Lk. Rb. (DLR)	3319.0	2868.0			Top contact is an erosional surface. Contact secured through gamma ray log interpretation.
Rustler Fm. (RUS)	2868.0	2560.0			Total inflow from rustler aquifers was less than 1.5 gallons per minute prior to liner installation. Subsequent to liner installation inflow rate dropped to less than 0.1 gallon per minute. TME 3178
49-er mbr (49R)	2868.0	2808.0	x		Groundwater, regional aquitard; at some locations a thin claystone has a transmissivity comparable to the Magenta. SAND90-2035J
Magenta mbr (MAG)	2808.0	2789.0	x		Groundwater, regional; SAND90-2035J
Tamarisk mbr (TAM)	2789.0	2711.0	x		Groundwater, regional aquitard; SAND90-2035J
Culebra D mbr (CUL)	2711.0	2694.0	x		Groundwater, regional; SAND90-2035J
Unnamed L mbr (ULM)	2694.0	2560.0	x		Groundwater, regional aquitard (siltstone unit at H-16); SAND90-2035J

Stratigraphic Unit/Engineering Feature	Unit/ Feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Salado Fm. (SAL)	2560.0	*	x		Regional potential for Groundwater (brine) occurrence at the Rustler /Salado Fm. contact; SAND90-2035J. Groundwater seeps at Fm. contact noted on lithologic log; TME-3178. Shaft did not penetrate base of unit.
Key (See Comments)		2529.0			Elevation 2529.00 ft.-msl calculated from level 880.00 ft. Bechtel Drawing 37-R-012 Rev. A, Exploratory Shaft Key Sections and Details
MB 100	2488.0	*			Top from stratigraphic survey ; WTSD-TME-3179
MB 101	2439.1	2435.1			
MB 102	2400.0	2398.7		x	Clay at base
MB 103	2386.4	2372.6		x	Potential brine seepage interval-inferred from AIS brine seepage conditions. Clay at base.
MB 104	2364.6	2363.9			
MB 105	2348.2	2347.8		x	Clay at base
MB 106	2328.7	2327.3		x	Clay at base
MB 107	2294.0	2293.3		x	Clay at base
MB 108	2284.8	2283.9		x	Clay at base
MB 109	2263.5	2237.0		x	Potential brine seepage interval-inferred from AIS brine seepage conditions. Interbedded Clay
MB 110	2205.4	2204.3		x	Clay at base
MB 111	2189.1	2188.2			
MB 112	2171.6	2168.9		x	Clay at base
MB 113	2144.4	2142.6		x	Clay at base
MB 114	2120.7	2120.0			
MB 115	2084.5	2081.8		x	Clay at base
MB 116	2073.5	2071.0		x	Clay at base
Vaca Triste (VACA TR.)	2061.8	2060.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 117	1994.2	1993.3		x	Clay at base
MB 118	1965.5	1963.0			
MB 119	1945.1	1943.3		x	
MB 120	1925.5	1924.4		x	Clay at base

Stratigraphic Unit/Engineering Feature	Unit/ Feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Zone A	1923.0	1913.8			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 121	1913.7	1911.5		x	Potential brine seepage interval-inferred from AIS brine seepage conditions. Clay at base.
MB 122	1903.7	1902.4			
Union Anhydrite	1874.5	1870.5			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 123	1791.8	1789.6			
MB 124	1783.8	1776.4		x	Potential brine seepage interval-inferred from AIS brine seepage conditions. Clay at base.
Zone B	1732.5	1729.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone C	1705.0	1696.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 125	1724.6	1722.9		x	Clay at base
MB 126	1688.2	1687.1		x	Clay - total section
MB 127	1662.3	1659.3		x	Clay at base
MB 128	1649.6	1648.2		x	Clay at base
Zone D	1639.5	1637.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone E	1637.0	1634.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone F	1634.3	1632.1			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone G	1632.1	1630.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone H	1630.0	1625.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 129	1625.0	1622.9		x	Clay at base
Zone I	1621.8	1613.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 130	1613.5	1612.5			Correlated with Air Intake and Exhaust Shafts.
MB 131	1545.5	1544.6			
Zone J	1544.6	1540.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 132	1511.1	1510.7		x	Clay - total section

Stratigraphic Unit/Engineering Feature	Unit/ Feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
MB 133	Absent	Absent			Pinched out.
MB 134	1453.7	1442.3		x	Clay at base
MB 135	1425.7	1424.2		x	Clay at top
MB 136	1382.3	1374.4		x	Clay at base
MB 137	1358.7	1357.5			
MB 138	1311.8	1311.1		x	Clay at base
Anhydrite "a" (ANH "a")	1288.4	1287.1		x	Clay at base
Anhydrite "b" (ANH "b")	1281.6	1280.7		x	Clay at base
Station Level		1247.0			Elevation 1247.00 ft.-msl calculated from level 2162.00 ft. (approximate) - Bechtel Drawing 37-R-010 Rev. A, Exploratory Shaft Key and Shaft Station Location Section. This level measurement needs to be confirmed with new measurement
					as it locates the station level below Marker Bed 139.
MB 139	1254.3	1252.3		x	Potential brine seepage interval - Anhydrite. Clay at base.
					Base of lithologic log terminates above MB 140. Total depth elevation is 1105.0 ft. msl.
MB 140					Potential brine seepage interval - Anhydrite

A.4.4 Waste Shaft Stratigraphic Database

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Top of Concrete	3408.5				Bechtel drawing 31-R-001-01D Rev. B, Waste Shaft 311 Development Sections (Top of Pad)
Ground Surface (SURF) /Finished Grade	3407.5				Ground surface (finish grade) elevation 3407.5 ft MSL, surveyed. Upper section of the shaft was not logged lithologically. Logging started at 3310.2 ft msl in the Dewey Lake Red Beds. Stratigraphic contacts are from lithologic log; WTSD-TME-038
Quaternary Sd (QSD)	3407.5				
Mescalero Caliche (MES)	Not mapped	Not mapped			
Gatuna Fm. (GAT)	Not mapped	Not mapped			
Santa Rosa Fm. (SR)	Not mapped	Not mapped			
Dewey Lk. Rb. (DLR)		2871.5		x	Top contact is an erosional surface. Clay (<6" thick)
Rustler Fm. (RUS)	2871.5	2565.3			
49-er mbr (49R)	2871.5	2813.0	x		Groundwater, regional aquitard; at some locations a thin claystone has a transmissivity comparable to the Magenta. SAND90-2035J
Magenta D mbr (MAG)	2813.0	2788.0	x		Groundwater; SAND90-2035J. Weeps WTSD - TME - 038
Tamarisk mbr (TAM)	2788.0	2702.5	x	x	Groundwater, regional aquitard; SAND90-2035J Thin clay layers (< 6" thick)
Culebra D mbr (CUL)	2702.5	2680.7	x		Groundwater, regional; DOE-WIPP 90-051
Unnamed L mbr (ULM)	2680.7	2565.3	x	x	Groundwater, regional aquitard (siltstone unit at H-16); SAND90-2035J, Thin clay layers (< 6" thick)
Salado Fm. (SAL)	2565.3	Did not penetrate	x		Regional potential for Groundwater (brine) occurrence at the Rustler /Salado Fm. contact; SAND90-2035J. No Groundwater at Fm. contact noted on lithologic log. Shaft did not penetrate base of unit.

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Key (See Comments)		2509.0			Elevation 2509.00 ft.-msl calculated from level 900.00 ft. Bechtel drawing 31-R-001-01D Rev. B, Waste Shaft 311 Development Sections and 31-R-002-01D Rev. A, Waste shaft 311 Shaft Lining and Key Section and Details
MB 100	*	*			Not marked on log
MB 101	2444.0	2442.0			
MB 102	2402.0	2401.0		x	Thin clay (<6" thick)
MB 103	2389.0	2374.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 104	2367.0	2366.0			
MB 105	2350.1	2349.0		x	Clay at base (<1" thick)
MB 106	2329.3	2328.5		x	Clay at base (<2" thick)
MB 107	2295.5	2295.0			
MB 108	2285.9	2285.3		x	Clay at base (<0.5" thick)
MB 109	2262.9	2236.9		x	Potential brine seepage interval–inferred from AIS brine seepage conditions. 1 ft. clay in middle of section
MB 110	2199.3	2196.0			
MB 111	2188.3	2188.0			
MB 112	2170.8	2168.5		x	Clay at base (<2" thick)
MB 113	2144.0	2142.3		x	Clay at base (<0.5" thick)
MB 114	2120.5	2119.5			
MB 115	2084.8	2081.5			
MB 116	2071.8	2069.0		x	Clay at base (<0.5" thick)
Vaca Triste (VACA TR.)	2060.5	2052.5			Potential brine seepage interval–inferred from AIS brine seepage conditions
MB 117	1993.2	1992.0		x	Clay at base (<3" thick)
MB 118	1969.8	1967.5		x	Clay at base (<0.5" thick)
MB 119	Absent	Absent			Section absent (pinched out).
MB 120	Absent	Absent			Section absent (pinched out).
Zone A	1923.8	1910.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 121	1910.0	1907.1		x	Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 122	1900.3	1899.0			
Union Anhydrite	1874.3	1867.0			Potential brine seepage interval-inferred from AIS brine seepage conditions

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
MB 123	1794.0	1787.0			
MB 124	1780.2	1771.5		x	Potential brine seepage interval - inferred from AIS brine seepage conditions. Clay at base (< 0.5' thick)
Zone B	1725.8	1720.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone C	1701.0	1691.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 125	Absent	Absent			Section absent (pinched out).
MB 126	1682.2	1681.2		x	Clay at base (<4" thick)
MB 127	1655.7	1653.5			
MB 128	1644.2	1642.2			
Zone D	1634.5	1632.5			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone E	1632.5	1630.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone F	1630.0	1627.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone G	1627.0	1625.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
Zone H	1625.0	1619.5			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 129	1619.5	1617.7		x	Clay at base (1 ft. thick)
Zone I	1616.5	1612.3			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 130	1608.1	1606.9			
MB 131	1539.3	1538.5		x	Thin clay layer at base.
Zone J	1538.0	1531.0			Potential brine seepage interval-inferred from AIS brine seepage conditions
MB 132	1508.0	1507.0		x	Clay at base (<0.5" thick)
MB 133	1489.8	1487.7		x	Thin clay layer at base.
MB 134	1445.3	1433.5		x	Clay at base (<4" thick)
MB 135	1417.2	1411.5			
MB 136	1373.3	1362.1		x	Thin clay layer at base.
MB 137	Absent	Absent			Section absent (pinched out).
MB 138	1299.5	1289.9		x	Clay at base (<1.5" thick)
Anhydrite "a" (ANH "a")	1276.1	1275.3		x	Clay at base (<0.25" thick)

Stratigraphic Unit/Engineering Feature	Unit/ feature Top (ft-msl)	Unit/ Feature Bottom (ft-msl)	Water/ Brine Obs.	Clay Obs.	Comments
Anhydrite "b" (ANH "b")	1268.6	1268.4		x	Clay at base (<0.25" thick)
Station Level	1259.0	1249.0			Elevation 1249.0 ft.-msl calculated from level 2160.0 ft. Bechtel drawing 31-R-001-01D Rev. B, Waste Shaft 311 Development Sections
					MB-139 thru 142 were not noted on lithologic log.
MB 139					Potential brine seepage interval - Anhydrite
MB 140					Potential brine seepage interval - Anhydrite

A.5 Conclusions

The evaluation of shaft stratigraphy and geohydrology at the WIPP has provided extensive information about shaft stratigraphy, shaft groundwater/brine occurrence, and shaft survey data. This information is outlined as follows:

A.5.1 Shaft Stratigraphy

- The SDB records the following information relevant to each shaft:
  - ◆ Engineering features (top of concrete, base of key, and station level)
  - ◆ Ground Surface (finished grade)
  - ◆ Stratigraphic unit contact name
  - ◆ Unit top MSL elevation
  - ◆ Unit bottom MSL elevation
  - ◆ Groundwater/brine observance
  - ◆ Clay observance
  - ◆ Comments relating to stratigraphic unit or engineering features.

  The evaluation has

- confirmed the vertical and lateral continuity of the majority of the named stratigraphic units among the four shafts;
- identified occurrences of clay in marker beds (as logged during the geologic mapping of each shaft) that could serve as impermeable layers upon which brine may migrate, or in some instances, if the clay was buried prior to dewatering, the clay layer can yield some water as it dewaters and consolidates after being exposed subsequent to shaft construction (Deal et al., 1995).
- provided a graphical display in the form of structural cross sections, derived from the compiled data base, that illustrate the horizontal and vertical relationships of named stratigraphic units among the WIPP shafts.

A.5.2 Shaft Groundwater / Brine Occurrence

The evaluation of WIPP geohydrology performed to identify regional intervals of groundwater occurrence in the Rustler Formation and shallower stratigraphic units, as well as brine seepage intervals in the Salado Formation penetrated by the shafts

- identified regional groundwater occurrence intervals in the Rustler Formation as well as 19 intervals of brine seepage within the Salado Formation penetrated by the four shafts;
- identified intervals of brine seepage through recent observations (July 1994) of the Salado Formation in the AIS. Currently, the surface Marker Bed 103 is the only seepage interval where the salt encrustations are visibly wet;
- identified typical hydraulic conductivity values for the primary lithologies encountered in the Salado Formation section penetrated by the shafts;
- provided a graphical display in the form of structural cross sections, derived from the compiled data in the SDB, that illustrate the vertical and potential lateral distribution of brine seepage intervals within the Salado Formation.

A.5.3 Shaft Survey Data

The shaft survey data were reviewed to evaluate the MSL elevations secured from the shaft as-built drawings relative to those recorded in the SDB and to determine a surface reference point to facilitate completion of sealing system design drawings and final seal emplacement. This review

- demonstrated relative consistency (within 6 in.) between surface elevations reported in geotechnical reports and working drawings and the data recorded on the Bechtel and Westinghouse as-built drawings for each shaft;
- identified the WIPP surveyed reference level 0'-0" (elevation of 3409.0 ft-MSL) used for computing below-surface depths (i.e., 3409.0 ft-MSL = Reference level 0'-0");
- identified the "top of concrete" for each shaft as a consistent surface reference point to be utilized for the development of the shaft seal design drawings;
- identified discrepancies between lithologic data obtained from geotechnical shaft reports and as-built data, by comparing the shaft SDB elevations to shaft as-built drawing elevations.

A.6 References

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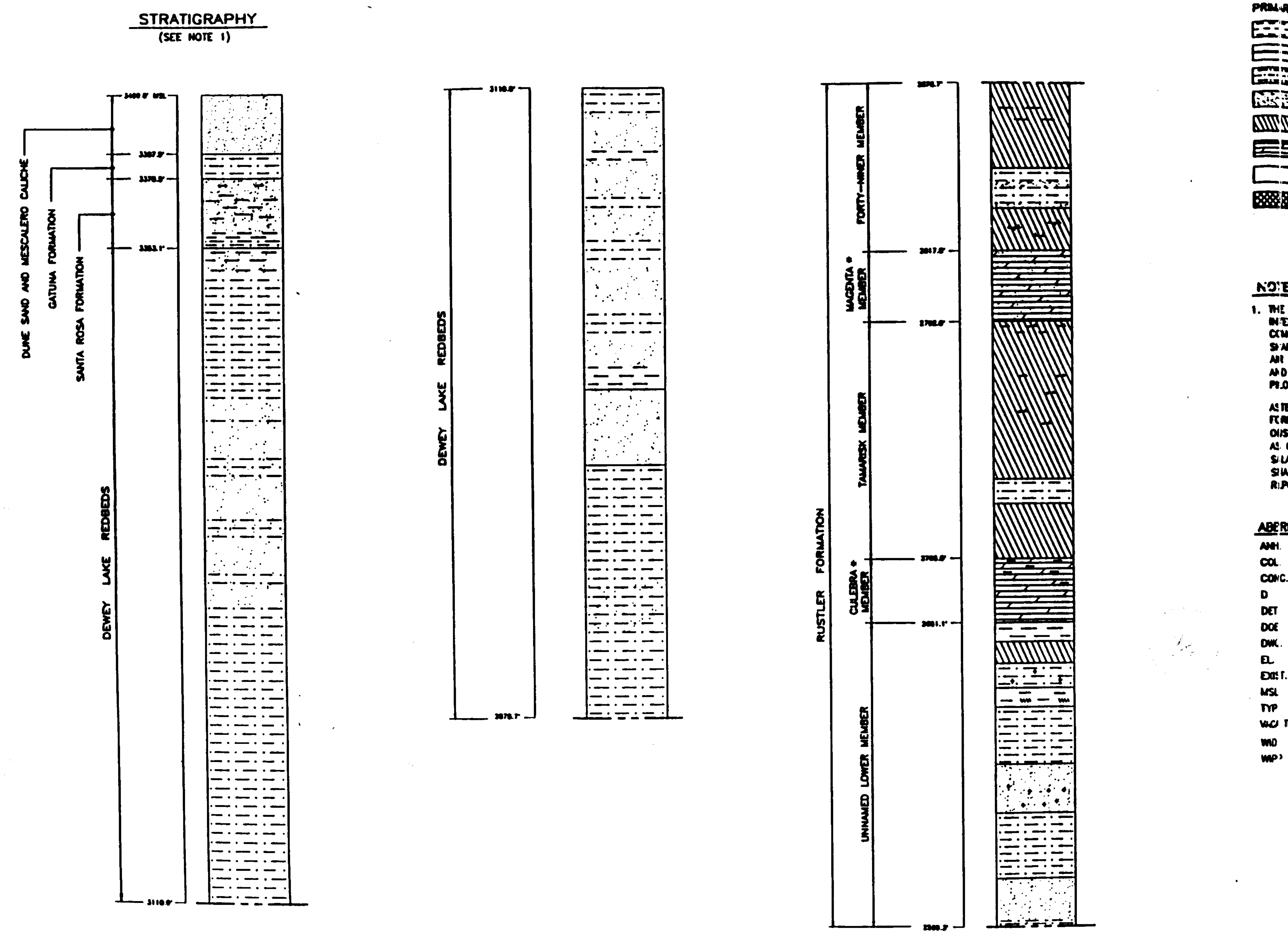
Appendix B:
Shaft Sealing System Drawings



LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES	SECONDARY CONSTITUENTS
MUDSTONE/CLAYSTONE	ARGILLACEOUS
CLAYSTONE BED	SILTY
SILTSTONE	SANDY
SANDSTONE	SULFATIC
ANHYDRITE/GYPSUM	DOLOMITIC
DOLOMITE	CALCAREOUS
HALITE	HALITIC
POLYHALITE	POLYHALITIC
	LANGBEINITE

NOTE:

1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT WALLS, DOE/WIPP-90-051, "GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WASTE ISOLATION PILOT PLANT", 1990, AND "LETTER REPORT ON THE RESULTS OF THE WASTE ISOLATION PILOT PLANT SHAFT STRATIGRAPHY CORRELATION PROJECT", 1994.

   ASTERISK(*) INDICATES GROUNDWATER (RUSTLER/SUPRA RUSTLER FORMATIONS) OR BRINE SEEPAGE/WEEPS (SALADO FORMATION) OBSERVED DURING THE MAPPING OF THE AIR INTAKE SHAFT. AS OF 1994, ONLY MB103 SHOWED VISIBLE MOISTURE ON THE SALADO FORMATION SURFACE EXPOSED WITHIN THE AIR INTAKE SHAFT, "BRINE SAMPLING EVALUATION PROGRAM 1992-1993 REPORT," 1994, DOE-WIPP 94-011.

ABBREVIATION:

ANH.	ANHYDRITE
COL.	COLUMN
CONC.	CONCRETE
D	DIAMETER
DET	DETAIL
DOE	DEPARTMENT OF ENERGY
DWG.	DRAWING
EL.	ELEVATION
EXIST.	EXISTING
MSL	MEAN SEA LEVEL
TYP	TYPICAL
VACA TR.	VACA TRISTE
WID	WESTINGHOUSE WASTE ISOLATION DIVISION
WIPP	WASTE ISOLATION PILOT PLANT

REV.	DATE	DESCRIPTION	BY	CK.	APP

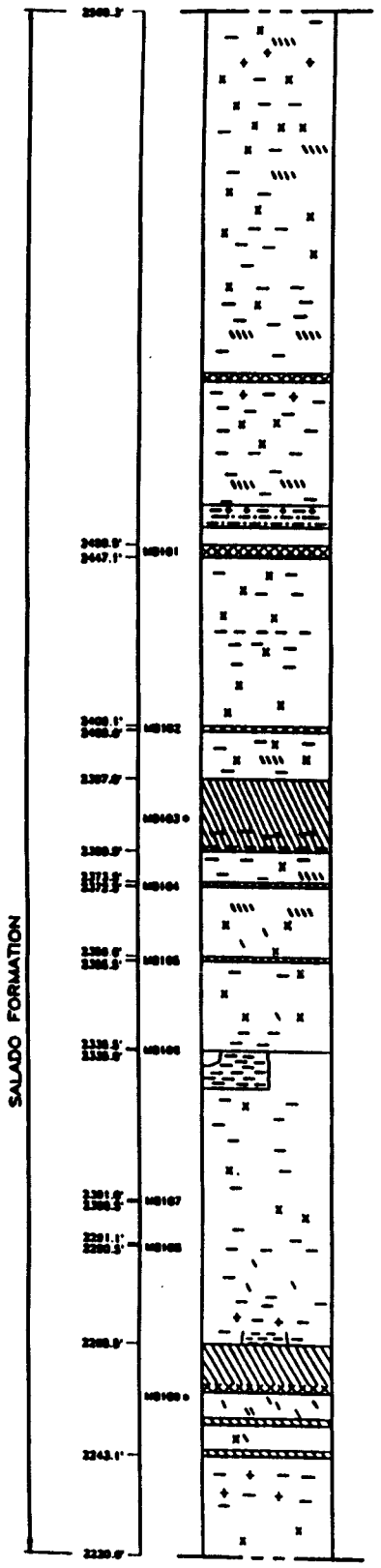
SANDIA NATIONAL LABORATORIES
WIPP A/E SUPPORT
WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
AIR INTAKE SHAFT
STRATIGRAPHIC PROFILE

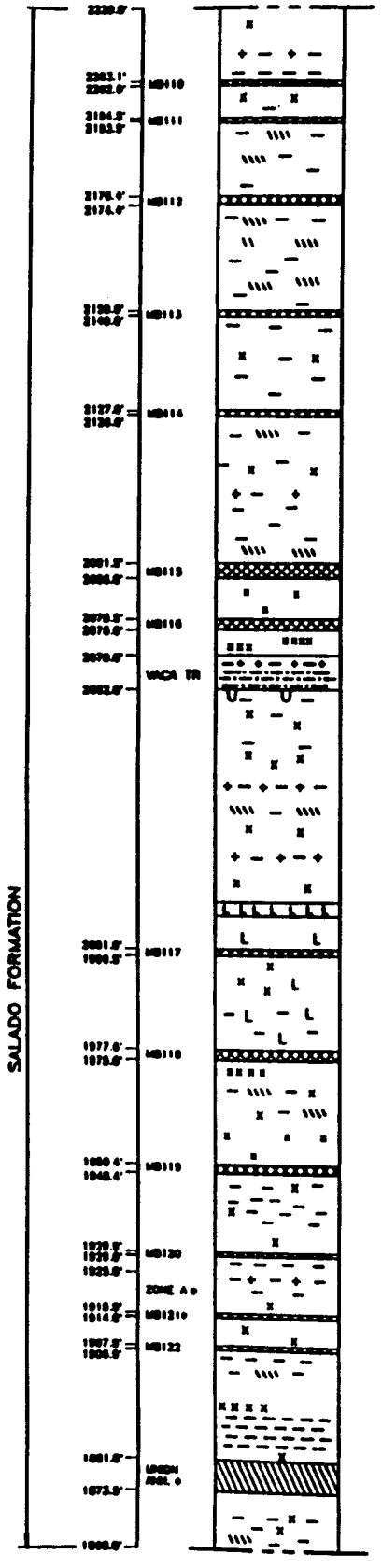
PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG. NO. 33-SNL-003 | SHEET NO. 1 OF 2

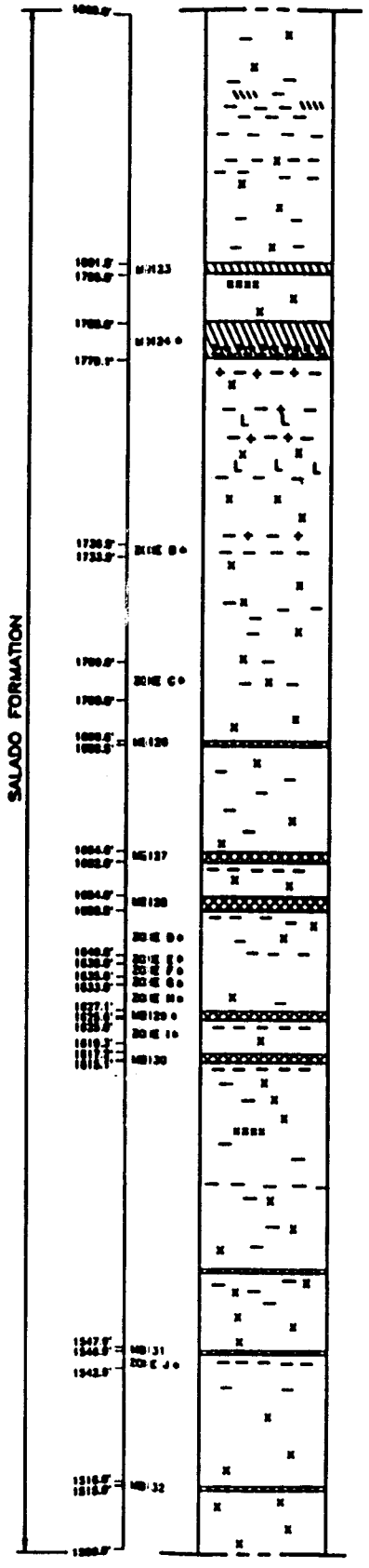
Figure B-1.

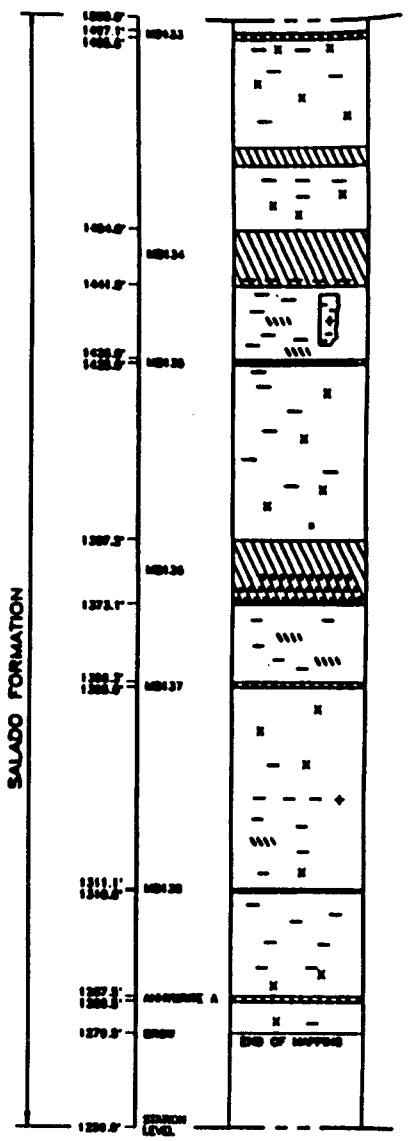
STRATIGRAPHY

(SEE NOTE 1 OF SHEET NO. 1)









LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES

- MUDSTONE/CLAYSTONE
- CLAYSTONE BED
- SILTSTONE
- SANDSTONE
- ANHYDRITE/GYPSUM
- DOLOMITE
- HALITE
- POLYHALITE

SECONDARY CONSTITUENTS

- ARGILLACEOUS
- SILTY
- SANDY
- SULFATIC
- DOLOMITIC
- CALCAREOUS
- HALITIC
- POLYHALITIC
- LANGBEINITE

SCALE IN FEET

0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AO-4089

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION

AIR INTAKE SHAFT
STRATIGRAPHIC PROFILE

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-003	SHEET NO. 2 OF 2

Figure B-2.

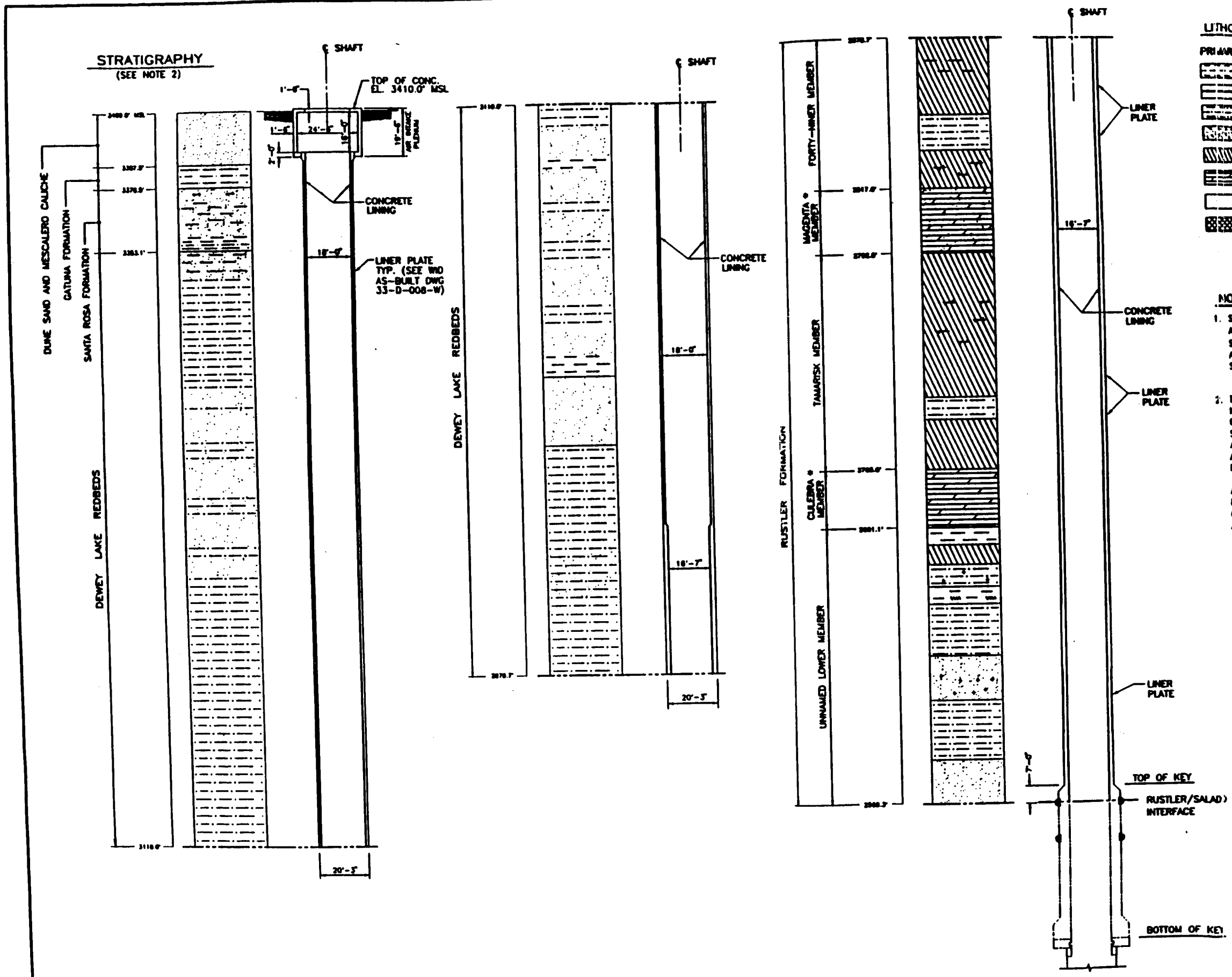
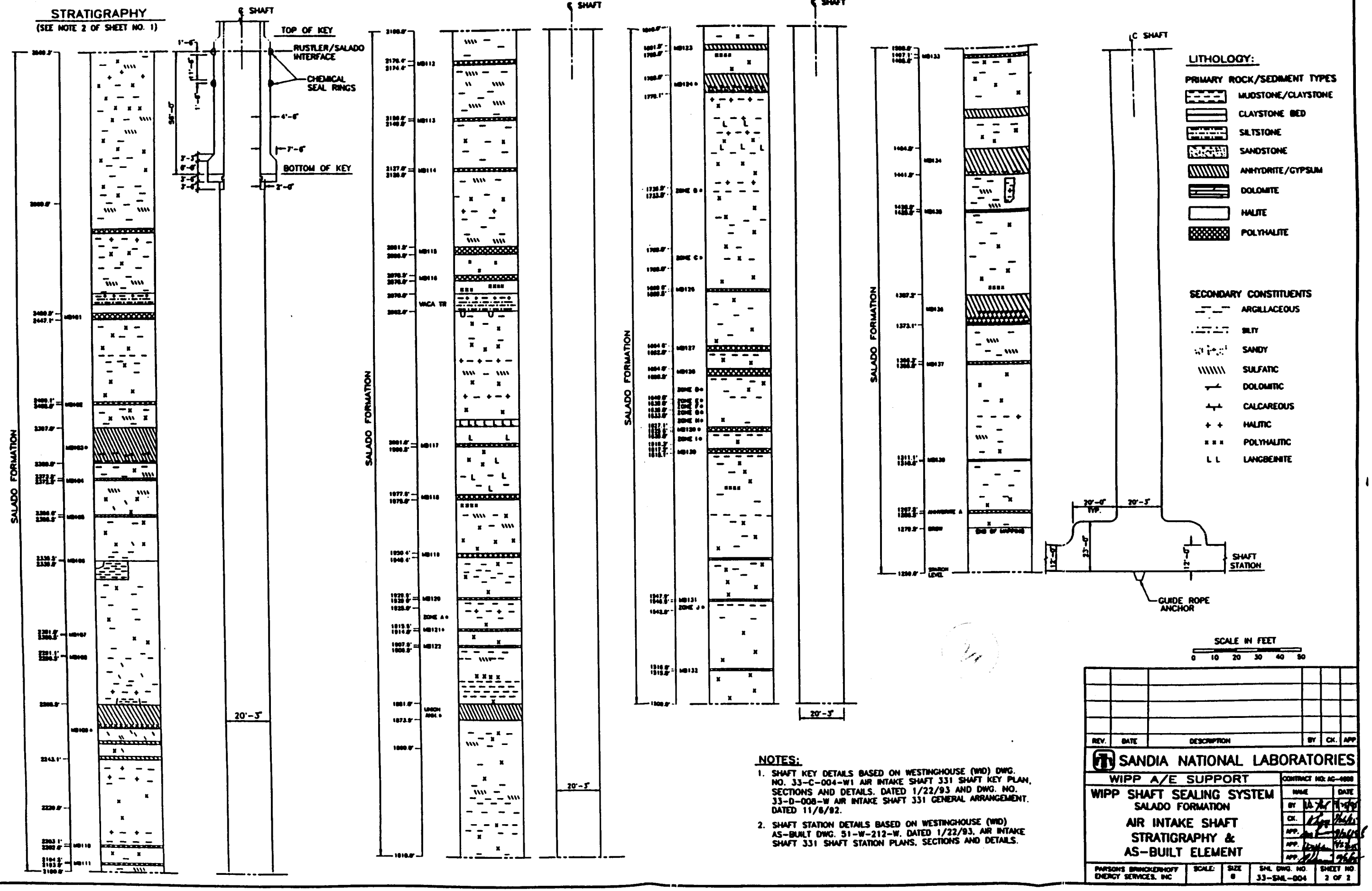

STRATIGRAPHY
(SEE NOTE 2)
℄ SHAFT
TOP OF CONC. EL. 3410.0' MSL
1'-6"
24'-0"
18'-0"
19'-6" AIR INTAKE PLENUM
CONCRETE LINING
LINER PLATE TYP. (SEE WID AS-BUILT DWG 33-D-008-W)
18'-0"
20'-3"
DUNE SAND AND MESCALERO CALICHE
GATUNA FORMATION
SANTA ROSA FORMATION
DEWEY LAKE REDBEDS
3400.0' MSL
3387.5'
3376.5'
3353.1'
3118.0'
DEWEY LAKE REDBEDS
3410.0'
3376.7'
℄ SHAFT
CONCRETE LINING
18'-0"
18'-7"
20'-3"
RUSTLER FORMATION
FORTY-NINER MEMBER
MAGENTA MEMBER
TAMARISK MEMBER
CULEBRA MEMBER
UNNAMED LOWER MEMBER
3378.5'
3347.0'
3288.0'
3188.0'
3081.1'
2948.5'
℄ SHAFT
LINER PLATE
18'-7"
CONCRETE LINING
LINER PLATE
LINER PLATE
7'-0"
TOP OF KEY
RUSTLER/SALADO INTERFACE
BOTTOM OF KEY
LITHOLOGY:
PRIMARY ROCK/SEDIMENT TYPES
MUDSTONE/CLAYSTONE
CLAYSTONE BED
SILTSTONE
SANDSTONE
ANHYDRITE/GYPSUM
DOLOMITE
HALITE
POLYHALITE
SECONDARY CONSTITUENTS
ARGILLACEOUS
SILTY
SANDY
SULFATIC
DOLOMITIC
CALCAREOUS
HALITIC
POLYHALITIC
LANGBEINITE
NOTE:
1. SHAFT COLLAR DETAILS BASED ON WESTINGHOUSE (WID) AS-BUILT DWGS. 33-C-001-W, DATED 1/22/93, AIR INTAKE SHAFT 331 SHAFT COLLAR/AIR INTAKE PLENUM PLAN, SECTIONS AND DETAILS AND 33-D-008-W, DATED 11/6/92, AIR INTAKE SHAFT 331 GENERAL ARRANGEMENT.
2. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT WALLS, DOE/WIPP-90-051, "GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WASTE ISOLATION PILOT PLANT", 1990, AND "LETTER REPORT ON THE RESULTS OF THE WASTE ISOLATION PILOT PLANT SHAFT STRATIGRAPHY CORRELATION PROJECT", 1994.
ASTERISK(*) INDICATES GROUNDWATER (RUSTLER/SUPRA RUSTLER FORMATIONS) OR BRINE SEEPAGE/WEEPS (SALADO FORMATION) OBSERVED DURING THE MAPPING OF THE AIR INTAKE SHAFT. AS OF 1994, ONLY MB103 SHOWED VISIBLE MOISTURE ON THE SALADO FORMATION SURFACE EXPOSED WITHIN THE AIR INTAKE SHAFT, "BRINE SAMPLING EVALUATION PROGRAM 1992-1993 REPORT," 1994, DOE-WIPP 94-011.
SCALE IN FEET
0 10 20 30 40 80
REV. DATE DESCRIPTION BY CK. APP
SANDIA NATIONAL LABORATORIES
WIPP A/E SUPPORT
CONTRACT NO: AS-0000
WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
AIR INTAKE SHAFT
STRATIGRAPHY &
AS-BUILT ELEMENTS
NAME DATE
BY
CK.
APP.
APP.
APP.
PARSONS BRINCKERHOFF ENERGY SERVICES, INC
SCALE:
SIZE B
SNL DWG. NO. 33-SNL-004
SHEET NO 1 OF 2

Figure B-3.

STRATIGRAPHY
(SEE NOTE 2 OF SHEET NO. 1)



NOTES:

1. SHAFT KEY DETAILS BASED ON WESTINGHOUSE (WID) DWG. NO. 33-C-004-W1 AIR INTAKE SHAFT 331 SHAFT KEY PLAN, SECTIONS AND DETAILS. DATED 1/22/93 AND DWG. NO. 33-D-008-W AIR INTAKE SHAFT 331 GENERAL ARRANGEMENT. DATED 11/6/92.
2. SHAFT STATION DETAILS BASED ON WESTINGHOUSE (WID) AS-BUILT DWG. 51-W-212-W. DATED 1/22/93, AIR INTAKE SHAFT 331 SHAFT STATION PLANS, SECTIONS AND DETAILS.

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4000

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
AIR INTAKE SHAFT
STRATIGRAPHY & AS-BUILT ELEMENT

	NAME	DATE
BY		
CK.		
APP.		
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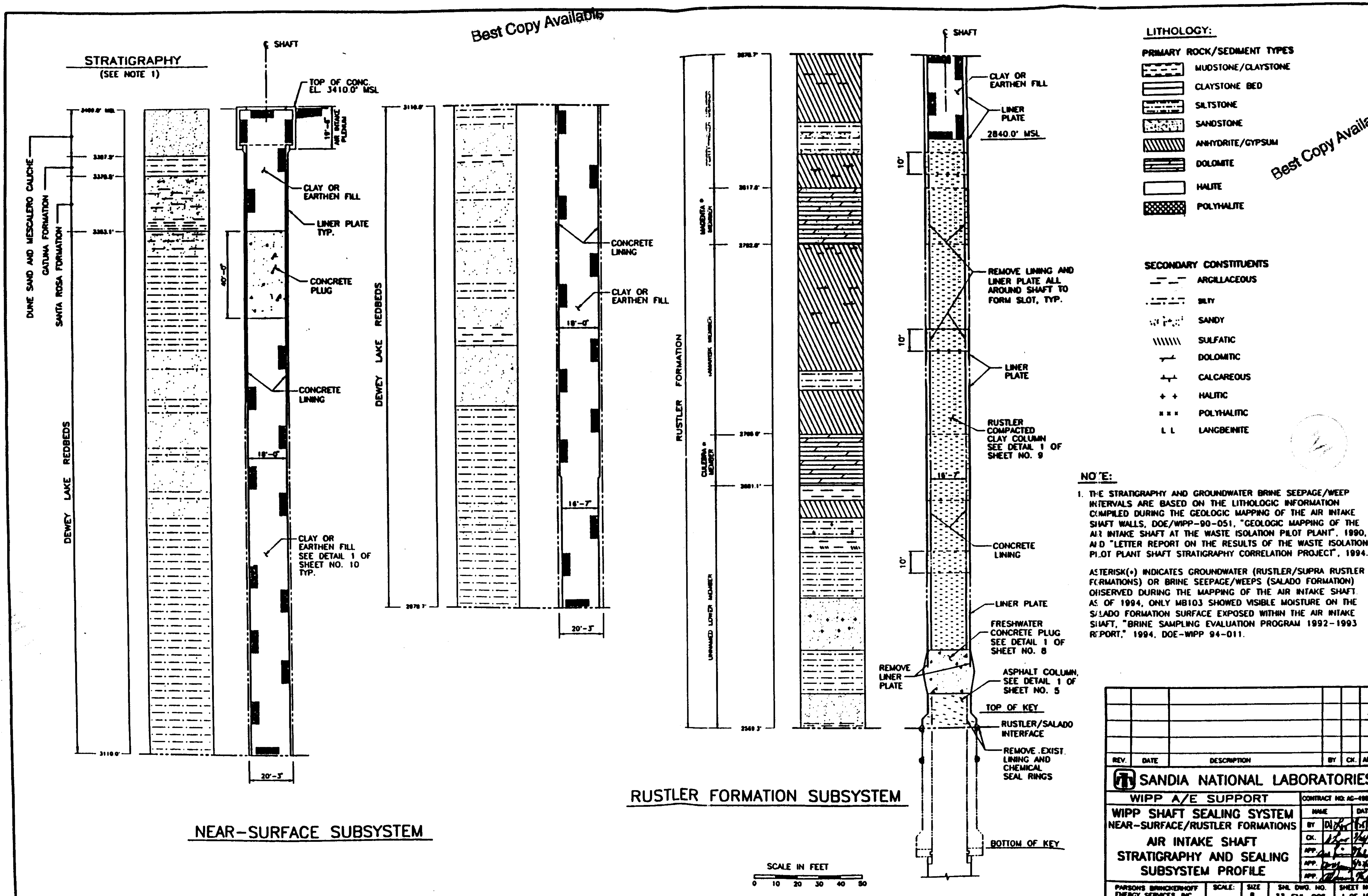
APP.		

PARSON'S BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-004	SHEET NO. 2 OF 2

Figure B-4.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STRATIGRAPHY
(SEE NOTE 1)
DUNE SAND AND MESCALERO CALICHE
GATUNA FORMATION
SANTA ROSA FORMATION
DEWEY LAKE REDBEDS
℄ SHAFT
TOP OF CONC. EL. 3410.0' MSL
AIR INTAKE PLENUM
CLAY OR EARTHEN FILL
LINER PLATE TYP.
CONCRETE PLUG
40'-0"
CONCRETE LINING
CLAY OR EARTHEN FILL SEE DETAIL 1 OF SHEET NO. 10 TYP.
20'-3"
NEAR-SURFACE SUBSYSTEM
RUSTLER FORMATION
MAGENTA * MEMBER
CULEBRA * MEMBER
UNNAMED LOWER MEMBER
LINER PLATE
2840.0' MSL
REMOVE LINING AND LINER PLATE ALL AROUND SHAFT TO FORM SLOT, TYP.
RUSTLER COMPACTED CLAY COLUMN SEE DETAIL 1 OF SHEET NO. 9
LINER PLATE
FRESHWATER CONCRETE PLUG SEE DETAIL 1 OF SHEET NO. 8
REMOVE LINER PLATE
ASPHALT COLUMN, SEE DETAIL 1 OF SHEET NO. 5
TOP OF KEY
RUSTLER/SALADO INTERFACE
REMOVE EXIST. LINING AND CHEMICAL SEAL RINGS
BOTTOM OF KEY
RUSTLER FORMATION SUBSYSTEM
SCALE IN FEET
0 10 20 30 40 50
LITHOLOGY:
PRIMARY ROCK/SEDIMENT TYPES
MUDSTONE/CLAYSTONE
CLAYSTONE BED
SILTSTONE
SANDSTONE
ANHYDRITE/GYPSUM
DOLOMITE
HALITE
POLYHALITE
SECONDARY CONSTITUENTS
ARGILLACEOUS
SILTY
SANDY
SULFATIC
DOLOMITIC
CALCAREOUS
HALITIC
POLYHALITIC
LANGBEINITE
NOTE:
1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT WALLS, DOE/WIPP-90-051, "GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WASTE ISOLATION PILOT PLANT", 1990, AND "LETTER REPORT ON THE RESULTS OF THE WASTE ISOLATION PILOT PLANT SHAFT STRATIGRAPHY CORRELATION PROJECT", 1994.
ASTERISK(*) INDICATES GROUNDWATER (RUSTLER/SUPRA RUSTLER FORMATIONS) OR BRINE SEEPAGE/WEEPS (SALADO FORMATION) OBSERVED DURING THE MAPPING OF THE AIR INTAKE SHAFT. AS OF 1994, ONLY MB103 SHOWED VISIBLE MOISTURE ON THE SALADO FORMATION SURFACE EXPOSED WITHIN THE AIR INTAKE SHAFT, "BRINE SAMPLING EVALUATION PROGRAM 1992-1993 REPORT," 1994, DOE-WIPP 94-011.
REV. DATE DESCRIPTION BY CK. APP
SANDIA NATIONAL LABORATORIES
WIPP A/E SUPPORT
CONTRACT NO. AC-4000
WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
AIR INTAKE SHAFT
STRATIGRAPHY AND SEALING
SUBSYSTEM PROFILE
PARSONS BRINCKERHOFF ENERGY SERVICES, INC
SCALE:
SIZE B
SNL DWG. NO. 33-SNL-005
SHEET NO. 1 OF 10

Figure B-5.

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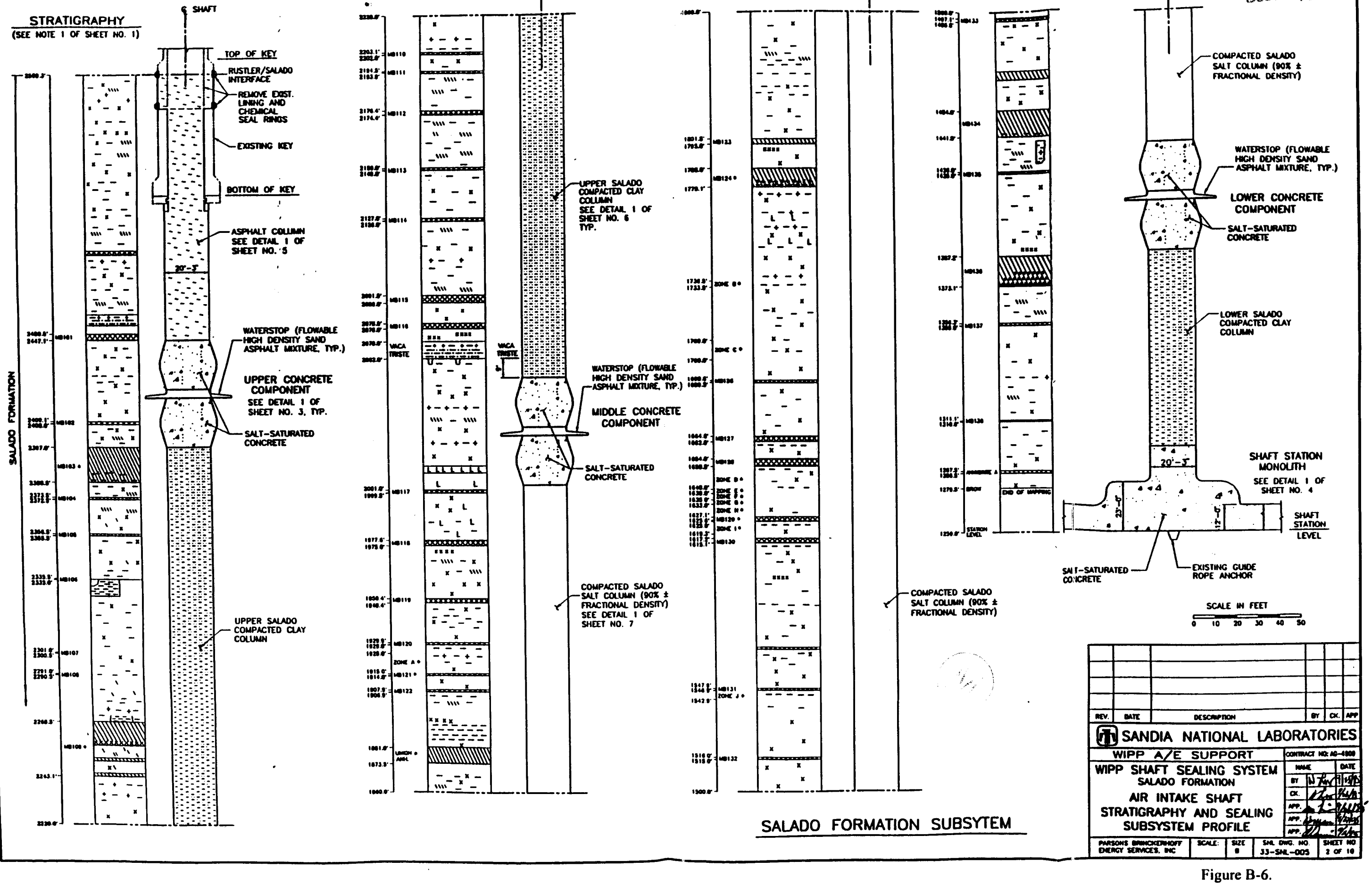

Figure B-6.

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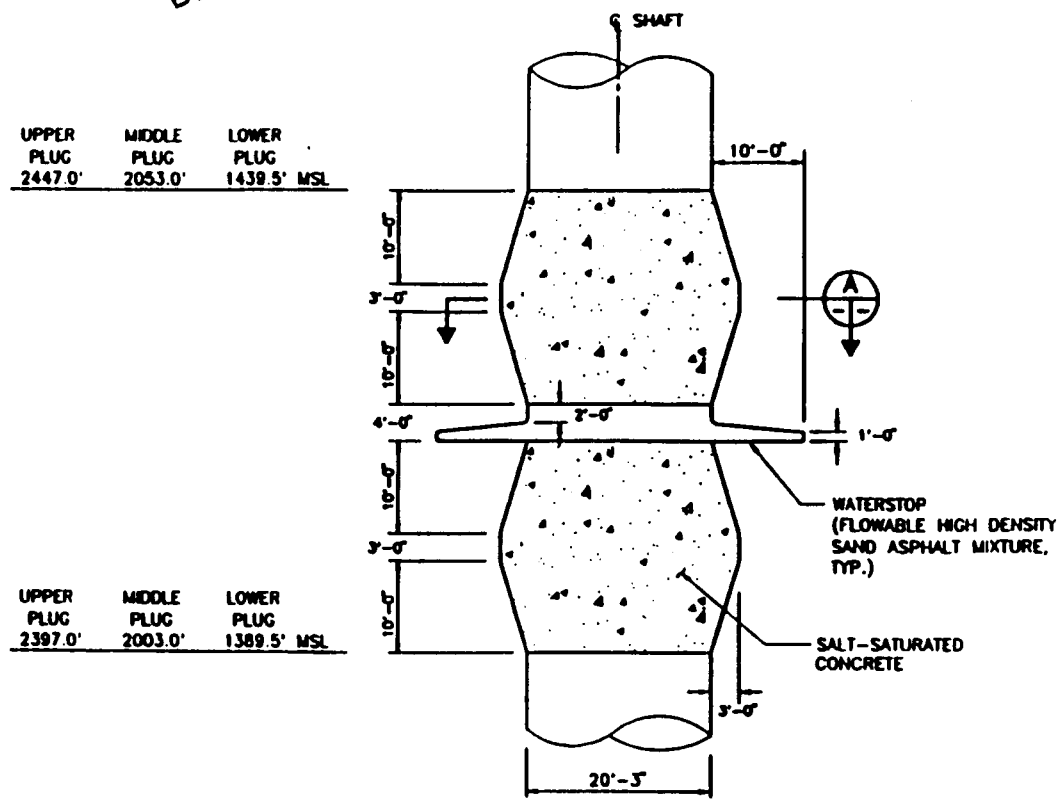
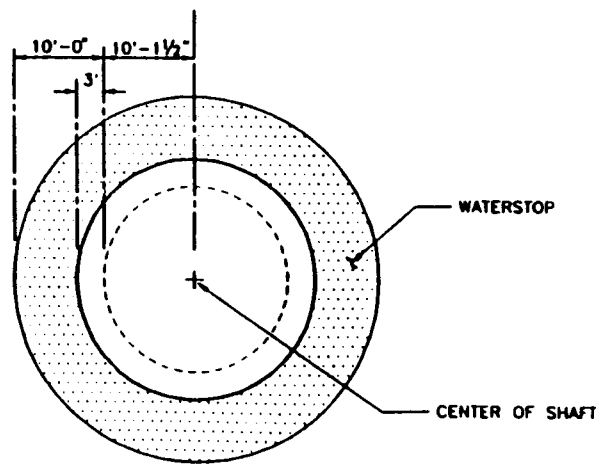


DETAIL 1 SHEET 2 | SHEET 3



SECTION A

TYPICAL SALADO MASS CONCRETE PLUG WITH WATERSTOP (3 LOCATIONS)

SCALE IN FEET
0 5 10 15 20 25

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AC-4888

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT CONCRETE COMPONENT IN SALADO FORMATION

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO 33-SNL-005	SHEET NO 3 OF 10

Figure B-7.

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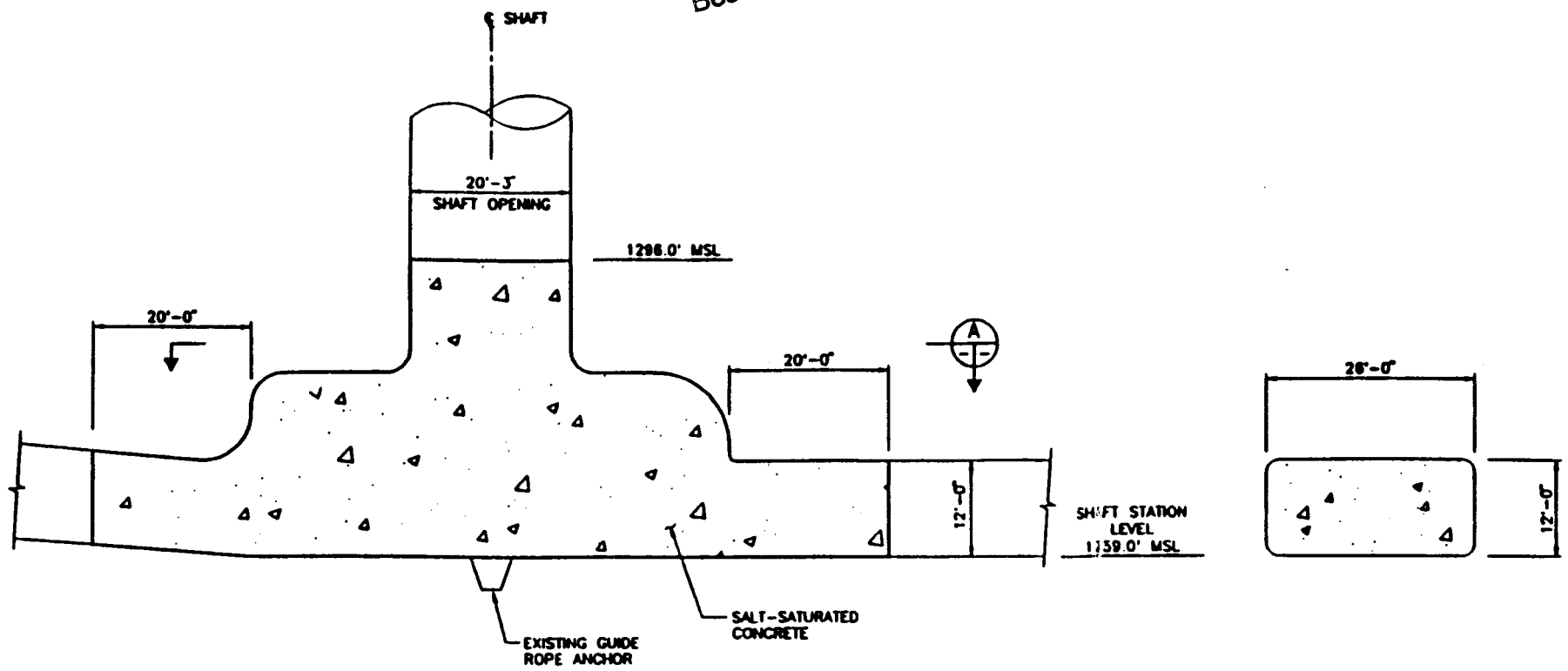
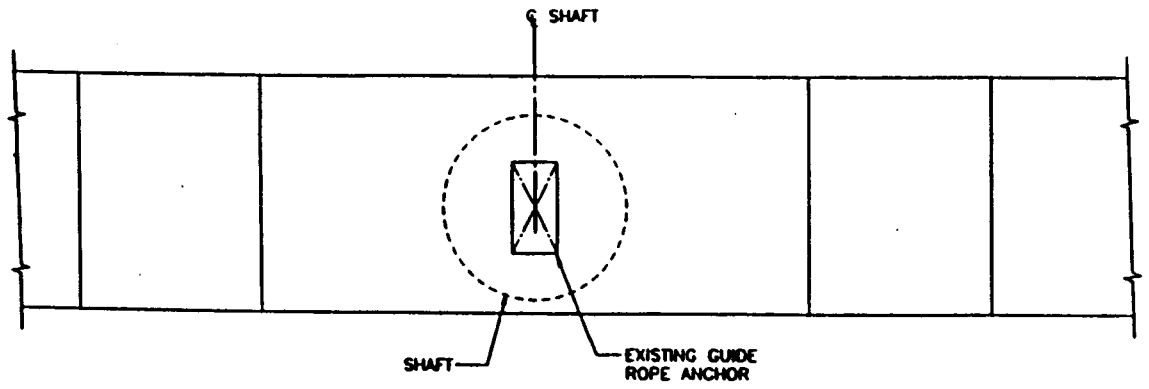


DETAIL 1 SHEET 2 | SHEET 4



SECTION A

SHAFT STATION MONOLITH

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: 80-4000

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
SHAFT STATION MONOLITH

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-003	SHEET NO 4 OF 10

Figure B-8.

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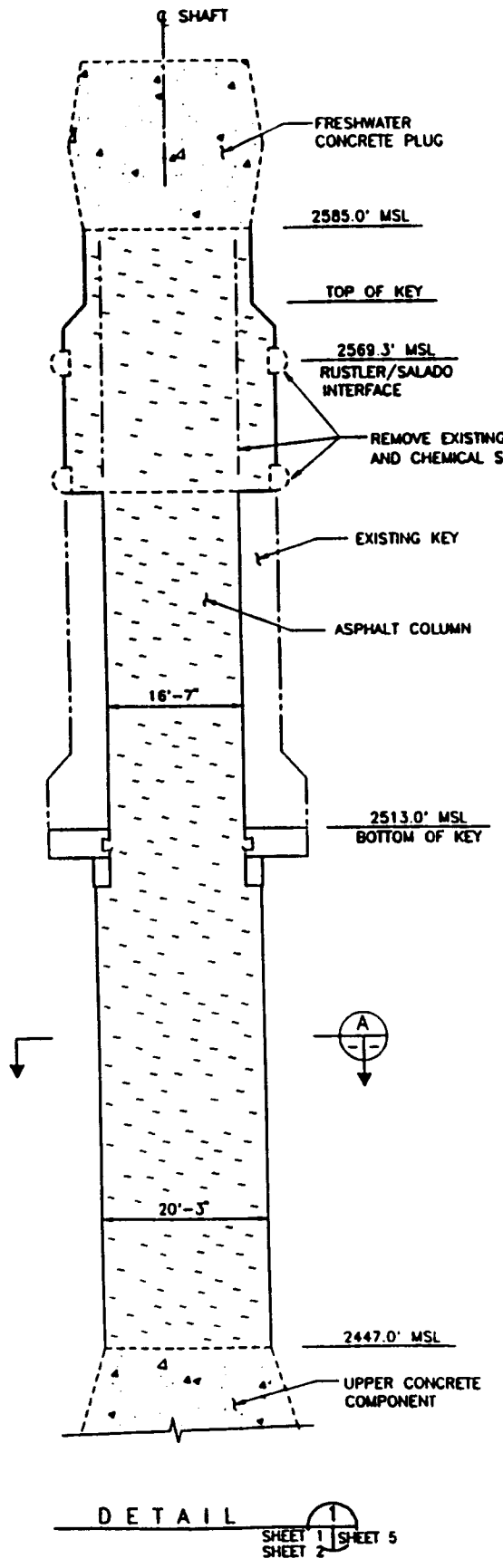

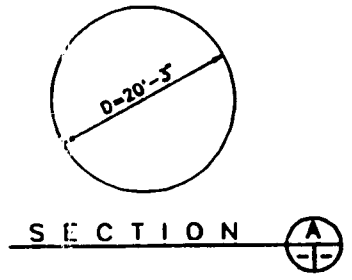

ASPHALT COLUMN
(2447' TO 2585' MSL)

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4988

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
ASPHALT COLUMN
(2447' MSL TO 2585' MSL)

	NAME	DATE
BY	W. [illegible]	7/15/[illegible]
CK.	[illegible]	7/16/[illegible]
APP.	[illegible]	7/16/[illegible]
APP.	[illegible]	7/16/[illegible]
APP.	[illegible]	7/16/[illegible]

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-005	SHEET NO 5 OF 10

Figure B-9.

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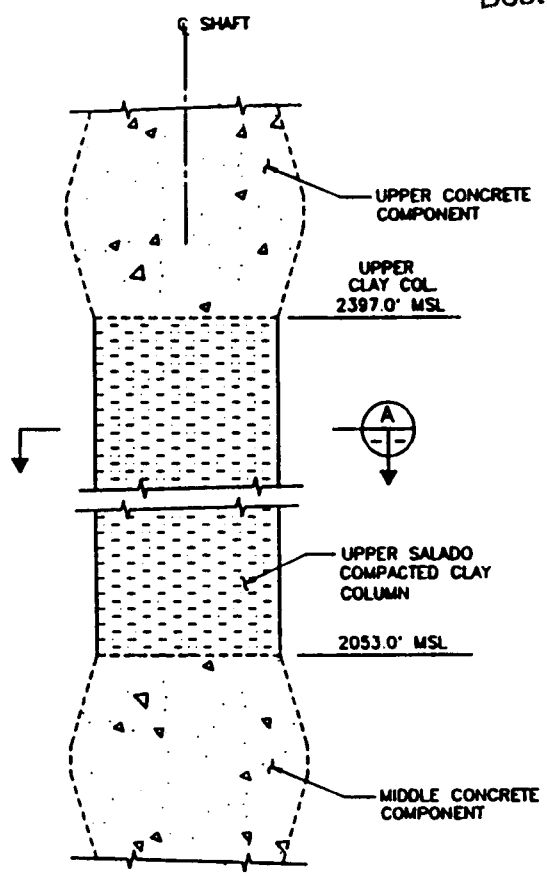
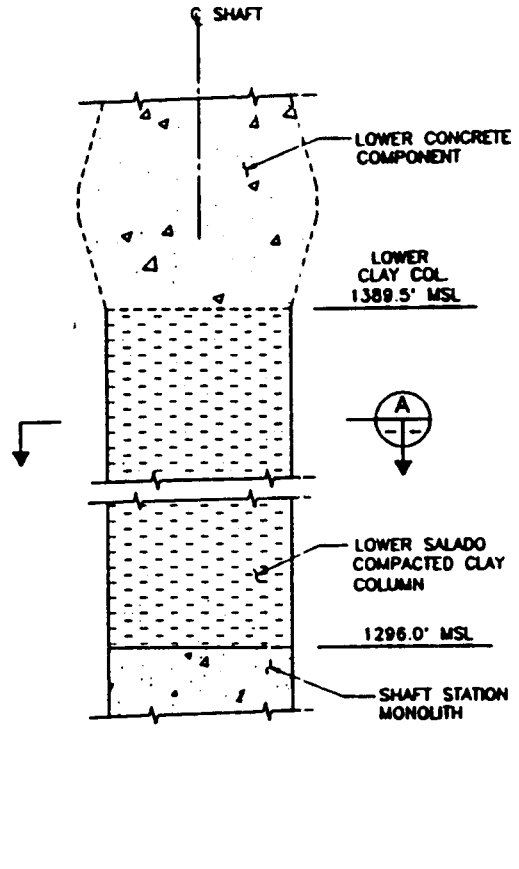
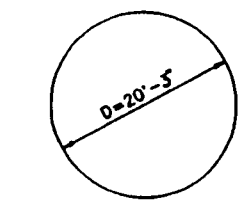


DETAIL 1 SHEET 2 SHEET 6





SECTION A

SALADO CLAY COLUMNS

(2 LOCATIONS)

SCALE IN FEET

0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4809

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
UPPER AND LOWER
SALADO CLAY COLUMNS

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-005	SHEET NO. 6 OF 10

Figure B-10.

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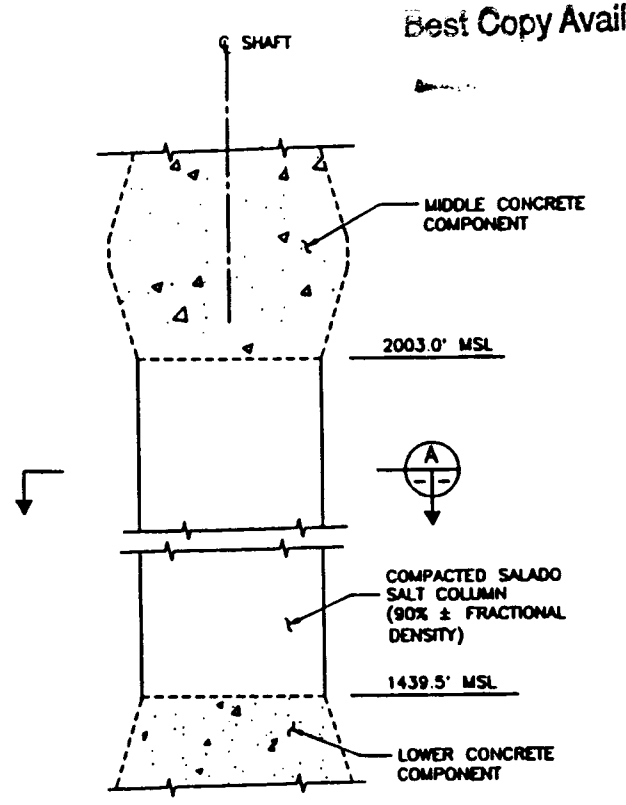
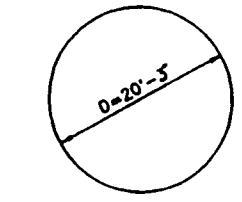


DETAIL 1 — SHEET 2 | SHEET 7



SECTION A–A

SALADO SALT COLUMN

SCALE IN FEET
0 10 20 30 40 50

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REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4000

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
SALADO SALT COLUMN

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-005	SHEET NO. 7 OF 10

Figure B-11.

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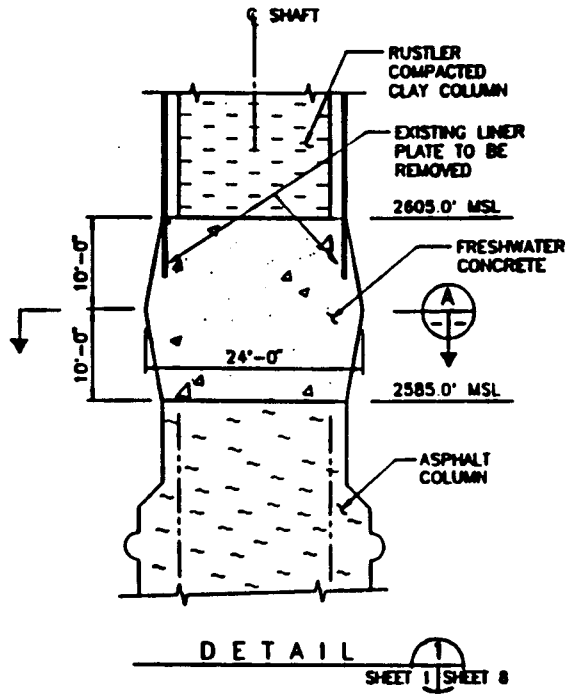

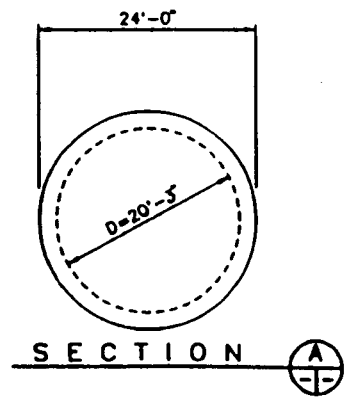

FRESHWATER CONCRETE PLUG

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4000

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
FRESHWATER CONCRETE PLUG

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-005	SHEET NO 8 OF 10

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Figure B-12.

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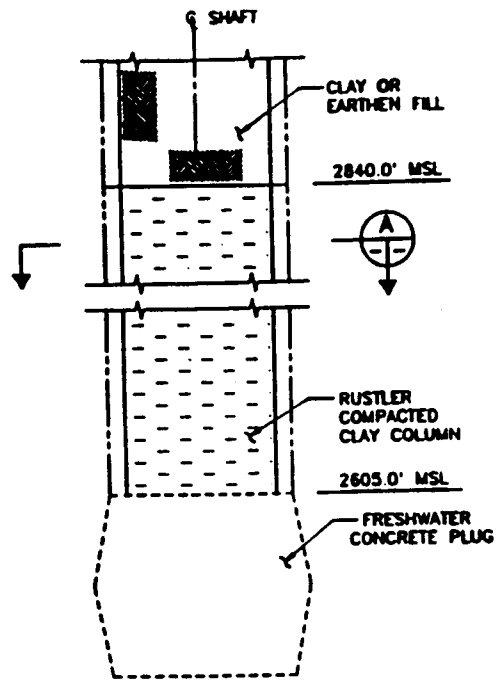
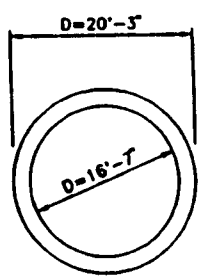


DETAIL 1 SHEET 1 SHEET 9



SECTION A

RUSTLER CLAY COLUMN

SCALE IN FEET
0 10 20 30 40 50

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REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4888

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
RUSTLER CLAY COLUMN

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO. 33-SNL-005	SHEET NO 9 OF 10

Figure B-13.

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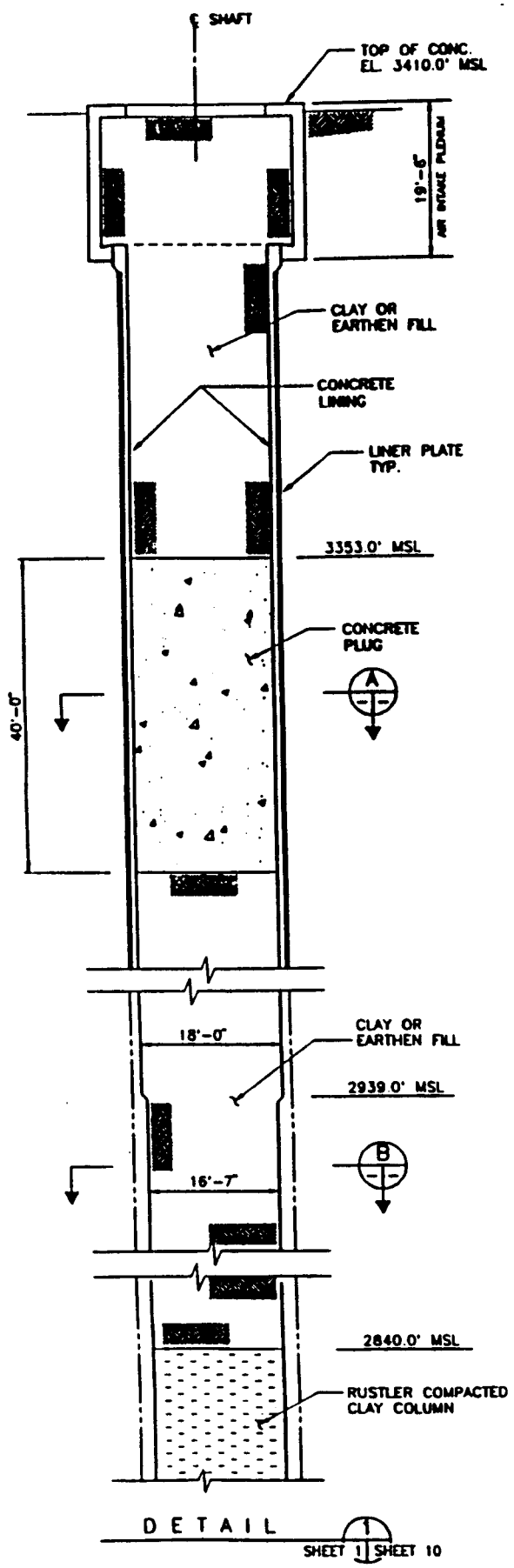
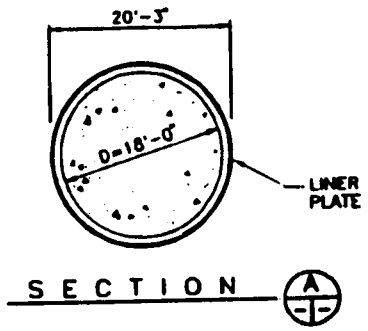
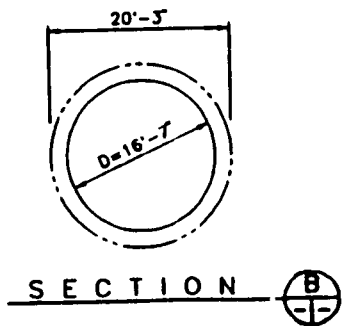






DEWEY LAKE CLAY/EARTHEN FILL
COLUMN AND CAP

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES
WIPP A/E SUPPORT
CONTRACT NO: AC-4908

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
DEWEY LAKE CLAY/EARTHEN FILL COLUMN AND CAP

	NAME	DATE
BY		
CK.		
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO 33-SNL-005	SHEET NO 10 OF 10

Figure B-14.

Appendix C:
A Modeling Study on Shaft Seal Permeability

Appendix C:
A Modeling Study on Shaft Seal Permeability

This appendix summarizes a modeling study conducted to evaluate the sensitivity of repository performance to permeability of the shaft seal system. The simulations as discussed here show that, for a composite shaft of 100 m length:

- to limit brine flow, a seal permeability of about 1×10^{-16} m^2 is sufficient and
- reduction of gas flow requires a seal permeability on the order of 1×10^{-18} m^2 or tighter.

C.1 Conceptual Models

A conceptual model of the repository comprises a tool used to evaluate the repository, the enclosed waste, and the surrounding geologic media. A conceptual model is the aggregate of processes, properties, and geometries considered within an analysis. It encompasses process models, which are verbal or mathematical descriptions of the conceptual model, a numerical model consisting of the computer code used to conduct simulations of the process model, and parameters. Parameters required for this conceptual model consist of data derived from field and laboratory experiments, and numerical quantities necessary for computer code implementation. The following sections identify the computer codes used for the simulations and briefly discuss the process models and parameter derivations for this study.

C.2 Computer Codes

All simulations were performed using BRAGFLO, a two-phase flow simulator developed by SNL. It has been designed to accommodate conceptual model changes and to be robust and numerically stable over a wide range of flow conditions. BRAGFLO is used by the WIPP Performance Assessment Group in the conduct of assessments for the program.

Fluid flow processes at the WIPP horizon are physically coupled to the creep closure of the surrounding salt. Implementation of a fully coupled system results in significant technical difficulties that cannot be practically overcome at the present time. A simplified approach has been used in this modeling study. The principal effects of disposal room closure on two-phase flow are captured through the use of a separate calculation for the effective porosity of a waste-filled room as a function of time and total moles of gas generated. The computer code SANCHO was used for the calculation. Results of the calculation are implemented in BRAGFLO through the use of a "look-up" table of porosity values.

C.3 Parameter Values

The calculations presented in this appendix were conducted to provide a baseline for a subsequent set of simulations used in a Systems Prioritization study. Parameter values and ranges were derived from the Position Papers and elicitation interviews with WIPP Principal Investigators. The parameter ranges used for the simulations incorporated both conservative and optimistic estimates of parameter values. Within the context of a sensitivity study, this parameter variation provides an excellent opportunity to investigate the system response to a wide range of inputs.

The physical properties for the geologic media, as well as those parameters governing gas generation, have significant quantitative variation. This variation is addressed through the use of a probabilistic, Latin Hypercube Sampling (LHS) method. The LHS approach generates a set of input vectors from the distribution of input parameters, which cover the space of parameter variation.

The sensitivity study presented here used a total of 75 input vectors, with seal permeabilities ranging from 10^{-13} to 10^{-19} m^2. The equivalent shaft region is subdivided into upper and lower regions. Each region consists of a Seal element and a Shaft element. These simulations assumed that only the Lower Seal element (length of 100 m) functioned as a fluid flow barrier. The remainder of the shaft regions were assumed to consist of a permeable fill (intrinsic permeability of 10^{-12} m^2) material.

C.4 Simulation Results

The performance measures used to assess the sensitivity of the system to material permeabilities are: (1) brine flow up or down the shaft and (2) gas flow up the shaft. These measures are consistent with design guidance that the shafts limit flow to acceptable levels. A scatter plot of the cumulative brine flow through the shaft is illustrated in Figure C-1. Results for all 75 input vectors are depicted on this plot. The cumulative brine flow was calculated at the top of the lower seal element. These results show that brine flows through the seal are not significantly reduced until the Lower Shaft permeability is reduced to 10^{-16} m^2. Zero brine flow is achieved with a permeability of 10^{-17} m^2. The cumulative gas flow for all input vectors is shown in Figure C-2. These results show that a reduction of gas flow up the shaft does not begin until the lower shaft permeability is reduced to 10^{-18} m^2.

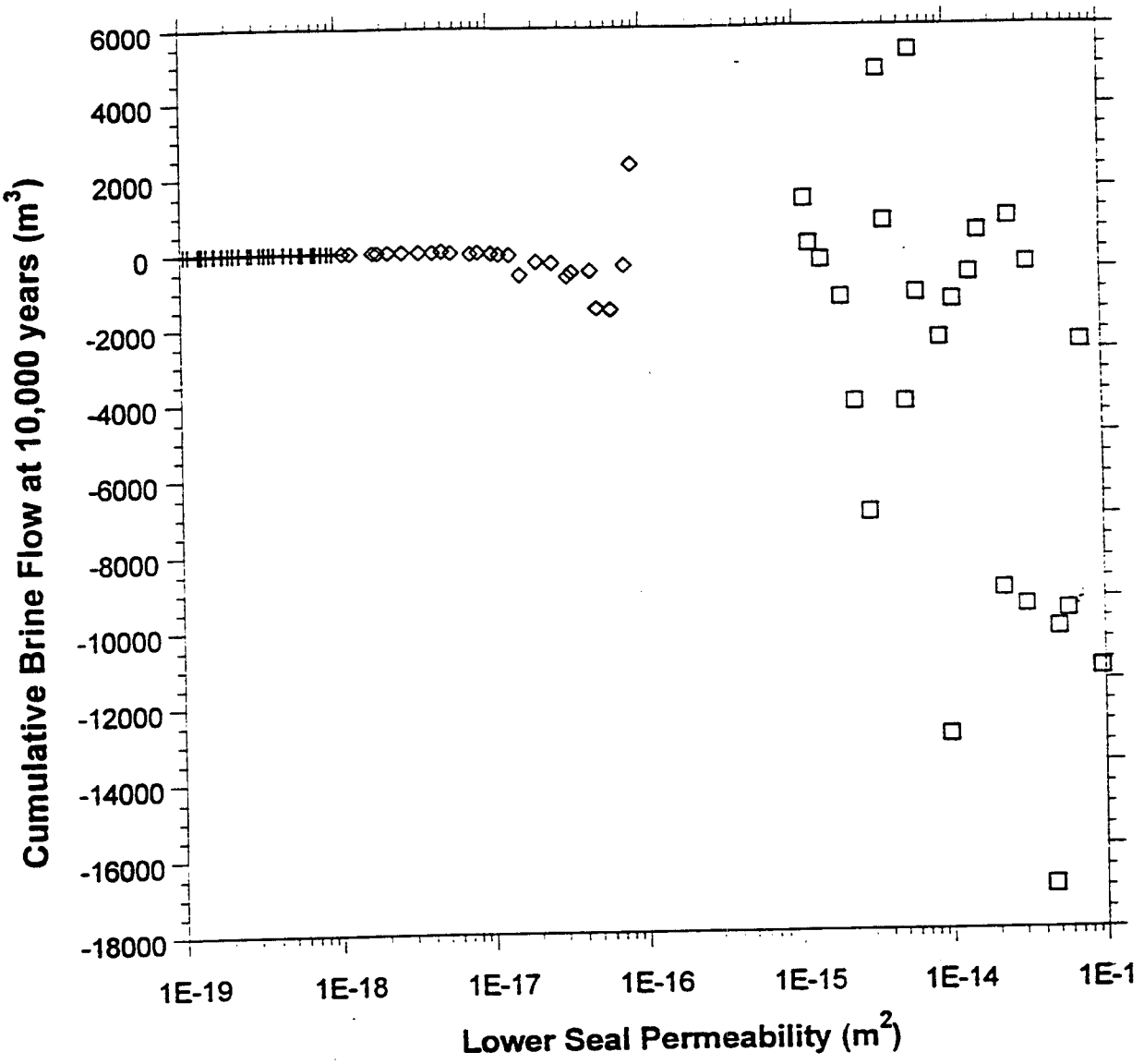


Figure C-1. Predicted cumulative brine flow through lower seal.

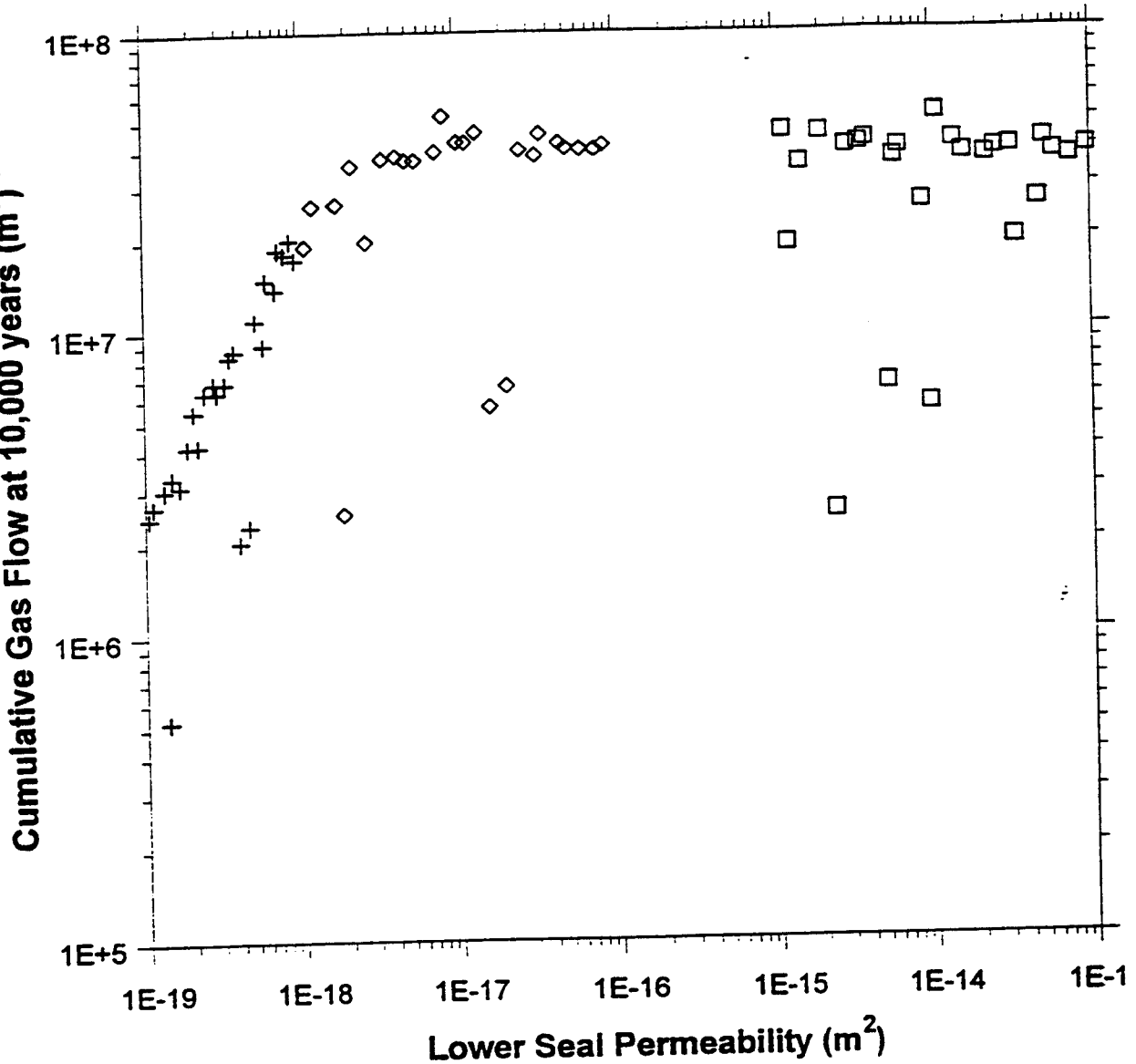
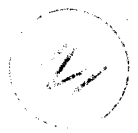


Figure C-2. Predicted cumulative gas flow through lower seal.

Appendix D:
Comparative Analysis of the Seal System Design



APPENDIX D:
Comparative Analysis of the Seal System Design

D.1 Introduction

The calculations presented in this appendix are scoping in nature. Verification of the performance of the seal system is currently being performed through detailed multi-phase flow simulations which model the dominant flow processes expected in the seal system. The comparison presented in this appendix provides evidence that the seal system described in this report meets the design guidance described in Section 2.

This appendix is organized into four sections in addition to the introduction. Section D.2 presents the quantitative design guidance for the WIPP shaft seal system as provided by modeling studies of the seal system. Section D.3 provides the specifics behind the analysis approach applied, as well as a discussion of analysis assumptions and inputs. Section D.4 presents the comparison of the design relative to the design guidance.

D.2 Design Guidance

The general requirement of limiting fluid flow through the seal system can be divided into specific functions based on the physical characteristics of the WIPP shaft sealing system and the surrounding media. The Rustler Formation is considered the primary source of brine to the shaft sealing system. The Salado Formation, although saturated, has a very low permeability and thus a low potential as a significant brine source. As currently conceptualized, the repository will produce significant quantities of gas capable of inducing significant pressure build-up at the base of the shaft over time. The WIPP shaft sealing system is designed to restrict the flow of gas at pressures less than lithostatic.

The primary source of significant groundwater flow to the shaft sealing system is the Rustler Formation. The upper shaft seal system must limit Rustler brine migrating down the shaft. The reasons for limiting brine migration in the seal system from the Rustler are: (1) to block water from reaching the repository; and (2) to limit the development of significant pore pressures in the compacted salt column.

The lower shaft seal system must also limit fluid flow. The lower seal system must limit gas or brine released from the repository horizon from migrating up the seal system. The reasons for limiting gas and brine from migrating up the shaft from the repository are: (1) to prevent the release of radionuclides or hazardous constituents; (2) to prevent significant pore pressures from building up in the compacted salt column during the 100 years following closure; and (3) to

prevent possible seal degradation from active circulation of fluids. The release of gas from the repository horizon through the shaft may not directly influence compliance. However, because gas has the potential to impede consolidation of the compacted salt column, the lower seal will need to prevent significant gas pressures from building in the compacted salt column for a period of 100 years.

Sensitivity modeling has recently been performed with the objective of determining the sensitivity of brine and gas flow within the WIPP shaft sealing system to shaft seal permeability. This sensitivity study has provided preliminary design guidance for the shaft sealing system. The sensitivity study modeled the four existing WIPP shafts as one equivalent shaft with an area equal to that of the four shafts. Results from the sensitivity study determined that, for a shaft seal to limit migration of brine, the seal must have an intrinsic permeability of less than or equal to 1 x 10^{-16} m^2 over an effective seal length of 100 m or greater. The simulation results also showed that to significantly impede gas migration from the repository, the lower seal must have an intrinsic permeability less than or equal to 10^{-18} m^2 over an effective seal length of 100 m or greater.

In this appendix, a comparative analysis will be performed based on the quantitative design guidance provided by the sensitivity analyses. This analysis does not represent a hydraulic analysis and seal system flow rates are not calculated. The analysis will compare each component of the seal system to the quantatative design guidance described above. This analysis will provide a method to determine if the sealing system design provides adequate sealing properties as compared to the design guidance.

D.3 Analysis Approach

The analysis compares flow potential as defined by hydraulic conductance for both the design cross-sectional seal and the expected disturbed rock zone (DRZ) and compares this to the quantitative design guidance. Seal material and rock permeabilities are also required as input. This section will define the analytical approach used, the analysis inputs, and the assumptions.

D.3.1 Analysis Methodology

Single-phase fluid flow through a porous medium is governed by Darcy's Law. Darcy's Law for steady-state flow can be expressed as:

$$Q = -KA\frac{dh}{dl} \qquad \text{(D-1)}$$

where Q is the volumetric flow rate (m^3/s), K is the hydraulic conductivity of the porous medium (m/s), dh is the difference in hydraulic head across the porous medium (m), dl is the length across which dh is measured (m), and A is the cross-sectional area normal to the flow direction (m^2). The hydraulic conductivity is a property of the porous medium and of the fluid saturating

the pore space. Hydraulic conductivity is equal to:

$$K = \frac{k\rho g}{\mu} \qquad \text{(D-2)}$$

where k is the intrinsic permeability of the porous medium (m^2), ρ is the fluid density (kg/m^3), g is the acceleration of gravity (m/s^2), and μ is the fluid viscosity (Pa • s). Using WIPP reference values for a brine, hydraulic conductivity is equal to intrinsic permeability multiplied by a factor equal to 6.69×10^6.

The design guidance for seal permeability and seal length resulting from model sensitivity calculations cannot be directly compared to the seal design for the Air Intake Shaft (AIS). The model combines all four WIPP shafts as one equivalent shaft with an area of 100 m^2. To compare sensitivity results to the seal design, one must consider permeabilities, lengths, and areas, which are different between the seal design and the model. The AIS has an area of approximately 30 m^2, which is approximately 30% of the shaft area modeled in the simulations.

Therefore, a method of couching the results from modeling (design guidance) into a form which can be compared to a seal design with variable length, permeability, and area relative to the model seal guidance is required. The term which allows this is the hydraulic conductance. The hydraulic conductance is a measure of a system's ability to transmit water and is equivalent to thermal conductance in heat flow problems. The hydraulic conductance of a porous medium is derived from area, length, and hydraulic conductivity, and is the inverse of the hydraulic resistance. The hydraulic conductance, defined in terms of intrinsic permeability, can be expressed as:

$$C = \frac{kA}{L}\frac{\rho g}{\mu} = \frac{KA}{L} \qquad \text{(D-3)}$$

where C is the hydraulic conductance (m^2/s), k is the intrinsic permeability (m^2), A is the area (m^2), L is the component length (m), ρ is the fluid density (kg/m^3), g is the acceleration of gravity (m/s^2), and μ is the fluid viscosity (Pa • s).

By using equation D-3, the design guidance for the upper and lower seals can be expressed as hydraulic conductance and can be used for direct comparison with the seal design presented in this report. To limit brine flow in the shaft, modeling indicated that a seal length of 100 m, permeability of 1×10^{-16} m^2, and area of 100 m^2 must exist in the shaft. Assuming a viscosity of 0.0018 Pa • s, a fluid density of 1230 kg/m^3, and an acceleration of gravity constant of 9.792 m/s^2, the brine seal guidance translates into a hydraulic conductance equal to 6.7×10^{-10} m^2/s. For limiting gas flow in the shaft, modeling indicated that a seal length of 100 m, permeability of 1×10^{-18} m^2, and area of 100 m^2 must exist in the shaft. Assuming fluid properties representative of a WIPP brine (see above), the gas seal guidance translates into a hydraulic conductance equal to 6.7×10^{-12} m^2/s. Because the AIS contributes 30% of the area of

the equivalent shaft, these hydraulic conductances should be reduced to 30% for comparison to the AIS seal dimensions. This results in a brine seal guidance hydraulic conductance of 2.0×10^{-10} m^2/s and a gas seal guidance hydraulic conductance of 2.0×10^{-12} m^2/s. In the calculation of hydraulic conductance, brine properties are assumed for both brine and gas. This assumption is justified because the analysis is comparative and the physical properties of the permeating fluid are unimportant as long as they are the same as those used to calculate the design guidance hydraulic conductance. Calculations predicting performance of the shaft sealing system require rigorous application of multiphase properties and are beyond the scope of this appendix.

To determine if the seal design meets the design guidance provided by modeling results, the hydraulic conductance of the AIS seal design is computed and compared to the design guidance. The computation of seal hydraulic conductance is based on a component-by-component basis consistent with the seal design description found in Section 3 of this report.

The hydraulic analysis considers the cross-sectional area of the seal for flow plus the cross-sectional area of the DRZ normal to the axis of the shaft. The hydraulic conductance of the cross-sectional seal and the DRZ are added to get the total hydraulic conductance of a specific component of the seal design, as illustrated in Figure D-1. For parallel flow, the appropriate law of composition is simply to add the hydraulic conductances of the seal and the DRZ. The zone with the largest hydraulic conductance dominates the total hydraulic conductance. The total seal system (seal plus DRZ) hydraulic conductance is then compared to the guidance hydraulic conductance.

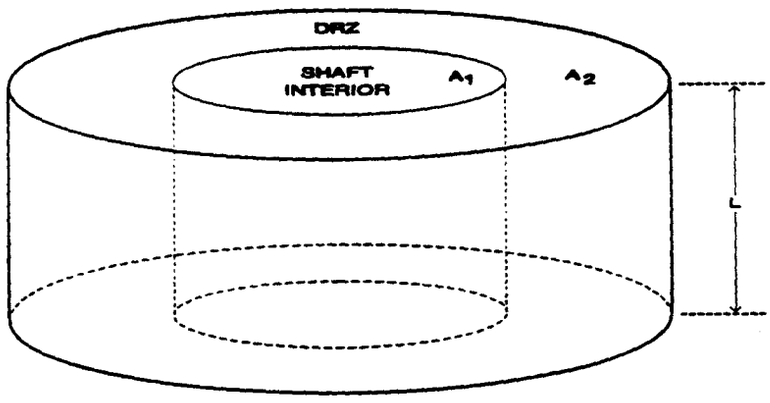


Figure D-1. Schematic of Seal System and Definition of Hydraulic Conductance

The determination of the DRZ hydraulic conductance is based on the assumption that the permeability is greatest in the DRZ near the excavation face and decreases log-linearly as one approaches the outer extent of the DRZ. Figure D-2 shows a schematic of a shaft with a DRZ of inner radius r_i and outer radius r_o. It is assumed that the permeability k_i at r_i is several orders of magnitude higher than the intact undisturbed permeability defined at r_o. The functional relationship between the variation in permeability as a function of radius is unknown. The calculations in this appendix assume that the change in permeability within the DRZ can be described by a linear change in log permeability. Therefore, for a given r_i, k_i, r_o, and k_o, an effective DRZ permeability is calculated which accounts for both the decrease in DRZ permeability and the increase in flow area as a function of radius away from the excavation. The equation for the effective DRZ permeability is

$$k_{DRZ} = \frac{2}{r_o + r_i}\left[\left(\frac{r_o(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_o - \left(\frac{r_i(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_i\right]$$

where Δr is equal to the outer DRZ radius minus the inner DRZ radius.

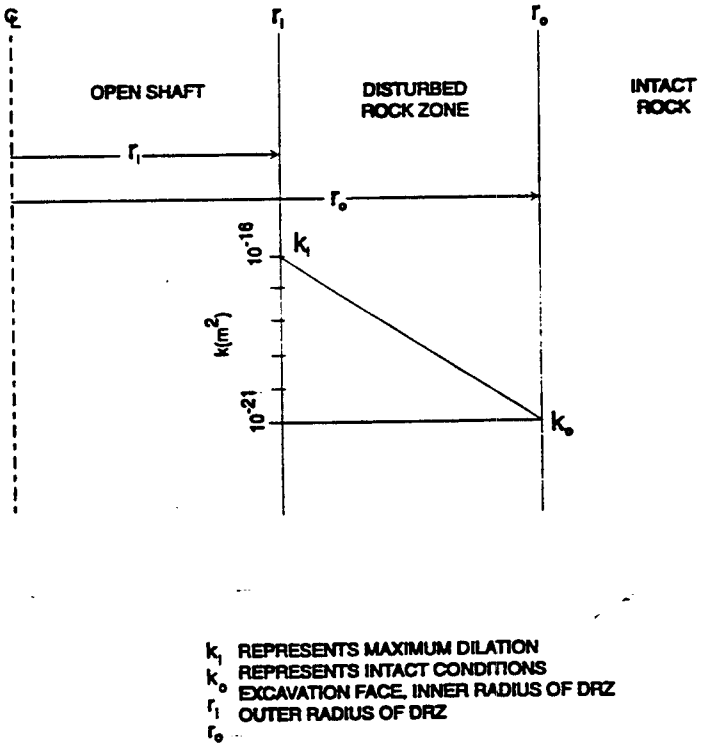


Figure D-2. Log-linear model for the calculation of an effective permeabillity of the DRZ.

D.3.2 Analysis Assumptions

There are several assumptions inherent in the calculation of hydraulic conductance. These assumptions are listed below.

- Reference fluid properties representative of WIPP brine are used in calculations of hydraulic conductance. Because the analysis is a comparative study, these properties are unimportant to the analysis.

- Flow through the seal system is limited to the cross-sectional seal and the DRZ. Interface flow is not considered; therefore the hydraulic conductance is calculated for the seal plus the DRZ only.

- The comparative analysis is performed for the AIS. The dimensions of the seal components and the DRZ components are representative of the AIS.

- Properties of the seal materials are described in Section 4. Transient seal permeabilities are used for concrete and for the compacted salt column. The concrete components are not assigned a sealing function after 100 years. They are replaced by a silty sand with a permeability of 1×10^{-14} m^2. The consolidated salt permeability varies as a function of relative density according to the Knowles-Hansen (Figure D-8) functional relationship;

- The Salado is modeled as argillaceous;

- Salt creep can be defined by the modified Munson-Dawson (M-D) creep material model (Munson et al., 1989). The salt DRZ can be described by the Multi-Deformation Coupled-Fracture (MDCF) material constitutive model which provides a continuum description of the response and the associated damage evolution of rock salt;

- Asphalt, for purposes of these calculations, is considered a porous medium. This is necessitated by the assumptions of the hydraulic evaluation. It is understood that asphalt is a separate phase from water or gas. The water permeability of asphalt liquid is effectively zero; therefore, this assumption is considered conservative;

- The seal system is evaluated at 0, 10, 50, and 100 years. In this analysis, hydraulic properties of the seal and DRZ are considered constant beyond 100 years.

D.3.3 Analysis Parameters

Several analysis inputs are required for the hydraulic conductance calculations. These include: (1) compacted salt column fractional density as a function of time; (2) DRZ radius as a function of time, depth, and sealing material; and (3) the intrinsic permeability of the seal materials and the Salado DRZ. These parameters are discussed below.

D.3.3.1 Reconsolidated Salt Fractional Density

The salt in the compacted salt column will continue to consolidate after emplacement in the shaft as a result of salt creep. RE/SPEC (1995) calculated the fractional density of a salt column in the Salado for various depths over a 1,000 year time period. The calculations were performed with a series of "pineapple slice" models at depths of 250 m, 350 m, 450 m, 550 m, and 650 m. These five depths were considered adequate to define the functional relationship between salt fractional density, depth, and time. The primary assumptions of the analysis are:

- The calculations are based upon finite deformation solutions;
- The initial fractional densities of the salt are 0.80, 0.85, 0.90, and 0.95;
- The stratigraphy of the Salado is not considered; instead the Salado is considered homogeneous as a clean or argillaceous halite;
- The shaft has a uniform diameter of 6.1 m;
- The initial stress state prior to excavation is lithostatic;
- The excavation occurs at -50 years and remains open for 50 years until time zero, when the salt seal material is emplaced instantaneously.

The crushed salt consolidation is governed by the constitutive model described by Callahan and DeVries (1991) and Callahan (1993). For the calculations presented in this appendix, the initial emplacement fractional density is 0.90. Using calculations presented in RE/SPEC (1995), the fractional density as a function of depth and time was determined for an initial fractional density of 0.90 through linear interpolation. Figure D-3 provides the fractional density relationship based on an initial emplacement density of 0.90 and the salt is argillaceous. These parameters are used to estimate the compacted salt column fractional density. Fractional density is then used to define the permeability of the salt seal (see Section D.3.3.3).

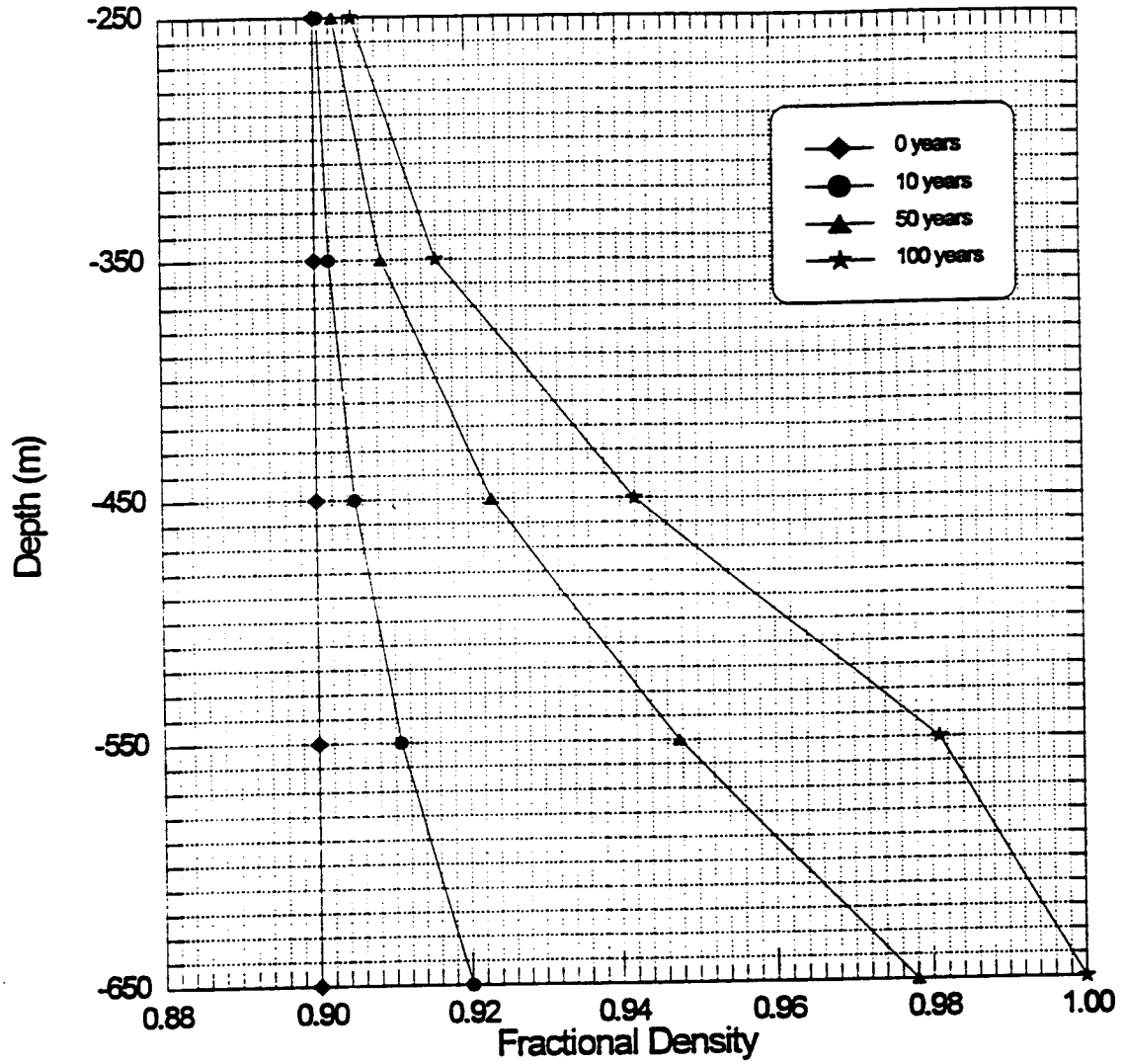


Figure D-3. Fractional density of reconsolidated salt for argillaceous salt.

D.3.3.2 Disturbed Rock Zone (DRZ) Definition

The Salado Formation between the depths of approximately 250 m to 650 m is primarily composed of halite, which exhibits time-dependent deformation. A DRZ develops around an excavation in response to the stress relief provided by the excavation. The extent of the DRZ will be reduced in halite as the salt creeps in on the sealing material creating back stresses on the shaft wall. The extent of the DRZ is a function of the type of halite surrounding the shaft, time, depth, and the stiffness of the sealing material. RE/SPEC, Inc. calculated the radial extent of the DRZ for times 0, 10, 25, 50, and 100 years after seal emplacement. The seal materials

considered in the RE/SPEC analysis are asphalt, compacted clay, crushed salt, asphalt concrete, and salt-saturated concrete. Asphalt concrete is not used in the shaft sealing system.

The calculations were performed with the finite-element program SPECTROM-32. The calculations assume that a material model describing salt creep can be defined by the Multi-Deformation, Coupled-Fracture (MDCF) material constitutive model, which provides a continuum description of the response and the associated damage evolution of rock salt. This model gives a measure (i.e., the damage stress) of the shear- and tensile-induced damage. The damage stress measure can be used as an indicator of the potential for damage, although it is not actual damage. These calculations indicate that the initial DRZ may extend as much as 80% of the shaft radius into the surrounding argillaceous salt, or may be nonexistent if the shaft is surrounded by clean salt. The healing of the DRZ is directly related to the stiffness of the material filling the shaft. The stiffer the material, the quicker the DRZ heals. In the Dewey Lake Redbeds and the Rustler Formation, the DRZ is not expected to heal since the rock types found in these formations do not exhibit time-dependent behavior. The assumptions of the analysis are:

- The calculations are based upon finite deformation solutions;
- The stratigraphy of the Salado is considered homogeneous as either a clean or an argillaceous halite;
- The initial stress state prior to excavation is lithostatic;
- Permeability changes in the salt DRZ are conservatively assumed to extend as far as the damage;
- The excavation occurs at -50 years and remains open for 50 years, when the salt seal material is emplaced instantaneously;
- The calculations were performed with a series of pineapple-slice models at depths of 250 m, 350 m, 450 m, 550 m, and 650 m.

Figures D-4 through D-7 show the DRZ extent (expressed as a multiple of the shaft radius) as a function of depth and as a function of backfill material for times 0, 10, 50, and 100 years after closure, respectively. At time zero, the DRZ is independent of backfill. Also at time zero, the asphalt waterstop DRZ radii are considered to be equivalent to the excavation radii plus 0.5 m. After 10 years, the DRZ is considered to have healed against the waterstops, and the DRZ radii will be equal to zero.

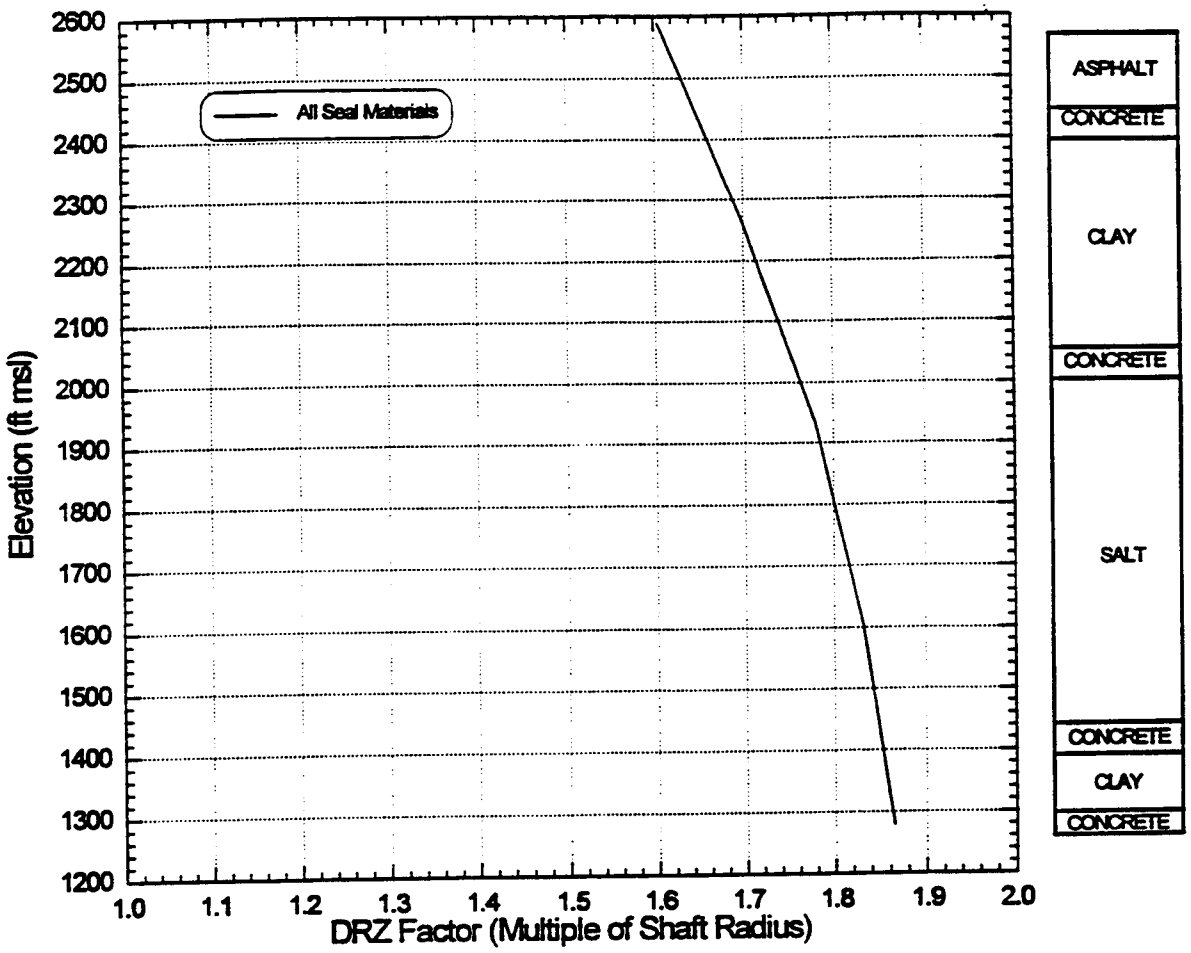


Figure D-4. Maximum DRZ extent at 0 years after closure.

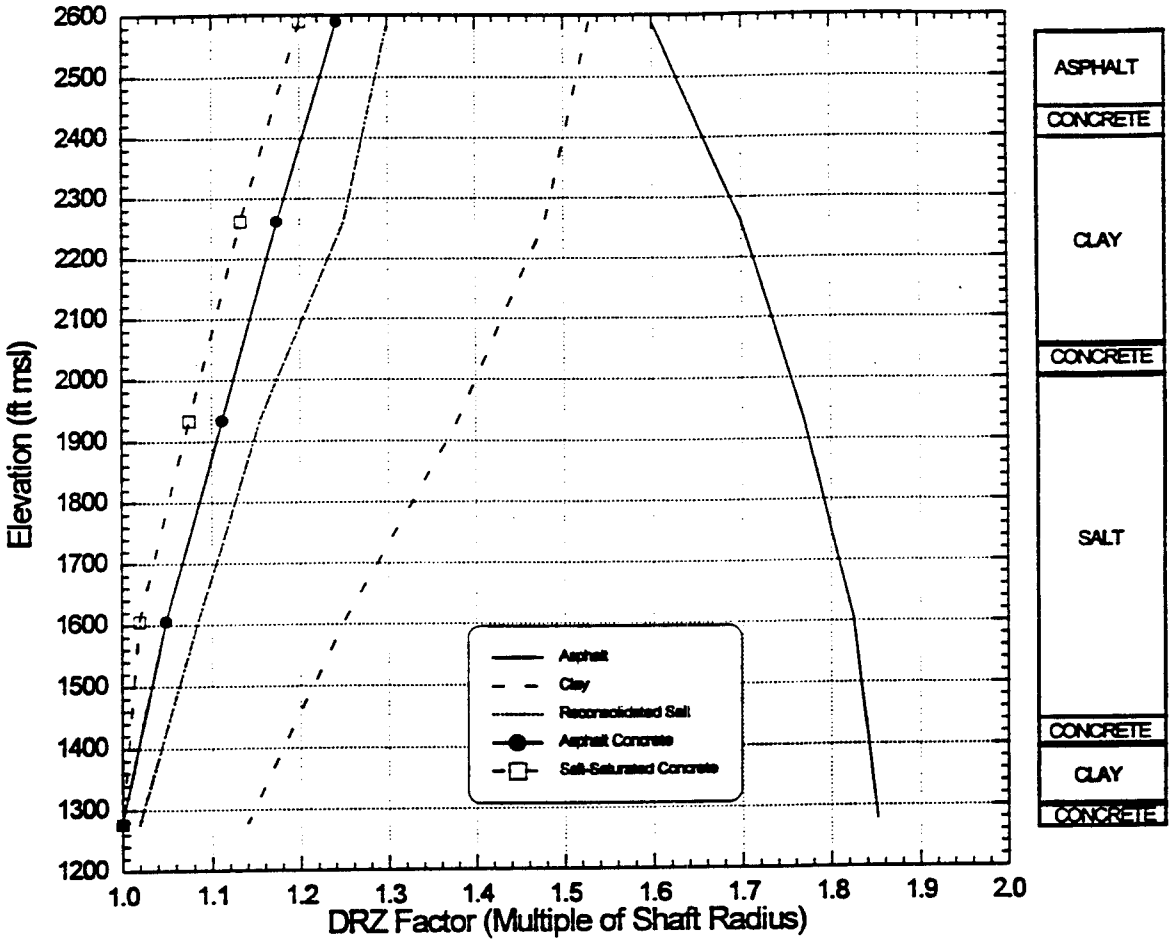


Figure D-5. Maximum DRZ extent at 10 years after closure.

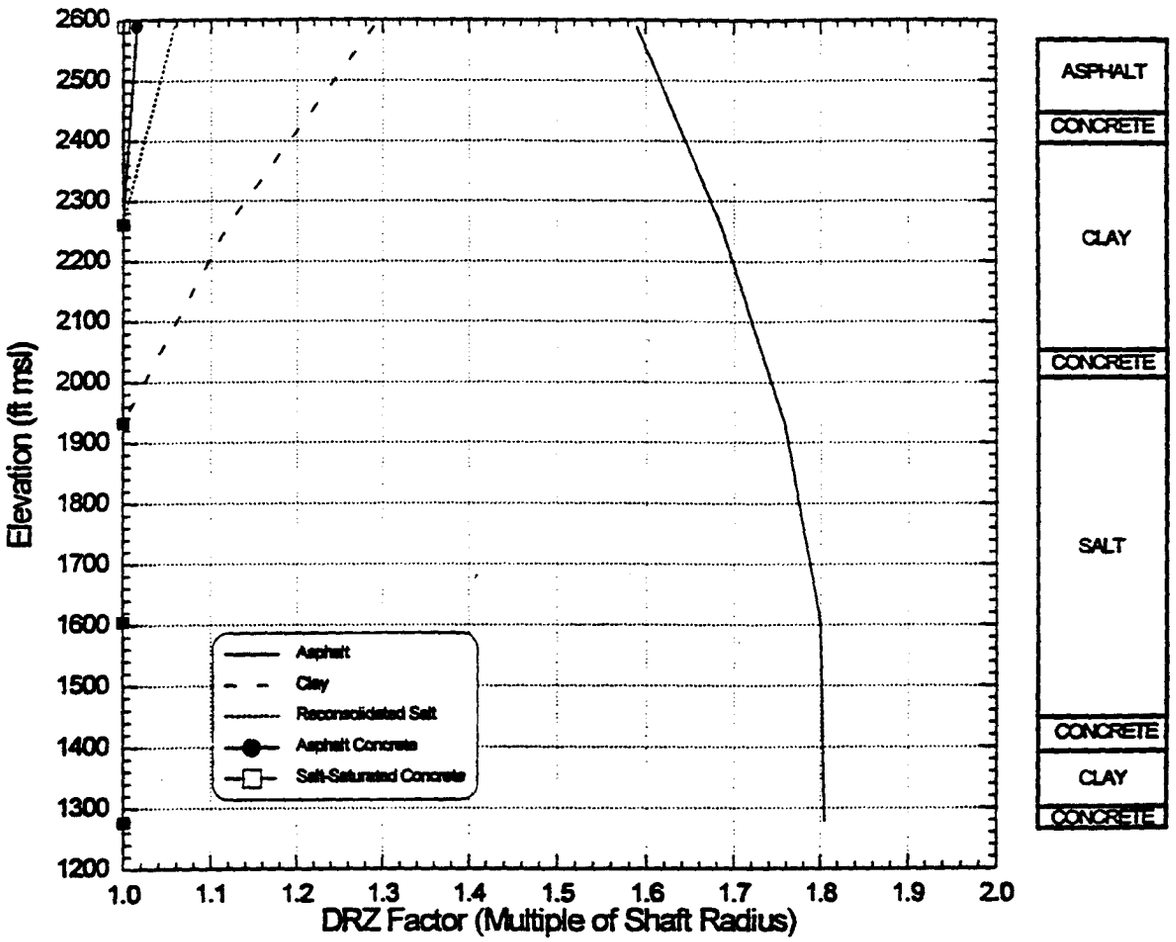


Figure D-6. Maximum DRZ extent at 50 years after closure.

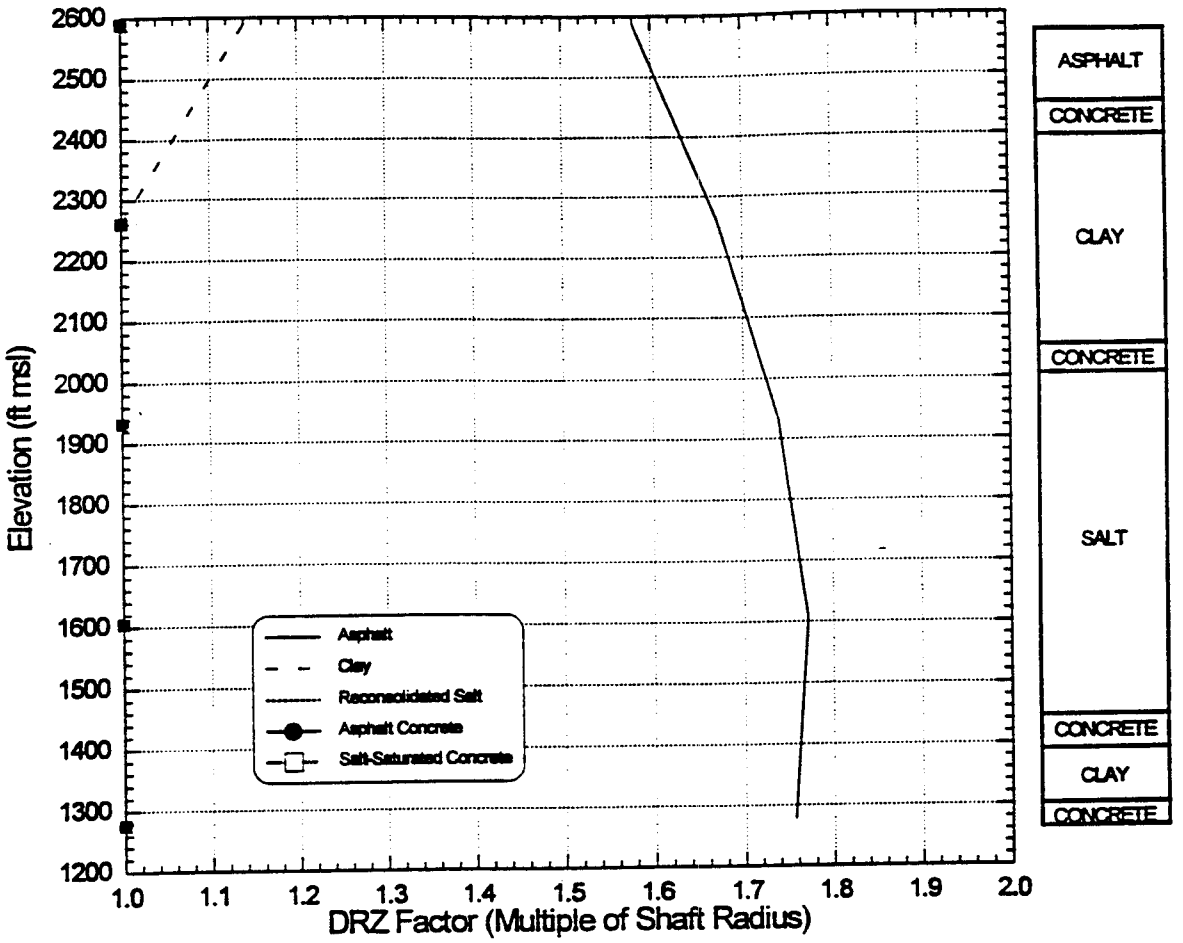


Figure D-7. Maximum DRZ extent at 100 years after closure.

D.3.3.3 Permeability

The permeability (also referred to as the intrinsic permeability) is required for all sealing materials and for the DRZ. The intrinsic permeability of a material is only a property of the pore geometry of a material and, unlike hydraulic conductivity, is not a function of properties of the permeating fluid. The materials and their associated physical properties are described in Section 4 of this report. For a complete listing of the seal material permeabilities, see Table 4-2.

The permeability of the compacted salt column is transient. As the salt consolidates, it

increases in density and decreases in permeability. Permeability measurements have been made for several samples of WIPP crushed salt at various fractional densities to describe the relationship between fractional density and permeability (Brodsky, 1994). The fractional density-permeability relationship used in these calculations is the Knowles-Hansen relationship which is shown in Figure D-8. This relationship is linear for argillaceous crushed salt at fractional densities from 0.88 to 1.0. The permeability varies from 1×10^{-11} m^2 at 0.85 to 1×10^{-21} m^2 at 1.0. The relationship is considered conservative in that it would over-predict permeability more often than under-predict permeability of WIPP crushed salt samples.

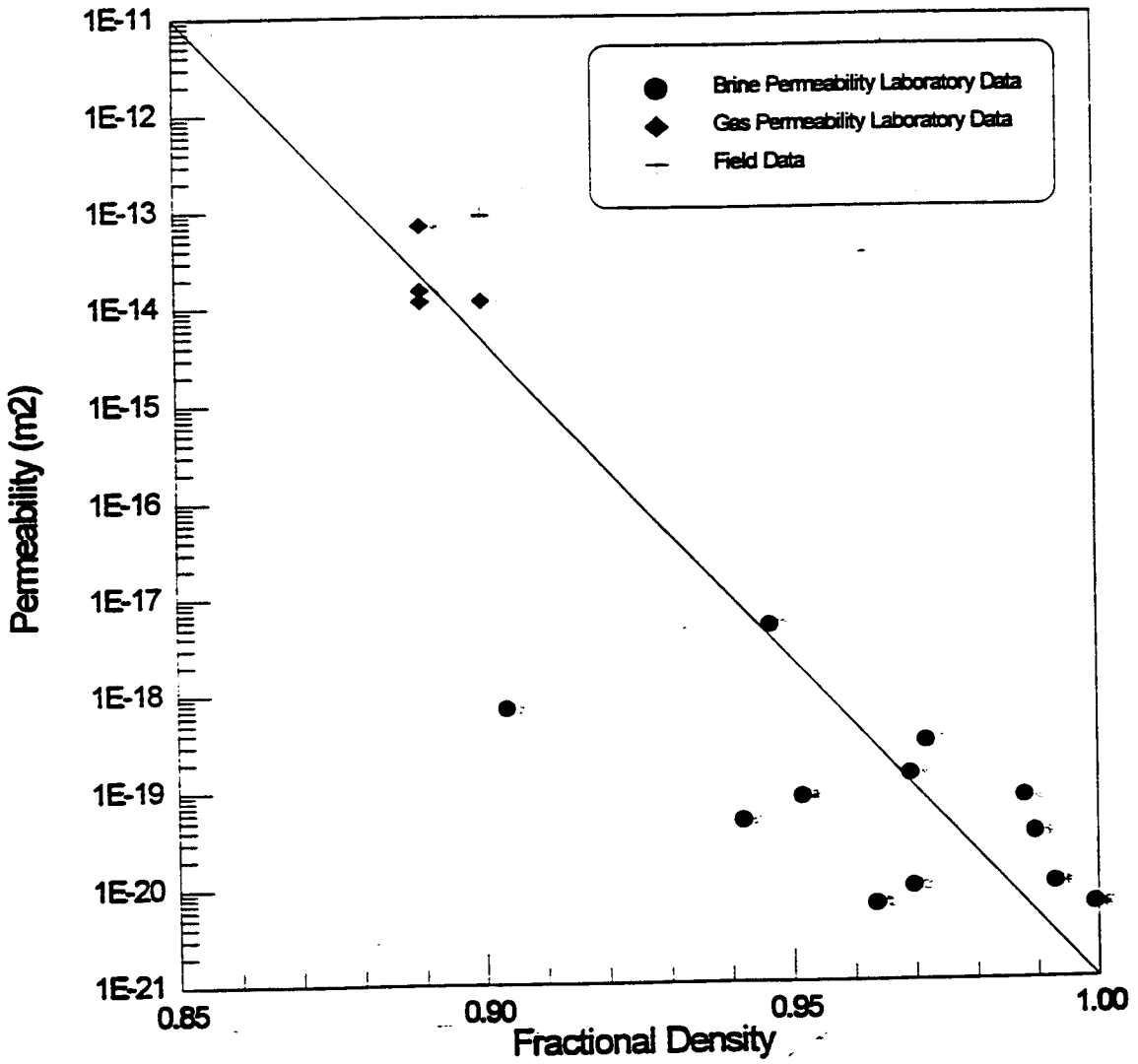


Figure D-8. Knowles-Hansen fractional density versus permeability relationship for WIPP crushed salt.

The effective DRZ permeability is estimated from the maximum disturbed permeability and the intact (undisturbed) rock permeability which can be found listed in Table 4-2. The effective DRZ permeability accounts for the decreasing DRZ permeability and the increasing flow area as a function of radius away from the excavation or into the DRZ.

D.4 Comparative Analysis of Seal System Design

The following sections discuss the current seal system design in regards to the design guidance. Because uncertainty is inherent in any engineered system, the design takes advantage of redundancy to minimize overall system uncertainty and to require multiple failure modes. As will be demonstrated, the current seal design offers redundancy in meeting the design guidance for seal hydraulic conductance.

The comparison to the design guidance is discussed in terms of an upper seal and a lower seal consistent with the functional needs of the sealing system. For purposes of this comparative analysis, the upper Salado seal is defined as the seal system between the Rustler-Salado interface and the bottom of the upper Salado compacted clay column. The lower Salado seal is defined as the seal system between the top of the compacted salt column and the bottom of the lower Salado compacted clay column.

D.4.1 Lower Salado Seal Components

The hydraulic conductance for each component comprising the lower seal was calculated. The hydraulic conductance for each component accounts for both the capacity for flow through the cross-sectional seal and the adjacent DRZ (if there is one predicted for the seal material at the time of interest). Table D-1 presents the hydraulic conductance calculated for each seal component comprising the lower seal at 0, 10, 50 and 100 years after closure. Hydraulic conductance is calculated for the cross-sectional seal, the DRZ, and the combination of the two (referred to as the total). In order to make comparisons to the design guidance easier, Table D-1 also contains the hydraulic conductance normalized to the lower seal guidance value of 2.0×10^{-12} m^2. The normalized hydraulic conductance is defined as the guidance hydraulic conductance divided by the calculated hydraulic conductance for the specific seal component. A calculated normalized hydraulic conductance with a value greater than or equal to unity indicates the guidance criteria are satisfied.

After 100 years, it is assumed that the concrete components fully degrade to the permeability of a silt to silty sand (1×10^{-14} m^2). This is considered a conservative assumption. By 100 years, the compacted salt column has healed to a permeability which provides a hydraulic conductance which by itself meets the lower seal criteria by a factor of 13. From 100 to 10,000 years, the permeability (i.e. hydraulic conductance) of the compacted salt column will continue to decrease approaching an intact salt magnitude. The clay will be stable in the WIPP environment and will maintain its sealing properties throughout the 10,000-year time frame. The asphalt may also be stable in the WIPP environment throughout the regulatory period. However, either the clay or consolidated salt components are sufficient to meet the design guidance.

Table D-1. Absolute and Normalized Hydraulic Conductance - Lower Seal Component

Element I	Material Type	Seal Component KA/L (m^2/s)	Normalized Seal Component (KA/L)	DRZ KA/L (m^2/s)	Normalized DRZ KA/L	Total KA/L (m^2/s)	Normalized Total KA/L
TIME = 0 YEARS							
9a	salt-saturated concrete	3.28E-11	0.061	2.50E-09	0.001	2.53E-09	0.001
9b	asphalt	4.26E-13	4.69	1.68E-09	0.001	1.68E-09	0.001
9c	salt-saturated concrete	2.47E-11	0.081	1.90E-09	0.001	1.92E-09	0.001
10	reconsolidated salt	5.19E-09	0.0004	4.62E-11	0.043	5.24E-09	0.0004
11a	salt-saturated concrete	3.28E-11	0.061	2.84E-09	0.001	2.87E-09	0.001
11b	asphalt	4.26E-13	4.69	1.68E-09	0.001	1.68E-09	0.001
11c	salt-saturated concrete	2.47E-11	0.081	2.15E-09	0.001	2.17E-09	0.001
12	compacted clay	7.30E-12	0.274	3.19E-10	0.006	3.26E-10	0.006
TIME = 10 YEARS							
9a	salt-saturated concrete	3.28E-11	0.061	2.99E-10	0.007	3.32E-10	0.006
9b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
9c	salt-saturated concrete	2.47E-11	0.081	2.13E-10	0.009	2.38E-10	0.008
10	reconsolidated salt	1.30E-09	0.0015	5.91E-12	0.339	1.31E-09	0.0015
11a	salt-saturated concrete	3.28E-11	0.061	3.13E-11	0.064	6.41E-11	0.031
11b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
11c	salt-saturated concrete	2.47E-11	0.081	1.18E-11	0.170	3.65E-11	0.055
12	compacted clay	7.30E-12	0.274	5.63E-11	0.036	6.36E-11	0.031
TIME = 50 YEARS							
9a	salt-saturated concrete	3.28E-11	0.061	—	—	3.28E-11	0.061
9b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
9c	salt-saturated concrete	2.47E-11	0.081	—	—	2.47E-11	0.081
10	reconsolidated salt	1.30E-11	0.153	—	—	1.30E-11	0.153
11a	salt-saturated concrete	3.28E-11	0.061	—	—	3.28E-11	0.061
11b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
11c	salt-saturated concrete	2.47E-11	0.081	—	—	2.47E-11	0.081
12	compacted clay	7.30E-12	0.274	—	—	7.30E-12	0.274
TIME = 100 YEARS							
9a	salt-saturated concrete	3.28E-11	0.061	—	—	3.28E-11	0.061
9b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
9c	salt-saturated concrete	2.47E-11	0.081	—	—	2.47E-11	0.081
10	reconsolidated salt	1.77E-13	11.3	—	—	1.77E-13	11.3
11a	salt-saturated concrete	3.28E-11	0.061	—	—	3.28E-11	0.061
11b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
11c	salt-saturated concrete	2.47E-11	0.081	—	—	2.47E-11	0.081
12	compacted clay	7.30E-12	0.274	—	—	7.30E-12	0.274

Note: Design guidance hydraulic conductance is equal to 2.0E-12 m^2/s

Table D-1. Absolute and Normalized Hydraulic Conductance - Lower Seal Component (concluded)

Element I	Material Type	Seal Component KA/L (m^2/s)	Normalized Seal Component (KA/L)	DRZ KA/L (m^2/s)	Normalized DRZ KA/L	Total KA/L (m^2/s)	Normalized Total KA/L
TIME > 100 YEARS							
9a	salt-saturated concrete	6.57E-07	0	—	—	6.57E-07	0
9b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
9c	salt-saturated concrete	4.95E-07	0	—	—	4.95E-07	0
10	reconsolidated salt	1.77E-13	11.3	—	—	1.77E-13	11.3
11a	salt-saturated concrete	6.57E-07	0	—	—	6.57E-07	0
11b	asphalt	4.26E-13	4.69	—	—	4.26E-13	4.69
11c	salt-saturated concrete	4.95E-07	0	—	—	4.95E-07	0
12	compacted clay	7.30E-12	0.274	—	—	7.30E-12	0.274

Note: Design guidance hydraulic conductance is equal to 2.0E-12 m^2/s

D.4.2 Upper Salado Seal Components

The hydraulic conductance for each material comprising the upper seal component was calculated. The hydraulic conductance for each component accounts for both the capacity for flow through the cross-sectional seal and the adjacent DRZ (if there is one predicted for the seal material at the time of interest).

Table D-2 presents the hydraulic conductance calculated for each seal material comprising the upper seal at 0, 10, 50 and 100 years after closure. Hydraulic conductance is calculated for the cross-sectional seal, the DRZ, and the combination of the two. In order to make comparison to the PA guidance easier, Table D-2 also contains the hydraulic conductance normalized to the guidance value of 2.0×10^{-10} m^2.

Table D-2. Absolute and Normalized Hydraulic Conductance - Upper Seal Component

Element I	Material Type	Seal Component KA/L (m^2/s)	Normalized Seal Component (KA/L)	DRZ KA/L (m^2/s)	Normalized DRZ KA/L	Total KA/L (m^2/s)	Normalized Total KA/L
TIME = 0 YEARS							
6	asphalt	5.52E-15	36200	1.74E-10	1.15	1.74E-10	1.15
7a	salt-saturated concrete	3.28E-11	6.09	2.14E-09	0.094	2.17E-09	0.092
7b	asphalt	4.26E-13	469	1.68E-09	0.119	1.68E-09	0.119
7c	salt-saturated concrete	2.47E-11	8.088	1.62E-09	0.123	1.65e-09	0.122
8	compacted clay	1.84E-12	109	6.56E-11	3.05	6.75E-11	2.96
TIME = 10 YEARS							
6	asphalt	5.52E-15	36200	1.72E-10	1.16	1.72E-10	1.16
7a	salt-saturated concrete	3.28E-11	6.09	5.38E-10	0.371	5.71E-10	0.350
7b	asphalt	4.26E-13	469	—	—	4.26E-13	469
7c	salt-saturated concrete	2.47E-11	8.09	3.93E-10	0.508	4.18E-10	0.478
8	compacted clay	1.84E-12	109	4.27E-11	4.69	4.45E-11	4.49
TIME = 50 YEARS							
6	asphalt	5.52E-15	36200	1.69E-10	1.18	1.69E-10	1.18
7a	salt-saturated concrete	3.28E-11	6.09	—	—	3.28E-11	6.09
7b	asphalt	4.26E-13	469	—	—	4.26E-13	469
7c	salt-saturated concrete	2.47E-11	8.09	—	—	2.47E-11	8.09
8	compacted clay	1.84E-12	109	9.71E-12	20.6	1.16E-11	17.3
TIME = 100 YEARS							
6	asphalt	5.52E-15	36200	1.69E-10	1.18	1.69E-10	1.18
7a	salt-saturated concrete	3.28E-11	6.09	—	—	3.28E-11	6.09
7b	asphalt	4.26E-13	469	—	—	4.26E-13	469
7c	salt-saturated concrete	2.47E-11	8.09	—	—	2.47E-11	8.09
8	compacted clay	1.84E-12	109	9.71E-12	20.6	1.16E-11	17.3
TIME > 100 YEARS							
6	asphalt	5.52E-15	36200	1.65E-10	1.21	1.65E-10	1.21
7a	salt-saturated concrete	6.57E-07	0	—	—	6.57E-07	0
7b	asphalt	4.26E-13	469	—	—	4.26E-13	469
7c	salt-saturated concrete	4.95E-07	0	—	—	4.95E-07	0
8	compacted clay	1.84E-12	109	—	—	1.84E-12	109

Note: Design guidance hydraulic conductance is equal to 2.0E-10 m^2/s

D.5 References

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WASTE ISOLATION PILOT PLANT

CARLSBAD, NM

SHAFT SEALING SYSTEM DESIGN

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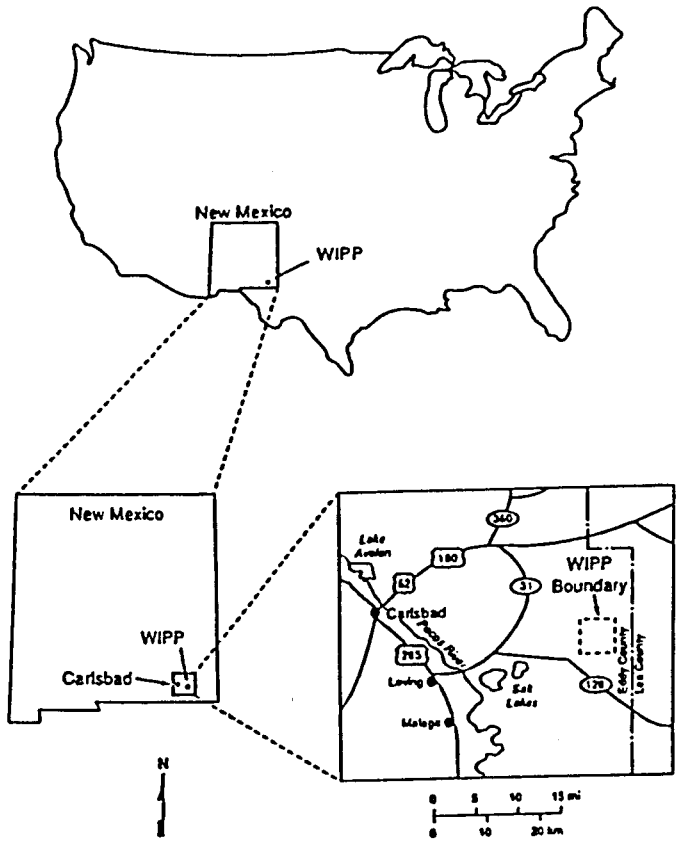
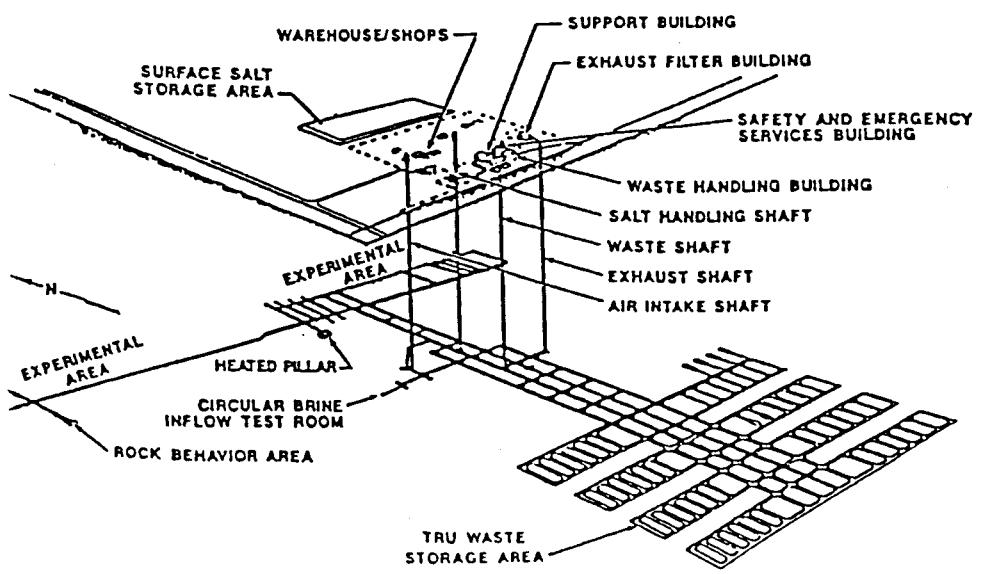
DESIGN DRAWINGS



WIPP LAYOUT



DRAWING NUMBER	TITLE
09-CS-00-G01	WIPP SHAFT SEALING SYSTEM SHAFT LOCATION PLAN, ABBREVIATIONS, GENERAL NOTES AND LEGEND
09-CS-31-G01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS WASTE SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-31-G02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION WASTE SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-31-L01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS WASTE SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-31-L02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION WASTE SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-31-S01	WIPP SHAFT SEALING SYSTEM WASTE SHAFT SHAFT STATION MONOLITH
09-CS-33-G01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS AIR INTAKE SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-33-G02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION AIR INTAKE SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-33-L01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS AIR INTAKE SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-33-L02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION AIR INTAKE SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-33-S01	WIPP SHAFT SEALING SYSTEM AIR INTAKE SHAFT SHAFT STATION MONOLITH
09-CS-35-G01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS EXHAUST SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-35-G02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION EXHAUST SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-35-L01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS EXHAUST SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-35-L02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION EXHAUST SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-35-S01	WIPP SHAFT SEALING SYSTEM EXHAUST SHAFT SHAFT STATION MONOLITH
09-CS-37-G01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS SALT HANDLING SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-37-G02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION SALT HANDLING SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS
09-CS-37-L01	WIPP SHAFT SEALING SYSTEM NEAR-SURFACE/RUSTLER FORMATIONS SALT HANDLING SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-37-L02	WIPP SHAFT SEALING SYSTEM SALADO FORMATION SALT HANDLING SHAFT STRATIGRAPHY & SEALING SUBSYSTEM PROFILE
09-CS-37-S01	WIPP SHAFT SEALING SYSTEM SALT HANDLING SHAFT SHAFT STATION MONOLITH
09-CS-00-S02	WIPP SHAFT SEALING SYSTEM CONCRETE COMPONENT IN SALADO FORMATION
09-CS-00-S03	WIPP SHAFT SEALING SYSTEM ASPHALT COLUMN
09-CS-00-S04	WIPP SHAFT SEALING SYSTEM UPPER AND LOWER SALADO COMPACTED CLAY COLUMNS
09-CS-00-S05	WIPP SHAFT SEALING SYSTEM COMPACTED SALT COLUMN
09-CS-00-S06	WIPP SHAFT SEALING SYSTEM CONCRETE PLUG
09-CS-00-S07	WIPP SHAFT SEALING SYSTEM RUSTLER COMPACTED CLAY COLUMN
09-CS-00-S08	WIPP SHAFT SEALING SYSTEM COMPACTED EARTHEN FILL AND CONCRETE PLUG

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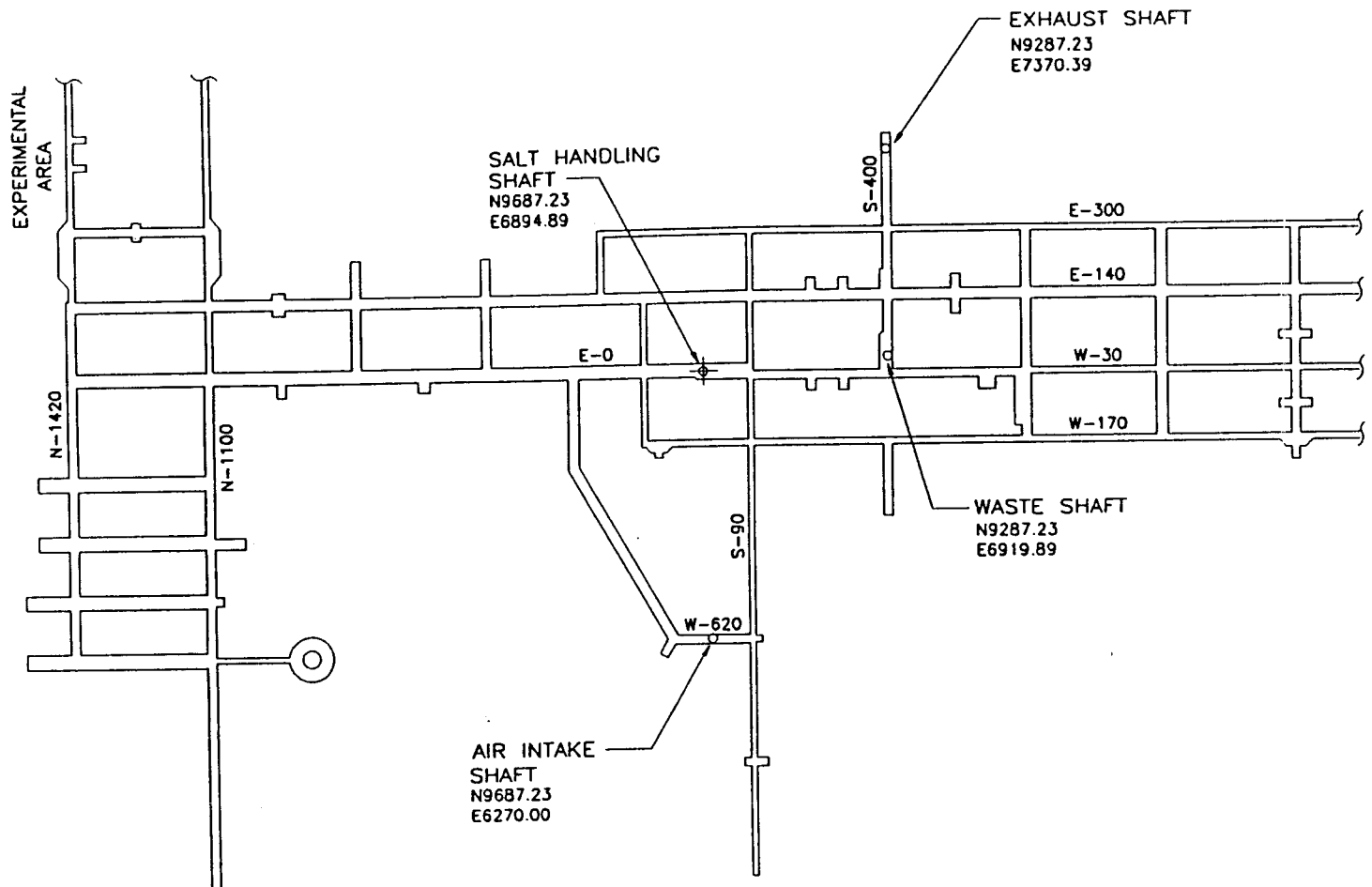


SHAFT SEALS LOCATION PLAN

N

SCALE IN FEET

0 100 200 300 400 500

GENERAL NOTES:

1. THE DRIFT NUMBERING SYSTEM (E-300, S-400, ETC.) IS BASED ON THE DIRECTION AND NOMINAL DISTANCE IN FEET THE DRIFT IS FROM THE SALT HANDLING SHAFT'S DESIGNATED CENTERLINE LOCATION OF N-000, E-000. THE WIPP PLANT COORDINATE SYSTEM CENTERLINE LOCATION FOR THE SALT HANDLING SHAFT IS N9687.23, AND E6894.89. THE PLANT COORDINATE SYSTEM IS DESCRIBED IN WESTINGHOUSE DRAWING NO. 51-W-109-W, UNDERGROUND EXCAVATIONS, DATED 6/15/92

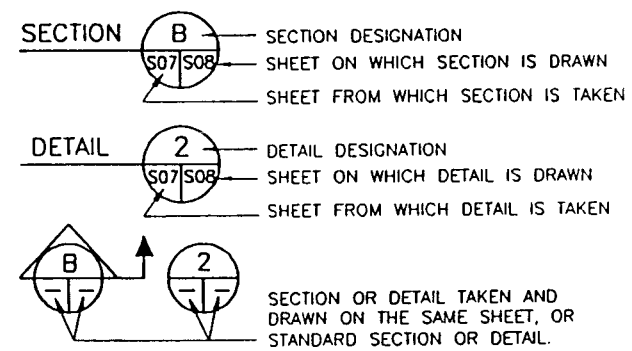
2. THE AS-BUILT DIMENSIONS AND DEPTHS AND/OR ELEVATIONS SHOWN IN THESE DRAWINGS ARE NOMINAL IN THAT DIMENSIONS MAY CHANGE DUE TO LOCAL VARIANCE OF THE STRATIFICATION, OPERATIONAL MODIFICATIONS MADE TO SUIT THE CREEP CLOSURE OF THE HALITE, AND OTHER OPERATIONAL REQUIREMENTS. THEREFORE THE AS-BUILT DIMENSIONS AND THE PERTINENT ELEVATIONS FOR SITING THE SEALING SYSTEM SHALL BE VERIFIED BY FIELD SURVEYING AND EXPLORATORY CORE DRILLING DURING SITE PREPARATION FOR THE FINAL CONSTRUCTION.

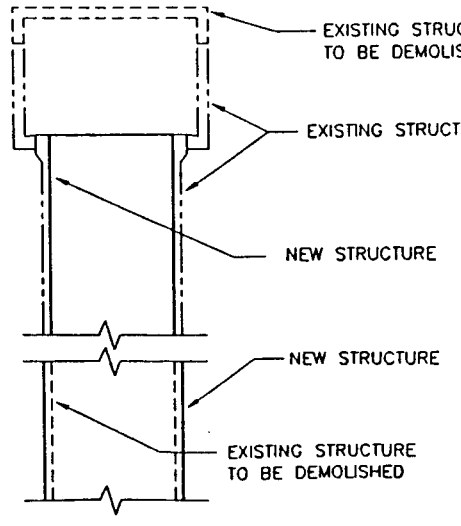
3. *FOR MATERIAL SPEC. SEE REPORT **XXXXX**, T.B.D.*

4. DRAWING NUMBERS:
   DRAWING NUMBERS ARE ASSIGNED AS FOLLOWS:
   09-CS-XX-AYY (XX-AYY),
   WHERE:
   - 09 = PB PROJECT NO. 13411A TASK NO 09,
   - CS = CIVIL AND STRUCTURAL
   - XX = 00 ..... GENERAL DRAWING
     - = 31 ..... WASTE HANDLING SHAFT
     - = 33 ..... AIR INTAKE SHAFT
     - = 35 ..... EXHAUST SHAFT
     - = 37 ..... SALT HANDLING SHAFT
   - AYY = DRAWING NUMBER

   FOR CLARITY ON DETAIL AND SECTION DESIGNATIONS, AND NOTES, THE "09-CS-" IS NOT SHOWN.

LEGEND FOR PROPOSED SHAFT SEALING SYSTEM:





ABBREVIATIONS:

℄	CENTERLINE
ANH	ANHYDRITE
CONC.	CONCRETE
CMP	CORRUGATED METAL PLATE
DOE	DEPARTMENT OF ENERGY
DWG	DRAWING
E	EAST
EL.	ELEVATION
EXIST.	EXISTING
FT.	FOOT, FEET
I.D.	INSIDE DIAMETER
HT.	HEIGHT
MB	MARKER BED
MIN.	MINIMUM
MSL	MEAN SEA LEVEL
N	NORTH
NO.	NUMBER
R	RADIUS
S	SOUTH
SMC	SALADO MASS CONCRETE
SPEC.	SPECIFICATION
T.B.D.	TO BE DETERMINED
TRU	TRANSURANIC
TYP.	TYPICAL
USGS	UNITED STATES GEOLOGICAL SURVEY
VACA TR	VACA TRISTE
W	WEST
WID	WESTINGHOUSE WASTE ISOLATION DIVISION
WIPP	WASTE ISOLATION PILOT PLANT

2

PRELIMINARY

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO. AG-4909

WIPP SHAFT SEALING SYSTEM

SHAFT LOCATION PLAN, ABBREVIATIONS, GENERAL NOTES AND LEGEND

	NAME	DATE
BY	DL	
CK.	SAR	
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PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG NO | SHEET NO

09-CS-00-G01

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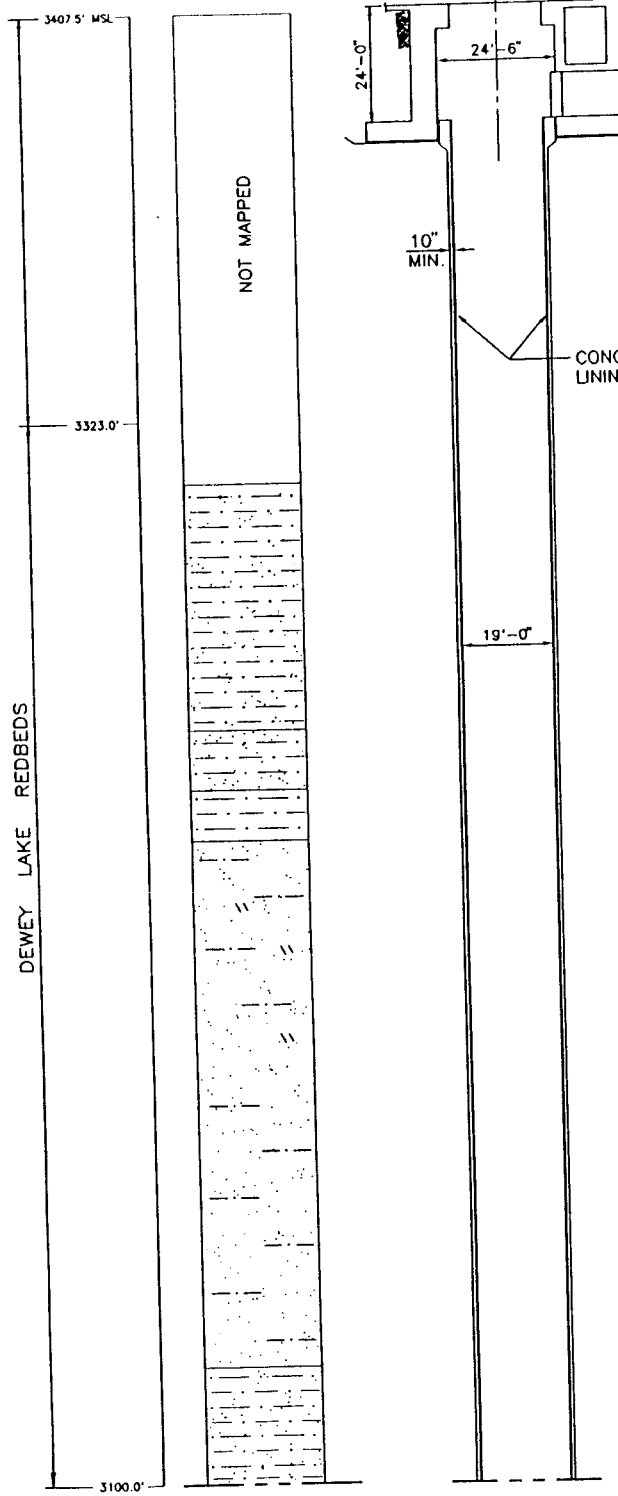
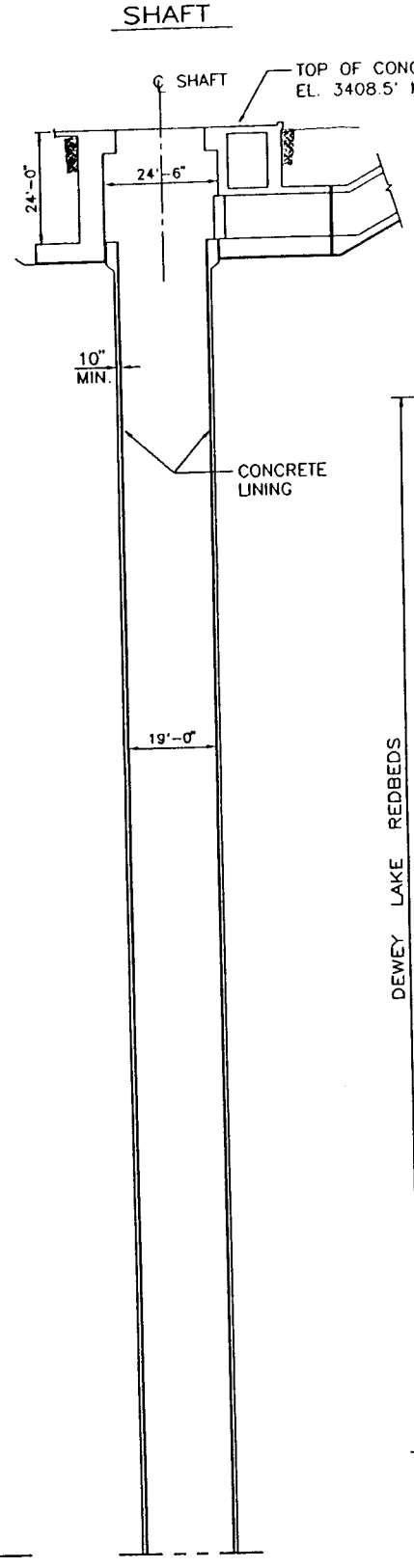
STRATIGRAPHY
(SEE NOTE 1)



SHAFT



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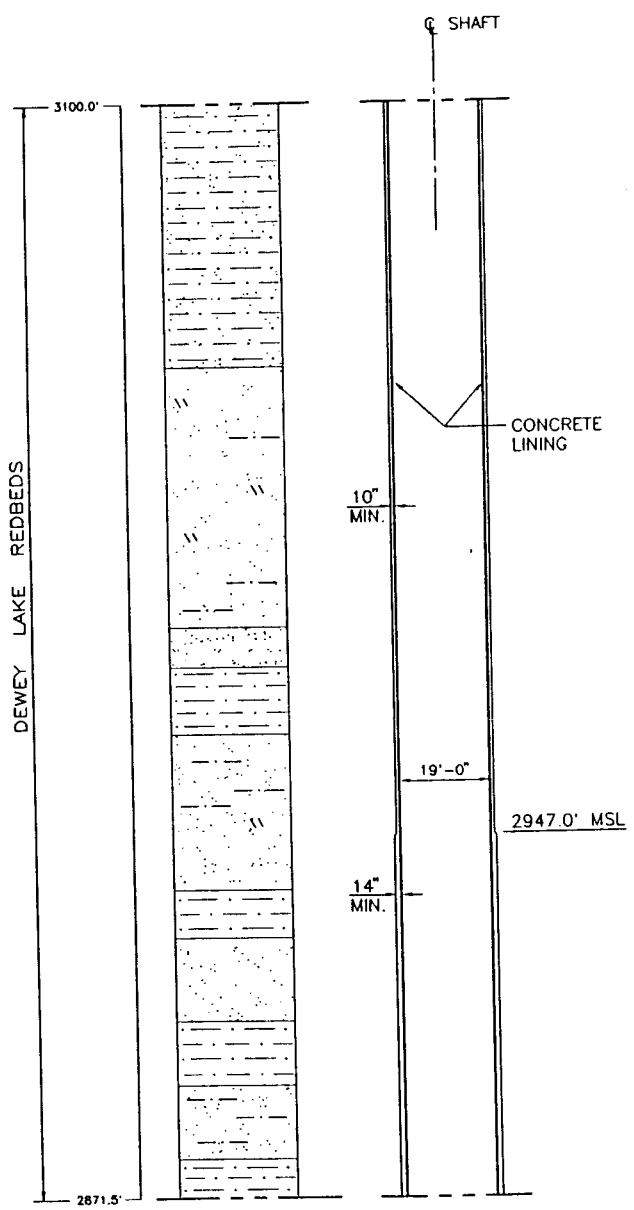

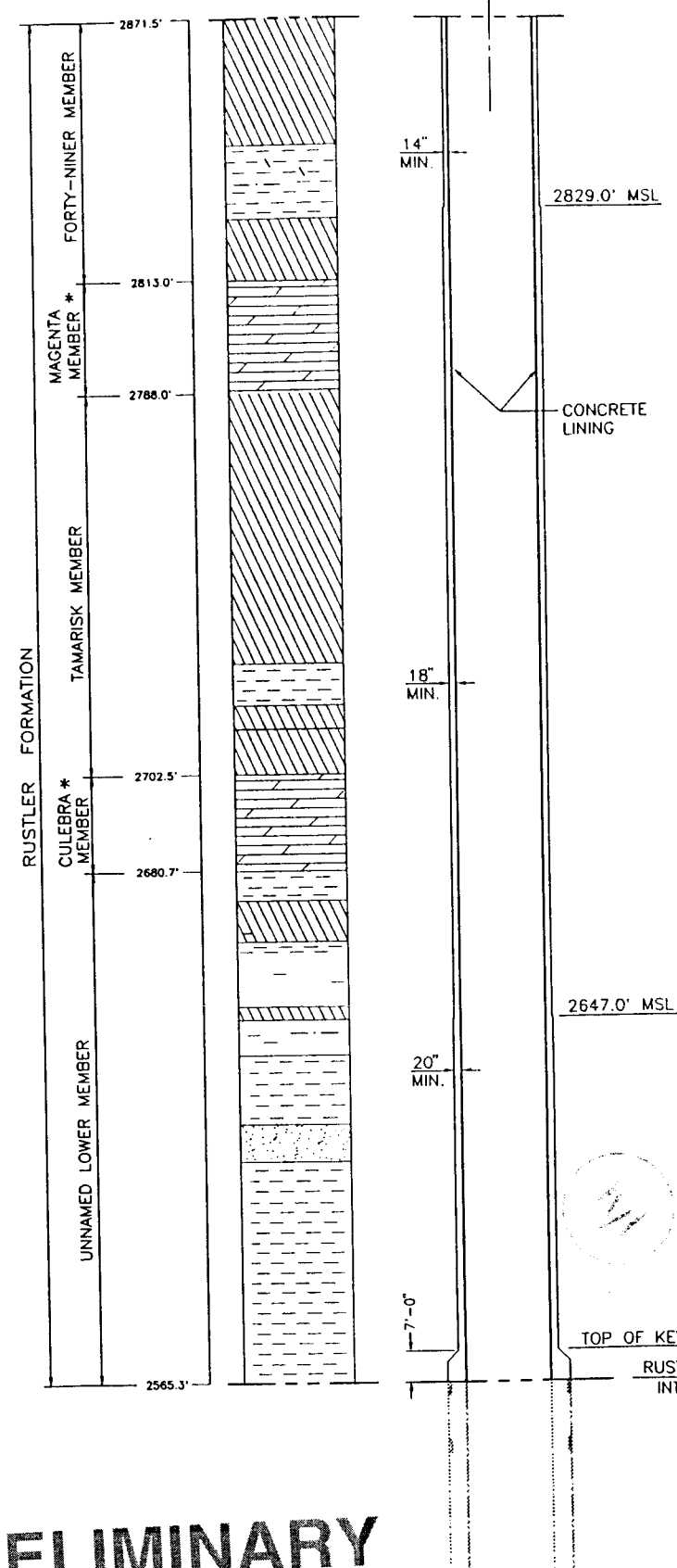

LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES	SECONDARY CONSTITUENTS
MUDSTONE/CLAYSTONE	ARGILLACEOUS
CLAYSTONE BED	SILTY
SILTSTONE	SANDY
SANDSTONE	SULFATIC
ANHYDRITE/GYPSUM	DOLOMITIC
DOLOMITE	CALCAREOUS
HALITE	HALITIC
POLYHALITE	POLYHALITIC

NOTES:

1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE WASTE HANDLING SHAFT WALLS, WTSD-TME 038, "GEOTECHNICAL ACTIVITIES IN THE WASTE HANDLING SHAFT WASTE ISOLATION PILOT PLANT (WIPP) PROJECT SOUTHEASTERN NEW MEXICO," 1984, AND APPENDIX A OF REPORT DOE/WIPP-95-3117, "WASTE ISOLATION PILOT PLANT SEALING SYSTEM DESIGN REPORT," 1995.

   STRATIGRAPHIC CONTACT AT THE TOP OF THE DEWEY LAKE REDBEDS WAS NOT RECORDED DURING MAPPING. ELEVATION SHOWN IS INTERPRETED FROM RECORDINGS OF THE SALT HANDLING AND EXHAUST SHAFTS.

   ASTERISK (*) WITHIN THE RUSTLER AND SUPRA RUSTLER FORMATIONS INDICATE GROUNDWATER OBSERVED DURING SHAFT MAPPING. ASTERISK (*) WITHIN THE SALADO FORMATION INDICATES A POTENTIAL BRINE SEEPAGE/WEEP INTERVAL. THESE POTENTIAL BRINE SEEPAGE/WEEP INTERVALS, LOCATED ABOVE THE SHAFT STATION LEVEL, ARE BASED ON OBSERVED INTERVALS OF BRINE SEEPAGE/WEEPS IN THE AIR INTAKE SHAFT THAT HAVE BEEN PROJECTED TO THE WASTE SHAFT. THE MAPPING OF THE WASTE SHAFT (HOLT & POWERS, 1984/WTSD-TME-038) DID NOT INDICATE OBSERVED SEEPAGE INTERVALS WITHIN THE SALADO FORMATION.

2. REFERENCE AS-BUILT DRAWINGS FROM WID:

WASTE SHAFT 311 SHAFT DEVELOPMENT SECTIONS	31-R-001-01D
WASTE SHAFT 311 SHAFT LINING & KEY SECTIONS AND DETAILS	31-R-002-01D
WASTE HANDLING BUILDING 411 HOIST TOWER FOUNDATION PLANS, ELEVATIONS, 76'-0" & 89'-0"	41-D-016-014
WASTE HANDLING BUILDING 411 HOIST TOWER FOUNDATION SECTIONS	41-D-018-014
AS-BUILT FOR WASTE SHAFT COLLAR	OGL A-001

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
WASTE SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS

	NAME	DATE
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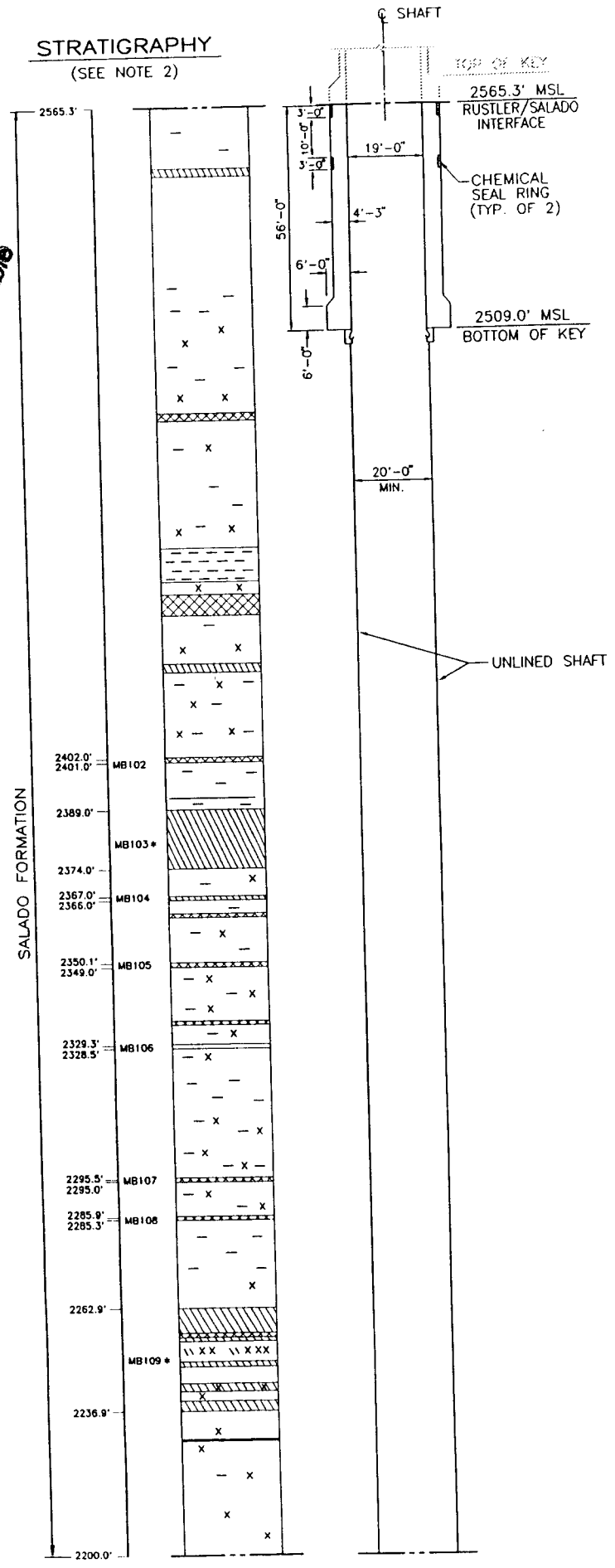
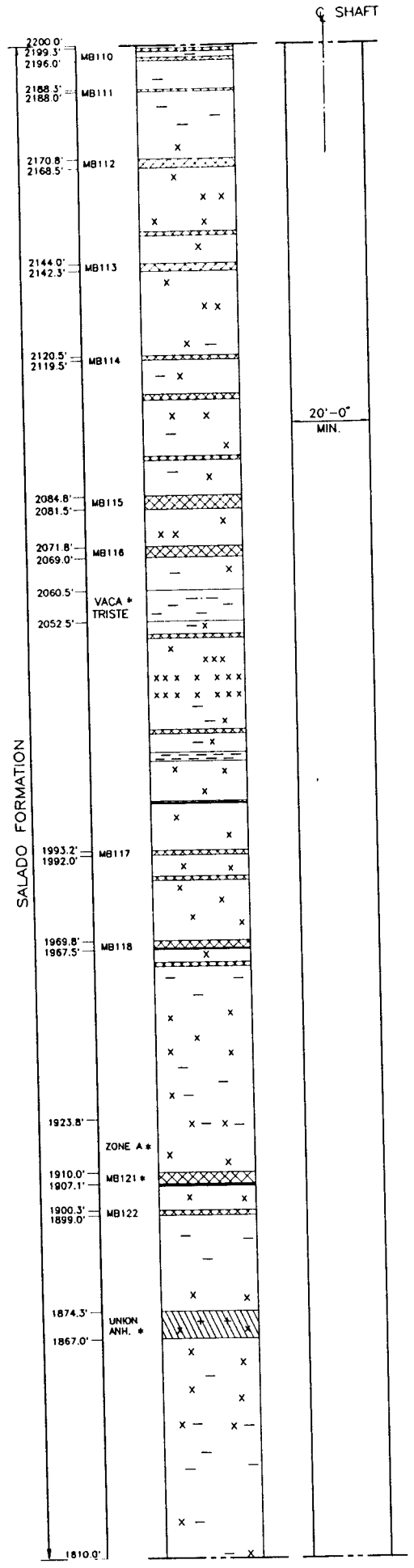
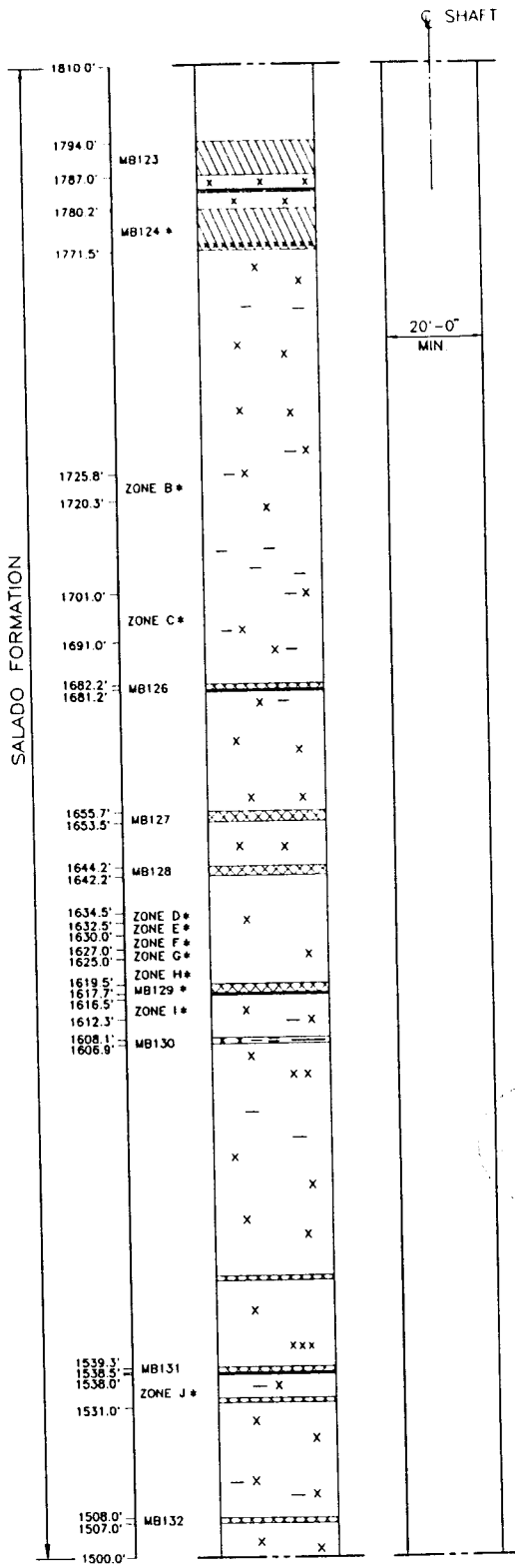
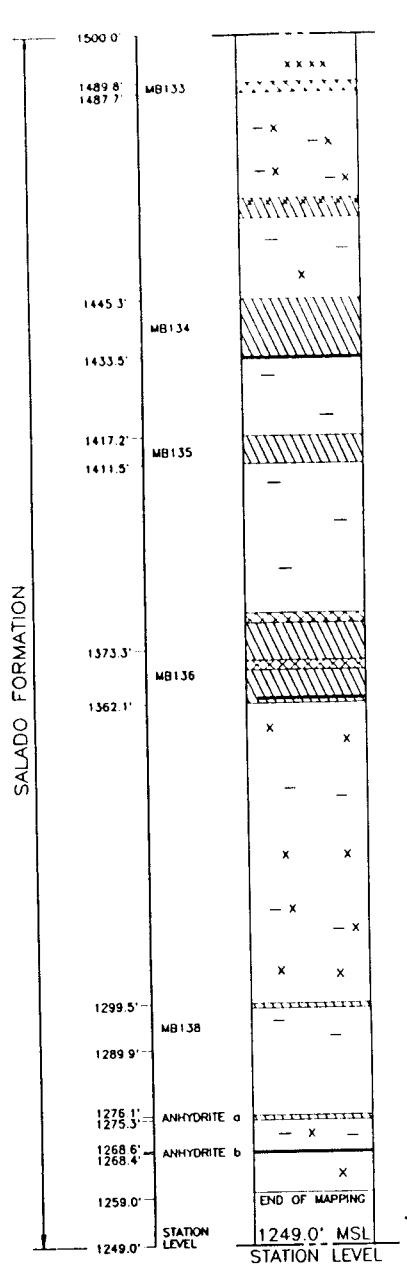
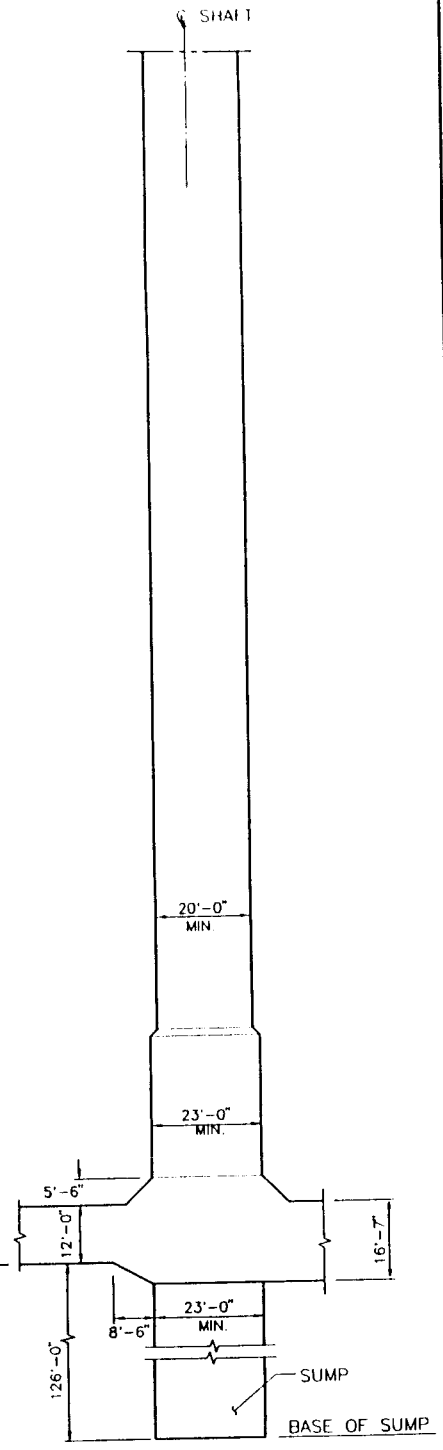
STRATIGRAPHY
(SEE NOTE 2)











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NOTES:
1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES AND ABBREVIATIONS.
2. SEE DWG. NO. 31-G01 FOR LITHOLOGY AND NOTES.

SCALE IN FEET
0 10 20 30 40 50

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
WASTE SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS

	NAME	DATE
BY	DL	
CK.	SAR	
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PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE | SIZE B | SNL DWG. NO | SHEET NO.

09-CS-31-G02

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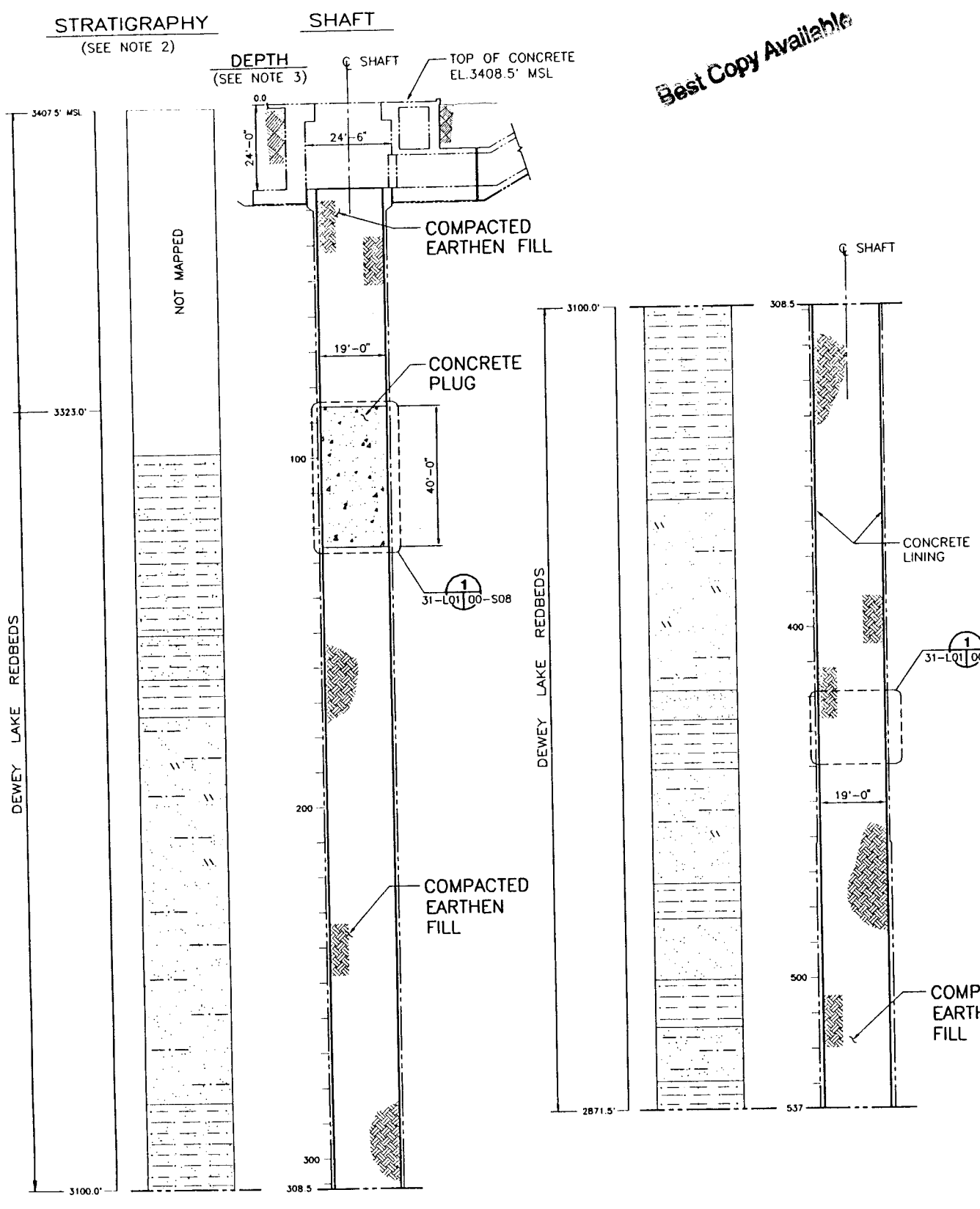

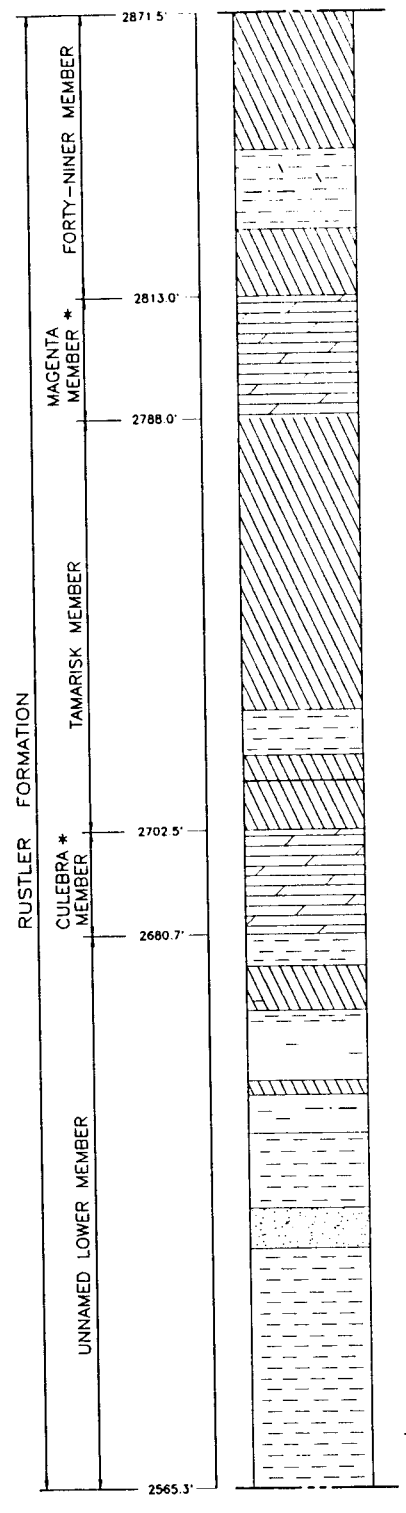

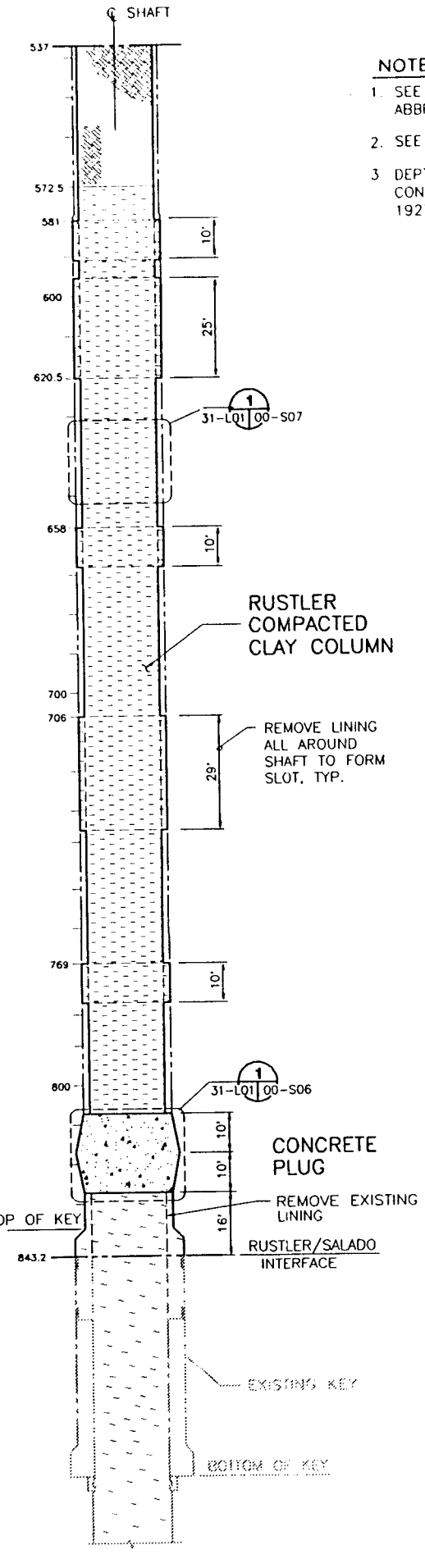

NOTES:

1. SEE DWG 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS
2. SEE DWG. 31-G01 FOR LITHOLOGY AND NOTES.
3. DEPTHS SHOWN ARE DISTANCES BELOW THE TOP OF CONCRETE, LOCATED AT EL. 3408.5' ABOVE MSL USGS 1927 NORTH AMERICAN DATUM.

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SCALE IN FEET
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REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
WASTE SHAFT
STRATIGRAPHY & SEALING
SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
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PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG NO | SHEET NO

09-CS-31-L01

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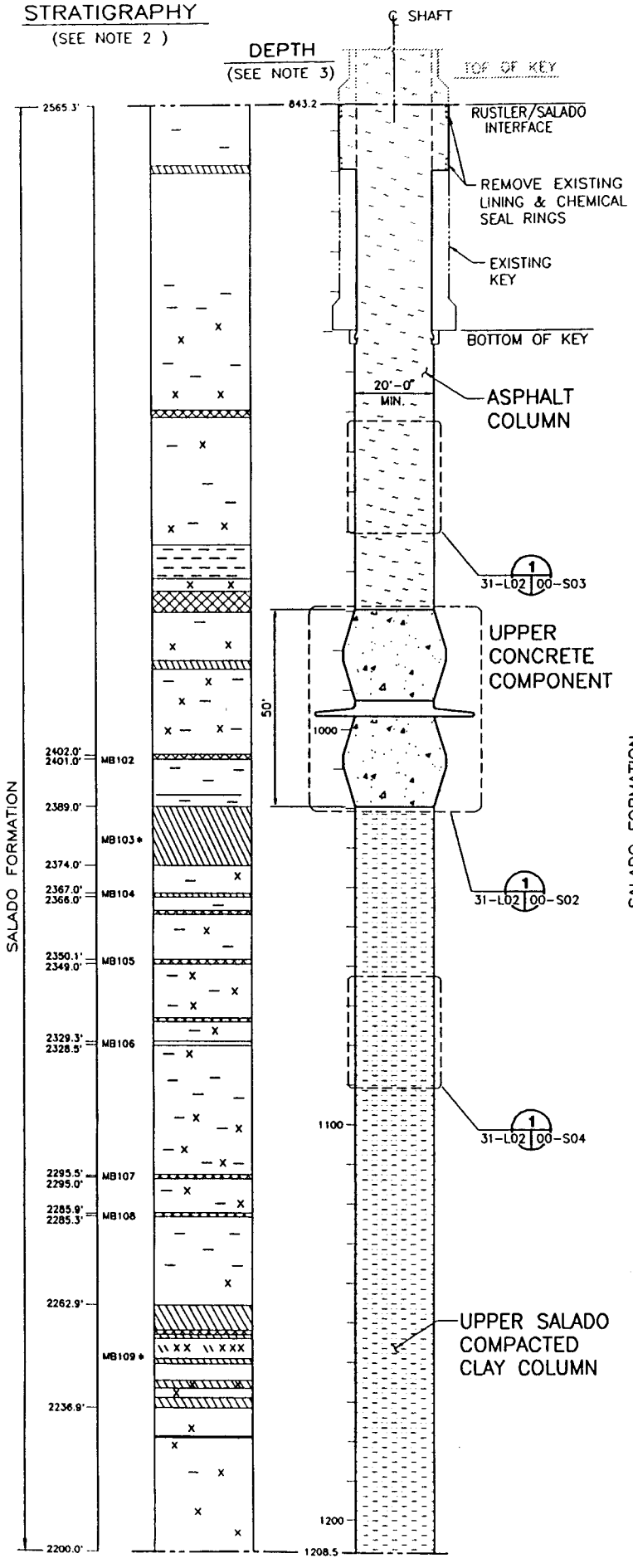

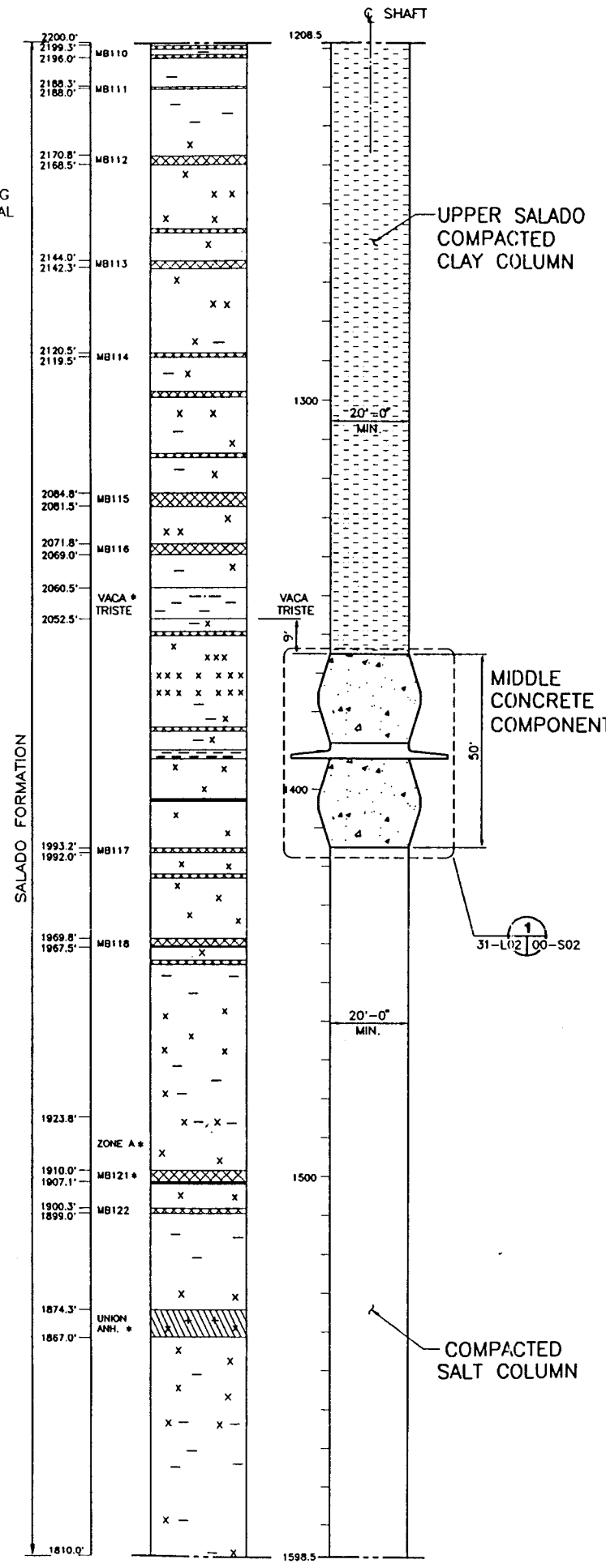

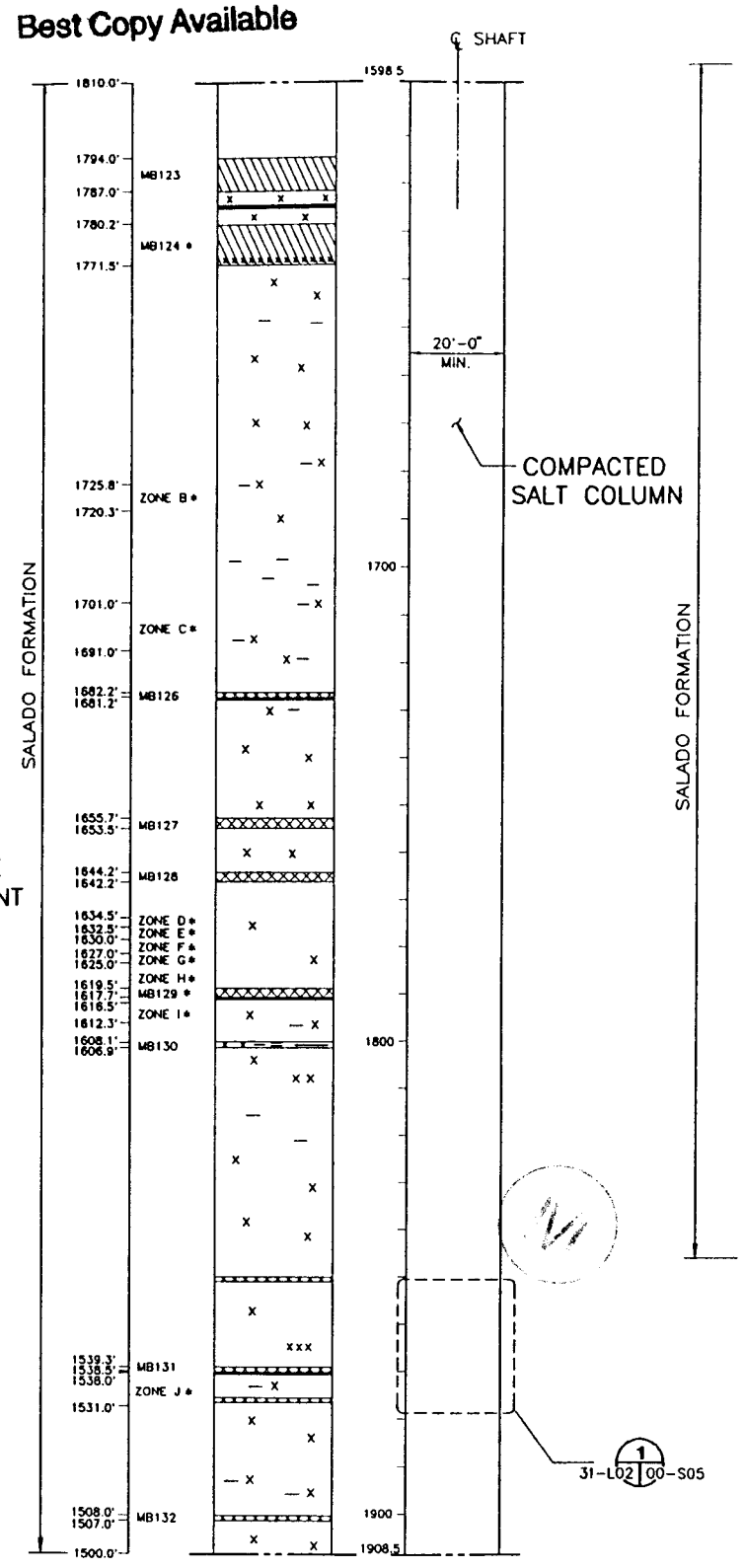

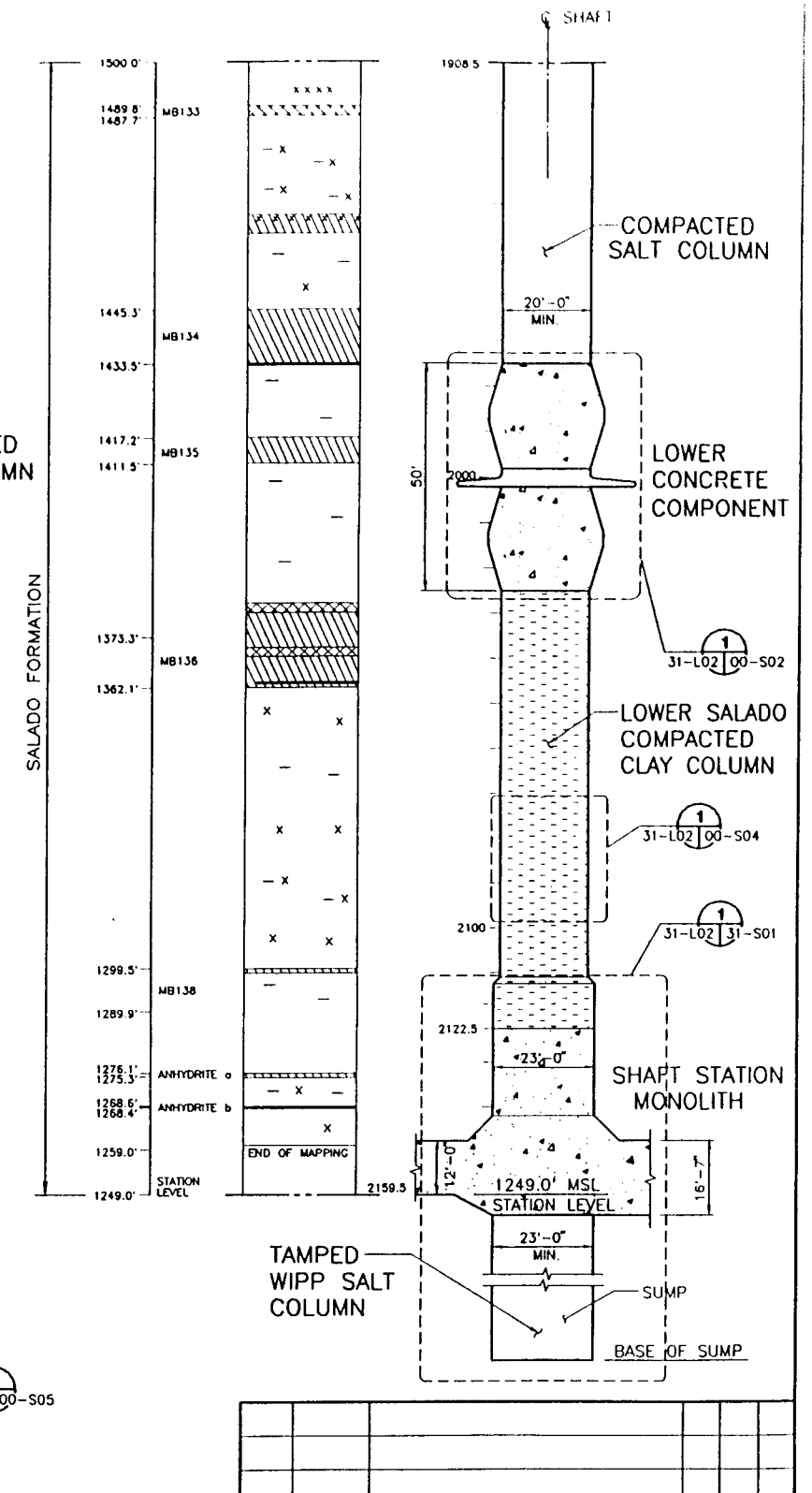

NOTES:

1. SEE DWG. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.
2. SEE DWG. 31-G01 FOR LITHOLOGY AND NOTES.
3. SEE NOTE 3 OF DWG. 31-L01.

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
WASTE SHAFT
STRATIGRAPHY & SEALING SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG NO.	SHEET NO

NAME: C:\A\WIPP\9\CS\CS31-L02.DWG DATE: NOVEMBER 29, 1995 TIME: 10:14 AM

09-CS-31-L02

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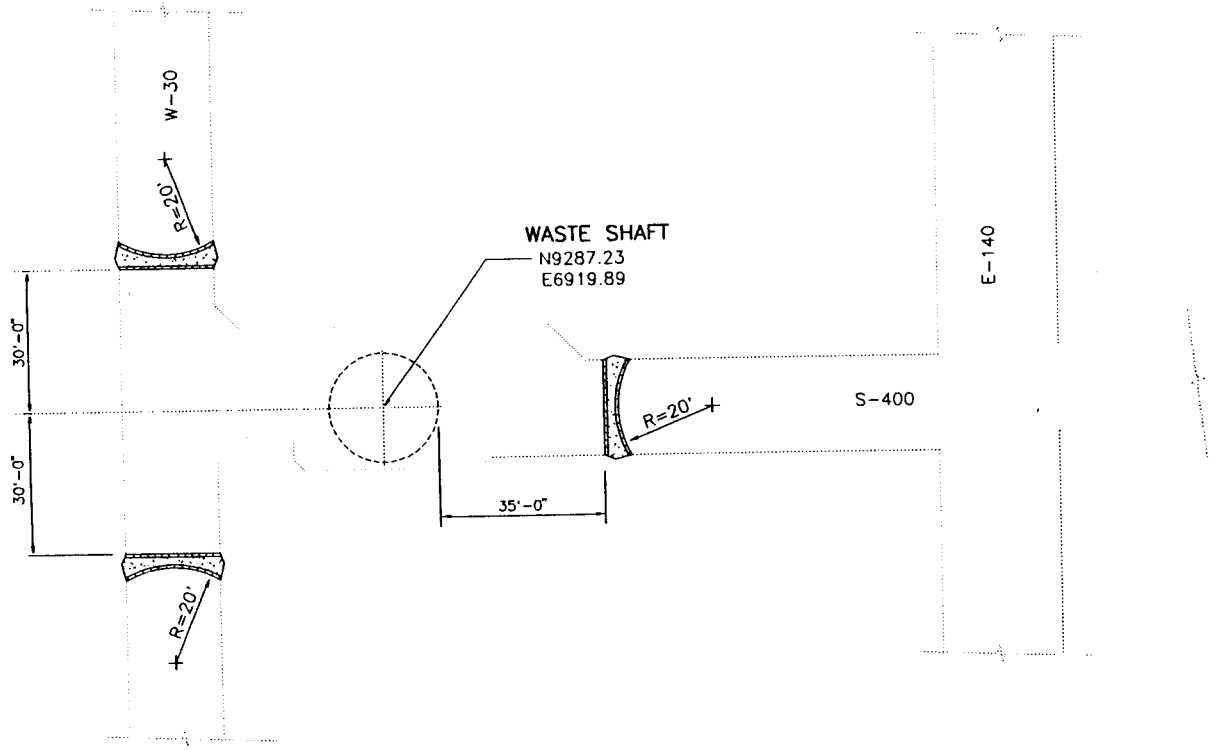
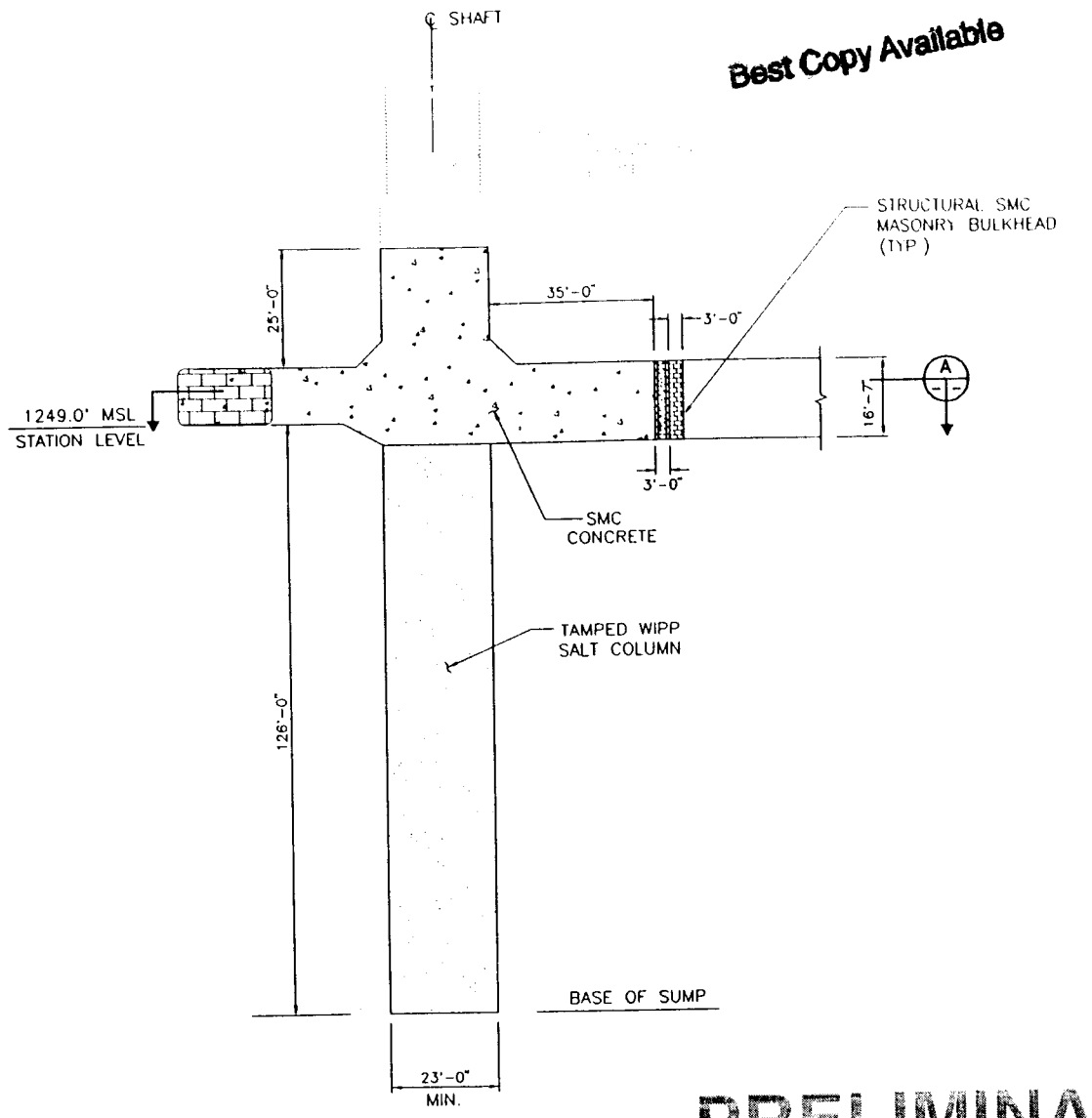


SECTION A

N



DETAIL 1 (31-L02 | 31-S01)

PRELIMINARY

NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.

Best Copy Available

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO. AG-4909

WIPP SHAFT SEALING SYSTEM

WASTE SHAFT
SHAFT STATION MONOLITH

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC.

SCALE:

SIZE B

SNL DWG. NO.

SHEET NO.

09-CS-31-S01

NAME: D:\WIPP\DWGS\CS31-S01.DWG DATE: FEBRUARY 12, 1996 TIME: 9:42 AM

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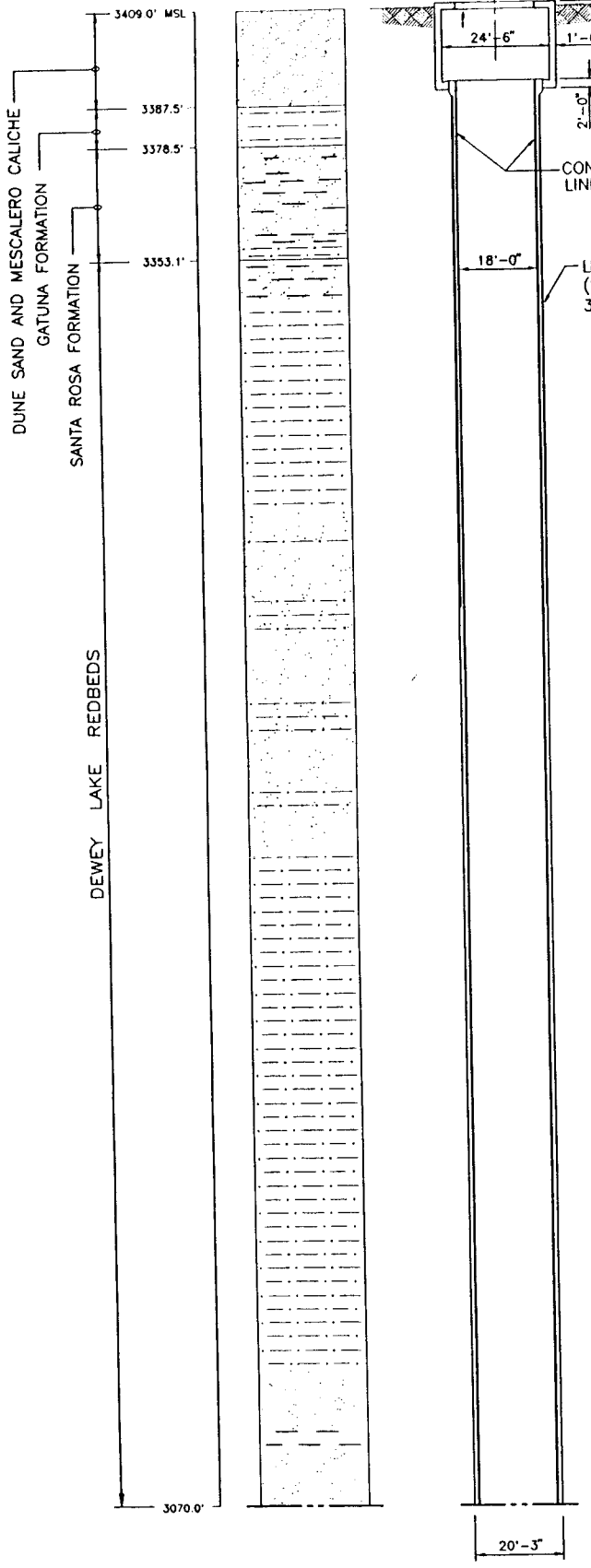
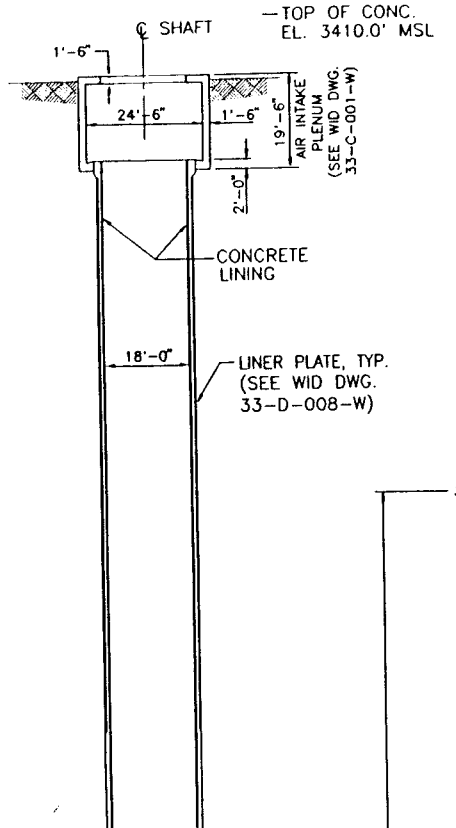
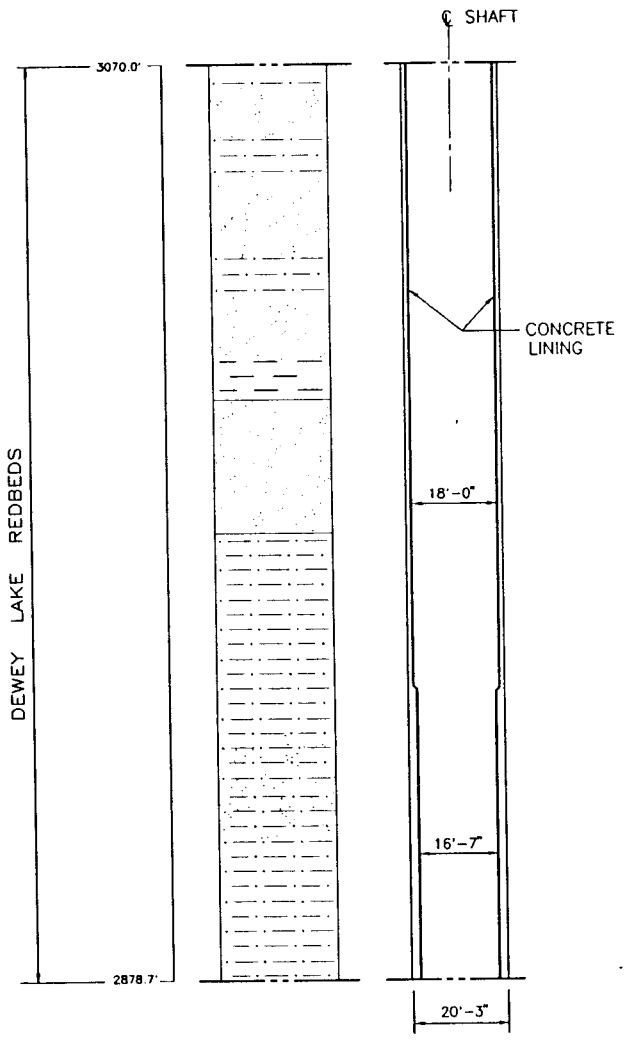
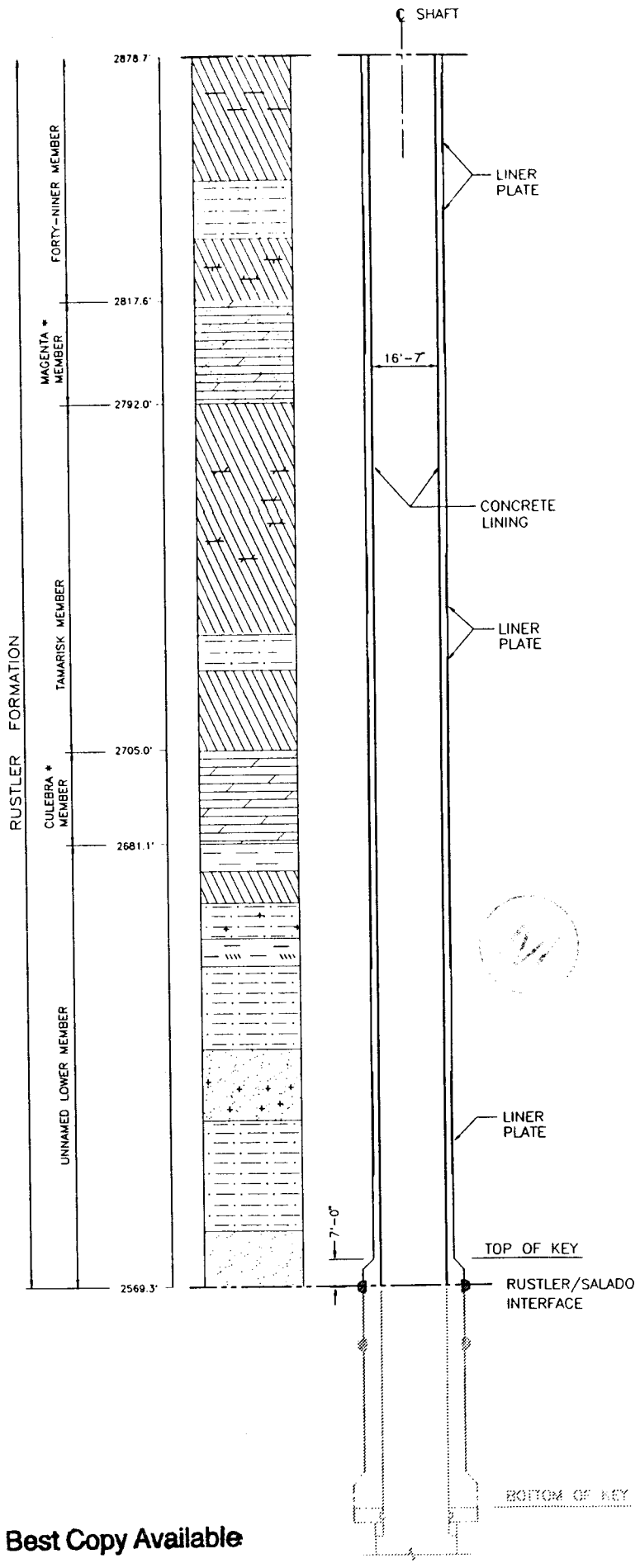
STRATIGRAPHY
(SEE NOTE 1)



SHAFT







Best Copy Available

LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES		SECONDARY CONSTITUENTS	
	MUDSTONE/CLAYSTONE		ARGILLACEOUS
	CLAYSTONE BED		SILTY
	SILTSTONE		SANDY
	SANDSTONE	\\\\\\\	SULFATIC
	ANHYDRITE/GYPSUM		DOLOMITIC
	DOLOMITE		CALCAREOUS
	HALITE	+ +	HALITIC
	POLYHALITE	x x x	POLYHALITIC
		L L	LANGBEINITE

NOTES:

1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT WALLS, DOE/WIPP-90-051, "GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WASTE ISOLATION PILOT PLANT", 1990, AND APPENDIX A OF REPORT DOE/WIPP-95-3117, "WASTE ISOLATION PILOT PLANT SEALING SYSTEM DESIGN REPORT", 1995.

   ASTERISK(*) INDICATES GROUNDWATER (RUSTLER/SUPRA RUSTLER FORMATIONS) OR BRINE SEEPAGE/WEEPS (SALADO FORMATION) OBSERVED DURING THE MAPPING OF THE AIR INTAKE SHAFT. AS OF 1994, ONLY MB103 SHOWED VISIBLE MOISTURE ON THE SALADO FORMATION SURFACE EXPOSED WITHIN THE AIR INTAKE SHAFT, "BRINE SAMPLING EVALUATION PROGRAM 1992-1993 REPORT," 1994, DOE-WIPP 94-011.

2. REFERENCE AS-BUILT DRAWINGS FROM WID:

AIR INTAKE SHAFT 331 SHAFT COLLAR / AIR INTAKE PLENUM PLAN, SECTIONS AND DETAILS.	33-C-001-W
AIR INTAKE SHAFT 331 SHAFT COLLAR / AIR INTAKE PLATFORM PLAN, SECTIONS AND DETAILS.	33-C-002-W
AIR INTAKE SHAFT 331 STRUCTURE PLAN, SECTIONS AND DETAILS	33-C-003-W1
AIR INTAKE SHAFT 331 SHAFT KEY PLAN, SECTIONS AND DETAILS	33-C-004-W1
AIR INTAKE SHAFT 331 LINING DETAILS	33-C-005-W
AIR INTAKE SHAFT 331 EXCAVATION AS-BUILT	33-D-002-W
AIR INTAKE SHAFT 331 GENERAL ARRANGEMENT	33-D-008-W
AIR INTAKE SHAFT 331 SHAFT STATION PLAN, SECTIONS AND DETAILS	51-W-212-W

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
AIR INTAKE SHAFT
STRATIGRAPHY &
AS-BUILT ELEMENTS

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

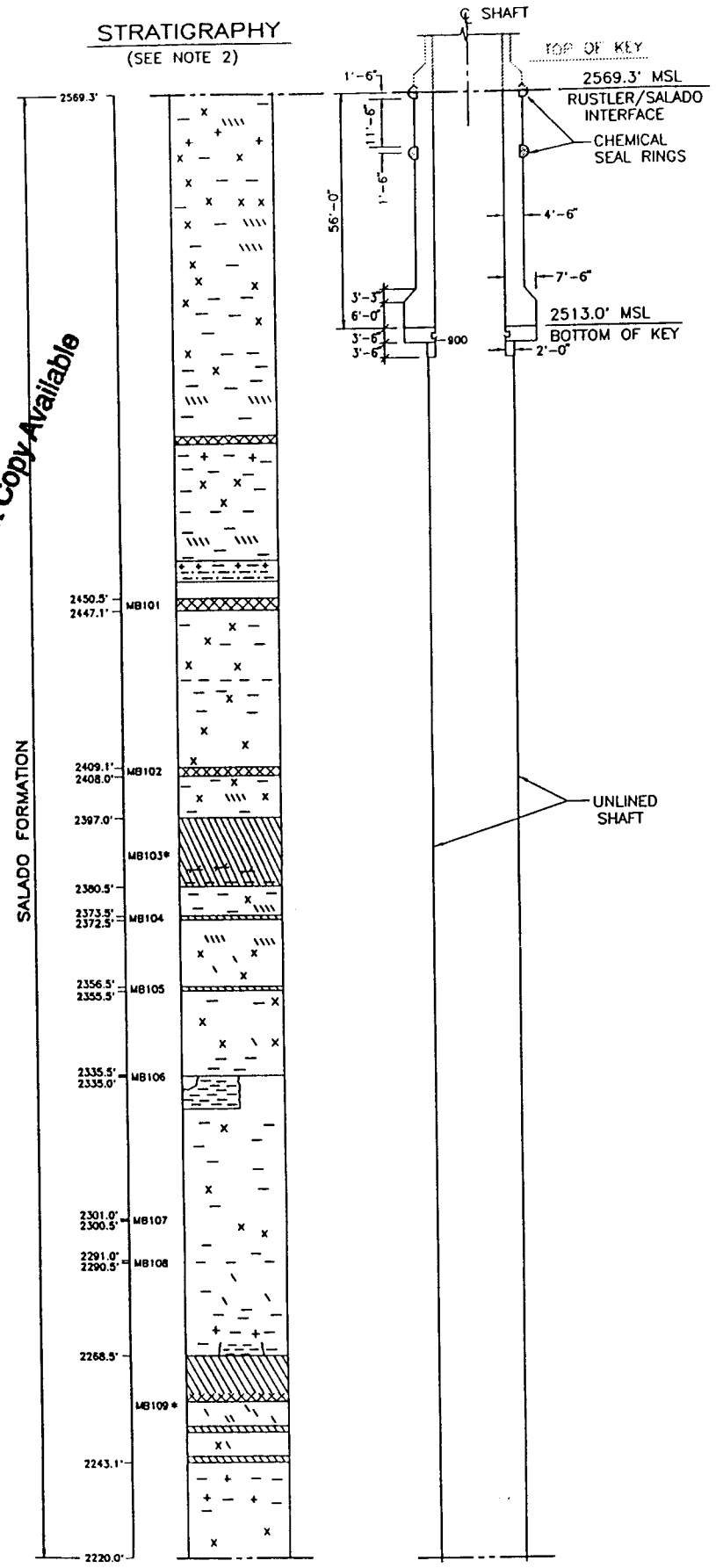
PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO.	SHEET NO.

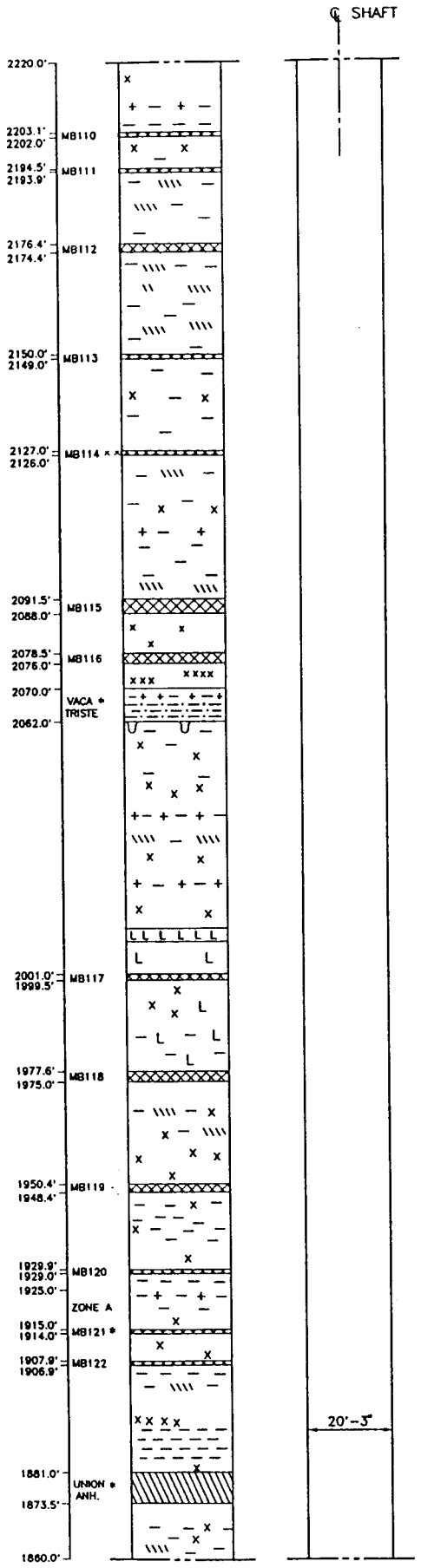
09-CS-33-G01

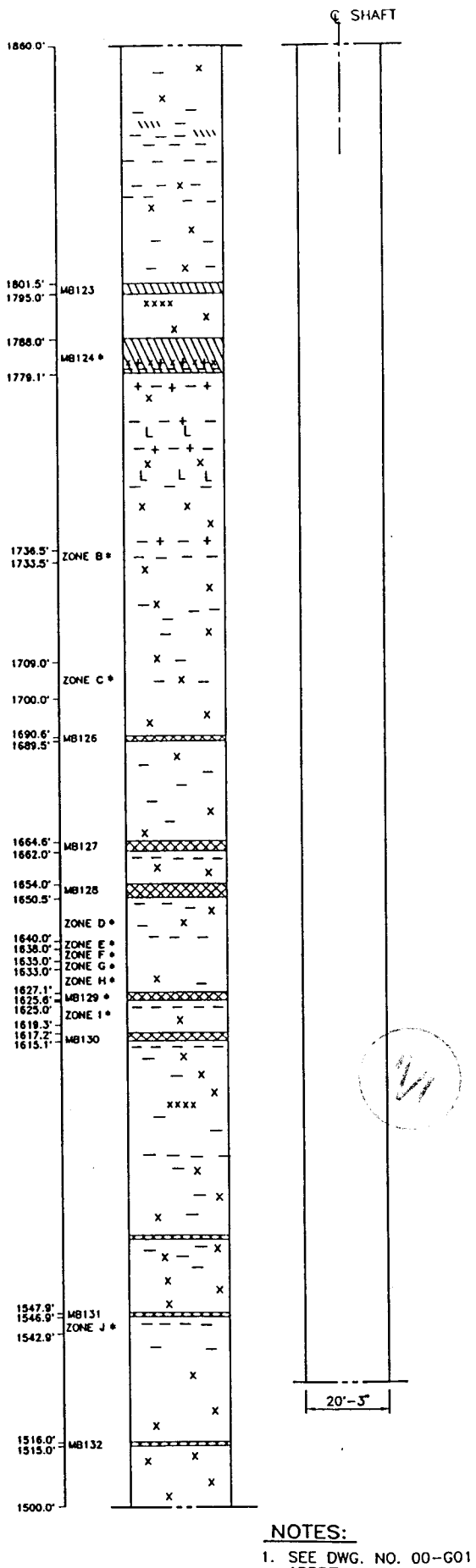
NAME: C:\A\WIPP\9\CS\CS33-G01.DWG DATE: FEBRUARY 02, 1996 TIME: 10:14 AM

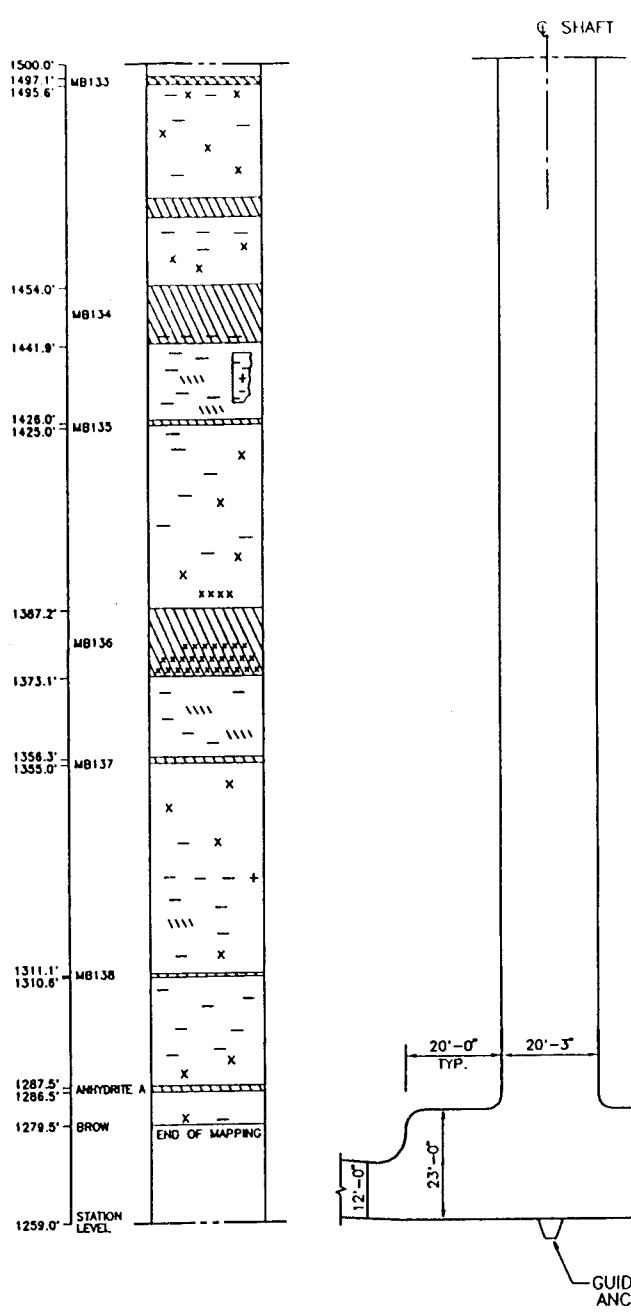
Best Copy Available

STRATIGRAPHY
(SEE NOTE 2)









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PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

NOTES:
1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES AND ABBREVIATIONS
2. SEE DWG. NO. 33-G01 FOR LITHOLOGY AND NOTES.

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

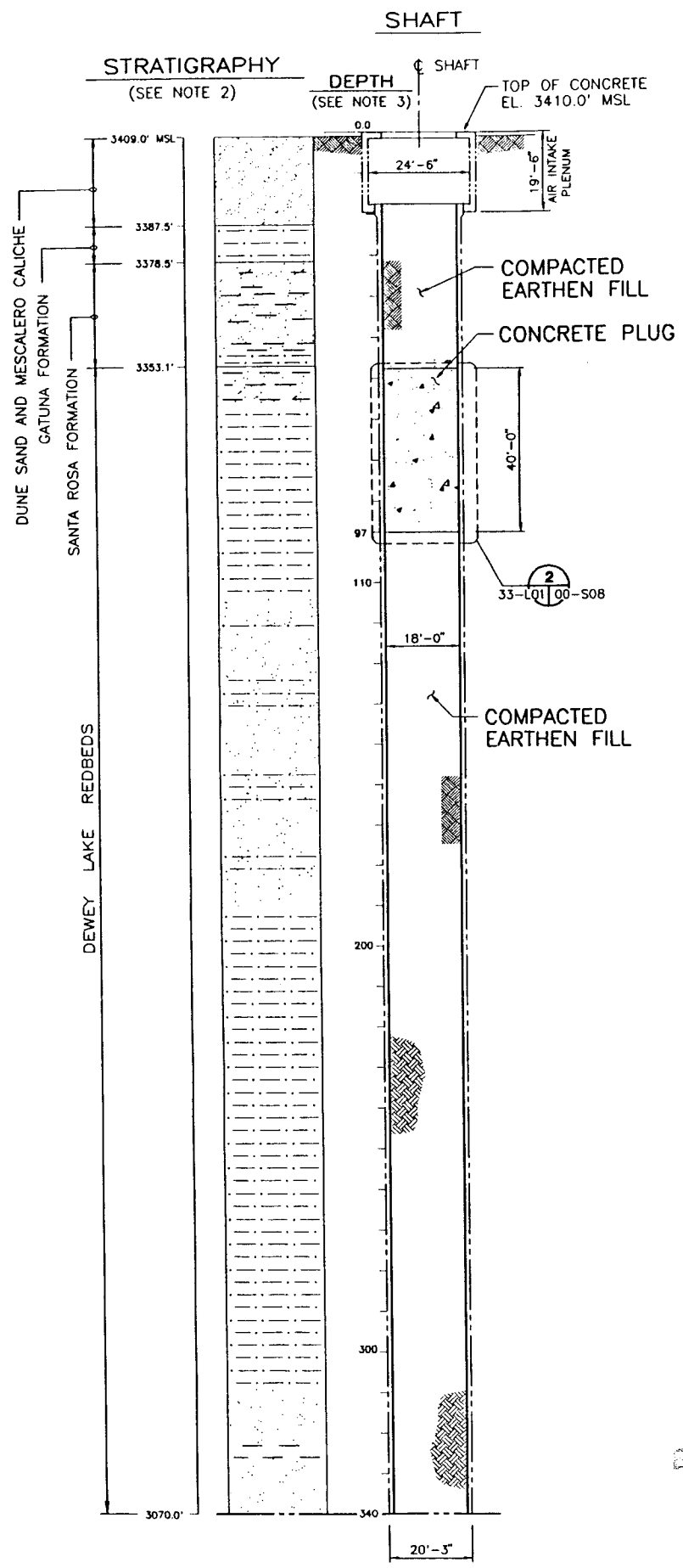
WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
AIR INTAKE SHAFT
STRATIGRAPHY &
AS-BUILT ELEMENTS

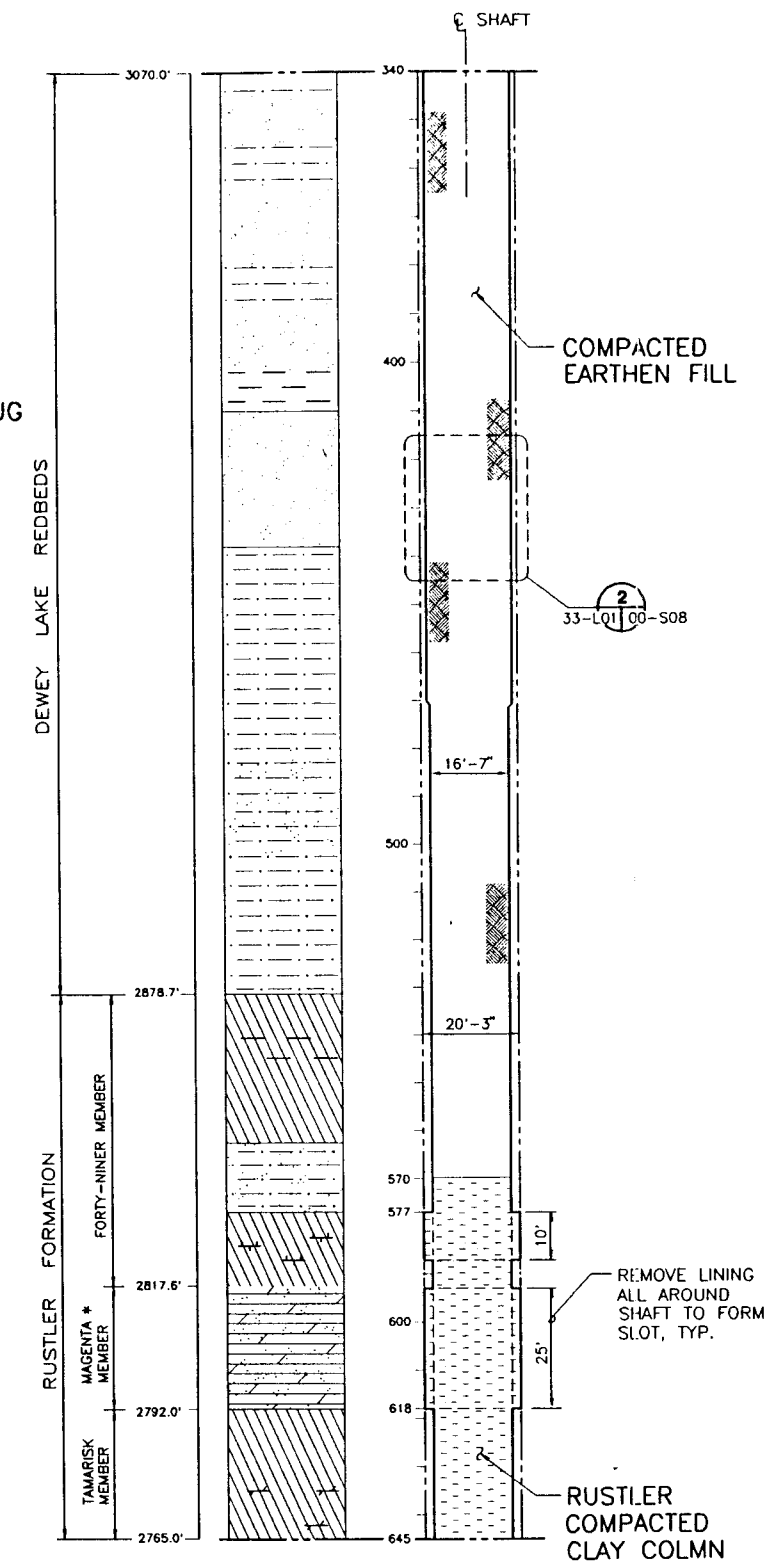
	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

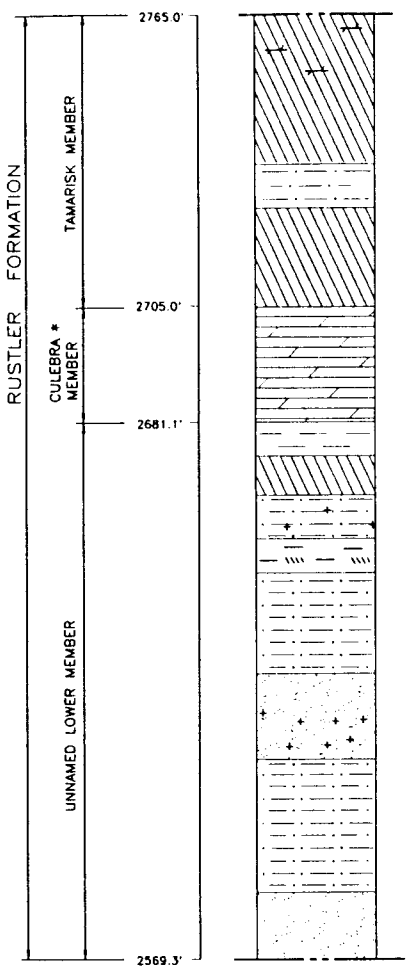
PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG. NO. | SHEET NO.

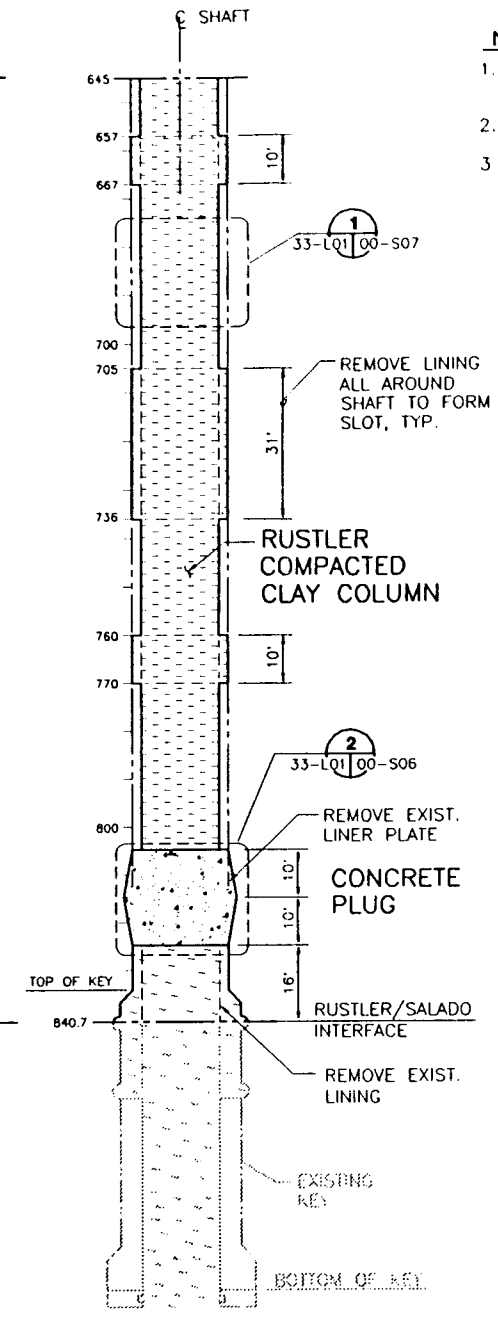
09-CS-33-G02

NAME: C:\A\WIPP\9\CS\CS33-G02.DWG DATE: DECEMBER 11, 1995 TIME: 9:56 AM









NOTES:

1. SEE DWG NO 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS
2. SEE DWG. NO. 33-G01 FOR LITHOLOGY AND NOTES.
3. DEPTHS SHOWN ARE DISTANCES BELOW THE TOP OF CONCRETE, LOCATED AT EL 3410.0' ABOVE MSL USGS 1927 NORTH AMERICAN DATUM

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PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
AIR INTAKE SHAFT
STRATIGRAPHY AND SEALING
SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO.	SHEET NO.

09-CS-33-L01

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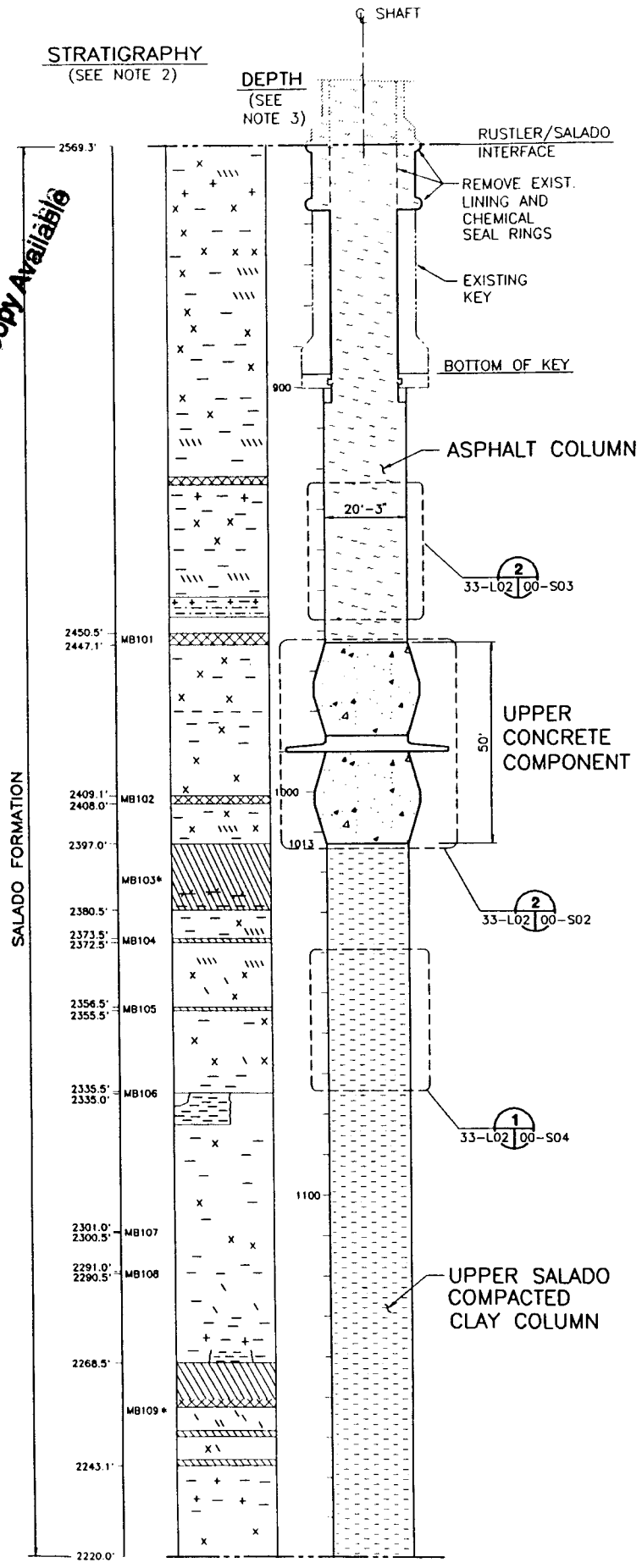

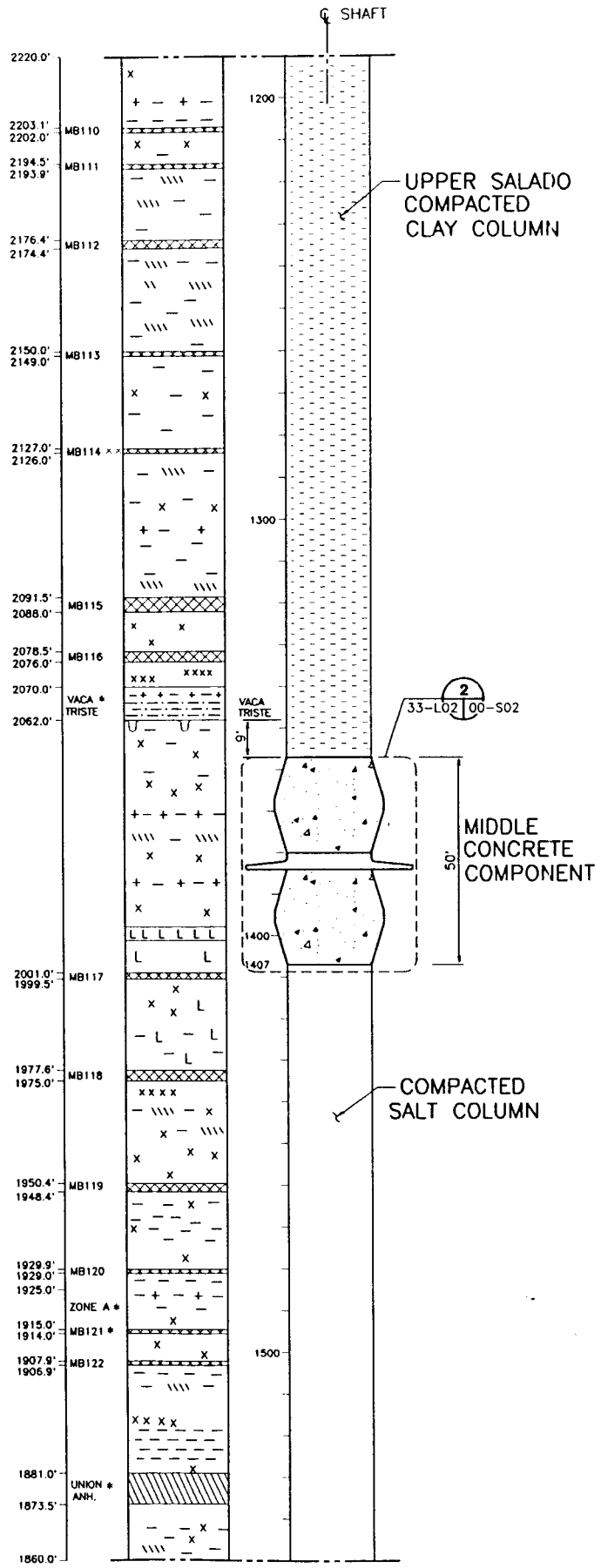

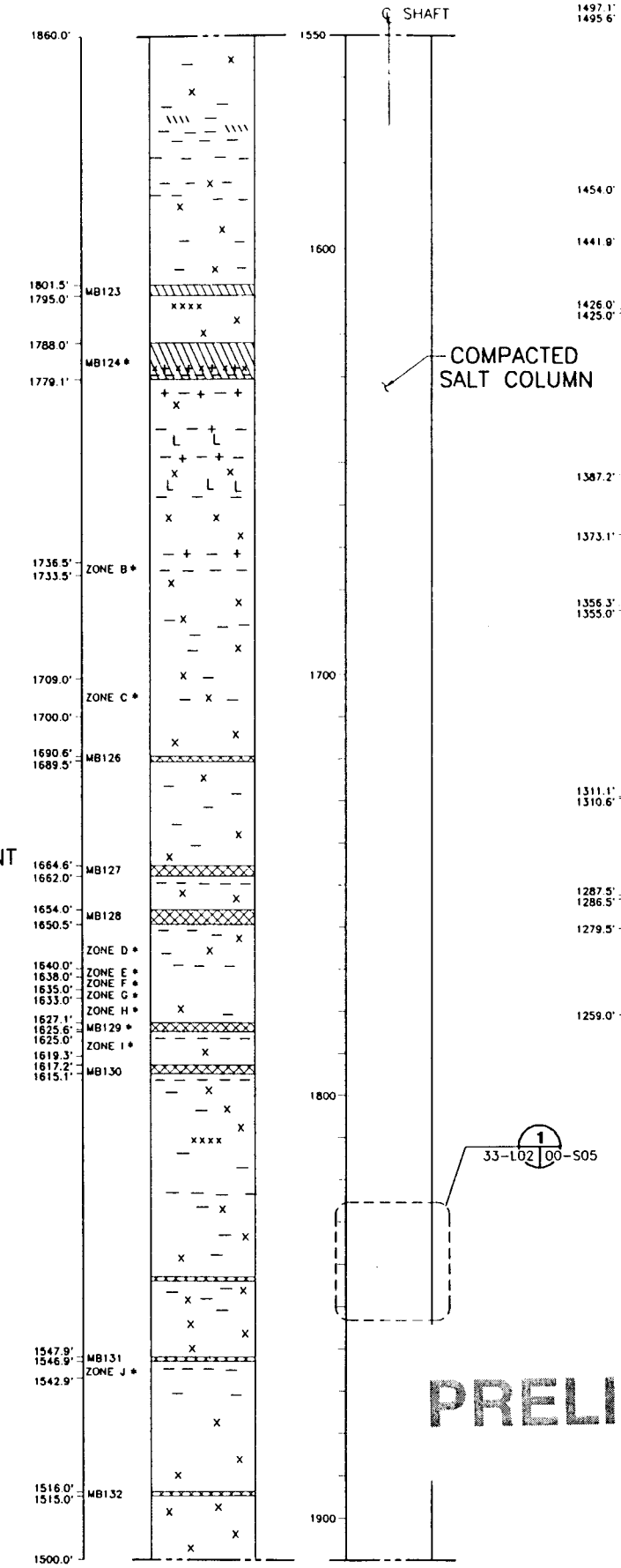

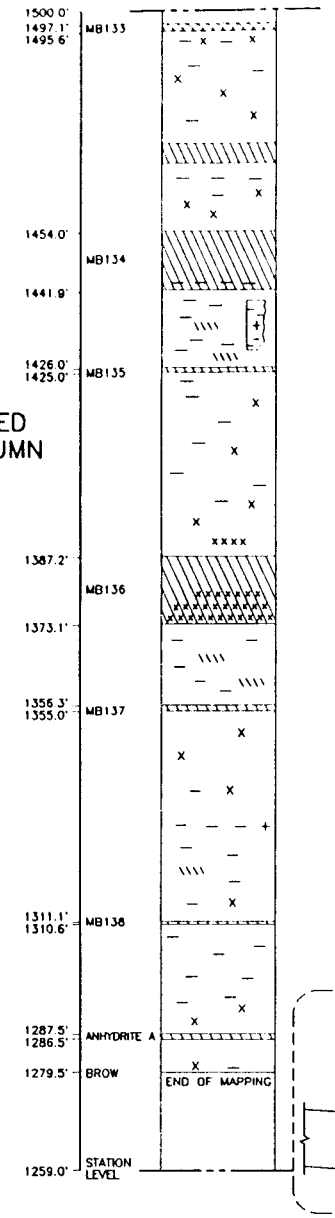

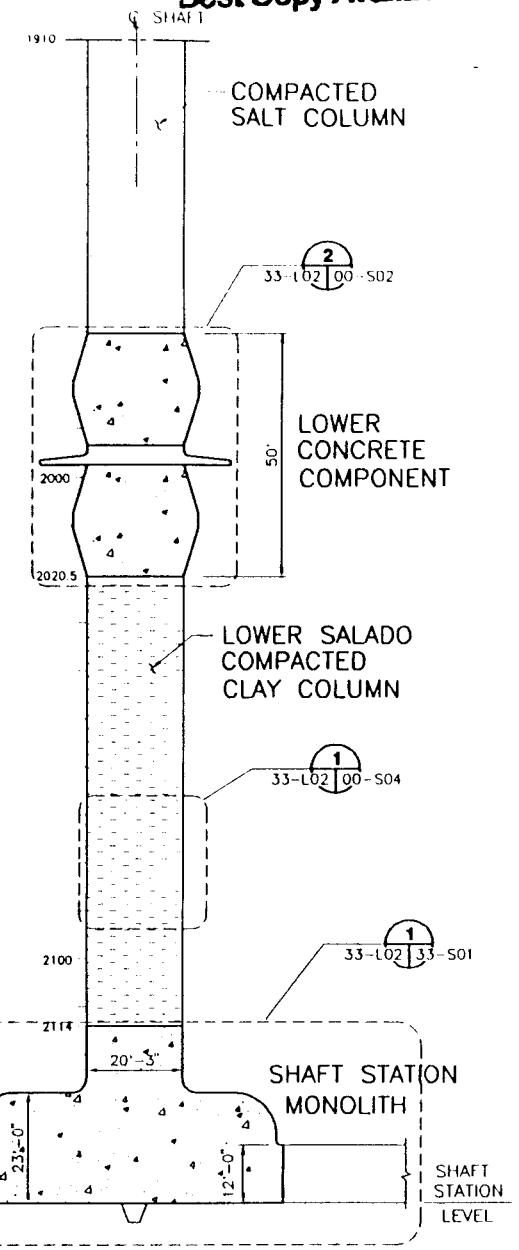

NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS
2. SEE DWG. NO. 33-G01 FOR LITHOLOGY AND NOTES.
3. SEE NOTE 3 OF DWG. 33-L01.

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

SALADO FORMATION SUBSYTEM

DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
AIR INTAKE SHAFT
STRATIGRAPHY AND SEALING SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG NO | SHEET NO

NAME: C:\A\WIPP\9\CS\CS33-L02.DWG DATE: FEBRUARY 12, 1996 TIME: 9:47 AM

09-CS-33-L02

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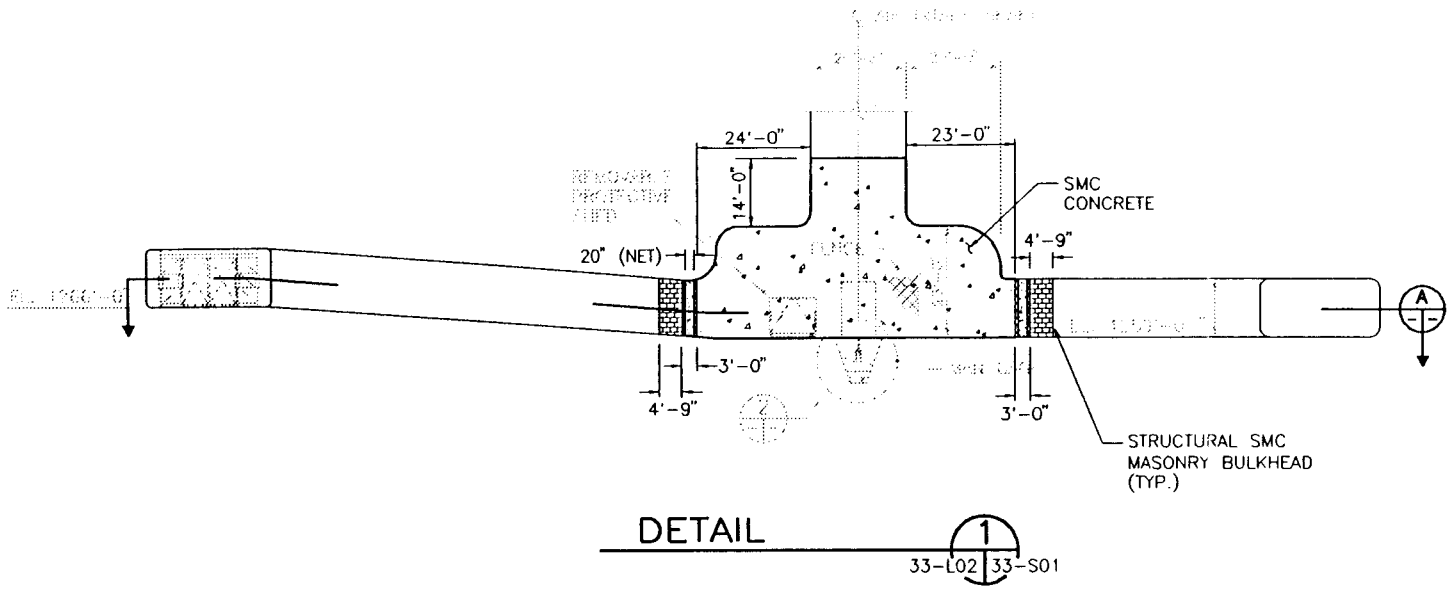
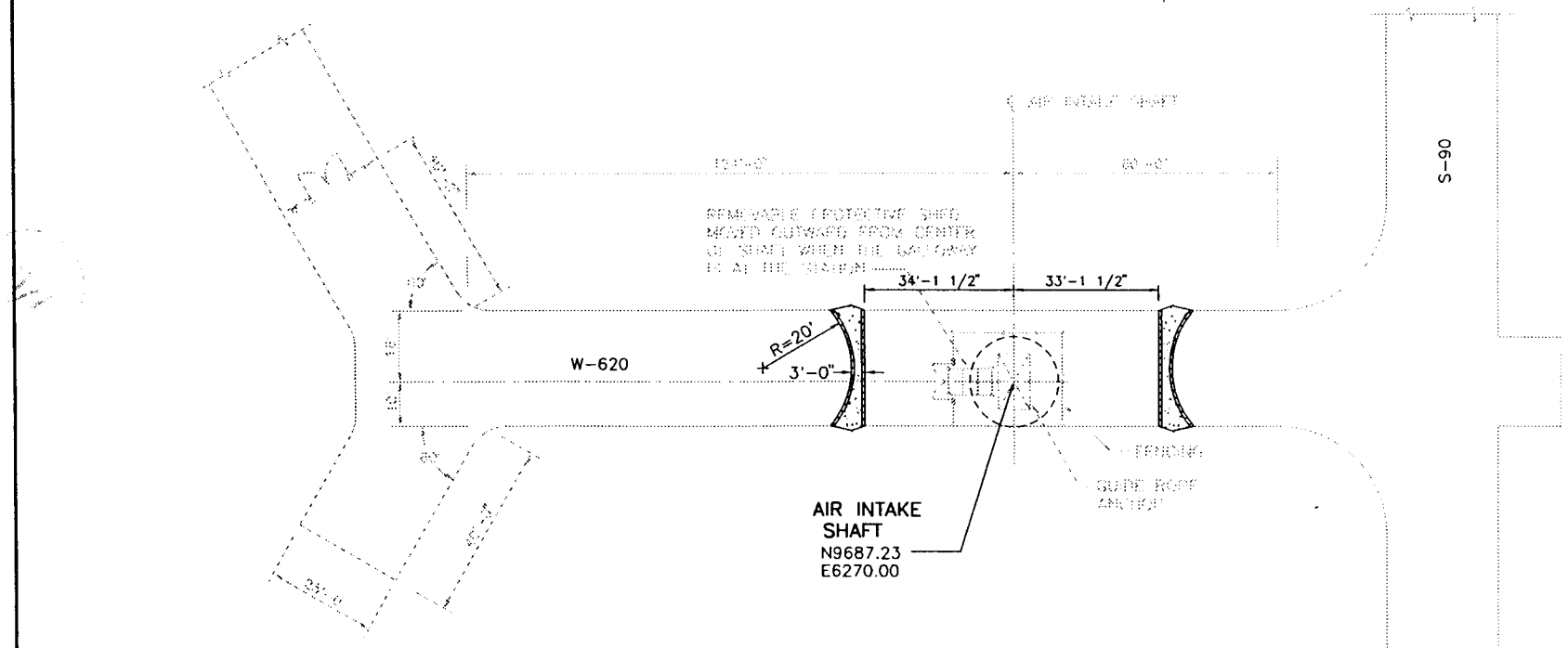


DETAIL 1 — 33-L02 | 33-S01



SECTION A — N

PRELIMINARY

NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.

SCALE IN FEET
0 10 20 30 40 50

REV	DATE	DESCRIPTION	BY	CK	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM

AIR INTAKE SHAFT
SHAFT STATION MONOLITH

	NAME	DATE
BY	DL	
CK	SAR	
APP		
APP		
APP		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO	SHEET NO

NAME: C:\A\WIPP\9\CS\CS33-S01.DWG DATE: FEBRUARY 01, 1996 TIME: 9:52 AM

09-CS-33-S01

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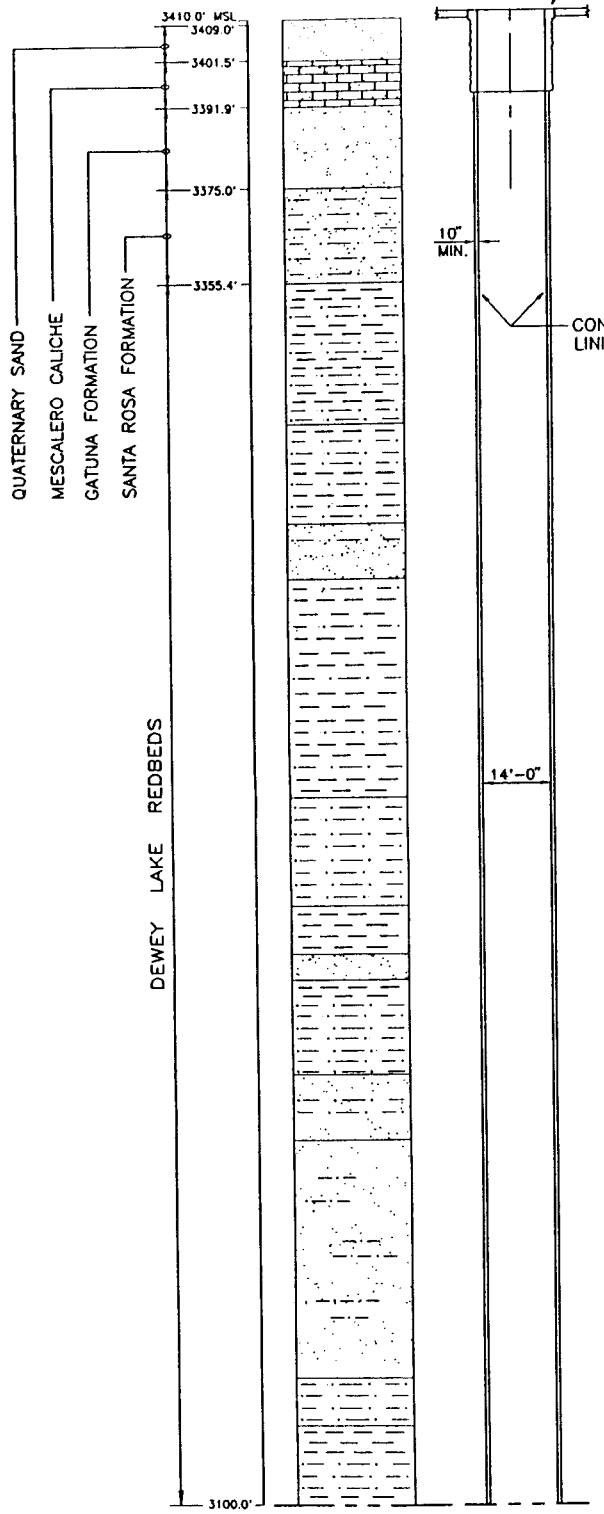
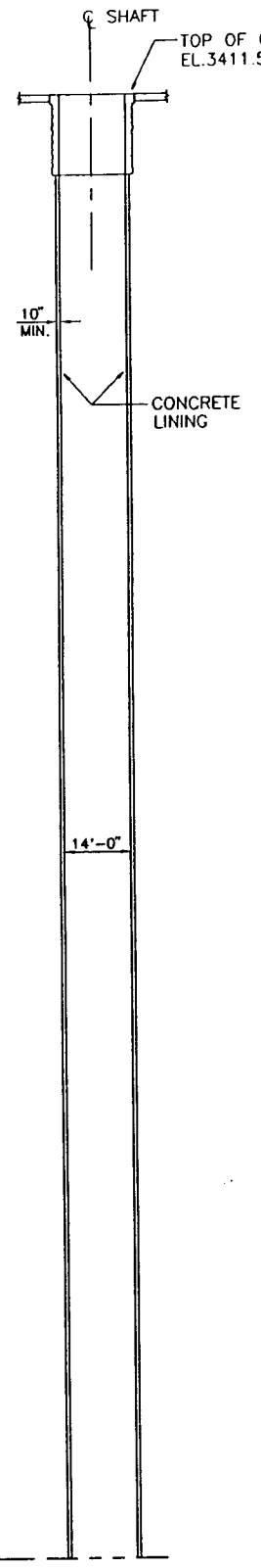
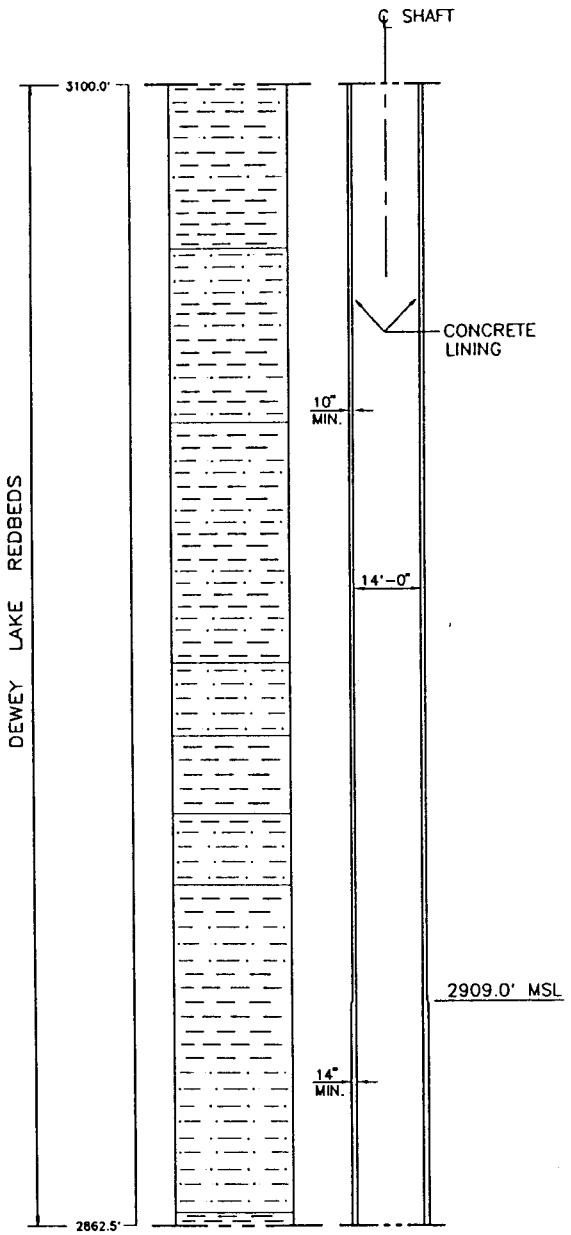
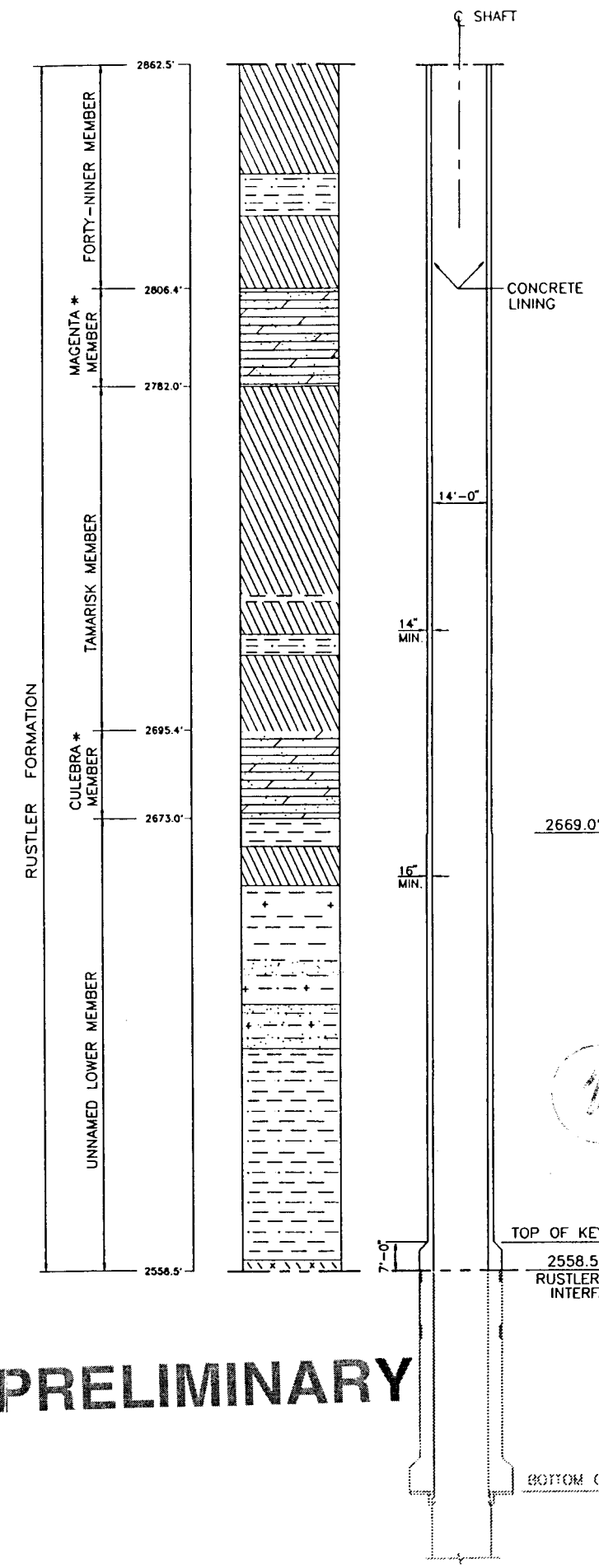
STRATIGRAPHY
(SEE NOTE 1)



SHAFT







LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES	SECONDARY CONSTITUENTS
MUDSTONE/CLAYSTONE	ARGILLACEOUS
CLAYSTONE BED	SILTY
SILTSTONE	SANDY
SANDSTONE	SULFATIC
ANHYDRITE/GYPSUM	DOLOMITIC
DOLOMITE	CALCAREOUS
HALITE	+ + HALITIC
POLYHALITE	x x x POLYHALITIC
CALICHE	

NOTE:

1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE EXHAUST SHAFT WALLS DOE-WIPP-86-008, "GEOTECHNICAL ACTIVITIES IN THE EXHAUST SHAFT", AND APPENDIX A OF REPORT DOE/WIPP-95-3117, "WASTE ISOLATION PILOT PLANT SEALING SYSTEM DESIGN REPORT", 1995.

   ASTERISK (•) WITHIN THE RUSTLER AND SUPRA RUSTLER FORMATIONS INDICATE GROUNDWATER OBSERVED DURING SHAFT MAPPING. ASTERISK (•) WITHIN THE SALADO FORMATION INDICATES A POTENTIAL BRINE SEEPAGE/WEEP INTERVAL. THESE POTENTIAL BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON OBSERVED INTERVALS OF BRINE SEEPAGE /WEEPS IN THE AIR INTAKE SHAFT THAT HAVE BEEN PROJECTED TO THE EXHAUST SHAFT. THE MAPPING OF THE EXHAUST SHAFT (HOLT & POWERS, 1986/DOE-WIPP 86-008) DID NOT INDICATE OBSERVED SEEPAGE INTERVALS WITHIN THE SALADO FORMATION.

2. REFENCE AS-BUILT DRAWINGS FROM WID:

EXHAUST SHAFT 351, SHAFT LINING AND KEY SECTION AND DETAILS	35-R-002-01D
EXHAUST SHAFT 351, GENERAL ARRRANGEMENT, PLANS AND SECTIONS	35-R-004-01D
EXHAUST SHAFT WINCH AND COLLAR LAYOUT - SHOWS PERMANENT COLLAR STRUCTURE	OGL-S-020--1FB
EXHAUST SHAFT, SHAFT DEVELOPMENT, PLAN, SECTIONS AND DETAIL	WTSD 390D064 (1 of 2)

SCALE IN FEET
0 10 20 30 40 50

PRELIMINARY

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
EXHAUST SHAFT
STRATIGRAPHY &
AS-BUILT ELEMENTS

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG NO	SHEET NO

09-CS-35-G01

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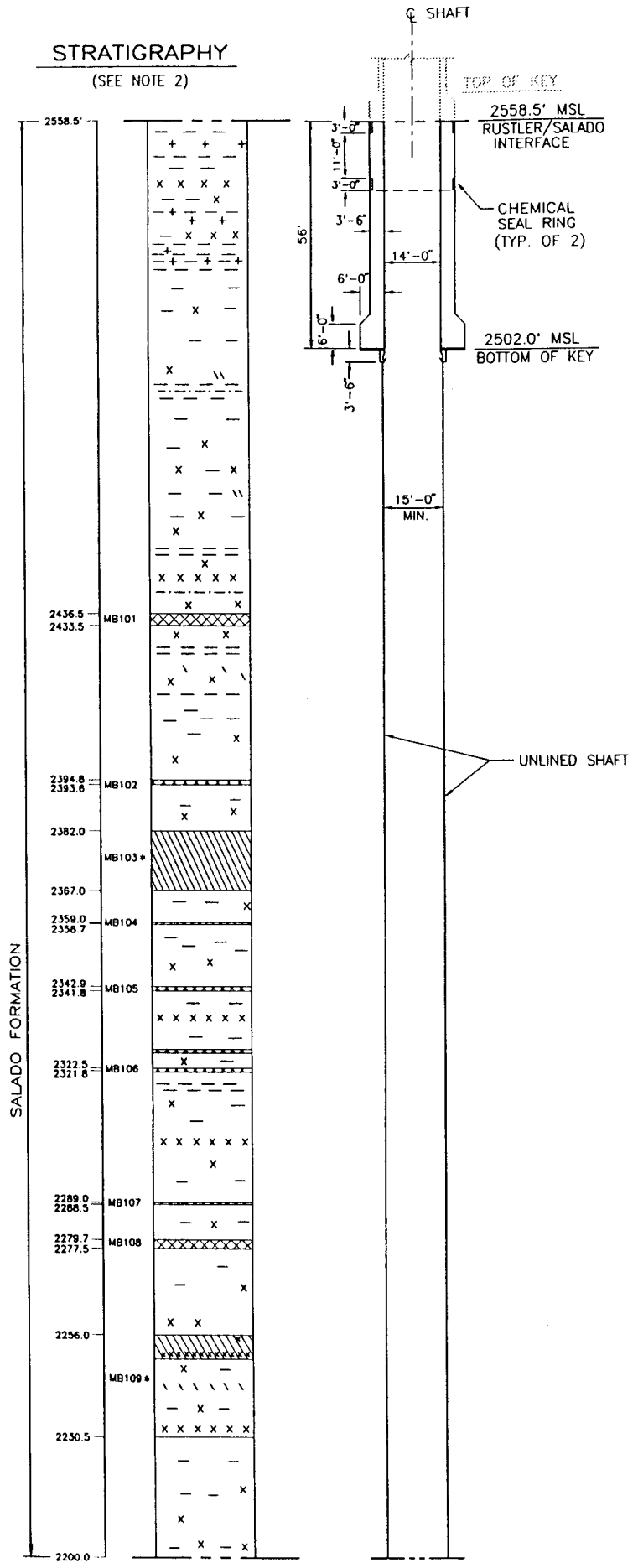
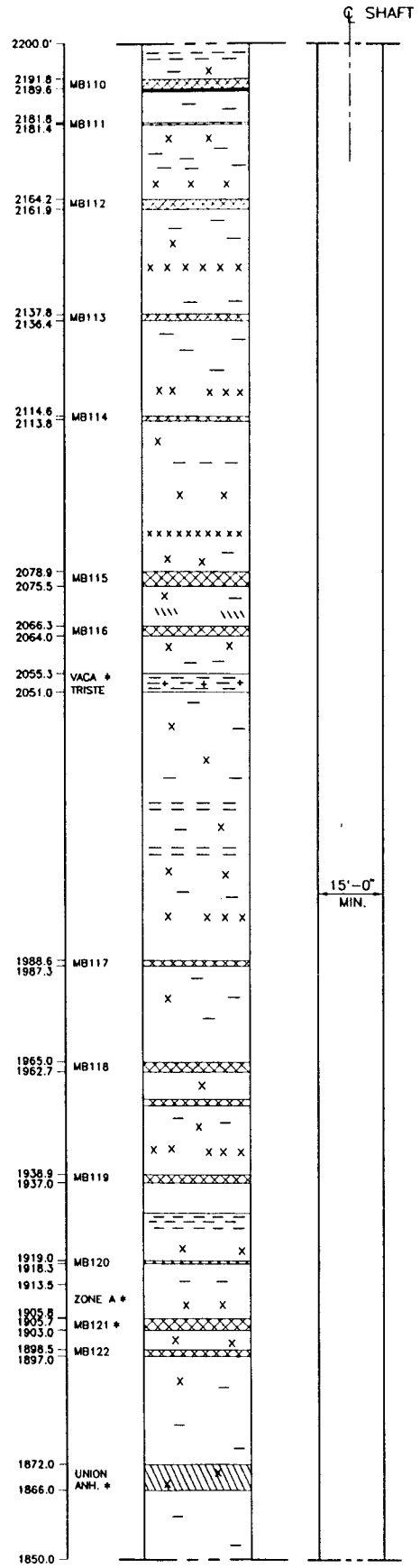
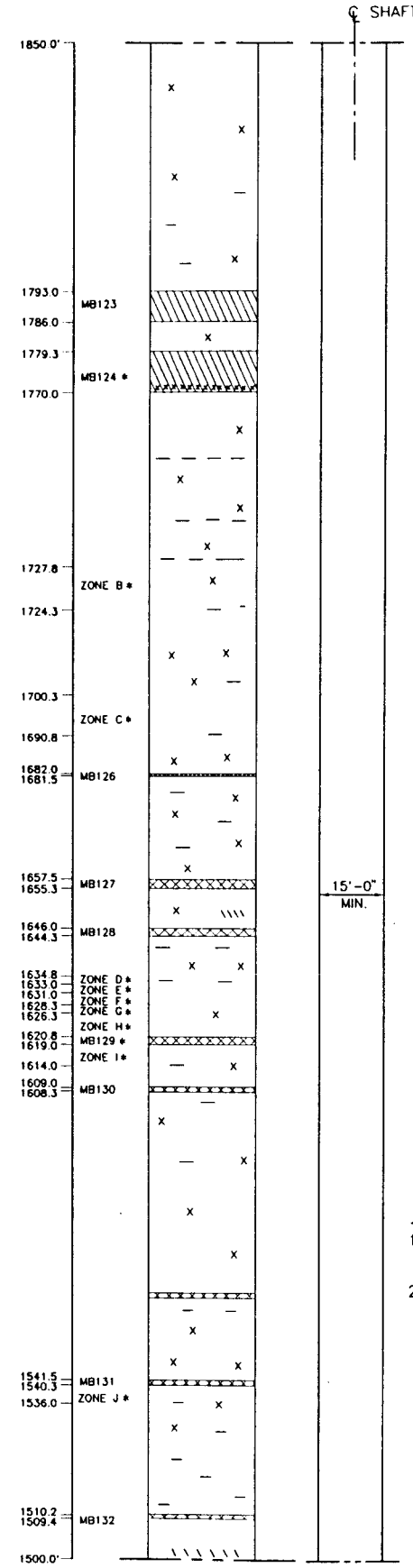
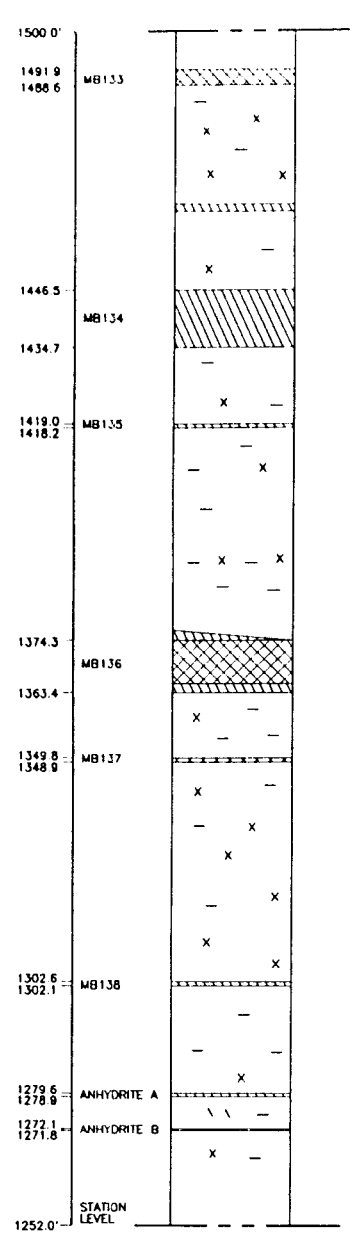
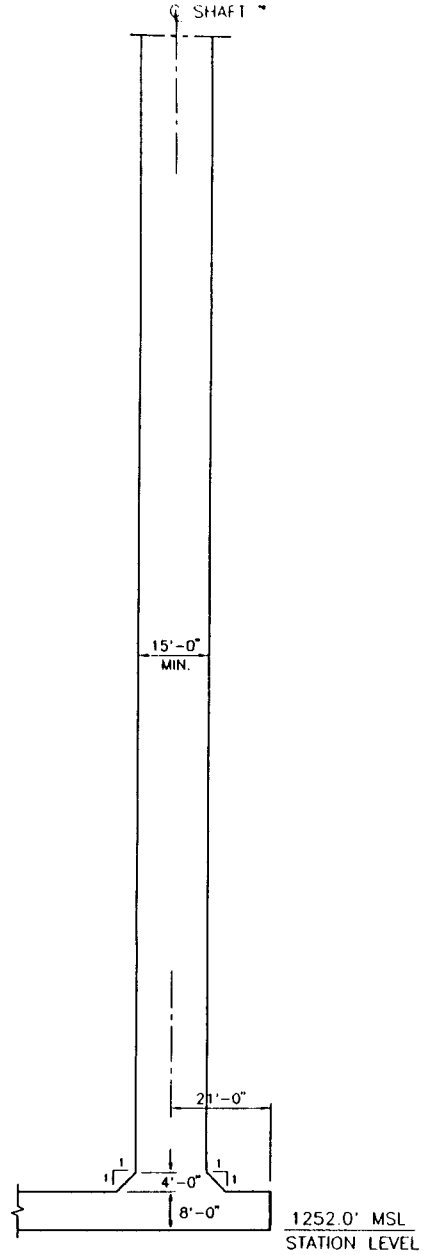
STRATIGRAPHY
(SEE NOTE 2)











NOTES:
1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES AND ABBREVIATIONS
2. SEE DWG. NO. 35-G01 FOR LITHOLOGY AND NOTES.

SCALE IN FEET
0 10 20 30 40 50

PRELIMINARY

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

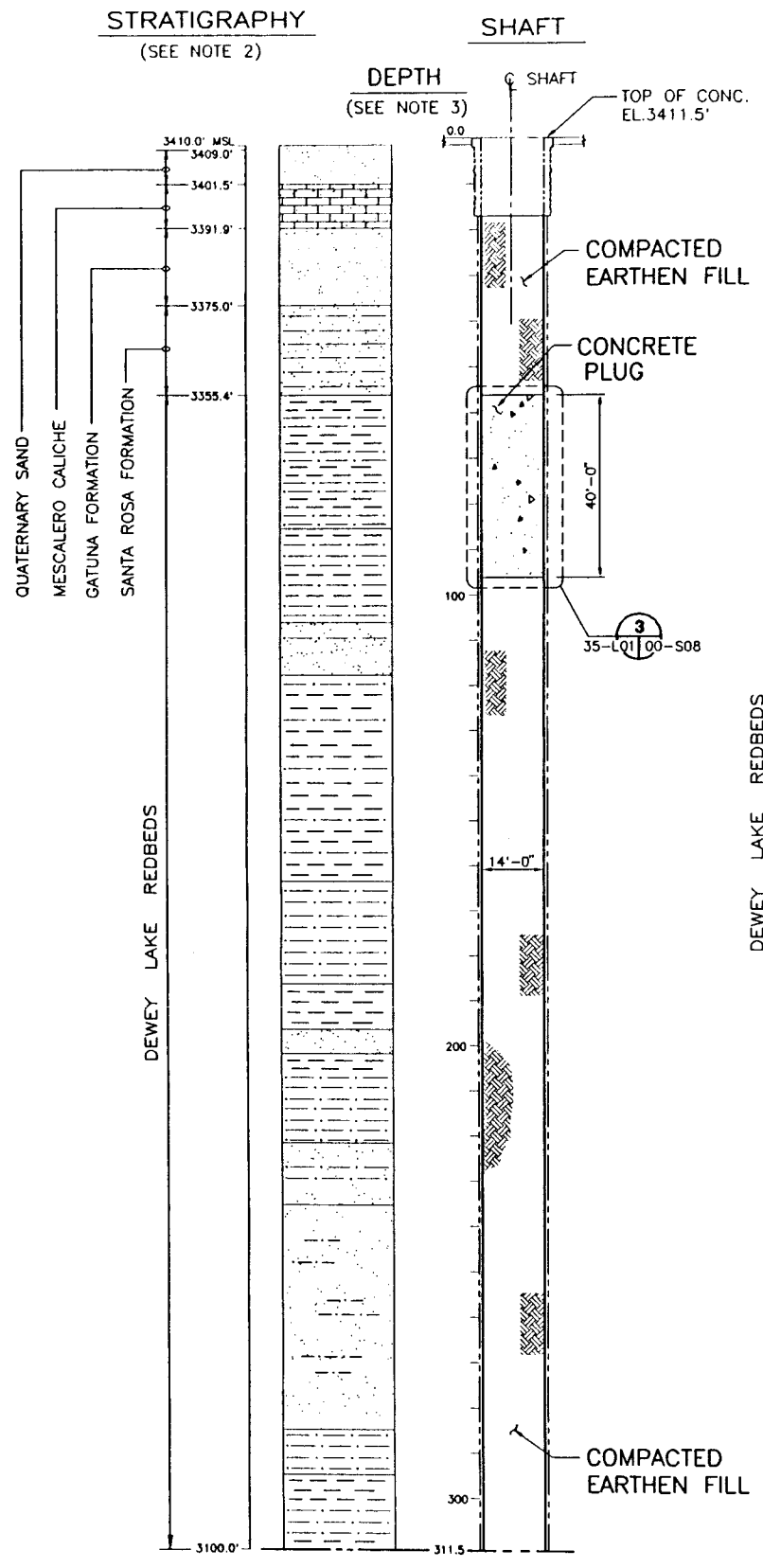
WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
EXHAUST SHAFT STRATIGRAPHY & AS-BUILT ELEMENTS

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG NO. | SHEET NO

09-CS-35-G02

NAME: C:\A\WIPP\9\CS\CS35-G02.DWG DATE: DECEMBER 11, 1995 TIME: 3:08 PM



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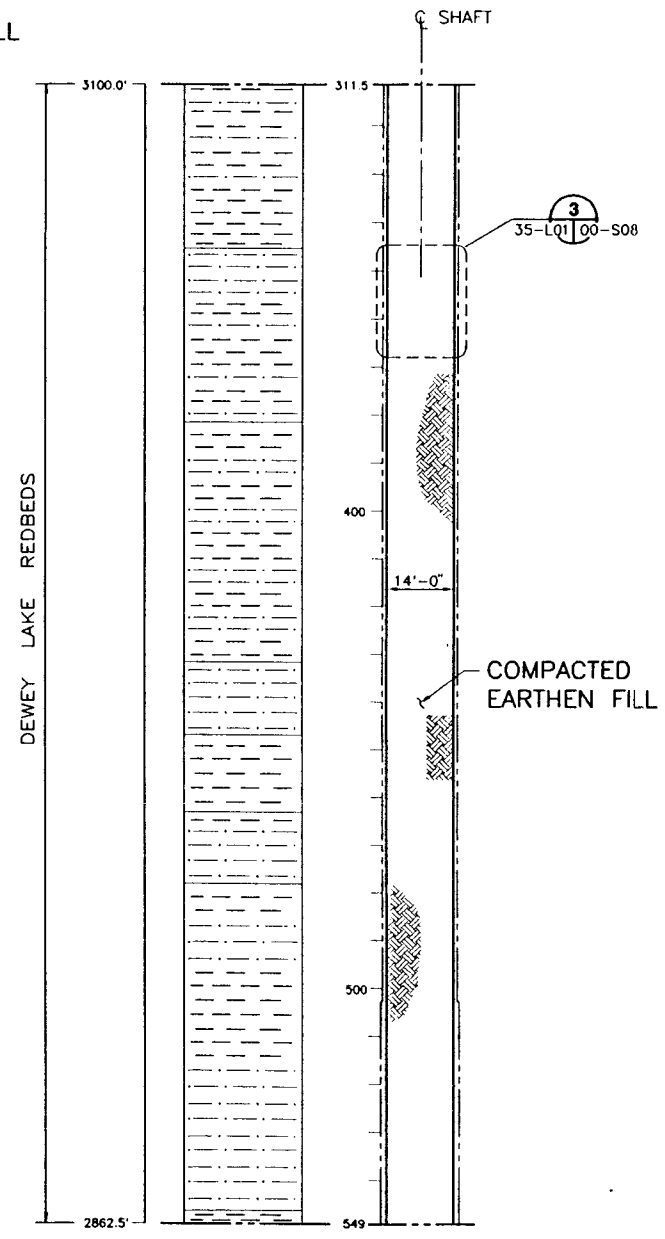

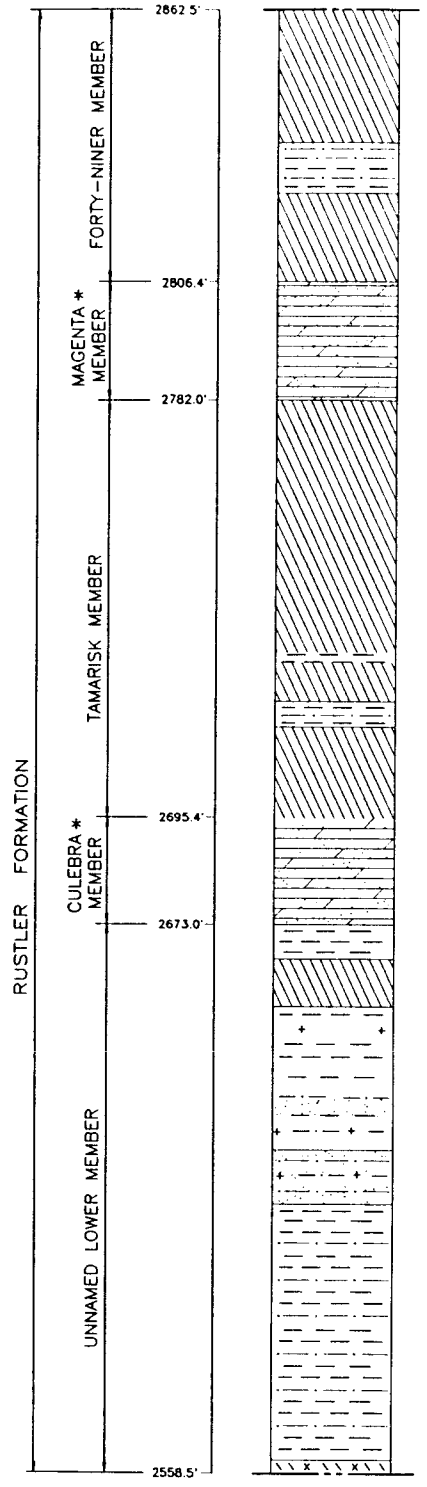

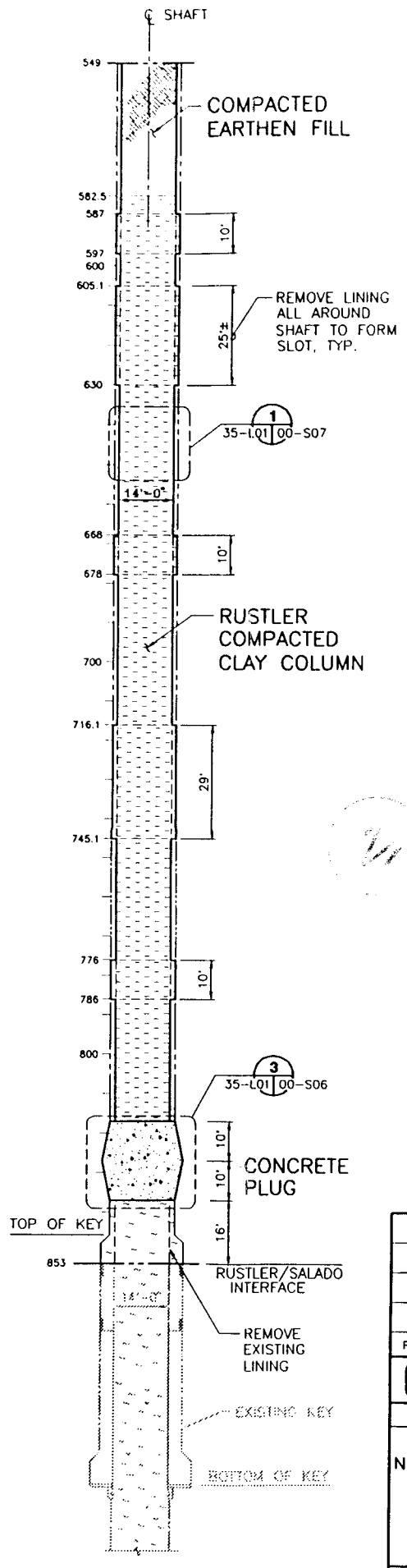

NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTE, LEGEND AND ABBREVIATIONS.
2. SEE DWG. NO. 35-G01 FOR LITHOLOGY AND NOTES.
3. DEPTHS SHOWN ARE DISTANCES BELOW THE TOP OF CONCRETE, LOCATED AT EL. 3411.5' ABOVE MSL USGS 1927 NORTH AMERICAN DATUM.

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PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
EXHAUST SHAFT
STRATIGRAPHY & SEALING
SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC	SCALE:	SIZE B	SNL DWG. NO.	SHEET NO.

NAME: C:\A\WIPP\9\CS\CS35-L01.DWG DATE: FEBRUARY 01, 1996 TIME: 10:01 AM

09-CS-35-L01

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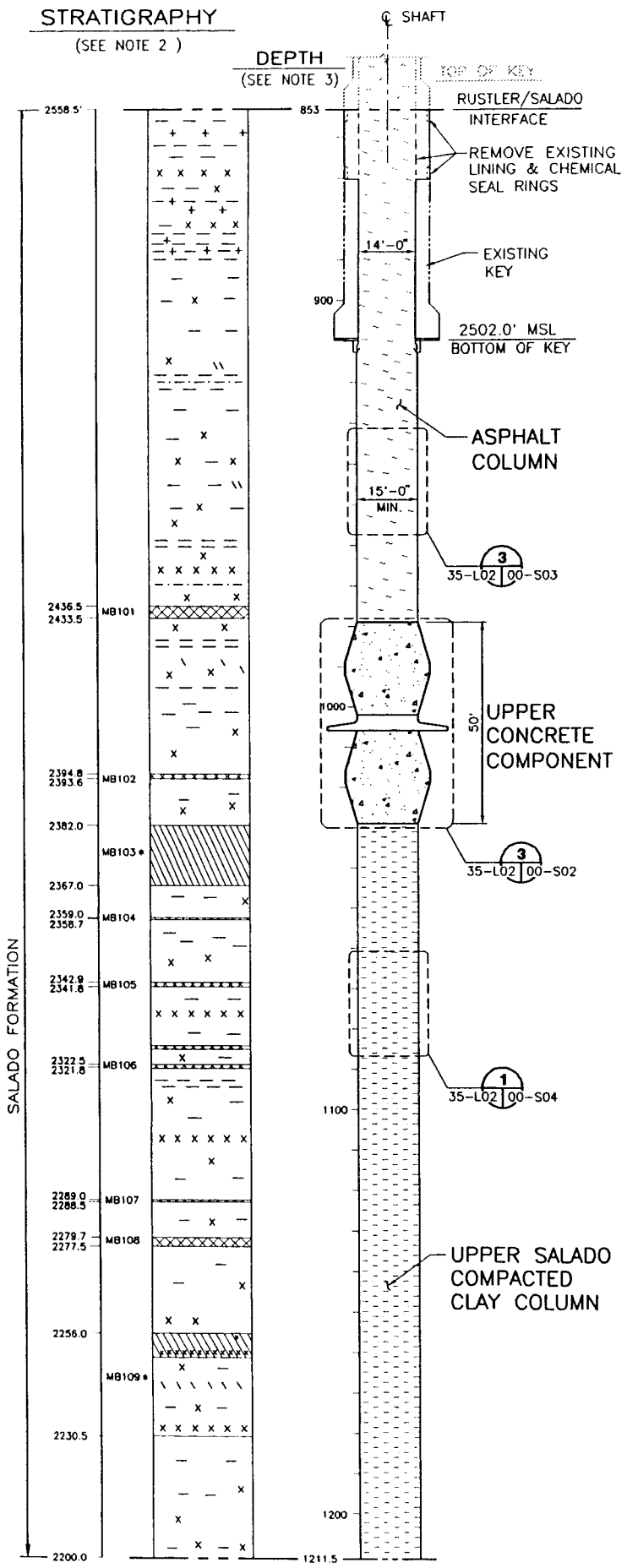

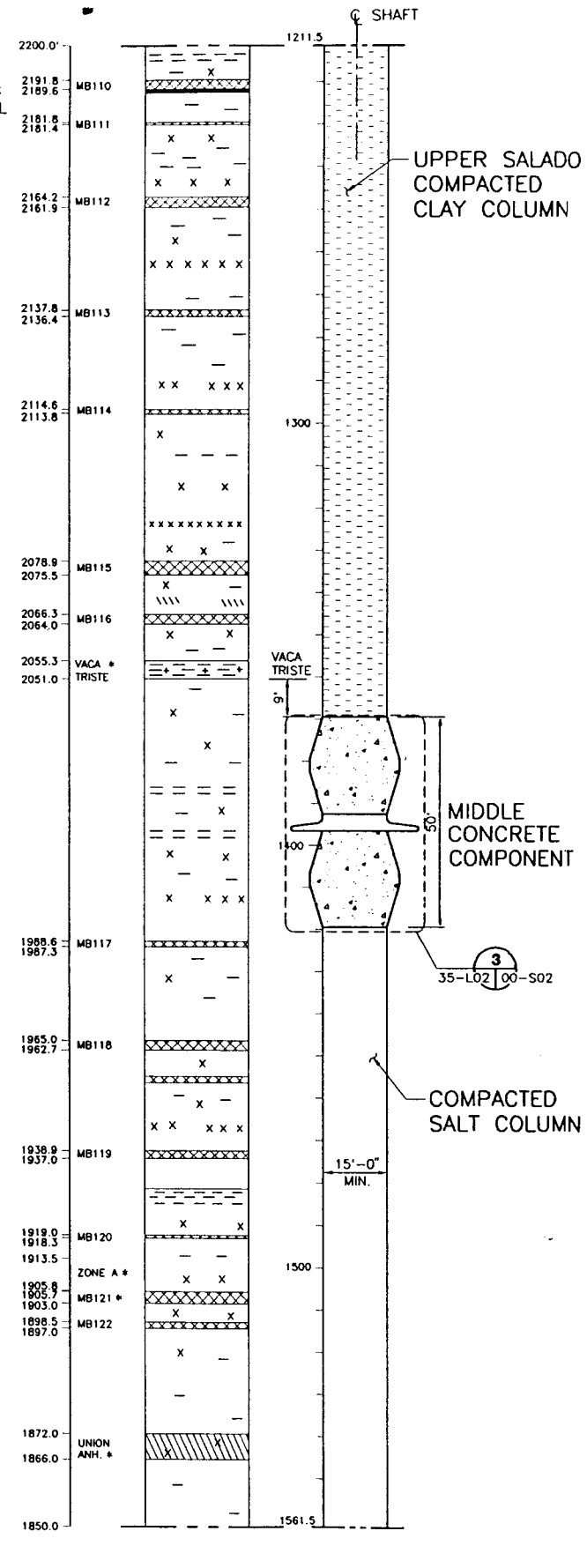

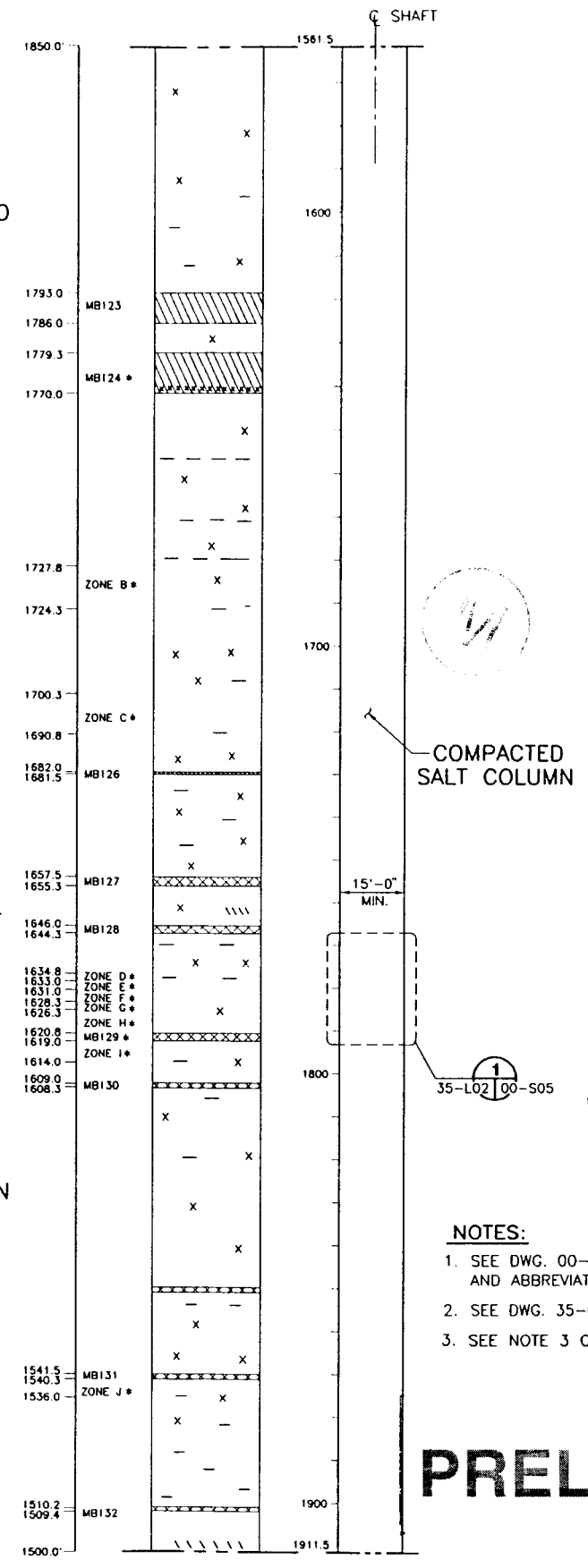

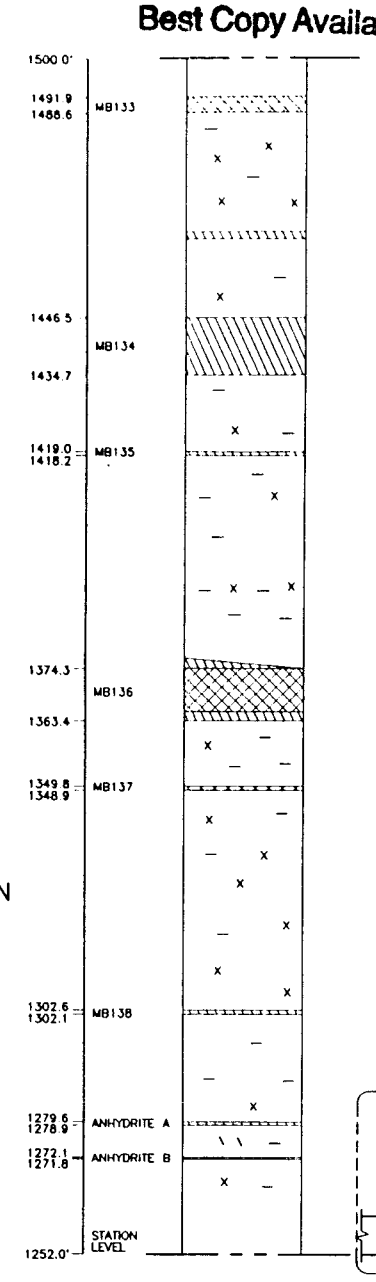

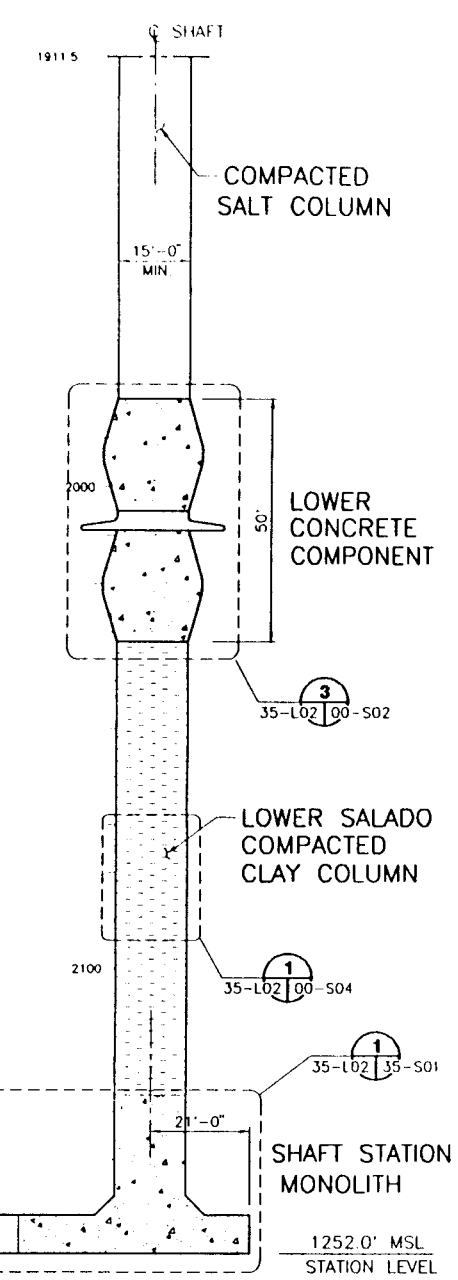

NOTES:

1. SEE DWG. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.
2. SEE DWG. 35-G01 FOR LITHOLOGY AND NOTES.
3. SEE NOTE 3 OF DWG. 35-L01.

SCALE IN FEET
0 10 20 30 40 50

PRELIMINARY

REV.	DATE	DESCRIPTION	BY	CK	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
EXHAUST SHAFT
STRATIGRAPHY & SEALING
SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG. NO | SHEET NO

09-CS-35-L02

NAME: C:\A\WIPP\9\CS\CS35-L02.DWG DATE: DECEMBER 11, 1995 TIME: 3:02 PM

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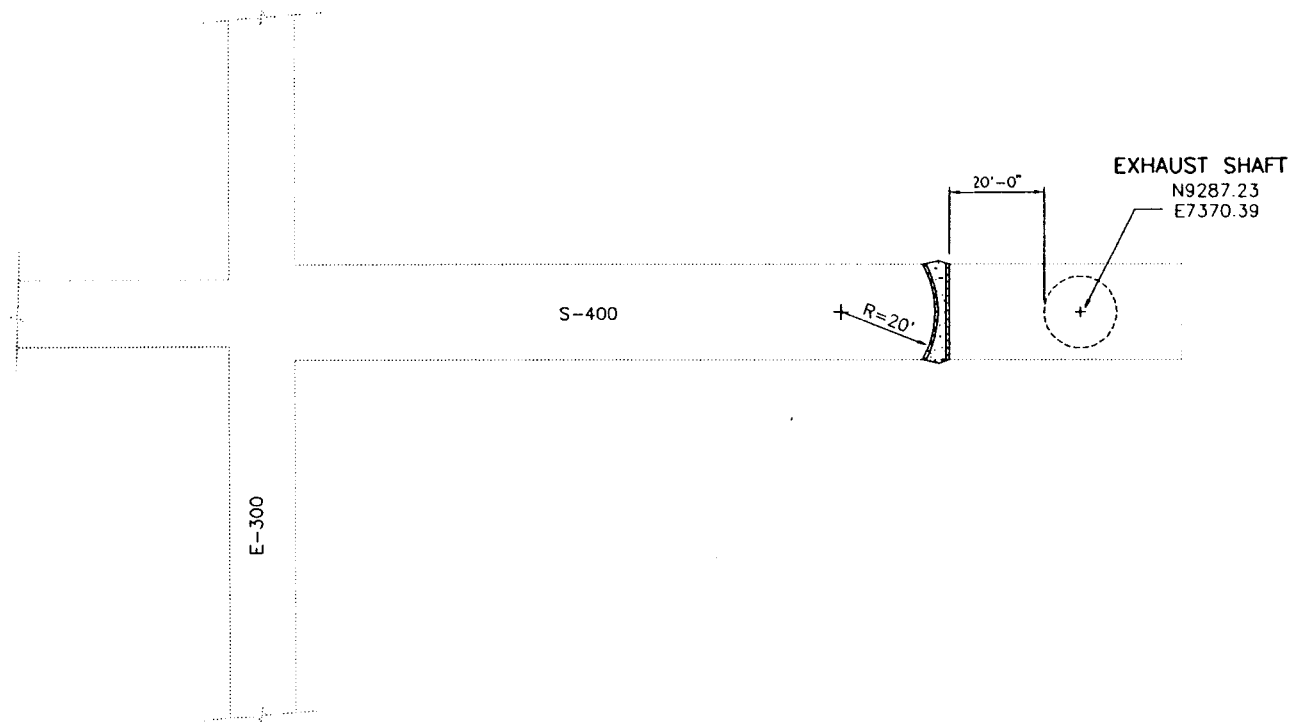

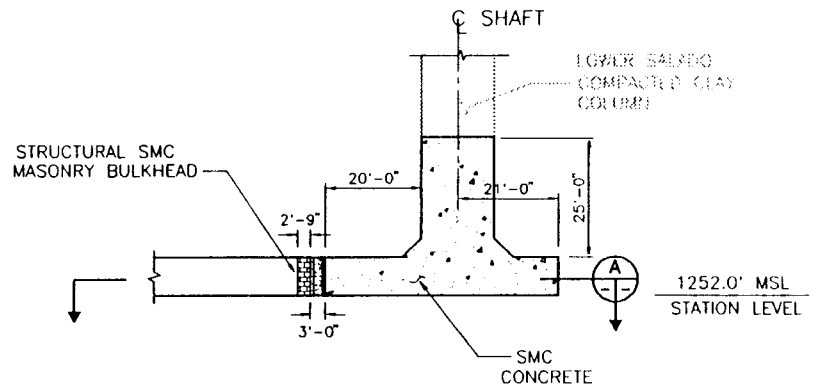

DETAIL (1) 35-L02 | 35-S01

SECTION (A) N

NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.

SCALE IN FEET
0 10 20 30 40 50

PRELIMINARY

REV.	DATE	DESCRIPTION	BY	CK	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO. AG-4909

WIPP SHAFT SEALING SYSTEM

EXHAUST SHAFT
SHAFT STATION MONOLITH

	NAME	DATE
BY	DL	
CK	SAR	
APP		
APP		
APP		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC.	SCALE	SIZE B	SNL DWG. NO.	SHEET NO.

NAME: C:\A\WIPP\9\CS\CS35-S01.DWG DATE: FEBRUARY 01, 1996 TIME: 10:06 AM

09-CS-35-S01

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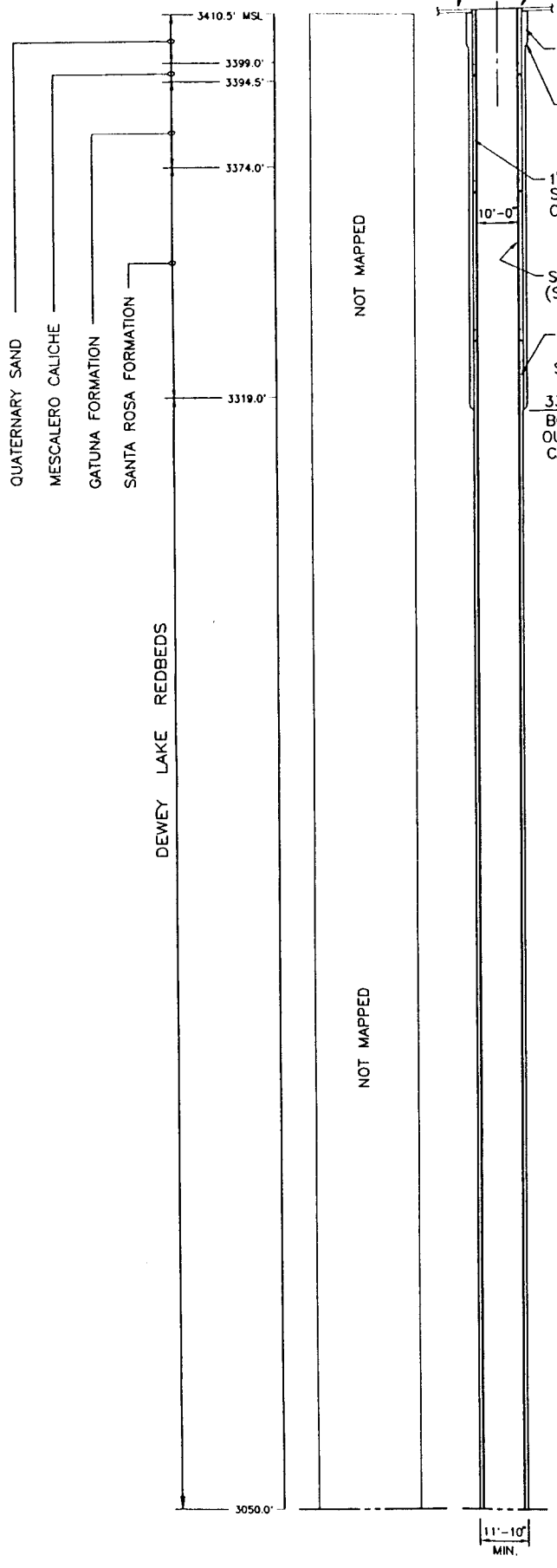
STRATIGRAPHY
(SEE NOTE 1)



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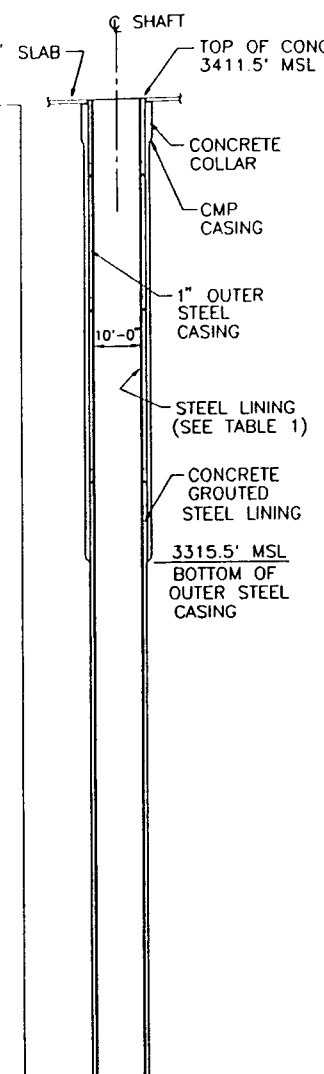

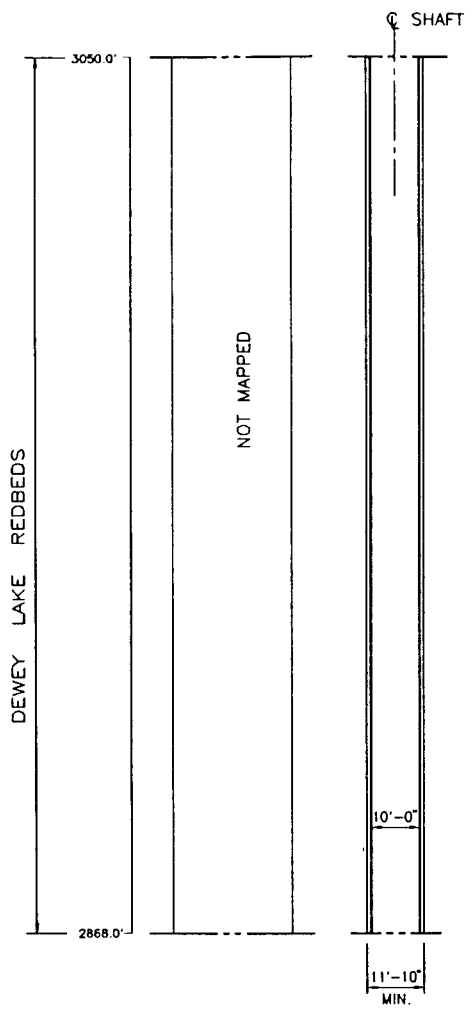

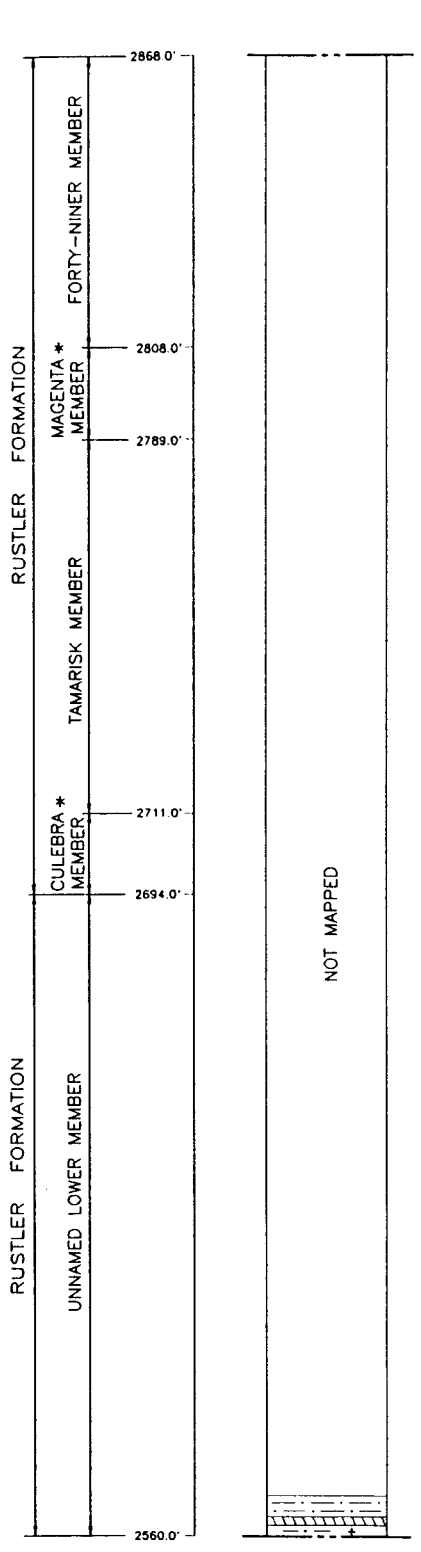

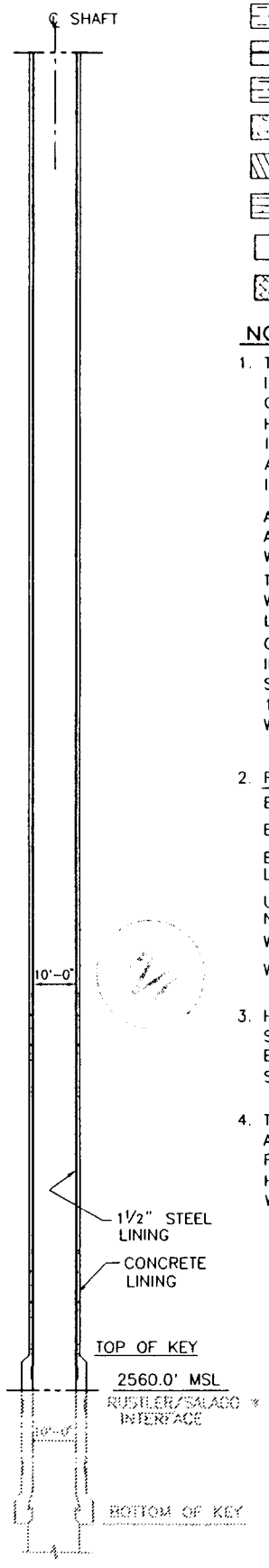

TABLE 1: STEEL LINING SCHEDULE
(SEE NOTE 4)

THICKNESS (IN.)	TOP EL. MSL	BOT. EL. MSL	SECTION LENGTH (FT.)
5/8	3411.5	3246	165.5
1	3246	2886	360
1¼	2886	2786	100
1⅜	2786	2686	100
1½	2686	2586	100
1½ PETAL BASKET	2586	2573	13
		TOTAL LENGTH	838.5

LITHOLOGY:

PRIMARY ROCK/SEDIMENT TYPES	SECONDARY CONSTITUENTS
MUDSTONE/CLAYSTONE	ARGILLACEOUS
CLAYSTONE BED	SILTY
SILTSTONE	SANDY
SANDSTONE	SULFATIC
ANHYDRITE/GYPSUM	DOLOMITIC
DOLOMITE	CALCAREOUS
HALITE	+ + HALITIC
POLYHALITE	x x x POLYHALITIC

NOTES:

1. THE STRATIGRAPHY AND GROUNDWATER BRINE SEEPAGE/WEEP INTERVALS ARE BASED ON THE LITHOLOGIC INFORMATION COMPILED DURING THE GEOLOGIC MAPPING OF THE SALT HANDLING SHAFT WALLS, TME 3178; "GEOTECHNICAL ACTIVITIES IN THE EXPLORATORY SHAFT-SELECTION OF THE FACILITY INTERVAL"; AND APPENDIX A OF REPORT DOE/WIPP-95-3117, "WASTE ISOLATION PILOT PLANT SEALING SYSTEM DESIGN REPORT", 1995.

   ASTERISK (•) WITHIN THE RUSTLER AND SUPRA RUSTLER FORMATIONS AND THE RUSTLER/SALADO FORMATION CONTACT INDICATES GROUNDWATER OBSERVED DURING SHAFT MAPPING. ASTERISK (•) WITHIN THE SALADO FORMATION INDICATES A POTENTIAL BRINE SEEPAGE/WEEP INTERVAL. THESE POTENTIAL BRINE SEEPAGE/WEEP INTERVALS, LOCATED ABOVE THE SHAFT STATION LEVEL, ARE BASED ON OBSERVED INTERVALS OF BRINE SEEPAGE/WEEPS IN THE AIR INTAKE SHAFT THAT HAVE BEEN PROJECTED TO THE SALT HANDLING SHAFT. THE MAPPING OF THE SALT HANDLING SHAFT (JAROLIMEK ET AL., 1983/TME-3178) DID NOT INDICATE OBSERVED SEEPAGE INTERVALS WITHIN THE SALADO FORMATION.

2. REFERENCE AS-BUILT DRAWINGS FROM WID:

EXPLORATORY SHAFT KEY SHAFT STATION LOCATION, SECTIONS	37-R-010
EXPLORATORY SHAFT KEY, SECTIONS AND DETAILS	37-R-012
EXPLORATORY SHAFT STATION DEVELOPMENT - EXPERIMENTAL LEVEL PLAN AND SECTIONS	37-R-019
UNDERGROUND BASE PLAN E-0 DRIFT FROM N-9900 TO N-9580	51-W-126-W5
WIPP EXHAUST SHAFT 120" I.D. CASING x 834'	FS-M3259-01
WIPP PROJECT 120" I.D. CASING LINER HOLE COMPLEX	FS M3259-02

3. HISTORICAL NOTE: SINCE ITS CONSTRUCTION, THE EXPLORATORY SHAFT HAS BEEN REFERRED TO AS THE EXHAUST SHAFT, THE EXPLORATORY SHAFT, THE CONSTRUCTION AND SALT HANDLING SHAFT, AND THE SALT HANDLING SHAFT.

4. THICKNESS OF STEEL LINING VARIES, LINING TYPE AND LENGTH ARE BASED ON FENIX AND SCISSON AS-BUILT DWGS. M3259-02, REV. 0, DATED 11/30/79, WIPP PROJECT 120" I.D. CASING LINER HOLE COMPLEX, AND M3259-01, REV. 1, DATED 10/13/80, WIPP EXHAUST SHAFT 120" I.D. CASING x 834'.

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
SALT HANDLING SHAFT
STRATIGRAPHY &
AS-BUILT ELEMENTS

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG. NO. | SHEET NO.

NAME: C:\A\WIPP\9\CS\CS37-G01.DWG DATE: DECEMBER 12, 1995 TIME: 2:07 PM

09-CS-37-G01

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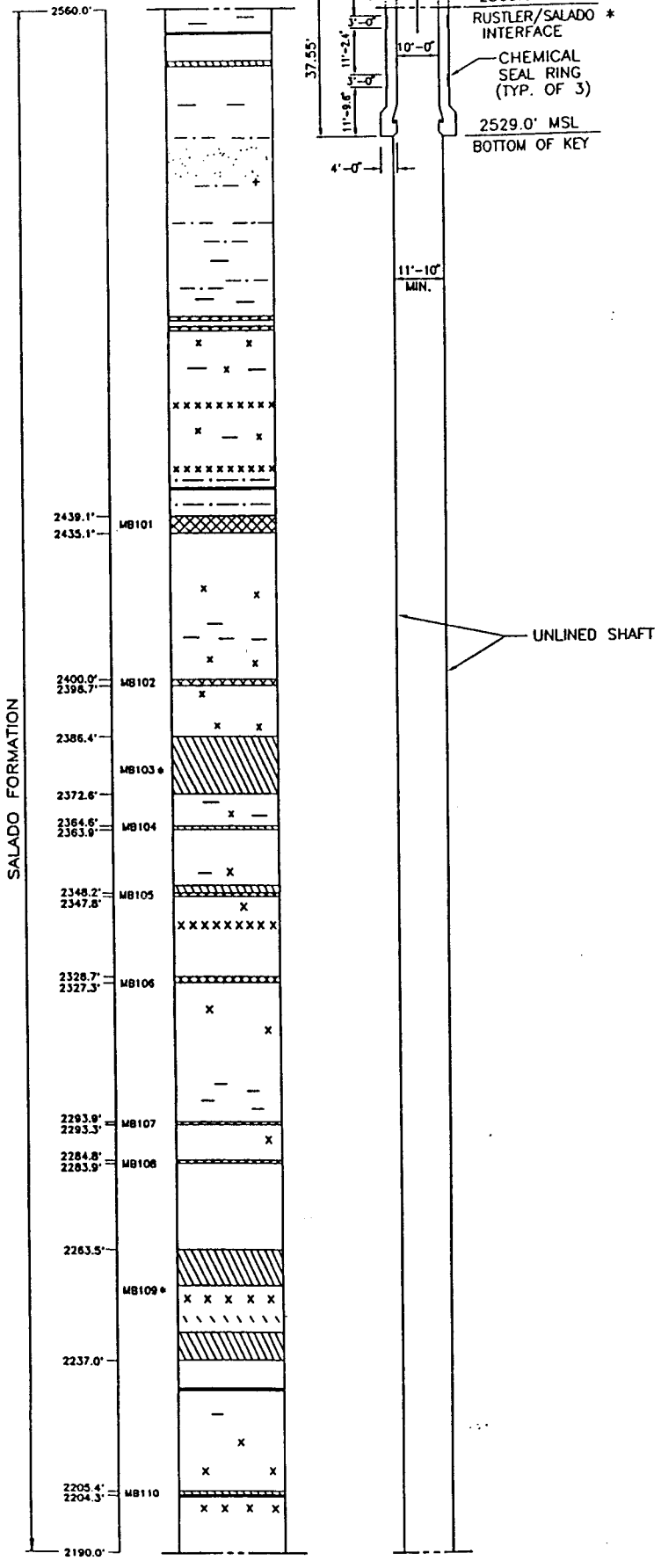
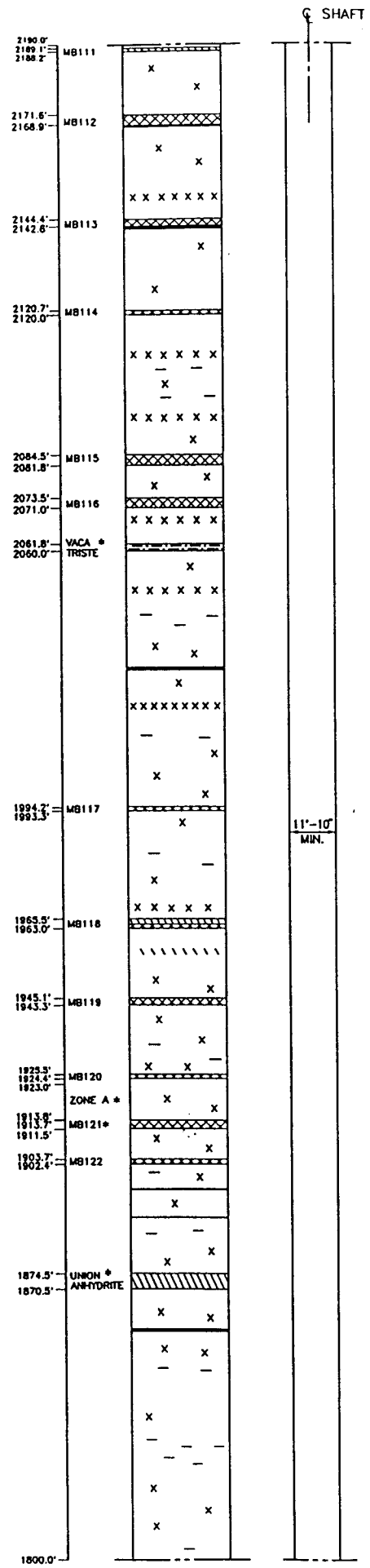
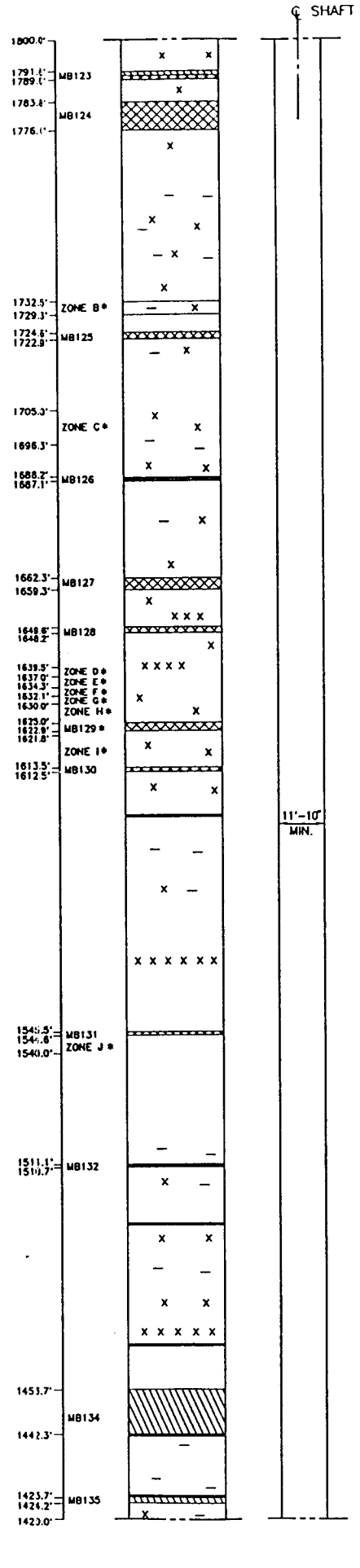
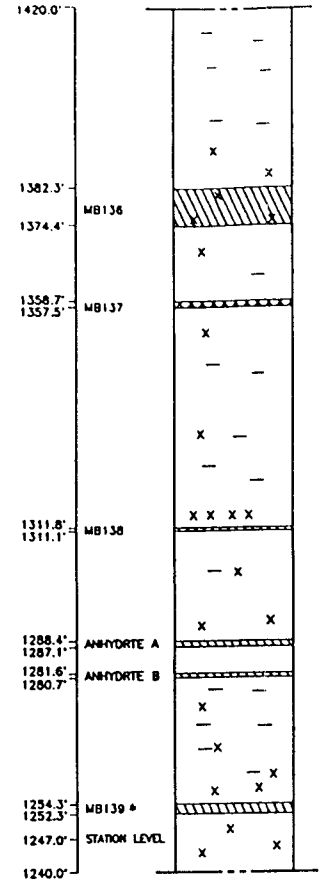
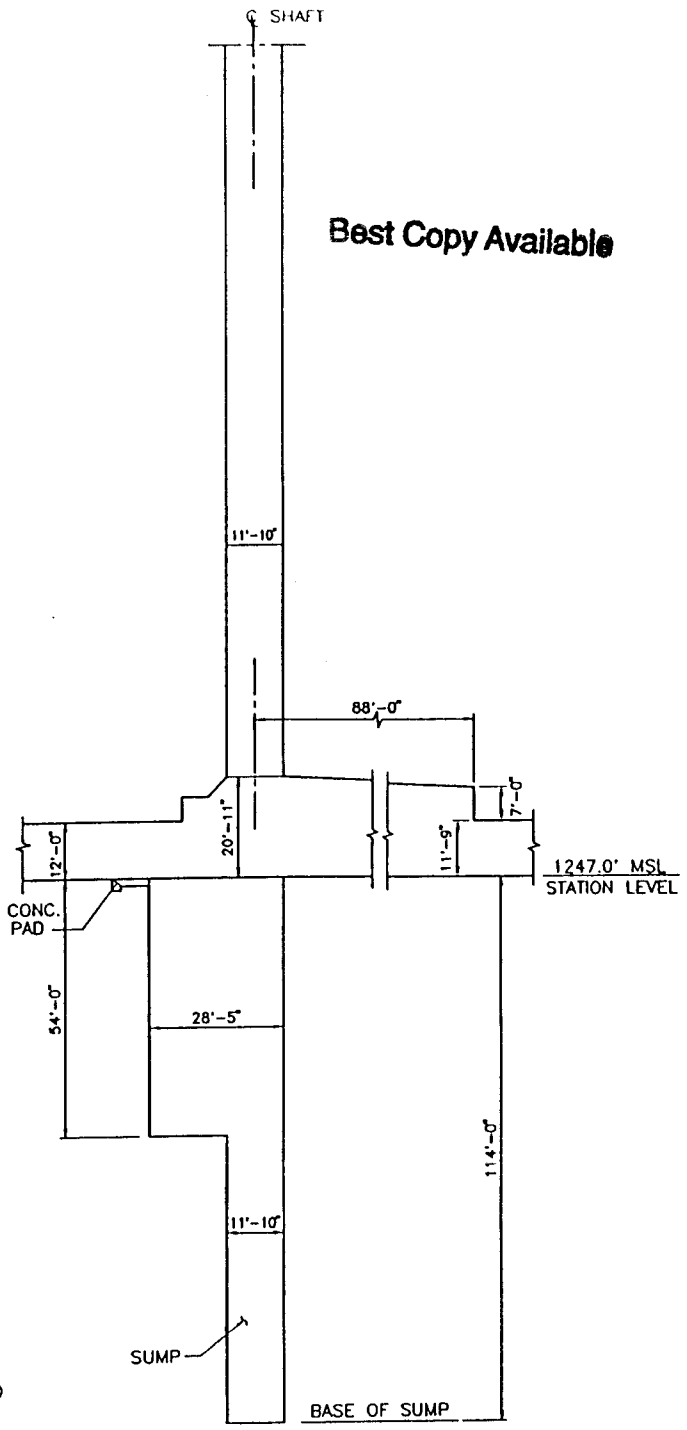
STRATIGRAPHY
(SEE NOTE 2)











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NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES AND ABBREVIATIONS
2. SEE DWG. NO. 37-G01 FOR LITHOLOGY AND NOTES.

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
SALT HANDLING SHAFT
STRATIGRAPHY &
AS-BUILT ELEMENTS

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
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PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG. NO. | SHEET NO.

09-CS-37-G02

NAME: C:\A\WIPP\9\CS\CS37-G02.DWG DATE: DECEMBER 12, 1995 TIME: 1:35 PM

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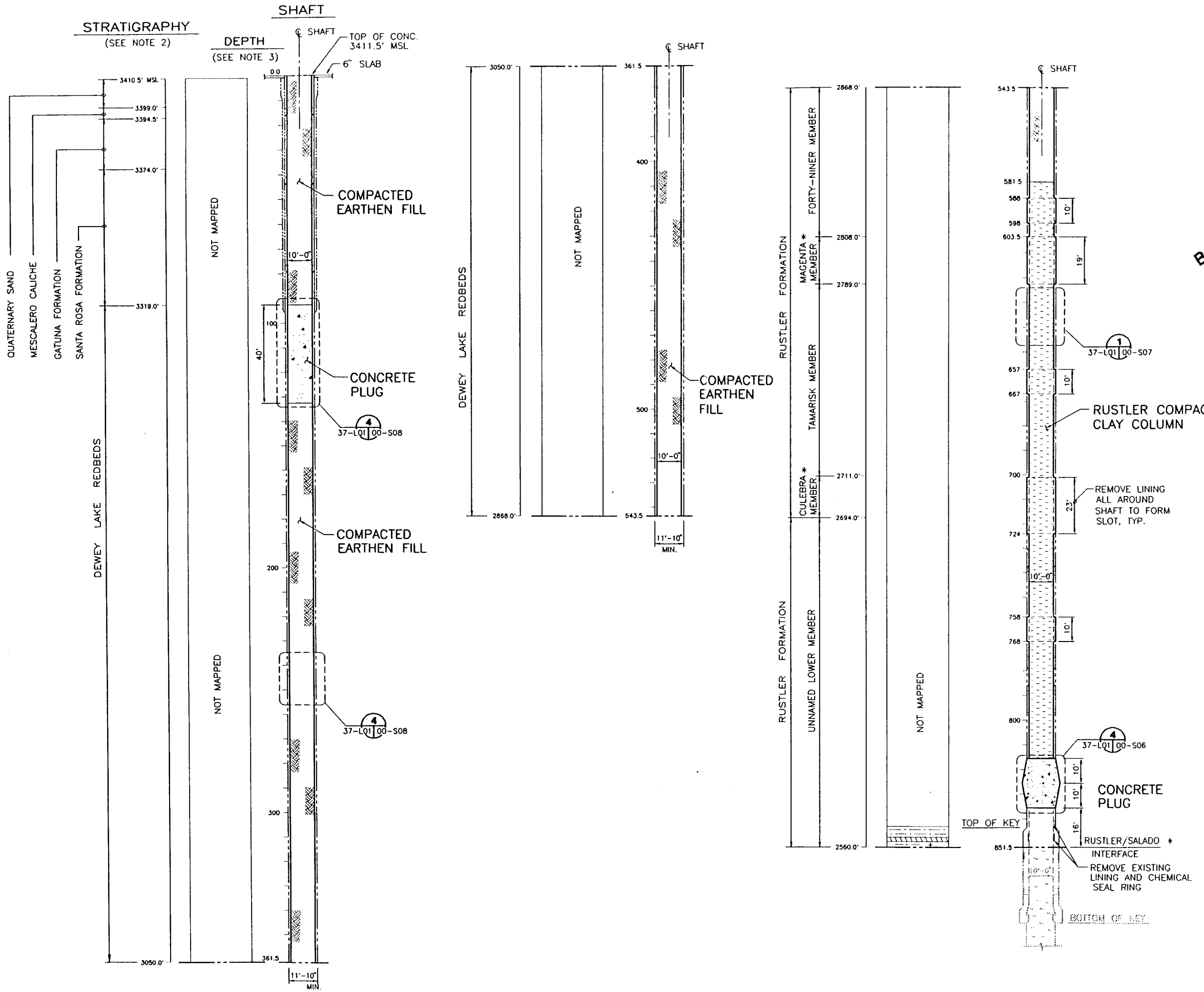

NOTES:

1. SEE DWG 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.
2. SEE DWG 37-G01 FOR LITHOLOGY AND NOTES.
3. DEPTHS SHOWN ARE DISTANCES BELOW THE TOP OF CONCRETE, LOCATED AT EL. 3411.5' ABOVE MSL USGS 1927 NORTH AMERICAN DATUM.

Best Copy Available

PRELIMINARY

SCALE IN FEET
0 10 20 30 40 50

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
NEAR-SURFACE/RUSTLER FORMATIONS
SALT HANDLING SHAFT
STRATIGRAPHY & SEALING
SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG. NO | SHEET NO.

09-CS-37-L01

NAME: C:\A\WIPP\9\CS\CS37-L01.DWG DATE: FEBRUARY 01, 1996 TIME: 10:23 AM

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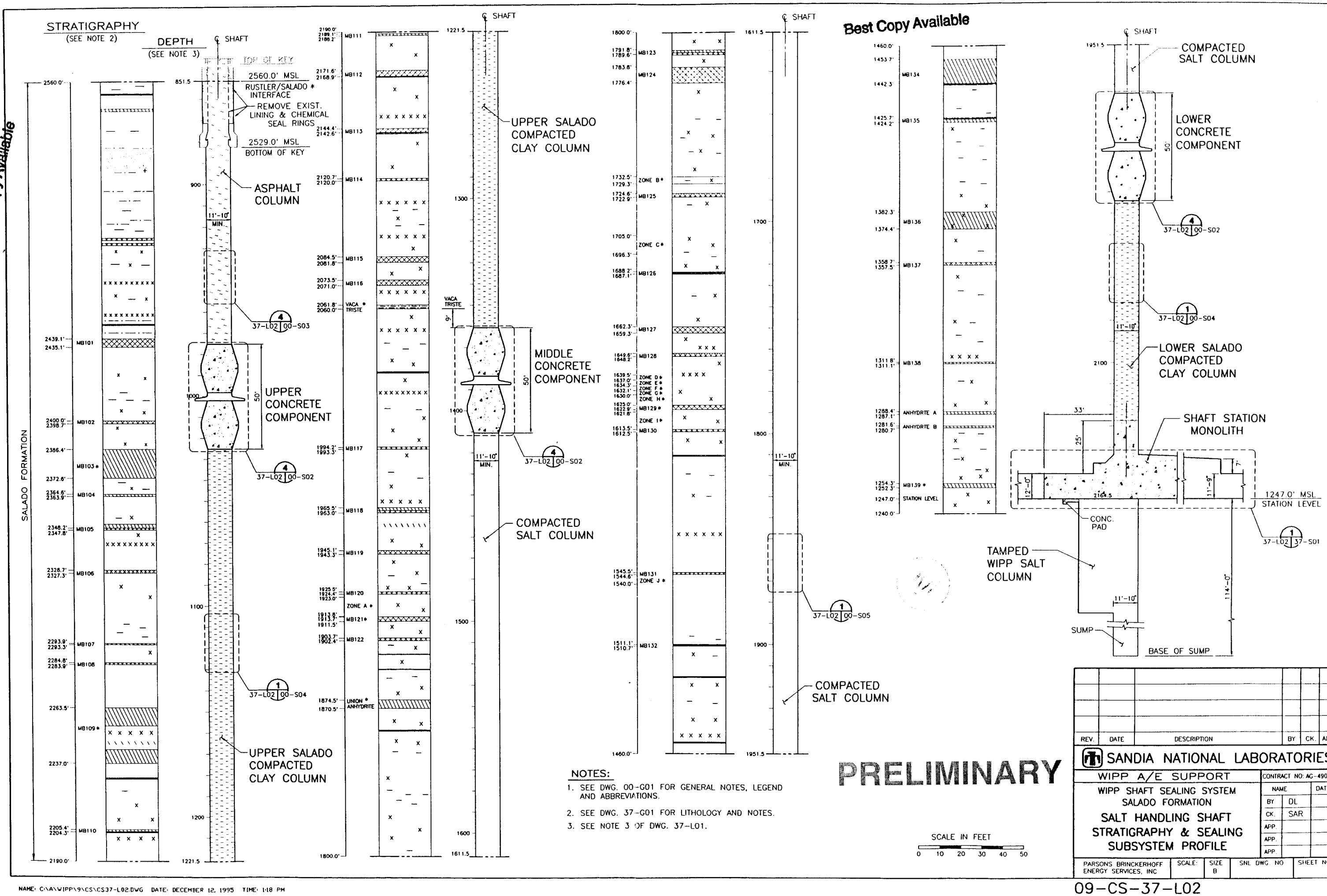

NOTES:

1. SEE DWG. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.
2. SEE DWG. 37-G01 FOR LITHOLOGY AND NOTES.
3. SEE NOTE 3 OF DWG. 37-L01.

SCALE IN FEET
0 10 20 30 40 50

PRELIMINARY

REV.	DATE	DESCRIPTION	BY	CK.	APP.

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM
SALADO FORMATION
SALT HANDLING SHAFT
STRATIGRAPHY & SEALING
SUBSYSTEM PROFILE

	NAME	DATE
BY	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC | SCALE: | SIZE B | SNL DWG NO | SHEET NO

NAME: C:\A\WIPP\9\CS\CS37-L02.DWG DATE: DECEMBER 12, 1995 TIME: 1:18 PM

09-CS-37-L02

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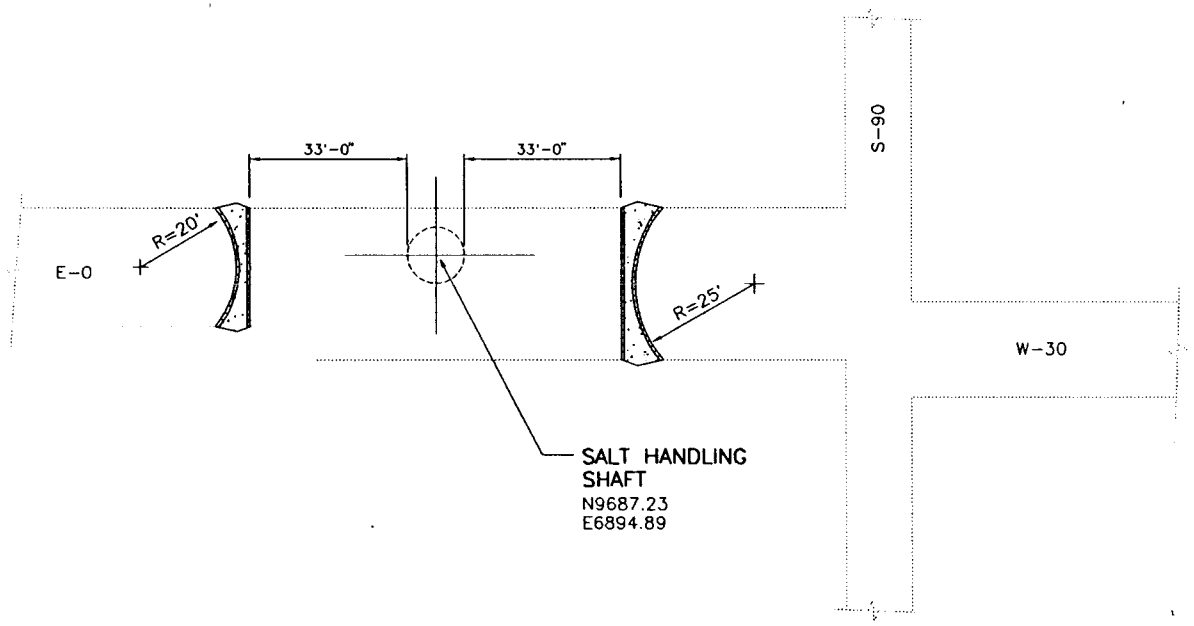

SECTION A

SCALE IN FEET
0 10 20 30 40 50

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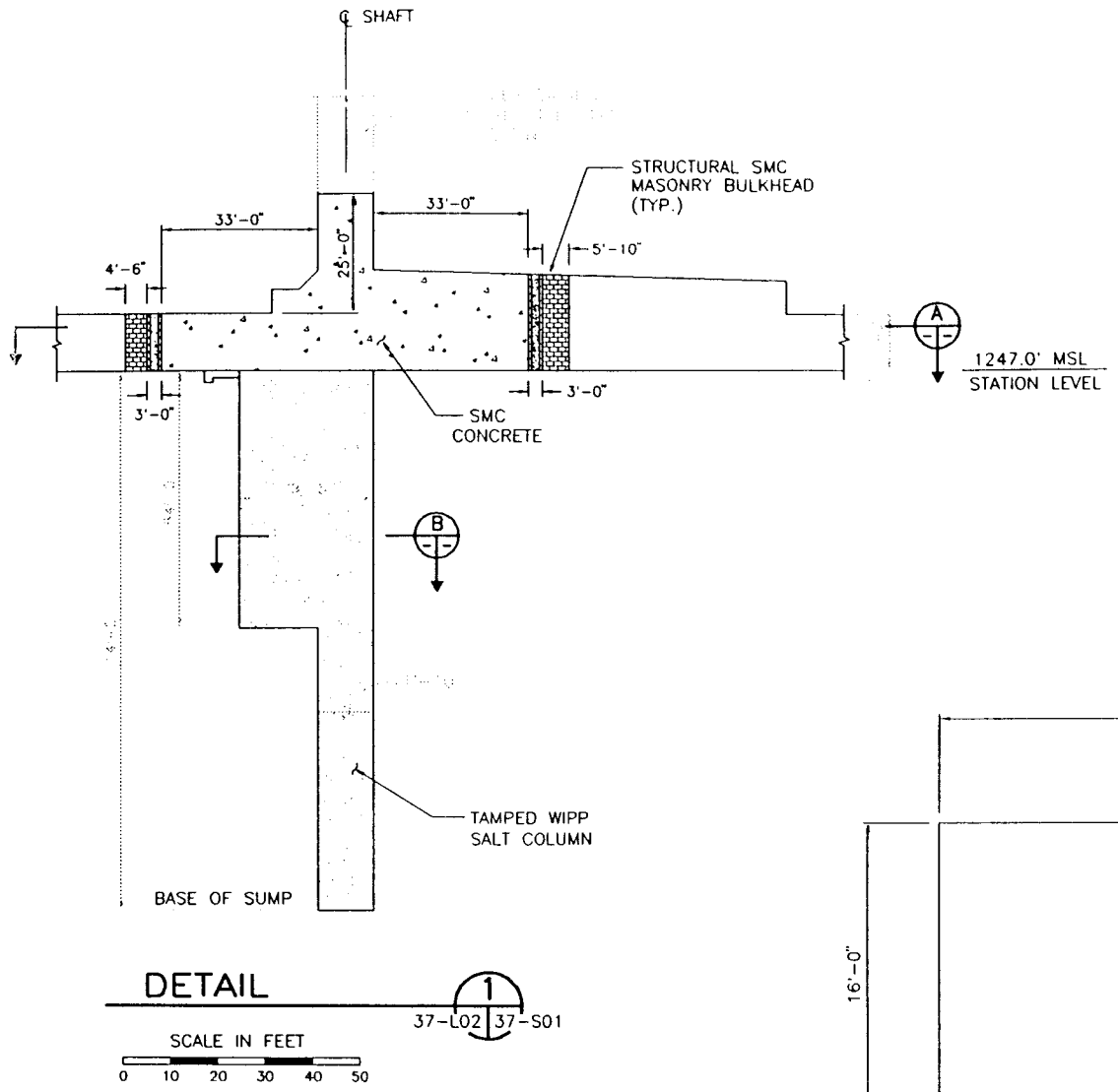

DETAIL 1 (37-L02 | 37-S01)

SCALE IN FEET
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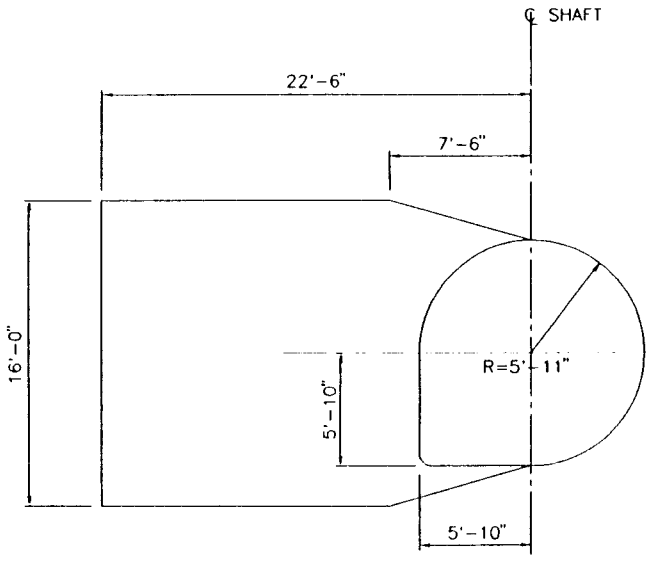

SECTION B

SCALE IN FEET
0 5 10 15 20

NOTES:

1. SEE DWG. NO. 00-G01 FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS.

PRELIMINARY

REV.	DATE	DESCRIPTION	BY	CK.	APP

SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO: AC-4909

WIPP SHAFT SEALING SYSTEM

SALT HANDLING SHAFT
SHAFT STATION MONOLITH

	NAME	DATE
BY.	DL	
CK.	SAR	
APP.		
APP.		
APP.		

PARSONS BRINCKERHOFF ENERGY SERVICES, INC. | SCALE: | SIZE B | SNL DWG. NO. | SHEET NO.

09-CS-37-S01

NAME: C:\A\WIPP\9\CS\CS37-S01.DWG DATE: FEBRUARY 12, 1996 TIME: 9:45 AM

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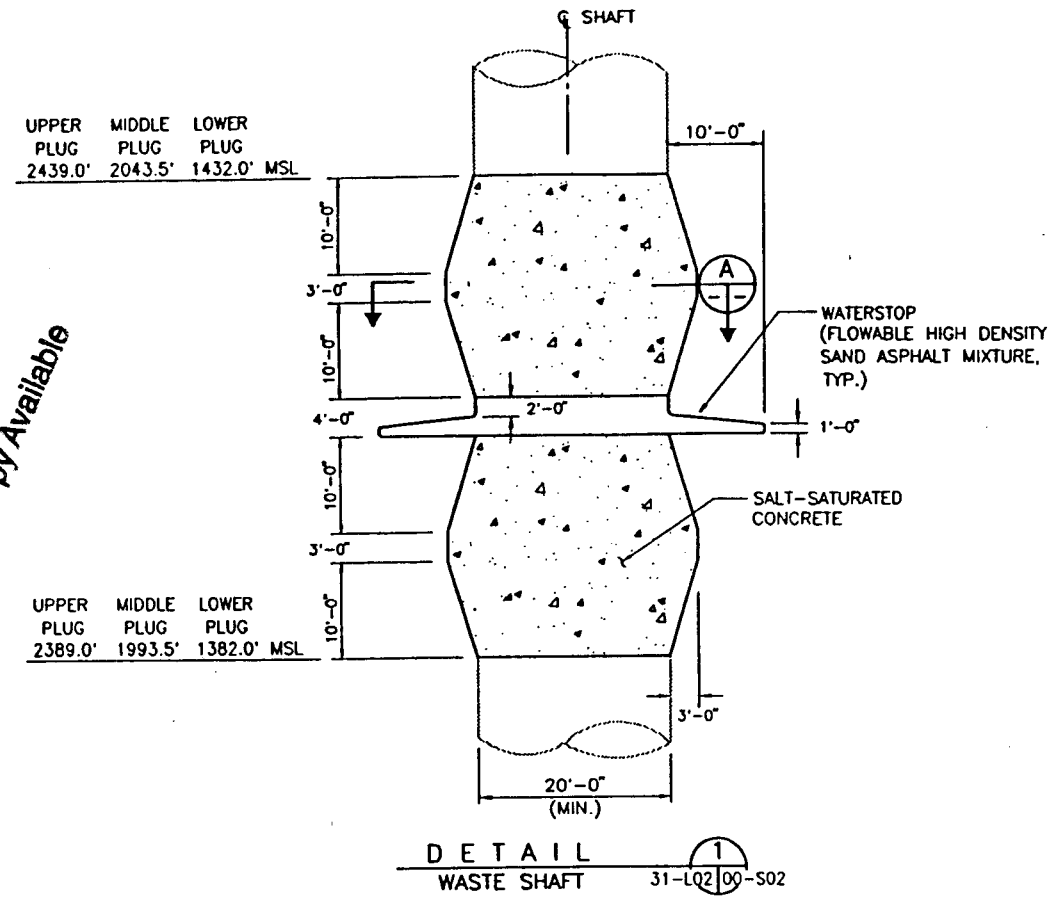
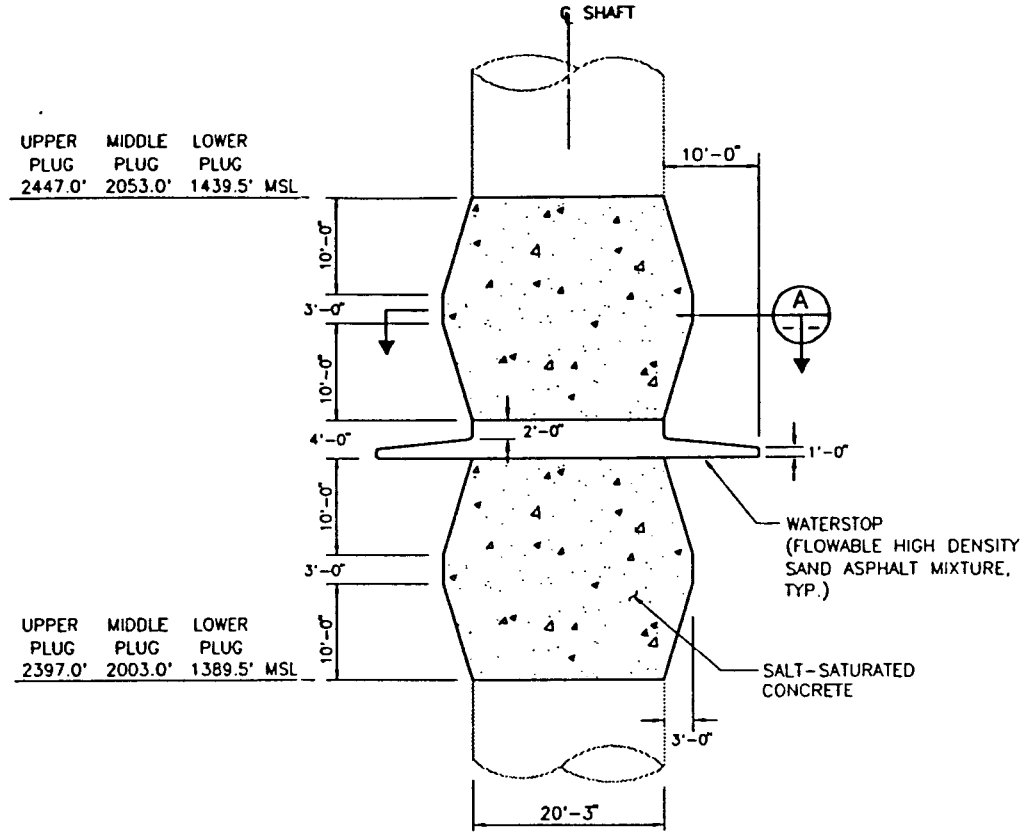


DETAIL 1
WASTE SHAFT 31-LQ2|00-S02



DETAIL 2
AIR INTAKE SHAFT 33-LQ2|00-S02

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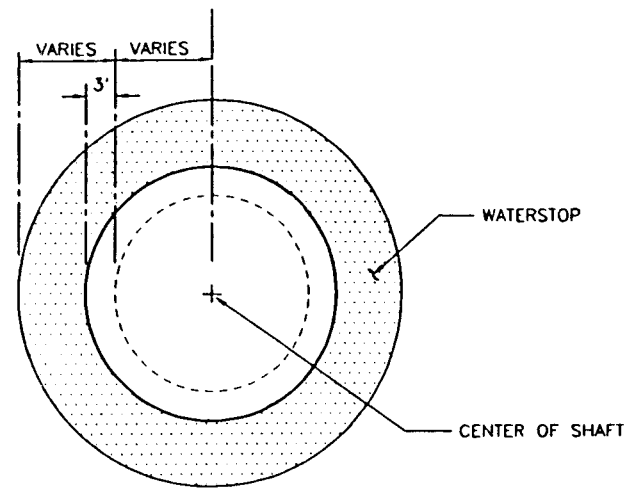

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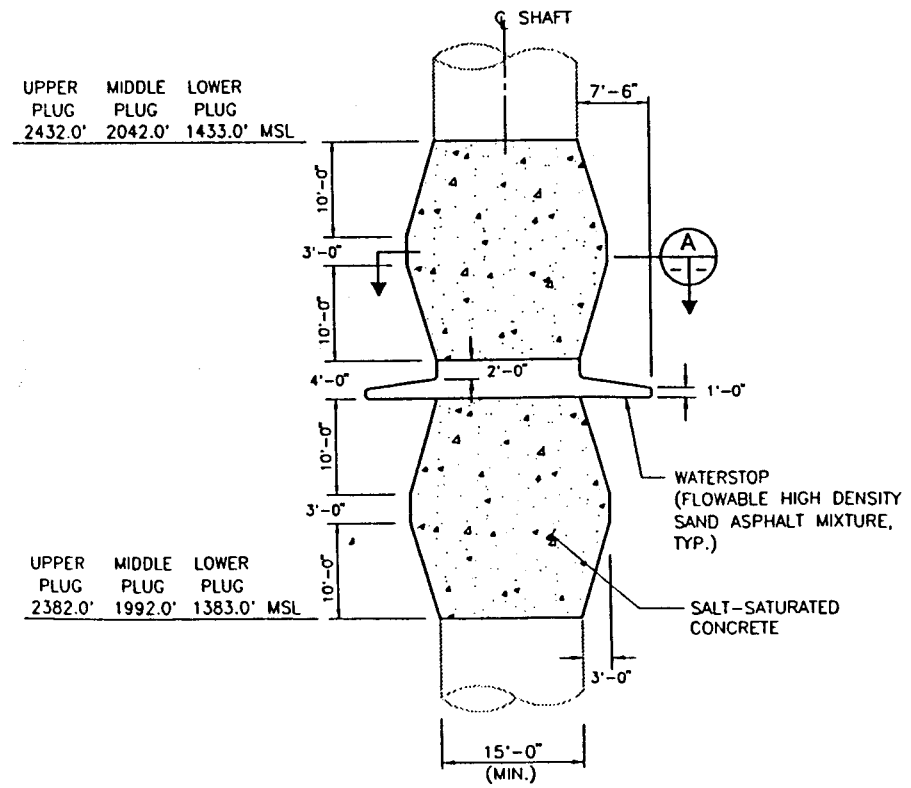

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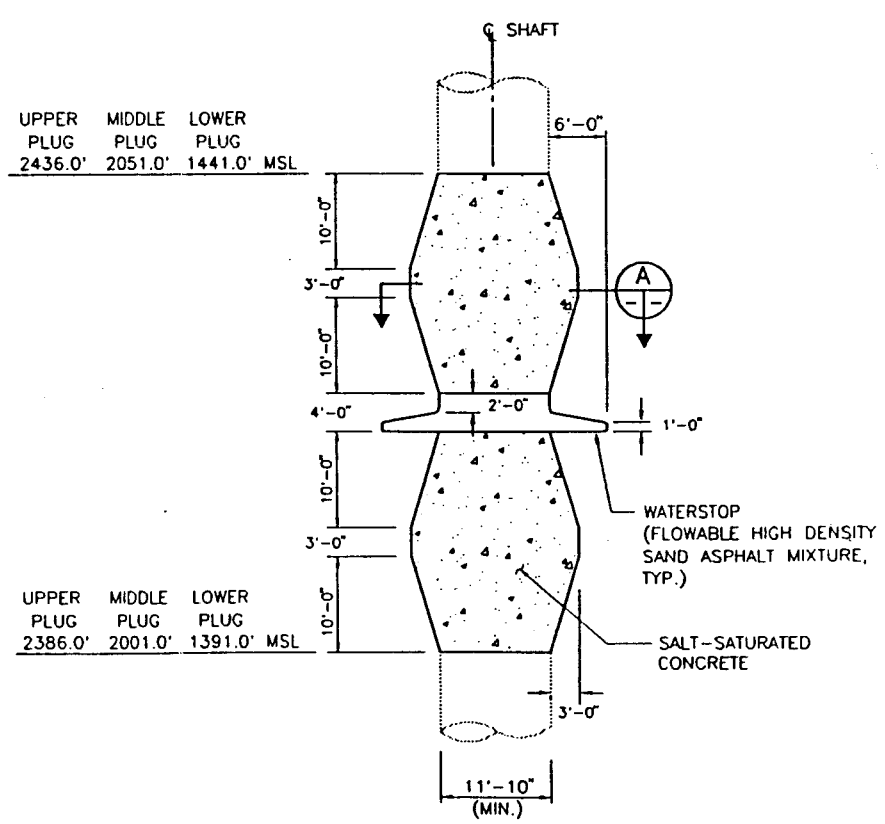

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SALT HANDLING SHAFT 37-LQ2|00-S02

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM

CONCRETE COMPONENT IN SALADO FORMATION

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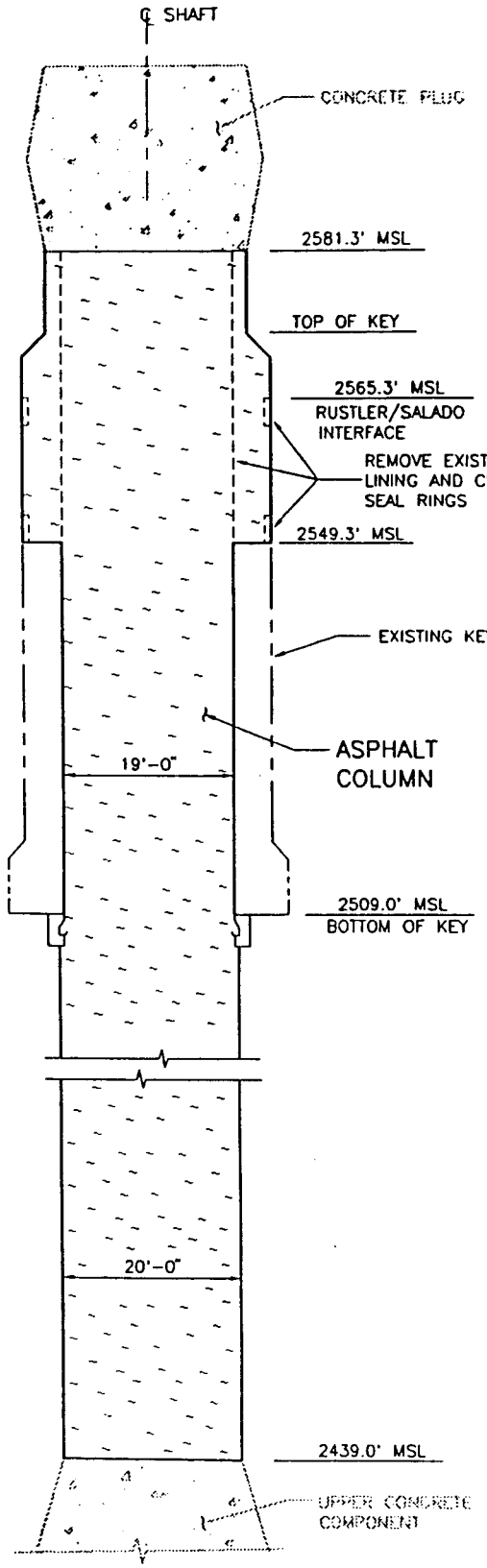

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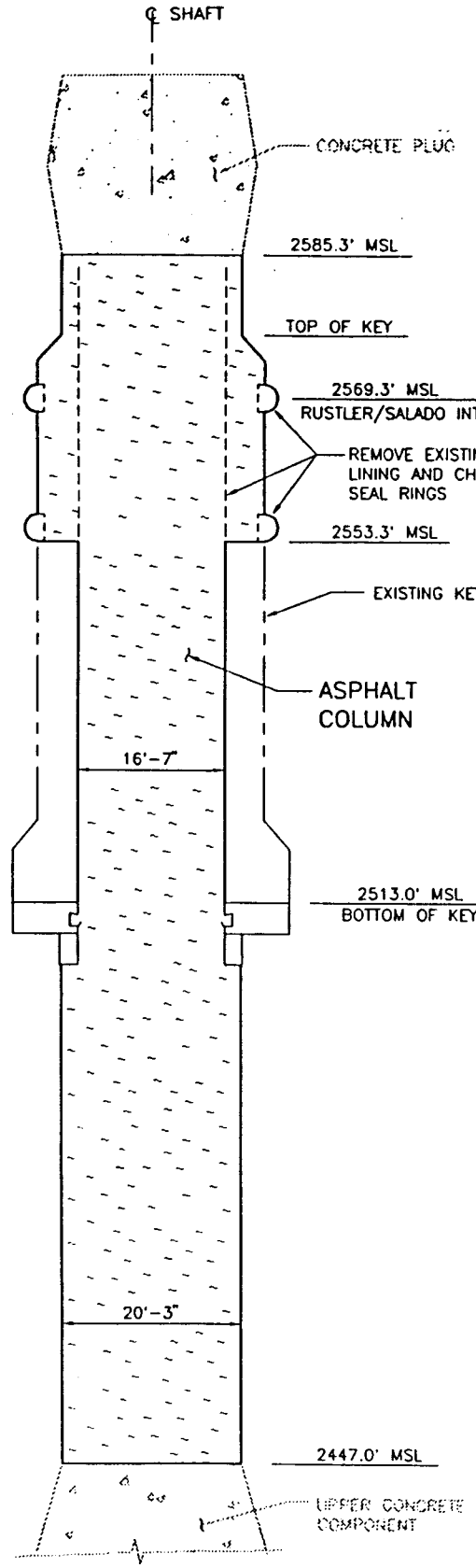

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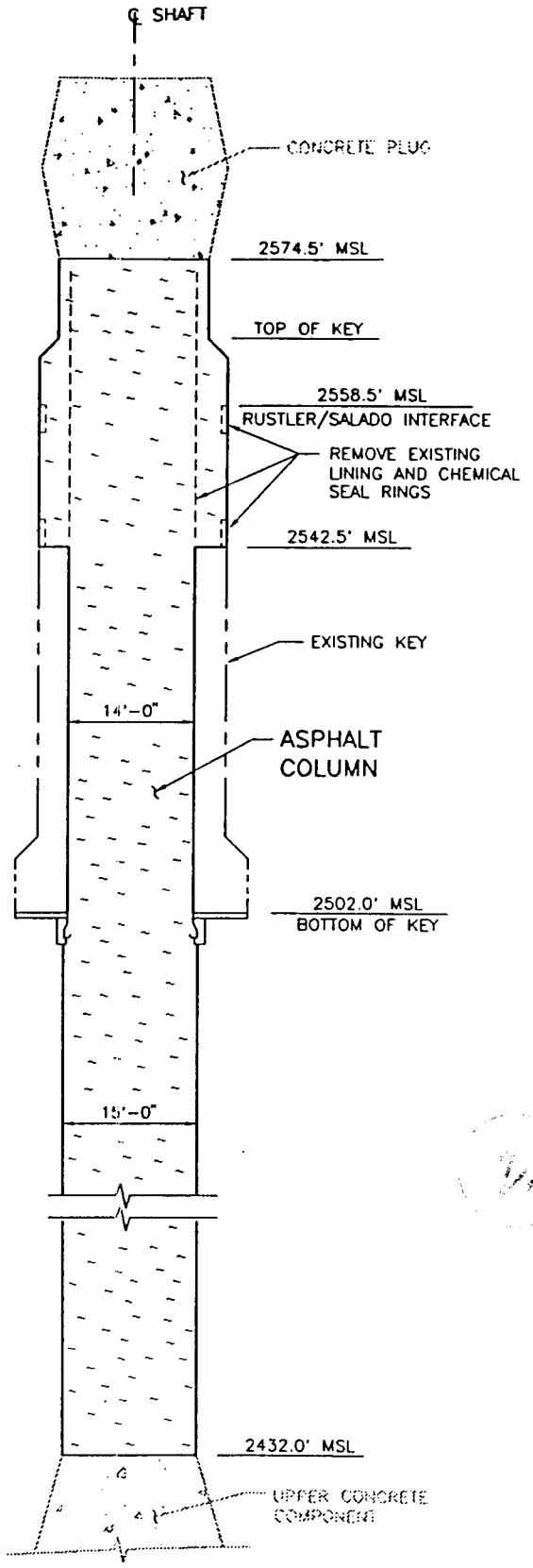

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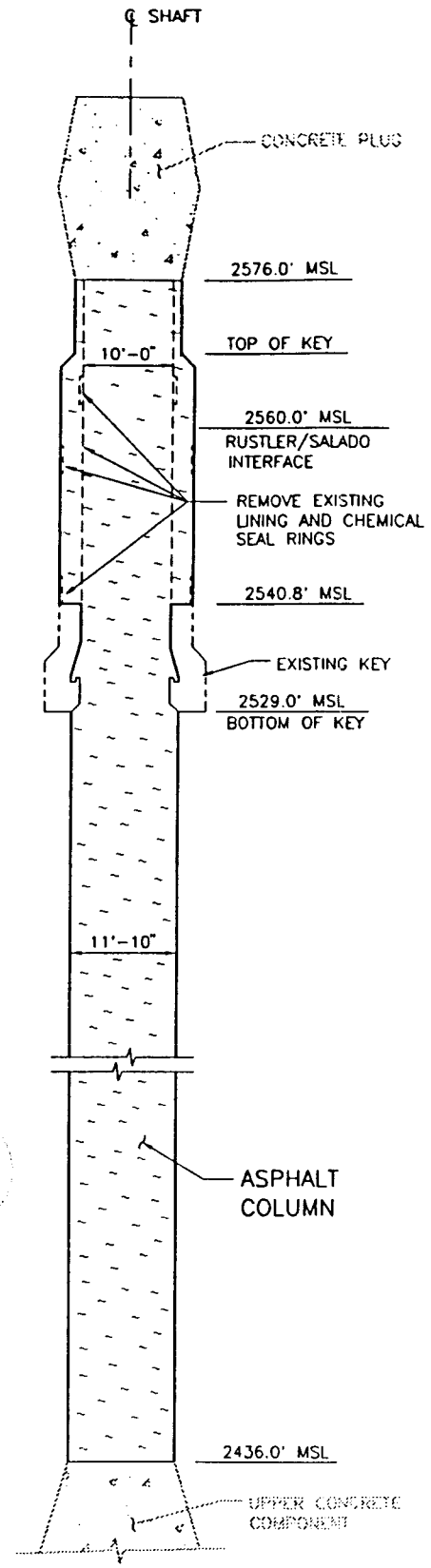

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO. AG-4909

WIPP SHAFT SEALING SYSTEM

ASPHALT COLUMN

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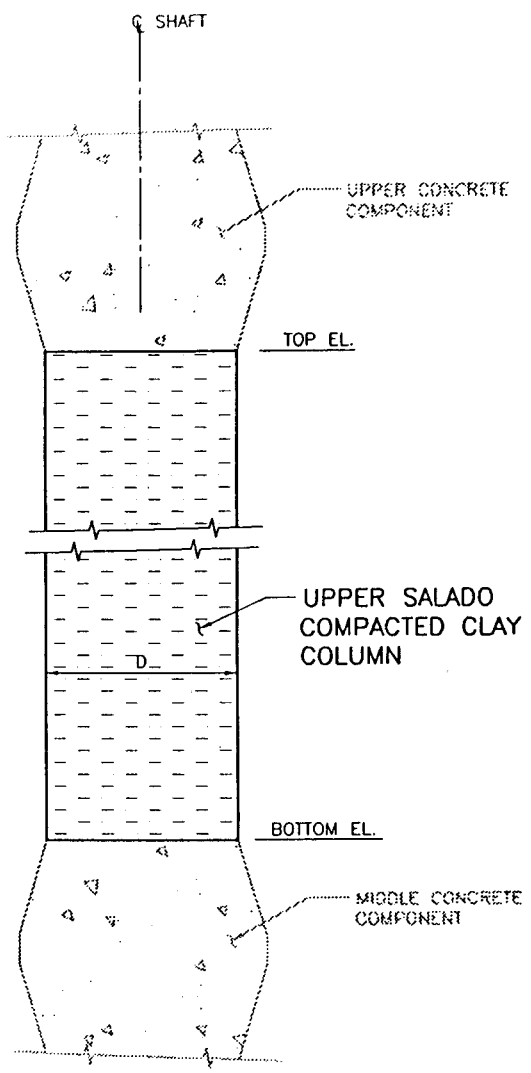

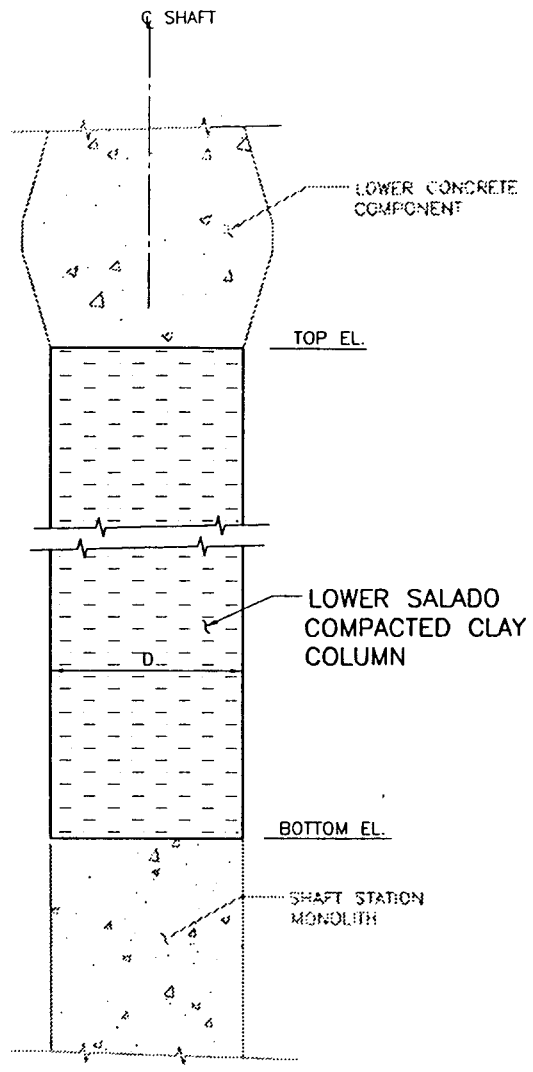

TABLE 1

SHAFT	NOMINAL SHAFT DIAMETER D (FT.)	UPPER SALADO COMPACTED CLAY COLUMN			LOWER SALADO COMPACTED CLAY COLUMN		
		TOP EL. (FT. MSL)	BOTTOM EL. (FT. MSL)	TOTAL HT. (FT.)	TOP EL. (FT. MSL)	BOTTOM EL. (FT. MSL)	TOTAL HT. (FT.)
WASTE	20.0	2389.0	2043.5	345.5	1382.0	1286.0	96.0
AIR INTAKE	20.25	2397.0	2053.0	344.0	1389.5	1296.0	93.5
EXHAUST	15.0	2382.0	2042.0	340.0	1383.0	1285.0	98.0
SALT HANDLING	11.83	2386.0	2051.0	335.0	1391.0	1284.0	107.0

DETAIL 1

SEE TABLE 1 FOR DETAILS
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35-L02
37-L02

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WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM

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UPPER AND LOWER SALADO COMPACTED CLAY COLUMNS

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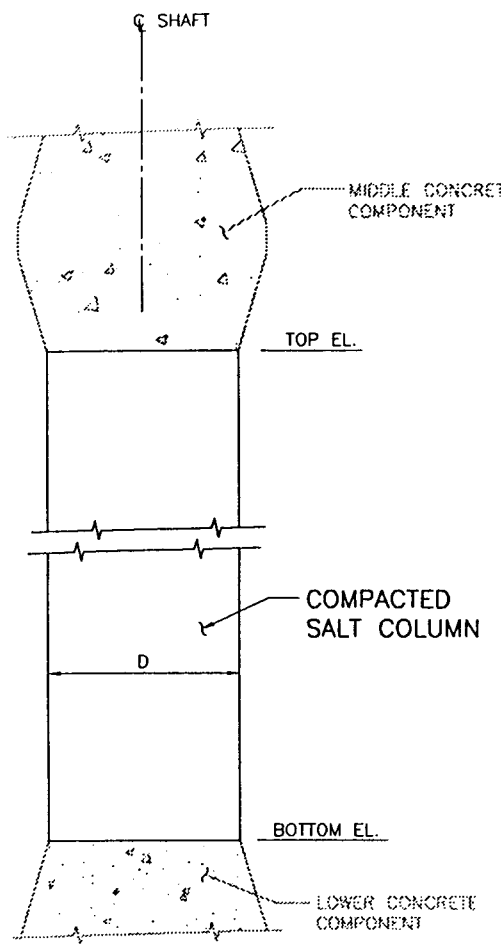

DETAIL 1

SEE TABLE 1 FOR DETAILS

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33-L02
35-L02
37-L02

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TABLE 1

SHAFT	NOMINAL SHAFT DIAMETER D (FT.)	COMPACTED SALT COLUMN		
		TOP EL. (FT. MSL)	BOTTOM EL. (FT. MSL)	TOTAL HT. (FT.)
WASTE	20.0	1993.5	1432.0	561.5
AIR INTAKE	20.25	2003.0	1439.5	563.5
EXHAUST	15.0	1992.0	1433.0	559.0
SALT HANDLING	11.83	2001.0	1441.0	560.0

PRELIMINARY

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AG-4909

WIPP SHAFT SEALING SYSTEM

COMPACTED SALT COLUMN

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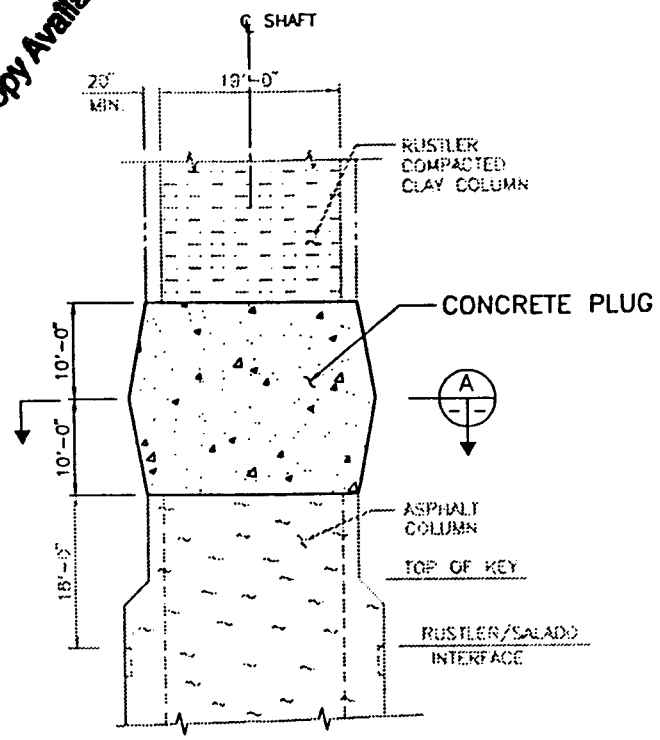

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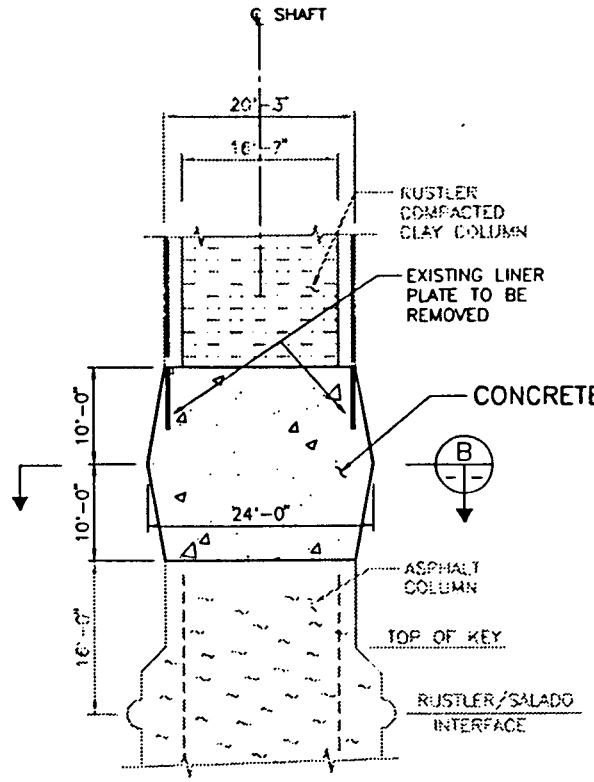

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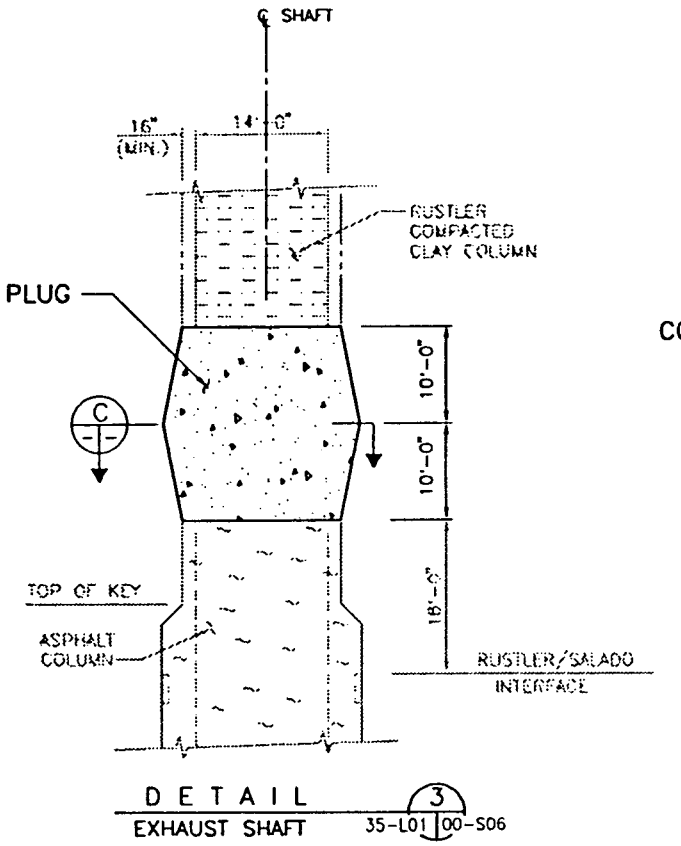

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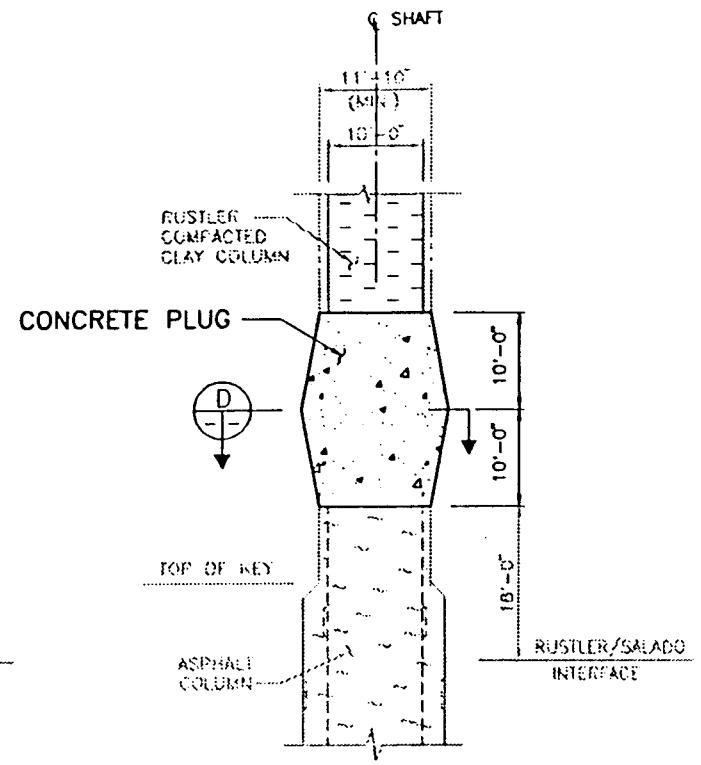

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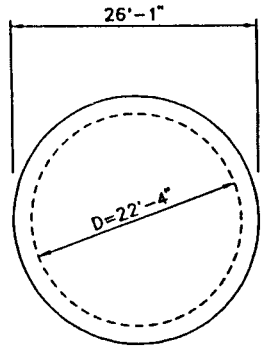

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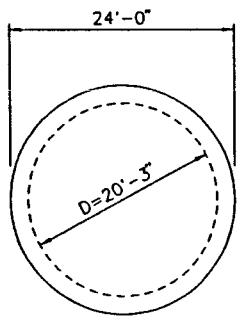

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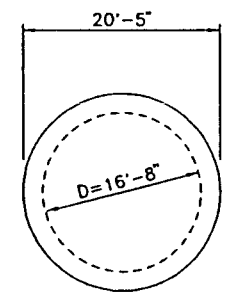

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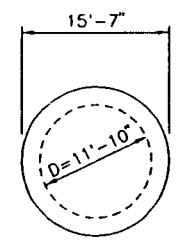

SECTION D

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT — CONTRACT NO AG-4909

WIPP SHAFT SEALING SYSTEM

CONCRETE PLUG

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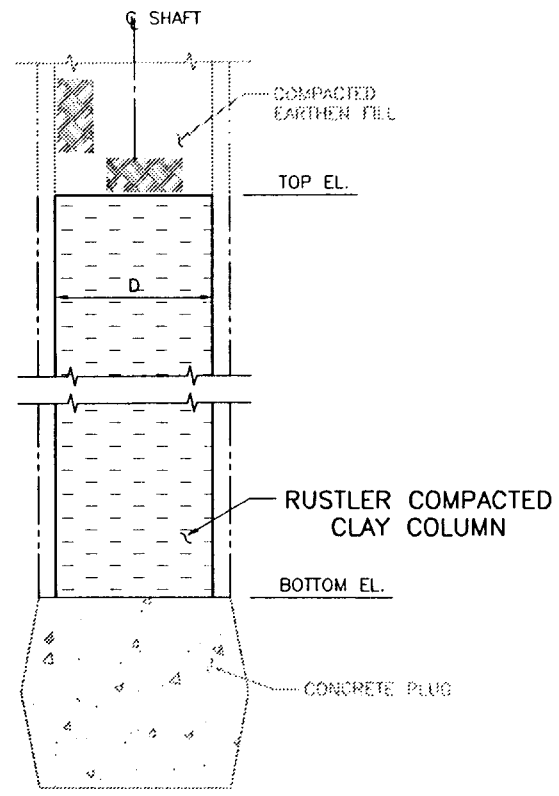

DETAIL 1
SEE TABLE 1 FOR DETAILS
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31-L01
33-L01
35-L01
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TABLE 1

SHAFT	NOMINAL SHAFT DIAMETER D (FT.)	RUSTLER COMPACTED CLAY COLUMN		
		TOP EL. (FT. MSL)	BOTTOM EL. (FT. MSL)	TOTAL HT. (FT.)
WASTE	19.0	2836.0	2601.3	234.7
AIR INTAKE	16.58	2840.0	2605.3	234.7
EXHAUST	14.0	2829.0	2594.5	234.5
SALT HANDLING	10.0	2830.0	2596.0	234.0

PRELIMINARY

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO. AC-4909

WIPP SHAFT SEALING SYSTEM

RUSTLER COMPACTED CLAY COLUMN

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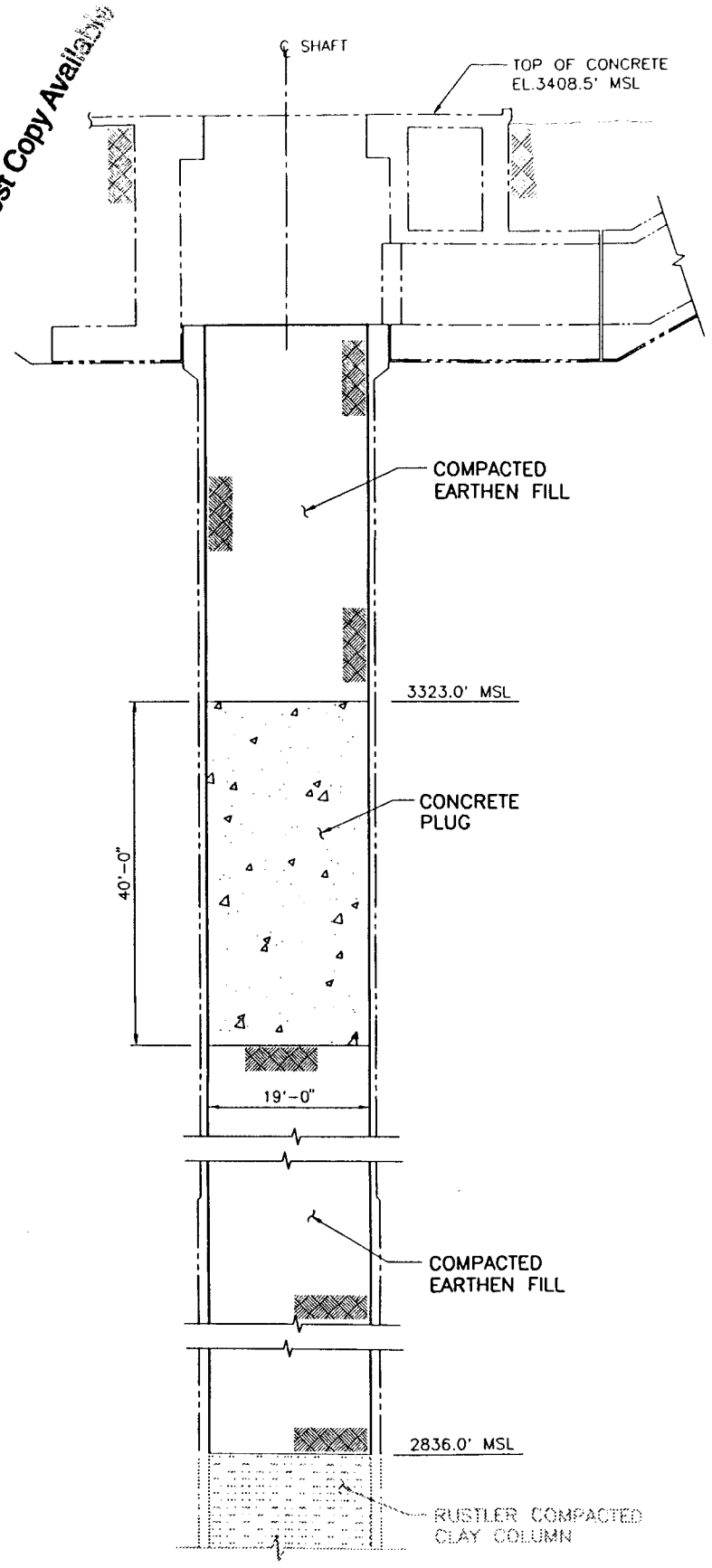

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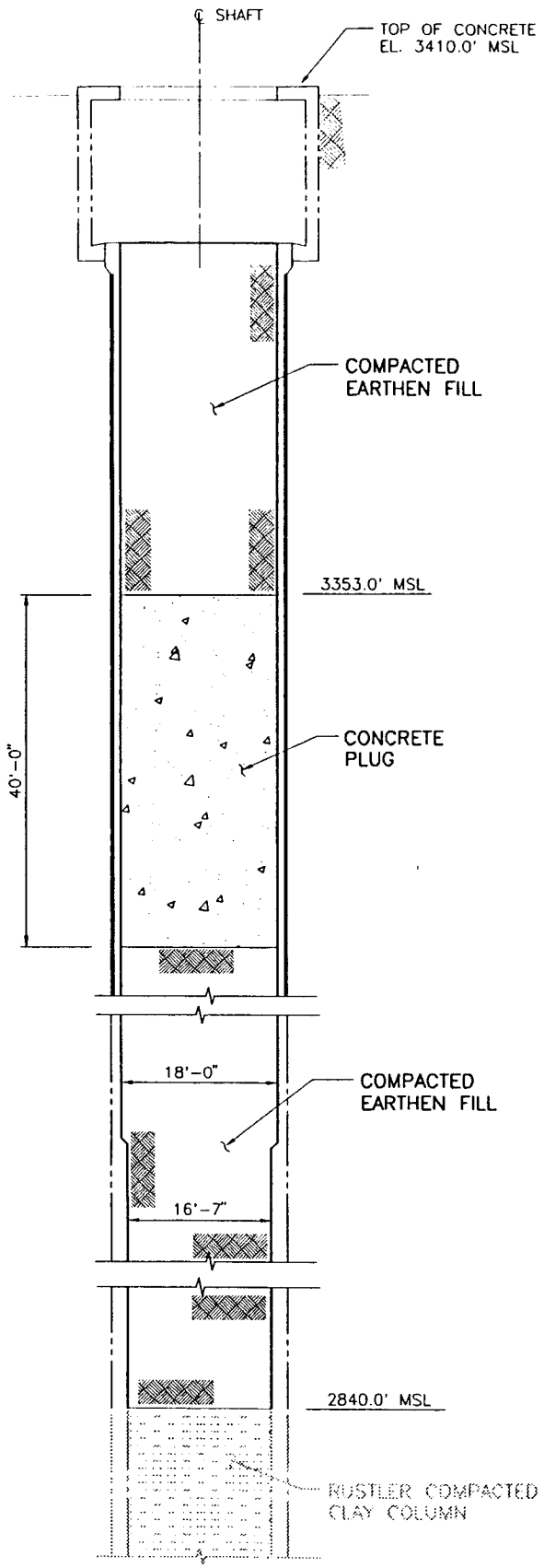

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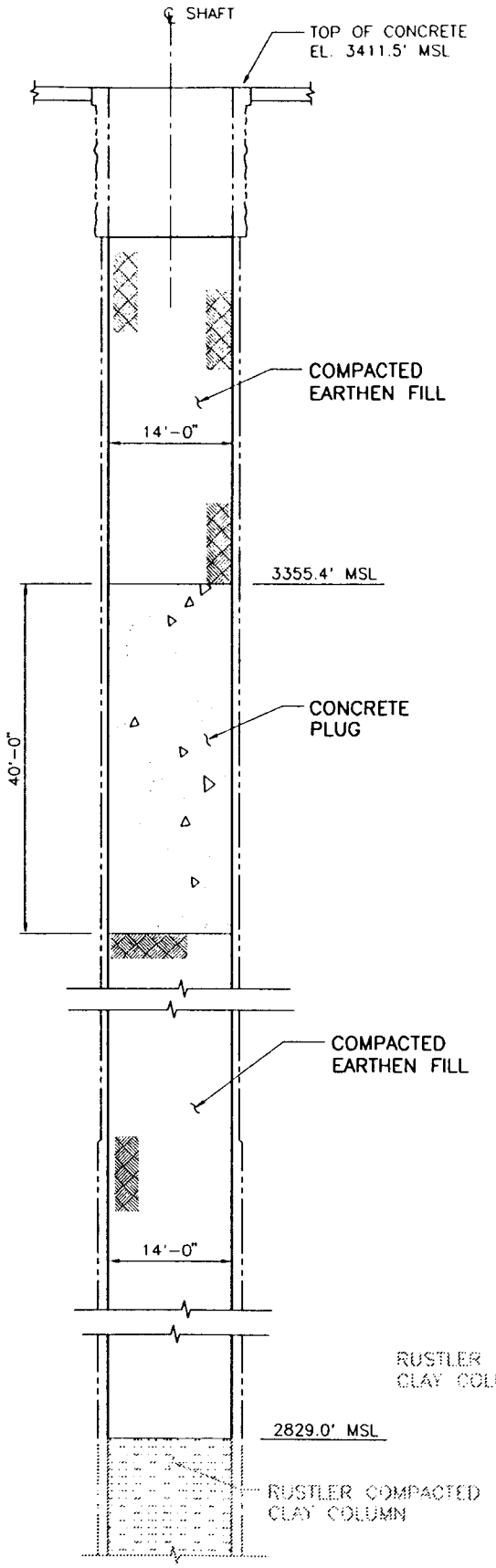

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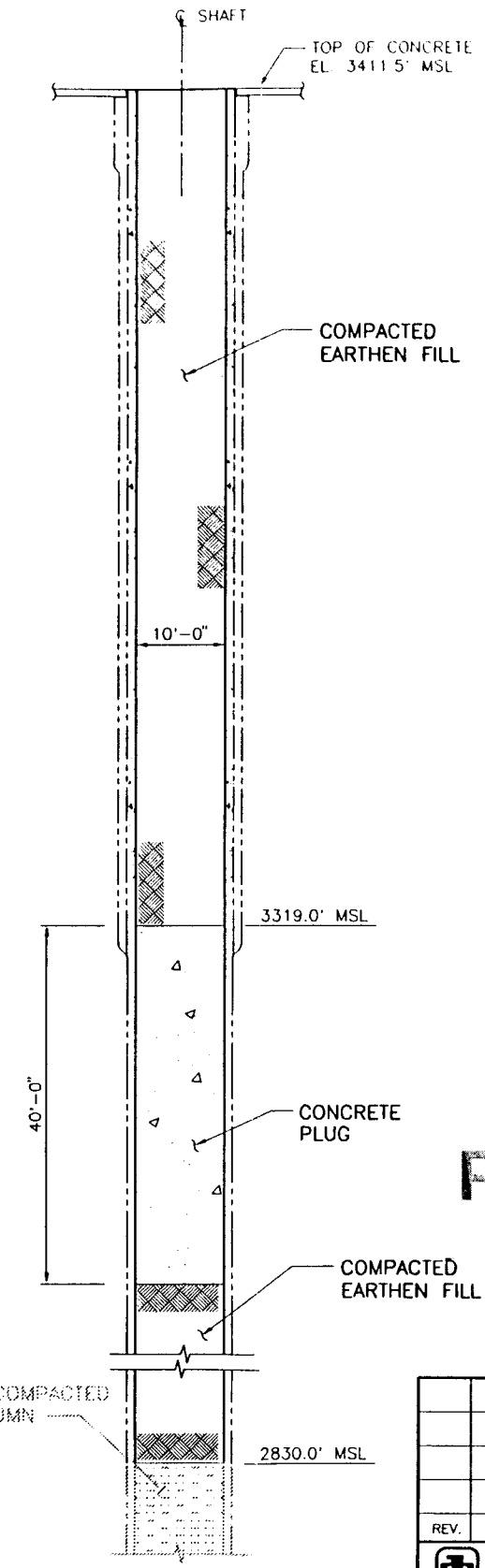

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SANDIA NATIONAL LABORATORIES

WIPP A/E SUPPORT

CONTRACT NO: AC-4909

WIPP SHAFT SEALING SYSTEM

COMPACTED EARTHEN FILL AND CONCRETE PLUG

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APPENDIX I3
CO-DETECTION OF HAZARDOUS AND RADIOACTIVE WASTE RELEASES

APPENDIX I3
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APPENDIX I3
CO-DETECTION OF HAZARDOUS AND RADIOACTIVE WASTE RELEASES

I3-1 Purpose

Within the Resource Conservation and Recovery Act (RCRA) Permit Application for the Waste Isolation Pilot Plant (WIPP), the concept of radiological monitoring is used to determine whether a release of hazardous constituents has occurred. This method is used in addition to the visual examinations and container inspections mandated by the RCRA. The purpose of this paper is to provide a justification for this approach.

I3-2 Definition

Co-detection is used to describe the detection of hazardous waste releases from containers by virtue of detection of a radioactive constituent release. Co-detection assumes the co-release of hazardous and radioactive materials and applies to all releases except the release of volatile organic compounds (VOC) from transuranic (TRU) mixed waste containers. Co-detection is used to identify the presence or absence of hazardous waste constituents based on the presence or absence of radioactivity. Co-detection does not provide any assessment with regard to concentration.

I3-3 Discussion

Co-detection provides the WIPP facility with a very sensitive method of detecting the release of non-VOC hazardous waste constituents through the use of surface sampling (swipes) and radioactivity counting. The feasibility of this approach depends on the nature of the hazardous waste portion of the TRU mixed waste, the nature of the TRU mixed waste, and the nature of the spills. The sections below discuss each of these factors.

I3-3a Nature of the Hazardous Waste Portion of TRU Mixed Waste

Based on the waste codes listed in the Part A and discussed in the WIPP Waste Analysis Plan (Chapter C of the permit application), the hazardous waste constituents consist mainly of EPA F-coded solvents and metals that exhibit the toxicity characteristic. The wastes that are to be shipped to the WIPP facility during the Disposal Phase have been placed into waste categories based on their physical and chemical properties. Waste category information is summarized in Table I2-1 with emphasis on the process that generated the waste. The waste generating processes can be described in five general categories:

1. Wastes (such as combustible waste) that result from cleaning and decontamination activities in which items such as towels and rags become contaminated simultaneously with hazardous constituents and radioactivity. In these cases, the

hazardous constituent and the radioactive constituent are intimately mixed, both on the rag or towel used for cleaning and as residuals on the surface of the object being cleaned. These waste forms are not homogeneous in nature; however, they are generated in a fashion that ensures that the hazardous and radioactive contaminants coexist throughout the waste matrix.

2. Wastes generated when materials that contain metals that are believed to exhibit the toxicity characteristic become contaminated with radioactivity as the result of plutonium operations (leaded rubber, some glass, and metal waste are typical examples). These materials may also become contaminated with solvents during decontamination or plutonium recovery activities.

3. A class of processes where objects that are not metals are used in plutonium processes and become contaminated with radioactivity. They are subsequently cleaned with solvents to recover plutonium. Surfaces of these objects (such as graphite, filters, and glass) are contaminated with both radioactive constituents and hazardous constituents.

4. Waste generating processes involving foundry operations where impurities are removed from plutonium. These impurities may result in the deposition of toxicity characteristic metals on the surfaces of objects, such as firebrick, ceramic crucibles, pyrochemical salts, and graphite, which are contaminated with residual quantities of radioactivity.

5. In all of the process waste categories in the lower half of the attached table, the hazardous constituent and the radioactivity are physically mixed together as a result of the treatment process. In these wastes, the release of any portion of the waste matrix will involve both the hazardous waste and the radioactive waste components, because the treatment process generates a relatively homogeneous waste form.

Some waste forms only contain radioactive contamination on the surface, because they are not the result of a treatment process or are not porous in form. These include glass, leaded rubber, metals, graphite, ceramics, firebricks, and plastics. In theory, a hazardous waste release could occur if the interiors of these materials became exposed and were involved in a release or spill. Such an occurrence is not likely during operations, because no activities are planned or anticipated that would result in the breaking of these materials to expose fresh surfaces.

Based on the information in the attached table and the discussion above, hazardous constituent releases could potentially occur in only one of two forms: 1) VOC and 2) particulate resulting from the catastrophic failure of a container. Mechanisms that can initiate releases in these forms are discussed subsequently. Regardless of how the release occurs, the nature of the waste and

the processes that generated it is such that the radioactive and hazardous components are intimately mixed. A release of one without the other is not feasible.

I3-3b Nature of the TRU Mixed Waste

TRU mixed waste is defined as waste in which radioactive waste constituents and hazardous waste constituents exist as co-contaminants. The processes that placed the radioactivity in the waste are, for the most part, the same processes that placed the hazardous constituent in the waste. Therefore, the TRU mixed waste forms are described in terms of both classes of constituents. The WIPP Waste Acceptance Criteria (WAC) document places limits on the waste that can be shipped to the WIPP facility based on the characteristics of the waste form. According to the WAC, certain waste forms with specific characteristics are not allowed at the WIPP facility. Liquid waste is one waste form that is not allowed. Waste forms with greater that 1 percent respirable fines (particulates less than 10 microns in diameter) are not allowed. Other limitations include a prohibition on pyrophoric materials, corrosive materials, ignitable waste, and compressed gases. Furthermore, TRU waste must contain 100 nanocuries or more of transuranic elements per gram of waste, which means that the radioactive component of the waste will always be present within the waste in significant concentrations. The limitations and restrictions are provided to ensure any waste form handled at the WIPP facility is stable and can be managed safely.

One benefit of waste form restrictions, such as no liquids or limited particulates, is that they limit the kinds of releases that could occur to those that would be readily detectable through visual inspection (i.e., large objects that fall out of ruptured containers) or through the use of radiation monitoring either locally or within the adjacent area to detect materials that have escaped from containers.

I3-3c Nature of the Releases

The fundamental operating philosophy at the WIPP facility is to handle only sealed containers of waste. This practice minimizes the opportunity for releases or spills. For the purposes of safety analysis, it was assumed that releases and spills during operations occur by either of two mechanisms: 1) surface contamination and 2) accidents.

Surface contamination is documented in the WIPP Final Safety Analysis Report (FSAR) to be the only credible source of contamination external to the containers during normal operations. Surface contamination is assumed to be caused by waste management activities at the generator site that result in the contamination of the outside of a waste container. *(Note: There are WAC limits on surface contamination; however, conservative assumptions were made regarding the occurrence of minor contamination.)* Contamination would most likely be particulates (dirt or dust) that would be deposited during generator-site handling/loading activities. This contamination would not be detected by visible inspections. Surface contamination is monitored upon arrival at the WIPP facility through the use of swipes and radiation monitoring equipment. U.S. Department of Energy (DOE) Orders require that off-site

shipments of radioactive waste be checked to assure that the radioactive surface contamination is below very low levels. Consequently, any surface contamination that may be detected at the WIPP facility will be very minor. Because the hazardous constituents, if present, also occur in minor concentrations as residues and traces within the waste, they represent very small health risks.

It should be noted that, with respect to surface contamination, detection using radioactivity is very sensitive and allows for the detection of contamination that may not be visible on the surface of the container. This exceeds the capability required by the RCRA, which is generally limited to inspections that detect only visible evidence of spills or leaks.

Releases due to accidents are modeled in the WIPP FSAR. Significant accidents within the waste handling process are assumed to result in the release and dispersion of particulate radioactive contaminants and VOCs. Radioactive releases of particulates are detectable using surface-sampling (swipe) techniques and the extensive network of radiation sensors located throughout the facility. An accidental release would be detected immediately by the operator or the health physics technician. The impact of VOC releases is discussed in Chapter D.

In summary, releases that are most likely at the WIPP facility involve the dispersion of particulates containing radioactivity. This radioactivity is readily detectable. On the other hand, the presence of hazardous constituents in these releases would likely go undetected due to their extremely low concentrations without conservative co-detection practices.

I3-4 Application of Co-detection

The use of co-detection applies to any situation calling for sampling or monitoring for nonvolatile releases. This includes initial sampling for surface radiological contamination upon receipt, sampling for contamination during waste handling activities, monitoring for releases of particulates or liquids during testing, sampling for contamination during decommissioning, sampling for contamination during packaging for off-site shipment, and sampling to demonstrate the effectiveness of decontamination activities that follow a release or spill and retrieval. Radiation monitoring and sampling are mandated by DOE Orders and provide an immediate indication of a release or spill, even when they are not visibly detectable. The basis for accepting co-detection is that the radioactivity is intimately mixed with the hazardous constituents to the extent that both are present in the waste. It can be assumed that a release or spill involving hazardous constituents (except VOCs) will also involve a release or spill of radioactivity. This assurance that hazardous and radioactive contaminants are mixed is based on the processes that generated the waste and the physical form of the waste. These processes mixed the hazardous and radioactive components, as described in Section 3.1, to the extent that detection of the radioactive component can lead to the conclusion that the hazardous component is also present. Conversely, the absence of the radioactive component indicates that no release or spill has occurred. The assumption that hazardous and radioactive materials are released

together is appropriate in that no reasonable release mechanisms that can be postulated which would separate the different types of contamination.

I3-5 Summary

The use of co-detection at the WIPP facility as a means of detecting both radioactive and hazardous waste constituents can be summarized as follows:

1. Two waste components are intimately mixed such that a release of one will be accompanied by a release of the other (except for gaseous releases of regulated VOCs).

2. Without the ability for co-detection using radiological sampling and monitoring, the hazardous constituents would likely go undetected because of their extremely low concentrations, unless visible evidence of a spill or release is present.

3. Radiation detection is sensitive enough to detect hazardous contamination, even in cases where the contamination is not visible.

4. Radiation sampling and monitoring provides easy and immediate detection of contamination.

5. The use of radiation for detection and the assumption that the hazardous constituents are also present lead to a conservative RCRA classification of spills and releases.

6. The use of radiation detection can be used to detect releases and contamination during all phases of operations, including retrieval and decontamination.

7. Even with the use of radiation detection to identify spills and releases, required RCRA inspections activities will be performed to assure that containers are not deteriorating.

TABLE I3-1
SUMMARY OF WASTE GENERATION PROCESSES AND WASTE FORMS

Waste Category	Hazardous Waste Codes	Description of Processes	Description of Waste Form
Combustibles	F001, F002, F003, D008, D019	Cloth and paper wipes are used to clean parts and wash down gloveboxes. Wood and plastic parts are removed from gloveboxes after they are cleaned. Lead may occur as shielding tape or as minor noncombustible waste in this category.	Materials such as metals may retain traces of organics left on surfaces that were cleaned. Waste may remain on the cloth and paper that was used for cleaning or for wiping up spills.
Graphite		Graphite molds, which may contain impurities of metals, are scraped and cleaned with solvents to remove the recoverable plutonium.	Surfaces may retain residual solvents. Lead may be used as shielding or may be an impurity in the graphite.
Filters	F001, F002	Filters are used to capture radioactive particulate in air streams associated with numerous plutonium operations and to filter particulate from aqueous streams.	Filter media may retain organic solvents that were present in the air or liquid streams.
Benelex® and Plexiglas®	F001, F002, D008	Materials are used in gloveboxes as neutron absorbers. The glovebox assembly often includes leaded glass. All surfaces may be wiped down with solvents to remove residual plutonium.	Surfaces may retain residual solvents from wiping operations. Leaded glass may also be present.
Firebrick and Ceramic Crucibles	F001, F002, F005, D006, D007, D008	Firebrick is used to line plutonium processing furnaces. Ceramic crucibles are used in plutonium analytical laboratories. Both may contain metals as surface contaminants.	Metals deposited during plutonium refining or analytical operations could remain as residuals on surfaces. Surfaces may retain residual solvents.
Leaded Rubber	D008	Leaded rubber includes lead oxide impregnated materials such as gloves and aprons.	The leaded rubber could potentially exhibit the toxicity characteristic.
Metal	F001, F002, D008	Metals range from large pieces removed from equipment and structures to nuts, bolts, wire, and small parts. Many times, metal parts will be cleaned with solvents to remove residual plutonium.	Solvents may exist on the surfaces of metal parts. The metals themselves potentially exhibit the toxicity characteristic.
Glass	F001, F002, D006, D007, D008, D009	Glass includes Raschig rings removed from processing tanks, leaded glass removed from gloveboxes, and miscellaneous laboratory glassware.	Solvents may exist as residuals on glass surfaces and in empty containers. The leader glass may exhibit the toxicity characteristic.
Inorganic Wastewater Treatment Sludge	F001-F003, D006-D009, P015	Sludge is vacuum filtered and stabilized with cement or other appropriate sorbent prior to packaging.	Traces of solvents and heavy metals may be contained in the treated sludge which is in the form of a solid dry monolith, highly viscous gel-like material, or dry crumbly solid.

TABLE I3-1 (CONTINUED)
SUMMARY OF WASTE GENERATION PROCESSES AND WASTE FORMS

Waste Category	Hazardous Waste Codes	Description of Processes	Description of Waste Form
Organic Liquid and Sludge	F001, F003	Organic liquids such as oils, solvents, and lathe coolants are immobilized through the use of various solidification agents or sorbent materials.	Solvents and metals may be present within the matrix of the solids created through the immobilization process.
Solidified Liquid	F001, F003, D006, D008	Liquids that are not compatible with the primary treatment processes and have to be batched. Typically these liquids are solidified with portland or magnesium cement.	Solvents and metals may be present within the matrix of the solids created through the immobilization process.
Inorganic Process Solids and Soil	F001, F002, F003, D008	Solids that cannot be reprocessed or process residues from tanks, firebrick fines, ash, grit, salts, metal oxides, and filter sludge. Typically solidified with portland or gypsum-based cements.	Solvents and metals may be present within the matrix of the solids created through the immobilization process.
Pyrochemical Salts	D007	Molten salt is used to purify plutonium and americium. After the radioactive metals are removed, the salt is discarded.	Residual metals may exist in the salt depending on impurities in the feedstock.
Cation and Anion Exchange Resins	D008	Plutonium is sorbed on resins and is eluted and precipitated.	Feed solutions may contain traces of solvents or metals depending on the preceding process.

APPENDIX CMP

CONFIRMATORY MONITORING PLAN

APPENDIX D20

AIR PATHWAY CONFIRMATORY MONITORING PLAN

(From the WIPP RCRA Part B Permit Application, Rev. 6)

Air Pathway Confirmatory Monitoring Plan for Volatile Organic Compounds During Waste Disposal at the Waste Isolation Pilot Plant

Westinghouse Electric Corporation
Waste Isolation Division
Waste Isolation Pilot Plant
Carlsbad, New Mexico

April 3, 1996

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1.0 INTRODUCTION

This document describes the confirmatory monitoring plan for volatile organic compounds (VOC) which may be entrained in the exhaust air from the Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico, during the disposal phase at the facility. This Monitoring Plan is designed to confirm the demonstration contained in the No-Migration Variance Petition (NMVP) that there will be no migration of VOCs from WIPP exceeding concentrations that pose unacceptable risks to human health and the environment. This Monitoring Plan includes the monitoring design, a description of sampling and analysis procedures, and quality assurance (QA) objectives and reporting activities.

1.1 BACKGROUND

The WIPP project was authorized by the U.S. Congress to provide a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from national defense activities and programs. The WIPP facility is constructed in a massive underground salt bed formation, with its design characterized as a "room and pillar" arrangement, allowing containerized solids or solidified waste to be placed in the excavations. Waste, equipment, and personnel enter the underground facility through designated shafts.

The hazardous waste management units, defined as waste panels, are located 2150 feet (ft)(655 meters(m)) below ground surface, in the WIPP underground. The waste panels consist of seven rooms and two access drifts each. Each room is approximately 300 ft (91 m) long, 33 ft (10 m) wide, and 13 f (4 m) high. Access drifts connect the

rooms and have the same cross section. The U.S. Department of Energy (DOE) intends to operate the facility in a manner that minimizes the number of panels that are open at any one time.

The panels provide room for 6.2 million cubic feet (ft^3) (175,600 cubic meters (m^3)) of transuranic (TRU) waste, of which 250,000 ft^3 (7080 m^3) may be remote handled (RH) TRU waste. The remainder will be contact handled (CH) TRU waste. The CH TRU waste package assemblies will be stacked up to three containers high across the width of the room in an interlocking triangular pitch. The RH TRU waste canisters will be inserted into predrilled horizontal holes bored into the room wall of the disposal area. The facility performance objectives are derived from 40 Code of Federal Regulations (CFR) Part 268 and are directed at permanently isolating the waste from the biosphere.

The NMVP (DOE, 1996) demonstrates theoretical compliance with the requirements of 40 CFR Part 268.6, which allows the disposal of wastes prohibited from land disposal only if it can be demonstrated that, to a reasonable degree of certainty, there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous. This Confirmatory Monitoring Plan describes a sampling and analysis program to confirm the theoretical no-migration calculations contained in the NMVP. The monitoring program will be capable of quantifying VOC concentrations in ambient mine air at WIPP. As demonstrated in the NMVP, other media are not considered viable contaminant transport pathways during the WIPP operational time frame and are therefore not addressed in this program. By the nature of WIPP operations, there is no credible mechanism for direct release of hazardous constituents to water or soil during the operational time frame.

For the disposal phase, the mine ventilation system is the only possible migration pathway.

Accordingly, this Confirmatory Monitoring Plan is designed to confirm that there will be no migration of VOCs from disposed wastes in the WIPP repository via the air pathway during the Disposal Phase. This plan addresses the following information requirements:

1. Rationale for the design of the monitoring program, based on:

   - Possible migration pathways from WIPP during the active life of the facility
   - Operations at WIPP
   - Strength of engineered and natural material components at WIPP
   - Optimum location of the hazardous constituent monitoring stations to confirm the migration calculations contained in the NMVP

2. Descriptions of the specific elements of the monitoring program, including:

   - The type of monitoring conducted
   - The location of the monitoring stations
   - The monitoring interval

- The specific hazardous constituents monitored
- The implementation schedule for the monitoring program
- The equipment used at the monitoring stations
- Sampling and analytical techniques used
- Data recording/reporting procedures

The results of baseline VOC monitoring at WIPP were used, in part, to refine the monitoring program that will be established for the Disposal Phase, during which full-scale waste emplacement activities will occur. The baseline VOC monitoring results are presented in Appendix BAD of the NMVP, and the environmental monitoring currently anticipated during both the operational and post-closure phases are presented in Chapter 6 of the NMVP.

1.2 WASTE DISPOSAL

The DOE will operate and maintain WIPP so that it is free of both chemical and radiological contamination. Therefore, as allowed by New Mexico Administrative Code 4.1, Subpart V §264.13, and consistent with joint U.S. Environmental Protection Agency (EPA) and U.S. Nuclear Regulatory Commission guidance, all waste sampling and analyses are conducted by DOE generator sites in accordance with established procedures. The generator conducts the required waste characterization activities for each container of waste to be sent to WIPP under a QA program. The reports resulting from waste characterization activities are then reviewed for completeness and acceptability at WIPP prior to transport of the wastes.

Waste will be disposed of in the seven rooms of a panel. Each panel will be closed when it is full using a panel closure system installed in each of the two panel access drifts as described in Appendix CLP of the NMVP. The closure system conceptual design consists of concrete block bulkheads and a poured concrete bulkhead. The concrete block bulkheads provide a ventilation barrier while the concrete bulkhead is being installed. The concrete component provides strength and stability for maintenance-free service during the operational period. The DOE's analysis of the bulkhead shows that the structure has sufficient rigidity and compressive strength to remain stable for creep and short-term dynamic loadings. Once a panel has been filled and closed, it will be managed per the requirements of the WIPP RCRA Part B Permit and a No-Migration Determination.

1.3 OBJECTIVES OF THE VOLATILE ORGANIC COMPOUND CONFIRMATORY MONITORING PLAN

As described in the NMVP, minute quantities of VOCs could be released from open and closed panels located at WIPP during the disposal phase of the project. Chapter 5 of the NMVP contains a demonstration that any VOCs released from panels would be below any concentrations of concern (COC). This plan describes how VOCs released from waste panels will be monitored to confirm the VOC concentration estimates contained in the NMVP. This plan is responsive to requirements of 40 CFR Part 268.6 and addresses confirmatory monitoring of waste management activities during the WIPP disposal phase.

2.0 TARGET VOLATILE ORGANIC COMPOUNDS

The wastes proposed for disposal at WIPP are described in Chapter 4 of the NMVP. Approximately 60 percent of the waste proposed to be emplaced at WIPP during the entire lifetime of the facility is classified as TRU mixed waste, which consists of waste that contains both radioactive and Resource Conservation and Recovery Act (RCRA)-regulated hazardous chemical components.

Generator knowledge of the wastes and the processes by which they are generated, as well as available analytical data, indicate that the VOCs most commonly present in the wastes and responsible for approximately 99 percent of the calculated RCRA-constituent posed human health risk (Appendix WAP of the NMVP) are as follows:

- 1,1-Dichloroethylene
- Carbon tetrachloride
- Methylene chloride
- Chloroform
- 1,1,2,2-Tetrachloroethane
- 1,1,1-Trichloroethane
- Chlorobenzene
- 1,2-Dichloroethane

- Toluene

Physical and chemical data for these target VOCs are presented in Table 2.1.

2.1 SOURCES OF VOLATILE ORGANIC COMPOUND EMISSIONS

Figure 2.1 depicts the initial WIPP underground facility configuration. Potential waste-related sources of VOCs include: 1) open panels containing vented waste drums, and 2) closed panels of disposed waste. Any VOC emissions from emplaced waste will pass by a monitoring system as it is directed to the exhaust shaft. Other activities not related to normal waste management activities may also lead to VOC emissions.

Nonwaste-related sources of VOCs at WIPP include background sources and emissions from operational activities in ambient mine air. Background sources of VOCs include any sources that emit VOCs to the ambient air that are drawn into the air intake shaft of the underground WIPP facility. Examples of background sources are oil and gas exploration and petroleum production activities in the WIPP vicinity, potash production, and motor vehicle emissions in the WIPP parking lot and on nearby roads. Sources of VOC emissions also exist below ground surface that are related to WIPP mine operational activities. Fuel combustion, painting activities, cleaning solvents, equipment exhaust, and air conditioners are potential sources of VOCs.

Chapter 5 of the NMVP establishes COCs for the VOCs from waste in open and closed panels. Therefore, the VOC Confirmatory Monitoring

Plan is designed to differentiate VOC concentrations attributed to open and closed panels from other potential sources. Accordingly, VOC monitoring performed to confirm the calculations in the NMVP will begin when waste emplacement commences in the first panel. Potential VOC sources other than open and closed panels will not be directly monitored at WIPP.

2.2 MIGRATION PATHWAY

The only pathway for migration of VOCs to the unit boundary during the operational phase is via airborne transport. Any VOCs released in the underground facility would become entrained in the underground ventilation air and released to the atmosphere through the exhaust shaft (Figure 2.1).

Chapter 5 of the NMVP identifies COCs in the Drift E-300 air pathway for the target VOCs. COCs at the panels have been extrapolated from the levels of concern at the unit boundary using a mathematical dispersion model and facility ventilation design data.

Table 2.1: Target Analytes for VOC Monitoring During the WIPP Disposal Phase

Target Analyte	Common Synonyms and Acronyms	Chemical Formula	Molecular Weight (g/mol)	Boiling Point (°C)*
1,1-Dichloroethylene	1,1-Dichloroethene, Vinylidene chloride, 1,1-DCE	$C_2H_2Cl_2$	96.95	31
Carbon tetrachloride	Tetrachloromethane	CCl_4	153.8	77
Methylene chloride	Dichloromethane	CH_2Cl_2	84.94	40
Chloroform	Trichloromethane	$CHCl_3$	119.4	61
1,1,2,2-Tetrachloroethane	sym-Tetrachloroethane, Tetrachloroethane	$C_2H_2Cl_4$	167.9	147
1,1,1-Trichloroethane	1,1,1-TCA, TCA, Methyl chloroform	$C_2H_3CCl_3$	133.42	74
Chlorobenzene	Monochlorobenzene, Benzene chloride	C_6H_5Cl	112.6	132
1,2-Dichloroethane	1,2-DCA, DCA, Ethylene dichloride, EDC, sym-Dichloroethane	$C_2H_4Cl_2$	98.96	83
Toluene	Methyl benzene	C_7H_8	92.13	111

°C Degrees Celsius
VOC Volatile organic compound
WIPP Waste Isolation Pilot Plant

* Handbook of Chemistry and Physics, 62nd Edition, CRC Press, 1982.

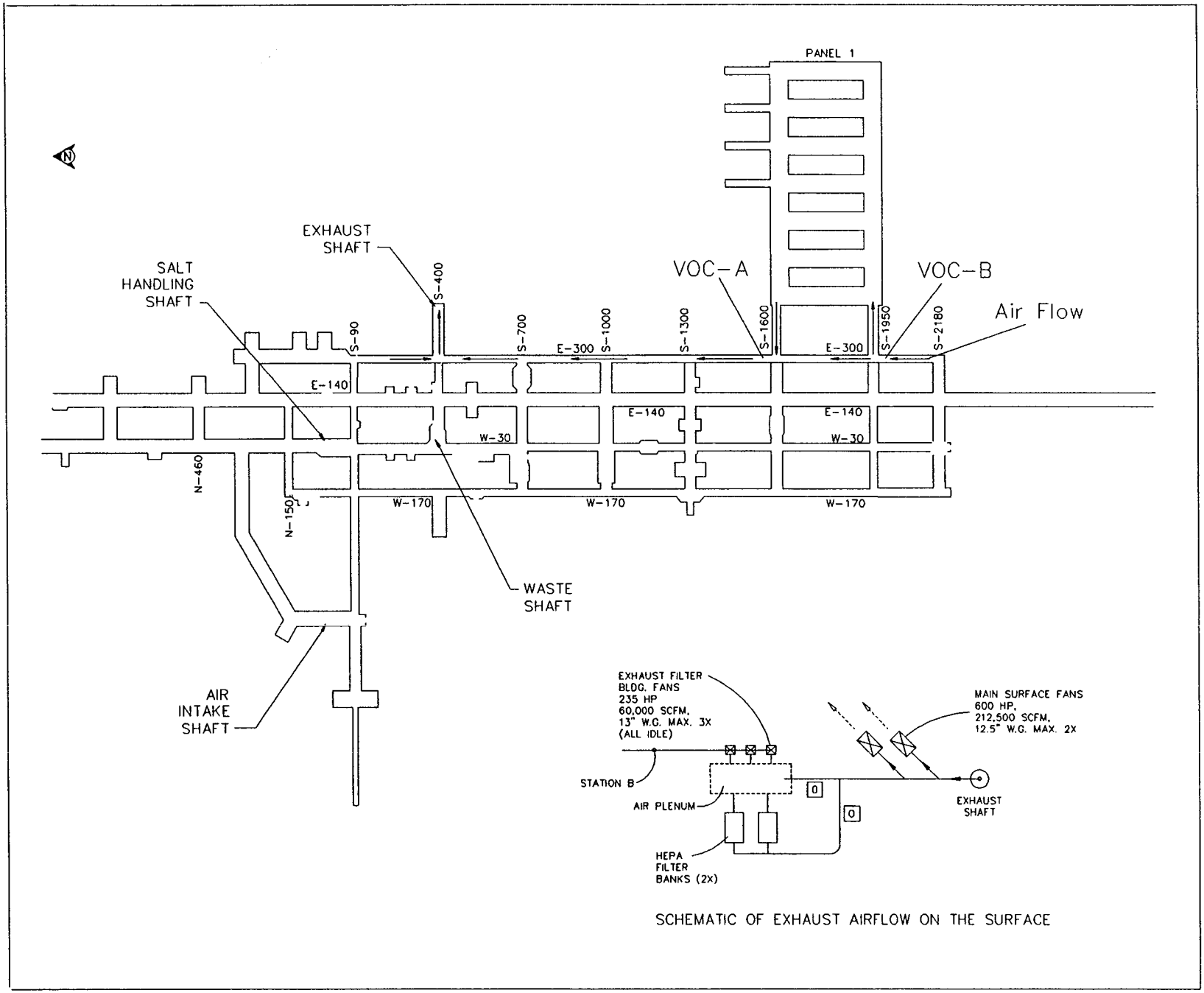


Figure 2.1 – Panel Area Air Flow

3.0 MONITORING DESIGN

Detailed design features of the VOC Confirmatory Monitoring Plan are presented in this section. The purpose of this program is to confirm that there is no migration of specific target VOCs exceeding any COC. This monitoring plan uses available sampling and analysis techniques to measure VOC concentrations. Available sampling equipment includes the standard WIPP VOC canister samplers with minor modifications.

3.1 SAMPLING LOCATIONS

Air samples will be collected at two locations in the facility to quantify airborne VOC concentrations. VOCs emanating from Panel 1 will be measured by placing one VOC monitoring station just downstream from Panel 1 at VOC-A and another station upstream from Panel 1 at VOC-B (Figure 2.1). In this configuration VOC-B will measure VOC releases from the upstream sources (i.e., Panel 2) and other background sources of VOCs, and VOC-A will measure upstream VOC releases plus any additional releases from Panel 1. A sample will be collected from each station on designated sample days. For each quantified target VOC, the concentration measured at VOC-B will be subtracted from the concentration measured at VOC-A to assess any release from Panel 1. Measurements from the first panel will confirm estimates of releases from all panels since the releases will be cyclic from panel-to-panel.

The sampling locations were selected based on operational considerations and the calculations presented in Chapter 5 of the NMVP. As discussed in Section 2.0, there are several different potential

sources of release for VOCs. These sources include incoming air from above ground, facility support operations, open waste panels, and closed waste panels. In addition, because of the ventilation requirements of the underground facility and atmospheric dispersion characteristics, any VOCs that are released from Panel 1 may be difficult to detect and differentiate from other sources of VOCs at any underground or above ground location further downstream of Panel 1. By measuring VOC concentrations close to the potential source of release (i.e., Panel 1), it will be possible to differentiate potential releases from background levels and confirm the theoretical calculations included in the NMVP.

3.1.1 E-300 Panel 1 Air Outlet (Station VOC-A)

Panel 1 will be the first open panel, and it will become the first closed waste panel once it is filled and the panel closure systems are installed and certified. Waste disposal activities will continue in Panel 2 during closure of Panel 1. Because Panel 1 is a potential source of VOC releases to the ventilation air traveling to the exhaust shaft, sampling station VOC-A has been established in the Drift E-300 downstream of the Panel 1 air outlet (Drift S-1600). The purpose of this station is to evaluate whether the concentrations of VOCs measured at this point are sufficiently higher than upstream concentrations to indicate potential migration from Panel 1. Therefore, concentrations of VOCs measured upstream of Panel 1 will be subtracted from those measured at station VOC-A and the resulting differences will be compared to the calculated COCs for Drift E-300.

The COCs for releases from waste panels have been calculated for each of the target VOCs in the Drift E-300 under normal operational conditions (see Chapter 5 of the NMVP). The calculated COC

difference between VOC-A and VOC-B, is presented in Table 3.1 for each of the nine target compounds, in terms of micrograms per cubic meter ($\mu g/m^3$) and parts per billion by volume (ppbv). As presented in Appendix BAD of the NMVP, baseline VOC monitoring has been performed at WIPP for three of the target VOCs (i.e., carbon tetrachloride, methylene chloride, and 1,1,1-trichloroethane). The average measured concentrations of these compounds entrained in the facility exhaust air are less than 2 percent of the COC presented in Table 3.1. These data demonstrate that it will be possible to differentiate between the VOC concentrations measured at VOC-A and VOC-B for comparison to the COCs presented in Table 3.1.

3.1.2 E-300 Panel 2 Air Outlet (Station VOC-B)

To quantify VOC concentrations upstream of Panel 1, another sampling station will be established in Drift E-300 downstream of the Panel 2 air outlet. Results from this monitoring station will allow target VOC concentrations in the ventilation air upstream of Panel 1 to be distinguished from any target VOCs that may be released from Panel 1. VOC concentrations measured at this location will consist of background concentrations entering the facility through the Air Intake Shaft, concentrations attributed to upstream facility operations, and concentrations from waste disposal activities in open Panel 2 after Panel 1 is closed. For each sampling event, target compound concentrations detected at VOC-B will be subtracted from those measured at VOC-A to assess VOC releases from Panel 1.

Table 3.1: Volatile Organic Compound Concentrations of Concern*

Compound	Molecular Weight (g/mol)	Drift E-300 µg/m³	Drift E-300 ppbv
1,1-Dichloroethylene	96.95	106	27
Carbon tetrachloride	153.8	35	6
Methylene chloride	84.94	1,130	326
Chloroform	119.4	23	5
1,1,2,2-Tetrachloroethane	167.9	92	13
1,1,1-Trichloroethane	133.42	3,300	600
Chlorobenzene	112.6	10,000	2,300
1,2,-Dichloroethane	98.96	20	10
Toluene	92.13	212,000	57,000

g/mol Grams per mole
µg/m³ Micrograms per cubic meter
ppbv Parts per billion by volume

* Calculated at 25 degrees Celsius (°C) and 760 millimeters of mercury (mmHg).

3.2 ANALYTES TO BE MONITORED

Based on acceptable knowledge, previous analytical data, and recent risk calculations (Appendix WAP and Chapter 5 of the NVMP), nine VOCs have been initially identified for monitoring. These compounds are listed in Table 2.1. The analysis will focus on routine detection and quantification of these compounds in collected samples. Other compounds may also be present in the samples. As part of the analytical evaluations, the presence of other compounds will be investigated. The analytical method will allow semi-quantitative evaluation of these compounds as tentatively identified compounds (TIC).

3.3 SAMPLING AND ANALYSIS METHODS

A technically sound, reliable, and versatile sampling method is required for the VOC monitoring program. The selected method must be able to definitively identify and quantify the initial nine target compounds. Another consideration is the desire to use EPA approved or recommended methods that provide data of known and documented quality. In addition, the present WIPP program includes a comprehensive VOC monitoring program established at the facility; equipment, training, and documentation for VOC measurements are already in place.

The method selected for VOC sampling is EPA Compendium Method TO-14 (EPA, 1988b; Winberry and others, 1990). The TO-14 sampling technique uses 6-liter SUMMA® passivated stainless-steel canisters to collect integrated air samples at each sample location. This method will be used for guidance in collecting the samples at WIPP. The samples will be analyzed using gas chromatography/mass spectrometry (GC/MS) under an established Quality Assurance/Quality

Control (QA/QC) program (WP 12-7) following guidance from the Draft EPA CLP-SOW for Volatile Organics Analysis of Ambient Air in Canisters (EPA, 1991). The Quality Assurance Project Plan (QAPP), WP 12-7, was prepared for the baseline monitoring program at the WIPP. It will be updated once the confirmatory monitoring plan is finalized.

The TO-14 method is an EPA-recognized sampling procedure for VOC sampling and speciation. It can be used to provide integrated samples, or grab samples, and compound quantitation for a broad range of concentrations. The sampling system can be operated unattended but requires detailed operator training.

As presently designed, the field sampling systems will be operated in the pressurized mode. In this mode, air is drawn through the inlet and sampling system with a pump. The air is pumped into an initially evacuated SUMMA® passivated canister by the sampler, which regulates the rate and duration of sampling. The passivation process forms a pure chrome-nickel oxide on the interior surfaces of the canisters. This type of container has been used routinely at WIPP in the past and has demonstrated sample storage stability for a wide variety of VOCs. At the end of each sampling period, the canisters will be pressurized to about two atmospheres absolute. In the event of shortened sampling periods or other sampling conditions, the final pressure in the canister may be less than two atmospheres absolute. Sampling duration will be approximately six hours, so that a complete sample can be collected during a single work shift.

The canister sampling system and GC/MS analytical method are particularly appropriate for the VOC Confirmatory Monitoring Program because a relatively large sample volume is collected, and

multiple dilutions and reanalyses can occur to ensure identification and quantification of target VOCs within the working range of the method. The contract required quantitation limits (CRQL) proposed by EPA are 5 ppbv or less for the nine target compounds (EPA, 1991), so that low concentrations can be measured. CRQLs are the EPA-specified levels of quantitation for EPA contract laboratories that analyze canister samples by GC/MS. The CLP-SOW expressly states how instrument detection limits are demonstrated. For the purpose of this monitoring plan, the CRQLs are defined as the method reporting limits (MRL). The MRL is a function of instrument performance, sample preparation, sample dilution, and all steps involved in the sample analysis process.

Detailed analytical standard operating procedures (SOP) and a QAPP have been prepared for EPA Method TO-14 canister analysis as part of the baseline VOC monitoring at WIPP. Revisions to these documents will be made as necessary to meet the QA/QC objectives described in Section 5.0. In addition, canister and sampling system cleaning and certification SOPs and QAPPs have been prepared. These procedures and plan will be consistent with the QA/QC objectives defined for the program.

Alternative sampling methods will be considered for deployment. One option will be to use subatmospheric samplers rather than pressurized sampling systems for stations VOC-A and VOC-B. In addition, remote sensing by proposed draft EPA Method TO-16, open-path fourier transform infrared spectroscopy (OP-FTIR) and extractive FTIR, may constitute supplemental or alternative methods for detecting VOCs released from waste panels at WIPP. WIPP personnel will continue to follow the development of emerging FTIR technology, and other potentially applicable technologies for assessing VOCs in the WIPP environment. Real-time monitoring with

a FTIR system may be a feasible future option for the VOC Confirmatory Monitoring Program.

3.4 Sampling Schedule

Many tasks will be completed prior to the initiation of VOC monitoring according to the monitoring plan. For example, power will be run to the monitoring station locations, engineering drawings will be created/revised for the monitoring stations, and program QAPP and SOP documentation will be finalized. Some sampling will be conducted prior to waste emplacement to troubleshoot the monitoring system. The purpose of collecting data during this phase will be to evaluate whether the monitoring systems and analytical methods are properly functioning. The troubleshooting period will be determined by VOC monitoring group personnel.

Confirmatory VOC sampling at Stations VOC-A and VOC-B will begin with initial waste emplacement in Panel 1. Sampling will continue during Panel 1 operations and will end no earlier than 6 months after the certified closure of Panel 1.

The environment within Panel 1 is not expected to vary substantially from day to day. If releases from Panel 1 do occur, concentrations in Drift E-300 may increase gradually over time as the panel is filled. Once the panel is filled and closed, the panel closure systems are designed to minimize air leakage from the relatively static panel environment. For these reasons, routine sampling will be conducted twice a week during the time Panel 1 is filled and for the first 6 months after the closure of Panel 1 has been certified.

VOC concentrations will be evaluated quarterly to assess whether the sampling results represent adequate confirmation of the emission calculations. If the average measured concentrations for the Panel 1 monitoring period confirm the calculations, no additional sampling will be performed. Confirmation will be achieved if the annual average concentration is below the predicted value. Monitoring will be extended for at least 12 months if no emissions are detected. However, the sampling frequency will be decreased to one per week. In addition, if a 12-month average target compound concentration exceeds the concentration of concern, additional sampling will be considered.

4.0 SAMPLING AND ANALYSIS PROCEDURES

This section describes the equipment and procedures that will be implemented during sample collection and analysis activities for VOCs at WIPP.

4.1 SAMPLING EQUIPMENT

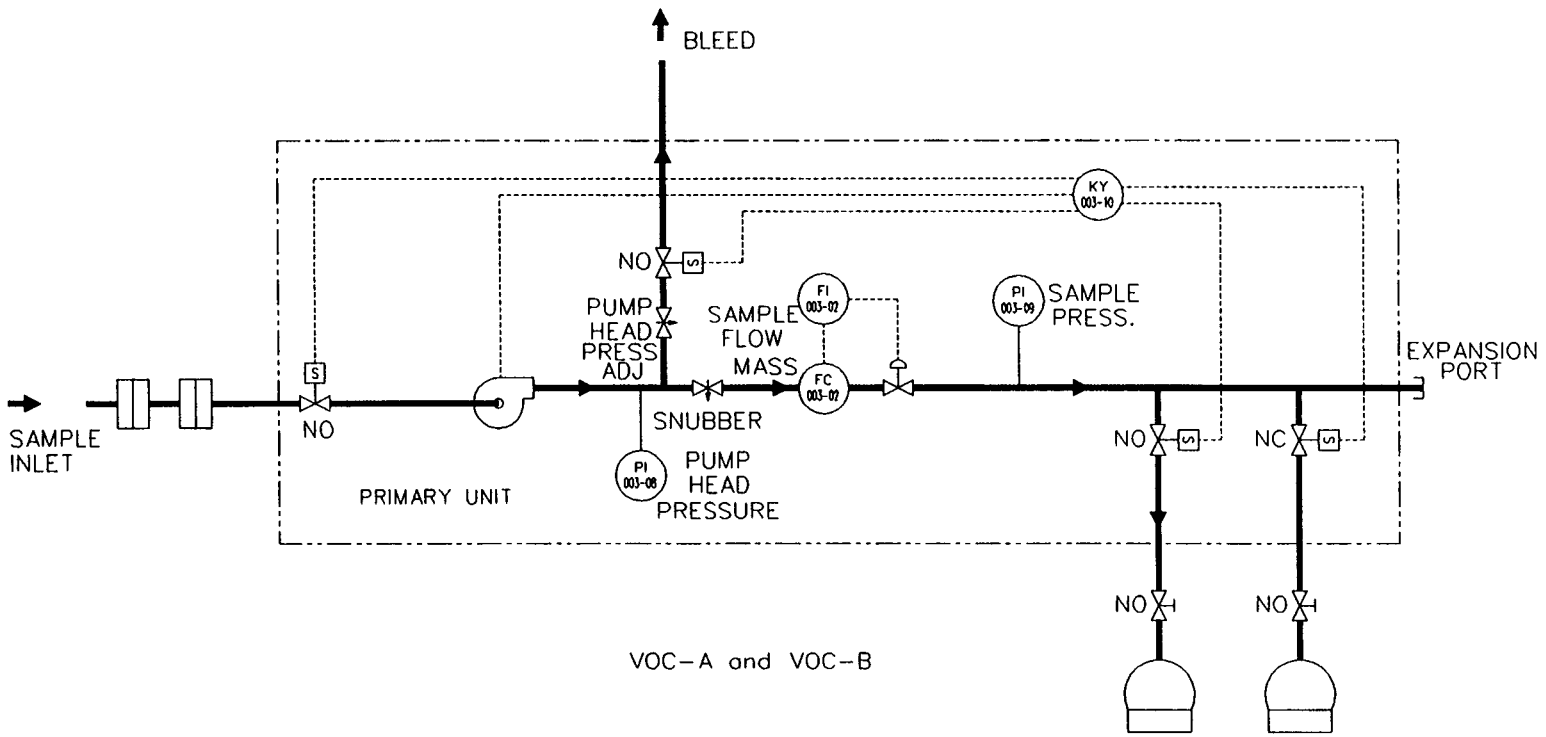
The sampling equipment that will be used during the study includes the following: 6-liter (L) stainless-steel SUMMA® canisters, and VOC canister samplers. A discussion of each of these items is presented below.

4.1.1 SUMMA® Canisters

Six-liter, stainless-steel canisters with SUMMA® passivated interior surfaces will be used to collect and store all ambient air and gas samples for VOC analyses collected as part of the monitoring processes. These canisters must be cleaned and certified prior to their use, as described by Compendium Method TO-14 and the draft EPA CLP-SOW for Analysis of Ambient Air in Canisters. A SOP describing this process in detail has been prepared by the analytical laboratory. Compendium Method TO-14 and the CLP-SOW (EPA, 1991) were used as guidance documents in the preparation of this SOP.

4.1.2 Volatile Organic Compound Canister Samplers

A conceptual diagram of a VOC sample collection unit is provided in Figure 4.1. Unless an alternate sampling method is selected, two



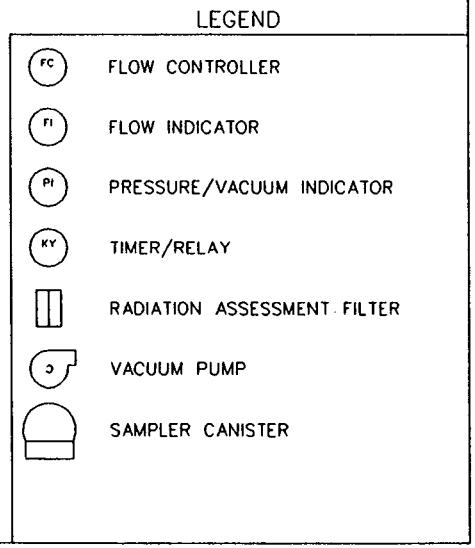


Figure 4.1 – VOC Monitoring System Design

such systems, VOC-A and VOC-B, will be operational at the time waste disposal operations begin in Panel 1. The sampling system consists of a sample pump, flow controller, sample inlet, two inlet filters in series to remove particulate matter, vacuum/pressure gauge, electronic timer, inlet purge vent, two sampling ports, and sufficient collection canisters so that any delays attributed to laboratory turnaround time and canister cleaning and certification will not result in canister shortages. Knowledge of sampler flow rates and duration of sampling will allow calculation of sample volume. The set point flow rate will be verified during sample collection by monitoring the mass flow indication. Prior to use, the sample collection units, including inlet line, will be tested and certified to demonstrate that they are free of contamination above the reporting limits of the VOC analytical method (see Section 5.0). Ultra high purity humidified zero air will be pumped through the sampling unit and collected in previously certified canisters as sampler blanks for analysis, as described in WP 12-7. A SOP describing in detail the cleaning and certification procedure for samplers (including pressure testing and target compound recovery evaluation) has been prepared.

4.2 SAMPLE COLLECTION

Samples collected from the underground facility should be representative of routine operations; therefore, six-hour integrated samples will be collected on each sample day. Alternative sampling durations may be defined for experimental purposes. The VOC canister sampler at each location will sample ambient air on the same programmed schedule. The sample pump will be programmed to sample continuously over a six-hour period during the work day. The units will sample at a nominal flow rate of 33.3 actual milliliters per minute over a six-hour sample period.

This schedule will yield a final sample volume of approximately 12 L. Flow rates and sampling duration may be modified as necessary for experimental purposes and to meet the data quality objectives.

Sample flow will be checked each sample day using the in-line mass flow controller. These flow controllers are initially factory-calibrated and specify a typical accuracy of better than 10 percent full scale. Additionally, each air flow controller is calibrated at a manufacturer-specified frequency using a National Institute of Standards and Testing (NIST) primary flow standard. Existing SOPs have been revised to address the specific calibration requirements of the VOC monitoring equipment.

Upon initiation of waste disposal activities in Panel 1, samples will be collected twice each week (at Stations VOC-A and VOC-B). Samples collected at the panel locations should represent the same matrix type (i.e., elevated levels of salt aerosols). To verify the matrix similarity, duplicate samples will be collected from each sampling station (stations VOC-A and VOC-B) during the first sampling event and at an overall frequency of five percent thereafter (see Section 5.1).

4.3 SAMPLE MANAGEMENT

Field sampling data sheets will be used to document the conditions under which each sample is collected. These data sheets have been developed specifically for VOC monitoring at the WIPP facility. The individuals assigned to collect the specific samples will be required to fill in all of the appropriate sample data and to maintain this record in sample logbooks. The program team leader will review these forms for each sampling event.

All samples will be maintained, and shipped if necessary, at ambient temperatures. Collected samples will be transported in appropriate containers. Prior to leaving the underground for analysis, all sample containers must undergo radiological screening. No potentially contaminated samples or equipment will be transported to surface.

Additional QA requirements for sample management contained in the sitewide Quality Assurance Program Description, WP 13-1, will be followed as appropriate. Chain-of-custody procedures will be followed closely, and additional requirements imposed by the laboratory for sample analysis will be included as necessary.

Individuals collecting samples will be responsible for the initiation of custody procedures. The chain of custody will include documentation as to the canister certification, location of sampling event, time, date, and individual handling the samples. Samples will be collected and handled in accordance with WP 12-7 and approved SOPs. Deviations from procedure will be considered a variance. Variances must be preapproved by the program manager and recorded in the project files. Unintentional deviations, sampler malfunctions, and other problems are nonconformances. Nonconformances must be documented and recorded in the project files. All field logs/data sheets must be incorporated into WIPP's records management program.

More detailed documentation of sample management is presented in WP 12-7, the QAPP for the VOC Monitoring Program (to be updated as described in Section 3.3).

4.4 SAMPLER MAINTENANCE

Routine sampler maintenance will be the responsibility of the sampling personnel. This maintenance will include, but not be limited to, replacement of damaged or malfunctioning parts without compromising the integrity of the sampler, filter changes, leak testing, and minor cleaning. Major cleaning and sampler cleanliness certification will be the responsibility of the sampling and analytical laboratory personnel. Additionally, complete spare units will be maintained onsite to minimize downtime because of sampler malfunction. A sampler preventative maintenance schedule has been developed and is included in WP 12-7. At a minimum, samplers will be certified for cleanliness initially, after any parts that are included in the sample flow path are replaced, or any time analytical results indicate potential contamination. All sample canisters will be certified prior to each usage.

4.5 ANALYTICAL PROCEDURES

Analytical procedures used in the analysis of VOC samples from canisters are based on EPA guidance in Compendium Method TO-14 (EPA, 1988b) and in the Draft CLP-SOW for Analysis of Ambient Air (EPA, 1991). Specific analytical SOPs and method validation data are in place at the program analytical laboratory for the performance of canister sample analyses. The technical approach for canister sample analysis is summarized below.

4.5.1 Sample Preparation

Because canisters will be pressurized during the sampling procedure, laboratory pressurization will not be necessary for analyses. Canister pressures will be verified by the laboratory when they are

received to confirm that significant losses did not take place during shipping and storage.

4.5.2 Analytical System Requirements

The GC/MS analytical system will consist of three major components: the sample introduction system, analyte separation system (GC), and the analyte detector system (MS).

- Sample Introduction System for Canisters: This system will include a drying tube to remove moisture from the gas stream. One or more cryogenic traps may be used to focus and desorb trapped material. Transfer lines within the introduction unit will be heated as necessary so that volatile compounds are not actively absorbed. Valves and solenoids will be heated and be of a low dead volume type. The introduction system will have an in-line mass flow controller. The introduction unit will be capable of introducing internal standards directly into the sample flow path.

- Analyte Separation: Analyte separation will be achieved by GC. The GC will be capable of subambient temperature programming.

- Detection System: Analyte detection will be accomplished by MS. The MS must be capable of scanning from 35 to 300 mass to charge ratio in one second or less, be fitted with a gas jet separator, a data system capable of storing all raw data, and a computer algorithm for analyte quantitation and forward library searching. All raw and processed GC/MS data must be stored on magnetic tape or disk and kept for the duration of this project.

4.5.3 Standard Preparation

Primary analytical standards will be prepared by the laboratory from commercially available, certified calibration gases. Alternatively, primary standards may be generated internally by the laboratory. Primary standards of analytes that are gases at standard temperature and pressure (STP) may be internally prepared in a static gas dilution bottle. For analytes that are liquid or solid at STP, a mixture may be made and loaded directly into a standard preparation cylinder. These internally generated standards will be checked against EPA audit cylinders or other reference materials to verify the accuracy of their concentrations.

Primary standards will be prepared for the nine target compounds as well as the internal standards. Secondary standards used for instrument calibration will be prepared from dilution of the primary standards.

4.5.4 Calibration Procedures

Prior to the analysis of a standard curve, the GC/MS system must undergo a mass calibration check. This check is performed by injecting 50 nanograms (ng) of 4-bromofluorobenzene (BFB) directly onto the capillary column. The requirements (criteria) for relative ion abundances for BFB, listed in Table 4.1, must be met before analyses may proceed. BFB requirements must be met for each 12 hours of operation.

Quantitative standards for the nine target analytes will be analyzed at five concentrations. These concentrations should

define the linear range of the instrument for these nine compounds; however, if some nonlinearity exists, concentrations may be determined by curve fitting or physically plotting the data. One standard concentration shall be at or near a concentration corresponding to the required MRL for each target compound. Relative response factors will be generated for each target compound. These response factors must meet the requirements listed in Section 5.1.3. As discussed above, if low concentration standards do not meet the linearity requirement, then a curve-fitting routine may be used. The method used to quantify the data must be reported with the analytical results.

Table 4.1: 4-Bromofluorobenzene Key Ions and Ion Abundance Criteria

Mass	Ion Abundance Criteria
50	8 to 40 percent of mass 95
75	30 to 60 percent of mass 95
95	Base Peak, 100 percent Relative Abundance
96	5 to 9 percent of mass 95
173	<2 percent of mass 174
174	>50 percent of mass 95
175	4 to 9 percent of mass 174
176	>93 percent but <101 percent of mass 174
177	5 to 9 percent of mass 176

4.5.5 Library Searches

In every sample analyzed, a forward search of the NIST library of mass spectra must be performed for all chromatographic peaks greater than 10 percent of the nearest internal standard.

4.5.6 Data Reporting

Sample target analyte concentrations will be quantified using the mid-range calibration standards and will be reported in ppbv. Non-target sample contaminants identified by NIST library searches will be reported as TICs, and concentration calculations will be based on the response of the nearest internal standard. The relative response factor used for quantitation, as well as copies of spectra with the library search results (purity and fit), will be submitted with the results. A table listing the run sequence with the corresponding internal standard area counts must be reported with the analytical results. A narrative describing any problems with sample analysis must be included. Any nonconformances must be included with the reporting of the data. Data reporting and documentation requirements are discussed in greater detail in WP 12-7.

4.6 LABORATORY SELECTION

Sample analyses will occur at the WIPP onsite analytical laboratory and/or at a suitable contract analytical laboratory. Upon selection of an offsite contract laboratory, measures shall be taken, in accordance with the current Westinghouse Waste Isolation Division procurement policies and procedures, to ensure that procured services conform to specified requirements. These measures

will generally include one or more of the following: 1) evaluation of the supplier's capability to provide services in accordance with requirements, including a history of providing similar services; 2) evaluation of objective evidence of conformance, such as laboratory document submittals; and 3) examination of delivered services.

4.7 LABORATORY PROCEDURES

Analytical laboratories that perform analyses for the VOC Confirmatory Monitoring Plan are required to develop and maintain, at a minimum, the following SOPs:

- Canister cleaning and certification
- Sampler cleaning and certification
- Analysis of VOCs in SUMMA® canisters
- Data QA and reporting

Laboratories are also required to maintain an internal program QA Manual, and to develop and prepare a QAPP covering cleaning and certification of canisters and laboratory analysis of canister samples. In addition, laboratories will be required to review and comply with WP 12-7.

5.0 QUALITY ASSURANCE

Many quality assurance objectives for the VOC Confirmatory Monitoring Plan have been addressed in Sections 3.0 and 4.0. For example, sample collection procedures are discussed, including justification of sampling location selection. Additional topics include discussions of sampling program operations, preparation of sampling equipment and sample containers, redundancy in sampling equipment and sample containers (including canister certification), a general sample management/control scheme, and the selection of analytical procedures. More detailed descriptions of these functions, as well as additional quality-related objectives, are addressed in WP 12-7. WP 12-7 has been prepared in accordance with the document entitled "EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations" (EPA, 1994) and the "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans" (EPA, 1983), and QA criteria listed in Table 5.1. This section addresses the methods to be used to evaluate the components of the measurement system and how this evaluation will be used to assess data quality. In addition, project activities will be performed in conformance with QA requirements described in WP 12-7.

5.1 QUALITY ASSURANCE OBJECTIVES FOR THE MEASUREMENT OF PRECISION, ACCURACY, SENSITIVITY, AND COMPLETENESS

Quality assurance objectives for the VOC Confirmatory Monitoring Plan will be defined in terms of the following data quality parameters:

Table 5.1: Quality Assurance Objectives for Accuracy, Precision, Sensitivity, and Completeness

Compound	Accuracy (Percent Recovery)	Precision (RPD)	Required MRL (ppbv)	Completeness (Percent)
1,1-Dichloroethylene	60 to 140	25	5	≥90
Carbon tetrachloride	60 to 140	25	2	≥90
Methylene chloride	60 to 140	25	5	≥90
Chloroform	60 to 140	25	2	≥90
1,1,2,2-Tetrachloroethane	60 to 140	25	2	≥90
1,1,1-Trichloroethane	60 to 140	25	5	≥90
Chlorobenzene	60 to 140	25	2	≥90
1,2-Dichloroethane	60 to 140	25	2	≥90
Toluene	60 to 140	25	5	≥90

These data quality objectives are based on control criteria proposed by EPA as presented in the Contract Laboratory Program Statement of Work for the Analysis of Ambient Air in Canisters (EPA, 1991).

EPA U.S. Environmental Protection Agency
MRL Method reporting limit
ppbv Parts per billion by volume
RPD Relative percent difference

- **Precision.** For the duration of this project, precision will be defined and evaluated by the relative percent difference (RPD) values calculated between field duplicate samples and between laboratory duplicate samples.

$$RPD = \frac{(A - B)}{[(A + B)/2]} \times 100$$

where:

A = Original sample result

B = Duplicate sample result

- **Accuracy.** Analytical accuracy will be defined and evaluated through the use of analytical standards. Because recovery standards cannot reliably be added to the sampling stream, overall system accuracy must be based on analytical instrument performance evaluation criteria. These criteria will include performance verification for instrument calibrations, laboratory control samples, and sample internal standard areas. These criteria will constitute the verification of accuracy for target analyte quantitation (i.e., quantitative accuracy). Evaluation of standard ion abundance criteria for BFB will be used to evaluate the accuracy of the analytical system in the identification of targeted analytes, as well as the evaluation of unknown contaminants (i.e., qualitative accuracy).

- **Sensitivity.** Sensitivity will be defined by the required MRLs for the program. Attainment of required MRLs will be verified by the performance of statistical method detection limit (MDL) studies in accordance with 40 CFR Part 136. The MDL represents the minimum concentration that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. An MDL study will be performed by the program analytical laboratory prior to sampling and analysis.

- **Completeness.** Completeness will be defined as the percentage of the ratio of the number of valid sample results received versus the total number of samples collected. Completeness may be affected, for example, by sample loss or destruction during shipping, by laboratory sample handling errors, or by rejection of analytical data during data validation.

5.1.1 Evaluation of Laboratory Precision

Laboratory sample duplicates and blank spike/blank spike duplicates (BS/BSD) will be used to evaluate laboratory precision. Quality assuarance objectives for laboratory precision are listed in Table 5.1, and are based on precision criteria proposed by EPA for canister sampling programs (EPA, 1991). These values will be appropriate for the evaluation of samples with little or no matrix effects. Because of the potentially high level of salt-type aerosols in the WIPP underground environment, the analytical precision achieved for WIPP samples may vary with respect to the

EPA criteria. RPDs for BS/BSD analyses will be tracked through the use of control charts. RPDs obtained for laboratory sample duplicates will be compared to those obtained for BS/BSDs to ascertain any sample matrix effects on analytical precision. BS/BSDs and laboratory sample duplicates will be analyzed at a frequency of 10 percent or one per analytical lot, whichever is more frequent. Precision windows and outlier criteria are addressed in WP 12-7.

5.1.2 Evaluation of Field Precision

Field duplicate samples will be collected at a frequency of five percent for both monitoring locations. Like the laboratory duplicate data, field duplicate data will be compared to the EPA precision criteria presented in Table 5.1, and matrix and sampling effects on precision will be assessed through comparison with internal laboratory precision data.

5.1.3 Evaluation of Laboratory Accuracy

Quantitative Accuracy

Quantitative analytical accuracy will be evaluated through performance criteria on the basis of: 1) relative response factors generated during instrument calibration, 2) analysis of laboratory control samples (LCS), and 3) recovery of internal standard compounds. The criteria for the initial calibration (5-point calibration) is that any single relative response factor for a particular target compound can differ by no more than 30 percent from the average of the five. After the successful completion of the 5-point calibration, it is sufficient to analyze only a midpoint standard for every 12 hours of operation. The midpoint

standard must pass the 30 percent difference acceptance criteria before sample analysis may begin.

A blank spike or LCS is an internal QC sample generated by the analytical laboratory by spiking a standard air matrix (humid zero air) with a known amount of a certified reference gas. The reference gas will contain the target VOCs at known concentrations. Percent recoveries for the target VOCs will be calculated for each LCS relative to the reference concentrations. Objectives for percent recovery are listed in Table 5.1, and are based on accuracy criteria proposed by EPA for canister sampling programs (EPA, 1991). LCSs will be analyzed at a frequency of 10 percent or one per analytical lot, whichever is more frequent. Recovery windows and outlier criteria are addressed in WP 12-7.

Internal standards will be introduced into each sample analyzed, and will be monitored as a verification of stable instrument performance. In the absence of any unusual interferences, areas should not change by more than 40 percent over a 12-hour period. Deviations larger than 40 percent are an indication of a potential instrument malfunction. If an internal standard area in a given sample changes by more than 40 percent, the sample must be reanalyzed. If the 40 percent criterion is not achieved during the reanalysis, the instrument must undergo a performance check and the midpoint standard must be reanalyzed to verify proper operation. Response and recovery of internal standards will also be compared between samples, LCSs, and calibration standards to identify any matrix effects on analytical accuracy.

Qualitative Accuracy

Qualitative accuracy in the identification of target VOCs will be evaluated by the relative ion abundance criteria established for the internal standard compound BFB. For each 12 hours of sample analysis, a 50-nanogram (ng) injection of BFB must be made, and the requirements listed in Table 4.1 must be met before the instrument may be used to analyze samples.

5.1.4 Evaluation of Sensitivity

The presence of aerosol salts in underground locations may affect the MDL of the samples collected in those areas. The intake manifold of the sampling systems will be sufficiently protected from the underground environment to minimize salt aerosol interference.

The MDL for each of the nine target compounds will be evaluated by the analytical laboratories before sampling begins. The initial MDL evaluation will be performed in accordance with 40 CFR Part 136 and with EPA/530-SW-90-021, as revised and retitled, "Quality Assurance and Quality Control" (Chapter 1 of SW-846) (1986).

5.1.5 Completeness

The expected completeness for this project is greater than or equal to 90 percent. Data completeness will be tracked monthly.

5.2 SAMPLE HANDLING AND CUSTODY PROCEDURES

Sample packaging, shipping, and custody procedures are addressed in WP 12-7 (see Sections 7.4 and 8.0).

5.3 CALIBRATION PROCEDURES AND FREQUENCY

Calibration procedures and frequencies for analytical instrumentation are listed in Section 4.5.4.

5.4 ANALYTICAL PROCEDURES

The analytical procedures for the VOC Confirmatory Monitoring Program, which are based on the draft CLP SOW for Analysis of Ambient Air in Canisters (EPA, 1991) and EPA guidance Method TO-14 (EPA, 1988b), are outlined in Section 4.5.

5.5 DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction and validation are addressed in the WP 12-7. A brief description of data reporting is given in Section 4.5; more detail on data reporting is provided in WP 12-7.

A dedicated logbook will be maintained by the operators. This log will contain documentation of all pertinent data for the sampling. Sample collection conditions, maintenance, and calibration activities will be included in this log. Additional data collected by other groups at WIPP, such as ventilation airflow, temperature, pressure, etc., will also be obtained to document the sampling conditions, as necessary.

Data validation procedures will be specified in the monitoring program QA protocols. At a minimum, all field data forms and

sampling logbooks will be checked for completeness and correctness. Sample custody and analysis records will be routinely reviewed by the QA officer and the laboratory supervisor.

Data will be summarized quarterly. Data summaries will include target VOC results for each sample collected as well as overall statistical summaries. Graphical summaries may also be included.

5.6 PERFORMANCE AND SYSTEM AUDITS

System audits will initially address startup functions for each phase of the project. These audits will consist of onsite evaluation of materials and equipment, review of canister and sampler certification, review of laboratory qualification and operation, and may, at the request of the QA officer, include an onsite audit of the laboratory facilities. The function of the system audit is to verify that the requirements in this plan and the QAPP, have been met prior to initiating the program. System audits will be performed prior to the initiation of the monitoring program.

Performance audits will be accomplished as necessary through the evaluation of analytical quality control data, by performing periodic site audits throughout the duration of the project, and through the introduction of third-party audit cylinders (laboratory blinds) into the analytical sampling stream. Performance audits will also include a surveillance/review of all data associated with canister and sampler certification, a project-specific technical audit of field operations, and a laboratory performance audit. Field logs, logbooks, and data sheets will be reviewed weekly. Blind-audit canisters will be introduced once

during the sampling period. Details concerning scheduling, personnel, and data quality evaluation are addressed in WP 12-7.

5.7 PREVENTATIVE MAINTENANCE

A brief description of sampler maintenance is described in Section 4.4. Maintenance of analytical equipment will be addressed in the analytical SOP.

5.8 CORRECTIVE ACTIONS

Nonconformances and corrective actions of noncomformances will be processed as outlined in the Quality Assurance Program Description (DOE 1994).

5.9 QUALITY ASSURANCE REPORTS TO MANAGEMENT

The results of audits will be reported in accordance with sitewide Quality Assurance Plan (QAP) and WP 13-005. Audit reports will include identification of findings and/or observations, as well as an assessment of the effectiveness of the QAP elements review.

6.0 ACRONYMS

BFB	4-Bromofluorobenzene
BS/BSD	Blank spike/blank spike duplicate
CFR	Code of Federal Regulations
CH	Contact handled
CLP	Contract Laboratory Program
COC	Concentration of concern
CRQL	Contract required quantitation limit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
g/mol	Grams per mole
GC/MS	Gas chromatography/mass spectroscopy
LCS	Laboratory control samples
MDL	Method detection limit
mmHg	Millimeters of mercury

MDL	Method detection limit
MRL	Method reporting limit
m/z	Mass to charge ratio
ng	Nanogram
NIST	National Institute of Standards and Testing
NMAC	New Mexico Administrative Code
NMVP	No-migration variance petition
OP-FTIR	Open-path fourier transform infrared spectroscopy
ppbv	Parts per billion by volume
QA/QC	Quality assurance/quality control
QA	Quality assurance
QAPD	Quality Assurance Program Description
QAPP	Quality Assurance Project Plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RH	Remote handled

RPD	Relative percent difference
SOP	Standard operating procedure
SOW	Statement of work
STP	Standard temperature and pressure
TIC	Tentatively identified compound
TRU	Transuranic
UHP	Ultra high purity
VOCs	Volatile organic compounds
WAC	Waste acceptance criteria
WAP	Waste analysis plan
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
$\mu g/m^3$	Micrograms per cubic meter
°C	Degrees Celsius

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WP 13-QA3003, Corrective Action Program.

WP 13-1, WIPP Sitewide Quality Assurance Program.

APPENDIX CONT

CONTINGENCY PLAN

CHAPTER G

RCRA CONTIGENCY PLAN

(From the WIPP RCRA Part B Permit Application, Rev. 6)

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RCRA CONTINGENCY PLAN
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CHAPTER G
RCRA CONTINGENCY PLAN

Introduction

The Waste Isolation Pilot Plant (WIPP) Project was authorized by the National Security and Military Applications of the Nuclear Energy Authorization Act of 1980 (Public Law 96-164). Its legislative mandate is to provide a research and development facility to demonstrate the safe disposal of radioactive waste resulting from United States defense activities and programs. The U.S. Department of Energy (DOE) is developing the WIPP facility to demonstrate the efficacy of an underground geologic repository for the safe disposal of transuranic (TRU) waste and TRU mixed waste currently stored at or generated by DOE defense installations.

The WIPP facility is owned and operated by the DOE and co-operated by its designated Management and Operating Contractor (MOC).

This Contingency Plan is prepared in accordance with the Resource Conservation and Recovery Act (RCRA) requirements codified in Title 20 of the New Mexico Administrative Code, Chapter 4, Part 1 (20 NMAC 4.1), Subpart V, §264.50 to §264.56, "Contingency Plan and Emergency Procedures," and submitted in compliance with 20 NMAC 4.1, Subpart IX, §270.14(b)(7). The purpose of this document is to define responsibilities, to describe coordination of activities, and to minimize hazards to human health and the environment from fires, explosions, or any sudden or nonsudden release of hazardous waste, or hazardous waste constituents to air, soil, or surface water (20 NMAC 4.1, Subpart V, §264.51 [a]). This plan consists of descriptions of processes and emergency responses specific to hazardous substances, contact-handled (CH) TRU mixed waste, remote-handled (RH) TRU mixed waste, and other hazardous waste handled at the WIPP facility.

G-1 General Information

The WIPP facility is located 26 miles (mi) (42 kilometers [km]) east of Carlsbad, in Eddy County in southeastern New Mexico, and includes an area of 10,240 acres (ac) (4,144 hectares [ha]). The facility is located in an area of low-population density, with fewer than 30 permanent residents living within a 10 mi (16 km) radius of the facility. The area surrounding the facility is used primarily for grazing, potash mining, and mineral exploration. Resource development that would affect WIPP facility operations or the long-term integrity of the facility is not allowed within the 10,240 ac (4,144 ha) that have been set aside for the WIPP Project.

The WIPP facility is designed to receive containers of TRU waste, which will be transported to the WIPP facility from the ten major and other minor DOE TRU mixed waste generator and/or storage sites. The waste will be emplaced in the bedded salt of the Salado Formation, 2,150 feet (ft) (655 meters [m]) below ground surface.

As a geologic facility for the management of TRU mixed waste, the WIPP repository is regulated as a "miscellaneous unit," as defined under 20 NMAC 4.1, Subpart V, §264.601 to §264.603. The areas at the WIPP facility subject to RCRA permitting include the surface container storage areas in the Waste Handling Building (WHB) and the parking area south of the WHB, and the areas below ground in which waste will be emplaced.

The WIPP facility includes other surface structures, shafts, and underground areas (Figures G-1, G-2, and G-3). Surface structures other than the WHB, that support TRU mixed waste management include:

Exhaust Filter Building - houses the filter banks to which the underground ventilation can be diverted in the unlikely event of a release of radionuclides.

Guard and Security Building - houses the facility security personnel and communications equipment necessary for them to perform their duties. Section G-4a specifies the duties of the security officers relative to contingency actions.

Safety and Emergency Services Building - houses the surface emergency response vehicles (fire truck, rescue truck, ambulance), Health Services (first aid), Emergency Operations Center, and the Dosimetry Laboratory. Table G-6 describes emergency equipment and associated locations.

Support Building - houses the Central Monitoring Room (see section G-4a).

Transuranic Package Transporter-II (TRUPACT-II) Maintenance Facility - located west of the CH bay, houses equipment required for conducting preventive maintenance and other activities required by the Nuclear Regulatory Commission (NRC) to maintain the Certificate of Compliance. No TRU waste management activities will occur in this facility.

Surface facilities used for storage of support equipment are identified in Table G-6.

Building 452, Safety and Emergency Services Facility, houses the emergency response vehicles, emergency equipment, the mine rescue room, mine rescue team equipment, and the Emergency Operations Center (EOC). The Hazardous Material Response Trailer is staged in the west parking area adjacent to Building 452.

A RCRA Operating permit is sought for TRU mixed waste management activities in the WHB, the parking area, and the disposal areas within the miscellaneous unit. The provisions of this Contingency Plan apply to hazardous waste management units (HWMU) in the underground waste disposal rooms, the WHB, the parking area, the Waste Shaft, and supporting TRU mixed waste handling areas. The remainder of the facility will not manage TRU mixed waste. However, hazardous substances in the remainder of the facility are included as possible triggers of the Contingency Plan. Inclusion is based on their National Fire Protection Association (NFPA)

ratings in addition to their storage quantities. The majority of hazardous substances on-site are not expected to trigger the contingency plan because they are present in the same form and concentration as the product packaged for distribution and use by the general public or are used in a laboratory under the direct supervision of a technically qualified individual. Superfund Amendments and Reauthorization Act (SARA) Title III excludes these from emergency planning reporting. The list of hazardous substances in large enough quantities to constitute a Level II incident (Section G-3) is provided in Table G-1. In addition to TRU Waste, these are the only hazardous substances currently on site which, if spilled, may be of sufficient impact to cause this Contingency Plan to be implemented. Magnesium Oxide (MgO) will be stored on-site in large quantities once CH-Waste emplacement begins. It will be used as backfill in the waste emplacement rooms as a pH buffer. The pH buffer will limit the solubility of radionuclides after the underground rooms are filled and closed. MgO is not a hazardous substance, a release of MgO will not create hazardous waste and poses no threat to human health or the environment, and is therefore not addressed in the Contingency Plan.

Wastes generated as a result of maintenance or response actions will be categorized into one of three groups and disposed of accordingly. These are: 1) nonhazardous wastes to be disposed of in an approved landfill, 2) hazardous nonradioactive wastes to be disposed of at an off-site RCRA permitted facility, and 3) TRU mixed waste to be disposed of in the underground HWMUs. Disposal of TRU mixed waste in the WIPP facility is subject to regulation under 20 NMAC 4.1, Subpart V. As required by 20 NMAC 4.1, Subpart V, §264.601, the DOE must demonstrate that the environmental performance standards for a miscellaneous unit, which are applied to the HWMUs in the underground, will be met. In addition, the technical requirements of 20 NMAC 4.1, Subpart V, §264.170 to §264.178 are applied to the operation of the container storage units in the WHB and in the parking area south of the WHB. Liquid wastes that may be generated as a result of the fire fighting water or decontamination solutions will be managed as follows:

Non-Mixed - Hazardous waste liquids contaminated only with hazardous constituents will be placed into containers and managed in accordance with 20 NNMAC 4.1, Subpart III, 262.34 requirements. The waste will be shipped to an approved off-site treatment, storage, or disposal facility.

Mixed - Liquids contaminated with mixed waste (inside the WHB) will be solidified as they are placed into containers with cement, Aquaset, or absorbent material in them and solidified in the WHB. The solidified materials will be disposed of in the underground WIPP repository as derived waste.

This chapter of the permit application describes the HWMUs, the TRU waste management facilities and operations, compliance with the environmental performance standards, and with the applicable technical requirements of 20 NMAC 4.1, Subpart V, §264.170 to §264.1789 and §264.601, respectively. The configuration of the WIPP facility consists of completed structures; including all buildings and systems for the operation of the facility.

Disposal Phase Overview

The Disposal Phase will consist of receiving both CH and RH TRU mixed waste shipping containers, unloading and transporting the waste containers to the underground HWMUs, emplacing the waste in the underground HWMUs, and subsequently achieving closure of the underground HWMUs in compliance with applicable state and federal regulations. The DOE is seeking a permit to perform these disposal and closure activities.

Panel closure and final facility closure activities will be performed in accordance with Chapter I of this permit application.

The TRU mixed waste that will be disposed at the WIPP facility results primarily from activities related to the reprocessing of plutonium-bearing reactor fuel and fabrication of plutonium-bearing weapons, as well as from research and development. This TRU mixed waste consists largely of such items as paper, cloth, and other organic material; laboratory glassware and utensils; tools; scrap metal; shielding; and solidified sludges from the treatment of wastewater. Much of this TRU mixed waste is also contaminated with substances that are defined as hazardous under 20 NMAC 4.1, Subpart II, Subparts C and D, and subject to the land disposal restrictions of 20 NMAC 4.1, Subpart VIII.

Waste Description

Waste destined for WIPP are, or were, produced as a byproduct of weapons production and have been identified in terms of waste streams based on the processes that produced them. Each waste stream identified by generators is assigned to a Waste Summary Category to facilitate RCRA waste characterization, and reflect the final waste forms acceptable for WIPP disposal.

These Waste Summary Categories are:

S3000—Homogeneous Solids
Solid process residues defined as solid materials, excluding soil, that do not meet the applicable regulatory criteria for classification as debris (20 NMAC 4.1, Subpart VIII, §268.2[g] and [h]). Included in solid process residues are inorganic process residues, inorganic sludges, salt waste, and pyrochemical salt waste. Other waste streams are included in this Waste Summary Category based on the specific waste stream types and final waste form. This category includes wastes that are at least 50 percent by volume solid process residues.

S4000—Soils/Gravel
This waste summary category includes waste streams that are at least 50 percent by volume soil. Soils are further categorized by the amount of debris included in the matrix.

S5000—Debris Wastes

This waste summary category includes waste that is at least 50 percent by volume materials that meet the criteria for classification as debris (20 NMAC 4.1, Subpart VIII, §268.2) as follows:

> Debris means solid material exceeding a 2.36 inch (60 millimeter) particle size that is intended for disposal and that is: 1) a manufactured object, 2) plant or animal matter, or 3) natural geologic material.

Included in the S5000 Waste Summary Category are metal debris, lead containing metal debris, inorganic nonmetal debris, asbestos debris, combustible debris, graphite debris, heterogeneous debris, and composite filters, as well as other minor waste streams.

Examples of waste that might be included in the S5000 Waste Summary Category are asbestos-containing gloves, fire hoses, aprons, flooring tiles, pipe insulation, boiler jackets, and laboratory tabletops. Also included are combustible debris constructed of plastic, rubber, wood, paper, cloth, graphite, and biological materials. Examples of graphite waste that would be included are crucibles, graphite components, and pure graphite.

Wastes may be generated at the WIPP facility as a direct result of managing the TRU and TRU mixed wastes received from the off-site generators. Such generated waste may occur in either the WHB or the Underground. For example, when TRU mixed wastes are received at the WHB, the shipping containers (TRUPACT-II and the RH cask) and the TRU mixed waste containers are checked for surface contamination. Under some circumstances,[1] if contamination is detected, the shipping container and/or the TRU mixed waste containers will be decontaminated. In the underground, waste may be generated as a result of radiation control procedures used during monitoring activities. The waste generated from radiation control procedures will be assumed to be TRU and/or TRU mixed waste. Throughout the remainder of this plan, this waste is referred to as "derived waste." All such derived waste will be placed in the rooms in HWMUs along with the TRU mixed waste for disposal.

Containers

The waste containers that will be used at the WIPP facility qualify as "containers," in accordance with 20 NMAC 4.1, Subpart I, §260.10. That is, they are "portable devices in which a material is stored, transported, treated, disposed of, or otherwise handled."

[1]Typically contamination that is less than six square feet in area and less than 2000 disintegrations per minute (dpm) alpha or 20,000 dpm beta/gamma, may be decontaminated. Containers that exceed these thresholds will be returned to the point of origin for decontamination.

TRU waste containers, containing off-site waste, are not opened at the WIPP facility. Derived waste containers are kept closed at all times unless waste is being added or removed.

Liquid waste will not be emplaced in the WIPP. TRU waste for emplacement in the WIPP shall contain as little residual liquid as is reasonably achievable. All internal containers (e.g., bottles, cans, etc.) must be well-drained, but may contain residual liquids. As a guideline, residual liquids in well-drained containers will be restricted to approximately one percent of the volume of the internal container. In no case shall the total liquid equal or exceed one volume percent of the waste container (e.g., drum or standard waste box [SWB]).

Special requirements for ignitable, reactive, and incompatible waste are addressed in 20 NMAC 4.1, Subpart V, §§264.176 and 177. The WIPP Waste Acceptance Criteria (WAC) precludes ignitable, reactive, or incompatible TRU mixed waste at the WIPP.

Description of Containers

CH TRU mixed waste containers will be either 55-gallon (gal) (208-liter (L)) drums singly or arranged into seven (7)-packs, 85-gal (321-L) drums (used as overpacks) singly or arranged into four (4)-packs, ten-drum overpacks (TDOP), or 66.3 ft^3 (1.88 m^3) SWBs. RH mixed waste containers will be 31.4 ft^3 (890-L) canisters.

Description of Surface Hazardous Waste Management Units

The WHB is the surface facility where waste handling activities will take place. The WHB has a total area of approximately 84,000 square feet (ft^2) (7,803 square meters [m^2]) of which 33,175 ft^2 (3,083 m^2) are designated for the waste handling and container storage of CH TRU mixed waste, and 21,318 ft^2 (1,981 m^2) are designated for the waste handling and container storage of RH TRU mixed waste. These areas are being permitted as a container storage unit. The concrete floors are sealed with an impermeable coating that has excellent resistance to the chemicals in TRU mixed waste and, consequently, provide secondary containment for TRU mixed waste. In addition, a parking area south of the WHB will be used for storage of waste in sealed shipping containers awaiting unloading. This area is also being permitted as a container storage unit. The sealed shipping containers provide secondary containment in this HWMU.

CH Bay and RH Bay Operations

The maximum processing rate for CH waste is 14 TRUPACT-IIs per day. Two shifts per day are planned; four days per week. The fifth day is for equipment maintenance with weekends available for more extensive maintenance, when necessary.

Once unloaded from the TRUPACT-IIs, CH waste containers (7-packs or SWBs) are placed in one of two positions on the facility pallet. The 7-packs or SWBs are stacked, as they arrive in the TRUPACT-II, on the facility pallets (one- or two-high, depending on weight considerations). The use of facility pallets will elevate the waste approximately 6 inches (in.) (15 centimeters [cm])

from the floor surface. Pallets of waste will then be relocated to the northeast area of the CH bay for normal storage. This storage area will be clearly marked to indicate the lateral limits of the storage area. This storage area will have a maximum capacity of seven facility pallets of waste during normal operations. These pallets will typically be staged in this area for a period of one to four days.

In addition, four TRUPACT-IIs, containing up to eight 7-packs or SWBs, may occupy the staging positions at the TRUPACT-II Unloading Docks (TRUDOCK).

The amount of RH TRU mixed waste disposal planned is two canisters per day, or eight per week, on the same shifts as CH waste operations.

During normal operations, a maximum of five RH canisters will be stored in the Hot Cell and a maximum of seven canisters will be stored in the Transfer Cell. The combined storage capacity of the Hot Cell and the Transfer Cell is 77 ft^3 (2.18 m^3). The floor and wall coatings provide an impermeable surface that serves as secondary containment in the Hot Cell and the Transfer Cell. The storage positions that hold the canisters have openings and stand-offs which keep the canisters from standing in liquid.

Aisle space shall be maintained in all CH Bay waste storage areas. The aisle space shall be adequate to allow unobstructed movement of fire response personnel, spill-control equipment, and decontamination equipment that would be used in the event of an off-normal event. An aisle space between facility pallets will be maintained in all CH TRU waste storage areas. Aisle space requirements shall not be met for RH canisters, since only one is expected to be processed at a time. Because of the high radiation fields, inspections and cleanup of spills and releases will not be conducted while waste is located in these storage areas. If a release were to occur, all waste canisters would be removed from the Hot Cell prior to initiating any clean up activities.

Parking Area

The area extending south from the WHB across the rail sidings is defined as the parking area container storage unit. This area provides space for 12 loaded TRUPACT-IIs and three loaded road casks or four rail casks, corresponding to 1,536 ft^3 (43.5 m^3) of CH waste and 125.6 ft^3 (3.56 m^3) of RH waste. Secondary containment and protection of the waste containers from standing rainwater are provided by the transportation containers.

The maximum number of TRUPACT-IIs that will be stored in the parking area is 20 percent of the TRUPACT-II fleet. This is equivalent to 12 TRUPACT-IIs, containing a maximum of 24 SWBs or 168 drums of CH waste. The TRUPACT-II safety criteria require that they be opened and vented at a frequency of at least once every 60 days. In addition, three road casks or four rail casks containing RH waste may be stored in this area. During normal operations the maximum residence time of any one container in the parking area storage area is four days. Therefore, during normal waste handling operations, TRUPACT-IIs will not require venting while located in the parking area storage area. Any off-normal event that drives residence times to 60 days or

greater in this storage area shall be mitigated by returning the shipment to the generator prior to the expiration of the 60 day NRC venting period or by moving the TRUPACT-IIs or casks inside the WHB where the waste will be removed and placed in one of the permitted storage areas.

Off-Normal Events

Off-normal events could interrupt normal operations in the waste management process line. Additional storage capacity is available on the west side of the CH bay for use during off-normal events. If such off-normal events occur, the New Mexico Environment Department (NMED) will be informed of: 1) how much waste is to be stored, 2) where the waste will be placed, 3) how any applicable secondary containment requirements will be met, and 4) how long the waste is expected to be located in the designated storage area. Waste stored in this area will be inspected at a frequency of at least once weekly, with the exception of the Hot Cell and the Transfer Cell, as previously noted. Any off-normal storage of hazardous waste, beyond the capacity of the WHB permit, will occur under an emergency permit issued by NMED under 20 NMAC 4.1, Subpart IX,§270.61. The DOE will not store RH waste at the facility outside the shipping cask beyond the permitted capacity of the Hot Cell and transfer cell.

Shipments of waste from the generator sites will be stopped in any event which results in an interruption to normal waste handling operations that exceeds three days. This will minimize the potential for large quantities of waste requiring storage in the parking area for extended periods of time.

Containment

The WHB has concrete floors, which are sealed with an impermeable coating that resists all but the strongest oxidizing agents. Such oxidizing agents do not meet the WAC and will not be accepted in TRU mixed waste at the WIPP facility. Therefore, TRU mixed wastes pose no compatibility problems with respect to the WHB floor.

During normal operations, the floor of the normal storage areas within the CH Bay shall be visually inspected on a weekly basis to verify that it is in good condition and free of cracks and gaps. Floors in the Hot Cell and the Transfer Cell can only be inspected when no waste is present. Inspections will occur at least annually when these areas undergo routine maintenance. However, limited camera inspections can be conducted when the Hot Cell contains waste. This less frequent inspection schedule is justified because of the high radiation fields that are present when waste is present and because these floors are not subjected to vehicle traffic.

Floor areas of the WHB used during off-normal events will be inspected prior to use and weekly while in use. Containers located in the permitted storage areas shall be elevated from the surface of the floor. Facility pallets provide about 6 in (15 centimeters [cm]). of elevation. Waste

containers that have been removed from TRUPACT-II shipping containers shall be stored at a designated storage area inside the WHB so as to preclude exposure to the elements.

Secondary containment at permitted storage areas inside the WHB shall be provided by the floor. These areas include the CH Bay floor, the Hot Cell, and the Transfer Cell. The parking area and TRUDOCKs do not require engineered secondary containment, since waste is not stored there unless it is protected by the TRUPACT-II shipping containers or the road casks. Floor drains, the fire suppression water collection sump, and portable dikes, if needed, will provide containment for liquids that may be generated by fire fighting. Sump capacities and locations are shown in Drawing 41-F-087-014. Residual fire fighting liquids will be placed in containers and managed as described above.

G-2 Response Personnel

Persons qualified to act as the RCRA Emergency Coordinator, as required by 20 NMAC 4.1, Subpart V, §264.55, are listed in Table G-2.

A RCRA Emergency Coordinator will be on-site at the WIPP facility 24 hours a day, seven days a week, with the responsibility for coordinating emergency response measures. RCRA Emergency Coordinators are listed in Table G-2, where five individuals have been designated primary RCRA Emergency Coordinators. This is because the on-duty Facility Shift Manager (FSM) is designated as the RCRA Emergency Coordinator. The five individuals shown serve as FSM on a rotating shift basis.

Persons qualified to act as the RCRA Emergency Coordinator are thoroughly familiar with this Contingency Plan, the TRU mixed waste and hazardous waste operations and activities at the WIPP facility, the locations of TRU mixed waste and hazardous waste activities, the locations on the site where hazardous materials are stored and used, and the locations of waste staging and accumulation areas. They are familiar with the characteristics of hazardous substances, TRU mixed waste and hazardous waste handled at the WIPP facility, the location of TRU mixed waste and hazardous waste records within the WIPP facility, and the facility layout. In addition, persons qualified to act as the RCRA Emergency Coordinator have the authority to commit the necessary resources to implement this Contingency Plan. Figure G-4 outlines the RCRA Emergency Coordinator's position relative to other organizations that provide support.

In addition to the RCRA Emergency Coordinator, the following individuals or groups have specified responsibilities during any WIPP facility emergency:

- Assistant Chief Office Warden (ACOW)—Persons assigned to take accountability for sections of the site, and then reporting the accountability to the Chief Office Warden.

- Central Monitoring Room Operator (CMRO)—The on-shift operator responsible for Central Monitoring Room (CMR) operations, including coordination of facility communications. The facility log is maintained by the CMRO.

- Chief Office Warden (COW)—A predesignated individual with responsibilities for complete surface accountability at staging areas in the event of an evacuation. The Chief Office Warden receives reports from the ACOWs.

- Emergency Response Team (ERT)—Supplemental group trained to respond to surface emergencies, to fight only incipient and exterior structure fires, to provide emergency first aid, and to respond to releases of hazardous waste or hazardous material. ERT members are part of the WIPP Supplemental Emergency Response Program.

- Emergency Services Technician (EST)—Regular employee whose job is that of full-time emergency responder. The EST acts as incident commander (on-scene coordinator) for all emergency response events. During non-emergency conditions, the EST conducts inspections of facility fire suppression systems, inspects emergency equipment, and trains supplemental emergency responders commensurate with duties to be performed. The EST is responsible for completion of specific sections of the "WIPP Hazardous Material Incident Report." Additional technical personnel complete identified sections of the report.

- First Line Initial Response Team (FLIRT)—Supplemental primary responders in the event of a general underground emergency for medical and hazardous material response. No fire response beyond incipient stage will be performed by the FLIRT. The FLIRT also provides backup support for the ERT in the event of a general surface-facility emergency. FLIRT members are part of the WIPP Supplemental Emergency Response Program.

- Mine Rescue Team (MRT)—Supplemental group responsible for underground reentry and rescue after an emergency evacuation. The MRT responds in accordance with 30 CFR Part 49 requirements. MRT members are part of the WIPP Supplemental Emergency Response Program.

- Office Warden—An individual assigned responsibility for assuring that personnel are evacuated from his/her assigned area or building during evacuations. Office Wardens maintain a list of all personnel in their specific area. This list is compared with the physical presence of personnel who assemble at the staging areas. The Office Wardens report area accountability to the ACOWs.

- EOC Staff-The EOC consists of a minimum staff, which includes Waste Isolation Division (WID) management personnel, three Operations representatives, one Environment, Safety, and Health representative (ES&H), and one Emergency

Management representative. The EOC staff can also include technical and logistic support personnel from WID Engineering, WID Public Affairs, WID ES&H, WID Operations, and DOE. Additional administrative support staff is made available from site personnel, these personnel provide message runners, communications, and computer assistance. The EOC is activated by the FSM. Since EOC staff are performing duties similar to their normal job functions and providing support related to their area of expertise, no specific RCRA training is required.

G-3 Implementation

The provisions of this Contingency Plan will be implemented immediately whenever there is an emergency event (e.g., a fire, an explosion, or a natural occurrence that involves or threatens hazardous or TRU mixed wastes or a release of hazardous substances, hazardous materials, or hazardous wastes) that could threaten human health or the environment, or whenever the potential for such an event exists as determined by the RCRA Emergency Coordinator, as required under 20 NMAC 4.1, Subpart V, §264.51(b). The following information is utilized for categorization of events to determine implementation of the contingency plan:

1. Medical Emergencies (does not implement the Contingency Plan)

2. Nonemergency (does not implement the Contingency Plan)

   a. Fire already out, did not involve any hazardous materials.
   b. Spill or release involved materials excluded according to the SARA Title III, Statute 42 U.S.C. 11021 (e). Such as:

      1) Any substance present in the same form and concentration as product packaged for distribution and use by the general public. (Example: Cleaning solutions)
      2) Any substance to the extent it is used in a laboratory under the direct supervision of a technically qualified individual.
      3) Petroleum, including crude oil or any fraction thereof, which is not otherwise specifically listed or designated as a hazardous substance by Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

3. Incident Level I: According to the NFPA 471, Responding to Hazardous Materials Incidents (See Table G-3). If the product(s) involved in the fire, explosion, spill or leakage meets the following criteria, it will be classified as a Level I incident and does not implement the Contingency Plan.

   a. The product does not require a U.S. Department of Transportation (DOT) placard, is a NFPA listed 0 or 1 for all categories, or is Other Regulated Materials A, B, C, or D.

b. The fire is under control and the reactivity rating of the material is less than a rating 2, indicating a low potential for subsequent explosion as the hazardous material can be considered normally stable.
c. There was no release or the release can be confined with readily available resources.
d. There is no life-threatening situation.
e. There is no potential environmental impact.

4. Incident Level II: According to NFPA 471, Responding to Hazardous Materials Incidents, (See Table G-3). If the product(s) involved in the fire, explosion, spill or leakage meets the following criteria, it will be classified as a Level II incident and the Contingency Plan will be implemented by the RCRA Emergency Coordinator.

a. The product requires a DOT placard, is an NFPA 2 for any categories, or is Environmental Protection Agency (EPA) regulated waste (Site-specific: Table G-1 and TRU waste) AND
b. The incident involves multiple packages.
c. There is potential for the fire to spread since the hazardous material's flammability level (rating 2) is below 200 degrees Fahrenheit, or the reactivity (rating 2) indicates that violent chemical changes are possible and thus may be explosive.
d. The release may not be controllable without special resources.
e. The incident requires evacuation of a limited area for life safety.
f. The potential for environmental impact is limited to soil and air within incident boundaries.
g. The container is damaged but able to contain the contents to allow handling or transfer of product.

5. Incident Level III: According to NFPA 471, Responding to Hazardous Materials Incidents. (See Table G-3) If the product(s) involved in the fire, explosion, spill or leakage meet the following criteria, it will be classified as a Level III incident and the Contingency Plan will be implemented by the RCRA Emergency Coordinator.

a. The product is a poison A (gas), an explosive A/B, organic peroxide, flammable solid, material that is dangerous when wet, chlorine, fluorine, anhydrous ammonia, NFPA 3 and 4 for any categories including special hazards, EPA extremely hazardous substances, and cryogenics. (Site specific: RH TRU waste.)
b. The site-specific container size for this incident level will be a tank truck or an RH waste canister.
c. There is potential for the fire to spread since the hazardous material's flammability level (rating 3 or 4) is below 100 degrees Fahrenheit, or the reactivity (rating 3 or 4) indicates that the material may explode.
d. The release may not be controlled even with special resources.
e. The incident requires mass evacuation of a large area for life safety.

f. Even though the NFPA guidelines for this incident level indicate that the potential for environmental impact is severe, due to the site engineering controls for RH Waste, the impact is contained within the HWMUs.
g. The container is damaged to such an extent that catastrophic rupture is possible.

The above categories include fire situations, weather conditions, natural phenomena, and explosions which will have to be evaluated to make an incident level determination. A Level II (potential threat to human health in localized area, potential for moderate on-site environmental impact) or Level III (potential threat to human health in a larger area, potential for severe environmental impact) incident by definition is considered to be a potential threat to human health or the environment and, therefore, is considered to be an emergency requiring activation of the Contingency Plan.

G-4 Emergency Response Method

Methods that describe how and when the WIPP Contingency Plan will be implemented cover the following 11 implementation areas:

1. Notification (Section G-4a)
2. Identification of hazardous materials (Section G-4b)
3. Assessment of the nature and extent of the emergency (Section G-4c)
4. Control, containment, and correction of the emergency (Section G-4d)
5. Prevention of recurrence or spread of fires, explosions, or releases (Section G-4e)
6. Management and containment of released material and waste (Section G-4f)
7. Incompatible waste (Section G-4g)
8. Post-emergency facility and equipment maintenance and reporting (Section G-4h)
9. Container spills and leakage (Section G-4i)
10. Tank spills and leakage (Section G-4j)
11. Surface impoundment spills and leakage (Section G-4k)

G-4a Notification

Notification requirements in the event of an emergency at a RCRA hazardous waste management facility are defined by 20 NMAC 4.1, Subpart V, §§264.56(a) and (d). Necessary

notifications in case of an emergency at the WIPP facility are described in this section (Figure G-4a). Personnel at the WIPP facility are trained to respond to emergency notifications.

Initial Emergency Response and Alerting the RCRA Emergency Coordinator

The first person to become aware of an incident shall immediately report the situation to the CMRO, and provide the following information, as appropriate:

- Name and telephone number of the caller
- Location of the incident and the caller
- Time and type of incident
- Severity of the incident
- Magnitude of the incident
- Cause of the incident
- Assistance needed to deal with or control the incident
- Areas or personnel affected by the incident

In addition to receiving incident reports, the CMRO, who is located in the Support Building (Building 451) (Figure G-1), continuously monitors (24 hours a day) the status of mechanical, electrical, and/or radiological conditions at selected points on the site, both above and below ground. Alarms to indicate abnormal conditions are located throughout the WIPP facility. The alarm(s) (e.g., fire, radiation) may be the first notification of an emergency situation received by the CMRO. The CMRO monitors alarms, takes telephone calls and radio messages, and initiates outgoing calls to emergency staff and outside agencies.

Once the CMRO is notified of a fire, explosion, or a release anywhere in the facility (either by eyewitness or an alarm), the RCRA Emergency Coordinator is immediately notified. Once notified, the RCRA Emergency Coordinator assumes responsibility for the management of activities related to the assessment, abatement, and/or cleanup of the incident.

A RCRA Emergency Coordinator is on-site at all times and, therefore, can be reached at any time via a two-way radio or over the public address (PA) and plectrons on-site. If the RCRA Emergency Coordinator is unavailable or unable to perform these duties, a qualified alternate RCRA Emergency Coordinator is available.

The EST is also notified in case of fire, explosion, or release. The RCRA Emergency Coordinator, in consultation with the EST as incident commander, determines if supplemental emergency responders are necessary. Notification of the ERT (surface) is made by the EST using the ERT pagers. If the EST is unable to make the notifications, the CMRO performs this function. The CMRO will notify the FLIRT using the Mine Page Phone System. If the MRT is needed the RCRA Emergency Coordinator will instruct the CMRO to make a PA announcement for the MRT to assemble in the Mine Rescue Room, located in building 452.

Off-shift personnel may be notified using the on-call list, which is updated weekly by the Emergency Management section of the ES&H Department. The FSM, CMRO, each individual on the on-call list, and WIPP Security receive copies of the on-call list. The CMRO may direct Security to make the notifications.

The response to an unplanned event will be performed in accordance with procedures based on the applicable federal, state, or local regulations and/or guidelines for that response. These include the U.S. Mine Safety and Health Administration (MSHA); NMAC; CERCLA; Chapter 74, Article 4B, New Mexico Statutes Annotated 1978, New Mexico Emergency Management Act; and agreements between the DOE and/or the WIPP MOC and local authorities (Section G-6) for emergencies throughout the WIPP facility.

After notification by the CMRO, the EST shall immediately investigate to determine pertinent information relevant to the actual or potential threat posed to human health or the environment. The information will include the location of release, type, and quantity of spilled or released material (or potential for release due to fire, explosion, weather conditions, or other naturally occurring phenomena), source, areal extent, and date and time of release. The EST shall provide information for classification of the incident, according to the emergency response guidelines, to the RCRA Emergency Coordinator. The RCRA Emergency Coordinator then classifies the incident after evaluation of all pertinent information. This classification must consider both direct and indirect effects of the release, fire, or explosion (e.g., the effects of any toxic, irritating, or asphyxiating gases that are generated, or the effects of any hazardous surface water run-off from water or chemical agents used to control fire and heat-induced explosions).

When the RCRA Emergency Coordinator determines that an Incident Level II or III has occurred, the Contingency Plan is implemented. The RCRA Emergency Coordinator then may choose to activate the EOC for additional support (Figure G-4). If the RCRA Emergency Coordinator determines that due to extenuating circumstances the potential to upgrade to an incident Level II or III exists, the RCRA Emergency Coordinator also may activate the EOC. The EOC will assist the RCRA Emergency Coordinator in mitigation of the incident with use of communications equipment and technical expertise from any WIPP organization (see Section G-4c).

The EOC staff will assess opportunities for coordination and the use of mutual-aid agreements with local outside agencies making additional emergency personnel and equipment available (Section G-6), as well as the use of specialized response teams available through various state and federal agencies. As a DOE facility, the WIPP facility may use the resources available from the Federal Response Plan, signed by 27 federal departments and agencies in April 1987, and developed under the authorities of the Earthquake Hazards Reduction Act of 1977 (42 U.S.C. 7701 et seq.) and amended by the Stafford Disaster Relief Act of 1988. Most resources are available within 24 hours. The WIPP facility maintains its own emergency response capabilities on-site. In addition to the supplemental emergency responders, radiological control technicians, environmental sampling technicians, wildlife biologists, and various other technical experts are available for use on an as-needed basis. The EST will continue as the on-scene incident commander communicating with the RCRA Emergency Coordinator.

Communication of Emergency Conditions to Facility Employees

Procedures for notifying facility personnel of emergencies depend upon the type of emergency. Methods of notification are:

- Local Fire Alarms

  The local fire alarms sound a bell tone and may be activated automatically or manually in the event of a fire.

- Surface Evacuation Signal

  The evacuation signal is a yelp[2] tone and is manually activated by the CMRO when needed. The CMRO shall follow the evacuation signal with verbal instructions and ensure the Site Notification System (i.e., the plectron) has been activated.

- Underground Evacuation Warning System

  The evacuation signal is a yelp tone and flashing strobe light. In the event of an evacuation signal, underground personnel will proceed to the nearest egress hoist station (Section G-7b) to be apprised of the nature of the emergency and the evacuation route to take. Underground personnel are trained to report to the underground assembly areas and await further instruction if all power fails or if ventilation stops. In that event, personnel will remain underground until power can be restored. MSHA requires personnel to be brought to the surface within 60 minutes if a ventilation outage occurs. This is done using the Air Intake Shaft Hoist, powered by the backup electric generators.

- Contingency Evacuation Notification

  If the primary warning system consisting of alarms and signals fails to operate when activated (as in a total power outage and failure of the back-up power systems), WIPP Security will be notified by the CMRO to initiate the contingency evacuation plan. In this event Security officers will alert personnel to evacuate the area and will check trailers, if possible, to ensure that personnel have been alerted/evacuated.

WIPP facility personnel are trained and given instruction during General Employee Training to recognize the various alarm signals and the significance of each alarm. WIPP facility employees and site visitors are required to comply with directions from emergency personnel and alarm

[2]The yelp tone increases from 500 to 1,000 hertz and drops to 500 hertz.

system notifications and to follow instructions concerning emergency equipment, shutdown procedures, and emergency evacuation routes and exits.

Notification of Local, State, and Federal Authorities

If it is determined that the facility has had a fire, an explosion, a spill, or a release of hazardous waste or hazardous waste constituents (included in 20 NMAC 4.1, Subpart II) in the miscellaneous unit or TRU mixed waste handling areas, or an emergency resulting in a release of a hazardous substance (included in 40 CFR §302.4 and §302.6 or the New Mexico Emergency Management Act, §74-4B-3 and §74-4B-5) that could threaten human health or the environment outside the facility, the RCRA Emergency Coordinator, after consultation with the DOE, will assure that local authorities are notified by telephone and/or radio, including:

- Carlsbad Police Department (telephone number: [505] 885-2111) (or 911)
- Carlsbad Fire Department (telephone number: [505] 885-2111) (or 911)
- Eddy County Sheriff (telephone number: [505] 887-7551)
- Hobbs Fire Department (telephone number: [505] 397-9308)

After local authorities are notified, the RCRA Emergency Coordinator will ensure notification of the following:

- New Mexico Environment Department (NMED)
  Department of Public Safety
  24-Hour Emergency Reporting Telephone Number: (505) 827-9329
  FAX number: (505) 827-9368

- Department of Public Safety WIPP Coordinator
  Telephone Number: (505) 827-9221
  FAX number: (505) 829-3434

- Hazardous Materials Emergency Response, Chemical Safety Office, Department of Public Safety, State Emergency Response Commission
  Telephone number: (505) 827-9223
  FAX number: (505) 829-3434

- National Response Center
  Telephone number: 1-800-424-8802
  FAX number: (202) 479-7181

- Local Emergency Planning Committee
  Telephone number: (505) 887-9511
  Fax number: (505) 887-1039

The first notification of public safety and regulatory agencies will include the following:

- The name and address of the facility and the name and phone number of the reporter
- The type of incident (fire, explosion, or release)
- The date and time of the incident
- The type and quantity of material(s) involved, to the extent known
- The exact location of the incident
- The source of the incident
- The extent of injuries, if any
- Possible hazards to human health and the environment (air, soil, water, wildlife, etc.) outside the facility
- The name, address, and telephone number of the party in charge of or responsible for the facility or activity associated with the incident
- The name and the phone number of the RCRA Emergency Coordinator
- The identity of any surface and/or groundwater involved or threatened and the extent of actual and potential water pollution
- The steps being taken or proposed to contain and clean up the material involved in the incident

The RCRA Emergency Coordinator will also be available to advise the appropriate local, state, or federal officials on whether or not local areas should be evacuated.

Notification of the General Public

Immediate notification of the general public through the public safety and emergency agencies listed above will be made by, or under the direction of, the RCRA Emergency Coordinator following an evaluation to determine if local adjacent areas need to be evacuated. This evaluation will be made in consultation with the DOE who has management responsibility for the land withdrawal area. DOE policy is to provide accurate and timely information to the public by the most expeditious means possible concerning emergency situations at the WIPP site that may affect off-site personnel, public health and safety, and/or the environment. A DOE Carlsbad Area

Office (DOE/CAO) Management representative is always on-call. This person is available by pager or telephone 24 hours a day.

A Hazards Assessment was conducted, which indicated no need for protective actions or emergency action levels, as defined by the DOE, for the facility. Therefore, no procedures are in place for evacuation of the public. Procedures are in place for notification of the public by radio, television, and newspapers for news items which might include notification of on-site emergency situations. These procedures include a Public Affairs Coordinator in the EOC who writes and transmits press releases to the Greene Street facility, where formal press conferences are conducted.

G-4b Identification of Hazardous Materials

The identification of hazardous wastes, hazardous waste constituents, or hazardous materials involved in a fire, an explosion, or a release to the environment is a necessary part of the assessment of an incident, as described in 20 NMAC 4.1, Subpart V, §264.56(b). RCRA hazardous waste and hazardous substances and materials listed in 40 CFR §302.4 and §302.6 or New Mexico Emergency Management Act, §74-4B-3 and §74-4B-5 and, involved in any release at the WIPP facility will be identified. The identification of likely hazardous materials at any location is enhanced because hazardous materials and hazardous waste are only stored or managed in specified locations throughout the WIPP facility. An attempt will be made to identify products involved by occupancy/location, container shape, markings/color, placards/labels, United Nations/North America/Product Identification Number, on-site technical experts, or field sampling. Further, the ES&H department maintains an updated inventory of hazardous materials/substances that are brought on site, and a master MSDS listing in the Safety and Emergency Services Facility, Building 452.

Sources of information available to identify the hazardous wastes, substances, or materials involved in a fire, an explosion, or a release at the WIPP facility include operator/supervisor knowledge of their work areas, materials used, and work activities underway; the WIPP Waste Information System (WWIS), which identifies the location within the facility of emplaced TRU mixed waste, including emplaced derived waste; and waste manifests and other waste characterization information in the operating record. The WWIS also includes information on wastes that are in the waste handling process. Also available are MSDSs for hazardous material in the various user areas throughout the facility, waste acceptance records, and materials inventories for buildings and operating groups at the WIPP facility. Information or data from the derived waste accumulation areas, the hazardous waste staging area, satellite staging areas, and nonregulated waste accumulation areas are included.

TRU mixed waste received by the WIPP facility during the Disposal Phase will be characterized for hazardous constituents prior to receipt, and acceptable knowledge will be used to characterize derived waste prior to emplacement.

Information required for identifying TRU mixed hazardous constituents in case of an incident is readily available through the WWIS and the waste acceptance records. Waste accepted at WIPP is already known to be compatible with all materials used to respond to an emergency. All non-TRU waste materials received on site, other than those listed in Table G-1, are in such small quantities that no reaction could develop which would trigger an Incident Level II or III response.

The RCRA Emergency Coordinator will have access to the WWIS through Waste Operations, and any personal computer connected to the site network, if any specific information is needed.

The RCRA Emergency Coordinator has access to the inventory lists and MSDSs in the Safety and Emergency Services Facility at all times.

G-4c Assessment of the Nature and Extent of the Emergency

Once the required notifications have been made, the RCRA Emergency Coordinator will ensure that the identity, exact source, amount, and areal extent of any released materials are determined, as required under 20 NMAC 4.1, Subpart V, §264.56(b). The RCRA Emergency Coordinator will determine whether the occurrence constitutes an emergency based on knowledge of the area and access to the waste identification/characterization information described in Section G-4b. An emergency will require response by only trained emergency response personnel. The RCRA Emergency Coordinator will be responsible for responding to immediate and potential hazards, using the services of trained personnel to determine: 1) the identity of hazardous wastes, hazardous waste constituents, and other hazardous materials involved in a release, as described in Section G-4b; 2) whether or not a release involved a reportable quantity of a hazardous substance; 3) the areal extent of a release; 4) the exact source of a release; and 5) the potential hazards to human health or to the environment.

After the materials involved in an emergency are identified, the specific information on the associated hazards, appropriate personal protective equipment (PPE), decontamination, etc., will be obtained from MSDSs and from appropriate chemical reference materials at the same location. These information sources may be accessed by the RCRA Emergency Coordinator or through several WIPP facility organizations, including Industrial Safety; Environmental Compliance and Support, both part of the ES&H department; and Hazardous Waste Operations Sections. Any other organization's expertise can also be utilized.

The emergency assessment requires determination of hazards involving evaluation of several criteria, including:

- Exposure: magnitude of actual or potential exposure to employees, the general public, and the environment; duration of human and environmental exposure; pathways of exposure

- Toxicity: types of adverse health or environmental effects associated with exposures; the relationship between the magnitude of exposure and adverse effects

- Reactivity: hazardous materials or hazardous wastes, which are not TRU mixed wastes, involved in an incident will be assessed for reactivity through accessing the MSDSs for the affected material and the recommended method(s) for managing such waste

- Uncertainties: considerations for undeterminable or future exposures; uncertain or unknown health effects, including future health effects

G-4d Control, Containment, and Correction of the Emergency

The WIPP facility is required to control an emergency and to minimize the potential for the occurrence, recurrence, or spread of releases due to the emergency situation, as described in 20 NMAC 4.1, Subpart V, §264.56 (e). The WIPP Emergency Response procedures utilize the incident mitigation guidelines in NFPA 471, Responding to Hazardous Materials Incidents, with initial response priority being on control, and those actions necessary to ensure confinement and containment (the first line of defense) in the early, critical stages of a spill or leak. The RCRA Emergency Coordinator is responsible for stopping processes and operations when necessary, and removing or isolating containers. TRU waste will remain within the WHB, parked TRUPACT-II containers, road casks, and the underground HWMU.

All Emergencies

The WIPP Emergency Response procedures include, but are not limited to, the following actions appropriate for control:

1. Isolate the area from unauthorized person by fences, barricades, warning signs, or other security and site control precautions. Isolation and evacuation distances vary, depending upon the chemical/product, fire, and weather situations.
2. Identify the chemical/product according to Section G-4b.
3. Drainage controls.
4. Stabilization of physical controls (such as dikes or impoundment[s]).
5. Capping of contaminated soils to reduce migration.
6. Using chemicals and other materials to retard the spread of the release or to mitigate its effects.
7. Excavation, consolidation, removal, or disposal of contaminated soils.
8. Removal of drums, barrels, or tanks where it will reduce exposure risk during situations such as fires.

If the facility stops operations in response to a fire, explosion, or release, the RCRA Emergency Coordinator must ensure continued monitoring for leaks, pressure buildup, gas generation, or

ruptures in valves, pipes, or other equipment, wherever appropriate. If operations continue, personnel normally assigned to these tasks will continue.

Both natural and synthetic methods will be employed to limit the releases of hazardous materials so that effective recovery and treatment can be accomplished with minimum additional risk to human health or the environment. A combination of the above methods to achieve protection of human health and the environment, with emphasis on two basic methods for mitigation of hazardous materials incidents - Physical and Chemical (Tables G-4, G-5) mitigation, will be used.

1. Physical methods of control involve any of several processes to reduce the area of the spill leak, or other release mechanism (such as fire suppression).

   A. Absorption is the process in which materials hold liquids through the process of wetting. Absorption is accompanied by an increase in the volume of the sorbate/sorbent system through the process of swelling. Some of the materials utilized in response to Level I incidents or Level II incidents involving liquids will be absorbent sheets of polyolefin-type fibers, spill control bucket materials (specifically for solvents, neutralization, or for acids/caustics), and absorbent socks for general liquids or oils.

   B. Covering refers to a temporary form of mitigation for radioactive incidents that will be utilized in response to Level II or Level III incidents involving TRU waste. These could include absorbent sheets, plastic, or actual ambulance blankets.

   C. Dikes or Diversions refer to the use of physical barriers to prevent or reduce the quantity of liquid flowing into the environment. Dikes may be soil or other barriers temporarily utilized to hold back the spill or leak. Diversion refers to the methods used to physically change the direction of the flow of the liquid. Absorbent socks or earth may be utilized as dikes or diversions for all levels of incidents.

   D. Overpacking is accomplished by the use of an oversized container. Overpack containers will be compatible with the hazards of the materials involved.

   E. Plug and Patch refers to the use of compatible plugs and patches to reduce or temporarily stop the flow of materials from small holes, rips, tears, or gashes in containers. A Series A hazardous response kit containing nonsparking equipment to control and plug leaks may be utilized for response to all levels of incidents.

   F. Transfer refers to the process of moving a liquid, gas, or some forms of solids, either manually or by pump, from a leaking or damaged container.

Scoops, shovels, jugs, and pails as well as drum transfer pumps for chemical and petroleum transfer are utilized as needed in response to all levels of incidents.

G. Vapor Suppression refers to the reduction or elimination of vapors emanating from a spilled or released material through the most efficient method or application of specially designed agents such as an aqueous foam blanket.

2. Chemical Methods of Mitigation

A. Neutralization is the process of applying acids or bases to a spill to form a neutral salt. The application of solids for neutralizing can often result in confinement of the spilled material. This would include using the neutralizing adsorbents.

B. Solidification is the process whereby a hazardous liquid is added to material such as an absorbent so that a solid material results.

The established procedures are based upon the incident level and a graded approach for nonradioactive, CH, or RH waste emergencies and initiated to:

1. Minimize contamination or contact (through PPE, etc.)
2. Limit migration of contaminants
3. Properly dispose of contaminated materials

Fire

The incident level emergency response identified in Section G-3 includes fire/explosion potential. WIPP fire response will be limited to incipient and exterior structure fires unless directed otherwise by the EST as part of a rescue life saving attempt. For internal structure fires, the Memoranda of Understanding (MOU) may be utilized.

The first option in mine fire response will be to apply mechanical methods to stop fires (e.g., cut electrical power). The last option in mine fire response will be to reconfigure ventilation. The following actions are implemented in the event of a fire:

1. All emergency response personnel at an incident will wear appropriate PPE.

2. Only fire extinguishing materials that are compatible with the materials involved in the fire will be used to extinguish fires. Compatibility with materials involved in a fire are determined by pre-fire plans, Emergency Response Guide Book (DOT, 1993), DOT labeling, and site-specific knowledge of the emergency response personnel. Water and dry chemical materials have been determined to

be compatible with all components of the TRU mixed waste. Pre-fire plans for the WHB are included in Figures G-10 and G-11.

Fires in areas of the WHB should not propagate, due to limited amount of combustibles, and the concrete and steel construction of the structures. Administrative controls, such as landlord inspections and EST inspections, help to insure good housekeeping is maintained. Combustible material and TRU mixed waste will be isolated, if possible. Firewater drain trenches collect the water and channel it into a sump. In areas not adjacent to the trenches, portable absorbent dikes (pigs) will be used to retain as much as possible, until it can be transferred to containers or sampled and analyzed for hazardous constituents. The co-detection principle (Appendix I3) is used.

3. If the fire spreads or increases in intensity, personnel will be directed to evacuate.

4. The RCRA Emergency Coordinator will remain in contact with responding personnel to advise them of the known hazards.

5. In order to ensure that storm drains and/or sewers do not receive potentially hazardous runoff, dikes will be built around storm drains to control discharge as needed. Collected waste will be sampled and analyzed for hazardous constituents, if possible, before being discharged to evaporation ponds. There are two ponds south of the security fence, opposite the WHB, that will collect drainage from the parking area. The rest of the site, inside the security fence, drains to the large pond to the west. Samples will be taken from these ponds, after the emergency has been abated, to determine any cleanup requirements. The WIPP Sampling Plan will be used.

6. The RCRA Emergency Coordinator maintains overall control of the emergency and may accept and evaluate the advice of WIPP facility personnel and emergency response organization members, but retains overall responsibility. Selection of methods and tactics of fire response is the responsibility of the Incident Commander.

7. The RCRA Emergency Coordinator will be in overall control of WIPP facility emergency response efforts until the emergency is terminated.

8. Materials involved in a fire can be identified in the following ways:

   - According to Section G-4b.

   - If the contents of the waste container cannot be determined based on its location and the label is destroyed by fire, the material will be treated as an unknown, evaluated for radiological contamination, and analyzed

according to methods in the EPA's "Test Methods for Evaluating Solid Waste Physical/Chemical Methods" (SW-846), Third Edition, after the fire has been extinguished.

- Airborne radioactivity samples may be obtained during a fire involving radioactive materials, using portable and fixed air samplers. Response personnel will be adequately protected from airborne radioactivity by their PPE required for fire response.

9. Only materials compatible with the waste may be used for fire response.

10. When cleanup has proceeded to the point of finding no radionuclide activity, then the "swipe" can be sent for analysis for hazardous constituents. The use of these confirmation analyses is as follows:

    - For waste containers, once radiologically clean and free of any visible evidence of hazardous waste spills on the container, it will be placed in the underground without further action.

    - For area contamination, once the area is cleaned up and is shown to be radiologically clean, it will be sampled for the presence of hazardous waste residues (for further information see Section G-4d, Emergency Termination Procedures).

11. Fire suppression materials used in response to incidents will be retained on-scene, where an evaluation will be performed to determine appropriate recovery and disposal methods.

Explosion

The following actions will be implemented in the event that an explosion that involves or threatens hazardous or TRU mixed waste or hazardous materials has occurred:

1. The area will be evacuated immediately.

2. The CMRO will immediately notify the appropriate emergency response personnel and the RCRA Emergency Coordinator about the explosion.

3. The Incident Commander will ensure that any injured personnel are treated and transported as necessary.

4. The RCRA Emergency Coordinator will remain in contact with responding personnel to advise them of the known hazards involved and the degree and location of the explosion and associated fires.

5. The RCRA Emergency Coordinator will be in command and may accept and evaluate the advice of WIPP facility personnel and emergency response organization members, but retains the overall responsibility. Selections of methods and tactics of response are the responsibility of the Incident Commander.

6. The RCRA Emergency Coordinator will be in overall control of WIPP facility emergency response efforts until the emergency is terminated.

7. When cleanup has proceeded to the point of finding no radionuclide activity, then samples may be taken for chemical analysis if there is visible evidence to suspect additional hazardous waste residues. Chemical residues on floor surfaces resulting from a hazardous waste explosion will be evaluated, sampled, analyzed (if required), isolated, and returned to appropriate containers, and surfaces will be cleaned using appropriate cleaners.

8. The RCRA Emergency Coordinator may shut down operational units (e.g., process equipment and ventilation equipment) that have been affected directly or indirectly by the explosion. Once the areas have been determined safe for reentry, processes may be reactivated.

Spills

Protection of response personnel at a hazardous material incident is paramount. The primary methods to protect personnel are time, distance, and shielding. If a Level II or III incident exists, the RCRA Emergency Coordinator will implement the following actions:

1. The immediate area will be evacuated.

2. The RCRA Emergency Coordinator will review facility records to determine the identity and chemical nature of released material.

3. Entry team procedures will be utilized, with special attention to the following:

   - Buddy system
   - Appropriate PPE
   - Backup rescue team
   - Supplemental communication signals (hand signals and hand-light signals)
   - Monitoring equipment
   - Exposure time limitations

4. If possible, the source of the release will be secured.

5. A dike to contain runoff may be built.

6. Emergency responders will ensure that storm drains and/or sewers do not receive potentially hazardous runoff or spilled material. They may build dikes around storm drains to control discharge.

7. Released wastes may be collected and contained by stabilizing or neutralizing the spilled material, as appropriate, pouring an absorbent over the spilled material, and sweeping or shoveling the absorbed material into drums or other appropriate containers. The absorbents have been determined to be compatible with all components of the TRU mixed waste.

8. No TRU mixed waste that may be incompatible with the released material will be managed in the affected area until cleanup procedures are complete.

9. The RCRA Emergency Coordinator will direct spill control, decontamination, and termination procedures described below.

Decontamination of Personnel

Decontamination of personnel with radioactive contamination is the responsibility of the Radiological Control (RC) section. If a person is contaminated with radioactivity during a site evacuation to the staging areas, the contaminated area will be covered before the person can be moved (under escort by RC personnel) to the staging area. The RC personnel will ensure the contaminated person remains segregated from other site personnel while under RC supervision.

In the event of an emergency that requires immediate evacuation of the area, the contamination can be covered by any method warranted, given the circumstance (e.g., clean clothing wrapped around the area). If the size of the radioactive contamination on the body is small and localized, it can be covered with clothing (e.g., glove, shoe cover, coveralls). If the size of the radioactive contamination on the body is large, it will be covered by dressing the individual in a full set of Anti-Contamination clothing (coveralls, hood, gloves, shoe covers, etc.).

If time and location permit and the contamination is on the face, it will be decontaminated immediately using a cloth moistened with tepid water (and a mild detergent, if necessary). If the size of the radioactive contamination on the individual's body is small and localized, it will be decontaminated using the same method as for the face, but after the individual has been transferred to an area appropriate for conducting decontamination.

If the individual is transferred to the staging area prior to decontamination, he/she will be decontaminated at:

- The portable decontamination shower (moved to the staging area),
- The decontamination trailer (moved to the staging area), or
- A temporary controlled area posted by RC personnel.

A portable shower is normally stored in the WHB. The decontamination trailer is stored in the northeast corner of the fenced parking area, adjacent to the WHB.

Control of Spills or Leaking or Punctured Containers of CH TRU Mixed Waste

In the event of spills or leaking or punctured containers of CH TRU mixed waste, the WIPP responds in three distinct phases: 1) the event, 2) the re-entry, and 3) the recovery.

1. During the event, the following immediate actions are completed: 1) stop work, 2) warn others (notify CMR), 3) isolate the area, 4) minimize exposure, and 5) close off unfiltered ventilation. These actions can take place simultaneously, as long as they are completed before proceeding to the re-entry phase.

2. During the re-entry phase, a Radiological Work Permit (RWP) is written for personnel to enter with protective clothing to assess the conditions, take surveys and samples, and mitigate problems that could compound the hazards in the area (cover up spilled material with plastic material sheeting and or any approved fixatives such as polyvinyl alcohol (PVA) or paint, place equipment in a safe configuration, etc.). Smears and air sample filters are counted. This information is used by cognizant managers, RC personnel, and As Low As Reasonably Achievable (ALARA) Committee representatives to determine an appropriate course of action to recover the area. A plan to decontaminate and recover affected areas and equipment will be approved with a RWP written to establish the radiological controls required for the recovery.

3. During the recovery phase, the plan will be executed to utilize the necessary resources to conduct decontamination and/or overpacking operations as needed. The completion of this phase will occur prior to returning the affected area and/or equipment to normal activities. The recovery phase will include activities to minimize the spread of contamination to other areas. These activities will involve placing the waste material in another container; vacuuming the waste material; overpacking the spilled, leaking, or punctured waste container; an or decontaminating the affected area(s). If an affected surface cannot be decontaminated to releasable levels, it may be covered with a fixative coating and established as a Fixed Contamination Area to prevent spread of contamination in accordance with Article 222.3 of WP 12-5, WIPP Radiological Control Manual, or it may be removed using heavy machinery and tools, packaged in approved waste containers, and emplaced in the underground. Every reasonable effort to minimize the amount of derived waste, while providing for the health and safety of personnel, will be made.

   Should a breach of a waste container occur at the WIPP that results in external contamination exceeding the small area "spot" decontamination levels, the affected container(s) (e.g., breached and contaminated) will be placed into an

available overpack container (e.g., 85-gal drum, SWB, TDOP, canister overpack). The decontamination of equipment and the overpacking of contaminated/damaged waste containers will be performed in the vicinity of the incident. For example, under normal operations waste will be handled only in the areas of the WHB for which a permit is being sought. Therefore, it is within these same areas that decontamination and/or overpacking operations would occur. By eliminating the transport of contaminated equipment to other areas for decontamination or overpacking, the risk of spreading contamination is reduced.

Equipment used during a spill cleanup or overpacking operation could include: cloths, brushes, scoops, absorbents, squeegees, tape, bags, pails, slings, hand tools, and others as needed for a given incident.

At the underground emplacement room, salt contaminated by a spill of TRU waste would be either covered or cleaned up, depending on location, extent, and spilled material, due to potential radioactive contamination spread via the salt dust. The contaminated salt would be covered, in accordance with Article 222.3 of WP 12-5, WIPP Radiological Control Manual, to isolate it from the workers, and the stacking of waste containers would resume or would be removed and packaged as site-derived waste using damp rags, hand tools and HEPA filtered vacuums.

The decontamination methods will initially involve wiping down structures, equipment, and other containers in the area with absorbent cloths moistened with tepid water. Surveys of these structures will take place and the need to continue decontamination activities will be established. If further decontamination is required, nonhazardous decontaminating agents, such as Liquinox©, Simple Green©, Windex©, citric acid, Bartlett Strip Coat©, and high pressure CO_2 will be used to prevent generating mixed waste.

RWPs and other administrative controls provide protective measures to help ensure that new hazardous constituents will not be added during decontamination activities.

Certain structures and/or equipment may be disassembled to facilitate decontamination or may be placed directly into a derived waste container. Items used in the spill cleanup and decontamination operations (e.g., swipes, tools, PPE, etc.) may also be placed into a derived waste container.

When decontamination is deemed by the recovery team to be complete, RC personnel will conduct one final, intensive radcon survey of the area and components in the area to release it for uncontrolled use. The free release criteria for items, equipment, and areas is < 20 dpm/100 cm^2 for alpha radioactivity and < 200 dpm/100 cm^2 for beta-gamma radioactivity. After cleanup is complete, facility personnel will complete an inspection and include the details of the spill and cleanup in the log.

Control of Spill or Leaking or Punctured Containers of RH TRU Mixed Waste

In the event a contaminated RH TRU waste canister is received, WIPP responds in three distinct phases: 1) the event, 2) the re-entry, and 3) the recovery. The RH canister is checked for surface contamination once it is withdrawn from the road cask to the Hot Cell and before it is placed in the transfer car to await emplacement in the underground.

1. Unlike CH waste, the RH waste canisters, by virtue of being in the Hot Cell, are isolated from personnel. If contamination is detected on the surface of an RH canister, it is placed in an overpack canister, plugged, and seal welded. The overpack canister is then placed in the transfer car to await emplacement in the underground. The CMR is notified and the waste handling and radiological control groups prepare a RWP for entry into the Hot Cell for contamination surveys and cleanup.

2. Once a RWP is written and the Hot Cell is devoid of RH canisters, personnel enter with protective clothing to assess the conditions, take surveys and smears, and record results. Results are utilized by cognizant managers, RC personnel and ALARA Committee representatives to determine the appropriate course of action to recover the area. A plan to decontaminate and recover affected areas and equipment will be approved with a RWP written to establish the radiological controls required for the recovery.

3. During the recovery phase, the plan will be executed to utilize the necessary resource to conduct decontamination and/or fixing operations as needed. The completion of this phase will occur prior to returning the affected area and/or equipment to normal activities. All accessible areas are decontaminated to releasable levels, or may be covered with a fixative coating and established as a Fixed Contamination Area to prevent the spread of contamination in accordance with Article 222.3 of WP 12-5, WIPP Radiological Control Manual.

   Equipment used during recovery could include: cloths, brushes, absorbent, squeegees, tape, bags, pails, slings, hand tools, and others as needed for a given incident.

The decontamination methods will initially involve wiping down structures and equipment in the area with absorbent cloths moistened with tepid water. Surveys of structures will be utilized to determine the need to continue decontamination activities. If further decontamination is required, nonhazardous decontaminating agents such as, Liquinox©, Simple Green©, Windex©, citric acid, Bartlett Strip Coat©, and high pressure CO_2, will be used to prevent generating mixed waste.

RWPs and other administrative controls provide protective measures to help ensure that new hazardous constituents will not be added during decontamination activities.

Certain structures and/or equipment may be disassembled to facilitate decontamination, contamination fixing, or may be placed directly into a derived waste container. Items used in recovery operations (e.g., swipes, tools, PPE, etc.) may also be placed into a derived waste container.

When recovery is deemed by the recovery team to be complete, RC personnel will conduct one final, intensive radcon survey of the area and components in the area to release it for uncontrolled use. The free release criteria for items, equipment, and areas is <20 dpm/100 cm^2 for alpha radioactivity and <200 dpm/100 cm^2 beta-gamma radioactivity.

After cleanup is complete, facility personnel will complete an inspection and include the details of the spill and cleanup in the inspection log.

Natural Emergencies

After a natural emergency (earthquake, flood, lightning strike, etc.) that involves hazardous waste or hazardous materials, the FSM will ensure the following actions are taken:

1. Inspect containers and containment for signs of leakage or damage. Inspect areas where containers are stored looking for leaking containers and for deterioration of containers and the containment system.

2. Inspect affected equipment or areas associated with hazardous waste management activities for proper operating mode in accordance with site procedures and manually check to ensure automatic and alarmed features on the units are working.

3. Inspect affected equipment or areas within the HWMUs in accordance with site procedures for damage.

4. Inspect electrical boards and overhead electrical lines for damage.

5. Check container areas for signs of leakage or damage to drums and containers.

6. Check affected buildings and fencing directly related to hazardous waste management activities for damage.

7. Conduct a general survey of the site looking for signs of land movement, etc.

8. Take any necessary corrective measures, however temporary, to rectify potential or real problems.

9. Record inspection results.

Roof Fall

There is no reason to believe that a roof fall will occur without prior knowledge, due to the design and operation of the WIPP total ground-control program. No roof-falls have occurred to date, a 14 year period, without significant prior knowledge.

The WIPP underground is routinely evaluated for stability and safety of the underground openings. These evaluations can be as simple as the MSHA required visual checks by personnel working in the area or as extensive as the expert review of the roof support system for Room 1 Panel 1 conducted in 1991. An in-depth evaluation of all of the accessible underground is performed on an annual basis as part of the formal ground control operating plans. Weekly visual and sounding inspections are performed by the Mining Operations personnel. More frequent inspections and evaluations are performed in areas where roof or ribs are in need of evaluations, based on visual observations by Geotechnical Engineering and Mining Operations personnel, analysis of rock deformation data, excavation effects program data acquired from observation holes, and support system performance.

This process applies not only to the waste disposal rooms but to the entire WIPP underground. Prior to waste emplacement, stability of each room will be evaluated. This evaluation will concentrate on the age and current performance of the installed support systems (if any) and the rate of roof beam expansion based on data from installed instrumentation. The roof support system's performance and surety, to provide the support necessary for the required time will be addressed. Criteria used will include design parameters such as the amount of load, the deformation of the installed system, and the number and type of component failures observed, if any. Geotechnical criteria will include parameters such as the type and quantity of fracturing, roof beam expansion rates, and future ground performance based on a predictive model.

Should the evaluation results indicate that remedial actions are necessary prior to placement of waste, experiences at the WIPP indicate that rebolting or installing supplemental support can extend the safe life of a room for several years.

After waste emplacement commences, geomechanical monitoring will continue with monitors that are tied into a computer network program. The readings obtained will provide information needed for the roof beam stability assessment. Visual observations of the ground and the support systems will also continue in all accessible areas. Based on the experiences from the Site and Preliminary Design Validation test rooms, it has been proven that any developing instability will be detected through monitoring. Multiple measures to deal with the observed conditions can be implemented months before an event to mitigate any risk associated with a roof fall in the storage room or any affected area within the mine. At a minimum, the affected area will be isolated and withdrawn from ventilation flow. Isolation operations will utilize current available methods, materials, and equipment.

Ground control conditions which could result in a fall can be divided into two scenarios: The first consists of spalling (falling) of individual small and localized rock falling on waste containers.

By definition, they can be considered insignificant as no damage to the drums can occur. The second consists of an entire section of roof falling on multiple stacks of waste containers. Each of these scenarios is discussed below.

Spalling-of-Ground

The possibility of a punctured container due to a spall-of-ground is very remote. The maximum distance between the room roof and a container of waste is 10 ft. Waste containers are designed to withstand impact loads of at least 1,000 pounds (lbs) dropped from a height of 6 ft. flat or 450 lbs dropped on a circumfrontial edge from a height of 4 ft. Both of which correspond to an allowable impact stress of 25,450 pounds per square inch (psi). Rocks from spalling are small and would not be of sufficient weight when striking a drum from a 10 ft vertical height to cause an impact stress of more than 25,450 psi. Taking into account the falling distance, average weight, and the typical shape of the salt rock, the conclusion is that puncturing a drum by spalling is non-credible.

Fall-of-Ground

Fall-of-ground occurs when a large section of roof beam falls onto the waste containers. As previously discussed, the possibility of this occurring in an active room is remote, due to continuous monitoring and engineered roof support systems. Roof falls in a room completely filled with waste are considered to be of no consequence as shown in analysis in the WIPP SAR, DOE/WIPP-95-2065, Rev. 0, Section 5.2.3.11. In addition, a filled room is isolated from ventilation by shutting ventilation bulkhead regulators at the room exit and removed from personnel access by erecting a barricade at the entrance to the room (the bulkhead at the exit of the room prevents access at the room's exit).

Both of the above events are considered non-credible because of the type and amount of monitoring and ground control efforts at WIPP. However, per the request of the NMED, the following actions have been developed and will be taken by the RCRA Emergency Coordinator should a rock fall occur in an active waste emplacement area of the repository:

Spalling-of-Ground

1. Determine whether the roof conditions allow for safe entry and if the waste container or containers in question are accessible.

   The process used to determine if a roof condition of a room will allow for safe entry is the same as the ground control inspection process used for inspection of the ground conditions and roof bolt integrity. The inspection will begin at a safe and sound roof starting point and consist of visual inspections of roof bolts, roof, and rib areas for missing or damaged bolts; deformed roof bolt plates; or roof and rib cracks, fractures, or separations. If during the visual inspection suspicious roof bolts, roof, or ribs are found, then operators will proceed with sounding the area

in question with a scaling bar for loose roof bolts, bad roof, or ribs (loose roof bolts will not ring when sounded). Bad roof or ribs will have a drummy, hollow, or un-solid sound when struck with the scaling bar. When this operation is performed, a safe avenue for retreat is always maintained. Also maintained is a position such that an unexpected event will not place personnel in a position where the scaling bar or material being scaled could fall on personnel. If the inspection reveals ground that cannot be safely scaled manually or with the available mining equipment, the affected area, up to and including the entire room, will be barricaded and removed from ventilation flow.

The criteria used to determine whether a waste container is accessible is based on the location of the container, the amount of waste in the room, and the expense of reaching the waste container safely versus the expense of abandonment of the room. For example, if the room is 95% filled and spalling-of-ground punctured a waste container at or near the exit of the room, the decision to isolate the room and move waste emplacement activities to the next room would be prudent.

2. Restrict access in ventilation flowpath downstream of the incident.

3. Restrict ventilation to the affected room to ensure that there is no spread of contamination (using the principle of co-detection) that may have been released. Survey for contamination and establish the boundaries.

4. Inspect containers and containment for signs of leakage or damage.

5. Cover the spill area with material such as plastic or fabric sheets or PVA, in a way that would safely isolate the area.

6. Determine if the covered spill area safely allows for continued waste disposal operations or whether further cleanup is required. If further cleanup is required, provide with cleanup methods described below. Note: Cleaning may not be required since this is the permitted disposal area.

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7. Inspect any affected equipment (vehicles, handling equipment, and communication and alarm equipment) for proper function.

8. Repackage spilled waste and breached waste containers into 55 or 85-gallon drums, SWBs, or TDOPs, depending on volume. Temporarily locate overpack waste containers in an adjacent room. Remove only those intact waste containers necessary to clear the area for decontamination.

9. At the underground emplacement room, salt contaminated by a spill of TRU waste will be covered with materials such as salt, plastic or fabric sheets or PVA to

isolate it from the workers or removed and packaged as site derived waste using damp rags, hand tools, and HEPA filtered vacuums.

10. Manage the radioactive debris as derived waste.

11. Characterize containers of waste based on the waste containers that were damaged.

12. Replace the removed and derived waste containers into the waste stack as appropriate and update the WWIS.

13. Document activities and record results.

Fall-of-Ground

1. Restrict access in ventilation flowpath downstream of the incident.

2. Withdraw the room from ventilation flow by closing bulkhead regulators.

3. Survey for radiological contamination and establish the boundary for a Radiological Buffer Area.

4. Install barricade devices to remove access.

5. At the underground emplacement room, salt contaminated by a spill of TRU waste will be covered with materials such as salt, plastic or fabric sheets, or PVA to isolate it from the worker or removed and packaged as site derived waste using damp rags, hand tools, and HEPA filtered vacuums.

The criteria used to determine whether to close the entire panel or just the affected room of waste containers would include the location of the roof fall and the stability of the unaffected roof area in the panel. Techniques to determine the stability would be the same as previously described in this section.

Structural Integrity Emergencies

The unique nature of the WIPP geologic repository makes the possibility of structural integrity failure in the underground implausible. In the unlikely event of a WIPP facility emergency involving underground structural integrity, the situation will be handled as a natural emergency. Monitoring and inspection procedures ensure the safety and integrity of the WIPP facility underground.

Emergency Termination Procedures

For the transition from emergency phase to cleanup phase, the following items must be complete:

- Emergency scene must be stable
- Release of hazardous substance must be stopped
- Reaction of hazardous substance must be controlled
- The released hazardous substance must be contained within a localized and manageable area
- The area of contamination must be adequately secure from unauthorized entry

At every incident involving hazardous materials, there is a possibility that response personnel and their equipment will become contaminated. Emergency response personnel have procedures to minimize contamination or contact, and to properly dispose of contaminated materials.

For nonemergencies and Incident Level I emergencies, the following methods of decontamination are available for personnel, environment, and/or equipment according to emergency response procedures:

- Absorption
- Adsorption
- Chemical degradation
- Dilution
- Disposal
- Isolation
- Neutralization
- Solidification

The Incident Commander (EST) will stay on-scene until the hazard has been mitigated. Any necessary verification of air, soil, or water samples will be directed by the RCRA Emergency Coordinator. Immediately after an emergency, the RCRA Emergency Coordinator must provide for treating, storing, or disposing of recovered waste, contaminated soil or surface water, or any other material that results from a release, fire, or explosion at the facility in accordance with standard operating procedures.

For Level II and III incidents after the emergency itself is controlled and contained, the RCRA Emergency Coordinator will be responsible for the development and implementation of an incident-specific decontamination plan.

PPE will be decontaminated according to procedure before it is returned to its storage location.

As part of the facility's defense-in-depth approach, equipment will be assumed to be contaminated after each hazardous material response and a thorough check for radioactive contamination will be conducted. If contamination is found, a technically sound decontamination process will be followed. Many types of equipment are difficult to decontaminate and may have to be discarded as hazardous or derived waste. Whenever possible, pieces of equipment will be disposable or made of nonporous material.

The "Start Clean-Stay Clean" operating philosophy of the WIPP Project minimizes probabilities for releases and subsequent decontamination. If radioactive contamination is detected on equipment, on structures, or in the air, it will be assumed that hazardous constituents may also be present. Co-detection methods (see Appendix I3, "Co-Detection of Hazardous and Radioactive Waste Releases") will be used along with other techniques as a detection method to determine when decontamination is required. Radiological cleanup standards will be used to determine the effectiveness of decontamination efforts. To provide verification of the effectiveness of the removal of hazardous waste constituents, once a contaminated surface is demonstrated to be radiologically clean, the "swipe" can be sent for analysis for hazardous constituents. The use of these confirmation analyses is as follows:

For waste containers, the analyses becomes documentation of the condition of the container at the time of emplacement. The presence of hazardous waste constituents on a container after decontamination will be at trace levels and will likely not be visible and will not pose a threat to human health or the environment. These containers will be placed in the underground without further action, once the radiological contamination is removed, unless there is visible evidence of hazardous waste spills or hazardous waste on the container and this contamination is considered likely to be released prior to emplacement in the underground.

For area contamination, once the area is cleaned up and is shown to be radiologically clean, it will be sampled for the presence of hazardous waste residues. If the area is large, a sampling plan will be developed using the guidance in the "Quality Assurance Project Plan for WIPP Site Effluent and Hazardous Materials Sampling" (Westinghouse 1994b). If the area is small, swipes will be used. If the results of the analysis show that residual contamination remains, a decision will be made whether further cleaning will be beneficial or whether final clean up must be deferred until closure. For example, if hazardous constituents react with the floor coating and are essentially nonremovable without removing the coating, then clean up will be deferred until closure, when the coatings will be stripped. In any case, appropriate notations will be entered into the operating record to assure proper consideration of formerly contaminated areas at the time of closure. Furthermore, measures such as covering, barricading, and/or placarding will be used as needed to mark areas that remain contaminated.

For all Contingency Plan emergency responses, the RCRA Emergency Coordinator will ensure, in keeping with standard operating procedures, that, in the affected area(s) of the facility:

- No waste that may be incompatible with the released material is treated, stored, or disposed of until cleanup procedures are completed

- All emergency equipment listed in the contingency plan is cleaned and fit for its intended use, or replaced before operations are resumed

G-4e Prevention of Recurrence or Spread of Fires, Explosions, or Releases

During an emergency, the RCRA Emergency Coordinator will ensure that reasonable measures are taken so that fires, explosions, and releases do not occur, recur, or spread to TRU mixed waste or other hazardous materials at the facility, as required under 20 NMAC 4.1, Subpart V, §§264.56(e) and (f). These measures include:

- Stopping processes and operations.

- Collecting and containing released wastes and materials.

- Removing or isolating containers of waste or hazardous substances posing a threat.

- Ensuring that wastes managed during an emergency are handled, stored, or treated with due consideration for compatibility with other wastes and materials on site and with containers utilized (Section G-4h).

- Restricting personnel not needed for response activities from the scene of the incident.

- Evacuating the area.

- Curtailing nonessential activities in the area.

- Conducting preliminary inspections of adjacent facilities and equipment to assess damage.

- Overpacking and/or removing damaged containers/drums from affected areas. Damaged equipment and facilities will be repaired as appropriate.

- Constructing, monitoring, and reinforcing temporary dikes as needed.

- Maintaining fire equipment on standby at the incident site in cases where ignitable liquids have been or may be released and ensuring that all ignition sources are kept out of the area. Ignitable liquids will be segregated, contained, confined, diluted, or otherwise controlled to preclude inadvertent explosion or detonation.

No operation that has been shut down in response to the incident will be restarted until authorized by the RCRA Emergency Coordinator. Sections G-4g, Incompatible Waste, and G-4h, Post-Emergency Facility and Equipment Maintenance and Reporting, address specific issues related to decreasing the possibility of a recurrence or spread of a release, a fire, or an explosion.

After resolution of the incident, a Root Cause Analysis will be conducted to review all Level II and Level III incidents for determination of cause, and the corrective action plan to prevent recurrence.

G-4f Management and Containment of Released Material and Waste

Once initial release or spill containment has been completed, the RCRA Emergency Coordinator will ensure that recovered hazardous materials and waste are properly stored and/or disposed, as required by 20 NMAC 4.1, Subpart V, §264.56(g). For spills of liquid, the perimeter of the spill will be diked with an absorbent material that is compatible with the material(s) released. Free-standing liquid will be transferred to a marked compatible container. The remaining liquid will be absorbed with an absorbent material and swept or scooped into a marked compatible container. Spill residue will be removed. Spills of dry material will be swept or shoveled into a labeled compatible recovery container. Material recovered from the spill will be transferred to clean containers or tanks or to containers or tanks that have held a compatible material. All containers will meet DOT specifications for shipping the wastes, and materials will be recovered.

Nonradioactive hazardous waste resulting from the cleanup of a fire, an explosion, or a release involving a nonradioactive hazardous waste or hazardous substance at the WIPP facility will be contained and managed as a hazardous waste until such time as the waste is disposed of, or determined to be nonhazardous, as defined in 20 NMAC 4.1, Subpart II, Subparts C and D. In most cases, hazardous materials inventories for the various buildings and areas at the facility will allow a determination of the hazardous materials present in any cleanup of a release or of the residues from an emergency condition. (The quantities of such spills are so small, it is not likely to trigger an Incident Level II or III.) When necessary, however, samples of the waste will be collected and analyzed to determine the presence of any hazardous characteristics and/or hazardous waste constituents; this information is needed to evaluate disposal options. EPA-approved sampling and analytical methods will be utilized. Hazardous wastes will be transferred to the Hazardous Waste Staging Area. The staging area is used to store hazardous waste awaiting transfer to an off-site treatment or disposal facility in accordance with applicable regulations (e.g., 20 NMAC 4.1 and DOT regulations). The Hazardous Waste Staging Area for nonradioactive hazardous waste is Buildings 474A and 474B, as shown in Figure G-1. Nonradioactive hazardous wastes will be shipped off-site for disposal at a RCRA permitted disposal facility.

Under normal operations, administrative controls will be implemented to ensure that hazardous materials and incompatible materials will not be introduced to the radioactive materials area during TRU mixed waste handling operations. Examples of administrative controls include

restricting the waste received in the TRU mixed waste management area(s) to TRU mixed waste properly manifested from the generator sites and ensuring that materials used in these area(s) are restricted to only those that have previously been determined to be compatible with the TRU mixed waste. The RCRA Emergency Coordinator will have access to building design information and information on specific equipment used within an area upon which to base a determination of the compatibility of materials with the area. If necessary, the RCRA Emergency Coordinator will use EPA-600/2-80-076, "A Method for Determining the Compatibility of Hazardous Waste," (EPA, 1980) for making compatibility determinations. Waste resulting from the cleanup of a fire, explosion, or release in the miscellaneous unit and the TRU mixed waste handling area will be derived from the received TRU mixed waste and will be treated and managed as TRU mixed waste.

In the event of a prolonged cessation of TRU mixed waste handling operations, TRU mixed waste can be placed in areas of the WHB that are available for such contingencies. These areas and the TRU mixed waste containers in them would be located so that adequate aisle space would be maintained for unobstructed movement of personnel and equipment in an emergency. Each shipping cask contains one canister of waste. Chapter D describes the HWMUs in detail, including the facility description, support structures and equipment, security, waste handling areas, ventilation, and fire protection.

The contaminated area will be decontaminated. If a release is to a permeable surface, such as soil, asphalt, concrete, or other surface, the surface material will be removed and placed in containers meeting applicable DOT requirements. Contaminated soil, asphalt, concrete, or other surface material, as well as materials used in the cleanup (e.g., rags and absorbent material) will be contained and disposed of in the same manner as dictated for the contaminant. Clean soil, new asphalt, or new concrete will be emplaced at the spill location.

If a spill occurs on an impermeable surface, the surface will be decontaminated with water and/or a detergent. In the event that the spilled material is water reactive, a compatible nonhazardous cleaning solution will be used. Contaminated wash water or cleaning solution will be transferred to an appropriate container, marked, and managed as described above for nonradioactive or radioactive liquid wastes.

In the event of a hazardous material or hazardous waste release, the RCRA Emergency Coordinator will ensure that no wastes will be received or disposed of in the affected areas until cleanup operations have been completed. This is to ensure that incompatible waste will not be present in the vicinity of the release.

Because of the restrictions which the WIPP facility places on generators, and because of control of WIPP operations, TRU mixed wastes and derived wastes will not contain any incompatible wastes. However, the areas established for the temporary holding of nonradioactive waste routinely generated at the WIPP facility is divided into bays to accommodate the management of wastes that may be incompatible. If waste is generated as the result of a spill or release of hazardous materials or nonradioactive hazardous waste, the waste generated as a result of

abatement and cleanup will be evaluated to determine its compatibility with other wastes being managed in the temporary holding areas. The evaluation will be by identifying the material or waste that was spilled or released and determining its characteristics (e.g., ignitable, reactive, corrosive, or toxic). The waste generated by the abatement and cleanup activities will be stored in that part of the temporary holding area that has been established to manage wastes with which it is compatible.

For small nonemergency liquid spills (e.g., a detergent solution leaking out of the pump handle during decontamination, a spill of hydraulic fluid while servicing a vehicle), spill control procedures will be used to contain and absorb free-standing liquid. The contaminated absorbent will be swept or shoveled into a compatible container and managed as described above. No notifications will be required, but site procedures require documentation of the incident.

G-4g Incompatible Waste

Implementation of the TRU WAC for the WIPP ensures that incompatible TRU mixed waste will not be shipped to the WIPP facility. Nonradioactive waste at the WIPP facility will be carefully segregated during handling and holding and will be transported within and off the facility. The RCRA Emergency Coordinator will not allow hazardous or TRU mixed waste operations to resume in a building or area in which incompatible materials have been released prior to ensuring that necessary post-emergency cleanup operations to remove potentially incompatible materials have been completed. In making the determination of compatibility, the RCRA Emergency Coordinator will have available the resources and information described in Section G-4b, Identification of Hazardous Materials. In addition, ES&H department personnel will be available for consultation. Finally, the RCRA Emergency Coordinator may use EPA-600/2-80-076, (EPA, 1980).

G-4h Post-Emergency Facility and Equipment Maintenance and Reporting

The RCRA Emergency Coordinator will ensure that emergency equipment that is located or used in the affected area(s) of the facility and listed in the Contingency Plan is cleaned and ready for its intended use before operations are resumed, as specified in 20 NMAC 4.1, Subpart V, §264.56(h)(2). Any equipment that cannot be decontaminated will be discarded as waste (e.g., hazardous, mixed, solid), as appropriate. The WIPP facility is committed to replacing any needed equipment or supplies that cannot be reused following an emergency. After the equipment has been cleaned, repaired, or replaced, a post-emergency facility and equipment inspection will be performed, and the results will be documented.

Cleaning and decontaminating equipment will be accomplished by physically removing gross or solid residue; rinsing with water or another suitable liquid, if required; and/or washing with detergent and water. Decontamination and cleaning will be conducted in a confined area, such as a wash pad or building equipped with a floor drain and sump isolated from the environment. Care will be taken to prevent wind dispersion of particles and spray. Liquid or particulate resulting from cleaning and decontamination of equipment will be placed in clean, compatible

containers. Waste produced in an emergency cleanup in the TRU mixed waste handling areas is derived waste and will be emplaced in the underground derived waste emplacement area. Waste resulting from decontamination operations elsewhere in the WIPP facility will be analyzed for hazardous waste constituents and/or hazardous waste characteristics to ensure proper management.

When the WIPP facility has completed post-emergency cleanup of waste and hazardous residues from areas where waste management operations are ready to resume and the RCRA Emergency Coordinator has ensured that emergency equipment used in managing the emergency has been cleaned or replaced and is fit for service, the notifications will be made by the DOE to the following: the EPA Region VI Administrator; the Secretary of the NMED; and any relevant local authorities. This post-emergency notification complies with 20 NMAC 4.1, Subpart V, §264.56(i), and is the responsibility of the RCRA Emergency Coordinator.

G-4i Container Spills and Leakage

The waste received at the WIPP facility must meet stringent WAC (e.g., no free liquids and less than one percent residual liquids), which will minimize the chances of waste container degradation and the possibility of liquid spills. The WIPP facility does manage drum quantities of lubricants, solvents, antifreeze, and recyclable spent solvents elsewhere at the facility. Should a spill or release occur from a container, the WIPP facility will immediately take the following actions, in compliance with 20 NMAC 4.1, Subpart V, §264.52(a) and §264.171:

- Assemble the required response equipment, such as protective clothing and gear, heavy equipment, empty drums, overpack drums, and hand tools
- Transfer the released material to a container that is in good condition or overpack the leaking container into another container that is in good condition
- Once the release has been contained, determine the areal extent of migration of the release and proceed with appropriate cleanup action, such as chemical neutralization, vacuuming, or excavation

G-4j Tank Spills and Leakage

The TRU mixed waste handling areas at the WIPP facility do not include tank storage or treatment of hazardous waste, as defined in 20 NMAC 4.1, Subpart I, §260.10, and as regulated under 20 NMAC 4.1, Subpart V, Subpart J. At the WIPP facility, tanks are used to store water and petroleum fuels only. The petroleum tanks store diesel and unleaded gasoline.

G-4k Surface Impoundment Spills and Leakage

The WIPP facility does not manage hazardous or TRU mixed waste using a surface impoundment, as defined in 20 NMAC 4.1, Subpart I, §260.10, and as regulated under 20 NMAC 4.1, Subpart V, Subpart K. Surface impoundment regulations are not applicable to the WIPP facility.

G-5 Emergency Equipment

A variety of equipment is available at the facility for emergency response, containment, and cleanup operations in both the HWMUs and the facility in general. This includes equipment for spill control, fire control, personnel protection, monitoring, first aid and medical attention, communications, and alarms. This equipment is immediately available to emergency response personnel. A listing of major emergency equipment available at the WIPP facility, as required by 20 NMAC 4.1, Subpart V, §264.52(e), is shown in Table G-6. Table G-7 identifies the locations where fire suppression systems are provided. Locations of the underground emergency equipment are shown in Figure G-5. The firewater-distribution system map is shown in Figure G-6. The underground fuel area fire-protection system is shown in Figure G-7.

G-6 Coordination Agreements

The DOE/CAO has established MOUs with off-site emergency response agencies for firefighting, medical assistance, hazardous materials response, and law enforcement. In the event that on-site response resources are unable to provide all the needed response actions during either a medical, fire, hazardous materials, or security emergency, the RCRA Emergency Coordinator will notify appropriate off-site response agencies and request assistance. Once on site, off-site emergency response agency personnel will be under the direction of the RCRA Emergency Coordinator.

The MOUs with off-site cooperating agencies are available from the DOE. A listing and description of the MOUs with state and local agencies and mining operations in the vicinity of the WIPP facility, as required by 20 NMAC 4.1, Subpart V, §264.37 and §264.52(c), are:

- An agreement among the DOE, the WIPP MOC, Mississippi Potash Inc., Western Agriculture Minerals, IMC Fertilizer, Eddy Potash Inc., and New Mexico Potash (June 6, 1994) provides for the mutual aid and assistance, in the form of MRTs, in the event of a mine disaster or other circumstance at either of the two facilities. This provision ensures that the WIPP MOC will have two MRTs available at all times when miners are underground, as required by DOE Order 5480.4, Environmental Protection, Safety, and Health Protection Standards.

- A joint powers agreement among the DOE; the City of Carlsbad, New Mexico; Eddy County, New Mexico; and the New Mexico Energy, Minerals, and Natural Resources Department for Alternate EOC (April 6, 1994) provides for the

coordination of emergency plans, including the DOE emergency radiological response plans; provides for participation in periodic exercises, drills, and training; provides for establishing and maintaining an alternate EOC at the Living Desert State Park; and assigns responsibilities to the participants.

- A memorandum of agreement between the City of Carlsbad, New Mexico, and the WIPP MOC for ambulance service assistance (August 13, 1981) provides that, upon notification by the WIPP MOC, the Carlsbad Fire Department will be dispatched from Carlsbad toward the WIPP site by a designated route and will accept the transfer of patient(s) being transported by the WIPP facility ambulance at the point both ambulances meet. If the patient(s) is not transferrable, the Carlsbad Ambulance Service will provide equipment and personnel to the WIPP facility ambulance, as necessary.

- A MOU between the DOE and the Guadalupe Medical Center Emergency Radiological Treatment Center for the Waste Isolation Pilot Plant (February 1, 1994) provides for the treatment of radiologically contaminated personnel who have incurred injuries beyond the treatment capabilities at the WIPP facility. The DOE will provide transport of the patient(s) to the Guadalupe Medical Center Emergency Radiological Treatment Center for decontamination and medical treatment.

- A MOU between the DOE and the Lea Regional Hospital Emergency Radiological Treatment Center for the WIPP (August 17, 1993) provides for the treatment of radiologically contaminated personnel who have incurred injuries beyond the treatment capabilities at the WIPP facility. The DOE will provide transport of the patient(s) to the Lea Regional Hospital Emergency Radiological Treatment Center for decontamination and medical treatment.

- A MOU between the DOE and the U.S. Department of Interior (DOI), represented by the Bureau of Land Management (BLM), Roswell District (July 19, 1994), provides for a fire-management program that will ensure a timely, well-coordinated, and cost-effective response to suppress wild fire within the withdrawal area using the WIPP incident commander for fire-management activities. The DOI will provide firefighting support if requested. In addition, the MOU provides for responsibilities concerning cultural resources, grazing, wildlife, mining, gas and oil production, realty/lands/rights-of-way, and reclamation.

- A mutual-aid firefighting agreement between the Eddy County Commission and the DOE (February 1, 1994) provides for the assistance of the Otis and Joel Fire Departments (a volunteer fire district created under the Eddy County Commission and the New Mexico State Fire Marshall's Office), including equipment and personnel, at any location within the WIPP Fire Protection Area upon request by an authorized representative of the WIPP Project. These responsibilities are reciprocal.

- A mutual-aid agreement between the City of Hobbs and the DOE (December 3, 1993) provides for mutual ambulance, medical, fire, rescue, and hazardous material response services; provides for joint annual exercises; provides for use of WIPP facility radio frequencies by the City of Hobbs during emergencies; and provides for mutual security and law enforcement services, within the appropriate jurisdiction limits of each party.

- A mutual-aid agreement between the City of Carlsbad and the DOE (November 24, 1993) provides for mutual ambulance, medical, fire, rescue, and hazardous material response services; provides for joint annual exercises; provides for use of WIPP facility radio frequencies by the City of Carlsbad during emergencies; and provides for mutual security and law enforcement services, within the appropriate jurisdiction limits of each party.

- A MOU between the DOE and the New Mexico Department of Public Safety (DPS) concerning Mutual Assistance and Emergency Management (March 19, 1992) applies to any actual or potential emergency or incident that: 1) involves a significant threat to employees of the DOE\DOE contractor or general public; 2) involves property under the control or jurisdiction of either the DOE or the State; 3) involves a threat to the environment which is reportable to an off-site agency; 4) requires the combined resources of the DOE and the state; 5) requires a resource that the DOE has which the State does not have, or a resource the State has which DOE does not have; or 6) involves any other incident for which a joint determination has been made by the DOE and the State that the provisions of this MOU will apply. The MOU provides that the DPS shall permit qualified and security cleared DOE Emergency Management members into the State EOC for the purpose of: a) coordinating communications functions; b) evaluating and maintaining communications capabilities; c) participating in exercises; d) link the State's High Frequency radio communications network with the DOE; and e) assisting the State during radioactive materials accidents that require joint operations or the use of the DOE Radiological Assistance Program team. The DOE shall permit qualified and security cleared members the State Emergency Management community into the DOE's EOCs for the purposes of coordinating communications and activities. Additional duties for each participant are specified for assistance in incidents or emergencies.

G-7 Evacuation Plan

If it becomes necessary to evacuate the WIPP facility, the assigned on-site and off-site staging areas have been established. The off-site staging areas are outside the security fence. The WIPP facility has implementation procedures for both surface and underground evacuations. Drills are performed on these procedures at the WIPP facility at least once annually. The following sections describe the evacuation plan for the WIPP facility, as required under 20 NMAC 4.1, Subpart V, §264.52(f).

G-7a Surface Evacuation On-site and Off-site Staging Areas

Figure G-8 shows the surface staging areas. Personnel report to their Office Wardens at designated staging areas where accountability is conducted. If site evacuation is necessary, the RCRA Emergency Coordinator will decide which staging areas are to be used and will advise Office Wardens of the selections. The RCRA Emergency Coordinator will communicate the locations to Office Wardens via office warden pager, radio, plectron, WIPP Security, or telephone, as appropriate. Office Wardens will direct personnel to the selected staging area outside the security fence. Personnel who are working in a contaminated area when site evacuation is announced, will assemble at specific staging areas to minimize contact with other personnel during the evacuation (Figure G-8).

Office Wardens conduct accountability of personnel assigned to their specific areas. For complete surface accountability, the Office Wardens report to their ACOW, who reports to the COW. When the COW has reports from all ACOWs, surface accountability is reported to the CMRO, who then notifies the RCRA Emergency Coordinator of the accountability.

The COW and all ACOWs have radios for communication between them and the CMRO. The Office Wardens, ACOWs, and COW also carry pagers with which they are notified of evacuations. At the staging areas Office Wardens report directly to their ACOW.

There are three off-site staging areas identified on Figure G-8. The RCRA Emergency Coordinator determines which staging area will be used. Security officers remain at the primary staging area gate 24 hours a day, and the vehicle trap is opened for personnel during emergency evacuations. The north gate has a single person gate and large gate which can be opened, similar to the main gates for the primary staging area. The east gate is a turnstile gate. Upon notification by the RCRA Emergency Coordinator, Security will respond, open gates, and facilitate egress for evacuation.

The on-site staging areas are identified in Figure G-8. These are used for building or area evacuations as determined by the RCRA Emergency Coordinator.

G-7b Underground Assembly Areas and Egress Hoist Stations

In the event of an underground or surface event, the RCRA Emergency Coordinator can call for underground personnel to report to assembly areas (Figure G-9). Underground personnel are also trained to immediately report to assembly areas under specific circumstances (i.e. loss of underground power or ventilation). If accountability is required, the underground will be evacuated. The Underground Controller is responsible for underground accountability by comparing the brass numbers with the brass tags signed out in the lamproom. Each assembly area contains a Mine Page Phone, miners aid station, and evacuation maps.

In accordance with 30 CFR §57.11, the mine maintains two escapeways. These escapeways are designated as Egress Hoist Stations. When an underground evacuation is called for, all underground personnel report to the Egress Hoist Stations.

Decontamination of underground personnel will be conducted the same way as described for surface decontamination. Contaminated personnel are trained to remain segregated from other personnel until RC personnel can respond to the incident at the underground location.

G-7c Plan for Surface Evacuation

Surface evacuation notification is initiated by the RCRA Emergency Coordinator directing the CMRO to sound the surface evacuation alarm. The Office Wardens assist personnel in evacuation from their areas. Evacuation routes and instructions are posted throughout the site.

If the EST notifies the ERT members by pager to respond to an identified area, these members will not depart the site during an evacuation, but will report to the EST for instructions and accountability. The EST notifies the COW of response members present. These personnel will not evacuate until released by the RCRA Emergency Coordinator.

G-7d Plan for Underground Evacuation

Notification for underground evacuation will be made using the underground evacuation alarm and strobe light signals. This notification equipment has battery-backup power and will continue to operate in the event of a power outage.

Personnel will evacuate to the nearest egress hoist station. Primary underground evacuation routes (identified by green reflectors on the rib) will be used, if possible. Secondary underground evacuation routes (identified by red reflectors on the rib) will be used if necessary (Figure G-5). Brass tags will be collected from personnel at the hoist collar on the surface, and taken to the Underground Controller, who functions as an Office Warden. When all brass tags are accounted for, underground accountability is reported to the RCRA Emergency Coordinator.

Upon reaching the surface, personnel will report to their on-site staging area to receive further instructions.

Members of the FLIRT and the MRT who may be underground, will evacuate the underground when an underground evacuation is called for. A reentry by the MRT will be performed according to 30 CFR 49 and MSHA regulations for reentry into a mine. The two MRTs are trained in compliance with 30 CFR 49 in mine mapping, mine gases, ventilation, exploration, mine fires, rescue, and recovery.

G-7e Further Site Evacuation

In the event of an evacuation involving the need to transport employees, the following transportation will be available:

- Buses/vans—WIPP facility buses/vans will be available for evacuation of personnel. The buses/vans are stationed in the employee parking lot.

- Privately Owned Vehicles—Because many employees drive to work in their own vehicles, these vehicles may be utilized in an emergency. Personnel may be directed as to routes to be taken when leaving the facility.

These vehicles may be used to transport personnel who have been released from the site by the RCRA Emergency Coordinator.

G-8 Required Reports

The RCRA Emergency Coordinator, on behalf of the DOE, must note in the operating record the time, date, and details of any incident that requires implementing this Contingency Plan. This notation will be in the facility log maintained by the CMRO. In compliance with 20 NMAC 4.1, Subpart V, §264.56(j), within 15 days after the incident, the Waste Isolation Division (WID) General Manager will ensure that a written report on the incident will be submitted to the EPA Region VI Administrator and to the Secretary of the NMED. The report must include:

- The name, address, and telephone number of the Owner/Operator

- The name, address, and telephone number of the facility

- The date, time, and type of incident (e.g., fire, explosion or release)

- The name and quantity of material(s) involved

- The extent of injuries, if any

- An assessment of actual or potential hazards to human health or the environment, where this is applicable

- The estimated quantity and disposition of recovered material that resulted from the incident

In addition to the above report, the WID General Manager will ensure that the ES&H Manager, or designee, submits reports to the appropriate agencies as listed in Tables G-8 and G-9.

In accordance with 20 NMAC 4.1, Subpart V, §264.56(i), the DOE will notify the Secretary of the NMED and EPA Region VI Administrator that the WIPP facility is in compliance with requirements for the cleanup of areas affected by the emergency and that emergency equipment used in the emergency response has been cleaned, repaired, or replaced and is fit for its intended use prior to the resumption of waste management operations in affected areas. The means the WIPP facility will use to meet these requirements are described in Sections G-4e, G-4f, G-4g, and G-4h.

The WIPP requires the EST to initiate the "WIPP Hazardous Materials Incident Report" if the Contingency Plan is implemented. A form is attached as Figure G-12. The form is initiated by the EST. The RCRA Emergency Coordinator, CMRO, Environmental Compliance & Support representative, and a Hazardous Waste Operations representative complete their respective sections.

G-9 Location of the Contingency Plan and Plan Revision

The owner/operator of the WIPP facility will ensure that copies of this Contingency Plan are present at controlled-document locations throughout the facility and are, consequently, available to all emergency personnel and organizations described in Section G-2. In addition, the owner/operator will make copies available to the following outside agencies:

- Mississippi Potash Inc., Western Agriculture Minerals, IMC Fertilizer, Eddy Potash Inc., and New Mexico Potash
- New Mexico Energy, Minerals, and Natural Resources Department for Alternate EOC at the Living Desert State Park Office, Carlsbad
- Carlsbad Fire Department, Carlsbad
- Guadalupe Medical Center, Carlsbad
- Lea Regional Hospital, Hobbs
- Otis Fire Department, Otis
- Hobbs Fire Department, Hobbs
- Joel Fire Department, Carlsbad
- BLM, Carlsbad
- Department of Public Safety, Carlsbad
- New Mexico State Police

The owner/operator of the WIPP facility will ensure that this plan is reviewed annually and amended whenever:

- Applicable regulations are revised
- The RCRA Part B permit for the WIPP facility is revised in any way that would affect the Contingency Plan
- This plan fails in an emergency
- The WIPP facility design, construction, operation, maintenance, or other circumstances change in a way that materially increases the potential for fires, explosions, or releases of hazardous waste or hazardous constituents or change the response necessary in an emergency
- The list of RCRA Emergency Coordinators change
- The list of WIPP facility emergency equipment changes.

REFERENCES

U.S. Environmental Protection Agency, "A Method for Determining the Compatibility of Hazardous Waste," EPA-600/2-80-076, 1980.

U.S. Department of Transportation, Emergency Response Guidebook, U.S. Government Printing Office, 1993.

Westinghouse Electric Corporation, 1994, "Quality Assurance Project Plan for WIPP Site Effluent and Hazardous Materials Sampling," WP 02-EM1, Westinghouse Electric Corporation, Carlsbad, New Mexico.

U. S. Department of Energy, "WIPP Safety Analysis Report," DOE/WIPP-95-2065, Rev. 0

U. S. Department of Energy, "WP 12-5, WIPP Radiological Control Manual".

TABLES

TABLE G-1
HAZARDOUS SUBSTANCES IN LARGE ENOUGH QUANTITIES TO CONSTITUTE A LEVEL II INCIDENT

Chemical Discription	Building Location	Hazard Category
Ethylene Glycol Solution - 35%	Buildings 411; 412; 451; 452; 486; 463; 474C; FAC 414	Immediate (acute) Delayed (chronic)
Gasoline, Unleaded GASC0001	FAC 480	Fire Immediate (acute) Delayed (chronic)
No. 1 Diesel Fuel Oil GASC0210	S-1300 Maint Shop U/G; FACs 480, 255.1 & 255.2; Transport Tank; Building 456 Trlr 911F	Fire Immediate (acute) Delayed (chronic)

TABLE G-2
RESOURCE CONSERVATION AND RECOVERY ACT EMERGENCY COORDINATORS

Name	Address	Office Phone	Home Phone
G. A. (Gerry) Burns (primary)[1]		234-8276 or 234-8635	
R. A. (Richard) Marshall (primary)[1]		234-8276 or 234-8695	
R. E. (Bob) Wade (primary)[1]		234-8272	
T. J. (Tim) Wygant (primary)[1]		234-8276 or 234-8377	
J. R. (Joe) Franco (primary)[1]		234-8276 or 234-8641	
M. B. (Byron) Cherry[2]		234-8276 or 234-8635	
B. J. (James) VanWinkle[2]		234-8276	
G. L. (Garrod) Ashford[2]		234-8272	
R. C. (Russ) Stroble[2]		234-8554	

[1]The on-duty Facility Shift Manager is the primary RCRA Emergency Coordinator pursuant to 20 NMAC 4.1, Subpart V §264.52 and is designated to serve as the RCRA Emergency Coordinator.

[2]The on-duty Facility Operations Engineer is the alternate RCRA Emergency Coordinator and is available as needed.

TABLE G-3
PLANNING GUIDE FOR DETERMINING INCIDENT LEVELS AND RESPONSE

INCIDENT CONDITION	INCIDENT LEVEL		
	I	II *	III *
Product identifications	Placard not required, NFPA 0 or 1 all categories, all Other Regulated Materials A, B, C, and D.	DOT placarded, NFPA 2 for any categories, PCBs without fire, EPA regulated waste. SITE SPECIFIC: Table G-1 and TRU waste AND	Poison A (gas), explosive A/B, organic peroxide, flammable, solid, materials dangerous when wet, chlorine, fluorine, anhydrous ammonia, radioactive materials, NFPA 3 and 4 for any categories including special hazards, PCBs and fire including special hazards, PCBs and fire DOT inhalation hazard, EPA extremely hazardous substances, and cryogenics. SITE SPECIFIC: Remote handled TRU waste
Container size	Container size does not impact this incident level.	Involves multiple packages.	Tank truck or RH waste cannister.
Fire/explosion potential	Under control.	May spread/may be explosive.	May spread/may be explosive.
Leak severity	No release or small release contained or confined with readily available resources.	Release may not be controllable without special resources.	Release may not be controllable even with special resources.
Life safety	No life-threatening situation from materials involved.	Localized area, limited evacuation area.	Localized area, limited evacuation area.
Environmental impact (Potential)	None.	Limited to incident boundaries	Contained within the Hazardous waste Management Units.
Container integrity	Not damaged.	Damaged but able to contain the contents to allow handling or transfer of product.	Damaged to such an extent that catastrophic rupture is possible.

* Contingency Plan is implemented

TABLE G-4
PHYSICAL METHODS OF MITIGATION

METHOD	CHEMICAL		RADIOLOGICAL	
	LIQUID	SOLUTION	LIQUID	SOLUTION
ABSORPTION	YES	NO	YES	NO
COVERING	YES	YES	YES	YES
DIKES, DIVERSIONS	YES	YES	YES	YES
OVERPACK	YES	YES	YES	YES
PLUG/PATCH	YES	YES	YES	YES
TRANSFER	YES	YES	YES	YES
VAPOR SUPPRESSION	YES	YES	NO	NO

TABLE G-5
CHEMICAL METHODS OF MITIGATION

METHOD	CHEMICAL		RADIOLOGICAL	
	LIQUID	SOLUTION	LIQUID	SOLUTION
NEUTRALIZATION	YES	YES[1]	NO	NO
SOLIDIFICATION	YES	NO	YES[2]	NO

(1) When solid neutralizing agents are used, they must be used simultaneously with water.
(2) This method could be utilized for mitigation of firewater involving TRU-waste.

TABLE G-6
EMERGENCY EQUIPMENT MAINTAINED AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Communications		
Building Fire Alarms	Manual and automatic; activation of automatic sprinkler system triggers fire alarm; locally audible, visual display and alarm in Central Monitoring Room (CMR)	Guard and Security Building, Pumphouse, Warehouse/Shops, Exhaust Filter Building, Support Building, CMR/ Computer Room, Waste Handling Building, TRUPACT Maintenance Facility, Salt Handling (SH) Shaft Station, Waste Shaft Station, Underground Fuel Station, SH Hoisthouse, Maintenance Shops, Guard Shack*, Auxiliary Warehouse, Core Storage Building, Engineering Building, Training Facility, Safety Building *local alarms; not connected to the CMR
Underground Fire Alarms	Automatic/Manual; have priority over other paging channel signals but not override intercom channels; alarms sound in the general area of the control panel and are connected to the underground evacuation alarms; they also interface with the CMR.	Fire detection and control panel locations: Waste Shaft, SH Shaft, Panel 1 (outside room 1), E-O/N-1200, Fuel Station #2
Sitewide Evacuation Alarm	Transmitted over paging channel of the public address system, overriding its normal use; manually initiated according to procedures requiring evacuation; automatically initiated by underground fire alarm systems for underground areas; audible alarm produced by tone generator at 10 decibels above ambient noise level (or at least 75 decibels); flashing strobe lights supplement audible alarm in high ambient noise areas; radios and/or pagers are used to notify facility personnel outside alarm range. Monthly test are performed on the PA, site notification alarms, and plectrons.	Sitewide
Vehicle Siren	Manual; oscillating; emergency services/response vehicles, is mechanical and electronic.	WIPP emergency vehicles
Public Address System	Includes intercom phones; handset stations and loudspeaker assemblies, each with own amplifiers; multichannel, one for public address and pages, and others for independent party lines.	Surface and underground
Intraplant Phones	Private automatic branch exchange; direct dial; provide communication link between surface and underground operations	Throughout surface and underground
Mine Page Phones	Battery-operated paging system	CMR, Mine Rescue Room, EOC, underground, and FSM desk.
Pagers	Manual; broadcast high-intensity, intermittent alarm signals for up to 60 seconds	Issued to individuals

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED
AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Plectrons	Tone-alert radio receivers placed in areas not accessible by the public address system	Sitewide
Portable Radios	Two-way, portable; transmits and monitors information to/from other transmitters	Issued to individuals
Plant Base Radios	Two-way, stationary, UHF/ VHF-FM; linked to Eddy County and Lea County Sheriff Departments, NM State Police, Carlsbad Emergency Radio (Carlsbad ambulance, fire, HAZMAT and police, Guadalupe Medical Center, and Otis Fire Department), and WIPP Channels 1-4 (Site Security, Site Operations and Site Emergency, maintenance, repeater to Carlsbad)	Various site locations
Mobile Phones	Provide communications link between WIPP Security and key personnel	Issued to individuals plus emergency vehicles,
	Spill Response	
SPILL-X-S Guns and Recharge Powder	Containment; (1)SPILL-X model SC-30-C(Gun) (1)SPILL-X model XC-30-S(Gun) (1)SPILL-X model SC-30-A(Gun); (1) A-Acid, 5 gallon bucket (Recharge Powder) (1)S-Solvent, 5 gallon bucket (Recharge Powder) (1)C-Caustic, 5 gallon bucket (Recharge Powder)	HAZMAT trailer
Absorbent Sheets	Containment or cleanup; (1) 3' x 100' Sheet	HAZMAT trailer
Absorbents	Grab and Go container; spill control bucket; (1) for solvents and neutralizing absorbents; 5 gallon bucket (1) for acids/caustics; 5 gallon bucket	HAZMAT trailer
Absorbent Material	Containment or cleanup; (1) 100 ft. rolled or equivalent socks " Pig" for general liquid (1) 100 ft. rolled or equivalent socks " Pig" for oil	HAZMAT trailer
Air Bag System	Extrication, Stabilization, Cribbing (1) bag system with tank kit and the following bag sizes: (1)12-ton, (1) 21.8-ton, (1)17-ton	Surface rescue truck
Air Chisel	Extrication (1) Capable of cutting 3/16" steel	Surface rescue truck

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED
AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Drum Transfer Pumps and Drum Opener	Containment or cleanup; (1) unit for chemical transfer (1) hand operated pump for petroleum transfer (1) drum opener	HAZMAT trailer
Floor Squeegee	Containment or cleanup; (1) straight rubber blade, nonwood handle	HAZMAT trailer
Foam Concentrate	AFFF 6% (4) 5-gallon pail	Fire truck # 1
Gas Cylinder Leak Control Kit	(1)Series A Hazardous Material Response Kit; contains nonsparking equipment to control and plug leaks	HAZMAT trailer
Portable Generator	(1)Backup power; 5,000 watt; 120 or 240 volt	Surface rescue truck
Hand Tools	Containment and cleanup; Underground rescue truck: (1)12# Sledge Hammer (1)3/8" Drive Socket Set (1)1/2" Drive Socket Set (1)3/4" Drive Socket Set (1)25' 1/2" Chain (1)6' Wrecking Bar (1)Bottle Jack (1)4# Hammer (1)18" Crescent Wrench (1)5' Pry Bar (1)2' Pry Bar (1)100' Extension Cord (1)4' Nylon Sling (1)6' Nylon Sling (1)10' Nylon Sling These tools are located in the HAZMAT Trailer. They are non-sparking. (1)14"L adjustable pipe wrench (1)15" multi-opening bung wrench (1)hammer/crate opener (1)8" pipe pliers (1)8" blade Phillips (1)#2 screwdriver (1)6" blade standard screwdriver (1)Claw Hammer	Underground rescue truck, HAZMAT trailer
Come-a-longs	(1) 4-ton; cable-type Ratchet lever tool designed specifically for lifting, lowering and pulling applications including jobs requiring rigging, positioning, and stretching. Used in rescue for extrication.	Surface rescue truck and underground rescue truck
Porta-power	(1) 10-ton hydraulic, hand-powered jaws used for extrication during rescues.	Surface rescue truck

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED
AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Jugs	Containment or cleanup; (4) 1-gallon plastic	HAZMAT trailer
Pails	Containment or cleanup; (3) 5-gallon plastic with lid	HAZMAT trailer
Portable Lighting	(1) Emergency lighting system; 120 volts; 500-watt bulbs, suitable for wet location	Underground rescue truck
Patching Kit	Series A Hazardous Response Kit; Class A; contains nonsparking equipment to control and plug leaks.	HAZMAT trailer
Scoops and Shovels	Cleanup; plastic; various sizes; nonsparking; nonwood handles (1) Scoop (3) Shovels	HAZMAT trailer
Medical Resources		
Ambulance #1	Equipped as per Federal Specifications KKK-A-1822 and New Mexico Emergency Medical Services Act General Order 35; equipped with a radio to Guadalupe Medical Center in Carlsbad, VHF radio, UHF medical frequency, cellular phone	Surface (Safety and Emergency Services Facility)
Ambulance #2	Electric cart; equipped with first aid kit, 2 stretchers, and other associated medical supplies	Underground
Rescue Truck	Special purpose vehicle; light and heavy duty rescue equipment; transports 1 litter patient, medical oxygen and supplies for mass casualties, fire suppression support equipment (rescue tool, air bag, K-12 Rescue Saw, 5,000-watt generator, self-contained breathing apparatus (SCBA), and much more equipment	Surface (Safety and Emergency Services Facility)

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Fire Detection and Fire Suppression Equipment		
Building Smoke, Thermal Detectors, and Manual Pull Stations	Ionization and photoelectric or fixed temperature/rate of rise detectors; visual display and alarm in CMR; manual pull stations. The underground has manual fire alarm pull stations located where personnel have access when evacuating. These are connected to the U/G evacuation alarm.	Guard and Security Building, Warehouse/Shops, Support Building, CMR/Computer Room, Waste Handling Building, TRUPACT Maintenance Facility, Waste Shaft Station, Underground Fuel Station, SH Hoisthouse, Engineering Building, Industrial Safety Building, Training Facility
Fire Truck # 1	Equipped per Class "A" fire truck per NFPA; capacity 750 gallons, with pump capacity of 1200 gallons per minute	Surface (Safety and Emergency Services Facility)
Rescue Truck # 2 (U/G)	(1) 125-pound dry chemical extinguisher (1) 150-pound foam extinguisher	Underground
Extinguishers	Individual fire extinguisher stations; various types located throughout the facility, conforming to NFPA-10.	Buildings, underground, and underground vehicles
Automatic Dry Chemical Extinguishing Systems	Automatic; 1,000-pound system (Purple K); actuated by thermal detectors or by manual pull stations	Underground fuel station
Sprinkler Systems	Fire alarms activated by water flow	Pumphouse, Guard and Security Building, Support Building, Waste Handling Building (contact- and remote-handled transuranic waste area only, except Hot Cell), Warehouse/ Shops Building, Auxiliary Warehouse Building, TRUPACT Maintenance Facility, Training Facility, SH Shaft Station, Exhaust Filter Building, Engineering Building, and Safety Building
Water Tanks, Hydrants	Fire suppression water supply; two 180,000-gallon capacity	Tanks are at southwestern edge of WIPP facility; pipelines and hydrants are throughout the surface
Fire Water Pumps	Fire suppression water supply; 125 pounds per square inch, 1,500 gallons per minute centrifugal pump, one with electric motor drive, the other with diesel engine; pressure maintenance pump	Pumphouse

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Hoses	Fire suppression water supply	Pumphouse, Guard and Security Building, Support Building, Waste Handling Building (contact- and remote-handled transuranic waste area only, except Hot Cell), Warehouse/ Shops Building, Auxiliary Warehouse Building, TRUPACT Maintenance Facility, Engineering Building, Exhaust Filter Building
Personal Protection Equipment		
Headlamps	Mounted on hard hat; battery operated	Each person underground
Underground Self-Rescuer Units	Short-term rebreathers; approximately 300	Each person underground
Self-Contained Breathing Apparatus (SCBA)	Oxygen supply; 4-hour units; approximately 14 Mine Rescue Team Draeger units	Mine Rescue Training Room
Chemical and Chemical-Supported Gloves	Body protection; (12 pair) inner-cloth, (12 pair) outer-pvc, (5 pair) outer-viton	HAZMAT trailer
Suit, Acid	Body protection; (4) acid	HAZMAT trailer
Suit, Fully Encapsulated	Body protection; used with SCBAs; full outerboot; (4) Level A; (4) Level B	HAZMAT trailer
Emergency Medical Equipment		
Antishock Trousers	Shock treatment; (2) inflatable, one on each ambulance	Ambulance # 1 and # 2
Laerdal 3000 QRS	Monitor/defibrillator	Ambulance # 1 and # 2

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED
AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Oxygen	Patient care; Size D: (2) Ambulance #1 (1) Underground Ambulance (1) Health Services Size E: (1) Rescue Truck (2) Underground Ambulance Size M: (1) Ambulance #1	Ambulance # 1 and # 2, surface rescue truck
Resuscitators (Bag)	Disposable bag resuscitation Ambulance #1: (2) adult size (1) child size Underground Ambulance: (2) adult size	Ambulance # 1, Ambulance # 2
Splints 	Immobilize limbs; (1) Adult traction splint, lower extremity, with limb-supporting slings, padded ankle hitch and traction device per ambulance. (2) Rigid splinting devices or equivalents, suitable for immobilization of upper extremities per ambulance. (2) Rigid splinting devices or equivalents, suitable for the immobilization of lower extremities. (1) Set of Airsplints: 6 assorted splints; hand/wrist, half arm, full arm, foot/ankle, half leg, and full leg per miner's aid stations.	Ambulance # 1 and # 2, Miner's Aid Stations
Stretchers	Patient transport; (2) Spine Boards, one short and one long, with nylon straps per ambulance. (also used to perform cardiopulmonary resuscitation) (2) Emergency Stretchers or scoops, or combination per ambulance (1) All-purpose multi-level ambulance stretch (gurney), with 3 safety straps and locking mechanism per ambulance. (1) Stretcher in each miner's aid station.	Various combinations in Ambulance # 1 and # 2, Miner's Aid Station
Suctions	For medical emergencies: Portable (1) Suction unit, capable of delivering at least 300 mm. HG on each ambulance.	Ambulances #1 and #2

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED
AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Trauma Kits	(1) adult blood pressure cuff and stethoscope (4) soft-roller bandages (3) triangular bandages (1) pkg. band-aids (2) trauma dressings (25) 4X4 sponges (1) roll adhesive tape (1) bite stick (1) penlight (1) sterile burn sheet (1) oropharyngeal airway (1) glucose substance (2) sterile gauze dressings	(1) kit in each: Ambulances #1 and #2, surface rescue truck
Miner's Aid Station	For First Aid Stations in the Underground (1) Stretcher--as referenced above per station (1) Set of airsplints--as referenced above per station (1) Blanket per station (1) Box of latex gloves (50) per station (5) Pathogen Wipes per station (1) First Aid Kit (24) per station; includes, (3) Band-Aid Combo Paks (2) Swabs, PVP (1) Antibiotic Ointment (1) Sting-Kill Swab (2) Dressing, compresses (2) Roller Bandages (2) Tape (2) Triangle Bandage (1) Eyedressing Pak (1) Burn Dressing (1) Ammonia Inhalants (1) User Log Sheet	Miner's Aid Stations

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
First Aid Supplies	According to General Order #35 (12) bandages, soft roller, self-ahdering type--4" or 6" x 5 yards. (6) triangular bandages, 40" (1) box band-aids (1) 1 pair bandage shears (6) Trauma dressings, 30" x 10" (6) Trauma dressings, 5" x 7" (50) 4" x 4" sponges, individually wrapped and sterile (2) rolls adhesive tape (1) penlight (2) sterile burn sheets (2) oropharyngeal airways -- adult (2) oropharyngeal airways -- child (Ambulance #1 only) (2) oropharyngeal airways -- infant (Ambulance #1 only) (1) Glucose substance (3) Occlusive dressings (1) Roll aluminum foil (6) Rigid cervical collars--2 each small, medium and large sizes (4) Cold packs (4) Heat packs (2) Bite sticks	Ambulance #1
First Aid Supplies	(2) Transfer sheets (2) Blankets	Ambulances #1 and #2
First Aid Supplies	(2) #16g angiosets (2) #18g angiosets (2) #20g angiosets (1) 1000cc LR IV fluid (1) 500cc NS IV fluid	Ambluances #1 and #2, surface rescue truck
General Plant Emergency Equipment		
Emergency Lighting	For employee rescue and evacuation, and fire/spill containment; linked to main power supply, and selectively linked to back up diesel power supply and/or battery-backed power supply	Surface and underground
Backup Power Sources	Two diesel generators, and lead-antimony battery-powered uninterruptible power supply (UPS); use limited to essential loads; manual or remote starting 1,100-kilowatt diesel generators with on-site fuel for 62% load for 3 days for selected loads; 30-minute battery capacity for essential loads	Generators are east of Safety and Emergency Services Building; UPS is located at the essential loads
Hoists	Hoists in Waste Shaft, Air Intake Shaft, and SH Shaft	Waste Shaft, Air Intake Shaft, SH Shaft
Portable Radiation Survey Equipment	α, B-γ survey meters	Operational Health Physics Office, Building 412

TABLE G-6 (CONTINUED)
EMERGENCY EQUIPMENT MAINTAINED
AT THE WASTE ISOLATION PILOT PLANT

Equipment	Description and Capabilities	Location
Radiation Monitoring Equipment	(5) Portable air samplers	Operational Health Physics Office located in Building 412
Emergency Shower	For emergency flushing of contaminated individual	Surface
Eye Wash Fountains	For emergency flushing of affected eyes	Various locations on surface and in the underground
Decon Trailer	Self-contained shower, change/survey room trailer for gross decontamination of personnel	West side of Building 412
Decon Shower	Three piece mobile shower unit for gross decontamination of personnel	Building 411
Overpack containers	14-85 Gallon drums 4-SWBs 1-RH Canister overpack for overpacking leaking or damaged containers	Building 411 Building 411 Building 411
HEPA Vacuums	2 HEPA Vacuums to be utilized for removal of contamination.	Waste Handling Building
Aquaset or Cement	100 lbs. of aquaset or cement material for solidification of liquid waste generated as a result of fire fighting water or decontamination solutions.	Waste Handling Building
Polyvinyl Alcohol or Paint	1 - 5 gallon bucket of approved fixative to be used during recovery.	Waste Handling Building
Deionized Soap/Detergent	4-1 Gallon bottles for decontamination of surfaces, equipment, and personnel	Building 411

TABLE G-7
TYPES OF FIRE SUPPRESSION SYSTEMS BY LOCATION

LOCATION	AS	AD	MPS	IFHC	PFE
Waste Handling Building	*		*	*	*
Support Building	*		*	*	*
Exhaust Filter Building	*		*	*	*
Water Pumphouse	*		*	*	*
Underground Support Areas (also has rescue truck)		*	*		*
Station A Effluent Monitoring Shed			*		*
Station B Effluent Monitoring Shed			*		*

(1)Symbols for WIPP fire-protection systems:

AS = Automatic Wet Pipe Sprinkler System
AD = Automatic Dry Chemical Extinguishing System
MPS = Manual Pull Stations
IFHC = Interior Fire Hose Connections
PFE = Portable Fire Extinguishers

(2)The Waste Handling Building and the Support Building contain the following:

- Automatic wet pipe sprinklers
- Interior fire hose connections
- Fire detection in the heating, ventilation, and air conditioning instrumentation (Support Building, only)
- Manual pull stations
- Portable fire extinguishers
- Automatic detectors

The Safety and Emergency Services Building contains the following:

- Automatic wet pipe sprinklers
- Manual pull stations
- Portable fire extinguishers
- Automatic detectors

The Core Storage Building contains the following:

- Automatic wet pipe sprinklers
- Portable fire extinguishers

(3)The Exhaust Filter Building, Underground Facilities, Warehouse/Shops Building, Water Pumphouse, and Salt Handling Hoist house and headframe also have portable fire extinguishers, manual pull stations, and automatic detectors.

TABLE G-8
HAZARDOUS RELEASE REPORTING, FEDERAL

Statute	Chemical Releases Covered	To Whom Report Must Be Made	What Must Be Reported	
			Immediately (Oral)	Subsequently (Written)
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA) (40 CFR Part 302)	"Reportable quantities" of CERCLA/SARA "hazardous substances."	National Response Center: (800) 424-8802, State Emergency Response Commission: (505) 827-9223 (New Mexico State Police, Hazardous Materials Emergency Response), and Local Emergency Planning Committee: (505) 887-9511	1) Chemical identification; 2) what hazardous substance; 3) quantity released; 4) time, location and duration of release; 5) media of release; 6) health risks and medical advice; 7) proper precautions (e.g., evacuation); and 8) name and phone number of reporter and facility.	As soon as practicable, update of oral notice and response action taken. Send report to: New Mexico State Emergency Response Commission, Department of Public Safety, Title III Bureau, P.O. Box 1628, Santa Fe, New Mexico, 87504-1628, and Local Emergency Planning Committee, 100 North Canal, P.O. Box 1139, Carlsbad, New Mexico 88221-1139. National Response Center will contact the U.S. Environmental Protection Agency (EPA). EPA may request a written report.
Emergency Planning and Community Right-to-Know Act (SARA Title III) (40 CFR Parts 302 and 355)	SARA Title III "extremely hazardous substances."	National Response Center: (800) 424-8802, State Emergency Response Commission: (505) 827-9223 (New Mexico State Police, Hazardous Materials Emergency Response), and Local Emergency Planning Committee: (505) 887-9511.	1) Chemical identification; 2) what extremely hazardous substance; 3) quantity released; 4) time, location and duration of release; 5) media of release; 6) health risks and medical advice; 7) proper precautions (e.g. evacuation); and 8) name and phone number of reporter and facility.	As soon as practicable, update of oral notice and response action taken. Send report to: New Mexico State Emergency Response Commission, Department of Public Safety, Title III Bureau, P.O. Box 1628, Santa Fe, New Mexico, 87504-1628, and Local Emergency Planning Committee, 100 North Canal, P.O. Box 1139, Carlsbad, New Mexico 88221-1139. National Response Center will contact the U.S. Environmental Protection Agency (EPA) for an address if a written report is requested by EPA.

TABLE G-8 (CONTINUED)
HAZARDOUS RELEASE REPORTING, FEDERAL

Statute	Chemical Releases Covered	To Whom Report Must Be Made	What Must Be Reported	
			Immediately (Oral)	Subsequently (Written)
Resource Conservation and Recovery Act (RCRA), 40 CFR §§264.56(a) and 265.56(a)	Any imminent or actual emergency situation.	State or local agencies with designated response roles, if their help is needed: Carlsbad Police Department: 885-2111; Carlsbad Fire Department: 885-2111; Eddy County Sheriff: 887-7551.	What assistance is required.	Not Applicable (NA)
RCRA, 40 CFR §§264.56(d), 264.56(i), 265.56(d), and 265.56(i)	RCRA "hazardous waste" release, fire, or explosion, which could threaten human health or environment outside the facility.	National Response Center: (800) 424-8802 and State Emergency Response Commission: (505) 827-9223 (New Mexico State Police, Hazardous Materials Emergency Response).	(1) Name and telephone number of reporter; (2) name and telephone number of facility; (3) time and type of incident; (4) name and quantity of materials involved; (5) extent of injuries, if any; and (6) possible health or environmental hazards outside the facility.	Prior to resumption of operations, notify that: (1) no waste that may be incompatible with released material is treated, stored, or disposed of until cleanup is complete, and (2) all emergency equipment listed in the Contingency Plan is cleaned and fit for its intended use. Send to Secretary, New Mexico Environment Department, 525 Camino de los Marquez, Santa Fe, New Mexico, 87503.

TABLE G-8 (CONTINUED)
HAZARDOUS RELEASE REPORTING, FEDERAL

Statute	Chemical Releases Covered	To Whom Report Must Be Made	What Must Be Reported	
			Immediately (Oral)	Subsequently (Written)
RCRA, 40 CFR §§264.56(i), 264.56(j), 265.56(i), and 265.56(j)	Any incident which triggers implementation of Contingency Plan.	New Mexico Environment Department, Emergency Response Office, 24-hour telephone: (505) 827-9329 or Monday to Friday, 8am to 5pm: (505) 827-2915 or (505) 827-0188.	NA	Within 15 days: 1) name, address and telephone number of owner/operator; 2) name, address and telephone number of facility; 3) date, time and type of incident (e.g. fire, explosion); 4) name and quantity of materials involved; 5) extent of injuries, if any; 6) possible hazards to human health or the environment; 7) estimated quantity of material that resulted from the incident. Prior to resumption of operations, notify that: 1) no waste that may be incompatible with released material is treated, stored, or disposed of until cleanup is complete, and 2) all emergency equipment listed in the Contingency Plan is cleaned and fit for its intended use. Send to Secretary, New Mexico Environment Department, 525 Camino de los Marquez, Santa Fe, New Mexico, 87503.

TABLE G-9
HAZARDOUS RELEASE REPORTING, STATE OF NEW MEXICO

Regulations	Chemical Releases Covered	To Whom Report Must Be Made	What Must Be Reported	
			Immediately (Oral)	Subsequently (Written)
Title 20 of the New Mexico Administrative Code, Chapter 4, Part 1 (20 NMAC 4.1), Subpart V and Subpart VI	RCRA "hazardous waste" releases, fire, or explosion, which could threaten human health or environment outside the facility.	National Response Center: (800) 424-8802; State Emergency Response Commission and (505) 827-9223 (New Mexico State Police, Hazardous Materials Emergency Response)	1) Name and telephone number of reporter; 2) name and telephone number of facility; 3) time and type of incident; 4) name and quantity of material involved; 5) extent of injuries, if any; and 6) possible health or environmental hazards outside the facility.	Prior to resumption of operations, notify that: 1) no waste that may be incompatible with released material is treated, stored, or disposed of until cleanup is complete, and 2) all emergency equipment listed in the Contingency Plan is cleaned and fit for its intended use. Send to Secretary, New Mexico Environment Department, 525 Camino de los Marquez, Santa Fe, New Mexico, 87503.
20 NMAC 4.1, Subpart V and Subpart VI	Any incident which triggers implementation of Contingency Plan.	New Mexico Environment Department, Emergency Response Office, 24-hour telephone: (505) 827-9329 or Monday to Friday, 8am to 5pm: (505) 827-2915 or (505) 827-0188.	1) Name and telephone number of reporter; 2) name and address of facility; 3) name and quantity of materials involved, to extent known; 4) extent of injuries, if any; and 5) possible hazards to human health or the environment, outside the facility.	Within 15 days: 1) name, address and telephone number of owner/operator; 2) name, address and telephone number of facility; 3) date, time and type of incident (e.g., fire, explosion); 4) name and quantity of materials involved; 5) extent of injuries, if any; 6) possible hazards to human health or the environment; and 7) estimated quantity of material that resulted from the incident. Prior to resumption of operations, notify that: 1) no waste that may be incompatible with released material is treated, stored or disposed of until cleanup is complete, and 2) all emergency equipment listed in the Contingency Plan is cleaned and fit for its intended use. Send to Secretary, New Mexico Environment Department, 525 Camino de los Marquez, Santa Fe, New Mexico, 87503.

TABLE G-9 (CONTINUED)
HAZARDOUS RELEASE REPORTING, STATE OF NEW MEXICO

Regulations	Chemical Releases Covered	To Whom Report Must Be Made	What Must Be Reported	
			Immediately (Oral)	Subsequently (Written)
New Mexico Emergency Management Act, Section 74-4B-5	Any accident (spill) involving hazardous materials (including hazardous substances, radioactive substances, or a combination thereof) which may endanger human health or the environment.	New Mexico Environment Department: (505) 827-9329, State Emergency Response Commission: (505) 827-9223 (New Mexico State Police, Hazardous Materials Emergency Response), and Local Emergency Planning Committee: (505) 887-9511	1) Name, address and telephone number of owner or operator; 2) name, address and telephone number of facility; 3) date, time and type of incident; 4) name and quantity of material(s) involved; 5) extent of any injuries; 6) assessment of actual or potential threat to environment or human health; and 7) estimated quantity and disposition of recovered material.	Written submission within one week of time permittee becomes aware of discharge. Same as oral and description of noncompliance and its cause, the period of noncompliance including exact dates and times, and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence. Send reports to New Mexico Environment Department, Chief, Ground Water Bureau, 525 Camino del los Marquez, Santa Fe, New Mexico, 87503, New Mexico State Emergency Response Commission Department of Public Safety, Title III Bureau, P.O. Box 1628 Santa Fe, New Mexico, 87504-1628, and Local Emergency Planning Committee, 100 North Canal, P.O. Box 1139, Carlsbad, New Mexico, 88221-1139.

TABLE G-9 (CONTINUED)
HAZARDOUS RELEASE REPORTING, STATE OF NEW MEXICO

Regulations	Chemical Releases Covered	To Whom Report Must Be Made	What Must Be Reported	
			Immediately (Oral)	Subsequently (Written)
New Mexico Water Quality Control Commission, Part 1, Section 203	Any discharge from any facility of oil or any other water contaminant in such quantities as may, with reasonable probability, injure or be detrimental to human health, animal or plant life, or property.	Chief, Ground Water Bureau, New Mexico Environment Department, or his counterpart in any constituent agency delegated responsibility for enforcement of the rules as to any facility subject to such delegation (505) 827-2918.	Within 24 hours: 1) the name, address, and telephone number of the person or persons in charge of the facility; 2) the name, address, and telephone number of the owner/operator of the facility; 3) the date, time, location, and duration of the discharge; 4) the source and cause of the discharge; 5) a description of the discharge, including its chemical composition; and 6) the estimated volume of discharge, and immediate damage from the discharge.	Submit within seven days: verification of the prior oral notification, also provide any appropriate additions or corrections to the information contained in the prior oral notification. Within 15 days: submit a written report describing any corrective actions taken and/or to be taken relative to the discharge. Send reports to Chief, Ground Water Bureau, New Mexico Environment Department, 525 Camino de los Marquez, Santa Fe, New Mexico, 87503.
New Mexico Underground Storage Tank Regulations-2	Any known or suspected release from an Underground Storage Tank (UST) system, any spill or any other emergency situation.	New Mexico Environment Department (Hazardous Waste Bureau): (505) 827-9329.	Within 24 hours: 1) the name, address, and telephone number of the agent in charge of the site at which the UST system is located, as well as the owner/operator of the system; 2) the name and address of the site and the location of the UST system on that site; 3) the date, time, location, and duration of the spill, release, or suspected release; 4) the source and cause of the spill, release, or suspected release; 5) a description of the spill, release, or suspected release, including its chemical composition; 6) the estimated volume of the spill, release, or suspected release; and 7) action taken to mitigate immediate damage from the spill, release, or suspected release.	Mail or deliver within seven days of the incident, a written notice describing the spill, release, or suspected release and any investigation or follow-up action taken or to be taken. Send reports to Underground Storage Tank Program, New Mexico Environment Department, 525 Camino de los Marquez, Santa Fe, New Mexico, 87503.

FIGURES

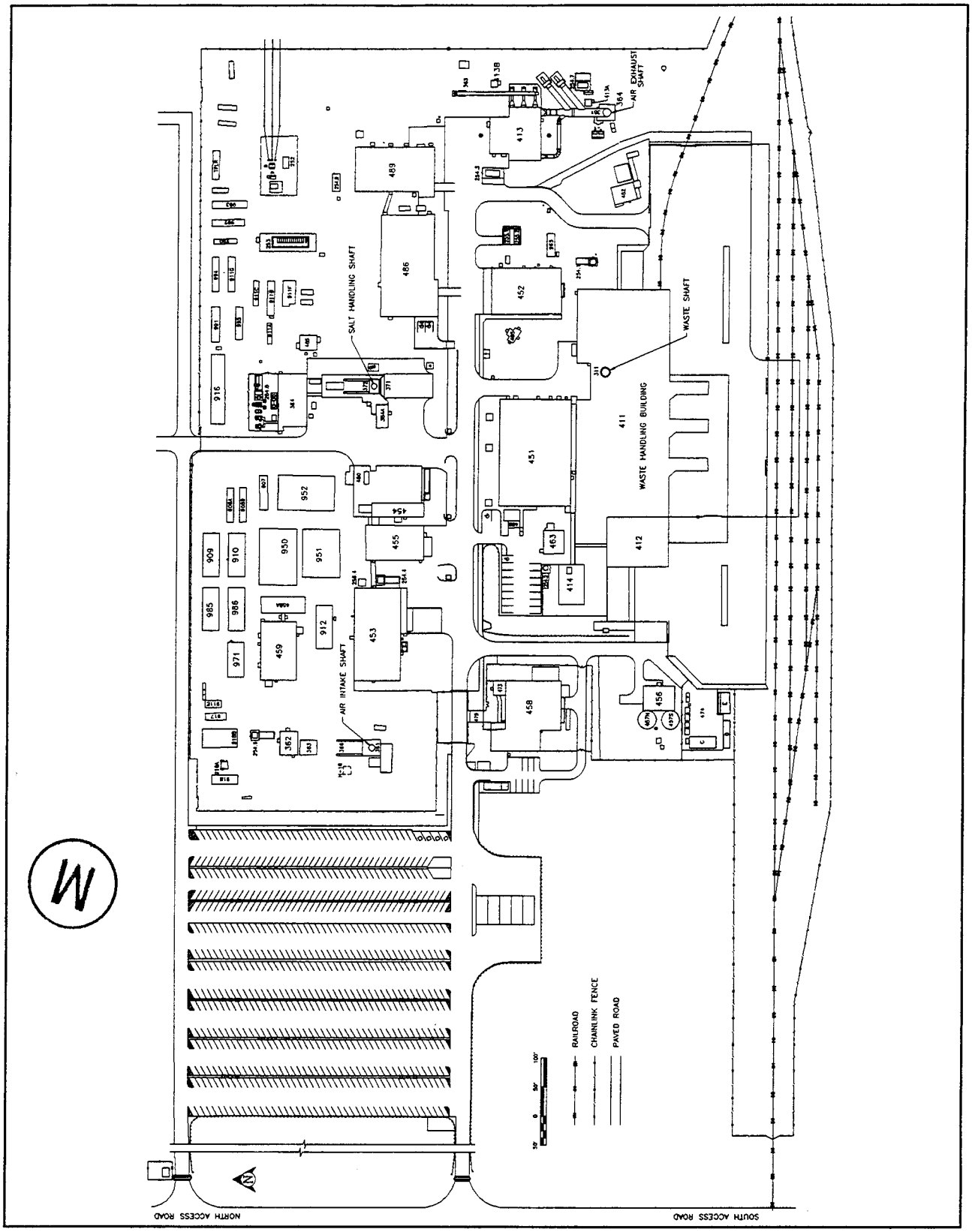
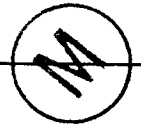


Figure G-1
WIPP Surface Structures



FACILITIES, USAGE AND STRUCTURE NUMBERS

BLDG./ FAC. #	DESCRIPTION
252	SPS UTILITY SUBSTATION
253	13.8 KV SWITCHGEAR 25P-SWG15/1
254.1	AREA SUBSTATION NO.1 25P-SW15.1
254.2	AREA SUBSTATION NO.2 25P-SW15.2
254.3	AREA SUBSTATION NO.3 25P-SW15.3
254.4	AREA SUBSTATION NO.4 25P-SW15.4
254.5	AREA SUBSTATION NO.5 25P-SW15.5
254.6	AREA SUBSTATION NO.6 25P-SW15.6
254.7	AREA SUBSTATION NO.7 25P-SW15.7
254.8	AREA SUBSTATION NO.8 25P-SW15.8
255.1	EMERGENCY GENERATOR #1 25-PE 503
255.2	EMERGENCY GENERATOR #2 25-PE 504
311	WASTE SHAFT
351	EXHAUST SHAFT
361	AIR INTAKE SHAFT
362	AIR INTAKE SHAFT/HOIST HOUSE
363	AIR INTAKE SHAFT/WINCH HOUSE
364	EFFLUENT MONITORING INSTRUMENT SHED A
365	EFFLUENT MONITORING INSTRUMENT SHED B
366	AIR INTAKE SHAFT HEADFRAME
371	SALT HANDLING SHAFT
372	SALT HANDLING SHAFT HEADFRAME
384	SALT HANDLING SHAFT HOISTHOUSE
384A	SALT HOIST OPERATIONS
411	WASTE HANDLING BUILDING
412	TRUPACT MAINTENANCE BUILDING
413	EXHAUST FILTER BUILDING
413A	EFFLUENT MONITORING ROOM A
413B	EFFLUENT MONITORING ROOM B
414	WATER CHILLER FACILITY & BLDG
451	SUPPORT BUILDING
452	SAFETY & EMERGENCY SERVICES FACILITY
453	WAREHOUSE/SHOPS BUILDING
454	VEHICLE SERVICE BUILDING
455	AUXILLIARY WAREHOUSE BUILDING

BLDG./ FAC. #	DESCRIPTION
456	WATER PUMPHOUSE
457N	WATER TANK 25-D-001A
457S	WATER TANK 25-D-001B
458	GUARD AND SECURITY BUILDING
459	CORE STORAGE BUILDING
459A	SANDIA ANNEX
463	COMPRESSOR BUILDING
465	AUXILIARY AIR INTAKE
468	TELEPHONE HUT
473	ARMORY BUILDING
474	HAZARDOUS WASTE STORAGE FACILITY
474A	HAZARDOUS WASTE STORAGE BUILDING
474B	HAZARDOUS WASTE STORAGE BUILDING
474C	OIL & GREASE STORAGE BUILDING
474D	GAS BOTTLE STORAGE BUILDING
474E	HAZARD MATERIAL STORAGE BUILDING
474F	WASTE OIL RETAINER
475	GATEHOUSE
480	VEHICLE FUEL STATION
482	EXHAUST SHAFT HOIST EQUIP. WAREHOUSE
485	SULLAIR COMPRESSOR BUILDING
486	ENGINEERING BUILDING
489	TRAINING BUILDING
816	SANDIA TEST WELL (NOT IDENTIFIED)
907	TRANS. & HAZ. MATERIAL HANDLING TRAILER
908A	ENVIRONMENTAL MONITORING LAB TRAILER
908B	UNIVERSITY CONSORTIUM TRAILER
909	PROJECT CONTROL TRAILER
910	ENVIRONMENTAL MONITORING TRAILER
911A	SITE LOCKSMITH TRAILER
911B	SANDIA M101 TRAILER
911C	SANDIA OFFICES TRAILER
911E	SANDIA TRAILER
911F	SANDIA B49 AND B49 ANNEX

BLDG./ FAC. #	DESCRIPTION
911G	SANDIA LABS TRAILER
912	TRAINING TRAILER
914A	TRAINING TRAILER
915	NEW MEXICO ENVIR. DEPT. TRAILER
916	SANDIA OFFICES TRAILER
917	AIS MONITORING
918	VOC TRAILER
918A	VOC AIR MONITORING STATION
918B	VOC LAB TRAILER
950	WORK CONTROL TRAILER
951	PROCUREMENT / PURCHASING
952	TRAILER (7-PLEX)
965	SAMPLE LABORATORY TRAILER
971	HUMAN RESOURCES TRAILER
982	MAINTENANCE TRAILER
985	QA TRAILER
986	PUBLICATIONS & PROCEDURES TRAILER
991	SANDIA OFFICES TRAILER
992	SANDIA CALIBRATION LAB TRAILER
993	SANDIA OFFICES TRAILER
994	SANDIA LAB TRAILER
995	SANDIA QA RECORDS TRAILER
SWR NO.1	SWITCHRACK NO. 1
SWR NO.2	SWITCHRACK NO. 2
SWR NO.3	SWITCHRACK NO. 3
SWR NO.4	SWITCHRACK NO. 4
SWR NO.6	SWITCHRACK NO. 6
SWR NO.7,7A,7B	SWITCHRACK NO. 7, 7A, 7B
SWR NO.7C	SWITCHRACK NO. 7C
SWR NO.8	SWITCHRACK NO. 8
SWR NO.9	SWITCHRACK NO. 9
SWR NO.10	SWITCHRACK NO. 10
SWR NO.11	SWITCHRACK NO. 11
--	SANDIA GENERATOR NO.1
--	SANDIA GENERATOR NO.2

Figure G-1a
Legend to Figure G-1

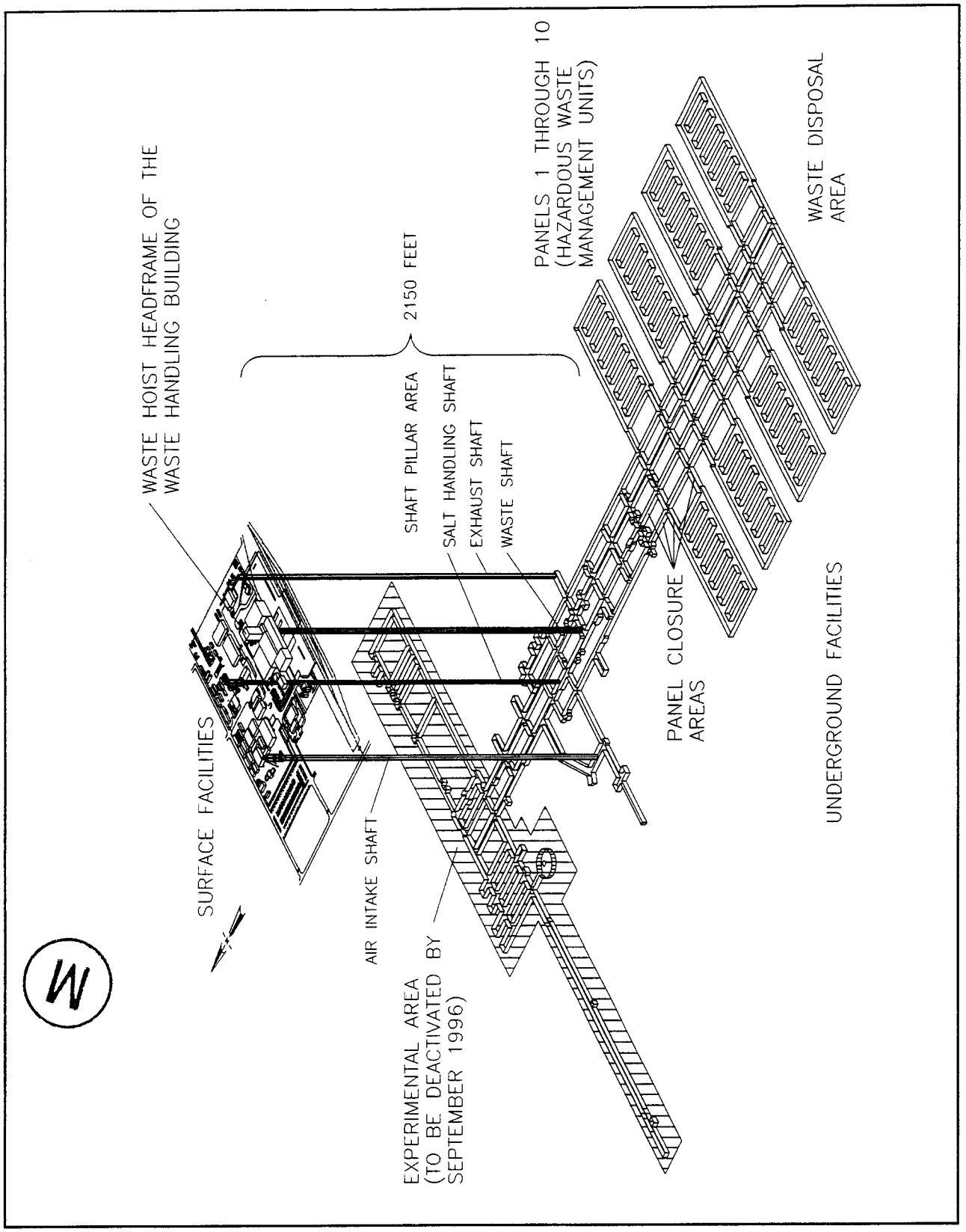


Figure G-2
Spatial View of the WIPP Facility

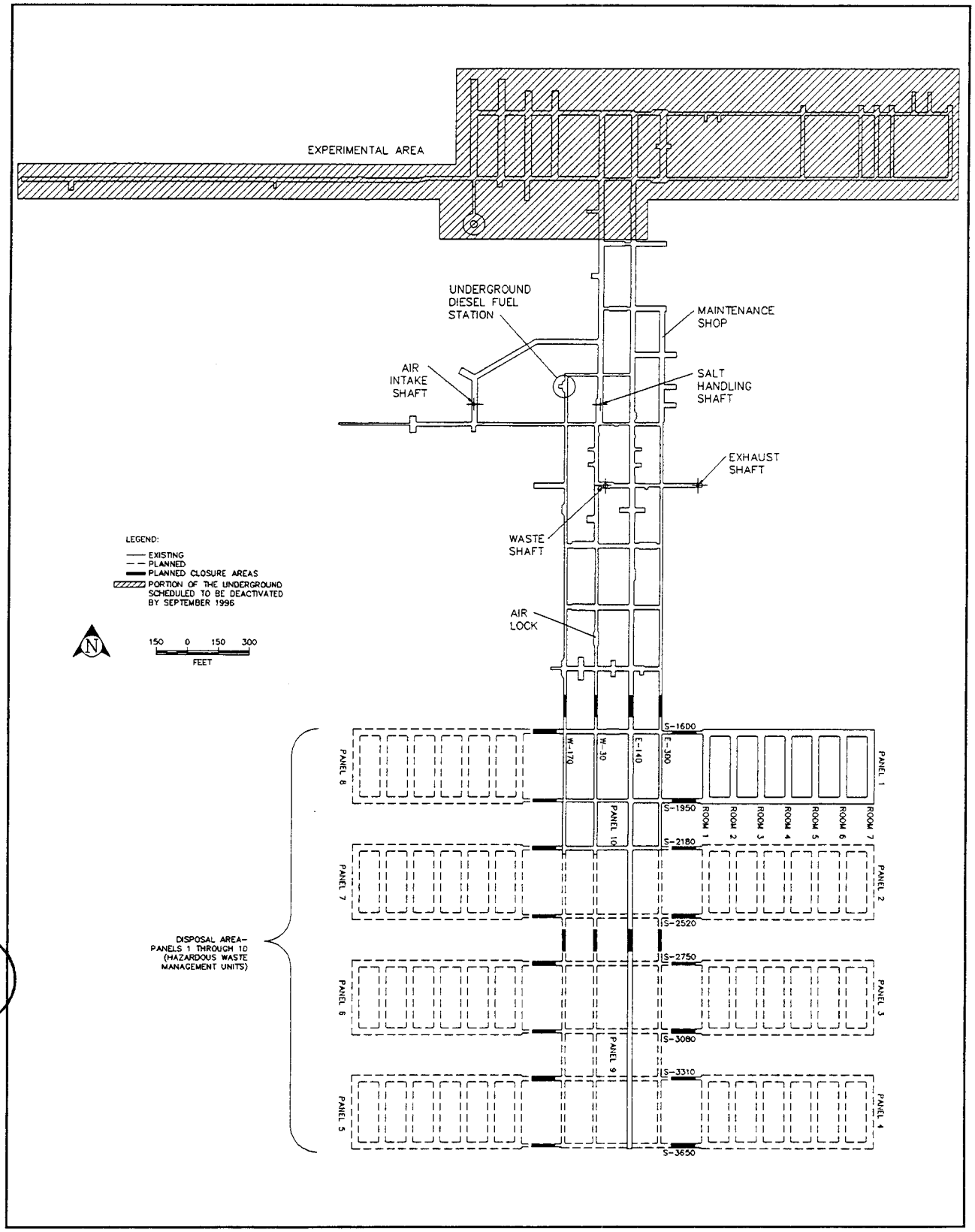


Figure G-3
WIPP Underground Facilities

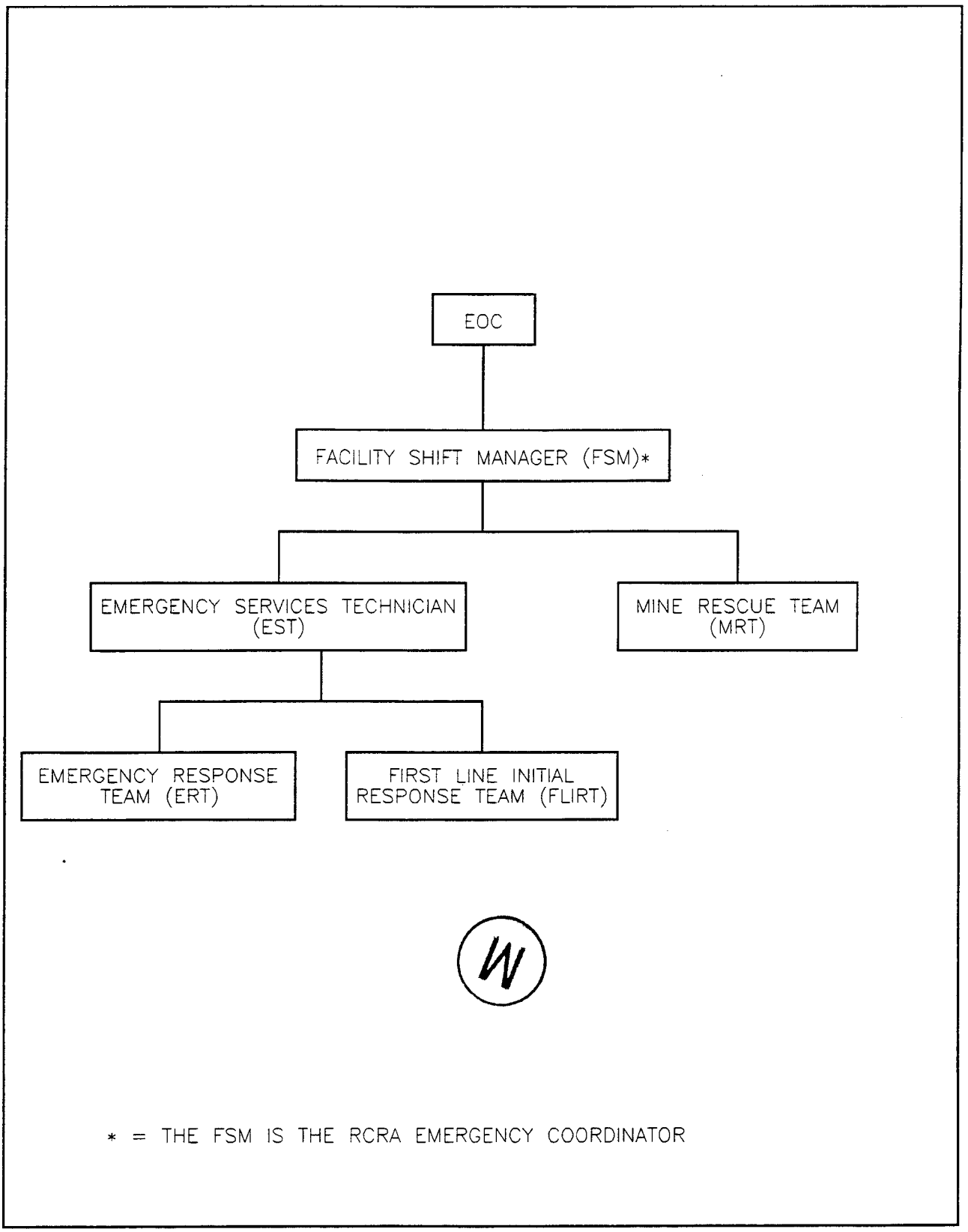


Figure G-4
Direction and Control Under Emergency Conditions In Which the Contingency Has Been Implemented

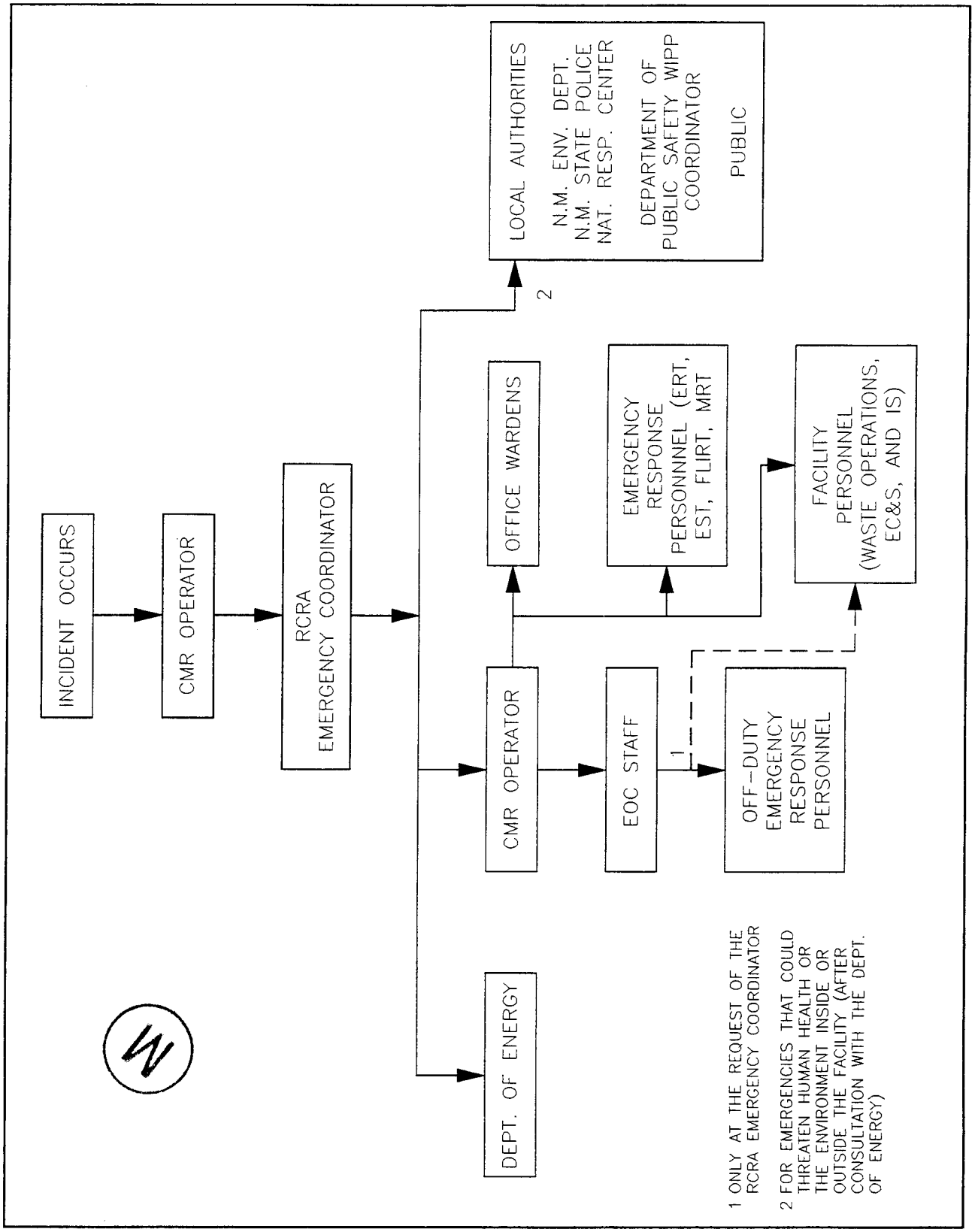


Figure G-4a
WIPP Facility Emergency Notifications

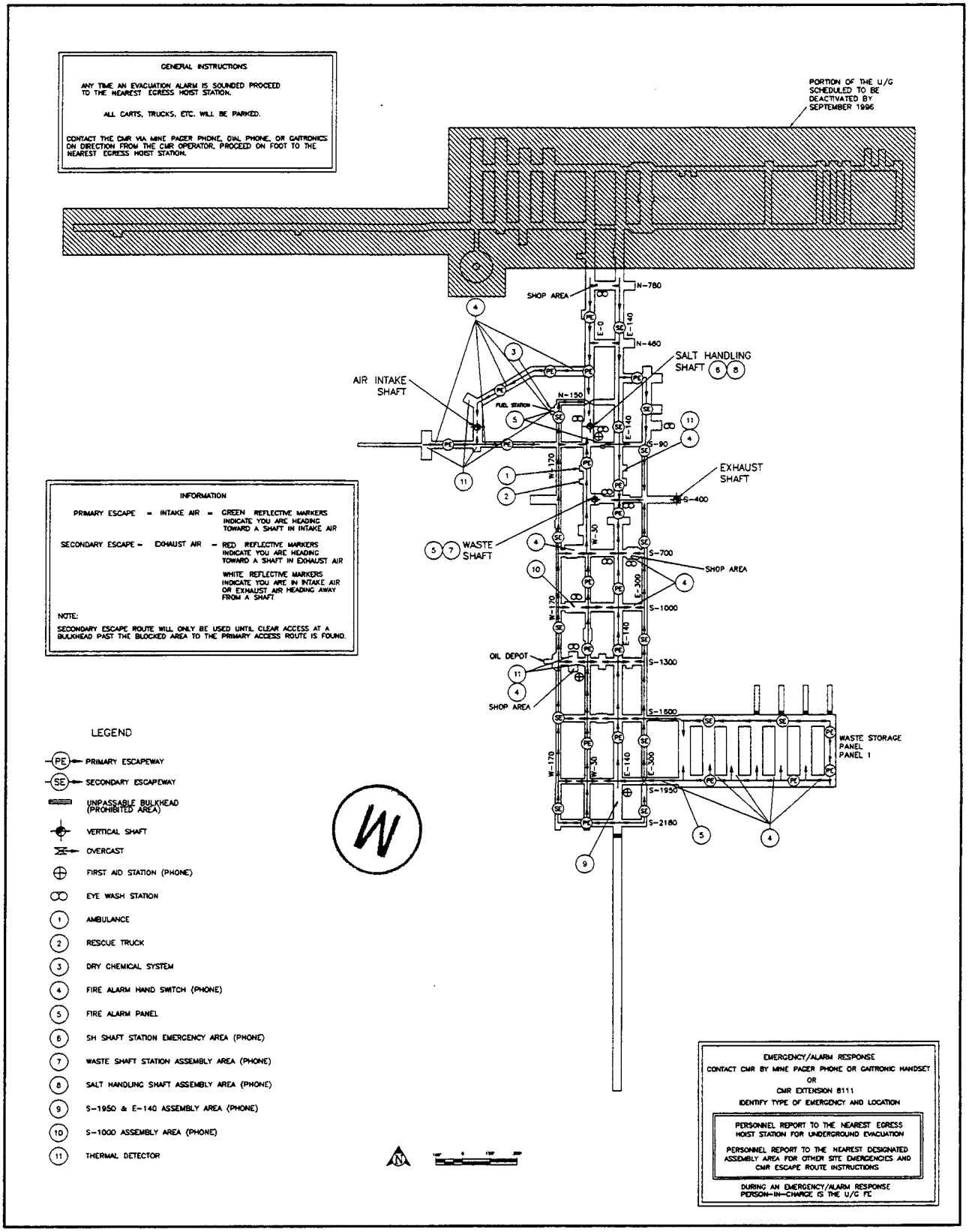


Figure G-5

Underground Emergency Equipment Locations and Underground Evacuation Routes

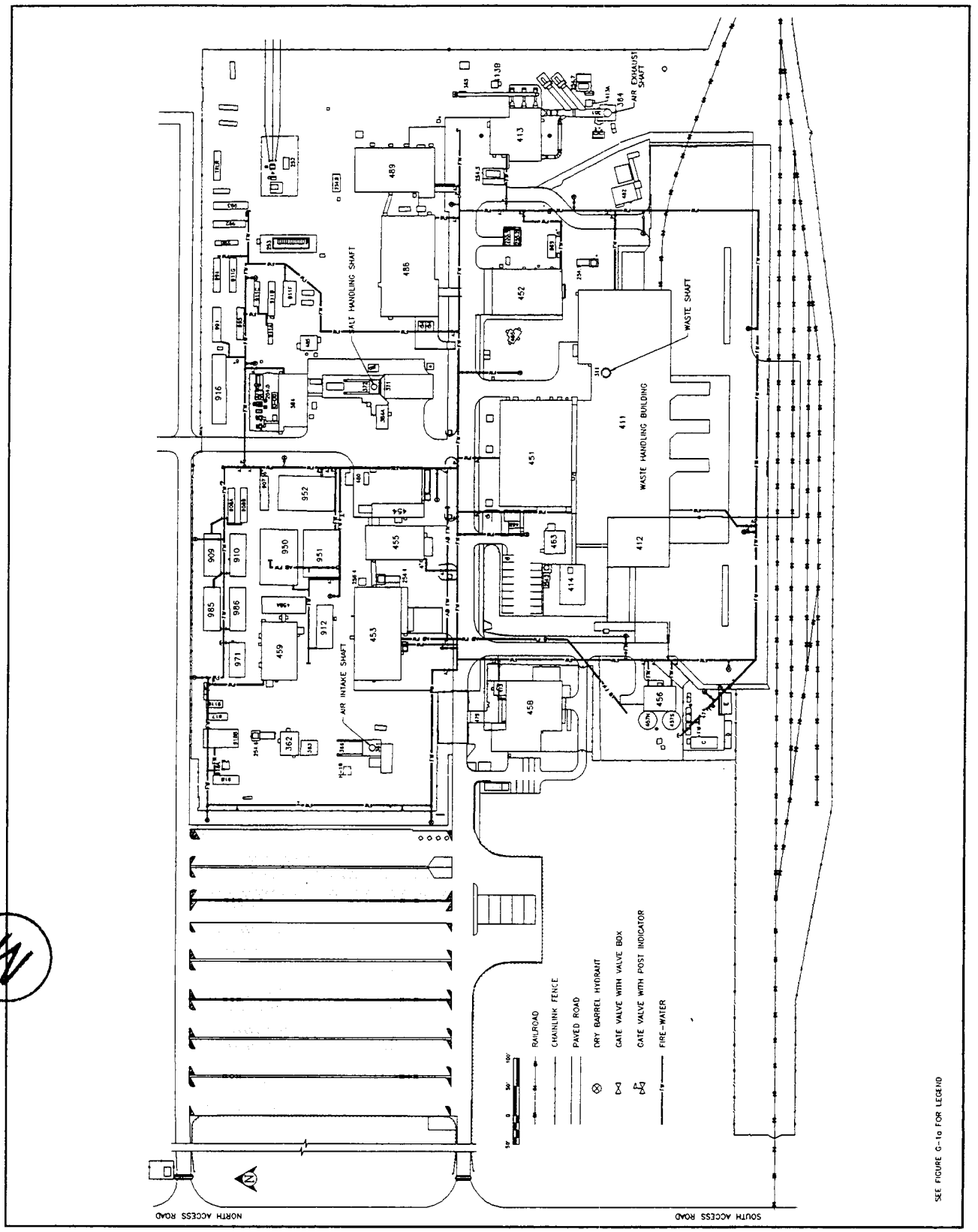


Figure G-6
Fire-Water Distribution System

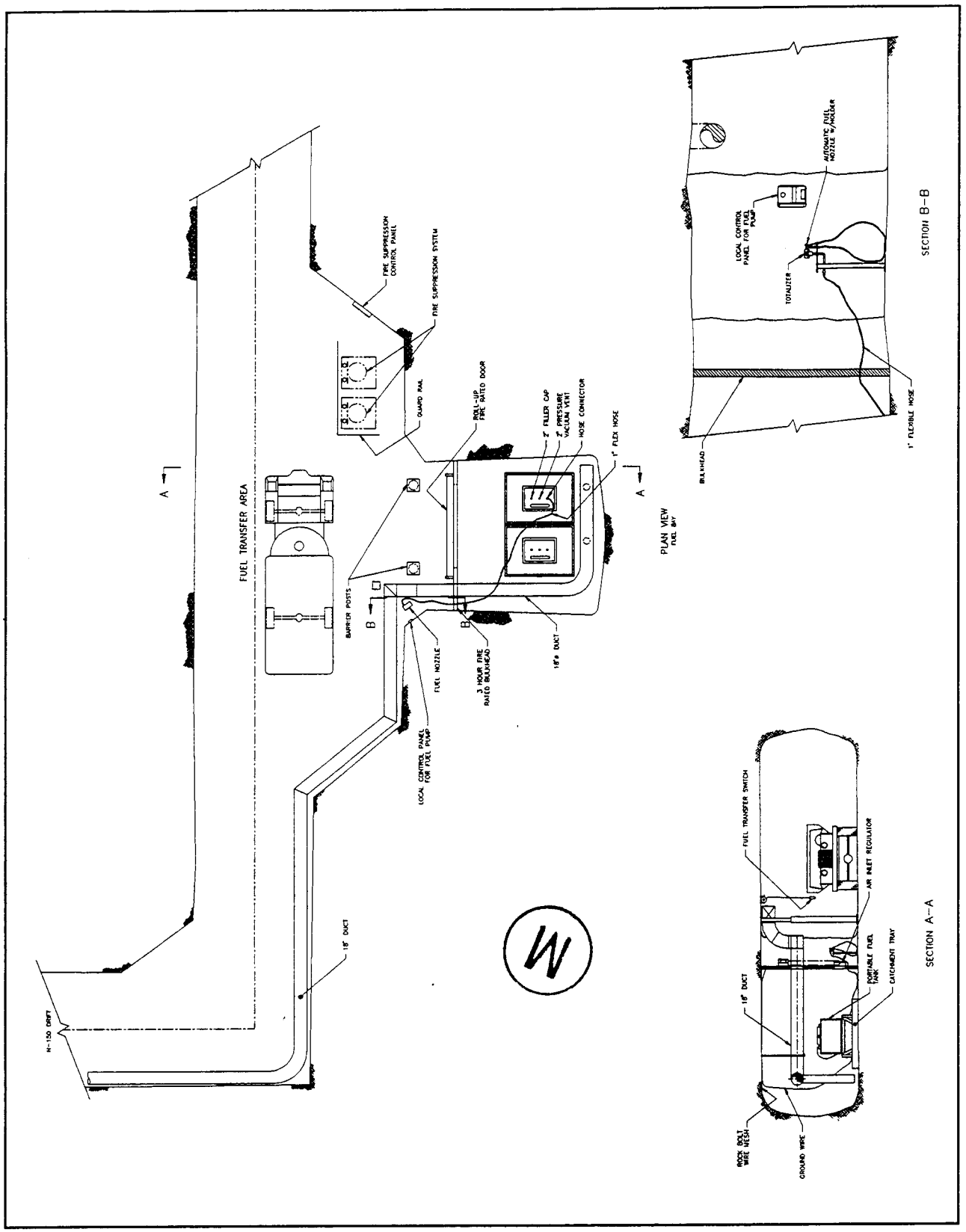


Figure G-7
Underground Diesel Fuel-Station Area Fire-Protection System

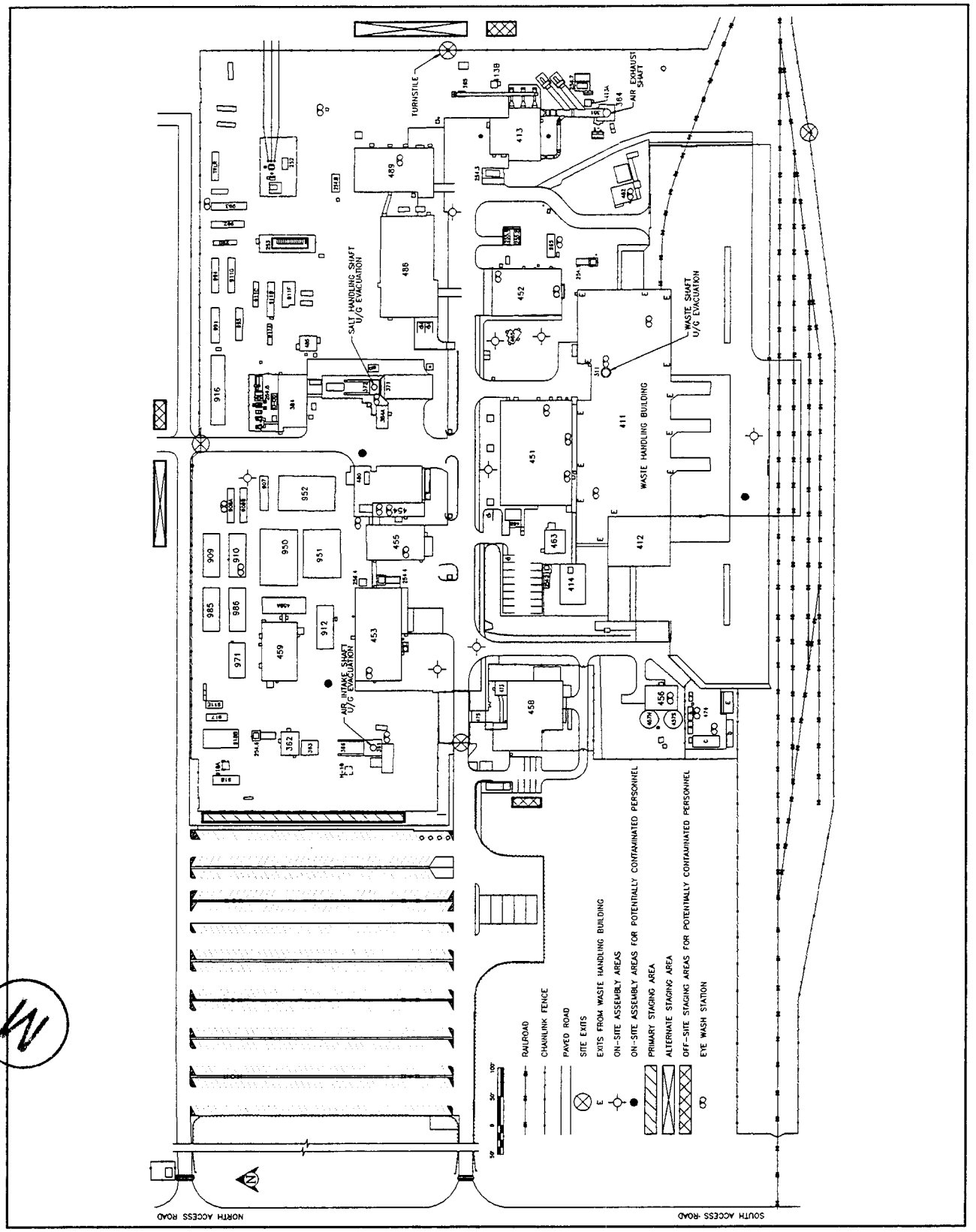


Figure G-8
WIPP On-Site Assembly Areas and WIPP Staging Areas

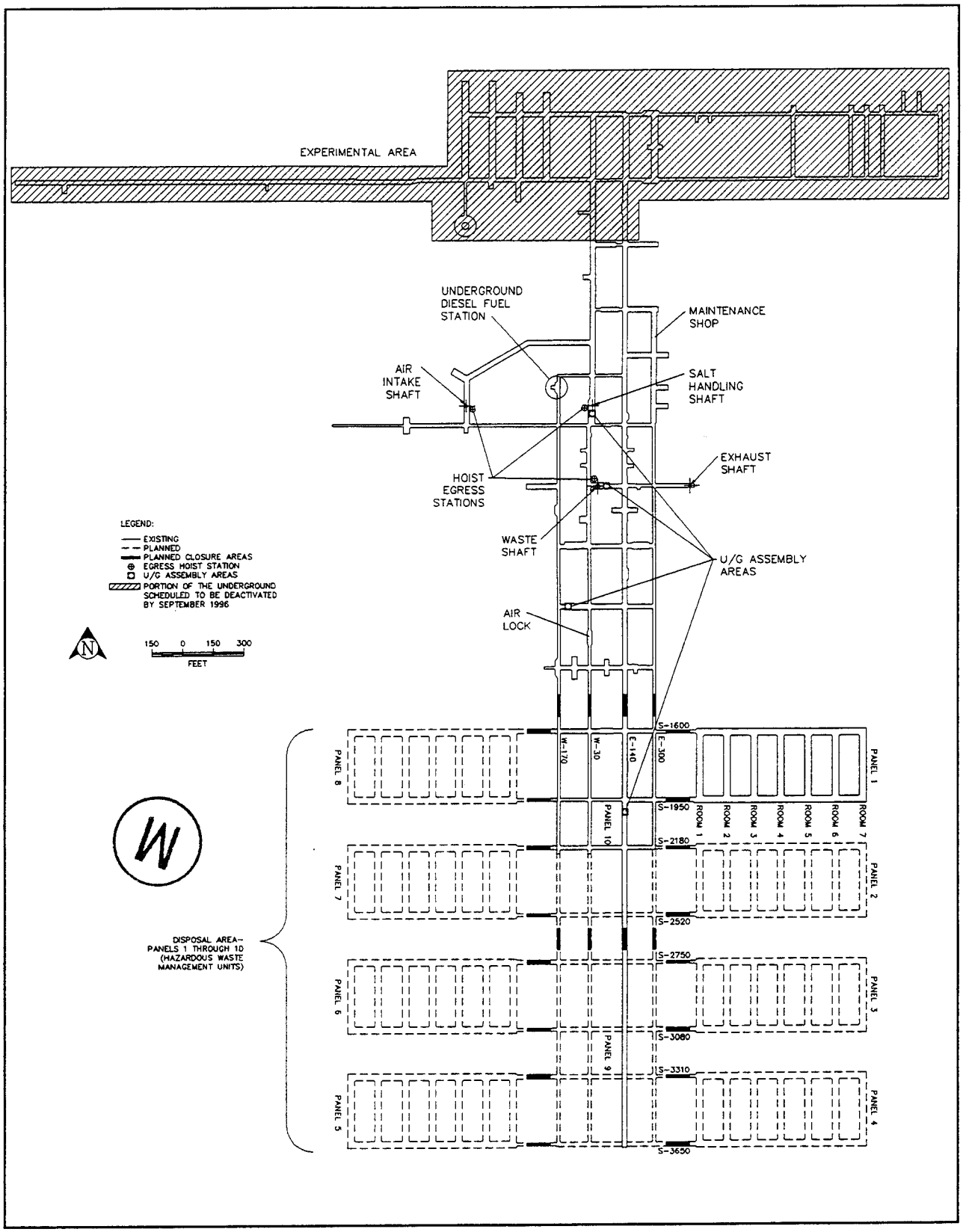


Figure G-9
Designated Underground Assembly Areas

Pre-Fire Survey

1. Bldg. Name: WASTE HANDLING BUILDING
2. Address: 411 SITE
3. Occ. Type: MAINTENANCE AND OPERATIONS PERSONNEL
4. Map #: 411-1 5. Landlord: JOE UPTERGROVE
6. Roof Const.: METAL 7. Floor Const.: CONCRETE
8. Date: 07/27/94 9. Revision Date: 07/27/95
10. Surrounding Bldgs.: 412, 463, 451, 452
11. Fire Hydrants: FH-#8 N, FH-#11 E, FH-#12 S, FH-#13 S,

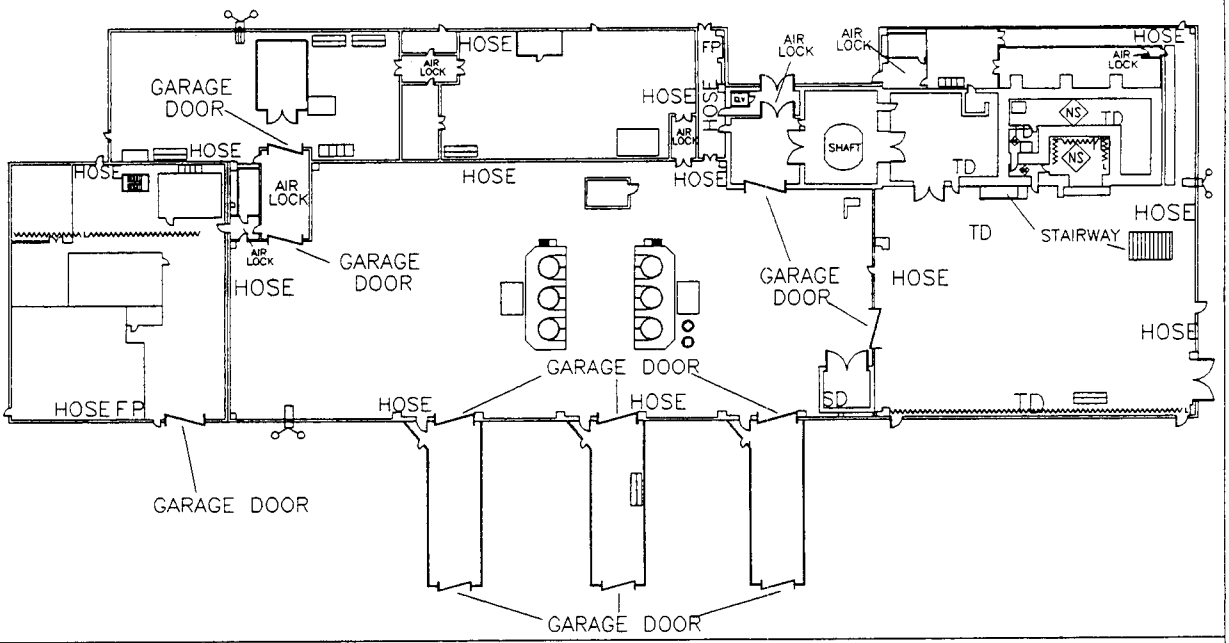
N

LEGEND

	ELECTRICAL PANEL
	FLAMMABLE CABINET
TD	THERMAL DETECTOR
	NONSPRINKLERED AREA
L	LADDER & WALKWAY
HOSE	75' FIRE HOSE
FP	FIRE CONTROL PANEL
SD	SMOKE DETECTOR
	STANDPIPE WITH F. D. CONNECTION

411

WASTE HANDLING BUILDING (1ST FLOOR)



12. Comments: NONE

13. Prepared By: JASON BRADLEY

Figure G-10

Pre-Fire Survey Plan for the First Floor of the Waste Handling Building

Pre-Fire Survey

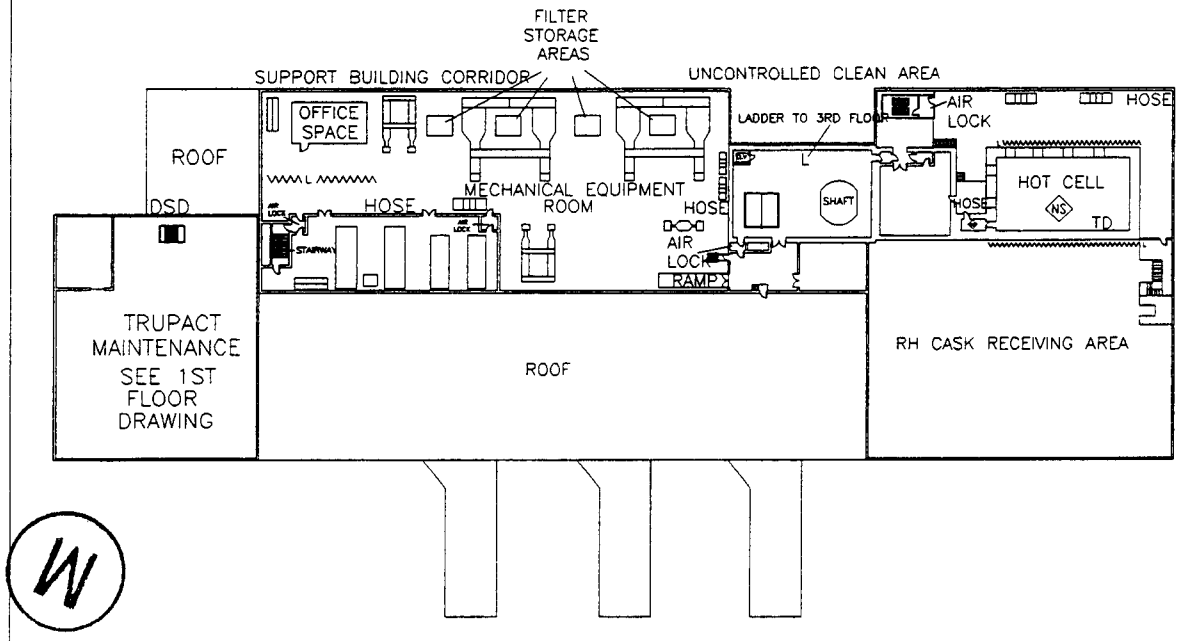
1. Bldg. Name: WASTE HANDLING BUILDING
2. Address: 411 SITE
3. Occ. Type: MAINTENANCE AND OPERATIONS PERSONNEL
4. Map #: 411-2 5. Landlord: JOE UPTERGROVE
6. Roof Const.: METAL 7. Floor Const.: CONCRETE
8. Date: 07/27/94 9. Revision Date: 07/27/95
10. Surrounding Bldgs.: 412, 463, 451, 452
11. Fire Hydrants: FH-#8 N, FH-#11 E, FH-#12 S, FH-#13 S,

N

LEGEND	
	ELECTRICAL PANEL
	FLAMMABLE CABINET
TD	THERMAL DETECTOR
NS	NONSPRINKLERED AREA
L	LADDER & WALKWAY
HOSE	75' FIRE HOSE
DSD	INDUCT SMOKE DETECTOR

411

WASTE HANDLING BUILDING (2ND FLOOR)



12. Comments: NONE

13. Prepared By: JASON BRADLEY

Figure G-11

Pre-Fire Survey Plan for the Second Floor of the Waste Handling Building

WIPP HAZARDOUS MATERIAL INCIDENT REPORT

Date:_____ Location:_____ Page 1 of 3

I. INITIAL INFORMATION: DATE:_____ TIME:_____

EST:_____ REPORTED LOCATION:_____

REPORTED BY:_____ DEPT.:_____

INITIALLY REPORTED TO:_____ DEPT.:_____

RESPONSIBLE MANAGER:_____ DEPT.:_____

II. WEATHER CONDITIONS: WIND DIRECTION:_____ WIND SPEED:_____mph TEMP.:_____ F

CONDITIONS (ie. icy, snowing, raining, cloudy, sunny):_____

III. TYPE OF INCIDENT (SPILL, LEAK, ETC.):_____ Fire Involved: [ ]YES [ ]NO

(If fire is involved attach a copy of the fire report)

MATERIALS INVOLVED	UN/NA NO.	QUANTITY	HAZARD CLASS	N.F.P.A. CLASS

IV. PERSONNEL INVOLVED IN CLEAN-UP ACTIVITIES

PERSONNEL/DEPT.	DECON METHOD/MEDICAL TEATMENT

V. PERSONNEL CONTAMINATED NOT INVOLVED IN THE CLEANUP ACTIVITIES

PERSONNEL/DEPT.	MATERIAL CONTACTED	DECON/MEDICAL TREATMENT

Figure G-12
WIPP Hazardous Materials Incident Report

WIPP HAZARDOUS MATERIAL INCIDENT REPORT

Date:_____ Location:_____

V. EQUIPMENT USED FOR CLEAN-UP AND CONTROL MEASURES

EQUIPMENT/MATERIAL/PPE	QUANTITY	DISPOSITION (decon or replacement)

VI. DESCRIPTION OF INCIDENT AND RESPONSE (including containment and control)

VII. TO BE COMPLETED BY ENVIRONMENTAL COMPLIANCE AND SUPPORT SECTION

Date:_____ Time:_____ of evaluation.

Waste Category_____ Disposal Method _____

Organization	DATE	TIME

EC&S Representative:_____
Print name Signature Date

Figure G-12 (Continued)
WIPP Hazardous Materials Incident Report

WIPP HAZARDOUS MATERIAL INCIDENT REPORT

Date: _____ Location: _____ Page 3 of 3

VIII. TO BE COMPLETED BY THE CMRO AND FSM

DEPARTMENT	PERSON CONTACTED	TIME	NOTIFIED BY
Facility Ops. (FSM)			
Emerg. Mgmt. (EST)			
EC&S			
Industrial Safety			
Facility Ops. (FM/FMD)			

CMRO: _____
Print name Signature Date

FSM: _____
Print name Signature Date

IX. TO BE COMPLETED BY HAZARDOUS WASTE OPERATIONS

Disposition: _____

Hazardous Waste Operations Representative: _____
Print name Signature Date

X. REVIEWS

Report submitted by: _____
Print name Signature Date

Emergency Management Manager: _____
Print name Signature Date

EC&S Manager: _____
Print name Signature Date

COMMENTS: _____

Figure G-12 (Continued)
WIPP Hazardous Materials Incident Report

DRAWINGS

REFERENCE DRAWINGS

WASTE HANDLING BUILDING 411 EQUIPMENT ARRANGEMENT PLAN EL. 100'-0" SHT 1 OF 6	41-0-501
WASTE HANDLING BUILDING 411 EQUIPMENT ARRANGEMENT PLAN EL. 100'-0" SHT 2 OF 6	41-0-502
WASTE HANDLING BUILDING 411 EQUIPMENT ARRANGEMENT PLAN EL. 122'-1" SHT 4 OF 6	41-0-504

THIS DRAWING IS UP-TO-DATE WITH THE FOLLOWING OUTSTANDING ENGINEERING CHANGE ORDERS: NONE

THIS DRAWING OBSOLETE AFTER 9-1-96

REV	DATE	ISSUE DESCRIPTION	BY	ENG	ECO	EWP
A	9/1987	DESIGN RESPONSIBILITY TRANSFERRED TO WESTINGHOUSE	R.L.	MB	2000	

NR	5	9/16/83	ISSUED FOR CONSTRUCTION	VRE	DRP	JFC	RB	MGT	
NR	4	21OCT 1983	ISSUED FOR APPROVAL	VRE	DRP	BJW	RB	MGT	
NR	3	8JUL 1983	GENERALLY REVISED AND ISSUED FOR PROGRESS REVIEW	GTA	DP	BJW	RB	RB	
NR	2	18FEB 1983	GENERALLY REVISED AND ISSUED FOR PROGRESS REVIEW	LRU	X	CT	RB	MGT	
NR	1	14OCT 1981	ISSUED FOR APPROVAL	LEM	DP	GFM	LJT	RB	
NR	0	30JUN 1981	ISSUED FOR PROGRESS REVIEW	GEM	DP	GFM	LJT	RB	
CE	REV	DATE	ISSUE DESCRIPTION	BY	CK'D	SUPV	P E	PEM	DOE

Best Copy Available

U.S. DEPARTMENT OF ENERGY
WASTE ISOLATION PILOT PLANT

SYSTEM CF02

BECHTEL
SAN FRANCISCO

WASTE HANDLING BUILDING 411 FIREWATER COLLECTION SYSTEM FLOW DIAGRAM

	7619	N/A
DFTG MGR DATE	ECO	PWR

CODE NUMBER

DWG TYPE	CL	VENDOR
0041	52	020

JOB NO. 12484

DRAWING APPROVED BECHTEL — DATE 11/18/83

DOE CONTRACT NUMBER DE-AC04-79AL10751

DRAWING APPROVED — DATE 11/18/83

DRAWING NO.	CCP	REV	PAGE NO.
41-F-087-014		B	2-205

34x44 'E' SIZE

APPENDIX D&D

DOE/WIPP-95-2072

Conceptual Decontamination and Decommissioning Plan for the Waste Isolation Pilot Plant

January 1995

Prepared for

United States Department of Energy

Westinghouse Electric Corporation
Waste Isolation Division

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02527

1.0 Site Decontamination and Decommissioning Plan

This plan serves to describe the objectives of decommissioning for the Waste Isolation Pilot Plant (WIPP), identifies the elements necessary to accomplish the decommissioning, and defines the steps to execute those elements in a safe and environmentally sound manner.

This document is not intended to delineate the requirements necessary for Resource Conservation and Recovery Act (RCRA) closure. Where this document interfaces with those requirements, there will be guidance that directs the reader to Chapter I of the RCRA Part B Permit Application.

The Waste Isolation Pilot Plant Land Withdrawal Act of 1992 (LWA), PL 102-579, Section 13(a) requires that within 5 years after the date of the enactment of the act (enacted October 30, 1992), the Secretary of Energy (herein called the Secretary) shall submit to the Congress, the State of New Mexico, the Secretary of the Interior, and the Administrator of the EPA, a plan for the decommissioning of WIPP. In addition to activities required under the Agreement (July 1, 1981, Agreement for Consultation and Cooperation, between the State of New Mexico and the U. S. Department of Energy, as amended), the plan shall conform to the disposal regulations that apply to WIPP at the time the plan is prepared, and the Secretary of Energy shall consult with the Secretary of the Interior and the State in the preparation of such plan.

The plan provides a strategy for progressing from the final actions of the Disposal Phase, through the Decontamination and Decommissioning Phase, and into the initiation of the Long-Term Monitoring Phase.

This plan describes a sequence of events for **decontamination** of the WIPP facilities and structures used to manage and contain TRU and TRU mixed waste during the receipt and emplacement operations. Alternative methods of decontamination are provided where practical. The methods for packaging and disposal of the waste generated (derived waste) during this process are discussed. The best available technology at the time of this plan's development, may become outmoded by future technology and alternative strategies . If alternative technologies are identified the affected stakeholder(s), the Secretary of the Interior and the State will be consulted prior to implementation.

Dismantling of the WIPP major structures will be detailed in specifications separate from this plan for each structure.

The disposal of uncontaminated equipment and residue is delineated in Sections 1.6.9, and 1.6.11. Radioactively contaminated and mixed wastes that meet the waste acceptance criteria for decontamination and decommissioning (DD-WAC) will be emplaced into the last Hazardous Waste Management Unit (HWMU) open in the underground. At the WIPP, HWMUs are designated as the combination of waste disposal rooms and connecting drifts that form a panel. Each panel is an HWMU. Equipment, structures, materials, and components will be decontaminated whenever

possible. Residues that meet the definition of "construction and demolition debris,"("'Construction and demolition debris' means materials generally considered to be not water soluble and nonhazardous in nature, but not limited to, steel, glass, brick, concrete asphalt roofing materials, pipe, gypsum wallboard and lumber from the construction or destruction of a structure project, and includes rocks, soil, tree remains, trees and other vegetative matter that normally results from land clearing. If construction and demolition debris is mixed with any other types of solid waste, it loses its classification as construction and demolition debris. Construction and demolition debris does not include asbestos or liquids including but not limited to waste paints, solvents, sealers, adhesives or potentially hazardous materials." SWMR-4, Section 105, Paragraph T) that are free of contamination may be disposed in a Construction Landfill. Mined salt remaining after closure and berm construction will be disposed under Sections 2 and 3 of the Minerals Act of 1947.

Other activities necessary to return the site to as near its original condition as possible are defined in Section 1.6.19.

Generally, stakeholder involvement in the decontamination and decommissioning activities, as well as socioeconomic impacts to the local communities, counties, and state will be provided in the appropriate National Environmental Policy Act (NEPA) documentation for decommissioning.

1.1 Facility Description

1.1.1 Background

The U. S. Department of Energy (DOE) was authorized by the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Public Law 96-164 (U. S. Congress, 1980) to develop a facility for demonstrating the safe disposal of transuranic (TRU) radioactive wastes generated as the result of national defense activities. This facility, known as the Waste Isolation Pilot Plant, has been constructed in southeastern, New Mexico, 26 miles east of the City of Carlsbad. The site encompasses 10,240 acres in a sparsely populated area. Land use in the area surrounding the WIPP land withdrawal area includes livestock grazing, potash mining, and oil and gas production.

The enactment of Public Law 96-164 authorized the continuation of the phased development of the WIPP. Phased development began with a siting phase during which several sites were evaluated and a preferred site was selected based upon the geological and hydrological factors. During this phase, the host rock and the depth of the facility were selected considering geologic, hydrologic, geochemical and rock-mechanics properties. In the next phase, the site and preliminary design validation phase, two shafts were constructed; an underground testing area was excavated; and geologic, hydrologic, and geotechnical investigations were continued to gain further information on the site's characteristics. Also during this phase, methods for assessing long-term performance were evaluated and advanced. The construction phase followed during which the WIPP facility was constructed, additional data about the site

were collected, and the tools needed for assessing performance were developed and refined. Surface structures were built and additional underground areas were excavated for further experimentation. At the conclusion of the construction phase, the DOE proposed to proceed into a test phase that would include testing with TRU waste.

In October 1992 Congress transferred jurisdiction of the land from the Secretary of the Department of the Interior to the Secretary of the DOE and reserved the land for use by the DOE for the WIPP Program. The LWA also provided additional authorization to continue the activities initiated by Public Law 96-164. The LWA requirements focus on the test phase and the criteria for certification of compliance with the long-term disposal regulations developed by EPA. In late 1993 the DOE announced that the WIPP would not conduct radioactive tests in the WIPP underground. While testing with radioactive waste will not be conducted at the WIPP, many requirements such as development of certification criteria by the EPA, and other requirements necessary to begin disposal are still applicable and are covered in several other documents.

1.1.2 General Plant Description

The waste will be disposed in Hazardous Waste Management Units (HWMU) located 2150 feet below the surface of the WIPP site in bedded salt. The facility capacity is limited to 6.2 million ft^3 of contact handled (CH) and remote handled (RH) TRU wastes many of which are also contaminated with hazardous waste. The RH waste is currently planned to be emplaced in the ribs of the excavated rooms and the CH waste is to be stacked in the excavated rooms.

As each HWMU is filled, the access drifts will be closed to prevent access by personnel and to decrease the potential for release of contaminants. The last HWMU will have space available for acceptance of decontamination waste generated (derived waste) during the execution of this plan.

Descriptions of topography, soils, geology, demography, meteorology, radiological and hazardous materials characteristics, radionuclide inventory, and environmental characteristics are available in the Draft Waste Isolation Pilot Plant Project Technical Baseline for Regulatory Compliance (Reference 54).

1.1.3 Structures

All structures will require removal of office furnishings, telephone service, site computer network, plumbing fixtures and piping, HVAC, electrical service, structure and foundation. Several structures will require the removal of compressed air, large equipment, fluid lines, etc. Removal specifications will be developed for each structure.

The Hot Cell in the RH portion of the Waste Handling Building may remain as part of the permanent marker system. Modifications to the structure may be required if it is determined that it will remain as an artifact. Such modifications will require engineering development.

Temporary Structures

For each temporary structure that exists at the time of decontamination and decommissioning, action requests will initiate work orders with specific instructions for all preliminary work. The actual removal and preparatory activities for removal may be performed by a subcontractor.

Following is a list of the temporary structures at the WIPP site:

906 - U/G OPERATIONS TRAILER
907 - TRANS & HAZ. MATL. HANDLING TRAILER
908A - ENVIRONMENTAL MONITORING LAB TRAILER
908B - UNIVERSITY CONSORTIUM TRAILER
909 - PROJECT CONTROL TRAILER
910 - ENVIRONMENTAL MONITORING TRAILER
911A - SITE LOCKSMITH TRAILER
911B - SANDIA M101 TRAILER
911C - SANDIA OFFICES TRAILER
911E - SANDIA TRAILER
911F - SANDIA B49 AND B49 ANNEX
911G - SANDIA LABS TRAILER
912 - TRAINING TRAILER
915 - NEW MEXICO ENVIRONMENTAL DEPT. TRAILER
916 - SANDIA OFFICES TRAILER
917 - AIS MONITORING
918 - VOC TRAILER
918A - VOC AIR MON. STATION
918B - VOC LAB TRAILER
950 - WORK CONTROL TRAILER
951 - PROCUREMENT/PURCHASING
952 - TRAILER (7-PLEX)
971 - OPERATIONS TRAILER
982 - MAINTENANCE TRAILER
985 - QA TRAILER
986 - PUBL. & PROC. TRAILER
988 - OPERATIONS TRAILER
991 - SANDIA OFFICES TRAILER
992 - SANDIA CAL. LAB TR.
993 - SANDIA OFFICES TRAILER
994 - SANDIA LAB TRAILER
995 - SANDIA QA RECORDS TRLR.

NOTE: This list (current as of 12/94 from the WIPP Site Facility Master Plan (Reference 2)) will be updated as needed.

Permanent Structures

Based upon the results of the Site Radiological Characterization Survey removal specifications or individual D&D plans will be developed for each of the following permanent structures:

PORT-A-CAMP
252 - SPS UTILITY SUBSTATION
253 - 13.8 KV SWITCHGEAR 25P-SWG15/1
254.1- AREA SUB NO. 1 25P-SW15.1
254.2- AREA SUB NO. 2 25P-SW15.2
254.3- AREA SUB NO. 3 25P-SW15.3
254.4- AREA SUB NO. 4 25P-SW15.4
254.5- AREA SUB NO. 5 25P-SW15.5
254.6- AREA SUB NO. 6 25P-SW15.6
254.7- AREA SUB NO. 7 25P-SW15.7
255.1- EMERGENCY GEN. #1 25-PE 503
255.2- EMERGENCY GEN. #2 25-PE 504
311 - WASTE SHAFT
351 - EXHAUST SHAFT
361 - AIR INTAKE SHAFT
362 - AIS/HOIST HOUSE
363 - AIS/WINCH HOUSE
364 - EFFLUENT MON. INSTR. SHED "A"
365 - EFFLUENT MON. INSTR. SHED "B"
366 - AIS HEADFRAME
371 - SALT HANDLING SHAFT
372 - SALT HANDLING SHAFT HEADFRAME
384 - SALT HANDLING SHAFT HOISTHOUSE
384A - LAMPHOUSE
411 - WASTE HANDLING BLDG. CH & RH
412 - TRUPACT MAINT. BLDG.
413 - EXHAUST SHAFT FILTER BLDG.
413A - MONITORING STATION "A"
413B - MONITORING STATION "B"
414 - WATER CHILLER FACILITY & BLDG.
451 - SUPPORT BLDG
452 - SAFETY & EMERG. SERVICES FAC.
453 - WAREHOUSE/SHOPS BLDG.
454 - VEHICLE SERVICE BLDG.
455 - AUXILIARY WAREHOUSE
456 - WATER PUMPHOUSE
457N - WATER TANKS 25-D-001A
457S - WATER TANKS 25-D-001B
458 - GUARD AND SECURITY BLDG.
459 - CORE STORAGE BLDG.
459A - SANDIA ANNEX
463 - COMPRESSOR BLDG.
465 - AUXILIARY AIR INTAKE
468 - TELEPHONE HUT
471 - NW ATMOS. MONITORING STATION
472 - INSTRUMENT BLDG.
473 - ARMORY BLDG.
474 - HAZARDOUS WASTE STORAGE FACILITY
474A - HAZARDOUS WASTE STORAGE BLDG
474B - HAZARDOUS WASTE STORAGE BLDG
474C - OIL & GREASE STORAGE BLDG.
474D - GAS BOTTLE STORAGE BLDG.
474E - HAZARD MATERIAL STORAGE BLDG.
474F - WASTE OIL RETAINER
475 - GATEHOUSE
480 - VEHICLE FUEL STATION
482 - EXH. SHAFT HOIST EQUIP. WAREHOUSE
485 - SULLAIR COMPRESSOR BLDG.
486 - ENGINEERING BLDG.
489 - TRAINING BLDG.
816 - SANDIA TEST WELL
ELECT. SWITCHBOARDS, SUBSTATIONS, AND SWITCHRACKS
ENVIRONMENTAL MONITORING SITES
FIRE MAIN RING HEADER
LANDFILLS
MICROWAVE TOWER
PIPELINE
POWERLINE
ROADS (Paved & Unpaved)
SANDIA GENERATOR NO. 1
SANDIA GENERATOR NO. 2
SEWAGE LAGOON & PIPING
SALT PILE
SNL UNDERGROUND ROOMS
UNDERGROUND STORAGE TANKS (fuel)
WELL PADS
WID UNDERGROUND FACILITIES

NOTE: This list (current as of 12/94 from the WIPP Site Facility Master Plan (Reference 2)) will be updated as needed.

1.1.4 Plant Structures Description

The WIPP is divided into three basic groups of structures; surface structures, shafts, and underground structures.

The WIPP facility surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground. The surface structures (excluding Port-a-camp, various storage areas, microwave tower, sewage treatment system, wells, pipeline, power line, access roads, environmental monitoring stations, landfills, Building 471 [Northwest Atmospheric Monitoring Station], Building. 472 [Instrument Building.] and roadbeds) are located in an area of approximately 35 acres within a perimeter security fence.

The primary surface operations at the WIPP facility are conducted in the Waste Handling Building (WHB), which is divided into several separate waste management areas. These areas include, the CH TRU waste handling area, the RH TRU waste handling area, the transuranic package transporter (TRUPACT-II) maintenance facility, and support areas.

The CH TRU waste handling area includes an outdoor truck loading and offloading area, a shielded storage room, an inventory and preparation area, and an overpack and repair room.

The RH TRU waste handling area includes: a shipping and receiving area; a shielded cell for shipping cask unloading, waste canister inspection, overpacking canisters, as required; a canister transfer cell; and facility cask loading.

The TRUPACT-II maintenance facility is a radiologically clean dedicated area, adjacent to the CH TRU waste side of the WHB. Decontamination of a TRUPACT-II, if required, would be accomplished in the CH TRU waste side of the WHB.

Other areas within the WHB include: a site-derived waste area; heating, ventilation, and air conditioning (HVAC) equipment area; and mechanical equipment areas.

The site-derived waste area, located in the WHB, is provided for the handling of waste produced on the site as a result of decontamination operations. Waste water collection from fire main activation in the CH TRU side of the WHB will collect in a sump located in the site-derived waste room. Waste water from fire main actuation in any area with potential contamination (radioactive and/or hazardous) will be reacted to under the Hazardous Materials Spill Response section of the Emergency Services Program Plan (Reference 77).

The WIPP surface structures include the Exhaust Filter Building, Engineering Building, Training Building, Support Building, Safety and Emergency Services Facility, Warehouse buildings, Guard and Security Building, Vehicle Service Building, a sewage treatment plant, underground fuel storage tanks (USTs), and other auxiliary buildings.

The Exhaust Filter Building contains banks of high efficiency particulate air (HEPA) filters that will be used to filter contaminated air from the underground in the unlikely event of a release. The underground ventilation system fans are located outside, adjacent to this building.

The Support Building provides office space, change rooms, and houses the Central Monitoring Room (CMR) and its supporting equipment.

The WIPP is accessible by both road and railway. Access to the site is from U.S. Highway 62/180, about 13 miles to the north, and from Highway 128, four miles to the south. Rail access is provided by a rail line connecting with a spur of the Atchison, Topeka, & Santa Fe railroad six miles southwest of the site.

WIPP has four vertical shafts that extend from the surface to the underground horizon. These are: the Waste Shaft, the Salt Handling (SH) Shaft, the Exhaust Shaft (ES), and the Air Intake Shaft (AIS).

The SH shaft is steel lined to the top of the salt formation (about 850 feet below the surface) and the other shafts are lined with concrete to the top of the salt formation.

The Waste Shaft is located between the CH TRU and RH TRU areas in the WHB. It is nominally 19 feet in diameter and is serviced by a hoist utilizing a hoist cage that is primarily used for transportation of CH TRU and RH TRU wastes from the surface to the underground storage areas. This shaft is also used to transport personnel, materials and supplies, and large equipment.

The SH Shaft is located beneath the salt handling headframe. It is nominally 10 feet in diameter and has a combined mancage/bottom dump salt handling skip. This shaft provides the only means of removing mined materials from the underground. It serves as the secondary ventilation supply shaft for the underground areas. The SH shaft is a route for power, control, monitoring and communication cables. Personnel can also be transported in this shaft.

Salt from the underground mining operations is brought to the surface via the Salt Shaft and stored in the salt pile north of the surface facilities.

The exhaust shaft is located adjacent to the Exhaust Filter Building. It is nominally 14 feet in diameter and serves as the exhaust air duct for the underground areas.

The underground ventilation system consists of five centrifugal exhaust fans, two parallel HEPA filter assemblies, isolation dampers, filter bypass, and associated ductwork. The two main exhaust fans provide unfiltered flow of up to 425,000 cubic feet per minute for normal underground operations. Three filtration fans can each provide 60,000 cubic feet per minute during filtration mode or reduced ventilation mode. Continuous Air Monitors (CAMs) are installed to detect airborne radioactive contaminants in the waste disposal area, the Waste Shaft and station, and in the discharge to the surface discharge stack. One alarm from the Station A Effluent

Sampling System or an alarm received from two like CAMs (two alphas or two beta/gammas) will cause automatic activation of the HEPA filtration system.

The AIS is located to the west of the warehouse. It has three diameters (18 feet concrete lined, 16 feet 7 inches concrete lined and 20 feet 3 inches unlined salt section) and is the primary supply of fresh air underground.

The underground structures are located on the storage horizon and consist of the waste storage area, the experimental area, the mining area, and the waste shaft station.

The waste storage area has four main entries, a number of crosscuts connect the main entries. The layout of the shafts and entries permits mining and storage operations to proceed simultaneously. New hazardous waste management panels will be mined as the preceding panel is filled with waste.

Each waste storage panel will consist of seven rooms. Each room is nominally 33 feet wide by 300 feet long by 13 feet high. The storage rooms are separated by salt pillars 100 feet wide by 300 feet long. The first 200 feet of each panel is 20 feet wide and 13 feet high to facilitate the closure of each panel. After the initial 200 feet the panel is widened out to 33 feet.

The waste shaft station located at the lower end of the waste shaft provides access for personnel and equipment to handle the waste.

Workshop and warehouse facilities are located at the storage horizon. Shops consist of a repair bay, a welding bay, a lubrication bay, an electrical shop, several parking areas, and a warehouse. Offices, electrical substations, and lunch rooms are also located at the storage horizon.

The experimental area of the mine used for experiments using simulated wastes and for geotechnical evaluations consists of several rooms and pillars that are used to perform rock mechanics tests, waste package and waste form experiments, and brine migration tests. In part, tests provided information used in room and pillar design of the waste storage area and support Performance Assessment activities/validation.

1.2 Description of Operating History

1.2.1 Initial Construction and Permitting

Development of the WIPP facility began with a siting phase (in 1973), during which several sites were evaluated and the present site was selected on the basis of extensive geotechnical research, supplemented by surface-based testing. Based upon the geologic properties of the selected site, the repository was designed and safety analyses were prepared. Subsequent research expanded the understanding of the geologic, hydrologic, geochemical, and rock-mechanics properties of the host rock and surrounding strata at the site. The siting phase ended with the publication of a Final

Environmental Impact Statement (FEIS) (Reference 20) in 1980 and associated Record of Decision (ROD), which evaluated alternatives for the safe, long-term isolation of TRU waste at the WIPP facility.

The construction phase followed, authorized by Public Law 96-164 (Reference 38) during which surface structures for receiving waste were built and underground excavations were completed for one panel of rooms designed for permanent waste emplacement. The DOE and the State of New Mexico entered into a Consultation and Cooperation Agreement (Reference 43) to affirm the intent to give consideration for concerns and cooperation in the resolution of those concerns. The end of the construction phase was marked by a decision by the DOE Energy Systems Acquisition Advisory Board (ESAAB), after all prerequisites for ending construction were met and documented (in 1991). These documents used the data collected since 1980 to evaluate the potential short-term and long-term impacts of the WIPP facility. In 1992 the Final Safety Analysis Report (FSAR) (Reference 49) was published.

At the conclusion of the construction phase, the DOE proposed to proceed into a test phase that would include testing with TRU and TRU mixed waste at the WIPP facility. Although the DOE has made the decision not to conduct underground tests with radioactive wastes in the WIPP facility, information regarding a compliance demonstration has not changed and this experimental data is being collected at the Idaho National Engineering Laboratory.

Upon a successful demonstration of compliance with applicable federal and state laws and regulations, and once the certification and approval requirements of the LWA are met, the WIPP facility will proceed through three other distinct phases: a disposal phase, a decommissioning phase, and a post-decommissioning phase. The disposal phase, projected to last 25 years, will consist of receiving, handling, and emplacing TRU and TRU-mixed waste in the repository for disposal. Additional scientific studies may continue during the disposal phase. The disposal phase will end when a decision is made to terminate further disposal activities or the repository has reached its capacity.

The decommissioning phase will follow the disposal phase. During the decommissioning phase the facility will be decontaminated and prepared for permanent closure. Closure of the HWMUs will be performed in accordance with the direction of Chapter I of the RCRA Part B Permit application. Surface facilities will be decontaminated and decommissioned, underground excavations will be closed, and shaft seals will be emplaced. This phase is projected to last eight years, with six years estimated for the RCRA closure portion.

The post-decommissioning phase will include the implementation of active and passive institutional controls. Active institutional controls may include activities such as long-term site access control and post-closure monitoring. Such controls will be implemented consistent with applicable regulations and permit conditions. Passive institutional controls will include notification devices such as permanent markers designed to reduce the likelihood of human intrusion, archival storage of WIPP

information off-site, and large earthen structures marking the repository footprint on the surface. The concept for permanently marking the WIPP, as required by Title 40 CFR 191.14(c), is described by a draft report listed in Attachment 3 (Reference 37).

1.2.2 Disposal Phase Operating History

As of this revision to the Conceptual Decontamination and Decommissioning Plan there is no disposal phase operating history.

1.3 Program Objectives

1.3.1 Decommissioning Objective

The main objective of decommissioning the WIPP site is to return the site to as close to the pre-construction condition, as reasonably possible, while protecting human health, the environment, and to meet NEPA and WIPP Land Withdrawal Act commitments.

1.3.2 Alternative Strategy

The decommissioning alternatives rejected in the Final Environmental Impact Statement included mothballing and in-place entombment.

These alternatives allowed for decommissioning the plant under the following credible situations:

- Decommissioning after the repository has been filled. The preferred methods would be in-place entombment of unusable underground structures, decontamination (as required), and dismantling of the surface structures.

- Decommissioning before the repository is filled, leaving open the possibility of later returning to fill it. Mothballing of the surface structures would be the preferred method for this situation. Due to creep closure the underground areas would require mining to obtain a safe work environment.

The present plan calls for decontaminating (as required) and dismantling surface facilities, entombing in the waste-disposal area all wastes generated in dismantling the surface facilities if they meet DD-WAC, close the remaining mine, and sealing the shafts and boreholes. Any wastes that do not meet the DD-WAC will be transported to an approved and permitted off-site facility.

Mothballing would consist of putting the plant into a state of protective storage for a few decades. This alternative would be selected if later repository operation or experiments were desired. It would require the eventual use of another alternative for the permanent decommissioning of the plant. The plant would be left generally intact except that all areas with hazardous levels of radiation would be isolated from the

public by suitable barriers and other means. Useful equipment could be decontaminated, if necessary, and removed from the site. Adequate radiation monitoring, environmental surveillance, and security procedures would be established to protect the health and safety of the public. The shafts and underground facilities would be left intact. This alternative was rejected.

Entombment applies mainly to the shafts and mine. Entombment of the surface facilities would be similar to mothballing except that the radioactive materials would be removed and placed in the mine or removed from the site. After the removal of usable equipment (and decontamination, if necessary), the vacated mine would be closed, and the shafts and boreholes would be sealed. In this alternative the mine and shafts would be permanently sealed; the surface facilities, however, would be available for some other use in the future. This alternative was rejected.

Decontamination and dismantling would involve the surface facilities, with the shaft and mine entombed as described above. Usable equipment would be decontaminated and removed; contaminated equipment and waste would be packaged and either placed in the mine or removed from the site if mine disposal were not feasible. Surface facilities would be demolished and debris removed or buried in the Construction and Demolition landfill. As nearly as possible, the surface would be returned to its original condition.

1.3.3 Cleanup Criteria

Criteria for the mixed waste decontamination is defined in 40 CFR 264, Subpart G--Closure and Post-Closure; WIPP RCRA Part B Permit Application, DOE/WIPP 91-005, Chapter I—Closure Plans, Postclosure Plans, and Financial Requirements, 20 New Mexico Administrative Code (NMAC) 4.1 Subpart V, Subparts G, I, and X, and DOE Order 5820.2A, Radioactive Waste Management.

Because of the type of waste management activities that will occur at the WIPP facility, waste residues that may be encountered during the operation of the facility and at closure may include waste generated as a result of the management of the waste containers (derived waste including rags and rubber gloves), waste generated as part of the closure activities (such as wipes used to sample the containers and equipment for potential radioactive contamination, solidified decontamination solutions, stabilized concrete dust from scabbler operations, equipment designed for disposal, contaminated salt that is excavated because of decontamination activities, etc.), and residues generated as a result of spill cleanup (rags, gloves, hazardous materials). All of the above wastes generated (derived wastes) during the operation and closure of the WIPP facility will be identified and managed as TRU mixed wastes.

Criteria for the radiological portion of the mixed waste decontamination is defined in DOE Order 5820.2A (Reference 22).

On the basis of "co-detection of hazardous and radioactive releases," decontamination will be considered complete for RCRA constituents when radiological decontamination has been accomplished. Radiological decontamination will be to less than or equal to:

	Loose	Fixed plus Removable
α	20 (dpm/100 cm^2)	500 (dpm/100 cm^2)
β-γ	200 (dpm/100 cm^2)	1000 (dpm/100 cm^2)

All surveys for contamination at the WIPP facility are based on the concept of co-detection. Co-detection is used to describe the detection of releases from containers by virtue of detection of radioactive contamination. Co-detection applies to all releases except the release of VOCs from TRU mixed waste containers. It provides the WIPP facility with a very sensitive method of detecting the release of non-VOC hazardous TRU constituents through the use of surface sampling (swipes) and radioactivity counting.

Decontaminated materials and equipment must be sampled in accordance with applicable procedures to assure that there are no RCRA constituents beyond the levels authorized for release. Items that are found to exceed the limits will be properly packaged and transferred to an appropriate treatment storage and disposal facility.

1.4 Program Management and Administration

1.4.1 Organization

A graphic representation of the management and operating contractor decontamination and decommissioning management organization is presented as Attachment 2.

1.4.2 Responsibilities

Decommissioning Project Manager - provides overall management of the decontamination and decommissioning effort. As the facility converts from the operational phase to the decommissioning phase, overall responsibility for the project management will shift to this individual.

Engineering Manager - provides engineering support for all D&D activities. Provides management oversight for licensing and regulatory compliance activities.

Construction Manager - provides control of maintenance activities, decommissioning utilities, structure removal, and shaft seal installation.

Operations Manager - provides management of radiological and chemical decontamination activities, mine closure process, facility operations, health physics, and environmental monitoring operations.

Administrative Manager - provides control of the budget and schedule, directs procurement activities, manages human resources, and manages training.

Safety/Security Manager - provides the overall safety oversight of the D&D activities. Provides for the physical security of the WIPP site.

QA Manager - identifies, develops and defines quality requirements applicable for the D&D process. Consults with line management in interpreting and implementing quality program elements, and provides performance-based independent assessment of quality affecting activities.

1.4.3 Decommissioning Project Team

The Decommissioning Project Team consists of the Department of Energy and the management and operating contractor.

1.4.4 Decommissioning Manpower

Decontamination and decommissioning process manpower will be developed from the WIPP workforce. As the operational phase is completed, personnel without proper job skills will be cross-trained for the new positions being created by the decommissioning phase. This process will reduce the need for layoffs, and provide a knowledgeable and experienced workforce.

1.4.5 Worker Health and Safety Training

Worker training for health and safety will be conducted in accordance with 29 CFR 1910.1200 and other applicable regulations. The basic training will be accomplisned through the general employee training course administered to all new employees and with annual refresher training for all employees.

For further information on training policies refer to the current procedures listed in Attachment 3 of this plan (References 3, 83-85).

Personnel will continue to qualify and maintain qualification on the systems and equipment that they will operate.

1.4.6 Use, Control, and Management of Subcontractors

Current procurement policies and procedures for subcontractor interface are listed in Attachment 3 of this plan (References 65, 85-87).

1.5 Program Schedule and Cost

1.5.1 Major Milestone Schedule - Narrative

A schedule of the D&D process is included in this document as Attachment 1.

Acquire permits and approvals for D&D activities.

Removal of equipment and closure of the underground experimental areas may commence as soon as the area is no longer required.

As personnel downsizing takes place, temporary surface structures will become empty, and removal may commence.

Removal of temporary surface structures will be initiated prior to the projected emplacement of the last shipment of waste.

A site radioactivity characterization study will be performed to determine what areas of the site will require decontamination, to facilitate selection of an appropriate decontamination and decommissioning strategy, and after the decommissioning, demonstrate that the residual radioactive and/or hazardous materials satisfy criteria for unrestricted release.

Excess underground equipment will be decontaminated if required, moved to the surface, and disposed of in accordance with applicable federal property management regulations (41 CFR 101).

When economically feasible all usable equipment and materials will be decontaminated and removed from the site. Surface facilities will be decontaminated as required.

Contaminated structural debris, equipment, and decontamination wastes that meet the DD-WAC, will be packaged and placed in the mine in the last panel. Decontamination will be performed using technologies that do not add materials which would cause the derived waste to violate the DD-WAC. Liquids and fine particulate would require stabilization prior to disposal in the mine. Perform closure of the last HWMU in the same manner as the other panels. As the mine is closed the equipment will back out and be removed.

Shafts will be sealed in accordance with acceptable techniques.

Each Solid Waste Management Unit (SWMU) will be closed in accordance with all applicable regulations and requirements when it is no longer required.

Dismantling of surface facilities will commence upon vacancy and completion of radiological survey and, if required, decontamination.

Uncontaminated debris and unusable equipment will either be shipped away from the site for disposal or disposed of in the construction and demolition landfill.

Decommission the sewage system and the NPDES storm water evaporation basins. Close all SWMUs.

Excess salt will be disposed of per the Minerals Act of 1947.

Electrical power, telephone lines, water, railroad spurs, and roads will be removed, as required (electrical power, RR spurs and roads should remain to the degree necessary to support future construction of the Permanent Marker System and Permanent Marker testing).

The surface will be regraded to approximately its original contours.

Markers will be provided consistent with the approved passive control strategy.

Monitoring and active control will be established.

Unneeded environmental monitoring stations will be removed.

The underground storage tanks used for the storage of fuels will be removed in accordance with applicable regulations.

A final decommissioning report will be developed.

1.5.2 Cost Estimate - Narrative

A cost estimate will be developed for these activities for the Decontamination and Decommissioning Plan required by the Land Withdrawal Act. A conceptual cost estimate is available from the Waste Isolation Division Long-Term Regulatory Compliance group.

1.6 Decommissioning Activities

1.6.1 Plant Radiological Characterization

Extensive radiological contamination surveys of all areas of the WIPP site will be performed. The results of these surveys will provide the basis for selection of technology for decontamination and decommissioning of the WIPP facilities. Along with the historical records of surveys performed during the operational life of the facility, the contamination surveys will provide evidence for release of structures, equipment, and components.

Radiological Survey and Sampling Program

The radiological survey and sampling program will be accomplished using current procedures listed in Attachment 3 of this plan (Reference 74).

1.6.2 Physical Inventory

A complete inventory of all site facilities, equipment, and assets is to be performed so that disposition requirements may be determined prior to the items becoming excess. This inventory is standard practice for every major facility change.

Facility Physical Inventory

This inventory can be accomplished utilizing the WIPP Site Facility Master Plan (Reference 2). This is a controlled drawing, which coupled with outstanding Engineering Change Orders provides a complete listing of the site facilities.

Site Physical Inventory

Property Management maintains a database of all site equipment valued at $1000 or more, all real property regardless of value, and sensitive items valued at $200 and above. This database includes information such as the Manufacturer's nomenclature and model/serial number(s), the date the equipment was put into service, purchase order number and depreciable life, etc.

1.6.3 Facility and Site Preparation

Individual specifications will be developed for each structure prior to removal. These specifications will include a statement of work, as-built drawings, construction specifications, disposition of materials, required worker training and qualifications, etc. Specific instructions can be found in current WIPP procedures listed in Attachment 3 of this plan (References 86, 87).

Temporary Structures

Temporary structures such as the trailers used for offices will be prepared for disposal following vacancy and radiological clearance. Utilities (power, telephone, water, sewage, computer network, alarms, etc.) will be removed by site personnel. Office equipment and furniture removal may be contracted. The removal of skirting, reinstallation of axles, and towing may be performed under contract.

Laydown Areas

Laydown areas will be designated for radiologically contaminated materials, hazardous waste, solid waste, and scrapped or salvaged equipment/materials. These areas should be located centrally to where the majority of work is to be performed. Hazardous waste will be collected, accumulated, and disposed in accordance with applicable regulations.

Support Services

- Power will be maintained from the SPS feed east of the site. No conversion to construction power will be necessary to perform structure removal.

- Telephone service will continue through the telephone hut until the size of the site makes it no longer economical to maintain the hut, at which time the GTE telephone service will be transferred to individual feeds.

- Water is supplied by the Double Eagle Water Line, owned by the City of Carlsbad, through their wells located approximately 30 miles north of the WIPP. Water is supplied by gravity flow through a 24-inch diameter pipeline to a junction point about 13 miles north of the site at U. S. Highway 62/180. This line is sized to provide 6000 gal/min for use by

others in addition to the peak flow rate required by the WIPP facility. Controls at the junction point give the WIPP facility priority over flows to all other users. A 10-inch diameter pipeline supplies 375 gal/min water flow from the tie in point to the WIPP facility by gravity flow.

The water supply to the site will continue until such time that the domestic and fire water requirements no longer exist. At that time the pipeline will be capped. Ownership of the waterline will be transferred to the City of Carlsbad. The portion of the pipeline that the City does not want, will be decommissioned and removed.

- Refuse removal will continue with contractor support until the facility is taken into the post-decommissioning long-term monitoring phase.

- Sewage treatment is currently performed in a series of settling treatment and evaporation ponds south of the site. When the number of personnel has decreased enough that the need for these ponds is no longer necessary, and may be supplanted by portable facilities, the ponds will be closed in accordance with applicable regulations.

1.6.4 Decontamination

The "Start Clean - Stay Clean" operating philosophy of the WIPP site will decrease the need for decontamination during the Decommissioning phase. However, the need for decontamination technology may arise.

Chemical Cleaning

Detergents - no detergents are currently planned for use in decontamination activities.

Solvents

Water in limited quantities (e.g. dampened rags) - is the primary solvent used for decontamination

Windex® - may be used on a limited basis

Radiacwash® - may be used only if water, Windex®, etc. are not effective in reducing contamination to acceptable release levels.

Nonchemical Decontamination

Polyvinyl Alcohol - is used to remove radiological contamination from smooth surfaces such as the waste handling building floor. The residue from this process is a solid plastic contaminated with radioactive material and hazardous waste. The residue of the Polyvinyl Alcohol may be disposed of in the underground as a mixed waste.

Sandblasting - this method of decontamination would create large quantities of contaminated waste for disposal and is not recommended.

Grinding - this method would create a smaller quantity of contaminated waste than sandblasting, and might be used in limited applications.

High-Pressure Water Spray - this method could create large volumes of water that would need to be treated or stabilized before disposal and is not recommended.

Scabbler Pistons and Needle Scalers - this method utilizes pneumatically operated reciprocating scabbler pistons and needle scalers to remove up to 3/16 inch of the concrete surface which is filtered and stored in the vacuum system prior to solidification and disposal.

Ice-blast Technology - uses compressed air and ice chips to remove loose or fixed plus removable radioactive contamination, with only 24 gallons of waste water per hour of operation.

Dry Ice Blasting - on impact, dry ice pellets sublimate from their solid state into gas, leaving only the removed contaminant for disposal. The process is practically non-abrasive on all surfaces, inert and non-conductive.

Partial Removal of Components

Partial removal of components will be performed when it is radiologically safe to remove a section of pipe, ventilation ducting, bracket, etc., when the larger component is not contaminated, and when the removal of a portion of the whole will significantly reduce the volume to be emplaced in the last panel.

Cost/Benefit Analysis

A cost/benefit analysis will be necessary for evaluation of the decontamination options in the event that the need for this technology arises. It is, however, too early as of this writing to make an estimate of the necessity for decontamination technology beyond that currently available at the WIPP site.

1.6.5 Rigging of Heavy Components

The Department of Energy Hoisting and Rigging Manual, DOE/ID-10500 (Reference 20), will be utilized in all hoisting and rigging operations conducted at the WIPP site during decommissioning. The manual quotes verbatim or paraphrases the requirements of the Occupational Safety and Health Administration and the American National Standards Institute. It was developed to encompass, under one cover, hoisting and rigging requirements, codes, standards, and regulations. In doing so, it eliminates the need to maintain extensive (and often incomplete) libraries of hoisting and rigging standards throughout the DOE.

1.6.6 Liquid Radwaste Processing

Present Capacity and Capability

There is currently no large scale capability for liquid radwaste processing at the WIPP facility. Depending on the type of decontamination equipment selected and the quantity of waste liquid created by that equipment, a decision will have to be made at a later date for this system's specifications.

Small quantities of liquid radwaste can be solidified using Aquaset® or an equivalent grade absorbent material.

Services to be Added

No new services are anticipated. Due to the small quantities of liquid waste that is anticipated during the decontamination and decommissioning of the WIPP, no additional equipment is deemed necessary at this time. If quantities should be greater than currently anticipated, then the following technologies may be utilized.

- Mobile Evaporators
- Demineralizers
- Mobile Solidification System

1.6.7 Solid Radwaste Handling, Packaging and Emplacement

Containers

Waste containers for emplacement in the WIPP shall be noncombustible and meet all applicable requirements of 49 CFR §173.412 for Type A packaging. Waste containers of various sizes, shown to meet Department of Transportation Type A requirements by methods detailed in DOE Evaluation Document for DOT 7A Type A Packaging, DOE/DP/00058-H1;MLM 3245 are acceptable at the WIPP.

Packaging

Waste packaging is included in the information for containers in the above subsection.

Emplacement

Decommissioning waste will be emplaced in the underground, utilizing approved waste handling operations procedures, in the last HWMU prior to closure of the unit. Containers that are not the standard waste box or 55-gallon drums, will require separate procedures to ensure that the containers are loaded into the panel in a safe and coordinated manner.

Interim Storage/Staging

No areas within the facility are being permitted as interim storage areas. Satellite accumulation area regulations will apply. See 40 CFR 262.34 for limitations on quantities, time, and methodology for accumulation of hazardous waste at the decommissioning site. Waste containers with radioactive mixed waste will remain at the location of decontamination effort until the container is filled or the decontamination at that location is completed. As decontamination progresses beyond the surface, the waste containers will be directly emplaced in the panel. Once a container of waste is filled, it will be moved to the storage area and emplaced in a prompt manner.

1.6.8 Nonradioactive Hazardous Waste Handling and Disposal

The handling and disposal of nonradioactive hazardous waste will be performed in accordance with applicable regulations and approved WIPP hazardous waste management procedures. There are approved procedures in place at this time (References 46, 55, 57).

Waste Packaging Process

Current WIPP procedures listed in Attachment 3 of this plan delineate the responsibilities and handling requirements for site generated nonradioactive hazardous waste at the WIPP (References 46, 55, 57). The waste packaging process is designed to protect human health and the environment from negative effects of hazardous waste by ensuring that hazardous waste is properly handled, accumulated, and transported to an approved off-site treatment/storage/disposal facility in accordance with all applicable local, state and federal regulations, DOE Orders and WID policies and procedures.

Transportation

Current WIPP procedures as listed in Attachment 3 of this plan delineate the responsibilities and requirements that provide for the shipment of nonradioactive hazardous materials by the Waste Isolation Division (WID) from the WIPP, in compliance with the DOE requirement for management of materials transportation as specified in DOE Order 1540.1A, and applicable laws and regulations related to the shipment of hazardous materials (References 21, 55).

Instructions for the on site transportation of hazardous material, hazardous waste and non-RCRA regulated material are provided in current WIPP procedures listed in Attachment 3 of this plan (Reference 57).

1.6.9 Solid Waste Handling and Disposal

Guidelines for the operation of the construction and demolition landfill in a manner which is protective of human health and the environment and ensures compliance with applicable local and state laws and regulations are contained in current WIPP procedures listed in Attachment 3 of this plan (Reference 56).

Identification of Laydown Areas

The primary laydown area for solid waste (other than construction landfill debris) will be designated on the asphalt pad southeast of the Waste Handling Building. Construction and demolition debris will be moved directly to the construction landfill.

Traffic Management of Waste Site

No scavenging will be allowed at the waste site. Prior to loading of vehicles for transport to the landfill, the waste will be characterized by process knowledge or sampling to not contain any hazardous wastes.

Local Registered Sanitary Landfill Site

The registered sanitary landfill site utilized by the WIPP site is currently located near Hobbs, NM. The landfill is not currently permitted, but will have a permit hearing in January 1995, permit submittal in June 1995, and approval is expected eighteen months following submittal.

Compaction

There is currently no requirement for compaction of the solid waste.

1.6.10 Removal of Radioactive Equipment

All equipment will be checked for the presence of radioactive contamination. If radioactive contamination is detected, the contaminated equipment will be assumed to be contaminated with the hazardous waste constituents of the waste in the containers that the equipment contacted. Contaminated equipment will be decontaminated to the clean limits specified in Section 1.3.3 of this document or placed in containers and managed as derived TRU mixed waste.

Isolation of System and Cutting of Pipe

The WIPP does not have piping systems that will carry radioactive materials. The closest approximation would be possible contamination of the air handling ductwork in the waste handling building. In the event that the site radioactive characterization or a routine survey detects contamination in any of the ductwork, specific work instructions will be developed for the decontamination and removal of that ductwork. Those instructions will be based on the level and extent of contamination found, using standard industry practices.

Exhaust Filter Building and HEPA Filters

The Exhaust Filter Building (EFB) and HEPA Filters associated with the EFB must be operable during underground ventilation. Emplacement of contaminated EFB HEPA filters requires underground ventilation.

Procedures will be developed to ensure that the following steps will be performed:

a. Underground operation will be halted

b. the EFB HEPA filters will be removed

c. If the EFB HEPA filters are contaminated beyond acceptable criteria, they will be packaged for emplacement in the underground

d. A radiological survey will be performed on the EFB and associated equipment

e. Decontamination will be performed on all EFB equipment that is contaminated

f. HEPA filters will be installed

g. The EFB ventilation systems will be tested to meet surveillance requirements

h. Underground operations will recommence

Performance of these steps will decrease the potential for TRU or TRU mixed waste being generated during the decommissioning of the EFB. In the unlikely event that there is radiologically contaminated waste generated during the EFB decommissioning, it may be designated as low level radioactive waste and shipped to a licensed disposal facility.

Sampling and Characterization

Radioactivity - Methods for assuring that equipment is not contaminated and ready for free release are listed in Attachment 3 of this plan (Reference 78).

Equipment decontaminated will require a verification survey before release for disposition.

Size/Volume Reduction

There is currently no requirement for size/volume reduction. However, the WIPP has an active waste minimization and pollution prevention plan which applies both size and volume reduction where possible. This technology will be considered during decommissioning and utilized if technically and economically feasible, or necessary for emplacement of this waste into the last HWMU.

Removal and Packaging

Removal of radioactive equipment will be performed under strict health physics control following the procedures specified in documents listed in Attachment 3 of this plan, and approved work instructions (Reference 74).

The waste will be packaged in approved containers as specified in Section 1.6.8 of this plan.

Emplacement

Decontamination wastes will be emplaced in the last HWMU as derived mixed waste.

1.6.11 Removal of Nonradioactive Equipment

Isolation of System and Cutting of Pipe

System isolation and pipe cutting is marginally applicable to the WIPP facilities. Separate work instructions will be developed for the removal of closed systems using standard industry practices.

Verification of Noncontaminated Condition

All systems external to the Waste Handling and Storage areas will have been declared clean to the limits specified in Section 1.3.3 of this document during the site radiological characterization survey. Systems within those areas will require health physics surveys prior to removal. All systems that contained or may have contained hazardous materials will require sampling and possible flushing prior to removal.

Removal and Packaging

Removal of nonradioactive equipment will be performed following approved work instructions which will be developed by Work Control.

Holding Area

Location - The asphalt pad southeast of the waste handling building will be designated as the primary holding area for nonradioactive equipment.

Traffic Management - Equipment awaiting disposition will be segregated from access by non-authorized personnel.

Disposition

Retired - Nonradioactive equipment that is not scrap or salvage will be placed on the excess property list.

Disposal - Nonradioactive equipment that cannot be retired will be dispositioned as scrap or salvage.

1.6.12 Removal of Power and Control Systems

Circuits will be de-energized and removed as equipment and facilities are made available for disconnect. The diesel generators will be maintained until all vital loads are removed. After all site loads are removed, the utility will be notified to remove their site feed.

Removal of the uninterruptable power supplies (UPS) will present no additional problems. All batteries will be removed and excessed.

Operations Interface

Close coordination between the operations and construction managers will be required to assure that necessary circuits for the remaining facility are maintained as the circuits are removed.

Switch-over to Construction Power

Primary power will be utilized until all its electrical systems are completely removed. Construction power is not required during the decommissioning of the site.

Disposition

Where economically feasible based upon the criteria of cost, condition, etc. electrical equipment will be retired or declared excess as appropriate.

1.6.13 Removal of Contaminated Surfaces

Potentially Contaminated Areas

Walls, Floors, and Structures - Surfaces that will be potentially contaminated are in the Waste Handling Building CH Bay, Overpack and Repair Room, RH Bay, Cask Unloading Room, Hot Cell, Cask Transfer Shuttle car, Shaft Access, Waste Handling Building Ventilation system, and Exhaust Filter Building.

Shafts and Drifts - The Waste Handling Shaft, Exhaust Shaft, exhaust drift, and the underground drift from the Waste Station to the waste panel are areas of potential contamination. The Exhaust Shaft and the E-300 drift from S-1600 to S-400 have the potential for contamination if an emplaced container is breached.

The waste packages are surveyed prior to downloading, and therefore the potential for waste shaft contamination is limited to waste conveyance accident scenarios, which are deemed incredible events. The Waste Shaft will be a part of the site radiological characterization survey, but it is not anticipated that any decontamination will be required in the shaft. All shafts and drifts will be surveyed for the site radiological survey, but it is anticipated that the need for decontamination, if any, will be confined to the access drifts from the waste station to the entrance to the final panel.

Removal Controls

Decontamination will commence at the areas farthest from the waste shaft and proceed to the shaft access, and recommence from the shaft waste station south to the last panel. The minimum volume of material should be removed to control the storage volume needed in the underground.

Removal Methods

Applicable methods of contamination removal are listed in Section 1.6.4.

1.6.14 Closure of Last Hazardous Waste Management Unit

Closure Survey

A radiological closure survey will be performed in accordance with approved procedures. RCRA closure will be performed in accordance with the specifics defined in Chapter I of the RCRA Part B Permit Application.

1.6.15 Closure of Mine Underground

Equipment Removal

Equipment and materials will be removed from the mine to the extent practicable.

Electrical Systems - Electrical systems will be removed as the closure progresses out of the mine.

Mining Equipment - As the mining equipment is no longer needed it will be removed through the waste handling shaft. Some pieces of the equipment may require disassembly or cutting to fit into the shaft.

Support Equipment - Support equipment such as golf carts, ambulance, fire truck, portable offices, etc. will be removed from the mine and dispositioned as they become excess.

1.6.16 Shaft Sealing and Plugging

Shafts will be plugged in accordance with acceptable sealing techniques.

Shaft Seals - An essential task during the decommissioning of the waste repository will be sealing the remaining holes and shafts. Shaft seal design alternatives have been studied for several years. A reference design is available.

1.6.17 Demolition and Removal of Structures

Criteria

All site structures with the possible exception of the Hot Cell portion of the Waste Handling Building are to be removed during the decommissioning. The Hot Cell in the RH portion of the Waste Handling Building may remain as part of the permanent marker system. Criteria for free release of structures is delineated in Section 1.3.3 of this document.

Removal of Contamination

Appropriate techniques will be applied for the conditions of the contamination including quantity of contaminant, location, worker health and safety, fixed or loose, surface to be decontaminated, etc.

Removal Techniques

Applicable methods of contamination removal are listed in Section 1.6.4.

Verification of Noncontaminated Status

Structures that were shown noncontaminated by the site radiological and hazardous constituent characterization and historical records may be removed when there is no further use for them. Structures that indicated radiological contamination, will require a verification survey after decontamination. Those structures that are then shown clean will be removed as the schedule permits.

Disposition

Transferred - Structures will be declared excess in accordance with applicable Federal and DOE Property Management Regulations.

1.6.18 Final Radiological Survey and Hazardous Constituent Analyses

The final radiological survey and hazardous constituent analyses will encompass the entire WIPP site.

Sampling and Statistical Analysis

Approved procedures will be utilized to perform the final radiation survey and swipe or material sampling.

Environmental Monitoring

A final environmental monitoring survey will be performed to assure that the facility has not created any environmental hazards. Environmental monitoring will continue after decommissioning concurrent with long-term monitoring.

Survey Plan

Surveys will be performed in accordance with approved procedures.

Confirm Structures Meet Disposition Objectives

All structures with the possible exception of the Hot Cell portion of the Waste Handling Building will have been removed. The final radiological survey of the Hot Cell will verify meeting disposition objectives.

1.6.19 Restoration of Site

Decommissioning of Solid Waste Management Units

There are 13 discernable groups of SWMU at the WIPP site. The following table lists those groups and their descriptions. All SWMUs will be characterized and closed in accordance with applicable federal and state regulations. Recontoured sites will be reclaimed in accordance with the WIPP Land Management Plan.

SWMU No.	Unit Type	Unit Description	Waste Description
001 a - ab	Mud Pits	Approximately 46 decommissioned mud pits are located on 28 drill pads, which were used for settling drill cuttings out of the drilling fluids being used in drilling holes to support hydrologic testing and monitoring, potash evaluation, and drilling for hydrocarbons.	Sodium- and potassium chloride saturated brine; starch; bentonite gel; diesel fuel; drill cuttings; metal cuttings; grease; hydraulic fluid; motor oil.

002 a - d	Salt and Top Soil Storage Areas	A total of four areas ranging in size from 3 to 15 acres used for salt and topsoil storage.	Salt; topsoil; traces of hydraulic oil; motor oil; diesel fuel; and scrap steel.
003 a - b	Landfills	Two landfills used for disposal of construction debris.	Foundation excavation soils; concrete; scrap wood; and metal.
004 a - c	Storage Yards	Three yards used for storage of construction and maintenance materials, wastewater, and used oils or materials that can be reclaimed or recycled.	Water contaminated with motor oil, hydraulic oil, and diesel fuel; used hydraulic oil, motor oil, antifreeze, glycol-based oils, chemical grout; used lead acid batteries; scrap metal. Used hydrocarbons are collected in containers.
005 a - c	Concrete Batch Plants	Three areas used as temporary locations for concrete batch plants.	Concrete; trace amounts of motor oil and grease.
006* a - b	Holding Ponds	Two ponds used to hold brine drilling fluid from the drilling of the salt handling and waste handling shafts.	Saturated brine; bentonite; drill cuttings; hydraulic oil and grease.
007 a - c	Evaporation Ponds	Three ponds used for the evaporation of water.	Water; soap; nonhazardous cleaning solutions; oil; unsaturated salt brine.
008 a - r	Surface Satellite Accumulation Areas	Ten hazardous waste or used petroleum product satellite accumulation areas; two hazardous waste staging areas.	Nonradioactive, site-generated wastes, collected in containers including spent solvents, aerosol cans, oily rags, expired chemicals, and paint products.
009 a - l	Underground Satellite Accumulation Areas	Ten hazardous waste or used petroleum product satellite accumulation areas.	Nonradioactive, site-generated wastes, including spent solvents, aerosol cans, oily rags, used oils, spent lead acid batteries, grout, and cement. Hazardous waste and used petroleum products are collected in containers.

010 a - d	Shaft Sumps**	An area at the bottom of each of the four WIPP shafts that collected construction debris or accumulated brine.	Welding residue; scrap wood and metal; salt; Class C cement; chem-seal; bentonite; grease and oil; cement and chem grout; Rustler formation brine; washwater.
011 a - e	Sewage Treatment Facility	Five ponds used for WIPP sewage treatment.	Sanitary waste; neutralized film developer, and oil.
012	Nonhazardous Solid Waste Collections Bins	Twenty portable bins used for solid waste collection.	Nonhazardous solid waste including nonliquid sanitary waste and industrial waste.
013 W	TRU Mixed Waste Management Units	Areas where transuranic (TRU) mixed waste was managed during the Disposal Phase. Includes contact and remote handled TRU areas of the Waste Handling Building and Panels 1 through 8 in the underground. Waste will be in approved containers.	Radioactive mixed waste consisting of TRU waste that is co-contaminated by various listed solvents, or which contain characteristic waste consisting mostly of metals.

*Both holding ponds designated as 006a and 006b have been remediated.

** The AIS & ES terminate at the storage horizon, but are designated as sumps for the RCRA Part B Permit application.

Removal of Site Boundary Structures

Fences - Fences around the surface facilities will be removed and either retired or transferred. A fence line shall be established to control access to the repository footprint area (the waste disposal area projected to the land surface.) for the active controls after closure. A standard five-strand barbed wire cattle guard fence shall be erected along the perimeter of the repository surface footprint. The fence shall have gates placed approximately mid-way along each of the four sides.

Guardhouse - Structures will be declared excess in accordance with applicable federal and DOE property management regulations.

Grading

Following removal of all structures and surfaces, as well as buried piping, conduit, and wiring, the surface will be graded to near the original contour.

Revegetation

Following closure of the WIPP site, the area will be replanted in accordance with applicable regulations and agreements.

Facility and Site Closeout

A final inspection of the facility will be conducted to ensure that the area has been returned to as close as reasonably possible to the surrounding landscape. Monitoring for assurance that the vegetation and animal populations are returning to normal will be accomplished within the Post-Closure Monitoring Program.

1.6.20 Facility Release and Reporting

Certification of Unrestricted Level for Release

Certification of unrestricted level for release will involve the evidence of historical reports of surveys and the results of the site radiological characterization survey conducted at the start of the decontamination and decommissioning effort, and the final radiological survey and hazardous constituent analysis.

Release of Site and Structures

Individual structures will be released as excess property as they are found free of contamination, as specified in Section 1.6.4 of this plan, and there is no further use for them at the site.

Final Program Report

A final program report will be issued for the decontamination and decommissioning program to summarize the decommissioning process and the steps taken to obtain closure status.

1.7 Facility Modification

1.7.1 Material Staging/Storage Facility

Laydown, staging, and storage areas will be designated for use during the decommissioning process. These areas will require the same level of survey and cleanup as the other portions of the site for free release and closeout.

It is anticipated that a staging area will be required for oils and ethylene glycol waste. There is an anticipated 1500 gallons of waste ethylene glycol with 3000 gallons of flush water waste. Drum storage or a roll-off tank (preferred method), will be required for the ethylene glycol waste. All ethylene glycol will be surveyed and sampled. Once a determination is made that the material is not radiologically contaminated, all ethylene glycol will be sent off-site to be recycled.

1.7.2 Liquid Treatment Facility

There is currently no requirement for a liquid treatment facility at the WIPP. However, all liquid site derived wastes will be solidified per current WIPP procedures and disposed of in the repository.

1.8 Waste Management

1.8.1 Radioactive Materials

Types

All radioactive waste generated will be designated as "derived" waste. The waste will not contain any constituents that would prevent it from meeting the DD-WAC, and will be emplaced in the last HWMU.

Quantities

The quantities of radioactive mixed waste that will be emplaced into the last HWMU at decommissioning of the WIPP facility is expected to be low due to the "start-clean, stay-clean" operating philosophy. All contamination events during the life of the facility will be controlled and cleaned immediately.

Dose Rates

To meet the criteria for conta- handled waste, the dose rates must not exceed 200 millirem per hour (mrem/hr).

1.8.2 Hazardous Wastes

Types

The WIPP facility controls the types and amounts of hazardous materials that are brought onto the site. Polychlorinated biphenyls and asbestos are excluded from use on the site. This process reduces the potential for hazardous wastes to be generated during D&D.

Quantities

The quantities of hazardous waste that will be generated during decommissioning of the WIPP facility is expected to be low due to the "start-clean, stay-clean" operating philosophy. All contamination events during the life of the facility will be controlled and cleaned before further work may continue in the area.

Disposition

Hazardous materials will be characterized and dispositioned utilizing the current WIPP procedures listed in Attachment 3 of this plan (References 33, 46, 51, 52, 55).

Packaging - Packaging will meet all applicable requirements.

On Site Storage - Nonradioactive hazardous materials will be stored in satellite waste accumulation areas, and transferred to the staging area in accordance with procedures listed in Attachment 3 of this plan.

Transportation - Nonradioactive hazardous materials will be shipped in accordance with procedures listed in Attachment 3 of this plan.

Disposal - Nonradioactive hazardous materials disposal will be at a permitted treatment, storage, or disposal facility.

1.9 Licensing and Regulatory Issues

1.9.1 Regulatory Compliance

Because of the stringent requirements for managing radioactive materials, the closure of the WIPP facility will require longer than the 180 days allowed in the regulations. Therefore, an extension to the 180 days must be requested for the closure in the permit application. If, for some unforeseen reason, closure cannot be completed within the time(s) specified, the DOE will request an extension to the closure time. This request will be submitted to the NMED in writing, at least 30 days before the expiration of the time allowed in the closure plan, and will describe the reason the extension is needed and estimate the amount of additional time needed to complete the closure. During the extended closure period, the DOE will continue to demonstrate compliance with applicable permit requirements and that all steps will be taken to prevent threats to human health and the environment as a result of TRU mixed waste management at the WIPP facility.

No later than the submission of the certification of closure of each hazardous waste disposal unit, the owner or operator must submit to the local zoning authority, or the authority with jurisdiction over local land use, and to the Regional Administrator, a survey plat indicating the location and dimensions of hazardous waste disposal units with respect to permanently surveyed benchmarks. This plat must be prepared and certified by a professional land surveyor. The plat filed with the local zoning authority,

or the authority with jurisdiction over local land use, must contain a note, prominently displayed, which states the owner's or operator's obligation to restrict disturbance of the hazardous waste disposal unit in accordance with the applicable regulations.

The Final Safety Analysis Report will require modification to meet the requirements of the Consultation and Cooperation agreement between the State of New Mexico and the U. S. Department of Energy.

A WIPP specific closure and post closure NEPA document will be developed prior to initiating the final closure phase.

1.9.2 Permit Modifications

Current Facility Status

The facility is currently awaiting authorization to receive TRU mixed waste for disposal.

Permit modifications may be necessary for decommissioning. Direction on this subject can be found in 40 CFR 270.41, 270.42, and 270.43.

40 CFR §270.41 Modification or Revocation and Reissuance of Permits, §270.42 Permit Modification at the request of the Permittee, and §270.43 Termination of Permits, are detailed in the Code of Federal Regulations.

Revisions to the FSAR will be required to incorporate the D&D changes in work scope, direction, organization, etc.

Development of an appropriate NEPA document, possibly a supplemental environmental impact statement will be necessary to address environmental changes resulting from substantial changes in the WIPP mission.

Prevention of Criticality

Adherence to the waste acceptance criteria for waste received at the site and for derived waste will assure that criticality is not an issue during the decontamination and decommissioning phase.

Release Prevention

Maintenance of the negative pressure in the waste handling areas and adherence to the applicable procedures will prevent the release of contaminants.

Decommissioning Activities Safety Analysis

DOE Order 5480.21, Unreviewed Safety Questions, Section 10, Program Requirements, requires that a contractor authorized to operate DOE nuclear facilities shall perform safety evaluations for all changes in facility and procedures as described

in the existing safety analyses and tests or experiments not described in the existing safety analyses.

Decommissioning is described in the Final Safety Analysis Report (FSAR), and this plan does not change the facility or procedures beyond that described in the FSAR.

The need for a decommissioning activities safety analysis will be evaluated prior to initiation of the decontamination and decommissioning plan. If a safety analysis is required for decommissioning activities, it will be documented through the FSAR update.

Changes to Operational Safety Requirements (OSR)

Decommissioning of WIPP is not expected to require a change in operational safety requirements. The requirements will need to be individually inactivated (as an unresolved safety question) as each of those systems covered by the OSRs are removed from service.

1.9.3 Residual Radioactivity

Post-Decommissioning Radiation Survey Program

Following decontamination (which will ensure the removal of waste residues at background levels) and decommissioning of the WIPP site, there will be no need for a radiation survey program. This may change in the final version of the Post-Closure Monitoring Plan.

Certification Requirements

Certification of post-decommissioning radiation levels will be provided in the post-closure notification to the State of New Mexico.

1.10 Records Disposition

Quality records generated during the decommissioning process will be identified on the decontamination and decommissioning section records inventory and disposition schedule. Following review of the records by cognizant personnel the records will be transmitted to Project Record Services.

A copy of records of waste disposal locations and quantities specified under 40 CFR §264.73(b)(2) will be submitted to the regional administrator and local land authority within 60 days of closure of the facility.

2.0 Supporting Documents

These documents are required to support the overall decommissioning program. This section provides a brief overview of the documents and document control numbers. Several of these documents will also address the requirements of the long-term protection plan for acceptable cleanup levels, sampling and analysis plans, and QA/QC specifications.

The documents listed below that are designated as "currently in place" are reviewed and updated periodically to ensure correctness with the current facility configuration and operational status.

2.1 Detailed Implementation Plan

A detailed implementation plan is not credible at this time for the completion of the decommissioning of the Waste Isolation Pilot Plant. Processes that are in current use and will be utilized for decontamination and decommissioning are detailed in procedures that are currently in place. New systems that are procured for the decontamination and/or decommissioning will require separate process specific procedures for operation. Prior to final waste emplacement a detailed implementation plan will be developed.

2.2 Engineering Plan

Procedures are currently in place which will direct engineering activities during the decommissioning process and are listed in Attachment 3 of this plan (References 58-70).

2.3 Cost, Schedule, and Financing Plan

Procedures are currently in place for financial aspects of decommissioning and are listed in Attachment 3 of this plan (References 86, 87).

At this date cost and schedule estimates are of little true value in predicting the actual numbers and timelines for 28 years in the future. A conceptual cost estimate is available from the Waste Isolation Division Long-Term Regulatory Compliance Group. A cost, schedule, and budget will be developed prior to final waste emplacement.

2.4 Solid Waste Management Unit Closure Plan

A plan will be developed for closure of the solid waste management units. The plan will be developed to accomplish the closures of the separate SWMUs in accordance with applicable regulations.

2.5 Health and Safety Plan

Procedures are currently in place to ensure the health and safety of workers and the public. These procedures are listed in Attachment 3 of this plan (Reference 72).

2.6 Quality Assurance Plan

Procedures are currently in place in to meet the requirements of DOE Order 5700.6C. These procedures are listed in Attachment 3 of this plan (Reference 82).

10 CFR 830.120 is implemented through DOE Order 5700.6C.

2.7 Emergency Plan

Emergency procedures are currently in place. These procedures are listed in Attachment 3 of this plan (Reference 76).

2.8 Environmental Report/NEPA Documentation

Procedures are currently in place for environmental reporting and NEPA documentation and are listed in Attachment 3 of this plan (References 47, 48, 50).

2.9 Radiological Protection Plan

Policies are currently in place for assuring that worker exposures to radiological and chemical hazards are kept low. These policies are listed in Attachment 3 of this plan (References 72, 73, 81).

2.10 Physical Security Plan

Procedures are currently in place for physical security. These Procedures are listed in Attachment 3 of this plan (Reference 71).

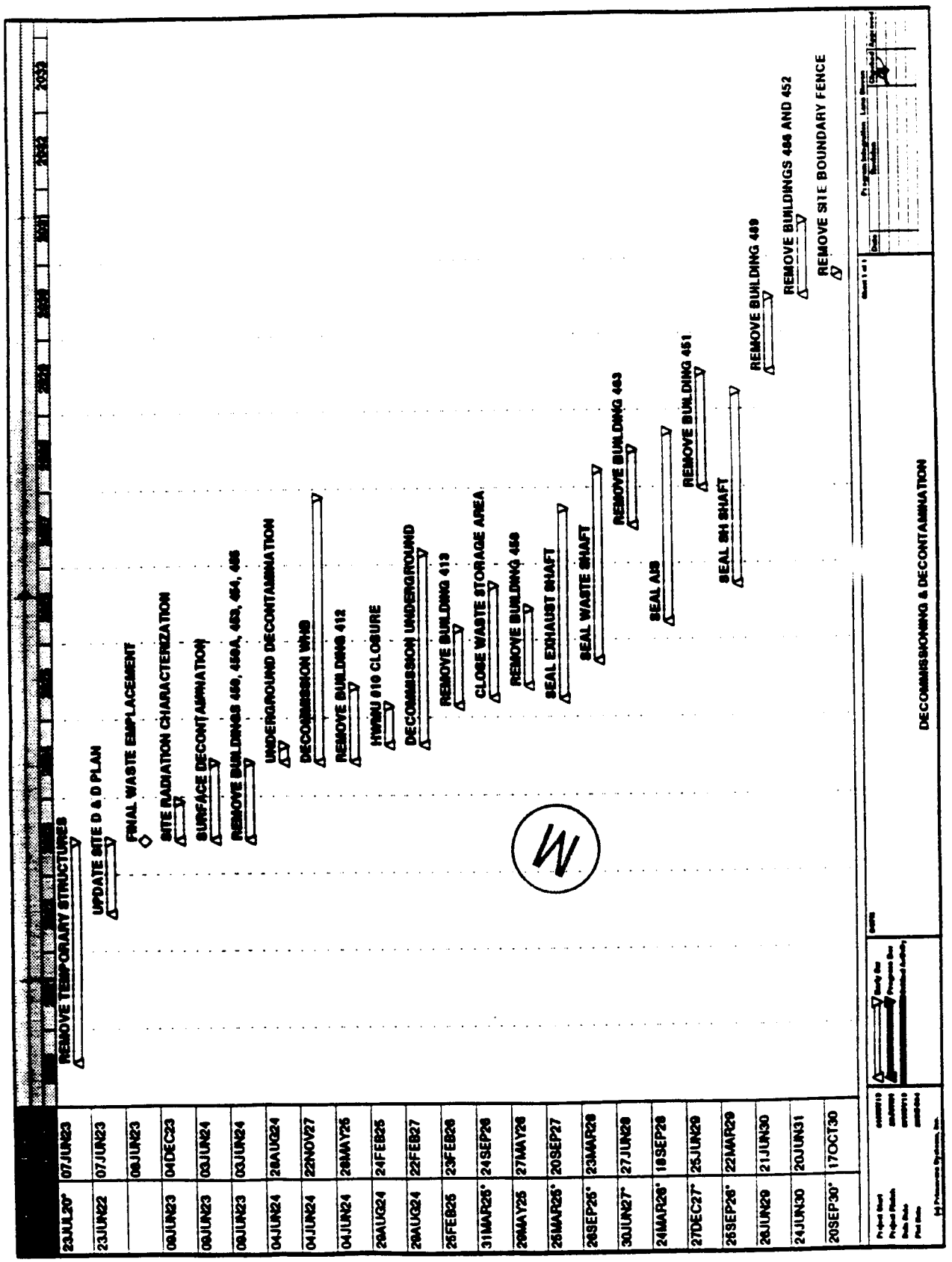
2.11 Environmental Monitoring Plan

Procedures are currently in place for environmental monitoring and are listed in Attachment 3 of this plan (References 44, 45, 52, 53).

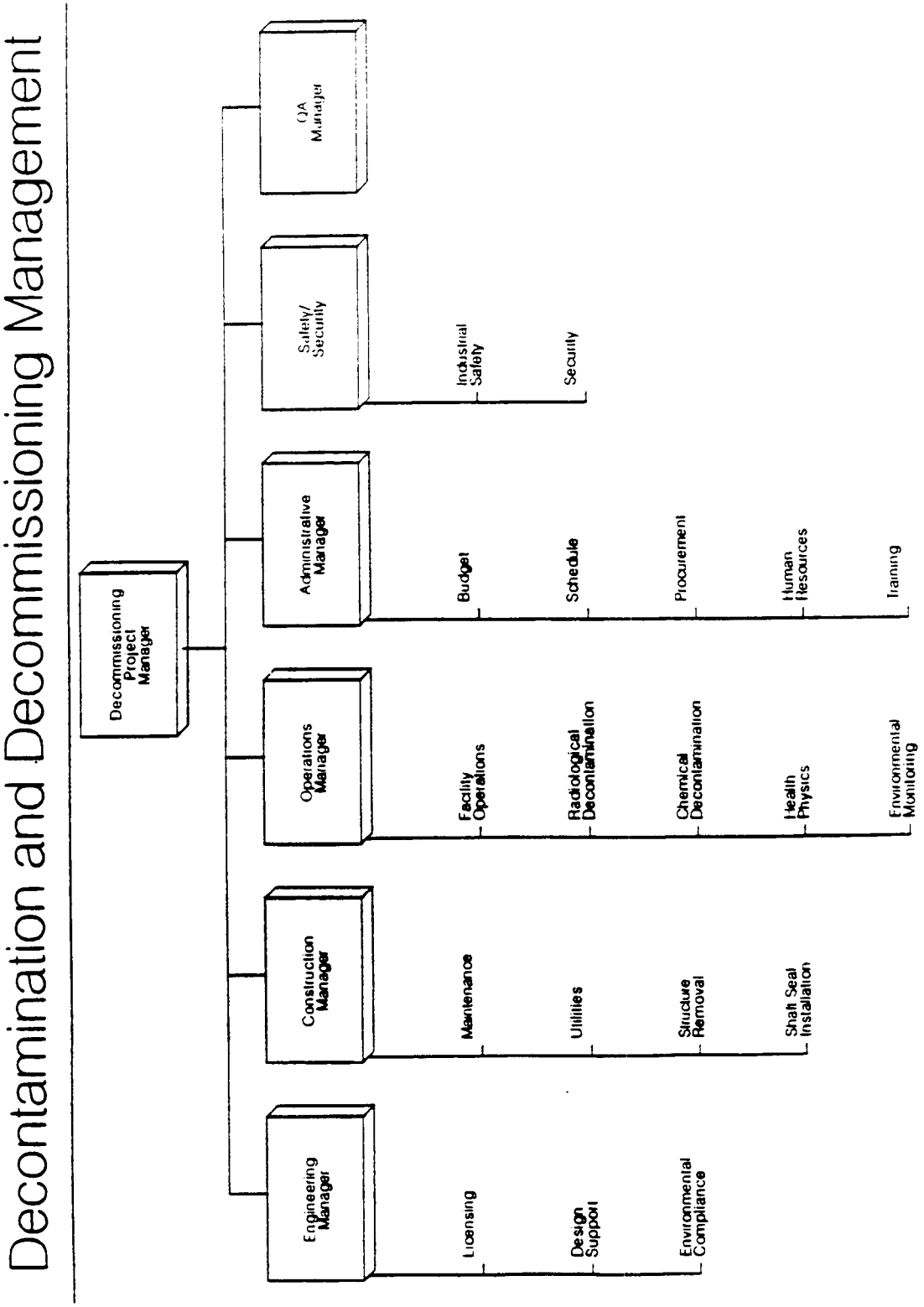
2.12 Supplemental Environmental Impact Statement

Development of a Supplemental Environmental Impact Statement will be necessary to address environmental issues resulting from substantial changes in the WIPP mission.

Attachment 1 Schedule



Attachment 2 Decontamination and Decommissioning Management



Attachment 3 References

1. 10 CFR 830.120, Quality Assurance requirements
2. 24-C-022-W, WIPP Site Facility Master Plan
3. 29 CFR 1910.1200, Hazard Communication
4. 40 CFR 191, Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
5. 40 CFR 194, Criteria for the Certification and Determination of the Waste Isolation Pilot Plant's Compliance with Environmental Standards for the Management and Disposal of spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
6. 40 CFR 261, Identification and Listing of Hazardous Waste
7. 40 CFR 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
8. 40 CFR 268, Land Disposal Restrictions
9. 40 CFR 270, EPA Administered Permit Programs: The Hazardous Waste Permit Program
10. 40 CFR 280, Underground Storage Tanks
11. 41 CFR 101, Federal Property Management Regulations
12. 41 CFR 109, Department of Energy Property Management Regulations
13. 49 CFR 100 THROUGH 199, Research and Special Programs Administration, Department of Transportation
14. ANSI/ANS-15.10-1981, American National Standard for Decommissioning of Research Reactors
15. ASTM E1167 87, Standard guide for Radiation Protection Program for Decommissioning Operations
16. ASTM E1278 88, Standard Guide for Radioactive Pathway Methodology for Release of Sites Following Decommissioning
17. ASTM E1281-89, Standard Guide for Nuclear Facility Decommissioning Plans
18. CAO QAPD (Quality Assurance Program Description)
19. DOE/EIS-0026, Final Environmental Impact Statement
20. DOE/ID-10500, Department of Energy Hoisting and Rigging Manual, April 1993, Assistant Secretary for Environment, Safety and Health, Washington, DC 20585
21. DOE Order 1540.1A, Materials Transportation and Traffic Management
22. DOE Order 5820.2A, Radioactive Waste Management
23. DOE Order 5820.2B, Draft (4/29/93) - Decontamination and Decommissioning of Radioactively Contaminated Facilities
24. DOE Order 5700.6C, Quality Assurance Program Implementation Guide
25. DOE/CAO-94-2003, WIPP Regulatory Compliance Strategy and Management Plan for Demonstrating Compliance to Long-Term Disposal Standards
26. DOE/WIPP 87-016, Draft Rev. 1, A Plan for the Implementation of Assurance Requirements in Compliance with 40 CFR 191.14 at the Waste Isolation Pilot Plant
27. DOE/WIPP 91-005, Waste Isolation Pilot Plant RCRA Part B Permit Application
28. DOE/WIPP 93-029, Waste Isolation Pilot Plant Repository Monitoring Program Strategic Plan

29. DOE/WIPP 94-024, Waste Isolation Pilot Plant 1994 Environmental Monitoring Plan
30. EIB/SWMR-4, New Mexico Solid Waste Management Regulations
31. General Plant Design Description (GPDD) Revision 0
32. HA:94:6528, Revision 2 to WIPP Active Controls after Closure Design Criteria, R. J. Rodriguez, 9/14/94
33. 20 New Mexico Administrative Code 4.1 Subpart V
34. IAEA Safety Series No. 105, The Regulatory Process for the Decommissioning of Nuclear Facilities
35. Minerals Act of 1947, (Act of July 31, 1947, 30 U.S.C. 602, 603.)
36. NUREG-0586, Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities
37. Permanent Marker Conceptual Design Report, Draft, Revision 2, November 1994
38. PL 96-164, Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
39. PL 102-579, Waste Isolation Pilot Plant Land Withdrawal Act
40. Waste Isolation Pilot Plant Project Technical Baseline for Regulatory Compliance.
41. Radiological Environmental Surveillance Air Sampling and Analysis at the WIPP Site, Carter, M. W., May 26, 1994, Westinghouse, Waste Isolation Division, Carlsbad, NM
42. WIPP-DOE-069, Waste Acceptance Criteria for the Waste Isolation Pilot Plant
43. Working Agreement for Consultation and Cooperation, Rev. 1, Section N (DOE, 1981)
44. WP 02-14 WIPP National Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan
45. WP 02-2, Environmental Compliance Assessment Program (ECAP) Plan
46. WP 02-601, Nonradioactive Hazardous Waste Management
47. WP 02-801, National Environmental Policy Act Compliance
48. WP 02-802, NEPA Evaluation, Tracking, and Monitoring
49. WP 02-9, WIPP Final Safety Analysis Report
50. WP 02-EC, National Environmental Policy Act Compliance Plan for the Waste Isolation Pilot Plant
51. WP02-EM1, WIPP Quality Assurance Project Plan for WIPP Site Effluent and Hazardous Materials Sampling
52. WP02-EM2, The WIPP Site Effluent and Hazardous Materials Sampling Plan
53. WP02-EM1001, Sewage System Discharge Monitoring and Compliance
54. WP 02-RC1, Draft Waste Isolation Pilot Plant Project Technical Baseline for Regulatory Compliance
55. WP 06-101, Shipping of Nonradioactive Hazardous Materials
56. WP 06-108, Construction Landfill Operation
57. WP 06-HM3108, Request for Disposal
58. WP 09, Engineering Conduct of Operations and Procedures Manual
59. WP 09-CN3022, Engineering Document Control and Distribution
60. WP 09-007, Engineering and Design Document Preparation and Change Control

61. WP 09-024, Configuration Management Board/Engineering Change Proposal (ECP)
62. WP 09-025, Engineering Data Transmittal/Design Input
63. WP 09-029, Cognizant Engineer Responsibilities
64. WP 09-031, Engineering Calculations
65. WP 09-033, Construction Labor Services
66. WP 09-034, Configuration Management Determination
67. WP 09-035, Site Development Planning and Project Authorization Process
68. WP 09-8, Specification Preparation Style Guide
69. WP 09-9, Configuration Management Plan
70. WP 09-CN3003, As Built Drawings: Process and Control
71. WP 11-7, WIPP Security Manual
72. WP 12-1, WIPP Safety Manual
73. WP 12-2, WIPP ALARA Manual
74. WP 12-5, WIPP Radiological Control Manual
75. WP 12-6, VOC Monitoring Plan
76. WP 12-9, WIPP Emergency Plan and Administrative Procedures Manual
77. WP 12-10, Emergency Services Program Plan
78. WP 12-HP, WIPP Operational Health Physics Procedures Manual
79. WP 12-HP1100, Monitoring and Surveys
80. WP 12-HP3200, Radioactive Material Control
81. WP 12-RE3000, Radiological Control Program
82. WP 13-1, WID Quality Assurance Program Description
83. WP 14-TR3402, WIPP Training Policies
84. WP 14-TR3501, General Employee Training
85. WP 14-TR3502, Training Requirements for Subcontractor Personnel
86. WP 15-6, Purchasing Policies and Procedures Manual
87. WP 15-605, Award and Administration of Construction Work

APPENDIX DEF

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APPENDIX DEF

DEF.1.0 GRAVITY-DRIVEN STRUCTURE IN THE CASTILE

This document describes the structural features in the Castile Formation that are commonly attributed to gravity-driven deformation. To properly present this subject, the data will first be shown in a general historical overview, permitting the reader to understand the sequence of investigations. The known extent of deformation in the Castile, how these structures are likely to develop in the future, how well they can be predicted, and the potential impact of these structures on the WIPP will also be discussed. Apart from the general geological impact, the performance of the WIPP as it might be affected by such structures is not specifically assessed here.

DEF.1.1 Background Information

For a number of years, it has been known that parts of the Castile Formation are deformed. Cross-sections of the basin geology through its margins have shown some evidence of deformation. Jones et al. (1973) provided a map of the isopachs of part of the Castile that clearly show much thicker portions in some areas along the northwestern to northern Delaware Basin, just inside the margin of the Capitan Reef. Very little information had been collated concerning deformation within the Delaware Basin until studies were initiated of the Delaware Basin as a possible site for radioactive waste disposal. Jones et al. (1973) is probably the clearest early presentation of this information, though the dissertation by Snider (1966) and the paper by Anderson et al. (1972) also reflect thicker sections in some Castile units adjacent to the reef.

In 1975, Sandia National Laboratories (SNL) drilled a third borehole, called ERDA-6, at a site (Figure DEF-1) that had been partially investigated by Oak Ridge National Laboratories (ORNL) during 1974. Two boreholes (AEC-7 and AEC-8) were drilled in 1974 by ORNL before SNL was assigned to carry out the task of investigating this site for radioactive waste disposal under programs that preceded WIPP. Formation boundaries and marker beds in ERDA-6 were structurally high compared to AEC-7 and 8, and the degree of deformation increased downward. At about 2,711-mi (826-m) depth, ERDA-6 began to produce pressurized brine and gas. The hole was tested extensively to determine the nature and origin of the brine. Beds within the Castile were displaced structurally upward, apparently by hundreds of feet (Jones 1981; Anderson and Powers 1978), and some of the lower units may have actually pierced upper units (Anderson and Powers 1978). Because of the desire for structurally uncomplicated units to simplify mining for a repository, the site under investigation at ERDA-6 was abandoned in 1975, and in 1975-76 the current site was initially selected and investigations began (Powers et al. 1978). As part of the selection criteria, a zone about 6 mi (10 km) wide inside the Capitan Reef was avoided because it included known deformed Castile and Salado (Griswold 1977). This is the first instance in which the site investigations were directly influenced by discovery of deformation in the Castile and lower Salado.

The present site for the WIPP was selected and initially investigated in 1976 to determine if the desired characteristics for the preliminary site selection were present (Griswold 1977; Powers et al. 1978). As the general criteria appeared to be met during this phase, the site and surrounding areas were characterized much more extensively and intensively beginning in 1977. Extensive new seismic reflection data were collected in 1977 and 1978 that began to reveal the deformed Castile north of the center of the site (Figure DEF-1.1). Because the principal effect was that the good quality Castile reflectors from the area south of the site center were "disturbed," the area to the north was dubbed the "disturbed zone" (DZ). It also became known as "the area of anomalous seismic reflectors" or "zone of anomalous seismic reflection data." The boundary of the DZ was variously described as being from about 0.5 to 1 mi (0.8 to 1.6 km) north of the center of the site, depending on the criteria to define the DZ. Powers et al. (1978) generally defined the DZ beginning about 1 mi (1.6 km) north of the site center, where the seismic reflector character was poor to uninterpretable, or "anomalous" (Borns et al. 1983). About 0.5 mi (0.8 km) north of the site center, it appeared that beds within the Castile Formation began to steepen in gradient, dipping to the south from a higher area to the north. The Environmental Evaluation Group (EEG) summarized various map limits to the DZ, including the area where the Castile dip begins to steepen (Neill et al. 1983). Borns et al. (1983) included two separate areas south of the site as part of the DZ based on seismic character.

The first new drillhole within the area encompassed by the DZ was WIPP-11, and it was located about 3 mi (5 km) north of the center of the WIPP site (Figure DEF-2). Long and Associates (1977) examined proprietary petroleum company data in 1976, and identified anomalous areas around the WIPP site, including the structural anomaly at the WIPP-11 location. Seismic reflection data acquired in 1977 indicated possible salt flowage within the Castile and a structure that could be similar to that at ERDA-6 (Sandia National Laboratories and U.S. Geological Survey 1979). WIPP-11 was drilled early in 1978, demonstrating the extensive deformation within the Castile and extending upward into the Salado. WIPP-11 did not encounter any brine or gas flows.

Seismic reflection data acquired in 1977 not only showed a zone of steepened dip of the Castile north of the site center, it also showed a possible fault offsetting parts of the Salado and Rustler Formations. A series of five boreholes was planned to provide detailed information on the structure of the Rustler/Salado contact. Four boreholes (WIPP 18, 19, 21, and 22) were required to demonstrate that there was no detectable offset on that contact in the area interpreted from 1977 seismic reflection data (Figure DEF-1). Later epochs (1978 and 1979) of seismic data in the same area, along with the drilling, continued to show generally poor resolution or uninterpretable data in the area of the DZ. These studies generally showed that the acoustic velocity of the upper section changes laterally, complicating further the interpretation of the deeper Castile structure. Through the WIPP 18-22 drilling program, the upper Salado and Rustler were determined to be fundamentally undisturbed over the southern margin of the disturbed zone where the Castile appears to dip to the south (Sandia National Laboratories and U.S. Geological Survey 1979).

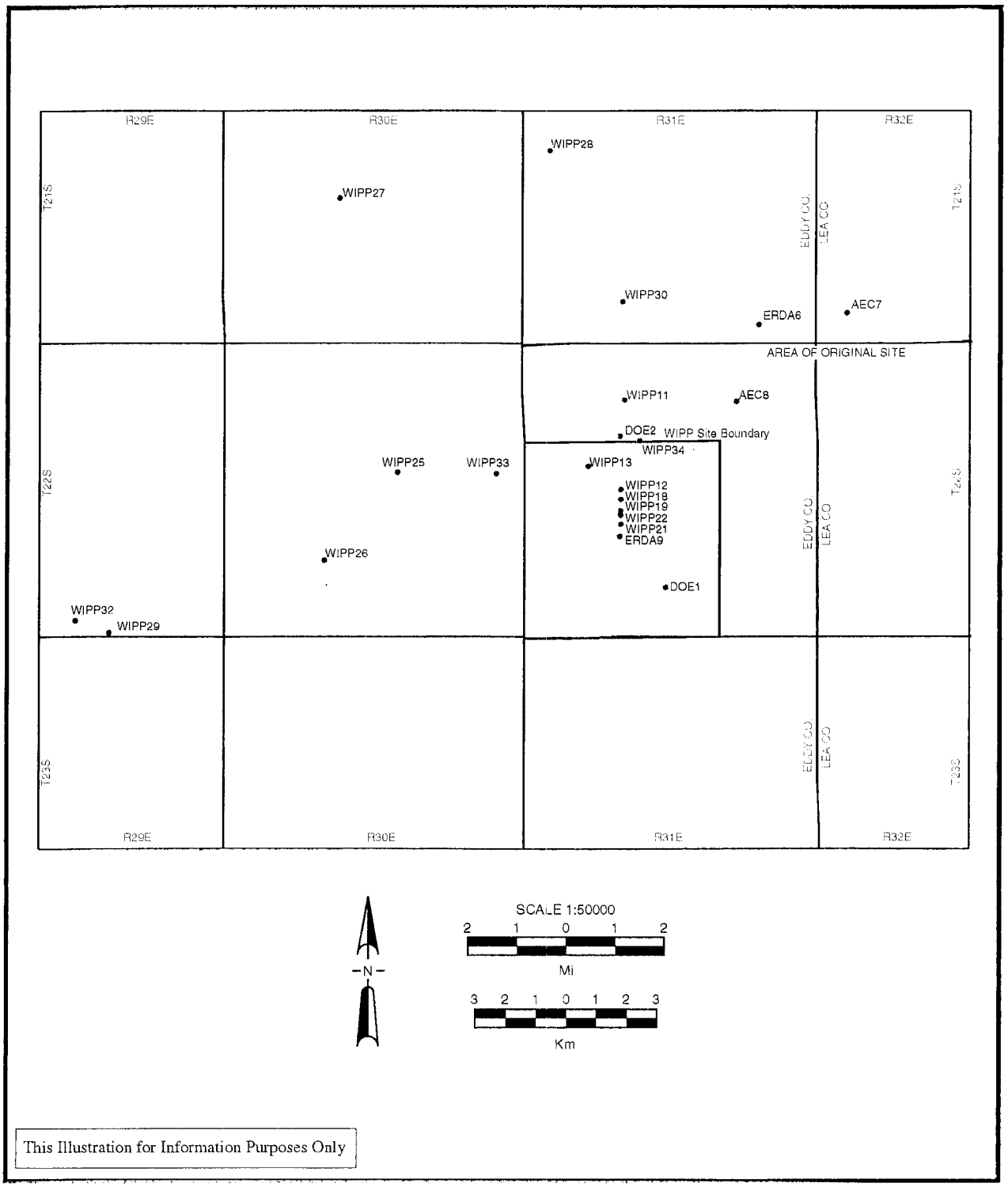

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Figure DEF-1. Location of Main Stratigraphic Drillholes

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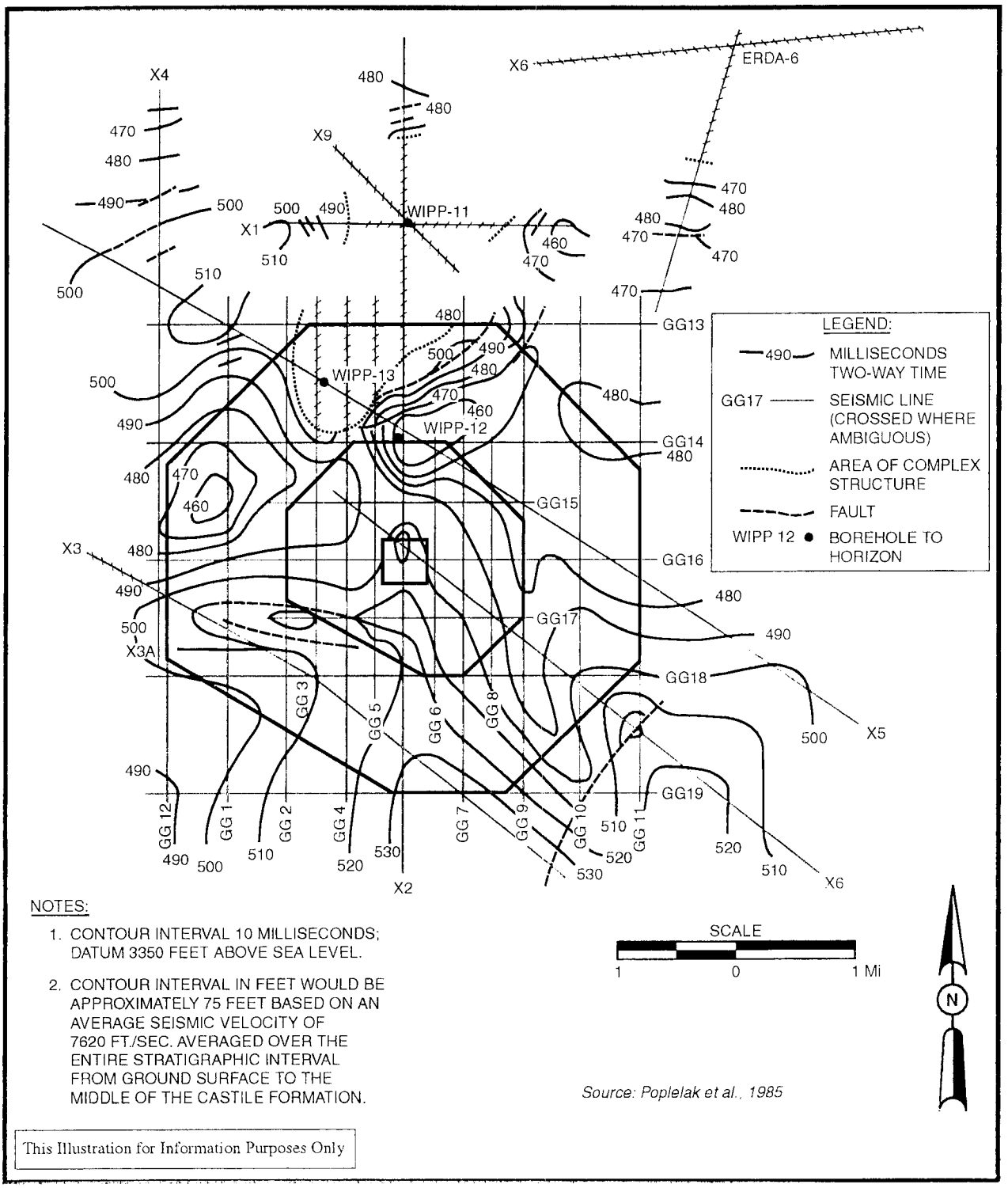

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Figure DEF-2. Seismic Time Structure Middle Castile Formation

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WIPP-12 was located approximately 1 mi (1.6 km) north of the site center to test the amount the Castile was elevated (Figures DEF-1, DEF-2). It was drilled late in 1978 to the top of the Castile and detected approximately 160 ft (50 m) of structural elevation compared to ERDA-9 and the center of the site (Sandia National Laboratories and D'Appolonia Consulting Engineers 1982c). The amount of disturbance of the Salado was not considered an impediment to underground development, though the underground storage facility was later reoriented from this northern area to an area south of the site center (see Section DEF.1.1). From drilling WIPP-12 and the WIPP 18-22 series, the southern margin of the DZ was considered to be much more gentle in structure, while the seismic character and WIPP-11 indicated much more severe deformation of the Castile further to the north.

Two additional phases of seismic reflection data were acquired in 1978 and 1979. These data mainly concerned the immediate site area (about 4 mi^2 [10 km^2]) and the southern edge of the DZ. They indicated much the same problems and margins associated with the DZ from the 1977 data. The latest seismic data (1979) were principally acquired to facilitate construction and Site and Preliminary Design Validation (SPIV) activities. As the project moved into SPIV activities, the DZ was little investigated directly during the period from about late 1979 until mid-1981.

A microgravity survey of the site area was conducted to determine if the structure within the DZ could be partially resolved by that method (Barrows et al. 1983; Barrows and Fett 1985). The large differences in density of halite and anhydrite might cause detectable differences in the gravity field locally if the units were displaced and/or thickened relative to the surrounding areas. The microgravity survey covered an area of "normal" stratigraphy from south of the WIPP site center to the area of WIPP-11 (Figure DEF-3). As interpreted by Barrows et al. (1983), the microgravity does not resolve the larger scale deformation within the Castile Formation. Based on the interpretation of probable shallow disturbance of the gravity field, WIPP-14 and WIPP-34 were drilled about 2 mi (3 km) north and about 0.5 mi (0.8 km) east of the site center (Figure DEF-1). These boreholes encountered normal stratigraphy within the Rustler and upper Salado (Sandia National Laboratories and D'Appolonia Consulting Engineers 1982c; Sandia National Laboratories and U.S. Geological Survey 1981) with some slight structural depression made apparent mainly by the deformation northeast of this area around ERDA-6 (Holt and Powers 1988). Barrows et al. (1983) attributed the gravity anomaly around WIPP-14 to decreased density within parts of the Rustler Formation, mainly from the difference in density due to anhydrite versus gypsum in WIPP-14. The overall difference in mass was attributed to karst processes by Barrows et al. (1983), rather than to deformation of any of the units associated with the DZ.

During the mapping of the first shaft drilled at the WIPP site Salt Handling Shaft (SHS), MB 139 was observed to have a few in. of relief on the basal contact and 2 to 3 ft (0.6 to 0.9 m) of relief on the upper surface. Jarolimek et al. (1983) interpreted the internal structure on these high points of MB 139 as showing a radial structure due apparently to gypsum growth textures and subsequent crushing, indicating a fundamentally depositional

origin to the relief, rather than any structural disturbance related to the DZ. Borns (1985) conducted an investigation of additional cores and holes drilled through MB 139, because EEG was concerned that the apparent structure was related to the DZ. Borns (1985) also concluded that the relief was not due to structural deformation, but mainly to erosion processes that carved part of the relief found on the top of the marker bed. From either point of view, the difference in relief on the upper and basal contacts of MB 139, in such a thin unit, were convincing evidence that a form of tectonic deformation was not involved.

In late 1981, WIPP-12 was deepened to test for the possible presence of brine and/or pressurized gas within the structure in the Castile Formation (D'Appolonia Consulting Engineers, Inc. 1982). The probability of producing brine/gas from WIPP-12 was considered reasonably low at the time, because most known pressurized brine/gas was associated with much more deformed units than the Castile at WIPP-12. Fractured anhydrite in the upper Castile did begin to yield pressurized brine and gas when intercepted late in 1981, and WIPP-12 and ERDA-6 were further tested. Later geophysical work (The Earth Technology Corporation 1987) suggests that the brine may underlie part of the WIPP facility, beyond the area usually included in the DZ. Though the U.S. Department of Energy (DOE) and EEG agreed that neither brine nor structure constituted a threat to health and safety, the proposed underground facilities were reoriented south of the site center, avoiding longer haulage and the slight structure encountered at the facility horizon (see Section DEF.1.1). As a consequence of the deepening and testing of WIPP-12, the link between structure and pressurized brine and gas was strengthened.

The last direct investigation of the DZ was a by-product of another investigation. DOE-2 was drilled approximately 2 mi (3 km) north of the center of the WIPP site to investigate the origin of a modest depression on MB 124 (Griswold 1977; Powers et al. 1978) that was detected in a corehole drilled by a potash company. DOE-2 was principally a test of the hypothesis that the depression was caused by ductile flow of halite in response to deep dissolution of halite by water from the Bell Canyon Formation (Mercer et al. 1987). Halite layers in the lower Salado were thicker than usual, indicating that part of the sequence had not been dissolved, and the Castile was very deformed. The Castile stratigraphy was not normal; the second halite was apparently squeezed out of the area during deformation. The stratigraphy in DOE-2 is apparently the result of processes that caused the DZ and is not the result of any dissolution (Borns 1987; Mercer et al. 1987).

The preceding paragraphs describe most of the direct investigations of the DZ and place them in their historical context. In the next few sections, more of the specific features of the DZ will be described, interpreted, and discussed to indicate the significance of the structures and processes of formation for the WIPP.

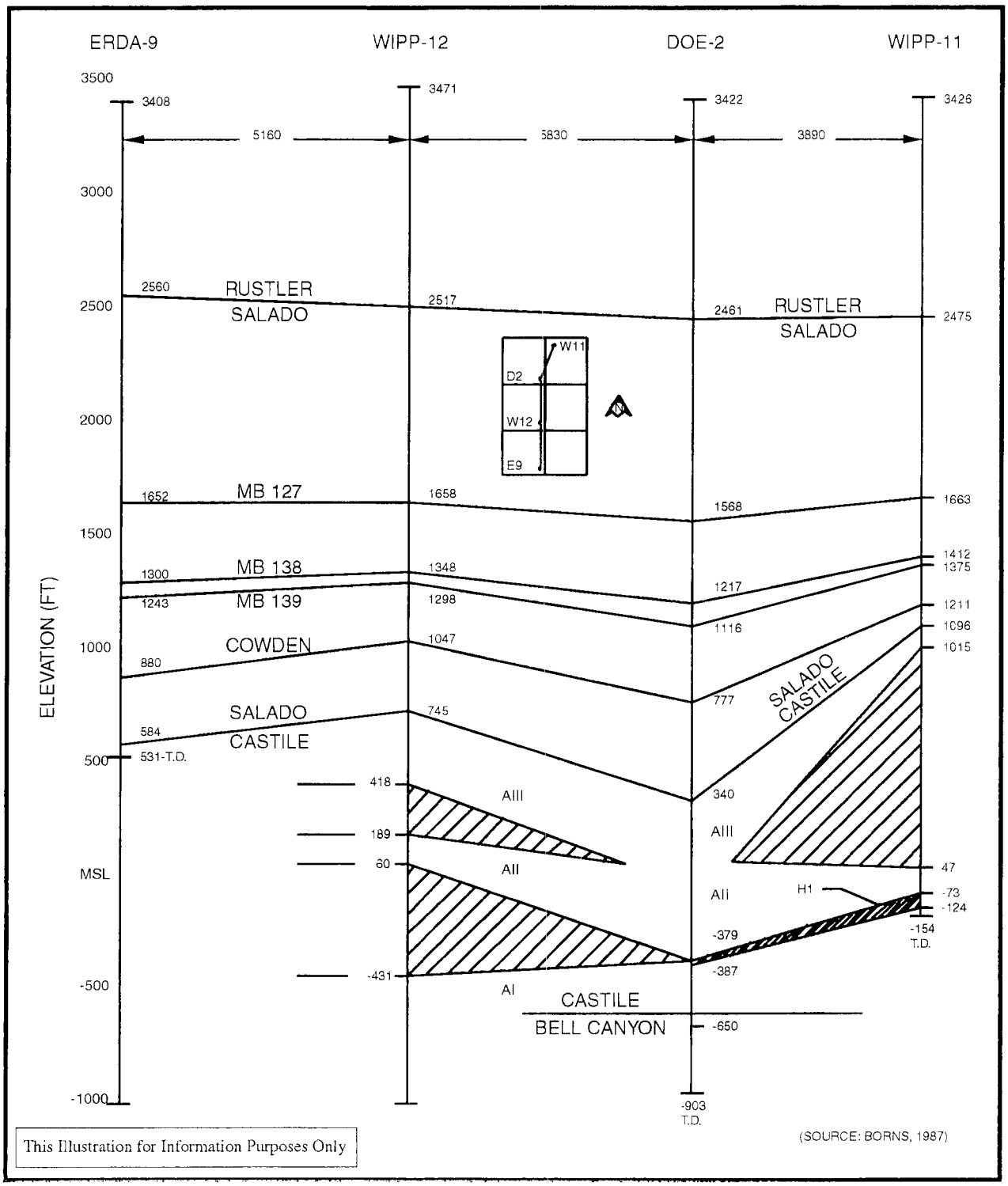

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Figure DEF-3. Fence Diagram using DOE-2 and Adjacent Holes

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DEF.1.2 Specific Features of the Disturbed Zone

The first specific feature of the DZ is its boundary. In Section DEF.1.1, the different concepts of the boundary depended on ideas of where the Castile began to change and steepen dip (about 0.5 mi (0.8 km) north of the site center, or where the various epochs of seismic data became unreliable to uninterpretable). Borns et al. (1983) present one diagram (Figure DEF-2) of the seismic time structure for the top of the Castile Formation that illustrates the variously defined boundaries as well as any diagram. The principal part of the DZ is defined by a lobate area (Figure DEF-2) shown as an "area of complex structure" where the seismic data are considered "ambiguous." The structurally-deformed area clearly includes an area about halfway between boreholes WIPP-12 and ERDA-9, as well as a larger area to the northeast. The two-way travel time contoured on the map is a function of depth; as the reflector is nearer the surface, the travel time to the reflector and back to the surface decreases. Thus, the areas enclosed with contours of smaller values should be structurally higher. (The top of Castile in WIPP-12 was 160 ft [50 m] higher than it is in ERDA-9). The map was not directly converted to depth because the seismic reflection and borehole geophysical logging programs demonstrate clearly that there are also lateral velocity variations within the upper part of the rock section, especially within the Rustler and Dewey Lake Formations. These velocity variations cannot be adequately extracted from the travel times to permit converting the travel time to depth. Nonetheless, the map demonstrates the general best information about the extent of the DZ. The central and southern part of the WIPP site area displays relatively uniform seismic travel time structure and nothing within the geological data contradicts that information to date.

The broad forms of the structures within the DZ are generally anticlinal and synclinal (Borns 1987), though they are not necessarily regular shapes. The best known shape for part of the DZ is between WIPP-12 and ERDA-9, where seismic information and several drillholes constrain part of the stratigraphy. There the structure tends to be a gently dipping limb of a anticlinal structure. Most of the remaining shapes attributed to the Castile within the DZ or related area are based more on one drillhole or a few drillholes that somewhat constrain the structure. WIPP-11, WIPP-13, DOE-1, and ERDA-6 are all examples. A generalized cross-section of the structure at ERDA-6 (Anderson and Powers 1978) shows a piercement structure and a regular shape; the piercement is based on stratigraphic inferences, but the shape is fundamentally uncontrolled by closely spaced data. WIPP-11 and WIPP-12 are both believed to penetrate anticlinal forms, though the structure is only partially known from drilling and seismic reflection data. DOE-2 is believed to lie in a synclinal structure, and contacts on various units show a nested series of depressions in the upper Salado (Borns 1987). There are too few drillholes into the Castile to reconstruct the detailed shapes of Castile structures. The seismic data are not well enough constrained to calculate depths to reflectors, and most reflectors are too "disturbed" to interpret in this area. The specific shapes of individual structures are unlikely to be defined in the near future.

Anderson and Powers (1978) contoured several structures within the Delaware Basin, including structures at Poker Lake at least grossly similar to ERDA-6. Borns and Shaffer (1985) reexamined the information from Poker Lake and concluded that the actual shape is poorly constrained. Outside of the area on the north side of the current WIPP site, the information available is too sparse to define the individual shapes of structural features on borehole data.

It is important to note that, to date, none of the structures are demonstrably associated with comparable structure on the underlying Delaware Mountain Group. Snyder (in Borns et al. 1983) does show an upthrown block (hoist) through WIPP-11 on the top of the Bell Canyon Formation that is based on his projection of the thickness of the lower Castile; WIPP-11 did not penetrate the complete Castile section. Other areas, such as the Poker Lake structures, may display some relief on the top of the Delaware Mountain Group, but Borns and Shaffer (1985) do not attribute the relief to faulting. They believe the relief existed before and during deposition of the overlying Castile units. The underlying units to the Castile Formation are, for the most part, uninvolved in the structures displayed by the Castile.

Structure contour and isopach maps of the Salado and Rustler over areas of complicated Castile structure also show that the overlying units are successively less involved in the structure (e.g., Section 7.2; Borns and Shaffer 1985; Borns et al. 1983; Holt and Powers 1988). Lower units that are thicker and deformed are overlain by units that are thinner and less structurally involved in the deformation. Under normal geological circumstances, e.g., dealing with a rock sequence of carbonates or siliciclastics, the deformation would be considered completed by the time of deposition of the lowermost undeformed rock unit. Here, within a much more plastic set of rocks, the same geological reasoning is of less value, as the rocks may compensate laterally for late deformation effects and produce the same results as seen here.

Borns (1983; 1987; Borns et al. 1983) has extensively examined the macroscopic to microscopic features from cores taken within the structurally deformed areas. These studies follow earlier, broader studies of macroscopic features from the "state line outcrop" (Kirkland and Anderson 1970) and ERDA-6 (Anderson and Powers 1978). Kirkland and Anderson (1970) reported that small-scale folding within the Castile outcrops is oriented consistently along the general north-south strike of beds in the Delaware Basin. From this, they concluded that the deformation was related to tilt of the basin, generally believed to be Cenozoic in age (e.g., Anderson 1978; King 1948; Borns et al. 1983), though authors differ in opinions of when this took place by tens of millions of years. Anderson and Powers (1978) used this apparent relationship to estimate that folding at ERDA-6 took place after the tilt of the basin. Jones (1981) estimated that deformation took place before the Ogallala Formation was deposited, because that unit is undeformed at the location of ERDA-6. Bachman (1980) and Madsen and Raup (1988) are among investigators who interpret angular relationships between various formations of the Ochoan Series, beginning with the Castile-Salado contact. These relationships require tilting of the existing beds to the east, as the angular unconformities are always

placed on the west side of the basin. Tilting of the basin may well have occurred through much of the time when the Ochoan Series was being deposited, as Holt and Powers (1988) present evidence that the depocenter for the Rustler Formation was displaced eastward from the Castile and Salado patterns and overlies part of the Capitan reef on the northeast side of the Delaware Basin. The Delaware Basin appears to have tilted at various times from the late Permian to at least the Cenozoic, and the conditions for deformation may well have existed since the late Permian. Direct evidence of the time of deformation has been difficult to obtain, and tilting of the basin, as a condition for the deformation, appears to have occurred at times beginning in the late Permian. Jones (1981) argues that the structure at ERDA-6 must be, in part, younger than Triassic, because Triassic rocks are also deformed over the deformed evaporites. He further believes that the structure must be older than late Cenozoic, because the Ogallala Formation over part of the structure is undeformed and erosionally truncates the upper part of the Triassic rocks. This may be the most conclusive age relationship demonstrated for any of these related structures. Conventional relationships with beds overlying deformed evaporites, such as that cited by Jones (1981) for the Ogallala, are suspect if the deformation ends or dies out vertically within the evaporites because of the potential for compensating deformation in evaporites (e.g., Borns 1983).

Borns (1983, 1987) reexamined the "state line outcrop," as well as the cores from various boreholes, and concluded that the styles of deformation present in these cores indicate a very complicated history, including episodes of deformation that are probably synsedimentary. The folding may, for example, display disharmonic or opposing styles that would not normally be attributed to a single episode of strain in a pervasive stress field. If all the deformation occurred in response to a single event, such as the tilting of the Delaware Basin, the folds and other strain indicators should all have a common orientation. Isoclinal folding may be very early, while asymmetric folding is often penetrative, indicating later time of origin. Fractures in more brittle units, such as the Castile anhydrites, are often very high angle to vertical and are considered one of the late deformation features in cores. These fractures in the larger anticlinal structures of the DZ are apparently the proximate source of pressurized brines and gases. Borns (1985, 1987) recognized that tilting of the basin, among other possible sources of stress, may have occurred at several different times and is not limited to a single Cenozoic event.

DEF.1.3 Hypotheses of Formation of Deformation in Castile

Several hypotheses have been advanced for the formation of the Castile structures in the DZ and other parts of the Delaware Basin (Borns et al. 1983). The five principal processes hypothesized as causes of the DZ are gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes (Borns et al. 1983). Each of these hypotheses will be briefly summarized, though gravity foundering due to density differences between halite and anhydrite is considered the leading hypothesis (Borns 1987).

Gravity foundering is based on the fact that anhydrite (about 2.9 gm/cc) is much more dense than halite (about 2.15 gm/cc). When anhydrite beds overlie halite, there is considerable potential for the anhydrite to sink and the halite to rise. This potential exists throughout much of the Delaware Basin in the Castile. Mathematical and centrifuge models of similar systems confirm the potential for such deformation and even suggest that the rate of deformation is about 0.02 in./year (0.05 cm/year) (Borns et al. 1983). At such a rate, the DZ could be inferred to develop over about 700,000 years (Borns et al. 1983). The principal difficulty with this hypothesis is that there are large areas of the Delaware Basin that remain undeformed, though the stratigraphy is similar to that within the DZ. The potential for gravity foundering exists over most of the basin, yet only a small part actually manifests such deformation. A special condition, localized higher water content, or an anomalous distribution of water, is hypothesized to explain why deformation is localized despite the pervasive density inversion (Borns et al. 1983). Pressurized brine and gas associated with some of these structures is at least consistent with this explanation.

Halite could potentially be removed from the evaporite section by dissolution and change the form of the evaporites. The density structure could be changed by removing salt near the surface, causing collapse and fill with sediment that is more dense than the removed salt (Anderson and Powers 1978). Borns et al. (1983) reviewed some of the evidence that evaporites were deformed near surficial sinks and concluded that there was certainly some association, but that the pattern of deformation did not match the shallow dissolution. If salt is dissolved from the lower Salado or Castile, then overlying beds should deform in response to the removal of mass. DOE-2 was drilled to test that hypothesis. Recrystallized halite has been offered as evidence of the passage of fluids, but there appears to be no unique relationship between recrystallized halite and deformation. In addition, certain halite sections appear much overthickened, which is clearly not directly due to halite removal. These features generally indicate that the halite can be squeezed and will "move" laterally. The fact that the Rustler shows no discernible overall structural lowering over the DZ (Holt and Powers 1988) suggests that dissolution of the lower Salado or Castile is not the origin of the deformation. The one area in which the Rustler is structurally affected is around ERDA-6, and there it is warped upward as noted by Jones (1981). Borns et al. (1983) do not believe that the Bell Canyon has been a source for brines in the Castile because of the chemistry (Lambert 1978, 1983) and the small volume.

Gravity sliding in the Delaware Basin could be driven by two physical situations: the general eastward dip and the dip off the Capitan Reef and forereef into the basin. In contrast to the gravity foundering mechanism, where movement is dominantly vertical, gravity would result in sliding blocks moving mainly laterally as well as downslope in this mechanism. Some of the deformation is adjacent to the reef (Jones et al. 1973), lending some substance to the hypothesis that the reef-forereef slope and facies changes could cause such sliding. Some deformation is in somewhat isolated portions of the basin (e.g., Poker Lake; Anderson and Powers 1978; Borns and Shaffer 1985), and these structures were originally interpreted to align along the strike of the basin (Anderson and

Powers 1978). Borns and Shaffer (1985) conclude that the data do not uniquely support that interpretation, and these structures may or may not support the concept of gravity sliding within the basin. Borns et al. (1983) also concluded that the timing of the various structures is an important factor in evaluating this hypothesis. As discussed above, neither the age of the various structures, nor the timing of the basin tilt, is well constrained. If tilting of the basin is an important event in forming these structures, the various macro- to microstructures should probably be consistently related. As in gravity foundering, much of the basin area has not reacted to what appears to be widespread similar stresses. Special circumstances, such as an anomalous distribution of water, may be necessary to overcome a threshold for deformation to occur.

In general, as temperature and pressure increase, gypsum dehydrates to form anhydrite and release free water. Borns et al. (1983) discuss the effects this process has on experiments in weakening the anhydrite. Borns et al. (1983) suggest, however, that a major difficulty with this hypothesis is that there should remain relicts of the original gypsum within the sedimentary column and these are not observed. Borns et al. (1983) suggest that mostly anhydrite was deposited in the Castile, and, as a consequence, the dehydration hypothesis has little observable support. More recently, pseudomorphs after gypsum have been recorded in every major anhydrite of the Castile (Harwood and Kendall 1988, personal communication; Hovorka 1988, Personal communication; Powers, unpublished data; Sandia National Laboratories and D'Appolonia Consulting Engineers 1982a). Gypsum certainly has been present in the Castile, though anhydrite cannot be dismissed as a possibly important primary mineral. Delicate forms of original gypsum crystals are sometimes preserved and pseudomorphed by anhydrite or halite. Each requires volume-for-volume replacement, probably through dissolution and crystallizing the replacement mineral. There are no observed fluid escape paths, and the gypsum may have been replaced very early in the sedimentary history. The additional major drawback of this hypothesis is that the process should be pervasive, while the deformation is localized. Special pleading for an additional factor is necessary in this process as in some other hypotheses.

Depositional or syndepositional processes have been invoked for some of the deformation in the Castile Formation. Borns et al. (1983) list four main mechanisms that have been suggested: penecontemporaneous folding, resedimentation, slump blocks off reef margins, and sedimentation on inclined surfaces. Penecontemporaneous folding requires consolidation of the units over relatively short times. Borns et al. (1983) also cite the lack of observed features that indicate the rocks were reexposed. Evaporite units in the Mediterranean contain resedimented material: turbidites, slumping, and mudflows with other clastic sediment. Borns et al. (1983) report that "the units of the WIPP area show little chaotic or clastic structures." They also apply the same argument of Kirkland and Anderson (1970) that the deformed units would have to be consolidated by the time of resedimentation.

In a more recent study of cores from the western part of the Delaware Basin, Robinson and Powers (1987) report a lobate unit of resedimented Castile anhydrite clasts overlying

both the lower anhydrite and halite of the Castile and underlying the second anhydrite. The apparently unconformable contact with both anhydrite I and halite I lies across the extension of the Huapache monocline that appears to have been still active during the time part of the Castile was deposited. Polyclasts within some beds of this unit demonstrate that the original anhydrite was partially consolidated and that a unit of clasts was also at least partially consolidated to provide the polyclasts. These units were consolidated early between the time halite I was deposited and anhydrite II began to be deposited.

In the rest of the basin, there is no apparent interval between the end of halite and beginning of the anhydrite deposition. The relationship clearly indicates that the western margin was an area of sulfate clast formation, deposition, and lithification over a very short interval of geologic time. Hovorka (1988, personal communication) indicates that similar clastic deposits occur in cores from nearer the eastern margin of the Delaware Basin. Snider (1966) proposed much earlier that sedimentation caused anomalous thickness of Castile units near the basin margin, and Billo (1986) presented a similar conclusion. Neither reported any textural evidence to support their conclusions.

Clearly, Castile rock has been resedimented, but in the area where textural data are available, only modest deformation appears to be present (Robinson and Powers 1987). At this time, there is little to suggest that such sedimentation resulted in the deformation in the DZ. There is also no direct evidence from the WIPP area that suggests slump blocks off the reef margin moved into the area, causing deformation. The high inferred slopes of some of these structures argues strongly against sedimentation on inclined surfaces (Borns et al. 1983).

The concept that deformation was syndepositional or penecontemporaneous with deposition appears mainly to be driven by the fact that deformation decreases upward through successive units. Normal geologic reasoning would support penecontemporaneous deformation, but does not take into account the rather plastic behavior of halite, allowing flow over high areas to move halite into low areas. Overlying units, such as the Rustler, are made of much less plastic material and do not respond as the Salado does. The deformation appears to be compensated in overlying units through deposition.

Overall, both gravity-driven mechanisms require some special additional conditions restricting deformation to small areas though most of the basin appears to be equally susceptible. Dissolution permits a more localized effect, but there does not appear to be an overall loss of mass in these areas and the chemistry of the fluids and hydrology of the units do not readily support the concept. Most of the syndepositional processes have no evidence to support them in the area of the DZ. Currently, the most favored hypothesis is gravity foundering, with a yet undetected anomalous distribution of fluid lowering the viscosity of halite locally to permit deformation.

DEF.1.4 Timing of Deformation

Most of the arguments about timing of deformation have already been discussed. Standard geologic arguments about relative timing, based on involvement of the overlying units, is unlikely to hold for the evaporite units. Jones (1981) notes that uplifted and arched Triassic rocks near the ERDA-6 borehole are truncated by the flat-lying, undeformed Pliocene Ogallala Formation. He interpreted this as an indication that salt movement was complete before deposition of the Ogallala. However, he does not explain either how the Triassic structure relates to the deeper DZ or how it is distinguished from near-surface dissolution effects (Borns et al. 1983). Castile rocks may have been deformed during any time period from Permian to the present. More to the point, for some hypotheses, the general conditions thought necessary to deform the Castile and Salado are still present, and mechanisms, such as gravity foundering, are potentially active (Borns et al. 1983).

An additional piece of data is relevant. Brines from ERDA-6 and WIPP-12 were analyzed, and the brines were calculated to have moved last about 800,000 years ago (Lambert and Carter 1984; Barr et al. 1979). One set of reasonable assumptions about brine chemistry and interactions with the rock leads to calculated residence times of about 25,000 to 50,000 years for these brines. This may relate to the last time that deformation was active on this structure, though it is not uniquely an indicator of deformation. The interaction between rock and water may have been strictly hydrologically driven, and may not require deformation at that time.

The second point of interest is that some modeling calculations indicate, as stated above, that the kinds of structures observed in the DZ may require periods on the order of 700,000 years to form. This calculation gives no indication of when the structures formed, but it is relevant to timing and assessing how these structures might affect the WIPP.

DEF.1.5 Importance to the WIPP

The structures interpreted from core retrieved from WIPP-12 and ERDA-6 serve as possible analogs to effects of deformation on the WIPP. The DOE and EEG have analyzed the effects of brine and structure at WIPP-12 and the southern portion of the site and concluded the geologic conditions represent no threat to health and safety (see Section DEF.1.1). In addition, both boreholes encountered brine only within the anhydrite units, and that is the experience of all other encounters of these larger brine inflows (Popielak et al. 1983). Anhydrite supports the fractures that provide porosity for the brine, and the anhydrite/halite units form an effective seal, as the pressurized brines and gas did not escape upward. The principal concern for isolation would be that the deformation, and its associated phenomena, such as pressurized brine and gas, could cause breaching of the repository and provide or make a pathway for the escape of the waste constituents. The period of time expected for development of the structure (700,000 years) is well beyond periods of regulatory concern. In addition, the evidence of

the pressurized brine and gas occurrences is that they are confined to these Castile anhydrite layers and do not breach the lower Salado to reach the stratigraphic level of the repository. There is nothing at present to indicate that these features will form in the time period of concern or that they can directly cause a breach of the repository.

DEF.2.0 SALADO PENETRATIONS

Within the 16-mi^2 (41-km^2) WIPP Site Boundary, 36 boreholes have been identified as penetrating into the Salado Formation (Figure DEF-4; Table DEF-2.1). Thirty of these boreholes terminate near the top of the Salado; the remaining six boreholes were completed through the Salado to deeper formations. These boreholes have either been plugged and abandoned, or recompleted for use as hydrologic monitoring wells.

The six wells that penetrate through the Salado are two exploration wells and four drilled in support of the WIPP. Two hydrocarbon exploration wells, Clayton Williams #1 Badger Unit and Michael Grace #1 Cotton Baby, were drilled within the WIPP Site Boundary. The location of these wells is shown on Figure DEF-4, and the construction information is provided in Table DEF-2.1. These wells did not produce economical quantities of hydrocarbons and were plugged and abandoned in accordance with the State of New Mexico plugging criteria. The four additional deep boreholes, WIPP-12, WIPP-13, DOE-1, and ERDA-9, were drilled as stratigraphic holes for geologic site characterization (Figure DEF-4; Table DEF-2.1). These four boreholes have been recompleted and are currently used for hydrologic testing and sampling.

Most of the 30 boreholes completed near the top of the Salado Formation were drilled in support of the WIPP. Seven of the boreholes (designated with an "H " prefix on Figure DEF-4) were drilled to just below the Rustler/Salado Formation contact and were completed as hydrologic exploration wells. These wells were completed with the section in the Salado Formation either left as an open hole or, in some cases, a cement plug was installed to prevent mixing of groundwater between the Rustler and Salado Formations. Five boreholes were drilled within the boundary to characterize the site stratigraphy. Four of these boreholes (WIPP-18, WIPP-19, WIPP-21, and WIPP-22) were subsequently recompleted for hydrological testing and sampling purposes and are currently in use. The remaining stratigraphic borehole, B-25, was drilled as part of the geotechnical foundation analysis program. This borehole was plugged, as described in Table DEF-2.1. Industry potash and WIPP potash assessment boreholes (designated as "D," "I," or "P," respectively, in Figure DEF-4) were drilled within the site boundary. These boreholes were plugged with cement and abandoned, except for borehole P-15. This borehole was plugged as described in Table DEF-2.1 and recompleted as a hydrologic test well.

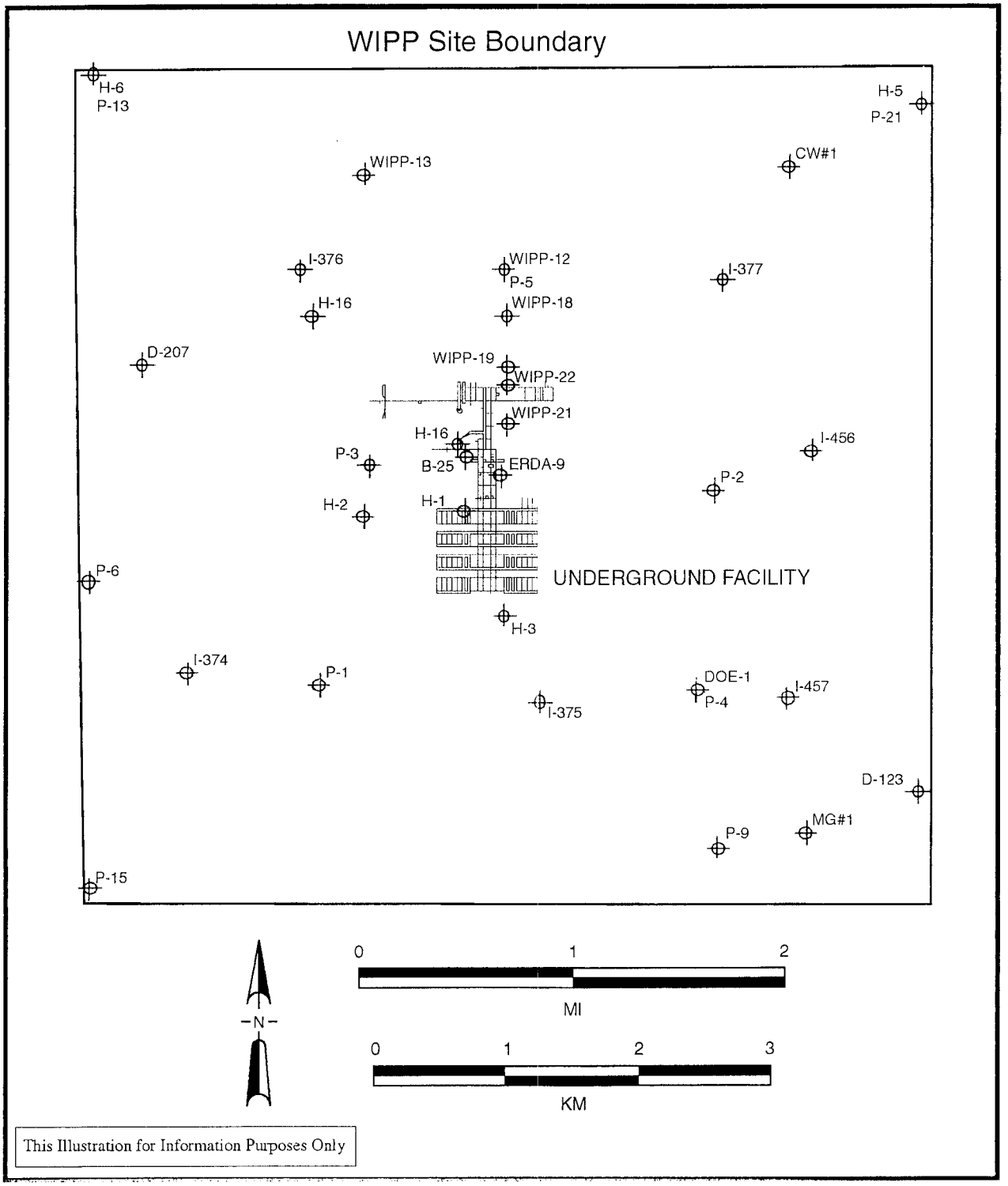

Figure DEF-4. Salado Drillhole Locations within WIPP Site Boundary

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Table DEF-2.1. Information for Boreholes Within the 16-Mi^2 WIPP Boundary

Borehole No.	Location T/R/SEC.	Completion Date	Total Depth (ft)	Purpose	Comments
B-25	22S/31E/20	2/13/79	902	Stratigraphy	Plugged and abandoned; cement plug from 902' to 461', sand from 461' to 5', cement plug from 5' to surface
CW#1	22S/31E/15	9/13/93	15,225	Hydrocarbon Explor.	Plugged and abandoned, 9/17/93
Cotton Baby	22S/31E/34	6/16/75	6,700	Hydrocarbon Explor.	Plugged and abandoned, 12/22/75
DOE-1	22S/31E/28	7/28/82	4,057	Stratigraphy	Converted to hydrologic monitoring
D-123	22S/31E/34	--	1,880	Potash Exploration	Plugged and abandoned
D-207	22S/31E/19	--	1,613	Potash Exploration	Plugged and abandoned
ERDA-9	22S/31E/20	6/26/76	2,875	Geo. Exploration	Converted to hydrologic monitoring
H-1	22S/31E/29	6/10/76	856	Hydro. Exploration	7" OD casing to 848', cement plug to 831'
H-2c	22S/31E/29	2/5/77	795	Hydro. Exploration	6-5/8" OD casing to 742', open hole to TD
H-3B1	22S/31E/29	8/12/76	902	Hydro. Exploration	6-5/8" OD casing to 891', cement plug to 864'

OD - Outer Diameter
TD - Total Depth

Table DEF-2.1. Information for Boreholes Within the 16-Mi^2 WIPP Boundary (continued).

Borehole No.	Location T/R/SEC.	Completion Date	Total Depth (ft)	Purpose	Comments
H-5c	22S/31E/15	6/3/78	1,076	Hydro. Exploration	5-1/2" OD casing to 1,024, open hole to TD
H-6c	22S/31E/18	6/26/78	741	Hydro. Exploration	5-1/2" OD casing to 699', open hole to TD
H-16	22S/31E/20	8/-/87	851	Hydro. Exploration	7" OD casing to 469', open hole to TD
H-18	22S/31E/20	10/-/87	831	Hydro. Exploration	7" OD casing to 673', cement plug to 766'
I-374	22S/31E/30	--	1,538	Potash Exploration	Plugged and abandoned
I-375	22S/31E/33	--	1,746	Potash Exploration	Plugged and abandoned
I-376	22S/31E/20	--	1,702	Potash Exploration	Plugged and abandoned
I-377	22S/31E/22	--	1,876	Potash Exploration	Plugged and abandoned
I-456	22S/31E/27	--	1,975	Potash Exploration	Plugged and abandoned
I-457	22S/31E/27	--	1,885	Potash Exploration	Plugged and abandoned

OD - Outer Diameter
TD - Total Depth

Table DEF-2.1. Information for Boreholes Within the 16-Mi^2 WIPP Boundary (continued).

Borehole No.	Location T/R/SEC.	Completion Date	Total Depth (ft)	Purpose	Comments
P-1	22S/31E/29	9/2/76	1,591	Potash Exploration	Plugged and abandoned; 4-1/2" OD casing from 591' to 974', plugged with cement
P-3	22S/31E/20	9/7/76	1,676	Potash Exploration	Plugged and abandoned; 4-1/2" OD casing from 490' to 826', plugged with cement
P-4	22S/31E/28	9/4/76	1,857	Potash Exploration	Plugged and abandoned; recovered all casing, plugged with cement
P-5	22S/31E/17	9/21/76	1,830	Potash Exploration	Plugged and abandoned; 4-1/2" OD casing from 435' to 1,003', plugged with cement
P-6	22S/31E/30	9/16/76	1,573	Potash Exploration	Plugged and abandoned; recovered all casing, plugged with cement
P-9	22S/31E/33	9/25/76	1,796	Potash Exploration	Plugged and abandoned; recovered all casing, plugged with cement
P-13	22S/31E/18	9/23/76	1,576	Potash Exploration	Plugged and abandoned; recovered all casing, plugged with cement

OD - Outer Diameter
TD - Total Depth

Table DEF-2.1. Information for Boreholes Within 16-Mi^2 WIPP Boundary (continued).

Borehole No.	Location T/R/SEC.	Completion Date	Total Depth (ft)	Purpose	Comments
P-15	22S/31E/18	10/15/76	1,465	Potash Exploration	Converted to hydrologic monitoring, cement plug from 1465 to 620 ft
P-21	22S/31E/15	10/26/76	1,915	Potash Exploration	Plugged and abandoned; recovered all casing, plugged with cement
WIPP-12	22S/31E/17	12/7/78	3,928	Geo. Exploration	9-5/8" OD casing to 1,001'; cement plug to 2,784'; converted to hydrologic monitoring
WIPP-13	22S/31E/17	8/6/78	3,856	Geo. Exploration	9-5/8" OD casing to 1,023'; open hole to TD, converted to hydrologic monitoring
WIPP-18	22S/31E/20	4/3/78	1,060	Stratigraphy	5-1/2" OD casing to 1,050'; cement plug to 1,050'; converted to hydrologic monitoring
WIPP-19	22S/31E/20	5/8/78	1,040	Stratigraphy	5-1/2" OD casing to 1,035'; cement plug to 1,035'; converted to hydrologic monitoring
WIPP-21	22S/31E/20	5/27/78	1,045	Stratigraphy	5-1/2" OD casing to 1,014'; cement plug to 1,014'; converted to hydrologic monitoring
WIPP-22	22S/31E/20	5/24/78	1,452	Stratigraphy	5-1/2" OD casing to 950'; cement plug to 941'; converted to hydrologic monitoring

OD - Outer Diameter
TD - Total Depth

N

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APPENDIX DIF

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APPENDIX D12

TRANSPORT CHARACTERISTICS ACROSS DRUM FILTER VENTS AND POLYMER BAGS

(From the WIPP RCRA Part B Permit Application, Rev. 6)

EGG-WM-11454

Transport Characteristics Across Drum Filter Vents and Polymer Bags

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ABSTRACT

The rate at which hydrogen (H_2) or a volatile organic compound (VOC) exits a layer of confinement in a vented waste drum is proportional to the concentration difference across the layer. The proportionality constant is the gas transport characteristic. A series of transport experiments were conducted to determine H_2 and VOC transport characteristics across different drum filter vents and polymer bags. This report reviews the methods and results of past investigators in defining transport characteristics across filter vents and polymer bags, describes the apparatus and procedures used in these experiments, compares the reported and estimated transport characteristics with earlier results, and discusses the impact of changing the transport characteristic values used in model calculations.

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SUMMARY

This report reviews the methods and results of past investigators in defining hydrogen (H_2) and volatile organic compound (VOC) transport characteristics across drum filter vents and polymer bags, describes the apparatus and procedures used in experiments performed at the Idaho National Engineering Laboratory (INEL) to quantify transport characteristics across drum filter vents and polymer bags, compares the reported and estimated transport characteristics with earlier results, and discusses the impact of changing transport characteristic values in model calculations.

A review of experiments conducted to measure H_2 and VOC diffusion characteristics across drum filter vents identified a wide variety of test vessel designs. In most cases, insufficient care was taken to minimize concentration gradient formation inside the test vessel. A series of filter vent diffusion tests were conducted at the INEL using a test vessel specifically designed to ensure that the assumption of uniform gas concentration in the test volume was valid. A cylindrical stainless steel vessel with a flat lid and base was designed to have a drum filter vent screwed in the center of the top lid. Separate side ports allowed for the introduction of gas and the sample collection with a gas-tight syringe. Because of variations in the filter housing assemblies, two different test vessels with internal volume between 55 and 60 cm^3 were constructed. The H_2 and VOC diffusion characteristics of NFT-012, NFT-013, and NFT-020 drum filter vents were determined. Pure hydrogen gas was used in the H_2 diffusion characteristic experiments. Two different gas mixtures—each containing 5 VOCs—were used in the VOC diffusion characteristic measurements. Each VOC concentration was between about 100 and 1,000 ppm. The gas mixture was introduced into a test vessel at a rate of 1,000 $cm^3\ min^{-1}$ for one minute to purge the vessel. Samples were withdrawn by gas syringe at regular time intervals and injected into a gas chromatograph to determine gas concentrations.

Multivariable two-level experiments with one replicate were designed to investigate the effect of bag closure type on H_2 and VOC transport from small polymer bags. Polyethylene and polyvinyl chloride (PVC) bags with heat-sealed or taped closures were prepared. In preparing the bags with taped closures, an effort was made to ensure that the surface area was the same as for the heat-sealed bags. Trichloroethylene (TCE) and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113) were used in the experiments.

Filter vent diffusion test results confirmed that test vessel configuration affects the calculated gas diffusion characteristic. Hydrogen diffusion characteristics calculated from experimental data using the INEL test vessels were about 10 to 25% greater than the highest previously reported values. In the TRUPACT-II safety analysis report (SAR), a hydrogen diffusion characteristic of 19×10^{-7} mol s^{-1} was used to calculate the maximum allowable decay heat limit per innermost layer of confinement. This value was the lowest value determined across six NFT-012 drum filter vents. However, NFT-012 drum filter vents are no longer used in the transportation of vented waste drums. The NFT-013 and NFT-020 drum filter vents are currently used in waste drum transshipment. The lowest H_2 diffusion characteristic measured for these drum filter vents using the INEL test vessels was 41×10^{-7} mol s^{-1}. The use of a H_2 diffusion characteristic of a different drum filter vent will have a far more significant impact on model results than higher values resulting from improved test vessel design and experimental procedure. A larger H_2 diffusion characteristic would result in a higher minimum allowable decay heat limit.

Results from unsteady-state experiments indicated that the H_2 transport characteristic for polymer bags with a taped closure was not significantly greater than for similar bags with no taped closure. Tests on PVC bags with a surface area between 2,000 and 3,000 cm^2 and bag thickness between 2.8 and 3.0 x 10^{-2} cm (11—12 mil) show that the H_2 transport from bags with a taped closure was only 20 to 30% greater than from heat-sealed bags. The relative percentage increase in the H_2 transport characteristic for bags with a taped closure compared to similar heat-sealed bags will decrease further with increasing bag surface area or decreasing bag thickness. Tests on polyethylene bags with a surface area of 2,000 cm^2 and bag thickness of 7.6 x 10^{-3} cm (3 mil) showed no difference at all in the H_2 transport characteristic for bags with different types of closure. Under these conditions, H_2 transport from small polymer bags was not significantly affected by the type of bag closure. This means that most small bags placed in vented waste drums could have either a taped closure or heat seal without significantly affecting H_2 transport from the bags. It was similarly concluded that gas transport from polymer bags containing TCE or Freon-113 in actual waste drums would not be significantly affected by bag closure type.

In model calculations in the TRUPACT-II SAR of the maximum allowable decay heat limit per layer of confinement, a H_2 transport characteristic of 5.60 x 10^{-7} mol s^{-1} had been used to estimate gas transport from a polymer bag with a taped closure. This value reported in the TRUPACT-II SAR was the difference of two H_2 transport characteristics measured across PVC bags with and without taped closures. Review of the original data indicates that the transport characteristic for at least one bag was not measured under steady-state conditions, as assumed. In addition, two unsteady-state experiments demonstrated that total H_2 transport across a small PVC bag with a taped closure is not significantly greater than a similarly sized PVC bag with no taped closure. The maximum allowable decay heat limit should have been calculated using the H_2 permeation characteristic reported in the TRUPACT-II SAR for a heat-sealed PVC bag which was 4.94 x 10^{-7} mol s^{-1}. This transport characteristic is 12% less than the value used in original calculations and would result in a slightly lower calculated decay heat limit, all other variables remaining the same. The average H_2 permeation characteristic across heat-sealed PVC bags measured in the INEL transport experiments was 2.04 x 10^{-7} mol s^{-1} and was less than the transport characteristic reported in the TRUPACT-II SAR because of smaller bag surface area.

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The VOC diffusion characteristic across a filter vent is used in the Waste Isolation Pilot Plant (WIPP) no-migration determination (NMD) variance petition to estimate the rate of VOC emissions from a vented drum. The diffusion characteristics for carbon tetrachloride and 1,1,1-trichloroethane across different drum filter vent types listed in the WIPP NMD variance petition were on the order of 10^{-11} mol s^{-1}. The explanation offered for the lower than expected VOC transport characteristics was a complex combination of Fickian and surface diffusion. A more likely explanation is that the experimental set-up resulted in significant concentration gradient across the test vessel volume. Several transport experiments, including one performed at the INEL, measured VOC diffusion characteristics on the order of 10^{-7} mol s^{-1}. This is approximately four orders of magnitude greater and significantly affects the calculation of the total anticipated VOC emissions from vented waste drums at the WIPP facility.

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ACRONYMS AND ABREVIATIONS

Freon-113	1,1,2-trichloro-1,2,2-trifluoroethane
GC	gas chromatograph
H_2	hydrogen
INEL	Idaho National Engineering Laboratory
NFT	Nuclear Filter Technology
NMD	no-migration determination
RFP	Rocky Flats Plant
SRP	Savannah River Plant
STP	standard temperature and pressure
TCA	trichloroethane
TCE	trichloroethylene
SAR	safety analysis report
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant

Transport Characteristics Across Drum Filter Vents and Polymer Bags

1. INTRODUCTION

The rate at which hydrogen (H_2) or a volatile organic compound (VOC) exits a layer of confinement in a vented waste drum is proportional to the concentration difference across the layer. The proportionality constant is the gas transport characteristic. Gas permeates through polymer bags or diffuses through openings in the layer boundary. The gas transport characteristic is the product of the gas transport property, such as permeability or diffusivity, and surface area divided by a characteristic length. Knowledge of the H_2 transport characteristics across drum filter vents and polymer bags was used in the safety analysis report for the TRUPACT-II Shipping Package (TRUPACT-II SAR) to calculate the maximum allowable decay heat limit per innermost confinement layer to ensure that the hydrogen concentration in payload materials does not exceed 5% by volume.[1] Knowledge of VOC transport characteristics is important in estimating VOC emission rates from vented waste drums[2] and VOC concentrations in the void volumes of a waste drum.[3,4]

Several investigators have measured H_2 and VOC transport characteristics across filter vents and polymer bags. All drum filter vent diffusion experiments used test vessels with different volumes and dimensions. Different experiments investigating H_2 transport from sealed polymer bags reached opposite conclusions whether gas transport across a taped closure was significantly greater than across a heat-sealed closure. The differences in reported values resulting from variations in test apparatus and procedures raise questions as to which values should be used in calculations concerning decay heat limits, total emissions rate, and other health and safety issues. A series of experiments was conducted at the Idaho National Engineering Laboratory (INEL) to measure H_2 and VOC transport characteristics across drum filter vents and polymer bags. The experiments were designed to address past discrepancies in the test vessel configuration and test procedures.

This report reviews the methods and results of past investigators in defining transport characteristics across filter vents and polymer bags, describes the apparatus and procedures used in a new set of transport experiments, compares the reported and estimated transport characteristics with earlier results, and discusses the impact of changing the transport characteristic values in model calculations. First, mathematical definitions of the transport characteristics are presented. Second, transport characteristics reported in earlier studies are reviewed with particular attention given to the experimental apparatus and procedures used. The report then describes experimental apparatus and test procedures used in the most recent INEL transport experiments to determine H_2 and VOC transport characteristics across different filter vents and polymers. Experimental test apparatus, procedures, and results from these experiments are compared with those described in earlier experiments. In addition, methods of estimating VOC diffusion characteristic across filter vents are examined. Finally, the implications of using these new H_2 and VOC transport characteristics in model calculations related to health and safety issues are discussed.

2. TRANSPORT CHARACTERISTICS

The primary mechanisms for gas transport from the void volume inside a layer of confinement with a polymer boundary are permeation across the polymer, diffusion across an opening in the boundary, and gas accumulation in the boundary as the result of the gas solubility in the polymer. The total unsteady-state gas transport rate is defined by summing the contribution of each transport mechanism

$$V c \frac{d(\Delta y_p)}{dt} = -\left(\frac{\phi \rho A_p P}{x_p} + \frac{D A_d}{x_d}\right) c \, \Delta y_p - V_p \frac{ds}{dt} \qquad (1)$$

where

V = void volume confined by polymer, cm^3

c = total gas concentration, mol cm^{-3}

Δy_p = gas mole fraction difference across polymer

t = time, s

ϕ = 76 T/(273.15 P)

T = temperature, K

P = pressure, cm Hg

ρ = gas permeability coefficient, cm^3 (STP) cm cm^{-2} (cm Hg)$^{-1}$ s^{-1}

A_p = polymer surface area across which VOC permeates, cm^2

x_p = polymer thickness, cm

D = gas diffusivity in air, cm^2 s^{-1}

A_d = cross-sectional area of opening across polymer boundary, cm^2

x_d = diffusional length across opening, cm

V_p = volume of polymer boundary, cm^3 polymer

s = gas concentration in polymer, cm^3 gas cm^{-3} polymer.

In the case where the gas concentration in the polymer has reached a near-constant value, the gas transport rate is the sum of the transport rates via permeation and diffusion

$$Vc\,\frac{d(\Delta y_p)}{dt} = -\left(\frac{\phi \wp A_p P}{x_p} + \frac{DA_d}{x_d}\right) c\,\Delta y_p \quad . \tag{2}$$

The total gas concentration is defined by the ideal gas law

$$c = \frac{P}{RT} \tag{3}$$

where R is the gas constant and equals 6236.6 cm^3 (cm Hg) mol^{-1} K^{-1}. Combining Equations (2) and (3) yields

$$Vc\,\frac{d(\Delta y_p)}{dt} = -(K_p + K_d)\,\Delta y_p \tag{4}$$

where

K_p = permeation characteristic, $4.46 \times 10^{-5}\ \phi \wp A_p P\ x_p^{-1}$, mol s^{-1}

K_d = diffusion characteristic, $DA_d P\ (RTx_d)^{-1}$, mol s^{-1}.

Solving Equation (4), the gas mole fraction difference is a function of time

$$\ln\left(\frac{\Delta y_p}{\Delta y_{p,0}}\right) = -\frac{(K_p + K_d)}{Vc}\,(t - t_0) \quad . \tag{5}$$

Plotting $\ln(\Delta y_p/\Delta y_{p,0})$ versus $(t-t_0)$ yields a straight line with a slope defined by Equation (5).

The unsteady-state rate of gas transport across a filter vent is defined as

$$Vc\,\frac{d(\Delta y_f)}{dt} = -D^* \Delta y_f \tag{6}$$

where

D^* = gas filter vent diffusion characteristic, mol s^{-1}

Δy_f = gas mole fraction difference across filter vent.

In the case of steady-state transport, the gas transport rates across all layers of confinement, including the filter vent, are equal to a constant rate r

$$r = (K_p + K_d)\,\Delta y_p = D^* \Delta y_f \quad . \tag{7}$$

3. PREVIOUS TRANSPORT CHARACTERISTIC MEASUREMENTS

This section summarizes the reported transport characteristics across drum filter vents and polymer bags from earlier investigations. Discussion is focused on the experimental apparatus and test procedures that may have affected the calculated transport characteristics.

3.1 Drum Filter Vents

Hydrogen or VOC diffusion characteristics across different filter vent types have been reported by a number of investigators. Three filter vent types studied, which contained a carbon-composite filter, were manufactured by Nuclear Filter Technology. Filter vent NFT-012, shown in Figure 1, was initially used at the Rocky Flats Plant (RFP). Filter vent NFT-013, shown in Figure 2, is now used at the RFP and the Savannah River Plant (SRP) in waste drums prepared for transshipment. The NFT-013 filter vent is an adaptation of the NFT-012; the NFT-013 has larger openings in the bottom and top of the filter housing assembly. The changes in the filter assembly were designed to increase the overall hydrogen diffusion characteristic across the filter vent. The NFT-020 filter vent, shown in Figure 3, is used at the INEL.

Peterson[a] determined hydrogen diffusion characteristics across carbon-composite filter vents identified as the types used at the RFP, the INEL, and the SRP. A schematic of the test vessel used to perform the diffusion experiments is shown in Figure 4. The test vessel volume was approximately 75 cm^3. An adapter connecting the filter vent to the test vessel probably resulted in the development of a concentration gradient within the vessel. Peterson did not identify the types of filter vents other than by the site where they were used. This author believes that the RFP and INEL filters were NFT-012 and NFT-020, respectively. The SRP filter vents tested are not thought to be NFT-013 filter vents because of NFT-013 filter vent was not being made at the date of the tests. Experimental results yielded H_2 diffusion characteristics across the NFT-012 and NFT-020 filter vents of $(23 \pm 2) \times 10^{-7}$ mol s^{-1} and $(39 \pm 10) \times 10^{-7}$ mol s^{-1}, respectively.

The Waste Isolation Pilot Plant (WIPP) no-migration determination (NMD) variance petition[2] reported diffusion characteristics for carbon tetrachloride and 1,1,1-trichloroethane (TCA) across NFT filters on the order of 10^{-11} mol s^{-1}. These values were approximately four orders of magnitude lower than values estimated using kinetic gas theory for ordinary diffusion. In a study by Peterson and Marshall,[b] VOC diffusion characteristics on the order of 10^{-7} were reported. The test vessel used in their VOC diffusion experiments, shown in Figure 5, had a internal volume of 60 cm^3 abd attempted to minimize the potential for concentration gradients in the system. The VOC diffused through the filter into another 60-cm^3 vessel with its lid removed. Peterson and Marshall assumed that this vessel configuration allowed sufficient convection to maintain the gas concentration immediately outside the filter at zero. They determined that the test vessel and gas sampling configuration in the earlier VOC diffusion study, shown in Figure 6, resulted in significant concentration gradients across the system. The average H_2 diffusion

a. Unpublished research results of determination of hydrogen diffusion characteristics across different filter types; S. H. Peterson, Westinghouse R&D Center, (July 1988).

b. Unpublished research results of VOC diffusion characteristics measurements across carbon-composite filters; S. H. Peterson and G. R. Marshall, Westinghouse R&D Center (October 1990).

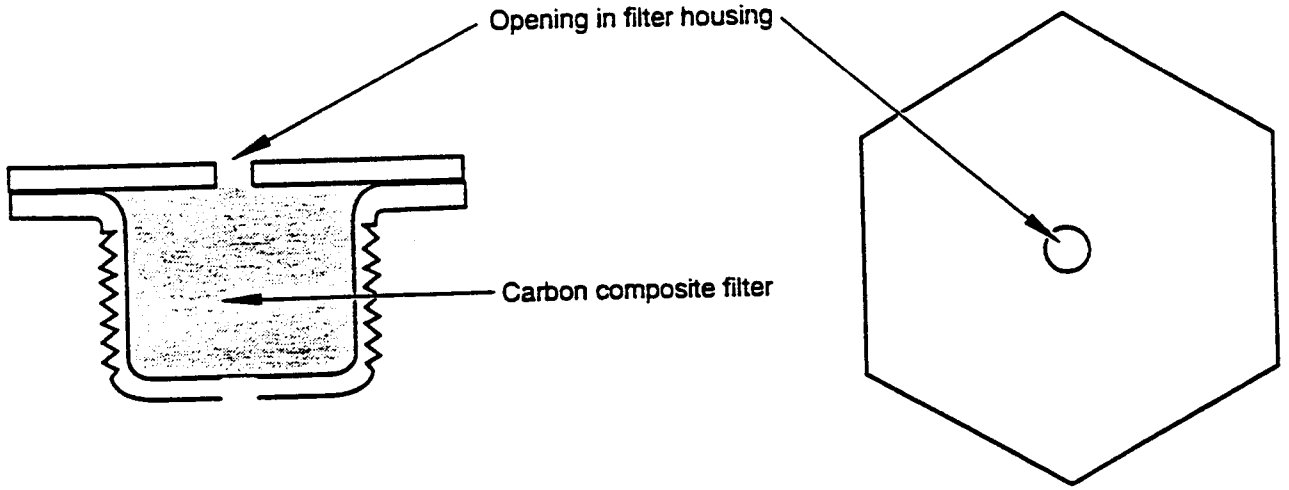

Figure 1. Schematic of NFT-012 filter vent (a) cross-section; (b) top.

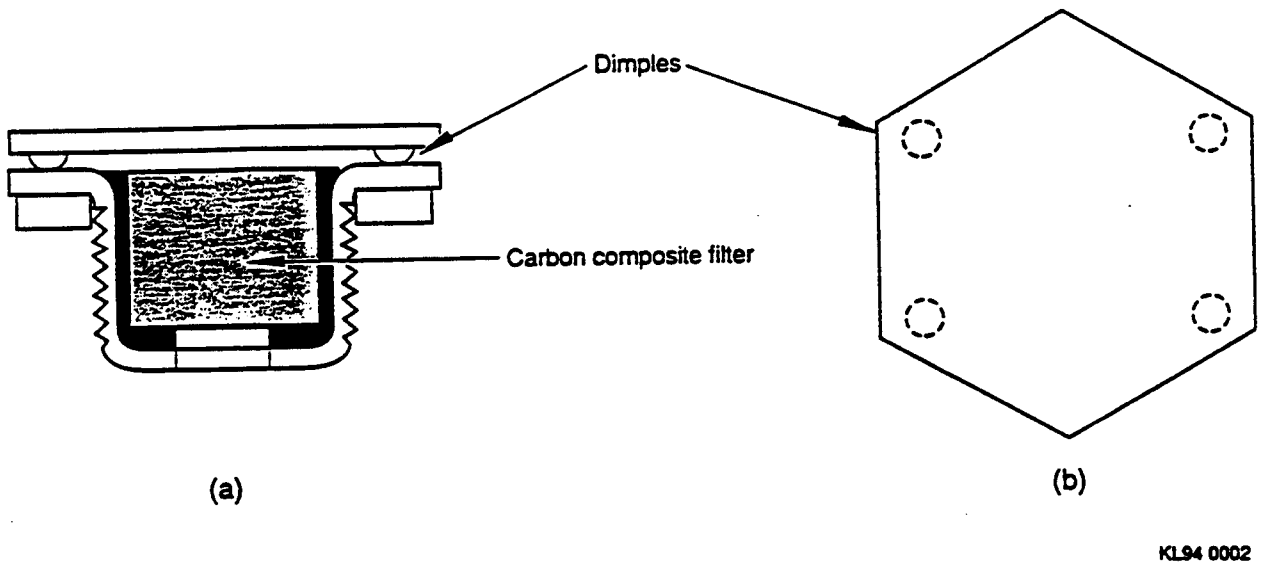

Figure 2. Schematic of NFT-013 filter vent (a) cross-section; (b) top.

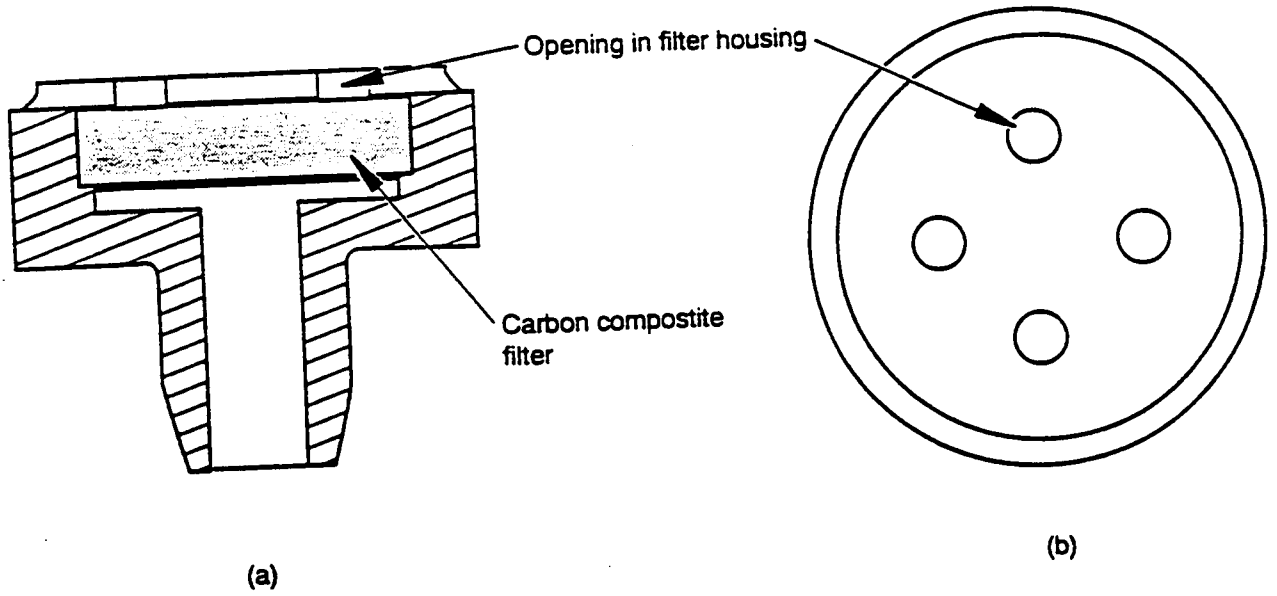

Figure 3. Schematic of NFT-020 filter vent (a) cross-section; (b) top.

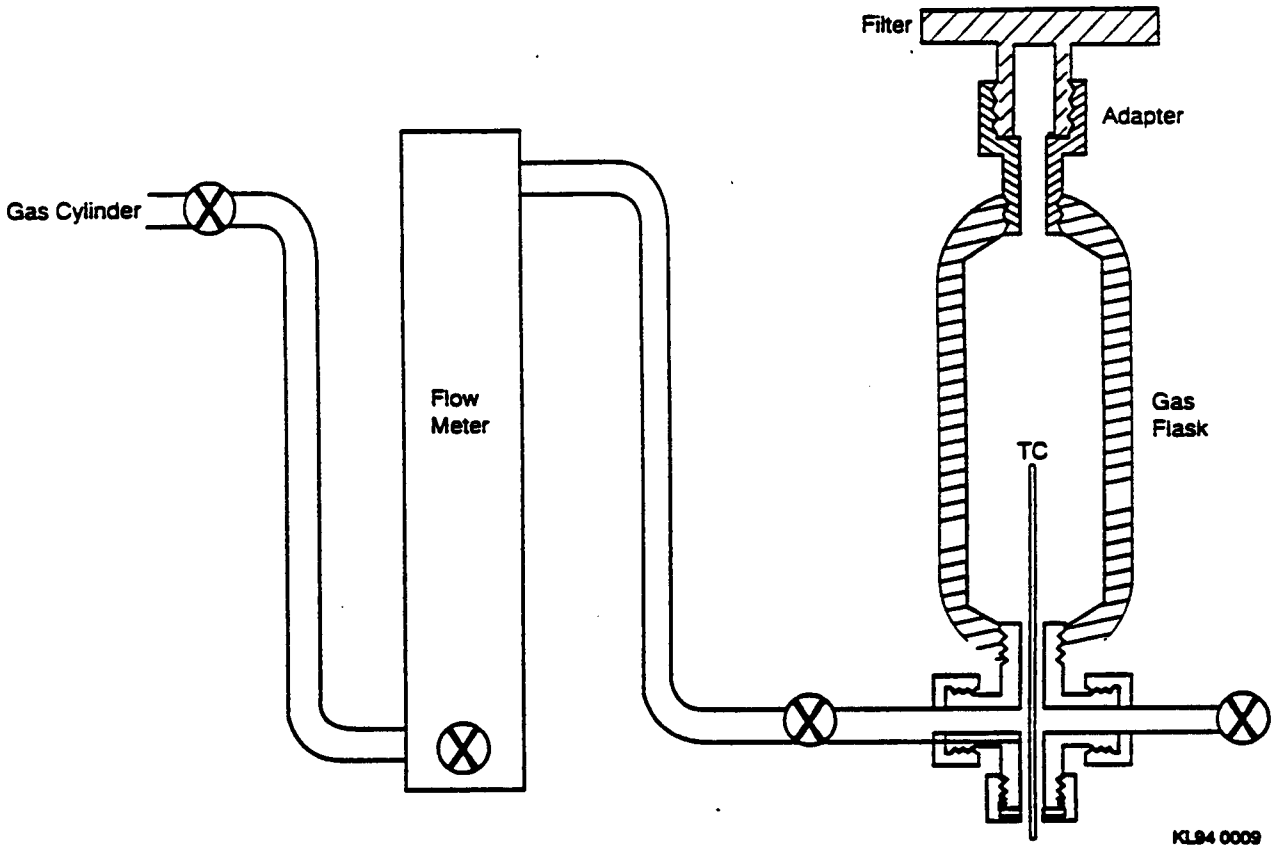

Figure 4. Schematic of experimental set-up used at Westinghouse to determine hydrogen diffusion characteristic across NFT filter vents (from unpublished research results of S. H. Peterson, Westinghouse R&D Center, July 1988).

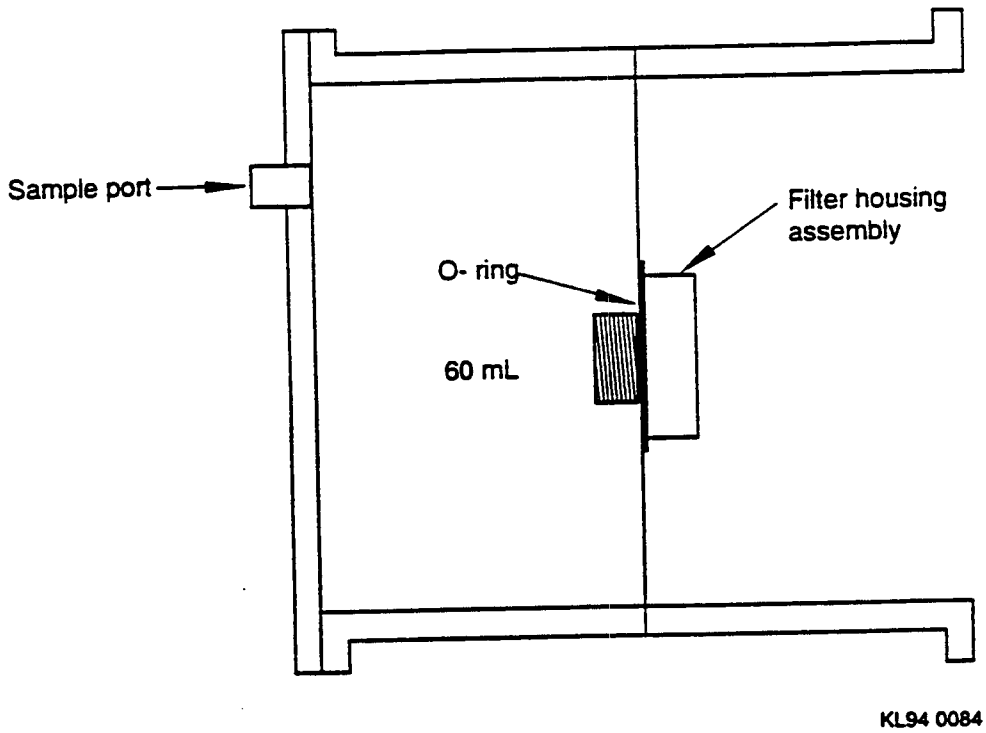

Figure 5. Schematic of experimental test vessel used at Westinghouse to determine VOC diffusion characteristics across NFT filter vents (from unpublished research result of S. H. Peterson and G. R. Marshall, Westinghouse R&D Center, October 1990).

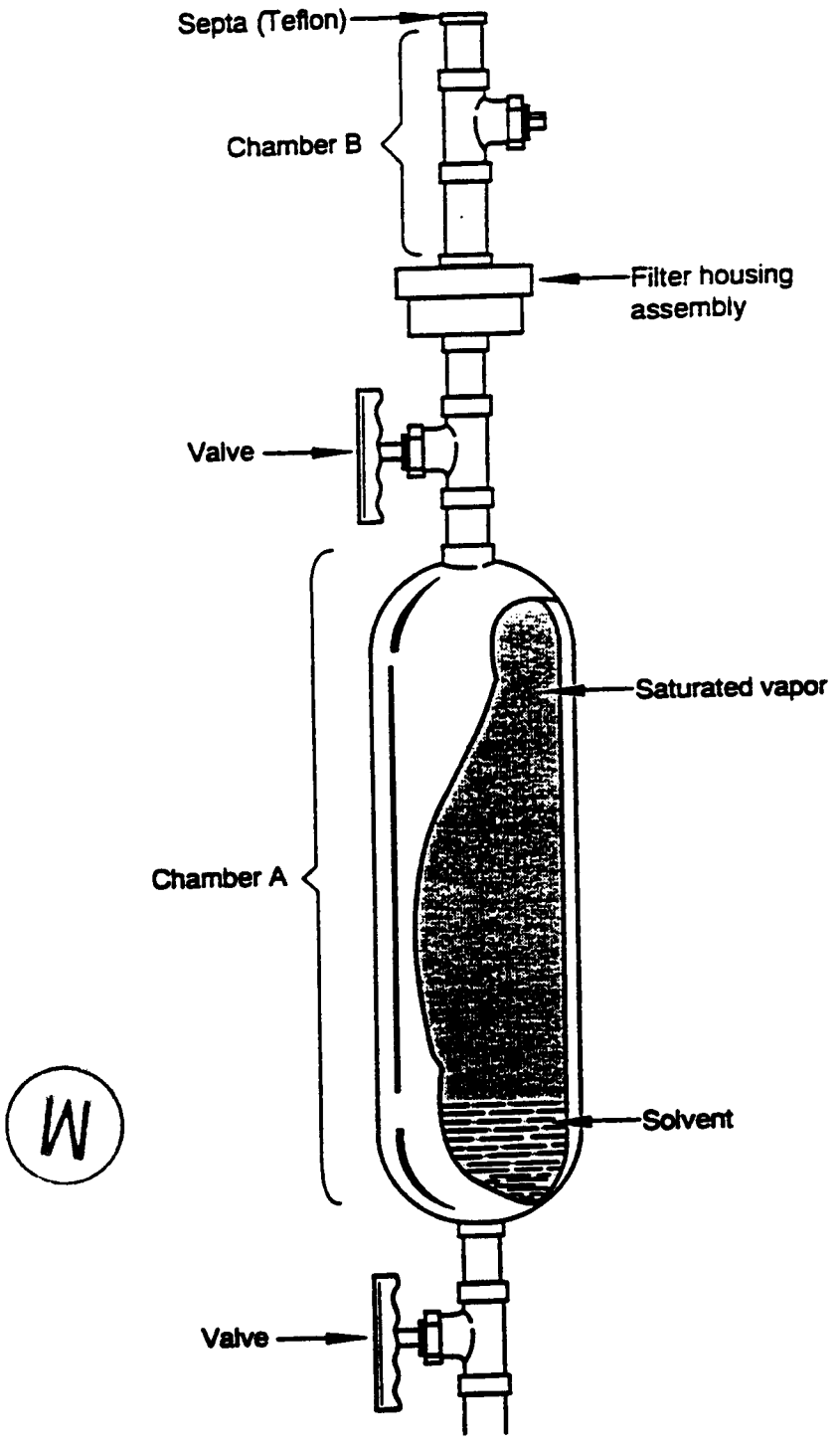

Figure 6. Schematic of experimental set-up used to determine VOC diffusion characteristics reported in the WIPP NMD variance petition.[2]

characteristic for NFT-013 filter vents was determined to be 74 x 10^{-7} mol s^{-1} using a different test vessel shown in Figure 7. The test vessel had a volume of 110 cm^3 with an approximate length of 20 cm and diameter of 3 cm. In addition, the filter vent was attached using an adapter that probably resulted in a concentration gradient across the gas chamber.

Another set of diffusion experiments was performed across NFT-013 filter vents.[c] The experimental equipment consisted of a 4.33-L container inside a larger vessel with a volume of 47.3 L. A H_2 gas mixture was introduced inside the smaller vessel. The H_2 concentration was measured inside each vessel. Hydrogen diffused across the filter vent located on the smaller vessel. Data from these experiments were used to calculate H_2 diffusion characteristics.[d] The average H_2 diffusion characteristic for five NFT-013 filter vents was (105 ± 3) x 10^{-7} mol s^{-1}. The hydrogen diffusion characteristic was determined for four NFT-013 filter vents using a 1.5-l test vessel.[5] The sample port was located near the top of the vessel to minimize its distance from the filter. The average value reported was (85 ± 3) x 10^{-7} mol s^{-1}.

A series of diffusion experiments was conducted that demonstrated the importance of the test vessel configuration on the calculated diffusion characteristic. The average H_2 diffusion characteristic for NFT-020 filter vents in the first set of experiments, using a test vessel shown in Figure 8a, was (24 ± 3) x 10^{-7} mol s^{-1}.[e] A modified test vessel configuration, shown in Figure 8b, reduced the distance between the filter vent and the vessel base.[f] The average H_2 diffusion characteristic for NFT-020 filter vents using the modified test vessel was (40 ± 2) x 10^{-7} mol s^{-1}. The increase in the reported diffusion characteristic was directly attributed to the test vessel modification.

The hydrogen diffusion characteristic across filter vents with sintered metal filters have been reported.[g] The filter vents were manufactured by Pall Advanced Separation Systems. The test vessel shown in Figure 8b was used in the diffusion tests. The average hydrogen diffusion characteristic for six filter vents comparable in size and dimensions to a NFT-020 filter vent was (39 ± 1) x 10^{-7} mol s^{-1}. The average hydrogen diffusion characteristic across two filter vents comparable in size and dimensions to a NFT-013 filter vent was (256 ± 45) x 10^{-7} mol s^{-1}. The large standard deviation was attributed to rapid transport from the test vessel which made it difficult to accurately reproduce experimental results.

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c. Unpublished report evaluating hydrogen diffusion across filter vents; D. T. Hobbs, Westinghouse Savannah River Corp. (July 1990).

d. Unpublished report evaluating hydrogen and VOC diffusion characteristics across NFT-012 and NFT-013 filter vents; K. J. Liekhus and D. A. Johnson, EG&G Idaho, Inc. (June 1994).

e. Unpublished research results concerning hydrogen diffusion characteristic measurements across NFT-020 filters; E. B. McNew and D. A. Johnson, EG&G Idaho Inc. (April 1992).

f. Unpublished research results concerning measurements of hydrogen diffusion characteristic across NFT-020 filter vents; E. B. McNew, EG&G Idaho Inc. (June 1992).

g. Unpublished research results reporting hydrogen diffusion characteristics measured across carbon composite and sintered metal filters; D. A. Johnson and K. Messick, EG&G Idaho Inc. (May 1993).

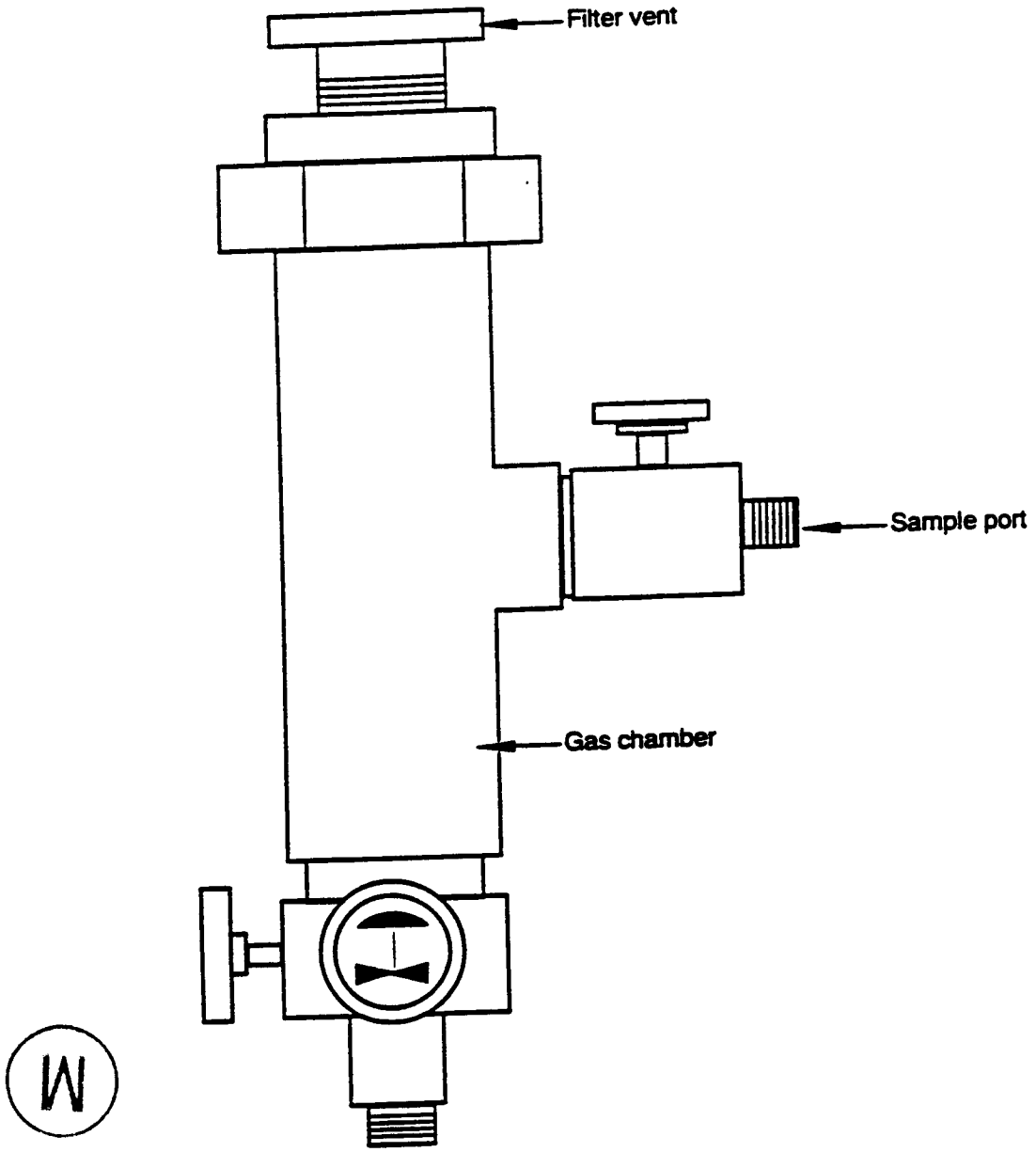

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Figure 7. Schematic of experimental test vessel used at Westinghouse to determine H_2 diffusion characteristics across NFT filter vents (from unpublished research result of S. H. Peterson and G. R. Marshall, Westinghouse R&D Center, October 1990).

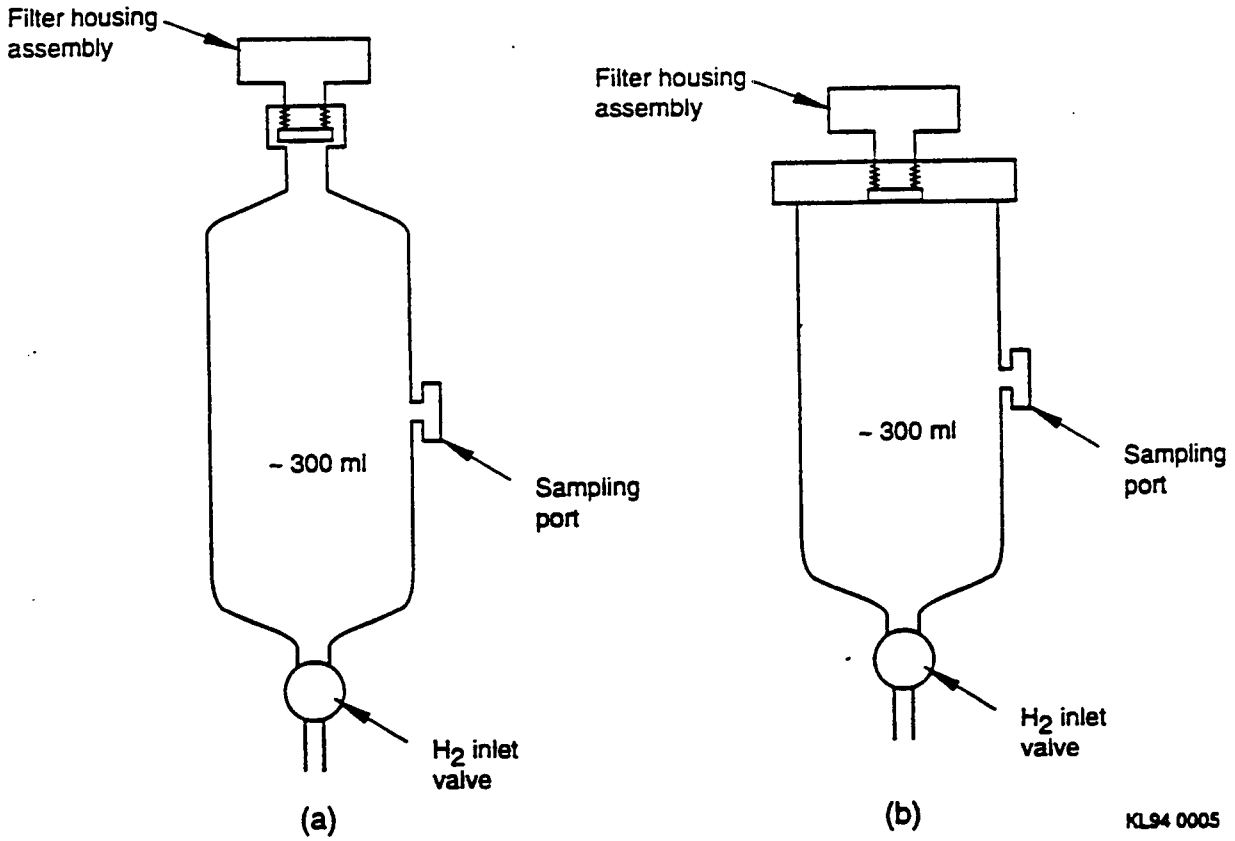

Figure 8. Schematic of test vessels used at the INEL to determine H_2 diffusion characteristic across NFT-020 filter vents (a) original design; (b) modified design (unpublished research results of E. B. McNew and D. A. Johnson, EG&G Idaho, Inc., April 1992; E. B. McNew, EG&G Idaho, Inc., June 1992).

3.2 Polymer Bags

The gas diffusion characteristic across different filter vents of the same design will be similar, allowing for variations in construction. Equation (4) shows that the permeation characteristics of different polymer bags do not have to be similar because, besides being a function of the gas-polymer permeability, they are also a function of the permeable surface area and bag thickness. The permeable area is the parameter that can have the greatest variation and depends upon how much waste is placed inside the bag and the type of bag closure.

Hydrogen transport characteristics for different layers of confinement in vented waste drums have been determined under assumed steady-state conditions.[1] The layers of confinement included polyethylene and polyvinyl chloride (PVC) bags as well as drum liners and drum filter vents. The polymer bags were sealed by a twist-and-tape or fold-and-tape method. The experiments consisted of simulating hydrogen generation by maintaining a controlled release of hydrogen gas in the innermost bag and monitoring the hydrogen concentration in all void volumes between the layers of confinement. The tests were terminated when it was determined that H_2 concentrations in all layers of confinement remained constant for at least twelve hours. A hydrogen mass balance at steady state allowed calculation of the gas transport characteristic across each layer of confinement.

The hydrogen diffusion characteristic of a taped bag closure of a small PVC bag was calculated as the difference between the H_2 transport characteristics of polymer bags with and without taped closures. A H_2 diffusion characteristic of 5.6×10^{-7} mol s^{-1} was reported for a taped closure. A hydrogen permeation characteristic of 4.9×10^{-7} mol s^{-1} was calculated for a 0.036-cm (14-mil) PVC heat-sealed bag with a permeable surface area of approximately 5,800 cm^3. The reported hydrogen flow rates into the bags at the time steady state was declared were not identical and ranged between 1.5 and 3.7 cm^3 hr^{-1}. The gas feed rate was not maintained at a constant value but adjusted as necessary to maintain H_2 concentration in the innermost bag at or near 4%.

Two experiments were conducted to identify hydrogen diffusion characteristics for 0.030-cm (12-mil) thick PVC bags with and without a taped closure.[5] In the first test, a bag was sealed over a circular plate with a surface area of approximately 2,800 cm^2 and a depth of approximately 2.5 cm. The bag was filled to atmospheric pressure with a 6% hydrogen/94% argon gas mixture. The plate was fitted with a sample port and samples were collected at regular intervals and analyzed by mass spectrometry. The hydrogen diffusion characteristic was calculated to be 2.8×10^{-7} mol s^{-1}. Another bag was prepared with a taped closure. The open end was twisted between 6 and 8 times, folded over so that the length of the twisted section end was halved, and then secured with tape wrapped around the folded material. The taped closure and sufficient bag material were removed and secured over the circular plate. Five different bags with a taped closure were prepared and tested. The average hydrogen diffusion characteristic across these samples was 3.6×10^{-7} mol s^{-1}.

4. NEW TRANSPORT CHARACTERISTIC MEASUREMENTS

The review of earlier drum filter vent diffusion experiments showed a wide variety of test vessel designs. In most cases, insufficient care was taken to minimize concentration gradient formation within the test vessel. A series of diffusion tests was conducted at the INEL using a test vessel specifically designed to minimize development of concentration gradients. A series of transport experiments was also conducted to identify H_2 and VOC transport characteristics across polymer bags and determine whether hydrogen transport across a small polymer bag with a taped closure is significant compared with permeation across the bag surface.

4.1 Experimental Apparatus

4.1.1 Drum Filter Vents

A cylindrical stainless steel vessel with a flat lid and base was constructed with an external diameter of 6.0 cm (2.4 in.) and an external height of 3.8 cm (1.5 in.). The vessel was designed for a drum filter vent to be screwed into the center of the top lid. Separate side ports allowed for the introduction of gas and the sample collection with a gas-tight syringe. Because of variations in the filter housing assemblies, two different test vessels were constructed. The internal volume of the test vessel used with NFT-012 and NFT-013 filter vents was 55 cm^3 and for the test vessel used with NFT-020 filter vents was 59 cm^3.

4.1.2 Polymer Bags

Polyethylene and PVC bags were heat-sealed or taped closed in a manner that ensured that the final surface area of the taped bags was approximately equal to that of the heat-sealed bags. The heat-sealed bags had a width of 30.5 cm (12 in.) and length of 33 cm (13 in.). The width of the taped bags was identical to that of the heat-sealed bags. The taped portion was approximately 15 cm (6 in.) long. Each bag held 3,750 cm^3 of gas without making the bag surface taut which meant that the internal bag and ambient pressures were equal. The average thickness of the polyethylene bags was 7.6×10^{-3} cm (3 mil) and of the PVC bags was 2.8×10^{-2} cm (11 mil).

Bag feedthroughs were fabricated from modified brass bulkhead unions with two backing washers, two teflon sealing washers, and an n-butyl O-ring. The outer sealing washer was machined to allow the O-ring to seat between the sealing washer and bag. The outer backing washer and outer teflon sealing washer were epoxied to the body of the bulkhead union. The teflon ferrules were used to seal the sample transfer lines.

The transport experiments were performed on an automated lab-scale system[3,4] that sampled and analyzed gas concentrations in the bags. The automated gas sampling system included a high- and low-level gas sampling manifold, a gas chromatograph (GC) with flame ionization and thermal conductivity detectors, a GC data station, a 10-port gas sampling valve, a mechanical vacuum pump, a microcontroller, and a process controller.

4.2 Experimental Procedure

In each experiment, the void volume of the filter vent test vessel or polymer bag was filled with a gas mixture and the average gas concentration was measured as a function of time. The rate of change in the gas concentration is directly dependent on the transport characteristic of the drum filter vent or polymer bag.

4.2.1 Drum Filter Vents

Pure hydrogen gas was used in the H_2 diffusion characteristic experiments. Two different gas mixtures were used in the VOC diffusion characteristic measurements. A VOC-gas mixture was introduced into the chamber that initially contained 1,010 ppmv methylene chloride, 1,020 ppmv TCA, 1,010 ppmv 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113), 301 ppmv carbon tetrachloride, and 297 ppmv trichloroethylene (TCE) in hydrocarbon-free air. Another VOC-gas mixture containing 764 ppmv methanol, 980 ppmv TCA, 398 ppmv toluene, 746 ppmv cyclohexane, and 99 ppmv p-xylene in hydrocarbon-free air was also used.

4.2.1.1 NFT-020 Filter Vent.[h] Two sets of experiments were conducted to determine if VOC loading of the carbon-composite material significantly affected the rate of VOC transport through a filter vent. A VOC gas mixture was introduced into the test vessel through the fill port at an approximate rate of 1,000 cm^3 min^{-1} for one minute to purge air out from the vessel. After the gas flow was discontinued, a clean filter was installed in the lid. The feed line was disconnected from the vessel and the feed port was capped. Gas samples were withdrawn by gas syringe at regular time intervals over 2 to 3 hours. Samples were injected into a gas chromatograph to determine VOC concentrations. In other tests, approximately one liter of VOC gas was introduced into a test vessel with the filter vent attached to the vessel. This procedure increased the amount of VOCs absorbed onto the carbon composite filter.

Hydrogen was introduced into a test vessel with a filter vent at about of 1,000 cm^3 min^{-1} for a period of one minute to purge air out from the vessel. Samples were collected over 40 minutes. The H_2 and VOC diffusion characteristics were determined for six filters. The room temperature during the tests was 298 K and the average ambient pressure was 64.4 cm Hg.

4.2.1.2 NFT-012 and NFT-013 Filter Vents. The gas mixture was introduced into a test vessel with filter vent attached through the fill port at about 1,000 cm^3 min^{-1} for one minute to purge the vessel. The feed line was disconnected from the vessel and the feed port was capped. Gas samples were withdrawn by gas syringe at regular time intervals. Samples were injected into a gas chromatograph to determine gas concentrations. The room temperature during the tests was 298 K and the average ambient pressure was 64.4 cm Hg.

Total sample duration for the VOC gas mixtures was approximately 45 minutes. For the NFT-013 filter vents, only four accurate measurements of the H_2 concentration in the test vessel could be obtained within the first 12 minutes. As a result, tests to determine the H_2 diffusion

h. Unpublished report concerning measurement and estimation of gas diffusion characteristic across NFT-020 drum filter vents; K. J. Liekhus and D. A. Johnson, EG&G Idaho, Inc. (December 1993).

characteristic were performed in triplicate for each filter vent. For NFT-012 filter vents, the turnaround time between samples was reduced, and six gas samples were collected during each test; thus, only one H_2 diffusion test was performed for each filter vent.

4.2.2 Polymer Bags

Multivariable two-level experiments with one replicate were designed to investigate the effect of bag closure type on H_2 and VOC transport from small polymer bags. Trichloroethylene and Freon-113 were used in the experiments. The process variables were the bag (0.0076 cm (3 mil) polyethylene or 0.028 cm (11 mil) PVC) and bag closure type (taped closure or heat-sealed). For each combination of bag and closure type, three bags were prepared. The bags were randomly distributed between the experiments and each bag was used twice.

5. RESULTS

5.1 Hydrogen Transport Characteristics

The average and minimum H_2 diffusion characteristics for each drum filter vent type are summarized in Table 1. The H_2 transport characteristics for polyethylene and PVC bags with a heat-sealed or taped closure are listed in Table 2. A general linear regression model was used on the experimental data to determine that at a level of significance of $\alpha = 0.05$, there was no significant difference in the H_2 transport characteristic across polyethylene or PVC bags with different closure types.

5.2 VOC Transport Characteristics

In experiments using the NFT-020 filter vents, the natural logarithm of the fraction of the initial VOC concentration in the test vessel was plotted as a function of time. Linear regression analysis was performed on each set of data to identify the slope and the correlation coefficient. The correlation coefficient, in all cases, was greater than 0.98. The VOC diffusion characteristics measured across six different clean and used filters are listed in Table 3. A students t-test at an α=0.05 level of significance showed that the difference in VOC diffusion characteristics for clean and used filter vents was significant for all VOCs except Freon-113. This was attributed to VOCs being adsorbed onto the carbon-composite materials. As a result, all later experiments had filter vents in place on the test vessel during gas purging instead of being put in place after purging. The average diffusion characteristics of nine different VOCs for NFT-012 and NFT-013 filter vents using this procedure are listed in Table 4.

A statistical linear model analysis of VOC transport characteristic experimental data was performed to identify if the total transport characteristic varied significantly as result of the bag closure type. The bag closure type did not significantly affect the TCE transport rate from polymer bags. A bag material-bag closure interaction was observed with Freon-113. Specifically, the transport characteristic for PVC bags with a taped closure was significantly higher than for any other bag material-closure type combination.

Table 1. Average and minimum H_2 diffusion characteristics (mol $s^{-1} \times 10^7$) across different NFT drum filter vents.

	Average	Minimum
NFT-012	28 ± 6[a]	17
NFT-013	117 ± 11	102
NFT-020	42 ± 1	41

a. One standard deviation.

Table 2. Hydrogen transport characteristics (mol $s^{-1} \times 10^7$) for polyethylene and PVC bags.

	Polyethylene	PVC
Twist-and-tape closure	5.93	2.99
	6.76	1.98
Heat-sealed closure	3.65	1.99
	8.72	2.09

Table 3. VOC diffusion characteristics (mol s^{-1} x 10^7) for clean and used NFT-020 drum filter vents.

Filter ID number	Methylene chloride	Freon-113	TCA	Carbon tetrachloride	TCE
HC7: Clean	3.75	2.74	2.87	2.85	3.32
HC7: Used	3.71	2.73	2.69	2.61	3.16
JD8: Clean	4.90	3.41	3.33	3.28	3.38
JD8: Used	4.75	3.64	3.39	3.08	3.27
NB5: Clean	4.84	3.69	3.54	3.39	3.37
NB5: Used	4.90	3.66	3.40	3.07	3.27
IE8: Clean	5.09	3.68	3.51	3.43	3.44
IE8: Used	4.44	3.59	3.38	3.24	3.43
GD9:Clean	5.11	3.72	3.62	3.49	3.68
GD9: Used	4.30	3.48	3.23	3.14	3.09
OE4: Clean	4.87	3.70	3.51	3.41	3.32
OE4: Used	4.44	3.43	3.14	3.02	2.86

Table 4. VOC diffusion characteristic (mol s^{-1} x 10^7) for NFT-012 and NFT-013 drum filter vents.

	NFT-012	NFT-013
Freon-113	3.20 ± 0.51[a]	10.4 ± 0.6
Methylene chloride	4.50 ± 0.67	17.7 ± 0.9
1,1,1-trichloroethane[b]	3.85 ± 0.60	10.4 ± 0.5
1,1,1-trichloroethane[c]	3.79 ± 0.57	11.0 ± 0.6
Carbon tetrachloride	3.83 ± 0.57	10.6 ± 0.5
Trichloroethylene	4.21 ± 0.53	13.9 ± 1.8
Methanol	6.00 ± 1.11	9.7 ± 0.9
Cyclohexane	4.00 ± 0.59	11.2 ± 0.5
Toluene	4.29 ± 0.50	13.2 ± 2.5
p-xylene	3.55 ± 0.29	11.7 ± 2.3

a. One standard deviation.

b. Gas mixture containing TCA, Freon-113, TCE, carbon tetrachloride, and methylene chloride.

c. Gas mixture containing TCA, methanol, cyclohexane, toluene, and p-xylene.

6. DISCUSSION

6.1 Drum Filter Vents

6.1.1 Hydrogen Diffusion Characteristic

The H_2 diffusion characteristics from this report and past investigations are summarized in Table 5 by the types of NFT drum filter vents. In all cases, values determined using the current INEL test vessel were greater than previously reported values. The higher values of H_2 diffusion characteristic are attributed to the test vessel configuration, the position of the filter vent relative to the gas sample location, and the validity of assuming a well-mixed gas volume. The test vessel used in the new diffusion studies minimized the distance between the base of the filter vent and had an internal volume between 55 and 60 cm^3. The lower diffusion characteristics in other small test vessels (75-110 cm^3) are attributed to the elongated geometry of the test cylinder. Filter vents were located at the top usually attached to an adapter and gas samples were collected from the middle of the test vessel. The design of these test vessels increased the likelihood of developing a concentration gradient in or near the test vessel. The larger diffusion characteristic value reported by Liekhus[d] was attributed to the fact that the H_2 concentration outside the 4.33-L test vessel was also measured which resulted in a more accurate knowledge of the concentration gradient across the vent.

6.1.2 VOC Diffusion Characteristic

6.1.2.1 Clean and Used Filter Vents. The filter treatment procedure passed approximately 100% of the molar capacity of the carbon-composite media over the filter in one minute, although only a fraction of the VOCs adsorbed onto the filter. The VOC diffusion characteristics for treated filters were slightly less than values calculated for untreated filters. This was attributed to a decrease in the VOC-adsorption capacity of the filters. The adsorption capacity of a clean filter may have enhanced the VOC transport rate across the filter. Thus, a more conservative estimate of VOC diffusion characteristics requires that tests be performed across filters exposed to VOC gas mixture before gas sampling.

It was assumed that the diffusion characteristic for each VOC was not influenced by the presence of the other VOCs. Values for TCA diffusion characteristics using two different gas mixtures (see Table 4) indicates that this was a valid assumption.

6.1.2.2 Estimating VOC Diffusion Characteristic. It has been proposed that the ratio of the VOC-to-H_2 diffusion characteristics is equal to the ratio of VOC-to-H_2 diffusivity in air

$$\frac{D^*_{voc}}{D^*_{H_2}} = \frac{D_{voc\text{-}air}}{D_{H_2\text{-}air}} \quad . \tag{8}$$

The VOC diffusion characteristic has been estimated using the hydrogen as a reference gas and the inverse ratio of molecular weights.[1] Thus, the ratio of diffusion characteristics is

Table 5. Comparison of reported H_2 diffusion characteristics (mol $s^{-1} \times 10^7$) for different drum filter vents.

	NFT-012	NFT-013	NFT-020
This report	28 ± 6[a]	117 ± 11	42 ± 1
Peterson[b]	23 ± 2	—	39 ± 10
Peterson[c]	—	74	—
Hobbs[d], Liekhus[e]	—	105 ± 3	—
McNew[f]	—	—	24 ± 3
McNew[g]	—	—	40 ± 2
Smith[h]	—	85 ± 3	—

a. One standard deviation

b. Unpublished report, S. H. Peterson, Westinghouse R&D Center (July 1988).

c. Unpublished report, S. H. Peterson and G. R. Marshall, Westinghouse R&D Center (October 1990).

d. Unpublished report, D. T. Hobbs, Westinghouse Savannah River Corp. (July 1990).

e. Unpublished report, K. J. Liekhus and D. A. Johnson, EG&G Idaho, Inc. (June 1994).

f. Unpublished report, E. B. McNew and D. A. Johnson, EG&G Idaho, Inc. (April 1992).

g. Unpublished report, E. B. McNew, EG&G Idaho, Inc. (June 1992).

h. Reference 5.

estimated as

$$\frac{D_{voc\text{-}air}}{D_{H_2\text{-}air}} = \sqrt{\frac{MW_{H_2}}{MW_{voc}}} \quad . \tag{9}$$

Gas diffusivity in air can be estimated at low pressures using an equation developed from a combination of kinetic theory and corresponding-states arguments[6]

$$D_{AB} = 2.745 \times 10^{-4} \frac{T^{1.823}}{P} \left[p_{cA}\, p_{cB}\right]^{1/3} \left[T_{cA}\, T_{cB}\right]^{-1/2} \left[\frac{1}{M_A} + \frac{1}{M_B}\right]^{1/2} \tag{10}$$

where

D_{AB} = mass diffusivity for gas(A)-gas(B) system, $cm^2\ s^{-1}$

p_{ci} = critical pressure of species i. atm

T_{ci} = critical temperature of species i, K

M_i = molecular weight of species i.

The ratio of VOC-to-H_2 diffusivity in air can be estimated using Equation (10)

$$\left[\frac{D_{voc-air}}{D_{H_2-air}}\right] = \left[\frac{p_{c,voc}}{p_{c,H_2}}\right]^{1/3} \left[\frac{T_{c,voc}}{T_{c,H_2}}\right]^{-1/2} \left[\frac{\frac{1}{M_{air}} + \frac{1}{M_{voc}}}{\frac{1}{M_{air}} + \frac{1}{M_{H_2}}}\right]^{1/2} \quad (11)$$

The experimental VOC-to-H_2 diffusion characteristic ratios and estimated ratio values predicted using Equations (9) and (11) are listed in Table 6.

The VOC-to-H_2 ratios for NFT-012 filter vents was greater than the corresponding ratios in the other filter vents. This phenomenon is attributed to the difference in the filter vent designs and highlights the limitation of using gas diffusivity data to estimate diffusion through porous media. The smaller openings at both ends of the NFT-012 filter vent result in decreased

Table 6. Experimental and estimated VOC/H_2 diffusion characteristic ratios.

	NFT-012	NFT-013	NFT-020	Eqn (9)	Eqn (11)
Freon-113	0.116 ± 0.014[a]	0.089 ± 0.005	0.081 ± 0.005	0.104	0.100
Methylene chloride	0.163 ± 0.020	0.151 ± 0.007	0.104 ± 0.010	0.154	0.128
1,1,1-trichloroethane	0.139 ± 0.016	0.092 ± 0.004	0.093 ± 0.007	0.122	0.105
Carbon tetrachloride	0.139 ± 0.017	0.091 ± 0.004	0.071 ± 0.005	0.114	0.105
Trichloroethylene	0.152 ± 0.015	0.119 ± 0.009	0.075 ± 0.005	0.123	0.108
Methanol	0.218 ± 0.028	0.083 ± 0.005	0.142 ± 0.033	0.250	0.168
Cyclohexane	0.145 ± 0.018	0.096 ± 0.005	0.104 ± 0.016	0.154	0.108
Toluene	0.155 ± 0.018	0.113 ± 0.011	0.086 ± 0.010	0.147	0.104
p-xylene	0.129 ± 0.014	0.100 ± 0.010	0.059 ± 0.009	0.137	0.095

a. One standard deviation.

diffusion rates for both hydrogen and the VOCs. However, the diffusion rate of the larger VOC molecules through the filter vent is more influenced by the carbon composite medium than H_2. Thus, compared with the other filter vents, the vent constrictions cause a relative larger decrease in H_2 diffusion characteristic than in the VOC diffusion characteristic, which results in an increase in the VOC-to-H_2 ratio. A comparison of predicted diffusion characteristic ratios using Equations (9) and (11) indicate that Equation (9) predicts larger VOC-to-H_2 ratios. Equation (9) was generally more accurate in estimating the ratio for NFT-012 vents. Equation (11) was generally more accurate in estimating the ratio for NFT-013 and NFT-020 filter vents. Neither equation adequately predicted the diffusion characteristic ratio for methanol across the filter vents. Methanol is difficult to analyze because of its propensity as a polar compound to adhere to surfaces.

6.2 Polymer Bags

In determining the best straight line fit of the VOC data for PVC bags, data taken in approximately the first 2.5 hours (9,000 s) were excluded. For hydrogen, data collected during the first 1,000 s were excluded. The nonlinear behavior over these times is attributed to the accumulation of gas in the polymer at the beginning of each trial. At the beginning of each trial, the polymer is relatively free of these compounds. During the course of the experiment, the gas content in the polymer approaches an equilibrium value. This equilibrium concentration may change during the experiment as the gas phase concentration in the void volume decreases, but the greatest rate of change occurs early in the experiment. For polyethylene bags, the data point at time zero was the only data excluded in the straight line fit for both H_2 and the VOCs. Freon-113 and TCE may have different solubility in each polymer, but the main reason for different times over which data exhibits nonlinear behavior is attributed to the total mass of the bags. The mass of the PVC bag was nearly four times greater than that of the polyethylene bag.

The statistical test identified a bag material-closure type interaction in the bags containing Freon-113. Specifically, the transport characteristic from the PVC bags with a taped closure were significantly greater than from any other polymer-closure type combination. Several possibilities exist that may explain this discrepancy. The PVC bags are thicker and, thus, the taped closure may be more difficult to seal tightly. However, since H_2 diffuses approximately an order of magnitude more quickly than the VOCs, H_2 transport rate from the PVC bags with a taped closure should be significantly greater than from heat-sealed bags; this was not observed. This indicates that a pathway that allows significant vapor or gas diffusion does not exist. A more likely explanation is that Freon-113 accumulates in new PVC bags during the initial stage of the experiments while it permeates relatively slowly from the bags. Unlike the bag holding the gas, the polymer in the taped closure is not directly exposed to the VOC vapor and will take longer to achieve an equilibrium concentration. As a result, Freon-113 is steadily drawn up through the base of the taped closure. Since H_2 has relatively low solubility in both polymers, the presence of the taped closure has a lesser effect on the total H_2 transport rate.

Two other studies investigated H_2 transport through PVC bags with heat-sealed and taped closures.[1,5] The differences in total bag surface area, bag material, and bag thickness make it difficult to draw any conclusions from direct comparison of transport characteristics. Hydrogen permeability across a polymer can be calculated from the transport characteristic of the heat-sealed bags given the bag surface area, thickness, gas volume, temperature, and pressure.

Assuming that the primary transport mechanism from heat-sealed bags is permeation and no pressure differential across the bag exists, the H_2 permeability across polyethylene and PVC were calculated to be 10 and 12 Ba (Ba = 10^{-10} cm^3(STP) cm cm^{-2} s^{-1} (cm Hg)$^{-1}$), respectively. This compares with reported values of 10 Ba across polyethylene and between 4 and 9 Ba across PVC.[7] Hydrogen permeabilities estimated from the H_2 transport characteristics in the TRUPACT-II SAR[1] and Smith et al.[5] were 9 and 14 Ba, respectively.

Comparison of the ratio of transport characteristics from taped closure and heat-sealed bags with similar bag thickness and surface area eliminates most of the effect of these variables. The ratios of the average H_2 transport characteristics from this report and two earlier investigations are listed in Table 7. The ratio of transport characteristics for polymers determined in unsteady-state experiments indicates that an increase in the overall transport characteristic resulting from the presence of a taped closure is not significant. This conclusion is different from that made from the steady-state experiment.[1] In the steady-state tests, the H_2 transport characteristic across the taped closure was determined as the difference between transport characteristics measured across similar PVC bags with and without a taped closure. The original data showed the H_2 concentration in the polymer bag with a taped closure was increasing during the final 12-hour period and was not at steady state.[1] Hydrogen gas flow was also not maintained at a constant rate, but continuously adjusted to maintain H_2 concentration at 4%. In addition, duplicate tests were not performed. In contrast, the unsteady-state experiment described in this report included tests across two different bags of the same material and closure type to calculate the average H_2 transport characteristic. Under these conditions, H_2 transport from small polymer bags was not significantly affected by the type of bag closure. This means that most small bags placed in vented waste drums could have either a taped closure or heat seal without significantly affecting H_2 transport from the bags.

Table 7. Ratio of average H_2 transport characteristic for bags with taped closures to average H_2 transport characteristic for heat-sealed bags.

Bag polymer	Ratio	Bag polymer	Ratio
Polyethylene	1.0	PVC[a]	1.2
PVC[b]	1.3	PVC[c]	2.1

a. 11-mil thick; 2,000 cm^2.

b. 12-mil thick; 2,800 cm^2 (Reference 5).

c. 14-mil thick; 5,800 cm^2 (Reference 1).

7. IMPACT OF TRANSPORT CHARACTERISTICS ON MODEL CALCULATIONS

The impact of different H_2 and VOC transport characteristics for filter vents and polymer bags used in earlier model calculations is discussed in this section.

7.1 Hydrogen Transport Characteristics

Test results showed that the configuration of the test vessel affects the calculated filter vent gas diffusion characteristic. Hydrogen diffusion characteristics calculated from experimental data using the INEL test vessels were about 10 to 25% greater than the highest previously reported values. A larger diffusion characteristic would result in higher minimum allowable decay heat limit. A hydrogen diffusion characteristic of 19×10^{-7} mol s^{-1} was used to calculate the maximum allowable decay heat limit per innermost layer of confinement in the TRUPACT-II SAR.[1] This value was the lowest value determined across six NFT-012 filters. However, NFT-012 filter vents are no longer used in the transportation of vented waste drums. The NFT-013 and NFT-020 filter vents are used. The lowest H_2 diffusion characteristic measured across these filter vents using the smaller INEL test vessel was 41×10^{-7} mol s^{-1}. The use of a H_2 diffusion characteristic of a different drum filter vent will have a far more significant impact on model results than higher values resulting from improved test vessel design and experimental procedure.

In model calculations of the maximum allowable decay heat limit per layer of confinement,[1] a H_2 transport characteristic of 5.60×10^{-7} mol s^{-1} was used as a conservative estimate of gas transport from a polymer bag with a taped closure. This value was the difference of two H_2 transport characteristics measured across PVC bags with and without taped closures, and was meant to describe H_2 transport through the taped closure. Experimental evidence indicates that the transport characteristic for at least one bag was not measured under steady-state conditions as assumed. In addition, two unsteady-state experiments demonstrated that total H_2 transport across a small PVC bag with a taped closure is not significantly greater than a similarly sized PVC bag with no taped closure. As a result, the maximum allowable decay heat limit should have been calculated using a H_2 permeation characteristic for a heat-sealed PVC bag. The H_2 permeation characteristic for a heat-sealed PVC bag reported in the TRUPACT-II SAR was 4.94×10^{-7} mol s^{-1}.[1] This transport characteristic is 12% less than the value used in original calculations and would result in a slightly lower calculated decay heat limit, all other variables remaining the same. In this report, the average H_2 permeation characteristic for heat-sealed PVC bags was 2.04×10^{-7} mol s^{-1} and is less than the transport characteristic reported in the TRUPACT-II SAR because of smaller bag surface area.

7.2 VOC-Filter Vent Diffusion Characteristic

The VOC diffusion characteristic across a filter vent is used in the WIPP NMD variance petition[2] to estimate the rate of VOC emissions from a vented drum. The diffusion characteristics for carbon tetrachloride and TCA across different drum filter vent types are on the order of 10^{-11} mol s^{-1}. It was estimated that rate of TCA emissions from a waste drum containing waste form Benelex/Plexiglass was 3.2×10^{-14} mol s^{-1}. The explanation for the lower than expected values was a complex combination of FIckian and surface diffusion. A more likely explanation is

that the experimental set-up resulted in significant concentration gradient across the test vessel volume. Peterson and Marshall[b] and this report demonstrated that actual VOC diffusion characteristics are on the order of 10^{-7} mol s^{-1}. Using the same TCA headspace concentration from a drum containing waste form Benelex/Plexiglass, the TCA emission rate from a drum with a NFT-012 filter vent is 1.0×10^{-9} mol s^{-1}. This is over four orders of magnitude greater and significantly changes the total anticipated VOC emissions from vented waste drums at the WIPP facility. The rate of VOC emissions will still decrease as the VOC drum headspace concentration decreases.

8. CONCLUSIONS

1. Higher H_2 and VOC diffusion characteristics for NFT drum filter vents were calculated using the INEL test vessels than measured in earlier experiments. The higher values are considered to be more accurate because of the small test vessel volume and the vessel configuration specifically designed to minimize concentration gradient formation.

2. Tests on PVC bags with a surface area between 2,000 and 3,000 cm^2 and bag thickness between 2.8 and 3.0 x 10^{-2} cm (11-12 mil) show that the H_2 transport characteristic from bags with a taped closure was only 20 to 30% greater than from heat-sealed bags. Tests on polyethylene bags with a surface area of 2,000 cm^2 and bag thickness of 7.6 x 10^{-3} cm (3 mil) showed no difference at all in the H_2 transport characteristic for bags with different types of closure. Under these conditions, H_2 transport from small polymer bags was not significantly affected by the type of bag closure. This means that most small bags placed in vented waste drums could have either a taped closure or heat seal without significantly affecting H_2 transport from the bags.

3. Gas transport from polyethylene or PVC bags containing TCE or Freon-113, or other VOCs with similar permeability across the polymer, would not be significantly affected by bag closure type in actual waste drums.

4. Two methods of estimating a VOC diffusion characteristic across a filter vent based on the measured H_2 diffusion characteristic and the estimated ratio of VOC-air diffusivity to hydrogen-air diffusivity were examined. The method estimating the ratio by the square root of the H_2-to-VOC molecular weight ratio was best for NFT-012 drum filter vents. The method estimating the ratio using the critical temperature and pressure of H_2 and the VOC as well as the molecular weight of H_2, VOC, and air was a better method for NFT-013 and NFT-020 drum filter vents.

5. Direct comparison of H_2 permeation characteristics measured in different experiments is difficult because the transport characteristic is a function of the total permeable surface area, bag thickness, and gas-polymer permeability. Instead, hydrogen-PVC permeabilities were estimated from hydrogen permeation characteristics for heat-sealed PVC bags from the INEL and earlier transport experiments, and were approximately equal.

6. The H_2 transport characteristic for a PVC bag with a taped closure reported in the TRUPACT-II SAR[1] was based on flawed experimental data. Steady-state conditions were assumed despite evidence that steady state had not been achieved. This led to the incorrect conclusion that significant gas transport occurred through the taped closure.

7. The H_2 permeation characteristic reported in the TRUPACT-II SAR for the heat-sealed PVC bag should have been used in model calculations of the maximum allowable decay heat limit per layer of confinement, instead of the H_2 transport characteristic reported for a taped closure of a PVC bag. This would have resulted in a slightly smaller calculated maximum allowable decay heat limit per innermost layer of confinement.

8. Model calculations of the maximum allowable decay heat limit per layer of confinement in the TRUPACT-II SAR used the minimum H_2 diffusion characteristic across a NFT-012 drum filter vent. The NFT-012 drum filter vent is no longer used in the transshipment of waste drums. The minimum H_2 diffusion characteristic across a NFT-020 filter vent should now be used in calculating the maximum allowable decay heat limit per innermost layer of confinement. The average H_2 diffusion characteristic across the NFT-020 filter vent is over two times greater than the NFT-012 value used in original calculations. This will result in an increase in the maximum allowable decay heat limit per innermost layer of confinement.

9. The VOC diffusion characteristics used in the WIPP NMD Variance Petition to estimate the rate of VOC emissions from a vented drum were too low as a result of flawed experimental set-up. The VOC diffusion characteristics across different NFT filter vents were found to be at least four orders of magnitude greater than values listed in the WIPP NMD Variance Petetion. This significantly changes the total anticipated VOC emissions from vented waste drums at the WIPP facility.

9. REFERENCES

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APPENDIX GAS

GAS GENERATION

APPENDIX D11

GAS GENERATION INFORMATION

(From the WIPP RCRA Part B Permit Application, Rev. 6)

Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: January 26, 1996

to: Martin S. Tierney (6741)

Yifeng Wang Larry Brush

from: Yifeng Wang & Larry Brush (Org. 6748)

subject: Estimates of Gas-Generation Parameters for The Long-Term WIPP Performance Assessment

Introduction

Steel corrosion and organic-material biodegradation have been identified as major gas-generation processes in the WIPP repository (Brush, 1995). Gas production will affect room closure and chemistry (Butcher, 1990; Brush, 1990). This memorandum provides the current estimates of gas-generation parameters for the long-term WIPP performance assessment. The parameters provided here include the rates of gas generation under inundated and humid conditions, the stoichiometric factors of gas generation reactions, and the probability of the occurrence of organic material biodegradation (Table 1). To satisfy the quality assurance (QA) requirement (QAP 9-5), we summarize all hand calculations for estimating these parameters in Appendices I and II.

Biodegradation of Organic Materials

Cellulosics, plastics, and rubbers have been identified as the major organic materials to be emplaced in the WIPP repository (DOE/CAO, 1996) and could be degraded by microbes in 10,000 years. Cellulosics has been demonstrated experimentally to be the most biodegradable among these materials (Francis et al., 1995). The occurrence of significant microbial gas generation in the repository will depend on: (1) whether microbes capable of consuming the emplaced organic materials will be present and active; (2) whether sufficient electron acceptors will be present and available; (3) whether enough nutrients will be present and available. Considering uncertainties in evaluation of these factors and also in order to bracket all possible effect of gas generation on the WIPP performance assessment, we assign a 50% probability to the occurrence of significant microbial gas generation.

- *Microbial Reactions*

Microorganism will consume cellulosics mainly via the following reaction pathways in the repository (Brush, 1995):

$$C_6H_{10}O_5 + 4.8\ H^+ + 4.8\ NO_3^- \rightarrow 7.4\ H_2O + 6\ CO_2 + 2.4\ N_2 \quad (1)$$

$$C_6H_{10}O_5 + 6\ H^+ + 3\ SO_4^{2-} \rightarrow 5\ H_2O + 6\ CO_2 + 3\ H_2S \quad (2)$$

$$C_6H_{10}O_5 \rightarrow 3\ CH_4 + 3\ CO_2. \quad (3)$$

We assume that Reactions 1 to 3 will proceed sequentially according to the energy yield of each reaction. Here we ignore the reaction pathways of aerobic respiration, Mn(IV) and Fe(III) dissimilatory reduction, since the quantities of O_2, Mn(IV) and Fe(III) initially present in the repository will be negligible relative to the other electron acceptors. In Reactions 1 to 3, biomass accumulation is also not taken into account. This is because significant biomass accumulation seems unlikely in the WIPP repository and the accumulated biomass, if any, will be recycled by microbes after all biodegradable cellulosics is consumed.

In addition to Reaction (3), methanogenesis may proceed via:

$$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O. \quad (4)$$

However, this reaction will be ignored in our calculations, because (1) no experimental data are available to evaluate the rate of this reaction and (2) the net effect of this reaction is to reduce the total gas generation and the amount of CO_2 in the repository and, therefore, it is conservative to ignore this reaction in respect of repository pressurization and actinide solubility.

- *Rates of Cellulosics Biodegradation*

The rate of cellulosics biodegradtion was measured by incubating representative cellulose materials (filter paper, paper towels, and tissue) in WIPP brine with microbes enriched from various WIPP environments (Francis & Gillow, 1994; Francis et al., 1995). The incubation experiments were conducted under various conditions: aerobic or anaerobic, inundated or humid, with or without bentonite, amended or unamended with nutrients or NO_3^-. Because the repository is expected to become anoxic shortly after waste emplacement and also because bentonite will not be added as a backfill according to the current waste emplacement plan, we think that the experimental data from anaerobic incubation without bentonite present are most relevant to expected WIPP conditions. Considering that the current experimental data are mostly for denitrification (Reaction 1), but not sulfate reduction (Reaction 2) and methanogenesis (Reaction 3) (Francis & Gillow, 1994; Francis et al., 1995), we assume that the ranges of the rates of cellulosics biodegradation via sulfate reduction and methanogenesis are equal to those observed for denitrification.

We use CO_2 production data to estimate the rates of cellulosics biodegradation. There are two advantages of using CO_2 production data: (1) there are experimental data available on the CO_2 dissolution in WIPP brine (Telander & Westerman, 1995) and, therefore, it is easy to correct the CO_2 production data for gas dissolution (Appendix I); (2) since cellulosics biodegradation did not reach the stage of methanogenesis in the experiments, according to

Reactions 1 and 2, the consumption of one mole carbon of cellulosics will produce one mole of CO_2. This 1:1 relationship is independent of oxidation state of carbon in cellulosics. Therefore, it is rather straightforward to determine the amount of cellulosics biodegraded from the amount of CO_2 produced.

Experimental data show a strong dependence of CO_2 generation on the concentrations of nutrients and nitrate (Francis & Gillow, 1994; Francis et al., 1995). The maximum CO_2 generation was observed in nitrate-and-nutrient-amended samples. In those experiments, after a short lag phase, CO_2 first linearly increased with time and then approached some limiting value as its production rate diminished. If we assume that biodegradation is nitrate- or nutrient-limited, the experimental data can be explained by Michaelis-Menton kinetics (Chapelle, 1993). Michaelis-Menton kinetics, which describes the dependence of microbial reaction rate on substrate concentration, can be expressed by:

$$V = \frac{V_{max} S}{K_s + S} \qquad (5)$$

where V is the microbial reaction rate; V_{max} is the maximum value of the rate; S is the concentration of the limiting substrate; K_s is a constant. Equation (5) states that the microbial reaction rate becomes independent of the substrate concentration, if the latter is high enough, i.e. $S >> K_s$ and $V = V_{max}$. In this circumstance, the reaction product will accumulate linearly with time before the substrate is sufficiently depleted. In other words, in our cases, the linear part of CO_2 vs. time curve will give the estimate of the maximum rate of cellulosics biodegradation.

From the experimental data of Francis & Gillow (1994) and Francis et al. (1995), we estimate the maximum and minimum rates of cellulosics biodegradation under inundated conditions to be 0.3 and 0.01 mole C/kg/year, respectively (Appendix I). The maximum rate is estimated from the data obtained from both NO_3^-- and nutrients-amended experiments, whereas the minimum rate is derived from the data obtained from the inoculated-only experiments without any nutrient and NO_3^- amendment. Under humid conditions, experimental data show no clear correlation between CO_2 production and nutrient concentration. The best estimate of the maximum rate of cellulosics biodegradation under humid condition is 0.04 mole C/kg/year (Appendix I). The minimum of the humid biodegradation rate is set to 0, corresponding to the cases where microbes become inactive due to nutrient and water stress.

- *Biodegradation of Plastics and Rubbers*

The rates of plastics and rubber biodegradation under expected WIPP conditions were

measured by Francis et al.(1995). The experimental data show that plastics and rubbers are much less biodegradable than cellulosics, although the data themselves are not sufficient for us to constrain the long-term biodegradation rate for plastics and rubbers. There are two factor that may potentially increase the biodegradibility of those materials: long time scale and cometabolism. Over a time scale of 10,000 years, plastics and rubbers may change their chemical properties and therefore their biodegradibility. Cometabolism means that microbes degrade an organic compound but do not use it as a source of energy or of their constituent elements, all of which are derived from other substrates (Alexander, 1994). In the WIPP repository, plastics and rubbers, which are resistant to biodegradation, may still be cometabolized with cellulosics and other more biodegradable organic compounds. Because of these uncertainties, we recommend a 50% chance for the biodegradation of plastics and rubbers in the event of significant microbial gas generation. We further suggest lumping plastics and rubbers into cellulosics and applying the ranges of cellulosics biodegradation rate to plastics and rubbers. This treatment is conservative in respect of repository pressurization and actinide solubility. We propose to use the following equation to convert plastics and rubbers to the carbon-equivalent quantity of cellulosics (Appendix I):

$$\text{total cellulosics (kg)} = \text{actual cellulosics (kg)} + 1.7\ \text{plastics (kg)} + \text{rubbers (kg)}. \quad (6)$$

Anoxic Steel Corrosion

According to current waste inventory estimates, a large amount of steels will be emplaced in the WIPP repository (DOE/CAO, 1996). Those steels will be capable of reacting with the repository brine to form H_2 gas. Both thermodynamic calculations and experimental observations indicate that the H_2 gas can be generated to pressures exceeding the lithostatic pressure at the WIPP horizon, if enough brine enters the repository (Brush, 1990; Telander & Westerman, 1993, 1995). Since the repository will become anoxic shortly after waste emplacement and sealing, we here focus only on anoxic steel corrosion.

- *Steel Corrosion in the Absence of CO_2 and H_2S*

In this case, steel corrosion will follow the reaction (Telander & Westerman, 1993, 1995):

$$Fe + 2\ H_2O \rightarrow Fe(OH)_2 + H_2. \quad (7)$$

In the Mg-rich WIPP brines (exemplified by Brine A), a significant fraction of Fe in the corrosion product is substituted by Mg. This substitution can substantially increase the stability of the corrosion product. Experimental observations indicate that steel corrosion can still proceed even at an 127 atm H_2 pressure (Telander & Westerman, 1995). Aside from this thermodynamic stability argument, the experimental observations indicate no

essential effect of Mg in the brine on the corrosion rate. As a matter of fact, the corrosion rates measured in Mg-rich Brine A are not significantly different from those measured in Mg-depleted Brine ERDA-6 (Telander & Westerman, 1995).

It was observed in the experiments that the steel corrosion rate decreased with time until some limiting rate was achieved (Telander & Westerman, 1995). Our long-term corrosion rate is estimated from the longest-term data available in a WIPP-relevant Brine A environment. The estimated inundated rate is 0.5 μm/year or 0.07 mole Fe /m^2/year (Appendix II). In addition, the corrosion rate is also found to increase with decreasing brine pH (Telander & Westerman, 1993, 1995). Without addition of CO_2 from microbial reactions, the pH in the repository is unlikely to go below its experimental value, which is about 10 (Telander & Westerman, 1993, 1995). Therefore, we recommend using 0.5 μm/year as the upper limit of inundated corrosion rate for the cases without microbial gas generation. On the other hand, the pH in the repository can be ~2 units higher than its experimental value due to the presence of $Ca(OH)_2$ as a cementious material in the waste, and thus, based on the scaling factor (= 0.01) given by Telander & Westerman (1995), the steel corrosion rate could be as low as 0.005 μm/year. In addition, the experimental work for Source Term Test Program (STTP) at Los Alamose National Laboratory indicates that salt crystallization on steel surface may possibly prevent the steel from corrosion. To include this possibility, we set the minimum inundated steel corrosion rate to 0.

The corrosion rate observed on specimens exposed to humid conditions is negligible, based on essentially non-existent presence of corrosion product and lack of apparent H_2 generation (Telander & Westerman, 1995). Therefore, we set the humid steel corrosion rate to 0.

- *Steel Corrosion in the Presence of CO_2 and H_2S*

In the event of significant microbial gas generation, steel corrosion can proceed via the following reactions in addition to Reaction (7) (Telander & Westerman, 1993, 1995):

$$Fe + CO_2 + H_2O \rightarrow FeCO_3 + H_2 \quad (8)$$

$$Fe + H_2S \rightarrow FeS + H_2. \quad (9)$$

One possible effect of CO_2 and H_2S on steel corrosion is that they may cause passivation of the steel. Steel passivation was observed in the experiments in which large quantities of CO_2 and H_2S were added to the reaction vessels. It usually took place after tens of days and was caused by the formation of a protective layer of $FeCO_3$ or FeS on steel surfaces (Telander & Westerman, 1995). However, we think that this passivation is unlikely to occur under the repository conditions. This is because the microbial production rate of CO_2 and H_2S is too slow and it will take an exceedingly long time period (relative to the experimental time scale) for these gases in the repository to reach their concentration levels required for

passivation under the experimental conditions. The conclusion of no steel passivation under the WIPP repository conditions is consistent with other studies (e.g., Ikeda et al., 1983; Schmitt, 1983). In fact, aside from the previously cited work of Telander & Westerman (1993), total passivation of steel by CO_2 and H_2S in low-temperature solutions has not been reported, though varying degrees of corrosion inhibition have been observed.

In the absence of passivation, the microbial generation of CO_2 and H_2S will increase steel corrosion rates in the repository either by lowering the repository pH or by initiating additional reaction pathways (Reactions 8 and 9) (Telander & Westerman, 1995). We take this effect into account by modifying the sampling range of steel corrosion rate. Obviously, Reactions 8 and 9 will be limited by microbial CO_2 and H_2S production, and therefore the upper limit of the reaction rate can be estimated from the maximum cellulosics biodegradation rate, which is 0.3 mole/kg cellulosics/year, equivalent to 6 μm/year of steel corrosion rate (Appendix II). Thus, in the event of significant microbial gas generation, the upper limit of steel corrosion rate is 6.5 μm/year, the sum of the maximum rates of Reactions 7 through 9. The corresponding lower limit will be kept the same as that estimated for the cases without CO_2 production, i.e. 0.0 μm/year. Under humid conditions, experimental results show a negligible effect of CO_2 and H_2S on steel corrosion (Telander & Westerman, 1995). We thus set the humid corrosion rate to 0.

Stoichiometric Factors in the Average-Stoichiometry Model

In the Average-Stoichiometry Model, which is currently implemented in BRAGFLO, microbial gas generation is represented by the overall reaction:

$$\frac{1}{6}C_6H_{10}O_5 + \textit{unknown} \rightarrow y\ \textit{gas} + \textit{unknown} \qquad (10)$$

and H_2 production due to steel corrosion is described by:

$$Fe + \frac{4+2x}{3} H_2O \rightarrow \frac{4-x}{3} H_2 + x\, Fe(OH)_2 + \frac{1-x}{3} Fe_3O_4. \qquad (11)$$

The stoichiometric factors x and y in Reaction 10 and 11 are estimated as follows.

- *Average-Stoichiometric FactorY in Microbial Reaction*

The stoichiometric factor y depends on the extent of the progress of each individual reaction pathway (Reactions 1 through 3). It can be estimated based on the inventory estimates of the transuranic waste to be emplaced in the Waste Isolation Pilot Plant (DOE/CAO, 1996; Drez, 1996).

First, we estimate the maximum quantities (in moles) of cellulosics and steels that will be potentially consumed in 10,000 years:

$$M'_{cel} = \min \left\{ \frac{6000 M_{cel}}{162}, \; 10000 R'_C M_{cel} \right\} \tag{12}$$

$$M'_{Fe} = \min \left\{ \frac{1000 M_{Fe}}{56}, \; 1410 R_{c,i} A \right\} \tag{13}$$

with

$$R'_c = \max \left\{ R_{m,i}, \; R_{m,h} \right\} \tag{14}$$

where M_{cel} and M_{Fe} are the quantities (in kg) of cellulosics and steels initially present in the repository; $R_{c,i}$ is the inundated steel-corrosion rate (μm/year); $R_{m,i}$ and $R_{m,h}$ are the sampled rates of cellulosics biodegradation under inundated and humid conditions respectively (mole/kg/year). In Equation (13), we use the factor of 0.141 mole/μm/m^2 to convert steel-corrosion-rate unit from μm/year to mole/m^2/year (Telander and Westerman, 1995). Here, we assume that cellulosics biodegradation and steel corrosion both follow zero order reaction kinetics. Next, we calculate the average stoichiometric factor y by distributing M'_{cel} into individual biodegradation pathways. Consider two extreme cases, corresponding to the maximum and minimum values of y: (1) no reaction of microbially produced CO_2 and H_2S with steel and steel-corrosion products; (2) complete reaction of microbially produced CO_2 and H_2S with steel and steel-corrosion products.

If no CO_2 or H_2S is consumed by reactions with steel and steel-corrosion products, we would expect the maximum quantity of microbial gas production in the repository and therefore the maximum value for y. We assume that Reactions 1 to 3 will proceed sequentially. The maximum value of y can be estimated by averaging the gas-yields for all reaction pathways:

$$y_{max} = \frac{\frac{8.4 M_{NO3}}{4.8} + \frac{9 M_{SO4}}{3} + \left(M'_{cel} - \frac{6 M_{NO3}}{4.8} - \frac{6 M_{SO4}}{3} \right)}{M'_{cel}} \tag{15}$$

where M_{NO3} and M_{SO4} are the quantities of NO_3^- and SO_4^{2-} (in moles) initially present in the repository.

If CO_2 or H_2S reacts with steel and steel-corrosion products, we expect that a significant quantity or, perhaps, all of these microbially produced gases would be consumed, thus forming $FeCO_3$ and FeS. This would result in the minimum value of y. The total gas consumed by those reactions (G) is:

$$G = \min\left\{\frac{6M_{NO3}}{4.8} + \frac{9M_{SO4}}{3} + \frac{3}{6}\left(M'_{cel} - \frac{6M_{NO3}}{4.8} - \frac{6M_{SO4}}{3}\right),\ M'_{Fe}\right\} \tag{16}$$

The minimum value of y can then be estimated by:

$$y_{min} = \frac{\frac{8.4M_{NO3}}{4.8} + \frac{9M_{SO4}}{3} + \left(M'_{cel} - \frac{6M_{NO3}}{4.8} - \frac{6M_{SO4}}{3}\right) - G}{M'_{cel}} = y_{max} - \frac{G}{M'_{cel}} \tag{17}$$

For each BRAGFLO simulation, *y* will be uniformly sampled over $[y_{min}, y_{max}]$:

$$y = y_{min} + \beta(y_{max} - y_{min}) \tag{18}$$

with $0 \le \beta \le 1.0$. The calculational scheme proposed here automatically correlates *y* with waste inventory estimates as well as with reaction rates.

The above calculational scheme does not take into account the SO_4^{2-} that will be brought into repository by brine inflow. Based the previous BRAGFLO simulations for undisturbed cases, the total volume of the brine entering the repository in 10000 years is unlikely to be larger than 2.2×10^7 liters; the value corresponding to the case with unrealistically low gas generation and therefore the worst repository flooding. With a typical SO_4^{2-} concentration of 200 mM in WIPP brines (Brush, 1990), we estimate that the amount of SO_4^{2-} brought into the repository by brine inflow would be less than 0.4×10^7 moles. This amount of SO_4^{2-} will increase the fraction of sulfate reduction pathway in total cellulosics biodegradation only by less than 1%. Therefore, neglecting the sulfate brought by brine inflow would introduce an error of no more than a few percents in y values.

• *Average-Stoichiometric FactorX in Steel Corrosion Reaction*

While magnetite (Fe_3O_4) has been observed to form on steel as a corrosion product in low-Mg anoxic brines at elevated temperatures (Telander & Westerman, 1995) and in oxic brine (Haberman & Frydrych, 1988), there is no evidence that it will form at WIPP repository temperatures. If Fe_3O_4 were to form, it would be expected that H_2 would be produced (on a molar basis) in excess of Fe consumed. But, the anoxic corrosion experiments did not show the production of H_2 in excess of Fe reacted. Therefore, we set the stoichiometric factor x to 1.0 in Reaction 11.

Table 1. Gas-Generation Parameters for the Long-Term WIPP Performance Assessment

Parameter	Estimated Value
Probability of occurrence of significant microbial gas generation	50%
Probability of occurrence of plastics and rubber biodegradation in the event of significant gas generation	50%
Rate of inundated cellulosics biodegradation	0.01 - 0.3 mole C/kg/year
Rate of humid cellulosics biodegradation	0.0 - 0.04 mole C/kg/year
Rate of inundated steel corrosion for the cases without microbial gas generation	0.0 - 0.5 μm/year[1]
Rate of humid steel corrosion for the cases without microbial gas generation	0.0 μm/year
Rate of inundated steel corrosion for the cases with microbial gas generation	0.0 - 6.5 μm/year
Rate of humid steel corrosion for the cases with microbial gas generation	0.0 μm/year
Stoichiometric factor x in Reaction 11	1.0
Stoichiometric factor y in Reaction 10	calculated from Eqn. (18)
Factor β in Equation 18	0 - 1.0
NO_3^- initially present in the waste[2]	2.6×10^7 moles
SO_4^{2-} initial present in the waste[2]	6.6×10^6 moles

1. Multiplying 0.141 mole/μm/m^2 will convert the unit of steel corrosion rate from μm/year to mole/m^2/year (Telander & Westerman, 1993). 2. See Appendix I.6.

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Appendix I. Hand Calculations for Estimating Microbial Gas generation Parameters

Name of person performing the calculations: Yifeng Wang, Jan. 26, 1996 Yifeng Wang
Name of person reviewing the calculations: Larry Brush, Jan. 26, 1996 Larry Brush

I.1 Correction for CO_2 Dissolution in the Brine

Data and definition of variables:

TCO_2: Total CO_2 produced in an incubating experiment (moles)
n: Measured CO_2 in headspace (moles)
C_l: Dissolved CO_2 (moles/l)
V_l: Brine volume = 0.104 (l) (Gillow, per. comm.)
V_g: Headspace volume 0.046 (l) (Francis & Gillow, 1994)
P: Partial pressure of CO_2 (atm)
K: Partition coefficient of CO_2 between brine and gas phase = 0.01 (mole/l/atm) (Telander & Westerman, 1995)
R: Gas constant = 0.082 (l•atm/mole/K)
T: Temperature = 303.15 (K)

Assumption: Gaseous CO_2 approximately follows the idea gas law during these experiments.

Calculations:

$TCO_2 = V_l*C_l + n = K*P*V_l + n = K*V_l*n*R*T/V_g + n = (K*V_l*R*T/V_g + 1)*n =$
$(0.01*0.104*0.082*303.15/0.046 + 1)*n = 1.56*n$ (moles).

I.2 Estimate of the Maximum Inundated Cellulosics Biodegradation Rate

Data:

Source: Francis et al. 1995, p. 41, 148-149.
Experimental conditions: anaerobic inoculated, nutrients and nitrate amended

We only take the linear part of CO_2 vs. time curve:

time	CO_2
69 days	6.1 μmol/g of cel.
411 days	163 μmol/g of cel.

Calculations:

(1) Rate = (163 - 6.1)/(411 - 69) = 0.459 micro-moles/g/day = 0.168 mole/kg/year.
(2) Correcting it for dissolved CO_2 (see I.1), we finally have:
maximum rate = 0.168*1.56 = 0.3 mole/kg/year.

I.3 Estimate of the Minimum Inundated Cellulosics Biodegradation Rate

Data:

Source: Francis et al. 1995, p. 148-149.
Experimental conditions: anaerobic, inoculated only,

time	CO_2
0 days	2.1 µmol/g of cel.
1034 days	14.0 µmol/g of cel.

Calculations:

(1) Rate = (14.0 - 2.1)/(1034 - 0) = 0.0115 µmol/g/day = 0.004 mole/kg/year.
(2) Correcting it for dissolved CO_2 (Appendix I.1), we finally have:
minimum rate = 0.004*1.56 = 0.01 mole/kg/year.

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I.4 Estimate of the Maximum Humid Cellulosics Biodegradation Rate

Data:

Source: Francis et al. 1995, p. 80.
Experimental conditions: anaerobic, inoculated only;
anaerobic, inoculated and amended

time	CO_2
6 days	(7.7 + 13.3)/2 = 10.5 µmol/g of cel.
415 days	(83.1 + 28.8)/2 = 56 µmol/g of cel.

Calculations:

Maximum rate = (56 - 10.5)/(415 - 6) = 0.11µmol/g/day = 0.04 mole/kg/year.

I.5 Convert Plastics and Rubbers to the Equivalent Quantity of Cellulosics

Data:

Source: Molecke (1979)

Celllulosics: $C_6H_{10}O_5$	M. W. = 162 g/mole
Polyethylene: $(-C_2H_4-)n$	M. W. = 28 g/mole
Polyvinychloride: $(-C_2H_3Cl-)n$	M. W. = 62 g/mole
Neoprene: $(-C_4H_5Cl-)n$	M. W. = 88 g/mole
Hypalon: $.(-(C_7H_{13}Cl)_{12}-(CHSO_2Cl)_{17}-]n$	M. W. = 3488 g/mole

Assumption:

Plastics: 80% polyethylene, 20% polyvinychloride
Rubbers: 50% neoprene, 50% hypalon
Based on Molecke (1979).

Calculations:

The P kilograms of plastics and R kilograms of rubbers are equivalent to the Q kilograms of cellulosics, based on carbon equivalence:

$Q = (0.8*2*162/28/6 + 0.2*2*162/62/6)*P + (0.5*4*162/88/6 + 0.5*101*162/3488/6)*R = 1.7\,P + R$ (kilograms)

I.6 Moles of NO_3^- and SO_4^{2-} Initially Present in the Waste

NO_3^-: $1.62x10^6$ kg (Drez, 1996) = $1000/62*1.62x10^6 = 2.6x10^7$ moles
SO_4^{2-}: $6.33x10^5$ kg (Drez, 1996) = $1000/96*6.33x10^5 = 6.6x10^6$ moles

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Appendix II. Hand Calculations for Estimating Steel Corrosion Parameters

Name of person performing the calculations: Yifeng Wang, Jan. 26, 1996 Yifeng Wang
Name of person reviewing the calculations: Larry Brush, Jan. 26, 1996 Larry Brush

II.1 Estimate of the Maximum Inundated Steel Corrosion Rate for the Cases without Microbial Gas Generation

Data:

(1) Anoxic corrosion rate obtained from the 12th to 24th month experimental data = 0.71 μm/year (Telander & Westerman, 1993, p. 6-14).

(2) Scaling factor for the long-term rate = 70% (Telander & Westerman, 1995, p. 6 - 19).

Calculation:

The maximum long-term steel corrosion rate = 0.71*70% = 0.5 μm/year.

II.2 Estimate the Maximum Inundated Steel Corrosion Rate for the Cases with Microbial Gas Generation

Data:

Total transuranic waste volume: 1.5×10^5 m^3 (DOE/CAO, 1996)
Drum volume: 0.208 m^3 (DOE/CAO, 1996)
Surface area of steel: 6 m^2/drum (Brush, 1995)
Maximum cellulosics biodegradation rate: 0.3 mole/kg/year (Appendix I.2)
Maximum inundated steel corrosion rate for the cases without microbial gas generation: 0.5 μm/year.
Total cellulosics (including plastics and rubbers): 2.1×10^7 kg (DOE/CAO, 1996; Appendix I.5)
NO_3^- initially present in the waste: 2.6×10^7 moles (Appendix I.6)
SO_4^{2-} initial present in the waste: 6.6×10^6 moles (Appendix I.6)

Assumption:

Reactions 8 and 9 will be limited by microbial CO_2 and H_2S production rate.

Calculations:

(1) Number of drums = $1.5 \times 10^5 / 0.208 = 7.2 \times 10^5$ drums.

(2) Total moles of C in cellulosics = $6 * 2.1 \times 10^7 * 1000 / 162 = 7.74 \times 10^8$ moles of C.

Molar fraction of cellulosics biodegraded via denitrification = $2.6 \times 10^7 / 7.74 \times 10^8 = 3\%$.

Molar fraction of cellulosics biodegraded via sulfate reduction = $6.6 \times 10^6 / 7.74 \times 10^8 = 1\%$.

(3) Maximum CO_2 and H_2S production rate for the whole repository = $(0.03 + 1.5*0.01 + 0.5*0.96)*0.3*2.1 \times 10^7 = 3.3 \times 10^6$ moles CO2/year.

(4) Total steel surface area = $6*7.2 \times 10^5 = 4.32 \times 10^6$ m^2.

(5) The maximum rate of steel corrosion via Reactions 8 and 9 = $3.3 \times 10^6 / 4.32 \times 10^6 =$ 0.8 mole Fe/m^2/year = 6 μm/year.

(6) The upper limit of inundated steel corrosion rate for the cases with microbial gas generation = 0.5 + 6 = 6.5 μm/year.

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Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: February 29, 1996

to: Palmer Vaughn (Org. 6749)

Yifeng Wang Larry Brush

from: Yifeng Wang & Larry Brush (Org. 6748)

subject: An Adjustment for Using Steel Corrosion Rates in BRAGFLO to Reflect Repository Chemical Condition Changes due to Adding MgO as a Backfill

In order to control the repository chemistry, a sufficient amount of MgO will be added to the repository as a backfill. Through chemical reaction, this backfill will practically remove all CO_2 generated by microbial reactions and thus prevent any possibility of CO_2 accumulation in the repository. Therefore, the previously-suggested enhancement of steel corrosion by CO_2 (Wang & Brush, 1996) will be no longer possible. In our previous memo (Wang & Brush, 1996), two set of inundated steel corrosion rates were provided: one is 0.0 to 0.5 μm/year for the cases without CO_2 present and another is 0.0 to 6.5 μm/year for the cases with CO_2 present. *Considering the chemical condition changes due to adding MgO as a backfill, we suggest using the rate of 0 to 0.5 μm/year for all BRAGFLO simulations.*

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Effects of Microbial Processes on Gas Generation Under Expected Waste Isolation Pilot Plant Repository Conditions

Progress Report Through 1992

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EFFECTS OF MICROBIAL PROCESSES ON GAS GENERATION UNDER EXPECTED WASTE ISOLATION PILOT PLANT REPOSITORY CONDITIONS

Progress Report Through 1992

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ABSTRACT

Microbial processes involved in gas generation from degradation of the organic constituents of transuranic waste under conditions expected at the Waste Isolation Pilot Plant (WIPP) repository are being investigated at Brookhaven National Laboratory. These laboratory studies are part of the Sandia National Laboratories - WIPP Gas Generation Program. Gas generation due to microbial degradation of representative cellulosic waste was investigated in short-term (< 6 months) and long-term (> 6 months) experiments by incubating representative paper (filter paper, paper towels, and tissue) in WIPP brine under initially aerobic (air) and anaerobic (nitrogen) conditions. Samples from the WIPP surficial environment and underground workings harbor gas-producing halophilic microorganisms, the activities of which were studied in short-term experiments. The microorganisms metabolized a variety of organic compounds including cellulose under aerobic, anaerobic, and denitrifying conditions. In long-term experiments, the effects of added nutrients

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Performed under Contract No. 67-8602 for Sandia National Laboratories, Waste Isolation Pilot Plant Gas Generation Program.

(trace amounts of ammonium nitrate, phosphate, and yeast extract), nutrients plus excess nitrate, and no nutrients on gas production from cellulose degradation were investigated. Results to date (up to 200 days of incubation) show that: (i) gas production was not detected in abiotic control samples; (ii) cellulose incubated without nutrients showed limited but sustained gas production; (iii) the addition of nutrients enhanced the biodegradation of cellulose as evidenced by an increase in the production of total gas, carbon dioxide, and nitrous oxide; (iv) in the presence of excess nitrate, gas production was the highest and nitrous oxide accumulated to varying amounts; (v) the addition of bentonite increased the background carbon-dioxide concentration and stimulated microbial activity specifically in aerobic samples; and (vi) in addition to total gas and carbon dioxide production, cellulose degradation in nutrient-amended samples was evidenced by the gradual bleaching of brown paper towel, the formation of gas bubbles, the formation of paper pulp, and the appearance of a red color at the bottom of the sample bottles, indicating the growth of halophilic microorganisms. Estimates of the total gas production on the basis of initial results ranged from 0.001 to 0.039 mL g^{-1} cellulose day^{-1}.

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1.0 INTRODUCTION

Transuranic (TRU) wastes contain alpha-emitting transuranium nuclides with half-lives greater than twenty years and concentrations greater than 100 nCi per gram. TRU wastes are generated from nuclear-weapons production and other related nuclear-processing procedures. The wastes include adsorbed liquids, sludges, organics, and cemented materials containing the following radionuclides: ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{244}Cm, ^{252}Cf, and a variety of metals. Typically, TRU waste is classified as either contact-handled (CH), which does not require shielding, or remote-handled (RH), which requires shielding because of the hazard of gamma-radiation exposure. The Waste Isolation Pilot Plant (WIPP) is a mined, geologic repository developed to demonstrate that radioactive transuranic wastes generated in defense-related activities can be safely and permanently disposed of underground. The WIPP is a U.S. Department of Energy facility located in southeastern New Mexico, about 2150 ft (656 m) below the surface, in a bedded salt, evaporite Permian formation. A major long-term concern is the potential for gas generation from the corrosion of Fe and Fe-based alloys, microbial degradation of cellulosic, plastic, and rubber materials, and radiolysis of brine and waste material by alpha-emitting radionuclides (Molecke, 1979; Brush, 1990). Gas generation can cause pressurization and the formation of fractures which could allow the radionuclides to migrate away from the disposal site.

Anoxic corrosion and microbiological activity are the two most important processes that may generate appreciable amounts of gas. The current estimate of gas production due to anoxic corrosion is 900 moles per drum of waste (Brush, 1991). Caldwell et al. (1979) reported that microbial gas production due to biodegradation of TRU waste could be significant. Recently, Lappin et al. (1989) estimated such production rates at 1 mole of gas per drum of waste per year for 600 years. Brush (1991) and Brush et al., (1990) proposed a minimum and maximum range at 0 to 5 moles per drum per year, as did the earlier estimates by Molecke (1979).

Laboratory studies are under way to determine the rate and extent of gas production due to radiolysis, corrosion, and microbial activity, to support the Sandia National Laboratories-WIPP Gas Generation Program efforts to assess the long-term performance of the WIPP repository. This report summarizes the progress and status of the WIPP-funded work at BNL and presents the microbiological data obtained from initiation through 1992. Studies of the effects of microbial processes have been underway at Brookhaven National Laboratory since 1991, funded under Sandia National Laboratories contract no. 67-8602.

Brookhaven National Laboratory has developed a Quality Assurance Program that complies with DOE Order 5700.6C. For EM projects the Laboratory interprets the requirements of 5700.6C in accordance with the applicable guidance provided in the EM Quality Assurance Requirements Document (QARD). This will ensure that the data generated will be valid, accurate, repeatable, and protected, and will withstand critical peer and other reviews.

1.1 Background

The WIPP waste repository is located 2150 ft (656 m) below ground surface, with 56 rooms planned or under construction in a bedded salt formation. About 6,800 drums of waste in 55-gallon (208-L) containers will be placed in each room of 3,640-m^3 capacity. Each drum will contain, on average, about 10 kg of cellulosic waste (approx. 70,000 kg of cellulosic per room), 70% of which is paper (Brush, 1990). The rest of the potentially biodegradable portion of the waste consists of plastic and rubber, and other organic compounds. Wastes consisting of inorganic process sludges from secondary waste treatment, containing a total of ~3 million moles of nitrate and a much smaller amount of phosphate, will also be emplaced in the WIPP (Brush, 1990; Brush et al., 1991).

Microorganisms can enter the WIPP from several sources, including: (i) association with the TRU waste; (ii) the surface environment via the mine ventilation systems and human intrusion; and (iii) resident populations in the salt crystals and brine formations. Alpha

radiation from TRU waste is not expected to have significant effects on microbial activity (Barnhart et al., 1980; Francis, 1990). Previous studies of low-level radioactive wastes and waste leachates have shown that microbes in the wastes can metabolize organic carbon compounds (Francis et al., 1980a,b; Francis, 1985). Halotolerant and halophilic microorganisms (10^1 to 10^5 colony forming units/mL) including aerobic, nitrate-reducing, and anaerobic bacteria were detected in the WIPP surficial environment and underground workings (R. Vreeland, West Chester University, Pennsylvania, to be published). Cellulose-degrading extreme halophiles from the underground workings also have been isolated (R. Vreeland, West Chester University, Pennsylvania, to be published). Introduced microorganisms, as well as resident or indigenous halotolerant and halophilic bacteria, can metabolize organic compounds and nitrate in the waste, and may generate metabolic byproducts, such as organic acids, alcohols, carbon dioxide, nitrous oxide, nitrogen, hydrogen, hydrogen sulfide, and methane.

1.2 Biochemistry of Cellulose Degradation

1.2.1 Biodegradation of Cellulose

The cellulosic portion of the TRU waste will approximately be comprised of the following (Brush, 1990): paper (70%), cloth (4%), plywood (10%), and lumber (16%) (untreated: 10% and, treated: 6%). In addition, the waste contains plastic materials (primarily polyethylene and polyvinylchloride) and rubber materials (primarily neoprene and hypalon), the characteristics of which may be altered by alpha-irradiation, which may enhance their biodegradability and potential for gas generation.

Cellulose, hemicellulose, and lignin make up the three major components of plant vascular material, lignocellulose. Lignin is a highly branched, constitutionally undefined aromatic polymer that makes up 15 to 38% of hardwood and softwood trees. It is considered highly resistant to biodegradation, although thermochemically modified lignin has been shown to biodegrade (Colberg and Young, 1982).

Cellulose is an unbranched polymer of several thousand D-glucose units linked together by β-1,4 glucosidic bonds. The strength of the polymer is derived from the multitude of hydrogen bonds, with concentrations of hydrogen bonds in microcrystalline regions and fewer bonds in amorphous regions. Cellulose is insoluble; therefore, hydrolysis is a prerequisite to microbial degradation. Hydrolysis of cellulose results in the formation of cellobiose, which is then hydrolyzed to glucose (Figure 1).

Biodegradation of cellulose by white-rot fungus *Trichoderma reesei* and the bacteria *Cellulomonas* has provided insights into the enzymology, the mechanisms of action, and the pathways of cellulose degradation. Several extracellular enzymes are involved in the breakdown of cellulose. The cellulase enzymes, consisting of exoglucanase (exoenzyme) and endoglucanase (endoenzyme), break the cellulose chains into various smaller fragments, starting with: (i) different 1,4-β-endoglucanases that attack the 1,4-β-linkages, randomly depolymerizing internal units; (ii) 1,4-β-exoglucanases that remove cellobiose from the non-reducing chain end of the molecule, and (iii) 1,4-β-glucosidases (cellobiase) that hydrolyze cellobiose to glucose (Priest, 1984). Amorphous regions of cellulose are degraded by both the endo- and exo-glucanases separately. Synergistic action of the two enzymes is necessary for degrading crystalline cellulose (Poulsen and Peterson, 1992). These enzymes (produced by a variety of aerobic and anaerobic bacteria, fungi, and protozoa) coordinate to hydrolyze cellulose into soluble components, which then are converted into a variety of end products. Bacteria, including aerobes such as *Cellulomonas sp.* and *Cellvibrio gilvus* (Bott and Kaplan, 1991), and anaerobes, such as *Clostridium sp.* (Benoit et al., 1992), *Clostridium thermocellum* (Lynd et al., 1989), *Acetovibrio celluloyticus* (Laube and Martin, 1981), and *Ruminococcus albus* (Pavlostathis et al., 1988) produce extracellular cellulase enzymes in the presence of cellulosics. These enzymes are induced by the presence of substrate (Hrmova et al., 1991) and are attenuated by soil and other absorptive materials (Hope and Burns, 1985). Close proximity of the cell to the substrate is necessary for degradation. A purified enzyme extract of *T. reesei* was shown to effectively degrade cellulose (Priest, 1984), and non-oxygen labile endoglucanase from *Clostridium thermocellum* was shown to strongly absorb to native

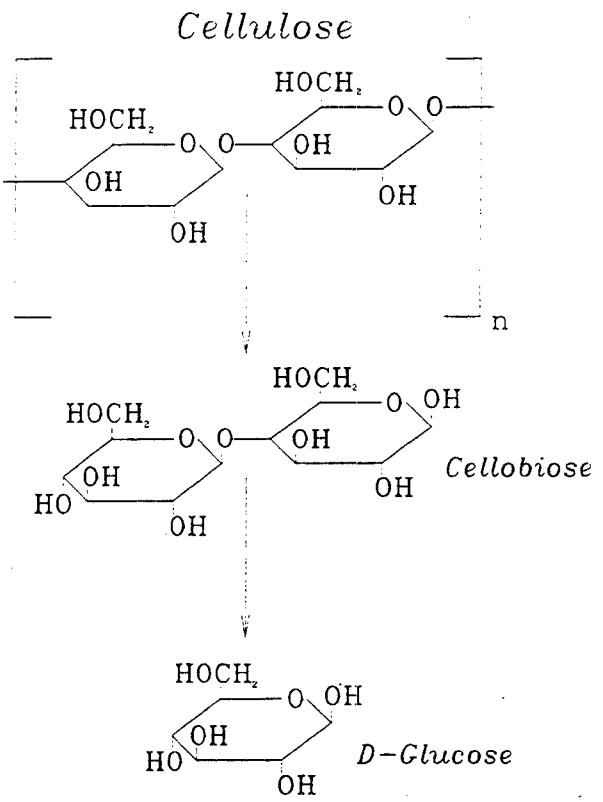

Figure 1. Cellulose Degradation Pathway.

cellulose (Ng et al., 1977). The rate of enzyme induction also depends upon the presence of the necessary nutrients, nitrogen and phosphorus (Skujins, 1976). Upon induction, hydrolysis by the cellulases is the rate-limiting step which, once achieved, follows first-order kinetics (Pavlostathis and Giraldo-Gomez, 1991). The available surface area is an important determinant of the rate of digestion of cellulose. In vitro studies of cellulytic bacteria from cow rumen demonstrated the importance for degradation of adherence of microbial cells to the cellulose surface, with fermentation rates correlated to surface area (Weimer et al., 1990). The primary hydrolysis products of cellulose are cellobiose and glucose, which then are converted to organic acids, carbon dioxide, hydrogen, and methane by various microbial processes.

Glucose, generated from cellulose, is readily used by a variety of microorganisms. The specific process depends on the availability of electron acceptors such as oxygen, nitrate, sulfate, and CO_2. In the presence of oxygen, carbon dioxide and water are formed during the oxidation of glucose:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

As oxygen is consumed, the alternate electron acceptors are used: nitrate, iron (III) oxides and hydroxides, manganese (IV) oxides and hydroxides, sulfate, and carbon dioxide. In the case of nitrate, dissimilatory reduction transforms nitrate to ammonium (dissimilatory nitrate reduction to ammonium (DNRA)) or to nitrous oxide, and then nitrogen (denitrification):

$$NO_3^- \rightarrow NO_2^- \rightarrow NH_4^+ \text{ (DNRA)}$$

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2 \text{ (Denitrification)}$$

Both processes are affected by the concentration of oxygen; the organisms catalyzing these transformations are microaerophiles or facultative anaerobes, capable of metabolism under low oxygen conditions or in its absence. Denitrification will slow down or cease with higher oxygen concentrations which inhibit the production of specific enzymes (Tiedje, 1988). Denitrifiers use several substrates, such as glucose and low molecular weight organic

acids and alcohols. The use of nitrate as an alternate electron acceptor may be significant in the WIPP because of the presence of nitrate in the waste, predominantly from process sludges.

In the absence of oxygen and nitrate, anaerobic microorganisms will dissipate electrons via fermentation of the carbohydrate:

$$C_6H_{12}O_6 \rightarrow 2C_3H_4O_3 \text{ (pyruvic acid)} + 4H^+$$
$$4H^+ + 2C_3H_4O_3 \rightarrow 2C_3H_6O_3 \text{ (lactic acid)}$$

Fermentation products, such as low molecular-weight organic acids and alcohols are available for preferential use by denitrifiers, sulfate reducers, and methanogens. Brines from the WIPP contain 160 to 300 mM sulfate (Brush, 1990); sulfate-reduction could be significant in the presence of metabolizable carbon. It occurs under reducing conditions (Eh -150 to -200mV, pH = 7.00), resulting in a change in Eh (-250mV) with growth and sulfide formation (Postgate, 1984):

$$2 \text{ lactate}^- + SO_4^{=} \rightarrow 2 \text{ acetate}^- + 2CO_2 + 2H_2O + S^{=}$$

Sulfate reduction results in the formation of H_2S and insoluble metal sulfides. Sulfate-reducing bacteria (SRB) convert lactate, pyruvate, alcohols, amino acids, and acids of the tricarboxylic acid cycle to acetate and CO_2. Glucose and other sugars seldom seem to be used directly by SRB.

The presence of CO_2, H_2, organic acids, and a low Eh generated by these anaerobic microbial processes provide a conducive environment for the growth of methanogenic bacteria. Methanogens can use (i) acetate; (ii) methanol; or (iii) carbon dioxide and hydrogen and produce methane:

(i) $CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$

(ii) $4CH_3OH \rightarrow 3CH_4 + CO_2 + 2H_2O$

(iii) $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$

Approximately 70% of the methane formed in sludge and freshwater sediments is due to reaction (i), whereas halophiles predominantly carry out reaction (ii).

Additionally, iron(III) reduction may be a significant process in the WIPP because of the presence of oxidized forms of iron. Iron reduction involves the oxidation of organic carbon concomitant with the reduction of iron, whereby iron is used as the electron acceptor in the absence of oxygen, resulting in the reduction and dissolution of Fe(III) to Fe(II). Manganese reduction results in the formation of soluble Mn(II) from Mn(IV). Soluble uranyl ions can be reduced to insoluble U(IV) by anaerobic bacteria (Francis et al., 1991; Lovely et al., 1992). Corrosion caused by microbes could transform metal ions at a passive surface, resulting in metal sulfide precipitates (Kearns et al., 1992). The use of hydrogen solely from passivation can result in the formation of methane by methanogens, accelerating cathodic depolarization and increasing corrosion (Lorowitz et al., 1992). Figure 2 shows microbiologically mediated redox processes.

1.2.2 Metabolic Diversity of Halophilic Microorganisms

Halobacteria isolated from hypersaline environments can metabolize a wide variety of organic compounds under aerobic and anaerobic conditions. Most of the extreme halophiles are archaebacteria; that is, they are a distinct group of microorganisms, apart from the eubacteria that make up the majority of prokaryotes, with an ancient lineage composed of other types of organisms adapted to extreme environments, such as alkaliphiles, thermophiles, and methanogens. Moderate halophiles grow best in an environment containing 0.5 to 2.5 M NaCl, while extreme halophiles grow best in 2.5 to 5.2 M NaCl (Kushner and Kamekur, 1988; Ventosa, 1988). Brines in the WIPP repository consist of 5.1-5.3 M chloride and 1.83-4 M sodium, 0.63-1.44 M magnesium, and 0.04-0.30 M potassium (Brush, 1990; Molecke, 1983).

Halophiles grow anaerobically by: (i) fermenting glucose, fructose, glycerol, citrate, and lactate (Javor, 1984); (ii) reducing nitrate to nitrogen gas using a variety of carbohydrates

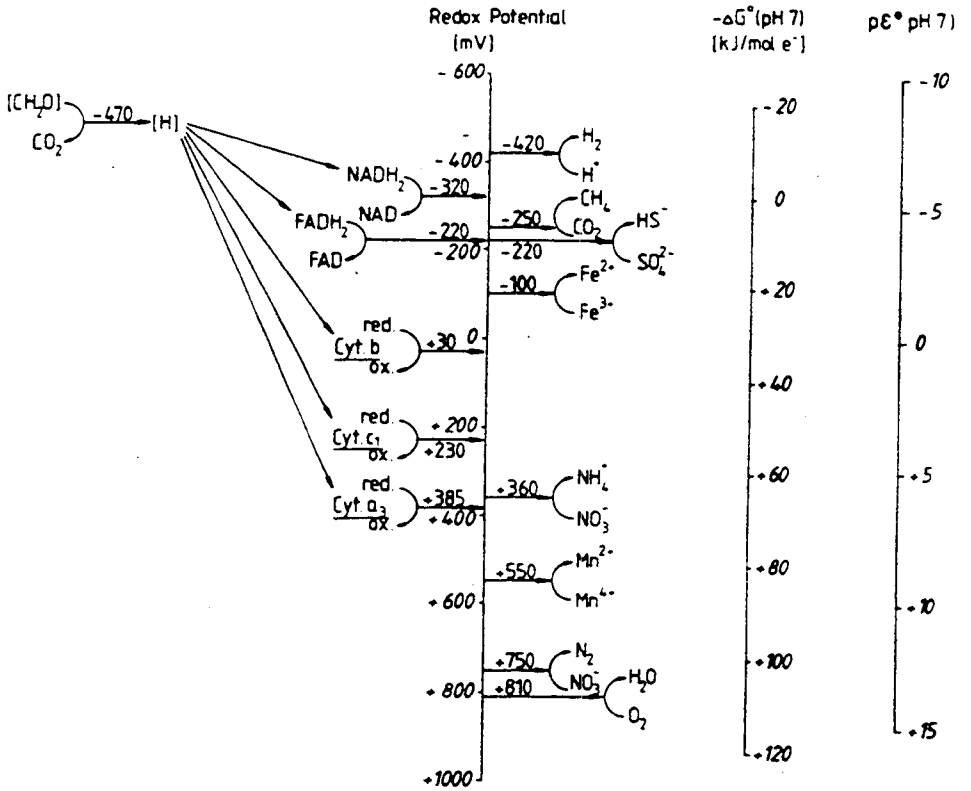

Figure 2. Electron-free energy for biologically mediated redox sequence with organic carbon (CH_2O) acting as the electron donor. Calculated for standard conditions at pH 7. (CH_2O) represents one-sixth of glucose (i.e. -153 kJ mol^{-1}), *from* Zehnder, A.J., and W. Stumm. 1988. "Geochemistry and Biogeochemistry of Anaerobic Habitats," *Biology of Anaerobic Microorganisms*. Ed. A. J. Zehnder. New York, NY: John Wiley and Sons. 19.

(Tomlinson et al., 1986); (iii) degrading chitin; and (iv) producing methane from methylamines, CO_2 and H_2 (Zhilina and Zavarzin, 1990). In hypersaline environments acetate-utilizing methanogens have been difficult to isolate (Zhilina and Zavarzin, 1990). Sulfate reducers also have been difficult to isolate, although saltmarsh sediments harbor abundant SRB populations (Dicker and Smith, 1985). The WIPP site contains a variety of halotolerant and halophilic bacterial populations. Isolates from underground brine seepages and salt crystals, and from brine and sediment from surficial lakes near the WIPP site, revealed a great diversity of colony characteristics when grown on solid media (R. Vreeland, West Chester University, Pennsylvania, to be published); these isolates used amino acids, glucose, and cellulose.

2.0 EXPERIMENTAL APPROACH

Laboratory experiments were designed to determine the potential gas generation due to biodegradation of cellulose under conditions expected in the WIPP repository (Figure 3). The experiments were divided into short-term (<6 months) and long-term (>2 years) ones. In the short-term experiments, we examined the influence of electron donors and acceptors on the activities of specific microbial processes relevant to the WIPP disposal environment. In the long-term experiments, we measured gas generation due to biodegradation of cellulose under realistic conditions expected in the WIPP repository after the waste was in place. The conditions include humid and inundated, and initially aerobic and anaerobic environments. The effects of addition of nutrients and bentonite also was investigated.

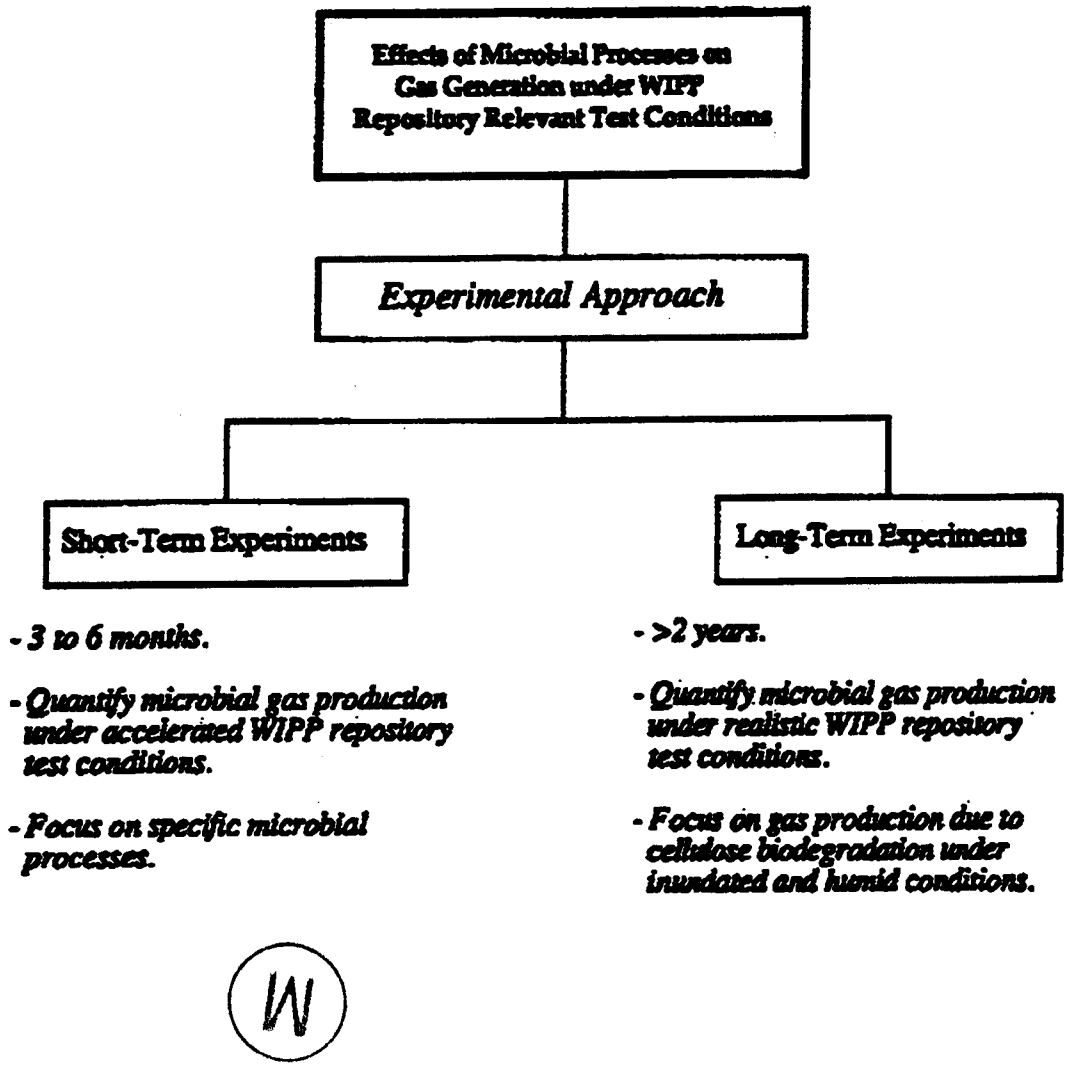

Figure 3. Experimental Approach

3.0 SHORT-TERM EXPERIMENTS

3.1 Rationale

The two main objectives of the short-term experiments were: (i) to determine gas production due to the activity of aerobes and anaerobes in the presence of specific electron donors (cellulose, glucose, succinate) and acceptors (oxygen, nitrate, sulfate) under hypersaline conditions; and (ii) to evaluate the suitability of inocula for use in the long-term experiments.

Anaerobic microbial processes were emphasized in the short-term experiments because they are expected to have the greatest impact on the long-term performance of the WIPP repository. These experiments provided an opportunity to specify aspects of the long-term investigations by manipulating the experimental variables. The microbes tested include those present in the brine collected from WIPP underground workings, surficial sediment slurries from the surrounding lakes at the WIPP site, and in axenic (pure) or mixed cultures isolated from these sources. In addition, analytical methods were tested and standardized during this phase.

3.2 Methodology

3.2.1 Sample Collection

Sediment and water samples from Nash Draw (near the WIPP site) and muck pile salt, rib salt, and brine (from the WIPP underground workings) were collected from August 21 to 25, 1991. Core samples of mud from Laguna Cinco, Quatro, Tres, and Surprise Springs, all in Nash Draw, were obtained using sterile iron pipes. Air was excluded by driving the core deep into the mud and capping it while submersed. Corrosion of iron end-caps also prevented contamination by oxygen. Lake brine samples were collected in sterile polyethylene containers from the four lakes as well as from Lindsey Lake, also in Nash

Draw. Mud and brine from all the lakes were also collected with sterile glass serum bottles, which were then stoppered and crimped to exclude air. Salt from the WIPP underground was collected using sterile spatulas and sterile containers. G-Seep brine from the WIPP underground was collected in sterile polyethylene bottles by Glen Barker, SNL.

The samples were shipped to BNL within two days after collection. The mud samples were extruded in a nitrogen-filled glove box and transferred to sterile serum bottles, fitted with butyl rubber stoppers, and stored at 4°C. Brine from Lindsey Lake and the WIPP site was also stored at 4°C. Viable bacteria in these samples were counted by Russell Vreeland, West Chester University, and the total number of bacteria and microbial activity were determined at BNL.

3.2.2 Direct Counts of Bacteria

Samples were shaken on a wrist-action shaker for 45 minutes to disperse the contents. One mL was removed with a sterile needle and syringe, dispensed into a snap-cap vial and preserved with 5% (v/v) glutaraldehyde. Double-stranded DNA specific stain 4'6-diamidino-2 phenylindole dihydrochloride (DAPI, Polysciences, Inc.) was added to the sample and it was incubated for seven minutes in the dark. The sample was filtered through a 0.2 μm black membrane filter (Poretics Corp.), and then placed on a slide and examined under oil-immersion at 1875 x magnification. Slides were prepared in triplicate for each sample, the blue-fluorescing cells were counted directly using a calibrated grid eyepiece under ultraviolet light. The DAPI stain differentiated the cells from salt grains: DNA-containing material was blue and the salt yellow (Coleman, 1980).

3.2.3. Activity Measurements

Production of gas by aerobes, anaerobes, and denitrifiers was determined in a mixed inoculum of WIPP salt and brine and Nash Draw brine and sediment. The carbon sources tested included glucose ($C_6H_{12}O_6$), cellulose ($[C_6H_{10}O_5]_n$), and succinate ($C_4H_6O_4$).

Two hundred g of S2180, W30 WIPP muck-pile salt were dissolved in sterile, deionized water and diluted to 1 L. To a 450 mL aliquot of the solution, 10 mL of Laguna Cinco mud slurry and 40 mL of Laguna Cinco lake water were added. The mixture was kept in an anaerobic glove box. Nine and a half mL of the mixture were added with a sterile syringe to 20 mL sterile serum bottles containing 0.5 mL of a sterile, concentrated nutrient stock solution containing 5 mg yeast extract, 10 mg potassium phosphate, 125 μmol ammonium nitrate, and 275 μmol glucose (See Appendix A). Aerobic samples were incubated with an initial headspace of air in sealed containers, whereas anaerobic samples were incubated in a nitrogen atmosphere after purging the samples several times with nitrogen. The serum bottles were fitted and sealed with butyl rubber stoppers. Denitrification activity was determined by adding a nutrient solution containing 5 mg yeast extract, 10 mg potassium phosphate, 125 μmol nitrate added as ammonium nitrate, 99 μmol nitrate added as potassium nitrate, and 185 μmol of succinate. These samples contained a total of 224 μmol of nitrate and were prepared anaerobically. A set of aerobe, anaerobe, and denitrifier treatments were also prepared by including approximately 0.5 g filter paper instead of the respective carbon sources, glucose and succinate.

Six samples were prepared for each treatment, two of which were treated with 1 mL of 10% formaldehyde to serve as abiotic controls. Brine samples without nutrients were also prepared, and two were treated with formalin to determine endogenous activity. The headspace gas of all the samples was analyzed after 48, 83, and 147 days of incubation at 30°C, and the total volume of gas, carbon dioxide, and nitrous oxide in the headspace determined (see Appendix B).

3.2.4 Denitrification Studies

In the absence of oxygen and in the presence of metabolizable organic carbon, some aerobic bacteria can use nitrate as an alternate electron acceptor. This process, called denitrification, or the reduction of nitrate, converts 80% or more of the available nitrate-N

to nitrogen gas (Tiedje, 1988). Nitrate is reduced to nitrogen by denitrifying bacteria via the following steps:

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2$$

Nitrate is also reduced by dissimilatory nitrate reduction to ammonium, but with either incomplete conversion to nitrogen or a far lesser yield of nitrogen (Tiedje, 1988). Nitrous oxide is an intermediate product and does not generally accumulate, although some halophiles accumulate nitrous oxide under certain conditions (Tomlinson et al., 1986).

Denitrification was observed in Nash Draw sediment slurry, G-seep, and a pure culture by the acetylene blockage technique (Yoshinari and Knowles, 1976). Acetylene inhibits the conversion (reduction) of N_2O to N_2, resulting in the stoichiometric accumulation of N_2O in the headspace (Balderston et al., 1976):

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \xrightarrow{C_2H_2} N_2$$

Acetylene was injected into the duplicate samples of each treatment to give a final concentration of 10%. Nitrous oxide in the headspace of each sample was measured with a gas chromatograph equipped with a ^{63}Ni electron capture detector (see Appendix B). Samples were analyzed at 0, 21, and 43 hours, and at appropriate intervals thereafter.

3.2.4.1 DENITRIFICATION IN SEDIMENT SLURRY SAMPLE

Laguna Cinco sediment (collected on August 22, 1991 and stored anoxically at 4°C for two months), and a fresh sample from the same site (collected on December 10, 1991) were examined for denitrifier activity. The fresh sample was examined within 48 hours of collection. The sample was mixed well, and a 1 mL slurry (August: 0.56 ± 0.01 g dry sediment; December: 0.59 ± 0.01 g dry sediment) was pipetted into sterile 20 mL serum bottles in a glove box filled with nitrogen. One mL of filter-sterilized (0.22 μm) brine (20%

w/v WIPP halite) was added to the slurries resulting in a final volume of 2 mL. The slurry contained the following nutrients: (i) no additions (unamended); (ii) 3 μmol succinate (carbon-amended); (iii) 300 nmol nitrate (nitrate-amended); and (iv) 3 μmol succinate and 300 nmol nitrate (carbon-and nitrate-amended at a C:N ratio of 10:1). Succinate was used as the carbon source to discourage the growth of fermentative organisms. Triplicate samples of each treatment were prepared. The pH of each treatment was measured at the beginning and end of the experiment. Formaldehyde-treated samples served as controls. The serum bottles containing samples were sealed with rubber stoppers in the glove box in a nitrogen atmosphere and incubated at 30°C. Denitrification was determined by the acetylene blockage technique.

3.2.4.2 DENITRIFICATION IN G-SEEP

G-Seep brine collected on December 10, 1991 from the WIPP underground workings was prepared within 48 hours of collection to assay for denitrification activity. Five mL aliquots of G-Seep brine were transferred into sterile serum bottles in an anaerobic glove box. One mL of filter-sterilized (0.22 μm) brine (20% w/v WIPP halite) with nutrients was added. The G-Seep samples contained the following nutrients: (i) no additions (unamended); (ii) 1.5 μmol succinate (carbon-amended); (iii) 150 nmol nitrate (nitrate-amended); and (iv) 1.5 μmol succinate and 150 nmol nitrate (carbon- and nitrate-amended). Formaldehyde-treated samples served as controls. Triplicate samples of each treatment were prepared, sealed with butyl rubber stoppers in the glove box in a nitrogen atmosphere, and incubated at 30°C. Denitrification was determined by the acetylene blockage technique. Samples were analyzed after 0, 3, 30, and 60 days.

3.3 RESULTS AND DISCUSSION

3.3.1 Bacterial Population

Table 1 shows the numbers of bacteria, both viable and non-viable, in brine samples from Nash Draw and in G-Seep from the WIPP underground. The direct counts of bacteria in Nash Draw samples range from 5.5 x 10^6 to 1.0 x 10^7 cells/mL. The G-Seep brine contained 7.2 x 10^4 to 3.2 x 10^6 cells/mL.

3.3.2 Activity Measurements

3.3.2.1 AEROBIC GLUCOSE METABOLISM

Table 2 shows the total gas, carbon dioxide, and nitrous-oxide production in the mixed inoculum slurry samples incubated initially under aerobic conditions with glucose, ammonium nitrate, yeast extract, and potassium phosphate. In the control samples, there was a slight increase in carbon dioxide due to abiotic reactions, but no nitrous oxide was detected. In amended samples, the concentration of both carbon dioxide and nitrous oxide increased.

3.3.2.2 ANAEROBIC GLUCOSE METABOLISM

Mixed inoculum incubated anaerobically with glucose, ammonium nitrate, yeast extract, and potassium phosphate showed little activity (Table 3). There was no significant production of carbon dioxide in amended samples. The reason for the lack of anaerobic metabolism of glucose in these samples is not known.

Table 1. Bacterial Populations in Nash Draw and G-Seep Samples

Brine Source	Number of Cells/mL
Nash Draw	
Surprise Springs	5.5×10^6
Laguna Cinco	6.8×10^6
Lindsey Lake	7.0×10^6
Laguna Tres South	9.0×10^6
Laguna Quatro	1.0×10^7
WIPP Underground Workings	
G-Seep #9	7.2×10^4
G-Seep #23	3.4×10^6

Table 2. Aerobic glucose metabolism by mixed inoculum.

Treatment*	Incubation Time (Days) 48 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	83 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	147 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control (n=2) [Formalin treated]	0.80 ± 0.10	14.0 ± 0.6	nd	1.31 ± 0.57	15.8 ± 0.2	nd	0.79 ± 0.60	20.1 ± 0.1	nd
Amended (n=4)	0.20 ± 0.20	76.9 ± 6.2	7.20 ± 4.58	0.83 ± 0.48	83.0 ± 15.3	8.75 ± 6.14	0.55 ± 0.43	80.4 ± 14.8	8.27 ± 5.71

* Each sample contained 125 µmoles of ammonium nitrate, 278 µmoles of glucose, 5 mg yeast extract, and 10 mg potassium phosphate not included

** Dissolved gas concentration

Table 3. Anaerobic Glucose Metabolism by Mixed Inoculum.

Treatment*	Incubation Time (Days) 48 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	83 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	147 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control (n=2) [Formalin treated]	0.60 ± 0.50	12.6 ± 0.3	nd	1.03 ± 0.23	13.5 ± 0.2	nd	0.13 ± 0.14	16.2 ± 0.1	nd
Amended (n=4)	nd	5.6 ± 0.15	nd	0.34 ± 0.20	7.72 ± 0.18	0.478 ± 0.030	-0.12 ± 0.12	8.00 ± 0.20	2.32 ± 1.59

* Each sample contained 125 µmoles of ammonium nitrate, 278 µmoles of glucose, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

nd = not detected

3.3.2.3 CELLULOSE DEGRADATION

3.3.2.3.1 Aerobic

Table 4 shows cellulose degradation in samples incubated initially under aerobic conditions with filter paper, ammonium nitrate, yeast extract, and potassium phosphate. Control samples showed no activity. A significant increase in carbon dioxide was observed after 83 days in amended samples. One sample produced 136 μmol of carbon dioxide, and the pressure increased to 4.47 psi. The paper in the bottle disintergrated and dissolved. Blackening of specific samples was noted after 147 days, indicative of sulfate reduction.

3.3.2.3.2 Anaerobic

Samples incubated anaerobically with filter paper, ammonium nitrate, yeast extract, and potassium phosphate showed a significant increase in activity after 48 days (Table 5). Nitrous oxide was detected in amended samples, but not in the controls. An increase in carbon dioxide was observed after 83 days. There was a large variation in gas production of anaerobic samples; one sample produced 103 μmol of carbon dioxide and the pressure reached 5.12 psi. The filter paper in this sample also disintegrated.

3.3.2.3.3 Cellulose Degradation in the Presence of Excess Nitrate

Mixed inoculum incubated anaerobically with filter paper, ammonium nitrate, yeast extract, potassium phosphate, and excess nitrate produced less nitrous oxide than the succinate-amended samples (Table 6). Only 20% of the nitrate was converted to nitrous oxide in the samples with acetylene. Carbon dioxide production was not significant until 147 days.

Table 4. Cellulose degradation by mixed inoculum under aerobic conditions.

Treatment*	Incubation Time (Days)								
	48			83			147		
	Gas Produced**			Gas Produced**			Gas Produced**		
	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control (n=2) [Formalin treated]	0.90 ± 0.20	10.9 ± 0.5	nd	1.65 ± 0.49	12.7 ± 0.1	nd	1.00 ± 0.43	14.7 ± 0.0	nd
Amended (n=4)**	nd	32.0 ± 1.9	7.29 ± 1.84	0.95 ± 0.61	57.1 ± 22.8	4.12 ± 1.38	nd	63.9 ± 20.7	5.97 ± 2.12

* Each sample contained 125 µmoles of ammonium nitrate, 0.5 grams of filter paper, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

*** Samples exhibited disintegration of the filter paper at 83 days

nd = not detected

Table 5. Cellulose Degradation by Mixed Inoculum Under Anaerobic Conditions.

Treatment*	Incubation Time (Days) 48 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	83 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	147 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control (n=2) [Formalin treated]	0.60 ± 0.00	11.3 ± 0.1	nd	1.02 ± 0.22	12.5 ± 0	nd	0.17 ± 0.17	14.3 ± 0.0	nd
Amended (n=4)									
1	nd	8.85	9.29	0.12	10.7	5.79	0.05	13.1	nd
2***	nd	6.83	10.7	3.48	65.0	nd	1.90	95.6	nd
3***	nd	9.12	nd	3.76	103	nd	0.77	90.8	nd
4***	nd	9.73	9.43	2.18	53.0	nd	3.81	105	nd
Mean	nd	8.63 ± 0.54	7.36 ± 2.14	2.39 ± 0.72	57.9 ± 16.5	1.45 ± 1.25	1.63 ± 0.71	76.1 ± 18.4	nd

* Each sample contained 125 µmoles of ammonium nitrate, 0.5 grams of filter paper, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

*** At 83 days, samples exhibited disintegration of filter paper

nd = not detected

Table 6. Cellulose Degradation by Mixed Inoculum in the Presence of Excess Nitrate.

Treatment*	Incubation Time (Days) 48 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	83 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	147 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control(n=2) [Formalin treated]									
(w/acetyl.)	nd	8.93	nd	1.03	11.9	nd	0.73	12.7	nd
(w/o acetyl.)	nd	9.90	nd	0.24	10.9	nd	-0.44	12.0	nd
Amended (n=4)									
(w/acetyl., n=2)	nd	5.24 ± 0.40	23.6 ± 1.2	0.38 ± 0.27	20.3 ± 11.4	19.5 ± 2.1	1.39 ± 1.97	56.7 ± 36.2	14.4 ± 1.7
(w/o acetyl., n=2)	nd	8.00 ± 0.95	5.59 ± 4.00	0.06 ± 0.02	8.13 ± 0.41	4.94 ± 0.78	3.62 ± 0.88	78.0 ± 5.2	nd

* Each sample contained 224 µmoles of nitrate, 0.5 grams of filter paper, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

nd = not detected

Cellulose degradation by mixed inoculum was observed in samples incubated under aerobic and anaerobic conditions and in the presence of excess nitrate. Disintegration of the filter paper in aerobic and anaerobic samples was noted after 83 days, indicating cellulose degradation. Analysis of these samples showed an increase in total gas, carbon dioxide, and nitrous-oxide production (Tables 4 and 5). The filter paper exhibited areas of thinning and clearing at 83 days in samples containing excess nitrate. At 147 days, the filter paper had fully disintegrated and carbon dioxide content had increased (Table 6). Aerobic samples containing cellulose showed little increase in carbon dioxide at 147 days; one sample turned black, possibly indicating the onset of sulfate reduction. This sample was checked after 220 days and the presence of hydrogen sulfide was confirmed by gas chromatography. Anaerobic samples also produced hydrogen sulfide at 147 days, and one sample showed blackening (Sample 2, Table 5).

3.3.2.4 DENITRIFICATION

Mixed inoculum samples incubated anaerobically with succinate, ammonium nitrate, yeast extract, potassium phosphate, and excess nitrate exhibited denitrification activity. Complete conversion of nitrate (224 μmol) to nitrous oxide (129 μmol) was noted in the presence of acetylene after 48 days of incubation (Table 7). The accumulation of nitrous oxide in amended samples without acetylene was much less than in the samples containing acetylene, indicating that nitrous oxide was converted to nitrogen. Control samples showed no activity. Additional studies on denitrification by WIPP sediment slurry brine and an axenic culture isolated from the brine are described next.

3.3.3 Denitrification Studies

3.3.3.1 DENITRIFICATION IN SEDIMENT

Microbial denitrification was analyzed in freshly collected sediment and stored sediment. Nitrous oxide was both being produced and converted to N_2 at the same time (acetylene was

Table 7. Denitrification Activity by Mixed Inoculum.

Treatment*	Incubation Time (Days) 48 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	83 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	147 Gas Produced** Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control(n=2 [Formalin treated]									
(w/acetyl.)	nd	8.93	nd	1.37	10.2	nd	1.08	11.8	nd
(w/o acetyl.)	nd	8.26	nd	nd	11.5	nd	nd	12.9	nd
Amended (n=4)									
(w/acetyl., n=2)	nd	3.43 ± 0.24	129 ± 2	0.50 ± 0.20	6.41 ± 0.05	114 ± 5	-0.12 ± 0.24	na	na
(w/o acetyl., n=2)	nd	51.0 ± 36.1	6.97 ± 2.12	1.07 ± 0.20	30.4 ± 21.5	12.1 ± 2.0	1.01 ± 0.39	na	nd

* Each sample contained 224 µmoles of nitrate, 185 µmoles of succinate, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

nd = not detected

na = not analyzed

not added to the samples) as shown in Figures 4A and 4B. The nitrous oxide concentrations reported in these studies do not include N_2O dissolved in the brine solution. Nitrous oxide was not detected in the control sample, which had been treated with formaldehyde. In unamended samples and samples amended with succinate, ~5 nmol of N_2O was detected at about 45 hours of incubation, and N_2O was not detected in the headspace thereafter. In samples amended with nitrate, the N_2O concentration reached its maximum (30 nmol gdw^{-1}) at about 200 hours and then disappeared rapidly by conversion to N_2 (Figure 4A). In the succinate-and nitrate-amended samples, much less N_2O was detected than in the nitrate-amended samples. Freshly collected samples showed little accumulation of N_2O in the headspace (Figure 4B), most probably due to rapid and complete denitrification.

The rates of denitrification in the unamended and amended (succinate and nitrate) sediment samples were determined by the acetylene blockage technique. Addition of acetylene inhibits the reduction of N_2O to N_2 and allows N_2O to accumulate in the headspace which is analyzed by gas chromatography. In Figures 5A and 5B and Table 8a and 8b, denitrification in stored (2 months) and freshly collected (assayed within 48 hours) samples are compared. In the stored samples, Figure 5A, denitrifying activity initially in the unamended sample was minimal. After a lag phase, denitrification proceeded at about 0.14 nmol N_2O gdw^{-1} h^{-1}. The rate is presented in Table 9a. The sediment contained sufficient indigenous carbon and nitrate to produce 23 nmoles of N_2O gdw^{-1}. Denitrification in the stored, carbon- amended samples was similar to that in the unamended samples (0.22 nmol N_2O gdw^{-1} h^{-1}). Denitrification activity in the stored sample was stimulated by the addition of nitrate. After an initial lag, the rate of denitrification was 1.36 nmol nitrous oxide gdw^{-1} h^{-1}.

A stimulatory effect on the rate and extent of denitrification was seen in both stored and fresh samples when carbon and nitrate were added. Denitrification proceeded at 1.78 nmol N_2O gdw^{-1} h^{-1}, finally producing 209 nmol nitrous oxide gdw^{-1} in the stored sample, translating to denitrification of 80% of the added nitrate. In the freshly collected sediment, without added carbon or nitrate, 205 nmoles of nitrous oxide gdw^{-1} were produced at a rate

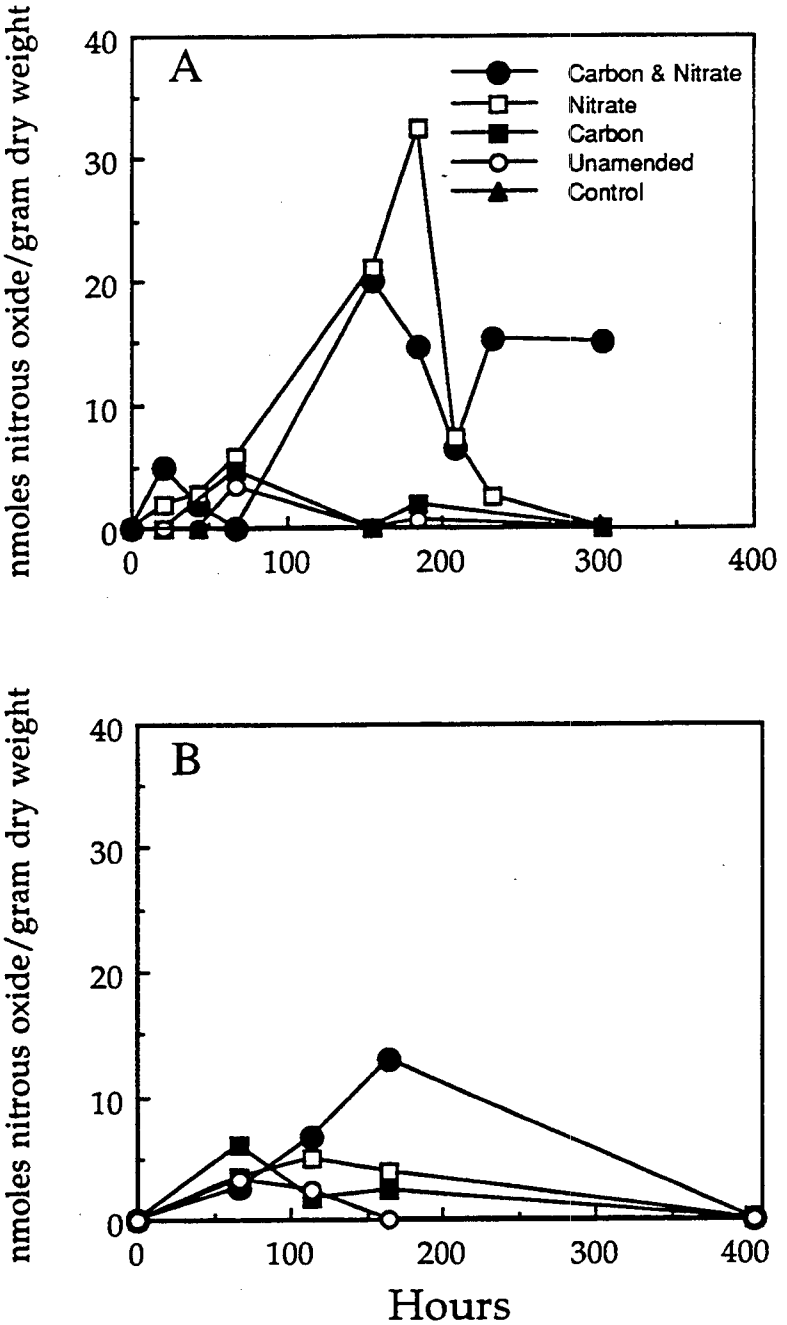

Figure 4. Denitrification by Laguna Cinco sediment; (A) stored sample. (B) fresh sample

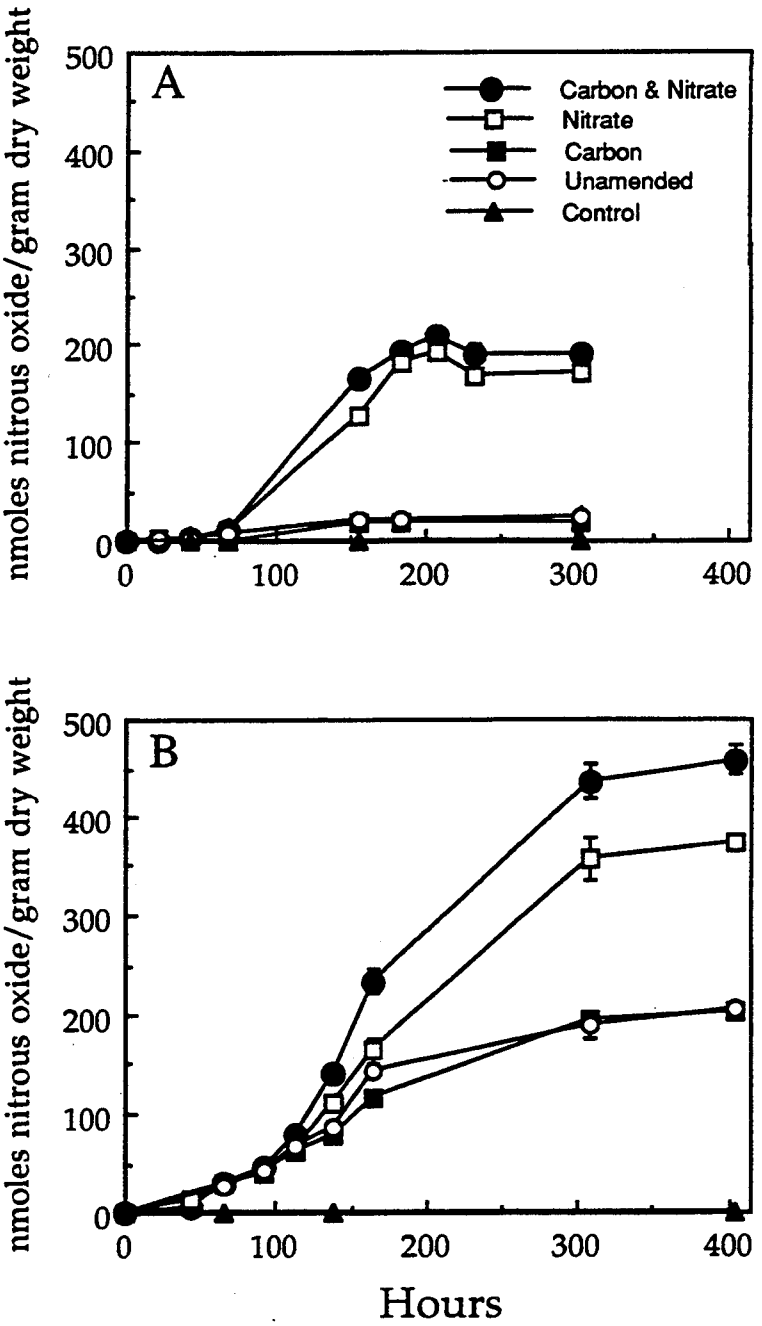

Figure 5. Denitrification determined by the acetylene blockage technique in (A) stored sample, (B) fresh sample

Table 8a. Denitrification in Laguna Cinco Sediment (Stored 2 Months)

Time	Control*	Addition: None	Carbon	Nitrate	Carbon & Nitrate
(Hours)		nmol nitrous oxide**/sample			
0	nd	nd	nd	nd	nd
21		1.96 ± 0.58	2.16	1.50 ± 0.11	0.514
42.5	nd	3.44 ± 0.64	na	3.21	3.86 ± 0.22
67		8.16	0.00 ± 0.00	9.64 ± 0.74	9.64
155	nd	20.7 ± 1.4	19.6 ± 0.1	129 ± 5	166 ± 6
183		22.3 ± 3.0	19.4 ± 0.9	183 ± 0	194 ± 2
207		na	na	192 ± 0	209 ± 2
231		na	na	168 ± 4	191 ± 9
303	nd	23.3 ± 1.5	18.3 ± 0.2	171 ± 8	191 ± 5

Table 8b. Denitrification in Laguna Cinco Sediment (Assayed Within 48 Hours)

Time	Control*	Addition: None	Carbon	Nitrate	Carbon & Nitrate
(Hours)		nmol nitrous oxide**/sample			
0	nd	nd	nd	nd	nd
45		na	na	13.6 ± 0.1	5.58 ± 3.94
66	nd	26.5 ± 1.1	29.0 ± 1.0	30.5	30.5
91.5		43.0 ± 0.3	44.2 ± 4.6	39.4 ± 1.2	45.2 ± 0.5
114	nd	68.6 ± 3.1	61.6 ± 1.8	65.6 ± 2.1	79.6 ± 1.2
138		86.0 ± 3.7	78.1 ± 1.5	110 ± 3	141 ± 5
165		142 ± 5	115 ± 3	164 ± 12	233 ± 12
309		188 ± 11	194 ± 2	357 ± 21	436 ± 18
405	nd	205 ± 1	202 ± 8	372 ± 3	458 ± 15

* Formalin treated samples
** Dissolved gas concentration not included
nd = none detected
na = not analyzed

Table 9a. Denitrification Rate (Stored Sample)*

Addition	Rate (nmol nitrous oxide/g dry weight/hour)
None (Unamended)	0.14
Carbon	0.22
Nitrate	1.36
Carbon and Nitrate	1.78

*Rate after lag phase, from 67 to 155 hours (see Table 8a).

Table 9b. Denitrification Rate (Fresh Sample)*

Addition	Rate (nmol nitrous oxide/g dry weight/hour)
None (Unamended)	1.17
Carbon	0.87
Nitrate	1.93
Carbon and Nitrate	3.00

*Rate after lag phase, from 66 to 165 hours (see Table 8b).

of 1.44 nmol nitrous oxide gdw^{-1} h^{-1}, as shown in Table 9b. These samples are not carbon-limited. Addition of nitrate, however, increased N_2O production, suggesting that these samples are nitrate-limited. In the absence of carbon or nitrate limitations in the freshly collected sediment, denitrification proceeded at 3.00 nmol N_2O gdw^{-1} h^{-1}, and resulted in the production of 458 nmol nitrous oxide gdw^{-1} (Table 8b); all of the total nitrate present was reduced.

These experiments show that microorganisms present in mud from Laguna Cinco denitrified 70-80% of the added nitrate in nitrate-amended samples and 80%-100% of the nitrate in carbon and nitrate samples. We added 540 nmol nitrate gdw^{-1} to each sample; therefore, complete conversion of the nitrate to nitrous oxide should yield 270 nmol N_2O gdw^{-1}. About 70% of the added nitrate was reduced to nitrous oxide in the stored sample, or 192 nmoles N_2O gdw^{-1} was produced. Freshly collected sediment with added nitrate produced 372 nmoles N_2O gdw^{-1}; 81% of the total nitrate present was reduced. This sediment contained a large quantity of indigenous nitrate.

Denitrification in unamended samples provides information about the nutrient conditions in the sediment. If all the available indigenous nitrate was converted to nitrous oxide in the carbon-amended sample, then the stored sediment contained about 40 nmoles of nitrate gdw^{-1}, and the fresh sediment contained 410 nmol gdw^{-1}. Similar conversions of nitrate to nitrous oxide using a pure culture were used to determine sub-ppb concentrations of nitrate in lake waters (Christensen and Tiedje, 1988). Thus, the assay can be used not only to detect the presence and activities of denitrifying organisms, but also to detect easily metabolizable low-molecular-weight organic carbon compounds in the environment (Francis et al., 1989).

The presence of metabolizable carbon and nitrogen compounds in the WIPP surficial environments has important implications. For example, a steady mix of microbial populations can be actively maintained when presented with an adequate supply of a

limiting nutrient. From the standpoint of the long-term experiment, we have shown, in part, that the organisms are active in the proposed inoculum.

The results also show that active denitrification under anaerobic conditions occurred in Laguna Cinco mud collected in August 1991 and stored for two months, and in mud collected in December 1991, and assayed within 48 hours. Therefore, the stored and fresh samples contain viable organisms that can be used as an inoculum for the long-term experiment.

3.3.3.2 DENITRIFICATION IN G-SEEP

Figure 6 and Table 10 show denitrification in G-Seep brine. In the carbon and nitrogen amended samples ~ 84% of the added nitrate (150 nmoles) was converted to N_2O (62.7 nmoles) after two months of incubation. The dissolved N_2O in the brine was not determined; hence, the N_2O values reported are not corrected for N_2 solubility. Lack of N_2O production in the unamended and carbon amended samples suggests that G-Seep brine is nitrate-limited. However, in the nitrate-amended samples, 45% of the added nitrate was converted to N_2O, indicating metabolizable carbon is present which eventually became limiting. These results also suggest that the microbes in the brine were able to readily metabolize the added carbon and nitrate via denitrification.

3.3.3.3 DENITRIFICATION BY AN AXENIC PURE CULTURE

A pure culture of a denitrifying bacterium was isolated from the sediment slurry sample during the initial denitrification experiments. The isolate was grown in the following medium: sodium succinate, 5 g; potassium nitrate, 1 g; yeast extract, 0.5 g; WIPP salt (20% w/v), 1000 mL; pH 6.85. The isolate, designated as BWFG-1, was a gram-negative rod, facultative anaerobe, and grew rapidly within 48 hours in the liquid medium. On solid medium, the culture produced circular, convex, light-orange colonies with entire margins.

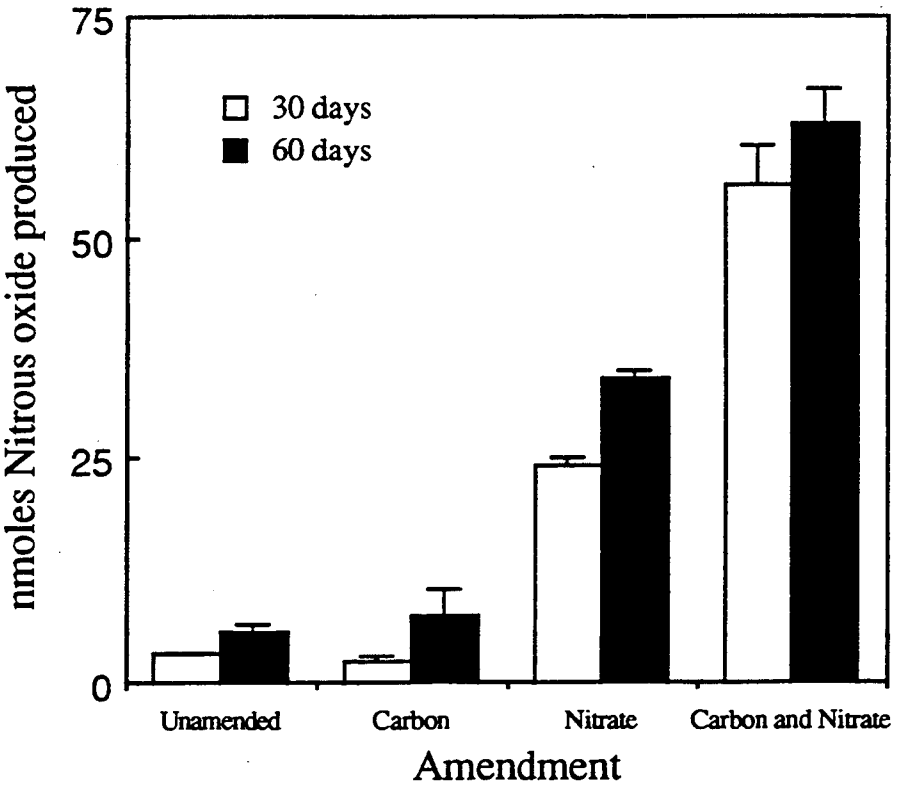

Figure 6. Denitrification in G-Seep Brine. [In C&N amended samples, 84% of the added nitrate was converted to nitrous oxide]

Table 10. Denitrification in G-Seep Brine

		Amendment*			
Time	Control*	Unamended	Carbon	Nitrate	Carbon & Nitrate
(Days)	----------	nmoles nitrous oxide***/sample			----------
0	nd	nd	nd	nd	nd
3.25	nd	nd	nd	nd	nd
30	nd	3.30 ± 0.01	2.53 ± 0.43	24.2 ± 0.8	55.9 ± 4.4
60	nd	5.72 ± 0.72	7.58 ± 2.98	34.0 ± 0.9	62.7 ± 4.0

Samples injected with acetylene to accumulate nitrous oxide
* Amendment: Carbon = 1.5 umol succinate, Nitrate = 150 nmol
** Formalin treated samples
*** Dissolved gas concentration not included
nd = none detected

BWFG-1 is an archaebacterium. This was confirmed by hybridization with fluorescently labeled oligodeoxynucleotide probes complementary to the 16S ribosomal RNA segment specific for archaebacteria (DeLong et al., 1989). Extreme halophiles were previously described in the literature as being archaebacteria, placing them in a distinct phylogenetic group of organisms that contains other genera from extreme environments, such as methanogens, thermoacidophiles, and alkalophiles (Ross et al., 1981).

The rate of denitrification by BWFG-1 was determined by adding 2.5 mL of a 24 h culture to 40 mL of medium in the presence of acetylene. Control samples included uninoculated medium, inoculated samples treated with 0.5% v/v formaldehyde, and inoculated samples without acetylene. Triplicate samples were incubated anaerobically at 30°C. The number of bacterial cells were counted using the DAPI method.

Production of nitrous oxide by the pure culture is shown in Figure 7 and Table 11. The bacterium denitrified nitrate at a rate 2.5 μmol h^{-1}. About 72% of the added nitrate (392 μmol) was converted to N_2O (142 μmol) in about three days; these N_2O values do not include the amount of N_2O dissolved in the growth medium. There was no accumulation of nitrous oxide in samples incubated without acetylene, indicating complete reduction of nitrate to N_2. In Figure 8, the direct counts of the bacteria during the course of denitrification are presented. A marked increase in the number of cells corresponding to nitrous oxide production was observed. The pH of the growth medium increased from 6.85 to 8.00 after three days, and turbidity measured spectrophotometrically at 600 nm was 0.08 at 0h, 0.58 at 29h, and 0.80 at 50h.

3.4 Summary, Short-Term Experiments

1. Direct microscopic examination of brine from Nash Draw lakes and from G-Seep showed that between 10^4 to 10^7 cells/mL bacteria are present.

2. Cellulose was degraded by a mixed culture derived from samples consisting of Nash Draw sediment slurry, salt crystals, and G-Seep brine in the presence of added nutrients (nitrate, phosphate, and yeast extract). Cellulose degradation was confirmed by an increase in carbon dioxide production and disintegration of filter paper.

3. Storage of sediment and lake water at 4°C for about two months did not significantly affect the activity of microbes in the samples.

4. The denitrification assay is a useful method to rapidly determine the activity of dentrifying microbes in WIPP samples. The assay also confirmed the presence of metabolizable carbon in the sediment and in WIPP brine.

5. Denitrifiers were detected in G-Seep, although their source was not identified.

6. An axenic culture of archaebacteria was isolated from the WIPP site and denitrified nitrate at a rate of 2.5 μmol h^{-1}. The characteristics and growth rate of this culture have been elucidated for future studies to examine the influence of environmental variables on specific microbial processes in the WIPP repository.

7. Short-term experiments have provided useful information on microbial activity under accelerated test conditions that are relevant to the WIPP repository; further work will include examination of the other anaerobic processes such as fermentation, sulfate reduction, and methanogenesis.

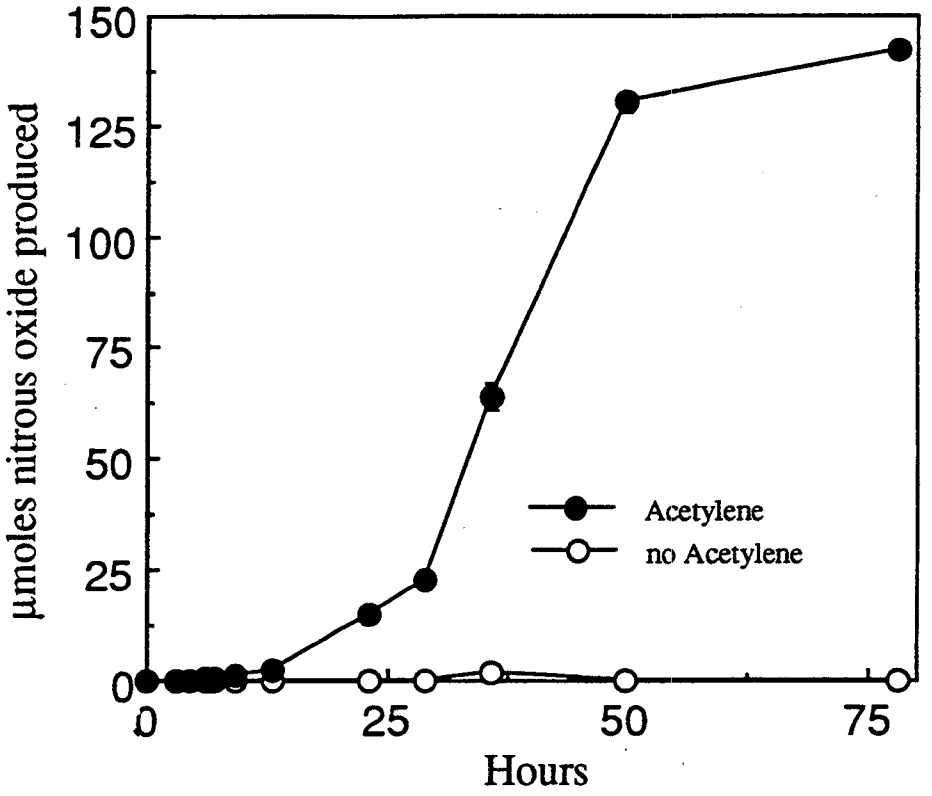

Figure 7. Denitrification by a pure culture of bacteria isolated from the WIPP site. [72% of added nitrate was converted to nitrous oxide at a rate of 2.5 µmoles/h]

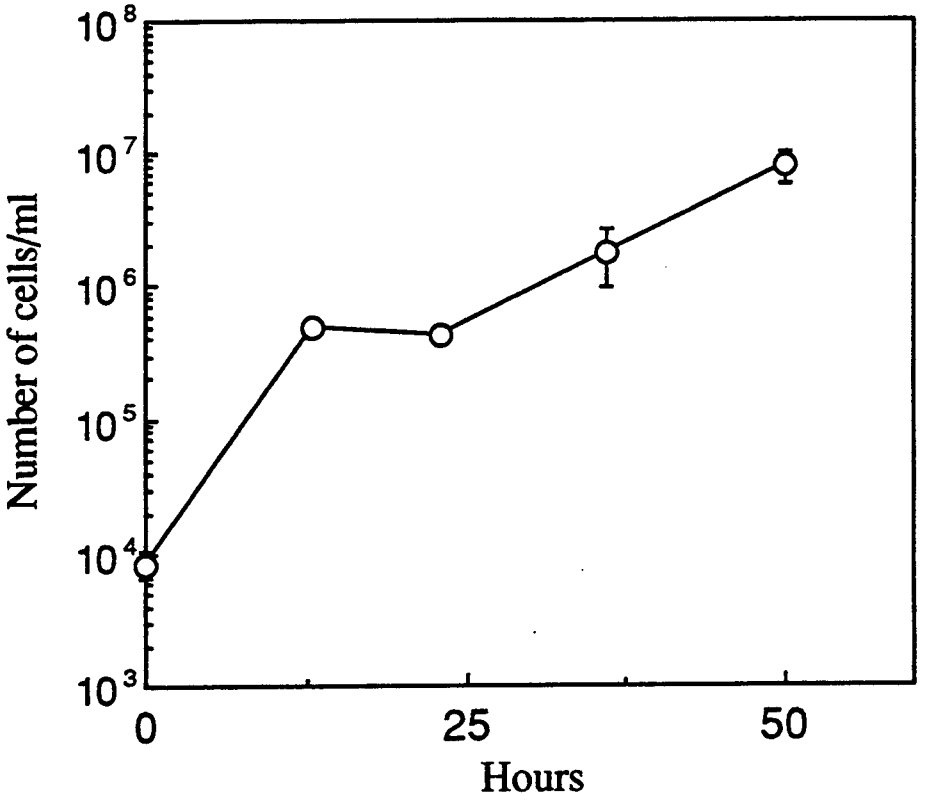

Figure 8. Growth of denitrifying bacteria.

Table 11. Denitrification by a Pure Culture Isolated from the WIPP Environment: Nitrous Oxide Production Over Time

Time (Hours)	Inoculated (w/o acetylene)	Inoculated (w/ acetlyene)	Inoc.* (w/o acet.)	Inoc.* (w/acet.)	Uninoc. (w/o acet.)	Uninoc. (w/acet.)
	----------μmoles nitrous oxide**/sample----------					
0	nd	nd	nd	nd	nd	nd
3	0.001 ± 0.001	0.011 ± 0.034	nd	nd	nd	nd
4.5	0.007 ± 0.002	0.245 ± 0.081	nd	nd	nd	nd
6	0.009 ± 0.002	0.434 ± 0.090	nd	nd	nd	nd
7	0.010 ± 0.003	0.563 ± 0.016	nd	nd	nd	nd
9.25	0.009 ± 0.003	0.990 ± 0.027	nd	nd	nd	nd
13	0.014 ± 0.003	2.33 ± 0.03	nd	nd	nd	nd
23	0.019 ± 0.003	15.2 ± 0.9	nd	nd	nd	nd
29	0.187 ± 0.084	23.0 ± 0.5	nd	nd	nd	nd
36	1.50 ± 0.38	63.8 ± 2.6	nd	nd	nd	nd
50	0.086 ± 0.059	130 ± 2	nd	nd	nd	nd
78	0.140 ± 0.030	142*** ± 1	nd	nd	nd	nd

Defined culture medium (per sample): 740 umoles succinate, 392 umoles nitrate, 20% w/v WIPP salt.
* = Sample treated with formalin (0.5%)
** = Dissolved gas concentration not included
*** = 72% of nitrate added converted to nitrous oxide
ND = none detected

4.0 LONG-TERM EXPERIMENTS

4.1 Objective

The objective of the long-term study is to determine the rate and extent of gas generation over the long term (>2 years) from cellulose biodegradation under humid and inundated conditions, in the presence and absence of added nutrients.

4.2 Rationale

The TRU waste that will be placed in the WIPP repository contains an average of about 10 kg of cellulosic material per drum, approximately 70% of which is paper (Brush 1990). Initially, the repository will be ventilated, but the addition of backfill (salt, or bentonite/salt mixture to fill void spaces around waste containers) will seal the drums inside the disposal rooms. Initially, the repository will also be dry, but after sealing, humid conditions will develop. The ambient humidity is expected to be 18 to 27 g/m^3 (about 74% relative humidity, RH), and the temperature about 30°C (Brush, 1990). Microenvironments of condensed liquid brine may exist under humid conditions. Diffusion of water vapor through high-efficiency particulate (HEPA) air filters on waste containers will result in humid conditions inside the containers. Eventually, corrosion or rupturing of the containers due to salt creep-room closure will expose the waste to salt and backfill. Process sludges from other breached waste containers are expected to be leached by the brine. This is presumed to be the major source of nitrate and phosphate (nutrients) in the repository. The accumulation of potentially intruding brines from the surrounding Salado Formation will most likely begin after sealing the rooms, which will inundate them. In the event of potential, inadvertent human intrusion, fluids may also seep in from the Castille Formation into the Salado Formation. The atmosphere inside the disposal environment will become anaerobic in the short-term (months to years) due to consumption of oxygen by corrosion, radiolysis, and microbial processes acting on the waste materials. Microenvironments of trapped air that contain oxygen will continue to exist after sealing. Radiolysis of organic

wastes will deplete oxygen, whereas radiolysis of nitrate-bearing sludges will release oxygen. Radiolysis of brines may also produce some oxygen.

A succession of microbial processes will occur under the changing environmental conditions inside the repository. Environment changes from aerobic to anaerobic, humid to inundated (and possibly back to humid), and asaline to saline will affect the activities of (i) microbes initially present in the waste, and (ii) resident and indigenous halotolerant or halophilic bacteria in the brine and salt. To examine the influences of various microbial processes on gas generation, samples were treated to simulate the following scenarios.

4.2.1 Aerobic (Sealed) Treatments

During the early stages of waste emplacement, the environment will be aerobic but will become anaerobic over time after closure because of corrosion, aerobic microbial activity, and radiolytic processes. In these long-term experiments, the cellulose samples will be placed in serum bottles, sealed with air, and incubated. The conditions will be initially aerobic and become anaerobic with time due to consumption of oxygen by aerobes, thus paving the way for anaerobic microbial activity.

4.2.1.1 SCENARIO 1

After emplacement and sealing of waste containers in WIPP disposal rooms, the intact and nearly intact containers will be isolated from backfill and brine. The humidity inside the disposal rooms is expected to be 18 to 27 g/m^3 (about 74% RH), and humidity inside the containers is expected to reach equilibrium with the room environment. The cellulose will be in an asaline, humid, aerobic environment for possibly months, years, or up to a few decades, as water vapor diffuses through the waste drum particulate filters. Microorganisms capable of cellulose degradation and gas production under these conditions will be active probably in an environment with a sub-optimal moisture content.

4.2.1.2 SCENARIO 2

Room closure and corrosion will breach many of the containers and expose the waste material to backfill, salt, and brine. The cellulose is expected to contact the salt and backfill material, and microbial degradation of the cellulose is expected to occur under saline, humid conditions.

4.2.1.3 SCENARIO 3

Influx of intruding brines from the Salado Formation, capillary rise through the backfill, and dissolution of brine will all tend to inundate some portion or all of the disposal rooms with brine. Inundation will accelerate the onset of anoxic conditions as any residual air pockets are flooded. Process sludge TRU wastes contain significant quantities of nitrate and lesser quantities of phosphate. The breach of these sludge containers and inundation by brine will then transport the nitrate and bring nonhalophilic, halotolerant and halophilic microbes into contact with cellulose.

Inundation of the WIPP waste by brine by the above or other processes will accelerate the activities of halophilic and halotelerant microbes. In particular, dentrification activity under microaerophilic and anaerobic conditions could be significant and may contribute to the total quantity and to the proportion of gases produced (N_2, N_2O, and CO_2).

4.2.2 Anaerobic Treatments

At least a portion of the WIPP repository wastes will be anaerobic at the start (within their containers possibly due to radiolysis and microbial action at the initial stages) and remain anaerobic thereafter. Under these conditions, short-term (i.e., operational phase) and long-term degradation of cellulosic waste by anaerobic microorganisms could be significant.

4.2.2.1 SCENARIO 4

Some of the cellulose in the disposal environment may become anaerobic before any significant aerobic microbial activity. Cessation of air flow from closure of the disposal rooms, and oxic corrosion plus radiolysis, may bring about anoxic conditions in a humid environment. If the cellulose is exposed to salt under humid conditions, halotolerant or halophilic microbes that can grow in humid and anoxic environments may be involved in degrading cellulose. With the onset of anoxic conditions, alternate electron acceptors such as nitrate and sulfate will be used by microbes in degrading cellulose and its degradation product intermediates.

4.2.2.2 SCENARIO 5

With the onset of brine intrusion in the disposal rooms, inundation will be more likely to cause anaerobiosis by forcing out any residual trapped air. Cellulose in contact with brine may undergo degradation by halophilic and halotolerant microbes present in the brine and waste. Because of the breaching of the waste containers, it is likely that nitrate originating in the sludges will be transported by the brine. It may come in contact with cellulosic wastes and enhance the degradation of cellulose.

Scenarios 3 and 5 will be examined in the long-term inundated experiment. Scenarios 1, 2 and 4 will be examined in a long-term humid experiment in CY1993. Figures 9 through 12 give the complete treatment matrix for the long-term inundated experiments.

4.3 Materials and Methods

4.3.1 Cellulosics

Simulated TRU cellulosic waste material was composed of four types of paper: (i) filter paper, (ii) white paper towel, (iii) brown paper towel, and (iv) Kimwipes® (lintless tissue

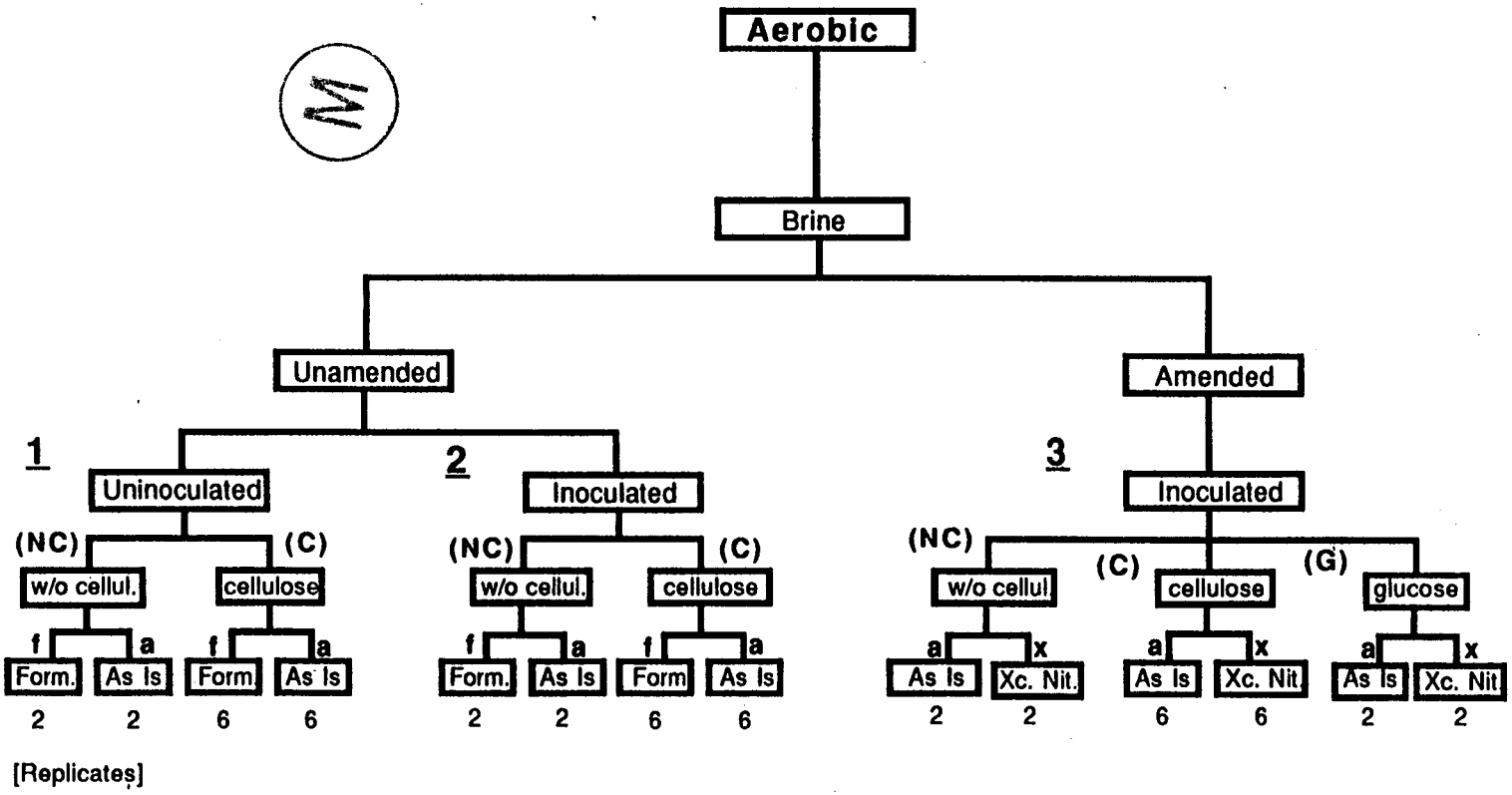

Figure 9. Long-term inundated experiment treatment matrix (aerobic samples).

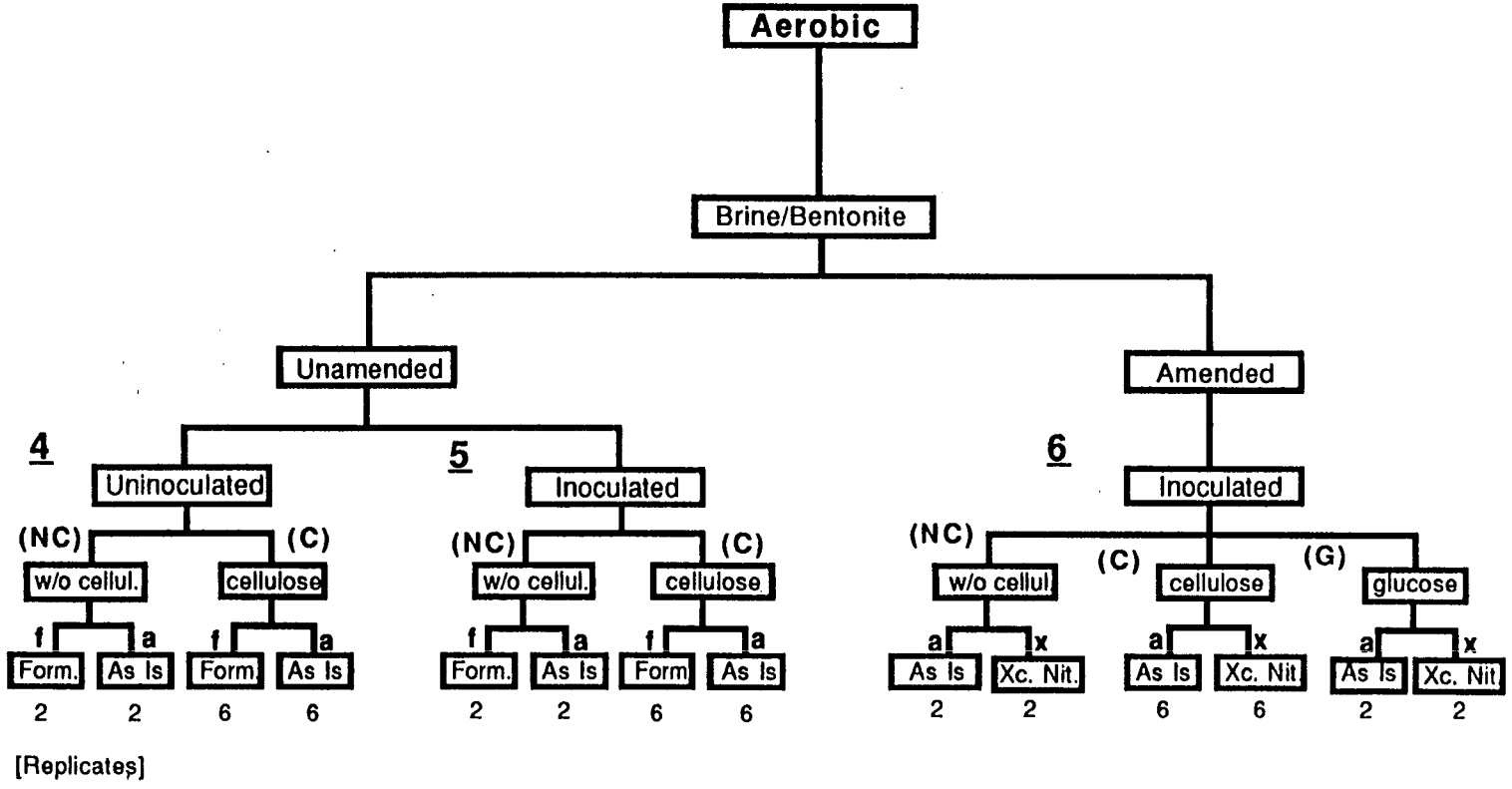

Figure 10. Long-term inundated experiment treatment matrix (aerobic samples containing bentonite).

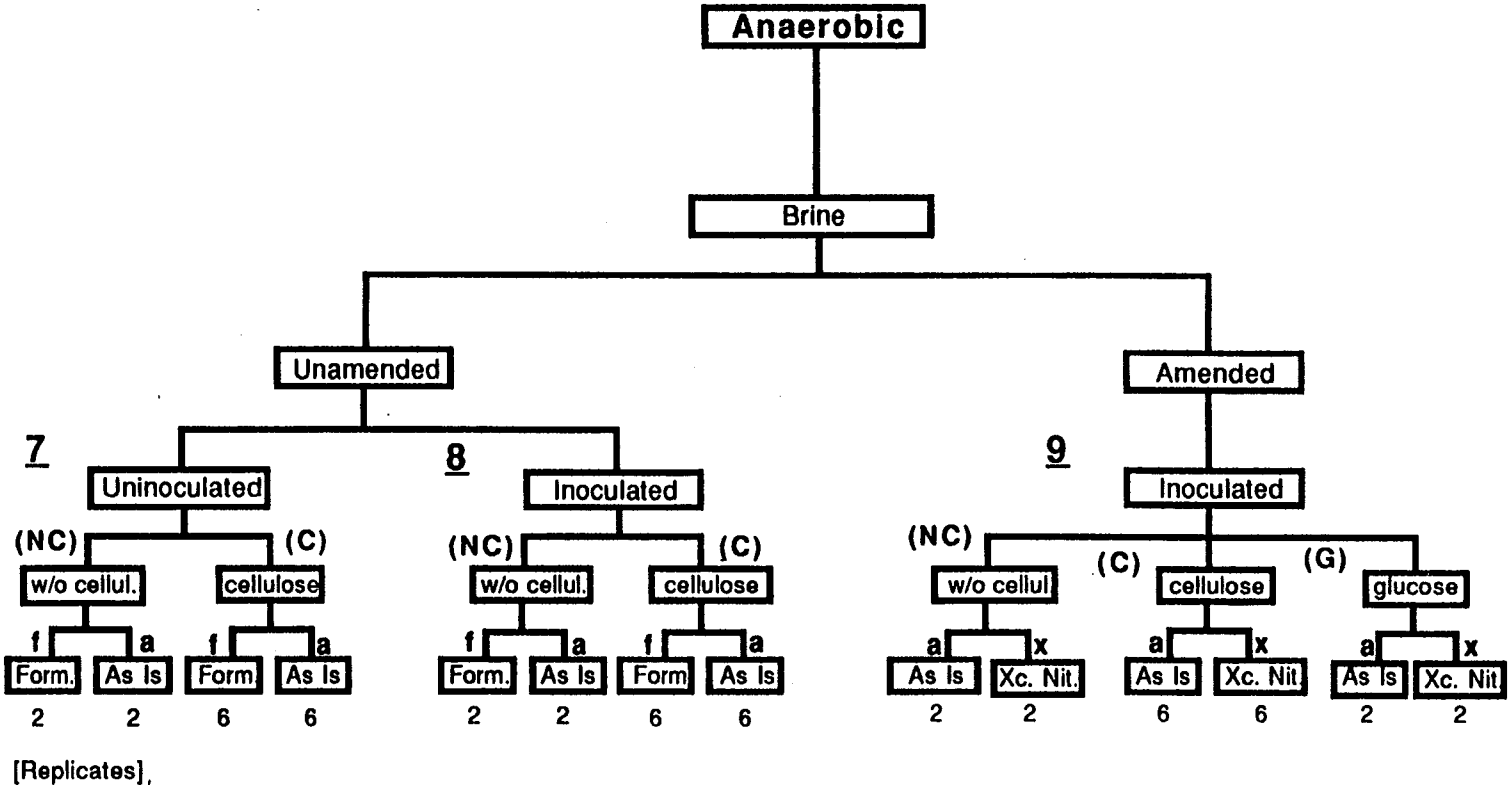

Figure 11. Long-term inundated experiment treatment matrix (anaerobic samples).

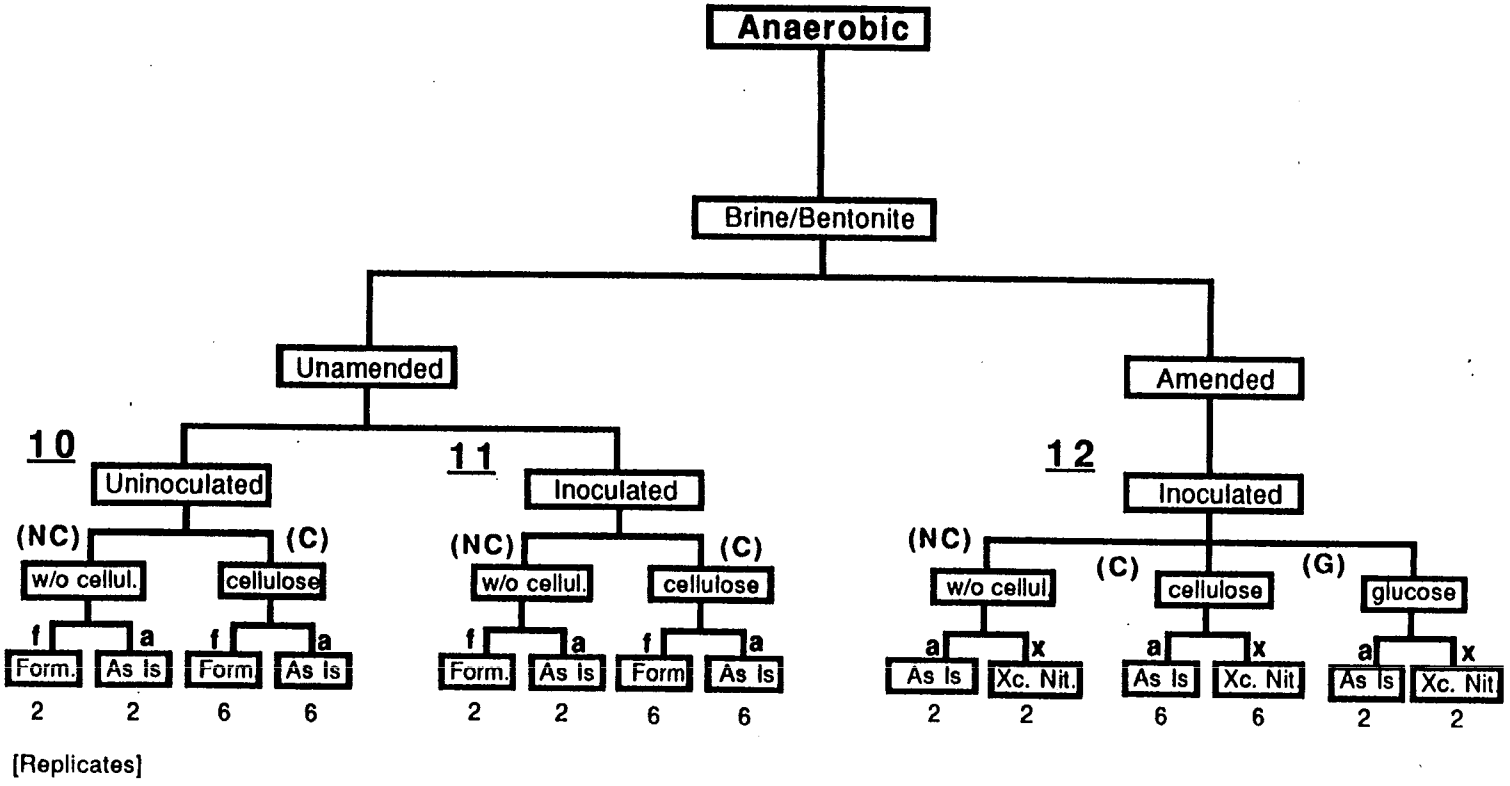

Figure 12. Long-term inundated experiment treatment matrix (anaerobic samples containing bentonite).

wipes). These papers are typical cellulosic wastes from laboratory and process activities. The four paper types were cut into strips in a large paper shredder, and then cut into 1 cm x 1 cm squares.

Samples of shredded paper types, each weighing 1.25 g, were thoroughly mixed and added to 160 mL acid washed (10% HCl), rinsed, sterile (autoclaved at 120°C, 20 psi for 20 min) serum bottles.

4.3.2 WIPP Brine

Fifteen liters of G-Seep #9 brine were provided by SNL and stored at 4°C until use.

4.3.3 Bentonite

Bentonite clay in two one-L containers was provided by SNL. The bentonite was a granular MX-80 Volclay bentonite available from the American Colloid Company of Belle Fourche, SD (Table 12).

4.3.4 Inoculum

The microbial inoculum used in these studies were obtained from the following three sources (Table 13): (i) mud and brine from Nash Draw: collected on December 12, 1991 and stored at 4°C, the mud was stored anoxically in serum bottles, (mud samples were filtered through sterile cotton in a nitrogen-filled glove box to remove large particulates); (ii) brine from the WIPP underground workings: 200 mL of G-Seep were collected on December 12, 1991; and (iii) asaline inoculum from laboratory contamination: 2.5 g of dust containing asaline microorganisms was gathered from laboratories in Bldg. 318 at BNL.

The mud, brine, and dust samples were then mixed together in a sterile beaker in a nitrogen-filled glove box. The total volume of the mixed inoculum was 583 mL. The

Table 12. Composition of Bentonite*.

Chemical Composition	$(NaCa)_{.35}$ $(Al_{1.60}Fe_{.15}Mg_{.25})$ $(Si_{3.90}Al_{.10})$ 0_{10} $(OH)_2$		
Montmorillonite Content	90 Percent		
Typical Chemical Analysis	Silica		63.02% SiO_2
	Alumina		21.08% Al_2O_3
	Iron (Ferric)		3.25% Fe_2O_3
	Iron (Ferrous)		0.35% FeO
	Magnesium		2.67% MgO
	Sodium and Potassium		2.57% Na_2O
	Calcium		0.67% CaO
	Crystal Water		5.64% H_2O
	Trace Elements		0.72%
Exchangeable Ions (Milli-equivalents/ 100 g)	Sodium	55-65	
	Calcium	15-25	
	Magnesium	10-15	
Moisture Content	10% Maximum as Shipped		
pH	8.5 - 10.5		

* Data provided by the American Colloid Company, Skokie, IL.

Table 13. Composition of Mixed Inoculum.

Source	Mud Slurry (mL)	Brine (mL)
Laguna Quatro Mud and Brine	60	40
Laguna Cinco Mud and Brine	35	40
Laguna Tres South Mud and Brine	13	40
Lindsey Lake Mud and Brine	50	40
Surprise Springs Mud and Brine	25	40
G-Seep Brine		200
Total	183	400

activity of the mixed inoculum was examined by incubation under aerobic and anaerobic conditions in the presence of metabolizabled substrate. The results are presented in Appendix E.

4.4 Sample Treatments

The treatments consisted of (a) 100 mL of brine, and (b) 100 mL of brine and 5 g mixed cellulosic papers. The samples were incubated with and without nutrients, which consisted of yeast extract (0.05%), potassium phosphate dibasic (0.1%), and ammonium nitrate (0.1%). Some samples also received excess nitrate as potassium nitrate (0.5%).

4.4.1 Anaerobic Sample Preparation

The serum bottles containing the mixed cellulosic papers were flushed with nitrogen and placed inside an anaerobic, nitrogen-containing glove box for 24 hours before inoculation to remove any trapped air. G-Seep brine (10 L) was removed from storage at 4°C and equilibrated overnight at room temperature. One hundred mL of the brine solutions (with and without nutrients or excess nitrate) were added to sample bottles with and without bentonite containing either no cellulose, cellulose, or glucose. Bentonite (6 g) was added to separate sample bottles inside the glove box to determine its influence on gas production. The samples were gently mixed to distribute the bentonite.

The microbial inoculum prepared from various sources was continually mixed and 4 mL was added to specific samples (3.8% V/V inoculum). The samples were gently mixed (to blend the inoculum) and then capped with butyl rubber stoppers. Control samples received 3 mL of 37% formaldehyde to give a final concentration of 1% formaldehyde.

4.4.2 Aerobic Sample Preparation

Aerobic (sealed) samples were prepared as described above with the following exceptions: 1) brine solutions were not purged with ultra high-purity (UHP) N_2, 2) the mixed inoculum was removed from the glove box; 3) brine was added to the bottles, inoculated, and capped with butyl rubber stoppers outside the glove box, thereby sealing air in the headspace. Appendix C has a detailed description of all the treatments (aerobic and anaerobic) and the number of replicate samples. All samples were placed in a 30 ± 2°C incubator.

4.4.3 Gas Analyses

The headspace gas of select samples was analyzed for total gas production, carbon dioxide, and nitrous oxide at time 0 (January 29, 1992) and thereafter at monthly intervals. Control samples were analyzed less frequently. The methods used for the headspace gas analyses are presented in Appendix B.

5.0 RESULTS AND DISCUSSION

The treatments consist of cellulose samples which were (i) uninoculated, (ii) inoculated with a mixed inoculum, (iii) inoculated and amended with nutrients, (yeast extract (0.05%), potassium phosphate (0.1%), and ammonium nitrate (0.1%)), and (iv) inoculated with nutrients plus excess nitrate (0.5% potassium nitrate).

The results presented for aerobic and anaerobic samples represent the amount of gas produced per gram of cellulose plus or minus 1 standard error of the mean (Figures 13 through 24) . A detailed description of the procedure used to calculate the results are given in Appendix D. Tables 1 through 12 in Appendix D present data on a per sample basis, and Tables 13 through 24 in Appendix D present data on a per gram cellulose basis. Gas production rates on a per gram cellulose per day basis are presented in this section in Table 14, and on a per drum of waste per year basis in Table 15.

5.1 Aerobic Treatments

5.1.1 Total Gas Production

Figure 13 shows the total gas produced in samples incubated with an initial atmosphere of air (aerobic). The formalin-treated control samples showed no increase in total gas production, and, in fact, showed a slight decrease. Likewise, uninoculated and inoculated samples which received no nutrients showed a slight decrease in total gas production (-0.18 mL g^{-1} cellulose and -0.34 mL g^{-1} cellulose respectively (Table 13, Appendix D)). The decrease in total gas may be due, in part, to sampling. A decrease in gas production was more evident in inoculated samples because of oxygen consumption, indicating the start of microbial activity, (oxygen was not analyzed in these samples but is planned for the future). In the nutrient-amended inoculated samples, an initial decrease in gas volume (-0.27 mL g^{-1} cellulose at 45 days) was followed by an increase after 69 days to 0.86 mL g^{-1} cellulose at 200 days at a rate of 0.008 mL g^{-1} cellulose day^{-1}. This rate was calculated from linear slope

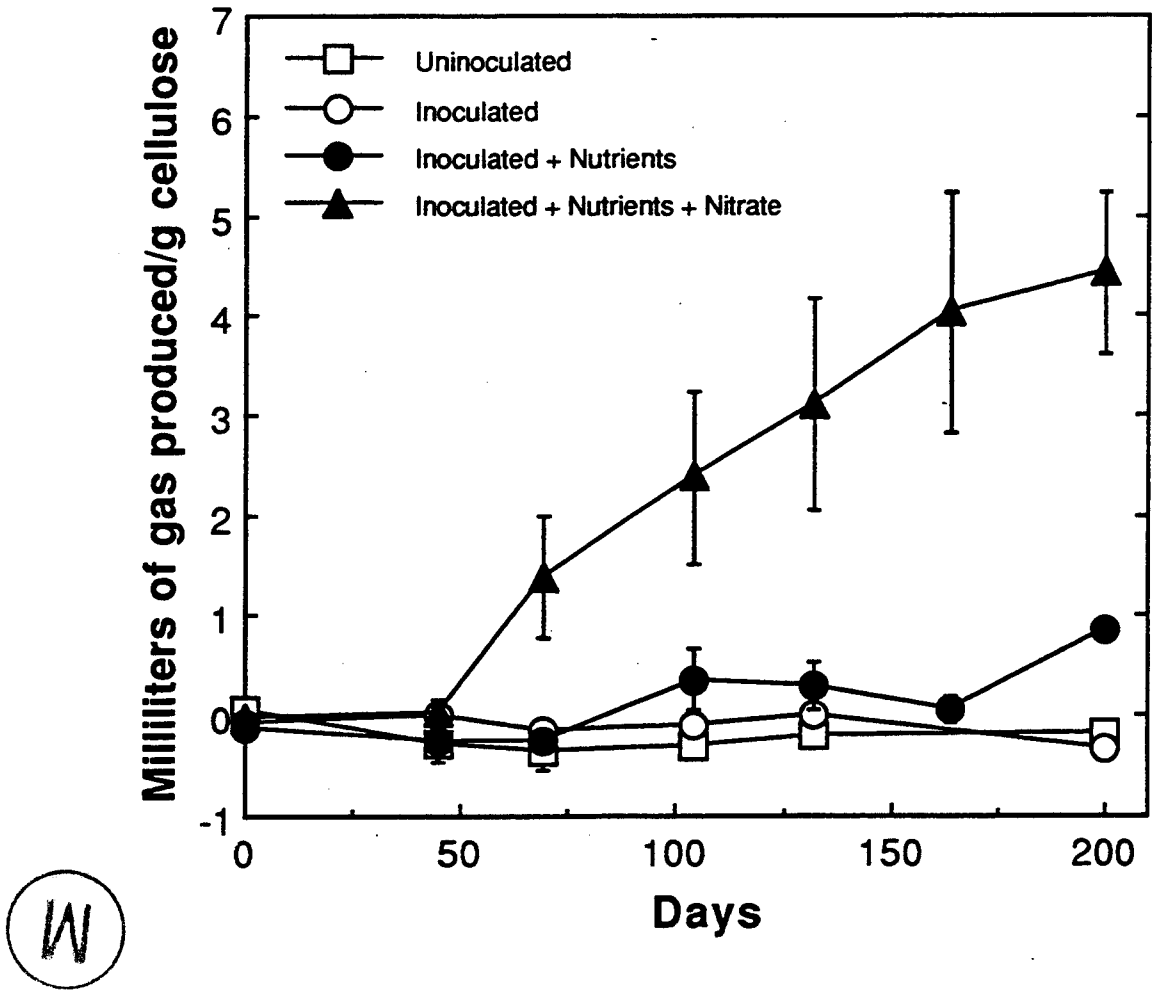

Figure 13. Total gas produced in samples incubated with an initial atmosphere of air.

of gas production from 69 to 200 days. Excess nitrate stimulated the rate of gas production (0.023 mL g^{-1} cellulose day^{-1} after 69 days) resulting in a total of 4.42 mL g^{-1} cellulose at 200 days. This stimulatory effect was also evidenced by the lack of a long lag-phase (see Figure 13) and was a result of the metabolism of dissolved carbon in the presence of nitrate.

Total gas production in aerobic samples containing bentonite is presented in Figure 14. Uninoculated and inoculated samples, with no added nutrients, did not produce gas. Inoculated samples containing nutrients produced 4.38 mL of gas g^{-1} cellulose after 200 days (Table 14, Appendix D), at a rate of 0.028 mL g^{-1} cellulose day^{-1}. In the presence of excess nitrate, the total production increased to 6.07 mL g^{-1} cellulose at 200 days at a rate of 0.034 mL g^{-1} cellulose day^{-1}. Enhanced total gas production was seen in samples containing bentonite, and was apparently due to a combination of abiotic and biotic factors, which are evident upon examining carbon dioxide evolution in the presence of bentonite.

Extrapolation of the gas production rates from mL per g cellulose per day to mol per drum of waste per year is accomplished with the following conversion factors: for an assumed average drum of transuranic waste, with about 10 Kg of cellulosic materials, a total gas generation rate of 0.01 mL g^{-1} cellulose day^{-1} corresponds to a gas generation rate of 1.6 mol gas per drum per year.

5.1.2 Carbon Dioxide Production

Uninoculated samples produced 4.00 μmol of CO_2 g^{-1} cellulose at 200 days, which was slightly less than the formalin treated controls (7.62 μmol g $cellulose^{-1}$), as shown in Figure 15 (and Table 15, Appendix D). However, inoculated samples produced 8.30 μmol of CO_2 g^{-1} cellulose, slightly higher than uninoculated and formalin-treated controls, due to the onset of microbial activity. Inoculated samples containing nutrients produced 40.8 μmol carbon dioxide g^{-1} cellulose at 200 days, at a rate of 0.283 μmol g^{-1} cellulose day^{-1}. In the presence of excess nitrate, 95.6 μmol carbon dioxide g^{-1} cellulose were produced at a rate of 0.484 μmol g^{-1} cellulose day^{-1}, more than twice that of samples without excess nitrate.

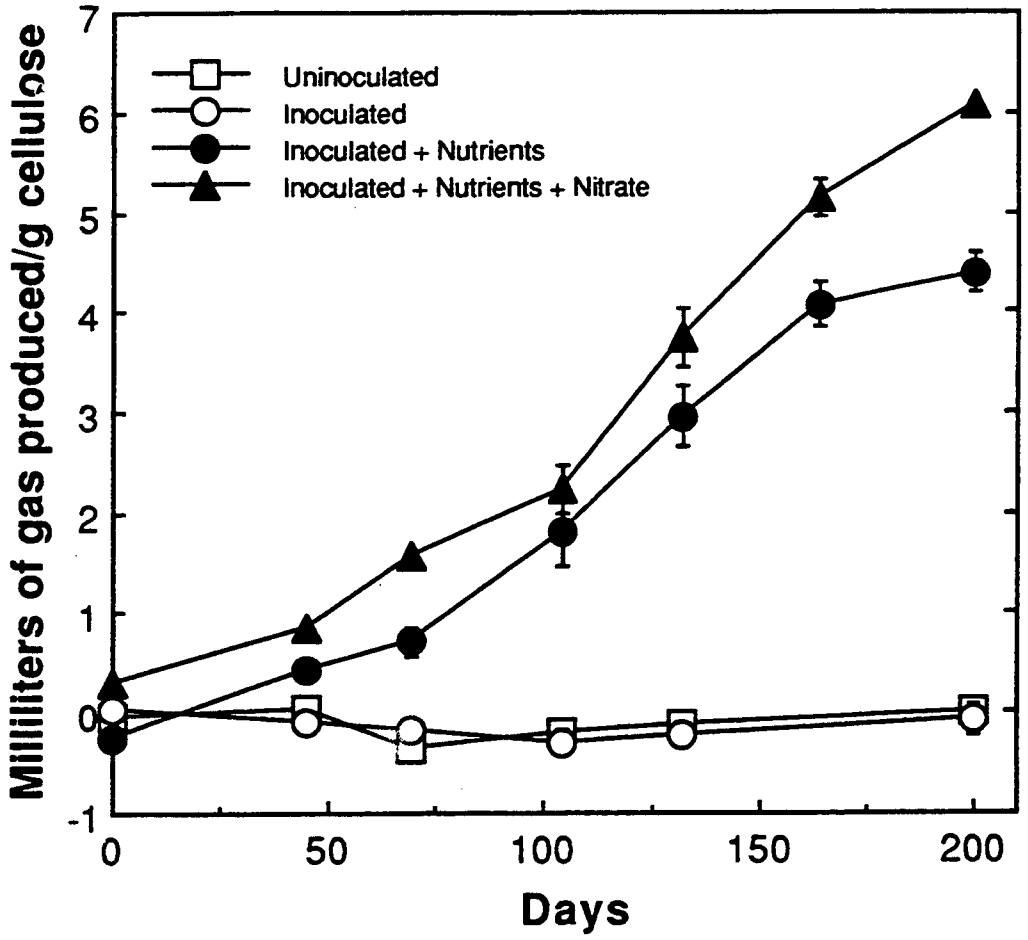

Figure 14. Total gas produced in samples containing bentonite incubated with an initial atmosphere of air.

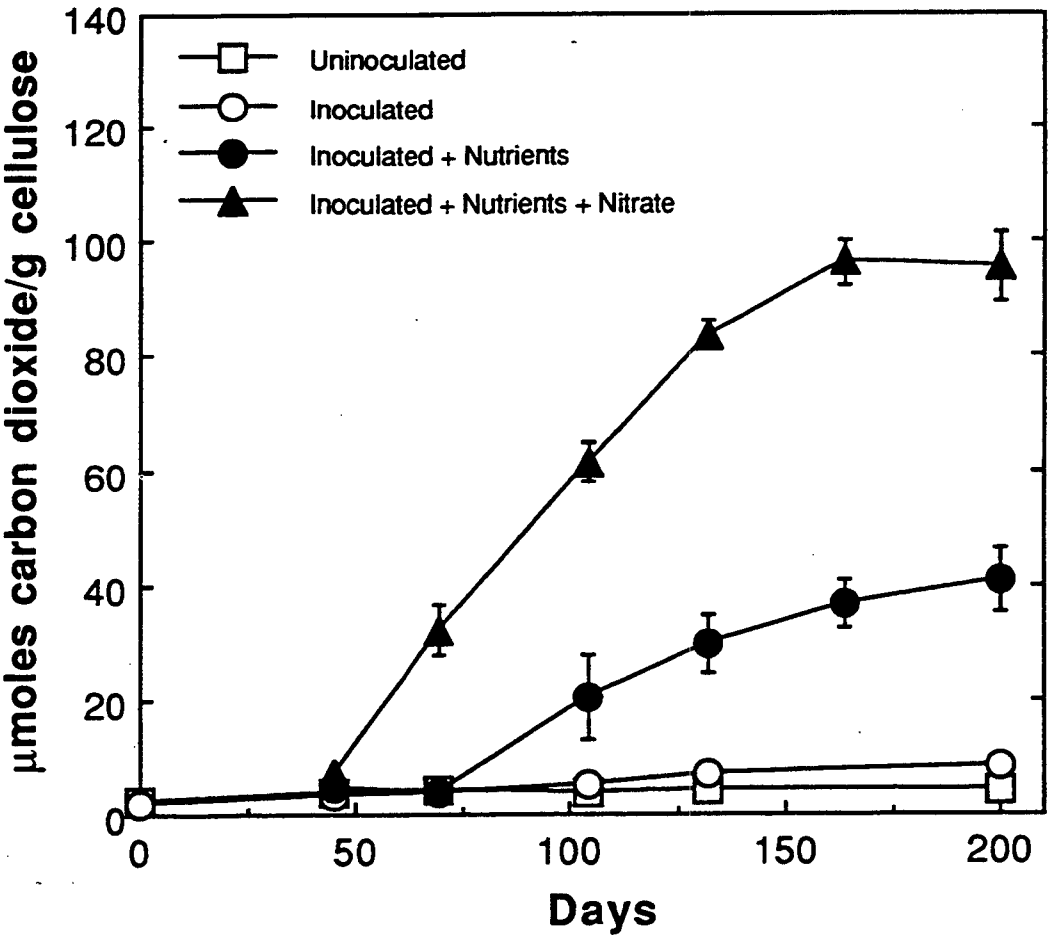

Figure 15. Carbon dioxide produced in samples incubated with an initial atmosphere of air.

Evidence of the growth of halophilic bacteria was noted in nutrient-amended samples by a red/pink color at the bottom of the bottles. This red coloration, characteristic of halophiles, is caused by the presence of bacterioruberin, a 50-carbon carotenoid pigment. This coloration was not seen in formalin-treated controls or unamended samples.

The addition of bentonite resulted in the production of a significant amount of abiotically produced carbon dioxide in samples without cellulose. Table 5, Appendix D shows that carbon dioxide increased from 17.7 μmol sample^{-1} to 40.0 μmol sample^{-1} without cellulose, inoculum and nutrients (sample 4(NC)-a), compared to the same treatment without bentonite. The latter treatment showed a slight increase, from 1.38 to 2.18 μmol sample^{-1} (see Table 2, Appendix D). Formalin-treated control samples also showed the same trend. The net effect was an increase in abiotically produced carbon dioxide (approximately 40 μmol sample^{-1}, (Table 5) by the addition of bentonite. Carbon dioxide production was insignificant in uninoculated unamended samples, (Figure 16). The inoculated unamended samples with bentonite produced 21.5 μmol g^{-1} cellulose at 200 days (Figure 16), whereas the samples without bentonite produced 8.30 μmol g^{-1} cellulose (Table 15, Appendix D). Nutrient-amended inoculated samples produced 69.8 μmol carbon dioxide g^{-1} cellulose, whereas nutrient-amended inoculated samples with excess nitrate produced 116 μmol g^{-1} cellulose at 200 days. After an initial lag of 69 days, carbon dioxide was produced at a rate of 0.533 and 0.869 μmol g^{-1} cellulose day^{-1} in nutrient-amended and nutrient-amended plus excess nitrate samples, respectively. These rates of carbon dioxide production are higher than the same treatments without bentonite (0.283 and 0.484 μmol g cellulose^{-1} day^{-1}, respectively). The buffering effect of $CaCO_3$, as well as minerals and trace elements including Fe, Al, Si and exchangeable cations (Na^+, Ca^{2+}, Mg^{2+}) and anions (SO_4^{2-}) present in the bentonite (Wanner et. al., 1992), may enhance microbial activity. Bentonite also provides an attachment site for microorganisms that may favor their growth.

Extrapolation of the carbon dioxide production rates from μmol per g^{-1} cellulose day^{-1} to mol drums^{-1} of waste year^{-1} is accomplished with the following conversion factor: for an assumed average drum of transuranic waste, with about 10 Kg of cellulosic materials, a

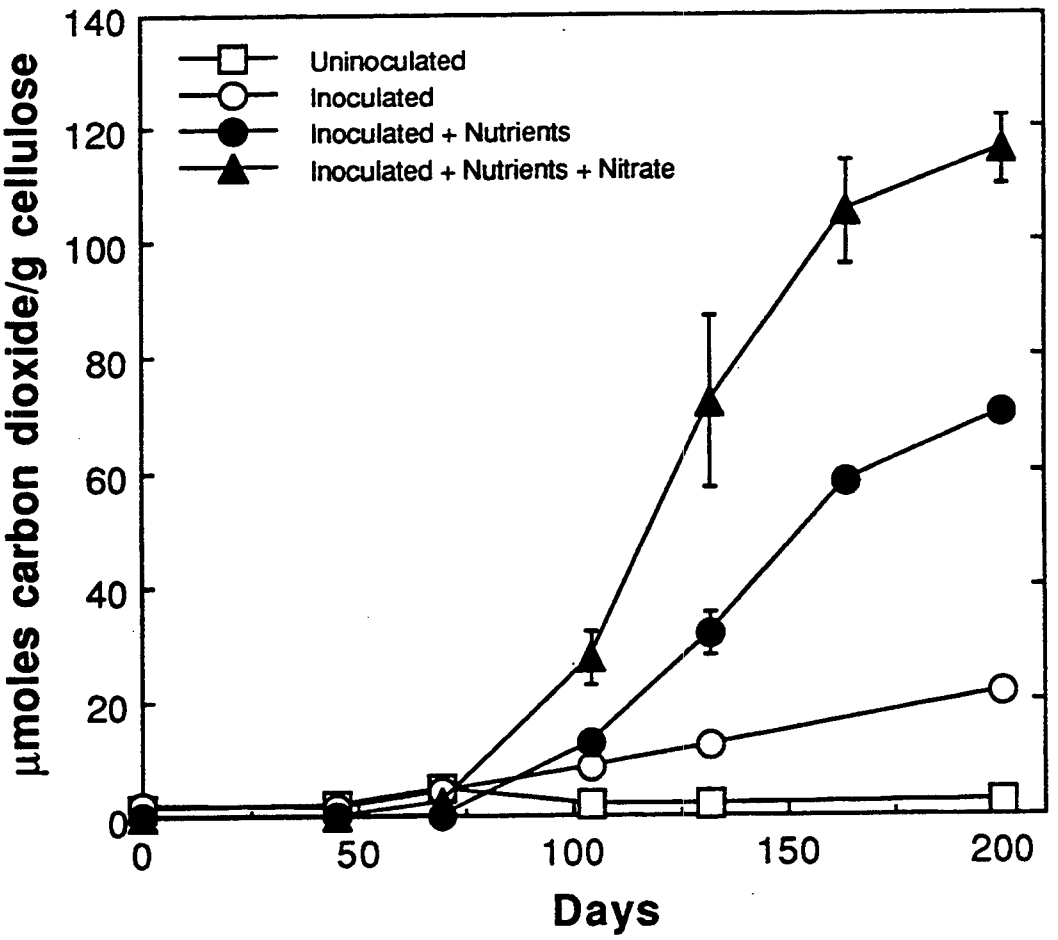

Figure 16. Carbon dioxide produced in samples containing bentonite incubated in an initial atmosphere of air.

carbon dioxide gas generation rate of 1.0 μmol CO_2 g^{-1} cellulose day^{-1} corresponds to 3.7 mol of gas $drum^{-1}$ $year^{-1}$.

5.1.3 Nitrous-Oxide Production

Nutrient-amended samples contained 250 μmol nitrate g^{-1} cellulose, while nutrient-amended samples plus excess nitrate contained 1240 μmol nitrate g^{-1} cellulose. Acetylene was not added to samples and, therefore, the nitrous oxide is both being produced and reduced to N_2 in these samples. Nitrous oxide was not detected in uninoculated or inoculated samples without amendments, indicative of the lack of microbial activity (see Figure 17). Nitrous oxide accumulated in the inoculated nutrient-amended samples, with production peaking at 24.4 μmol g^{-1} cellulose at 132 days and then declining to 1.76 μmol g^{-1} cellulose at 164 days (Table 17, Appendix D). Nitrous-oxide was produced at a rate of 0.674 μmol g^{-1} cellulose day^{-1} from 69 to 104 days. In the presence of excess nitrate, nitrous oxide was produced at the rate of 0.835 μmol g^{-1} cellulose day^{-1}, reaching 115 μmol g^{-1} cellulose at 200 days.

In the presence of bentonite, nitrous oxide was not detected in uninoculated and inoculated unamended samples (see Table 18, Appendix D and Figure 18). The addition of nutrients to inoculated samples stimulated nitrous oxide production from 69 to 104 days at 1.00 μmol g^{-1} cellulose day^{-1}. Thereafter, N_2O did not accumulate in the headspace, probably because of depletion of available nitrate, or rapid conversion of N_2O to nitrogen gas. In the presence of excess nitrate, nitrous oxide was produced at a rate of 0.589 μmol g^{-1} cellulose day^{-1}, reaching a maximum (82.7 μmol g^{-1} cellulose) at 200 days. The continued accumulation of nitrous oxide at 200 days was probably due to the abundance of available nitrate. Addition of bentonite did not result in a substantial accumulation of N_2O in the headspace, suggesting that N_2O was rapidly converted to N_2 as soon as it was formed. Samples with and without bentonite exhibited the same trend (Figures 17 and 18), although less N_2O was detected in the former.

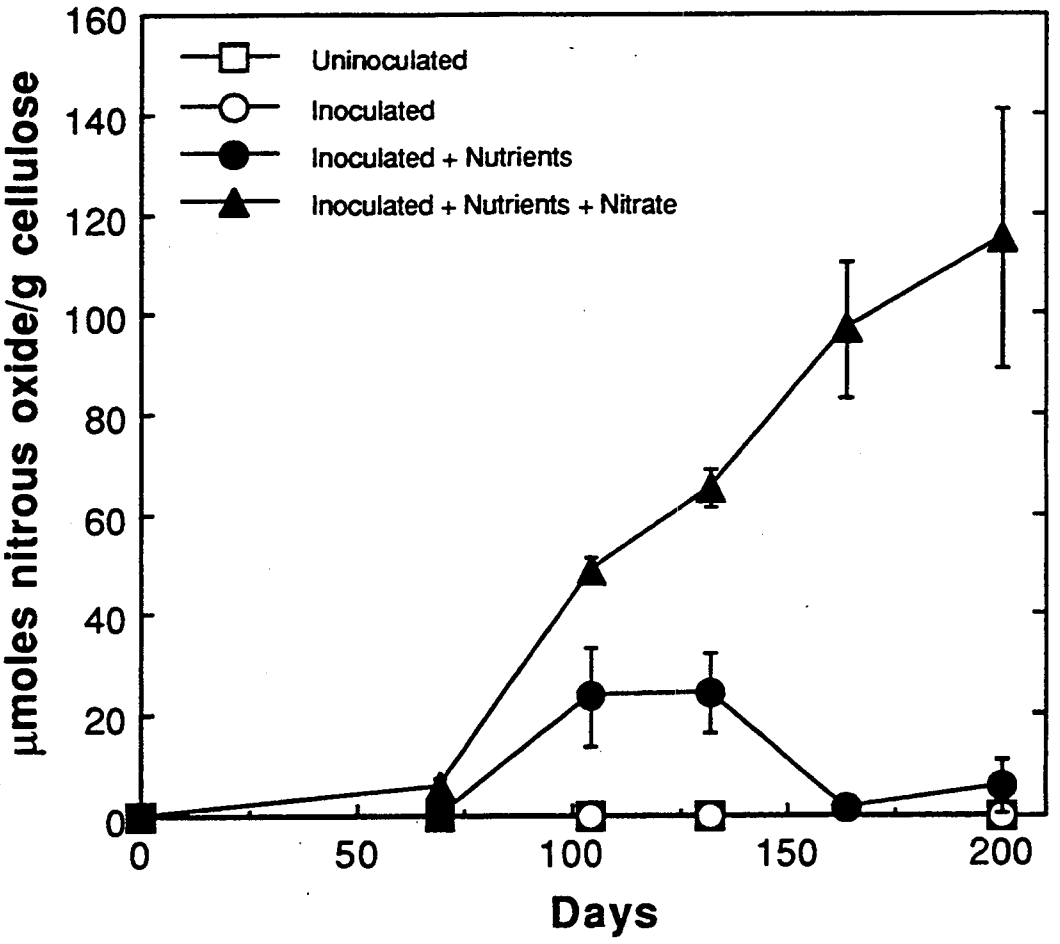

Figure 17. Nitrous oxide produced in samples incubated with an initial atmosphere of air.

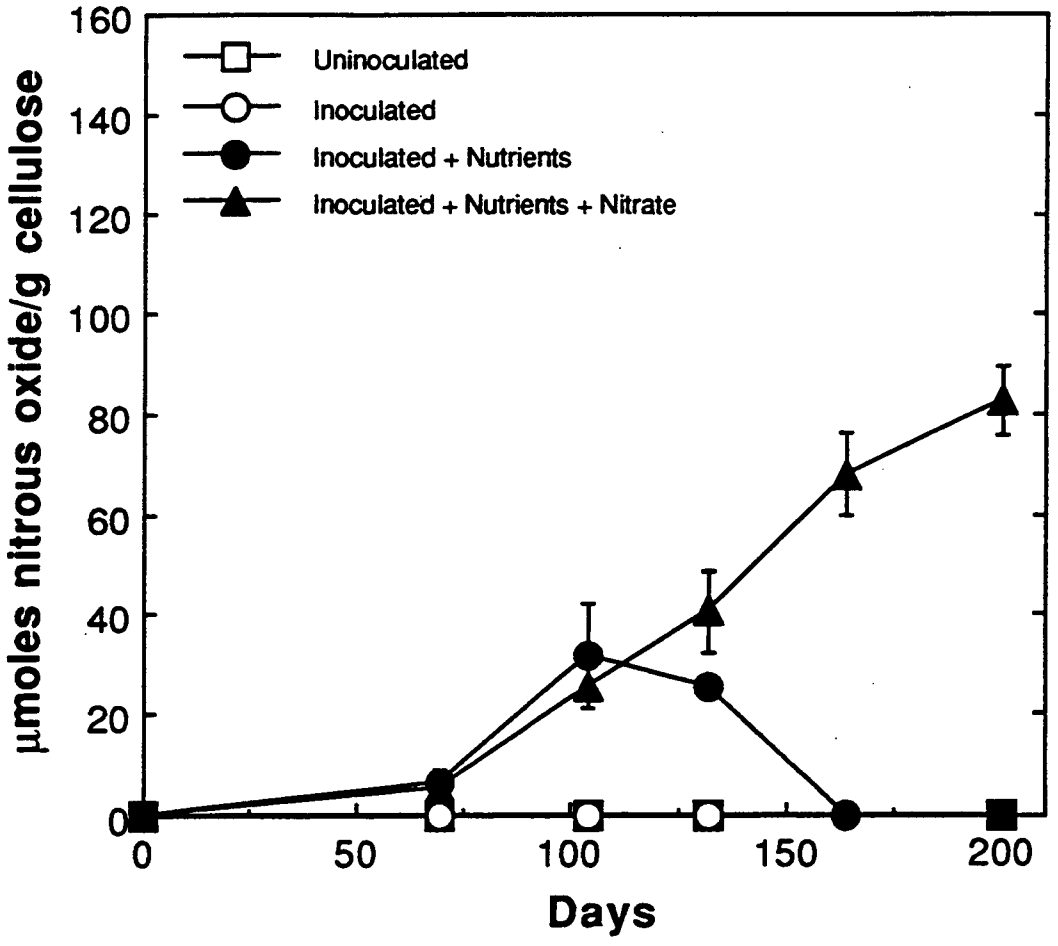

Figure 18. Nitrous oxide produced in samples containing bentonite incubated with an initial atmosphere of air.

5.2 Anaerobic Treatments

5.2.1 Total Gas Production

Figure 19 shows the total gas produced in samples incubated under anaerobic conditions in the presence of nitrogen. Uninoculated samples showed a slight loss of gas of about 3.20 mL sample^{-1}, presumably due to sampling. Inoculated samples without nutrients produced 0.59 mL g^{-1} cellulose at 200 days (see Table 19, Appendix D). After a lag of about 45 days, total gas production increased in inoculated samples containing nutrients, which produced 2.27 mL g^{-1} cellulose at a rate of 0.021 mL g^{-1} cellulose day^{-1}. With nutrients plus excess nitrate, 5.44 mL of gas were produced at a rate of 0.039 mL g^{-1} cellulose day^{-1}.

Figure 20 shows total gas produced in anaerobic samples containing bentonite. Uninoculated, unamended samples showed a net loss at 200 days to -0.28 mL g^{-1} cellulose (Table 20, Appendix D), due to a combination of sampling and data correction. Inoculated, unamended samples produced 0.81 mL g^{-1} cellulose after a lag of 69 days, at a rate of 0.007 mL g^{-1} cellulose day. In nutrient-amended samples, the addition of bentonite had no significant effect and gas production was similar to samples without bentonite (Figure 19). In contrast the addition of bentonite increased gas production in aerobic-amended samples. Inoculated amended samples produced 1.92 mL of gas at a rate of 0.013 g^{-1} cellulose day^{-1}, and inoculated samples with excess nitrate produced 3.52 mL of gas at a rate of 0.025 g^{-1} cellulose day^{-1}.

5.2.2 Carbon Dioxide Production

Uninoculated samples produced only about 3.59 μmol carbon dioxide g^{-1} cellulose over 200 days (Figure 21), but in the presence of inoculum, carbon dioxide increased to 5.47 μmol g^{-1} cellulose (Table 21, Appendix D). After a lag of 69 days, inoculated samples amended with nutrients produced 26.0 μmol carbon dioxide at a rate of 0.198 μmol g^{-1}

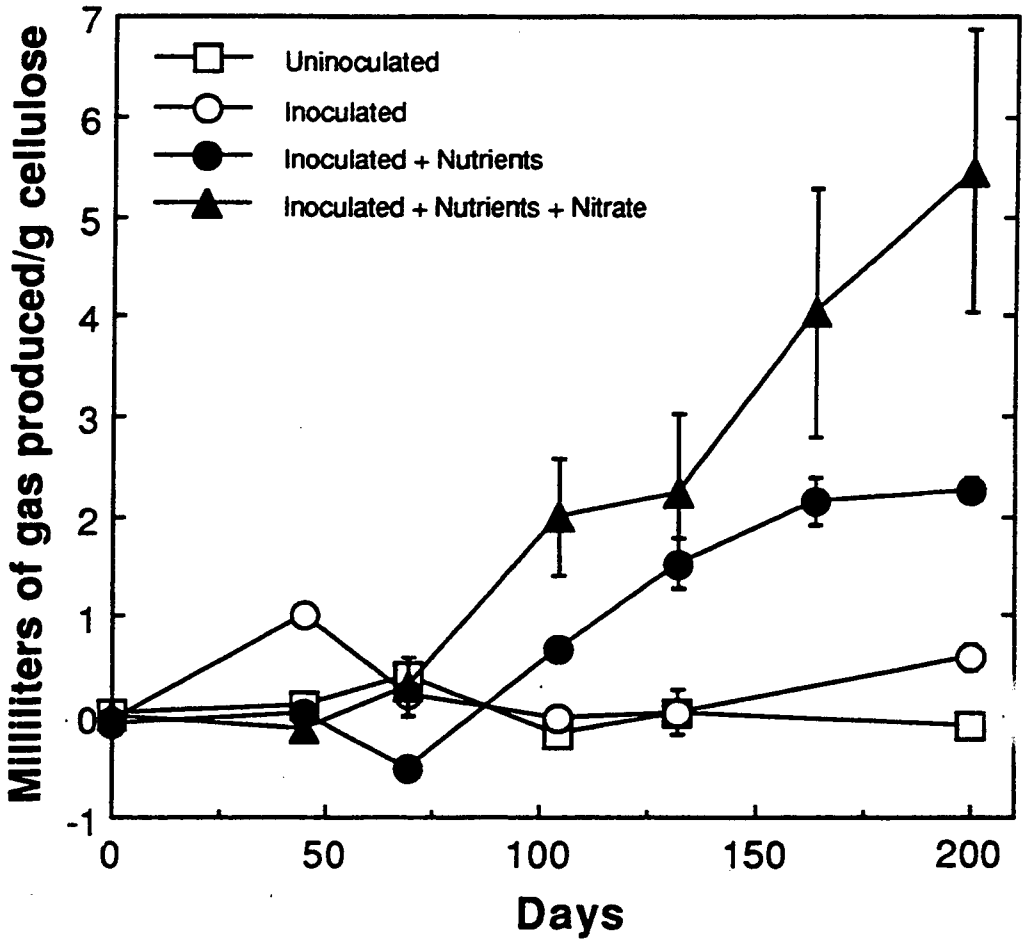

Figure 19. Total gas produced in anaerobic samples.

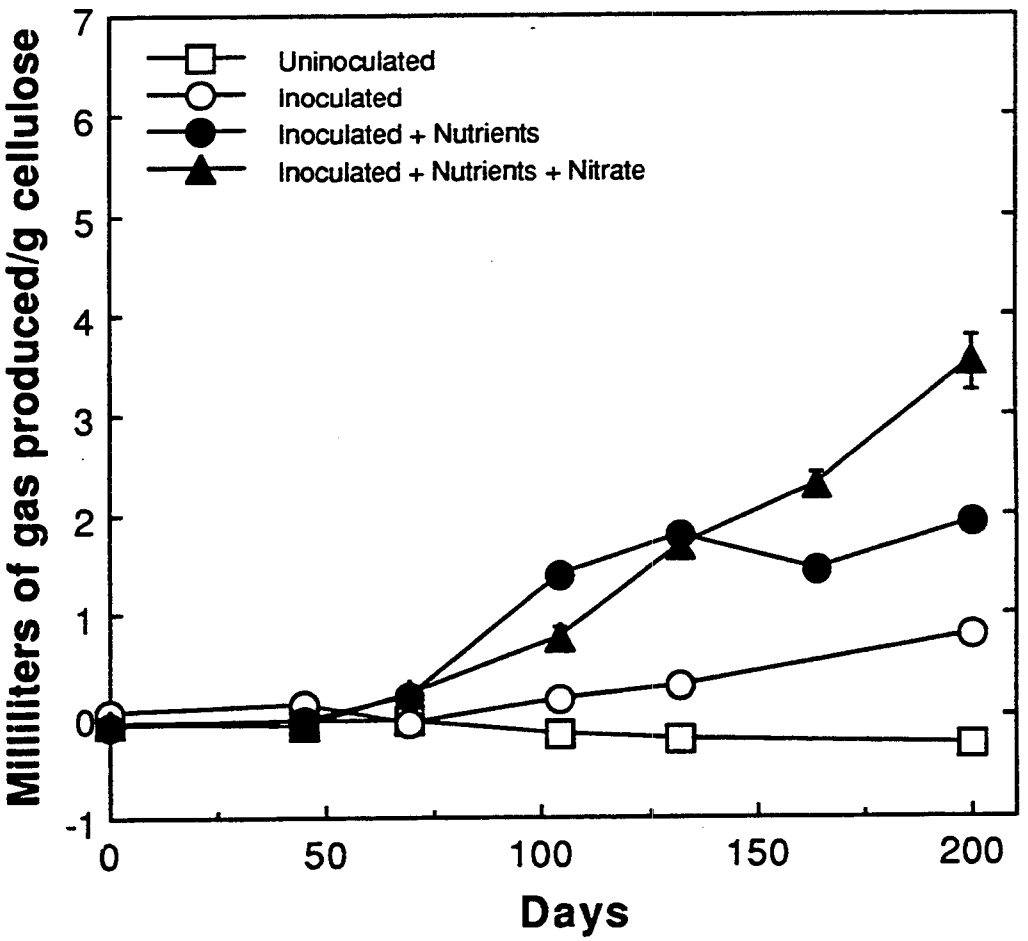

Figure 20. Total gas produced in anaerobic samples containing bentonite.

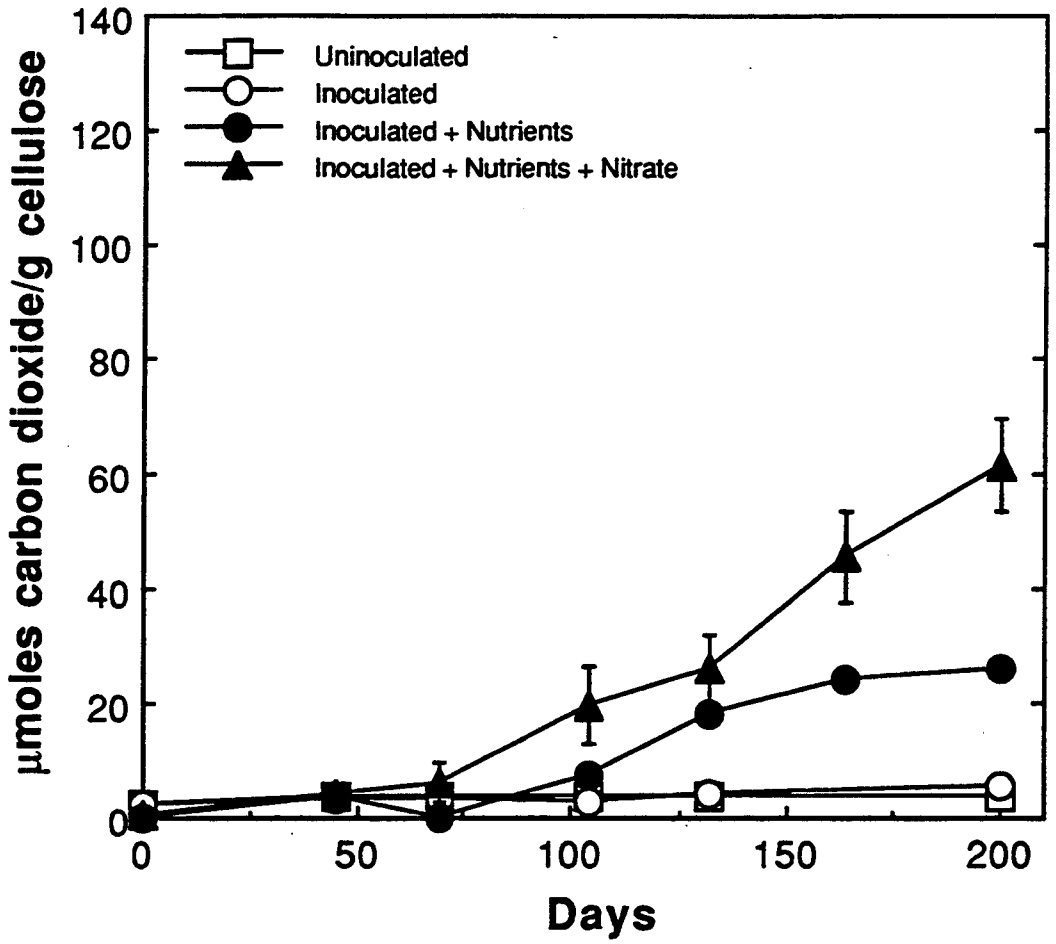

Figure 21. Carbon dioxide produced in anaerobic samples.

cellulose day^{-1} (Table 21, Appendix D). Addition of excess nitrate stimulated carbon dioxide production to 61.4 μmol at the rate of 0.422 μmol g^{-1} cellulose day^{-1}.

Figure 22 shows carbon dioxide production in anaerobic samples containing bentonite. Uninoculated unamended samples produced 0.22 μmol g^{-1} cellulose at 200 days, while inoculated unamended samples produced 8.28 μmol g^{-1} cellulose. The addition of bentonite enhanced the background (abiotic) carbon dioxide concentration by about 40.0 μmol (Table 22, Appendix D). Inoculated samples plus nutrients produced 31.8 μmol carbon dioxide g^{-1} cellulose over 200 days at a rate of 0.236 μmol g^{-1} cellulose day^{-1}. Inoculated samples with nutrients plus excess nitrate produced 35.0 μmol carbon dioxide g^{-1} cellulose over 200 days at a rate of 0.252 μmol g^{-1} cellulose day^{-1}.

5.2.3 Nitrous Oxide Production

The rate of nitrous oxide accumulation in anaerobic samples is shown in Figure 23. Nitrous oxide was not detected in either uninoculated or inoculated samples (Table 23, Appendix D). In the inoculated, amended samples, nitrous oxide accumulated to 15.5 μmol after 100 days and remained relatively unchanged up to 200 days. In the presence of excess nitrate, nitrous oxide was produced after 69 days at a rate of 0.602 μmol g^{-1} cellulose day^{-1}, reaching a concentration of 79 μmol at 200 days. In contrast, nitrous oxide accumulation was higher in aerobic samples (see Figure 15) than anaerobic samples.

Figure 24 shows nitrous oxide production in anaerobic samples containing bentonite. Nitrous oxide was not detected in uninoculated and inoculated samples (see Table 24, Appendix D). In inoculated samples with nutrients, only trace amounts of nitrous oxide were detected at 104 and 164 days. In the inoculated samples containing excess nitrate, nitrous oxide was produced at a rate of 0.647 μmol g^{-1} cellulose day^{-1} after 104 days and reached 62.1 μmol g^{-1} cellulose at 200 days. In comparison to treatments without bentonite, less nitrous oxide accumulated when bentonite was present. This may be caused by either a suppression or an enhancement of denitrification activity (enabling the complete conversion of nitrous oxide to nitrogen without accumulation of nitrous oxide).

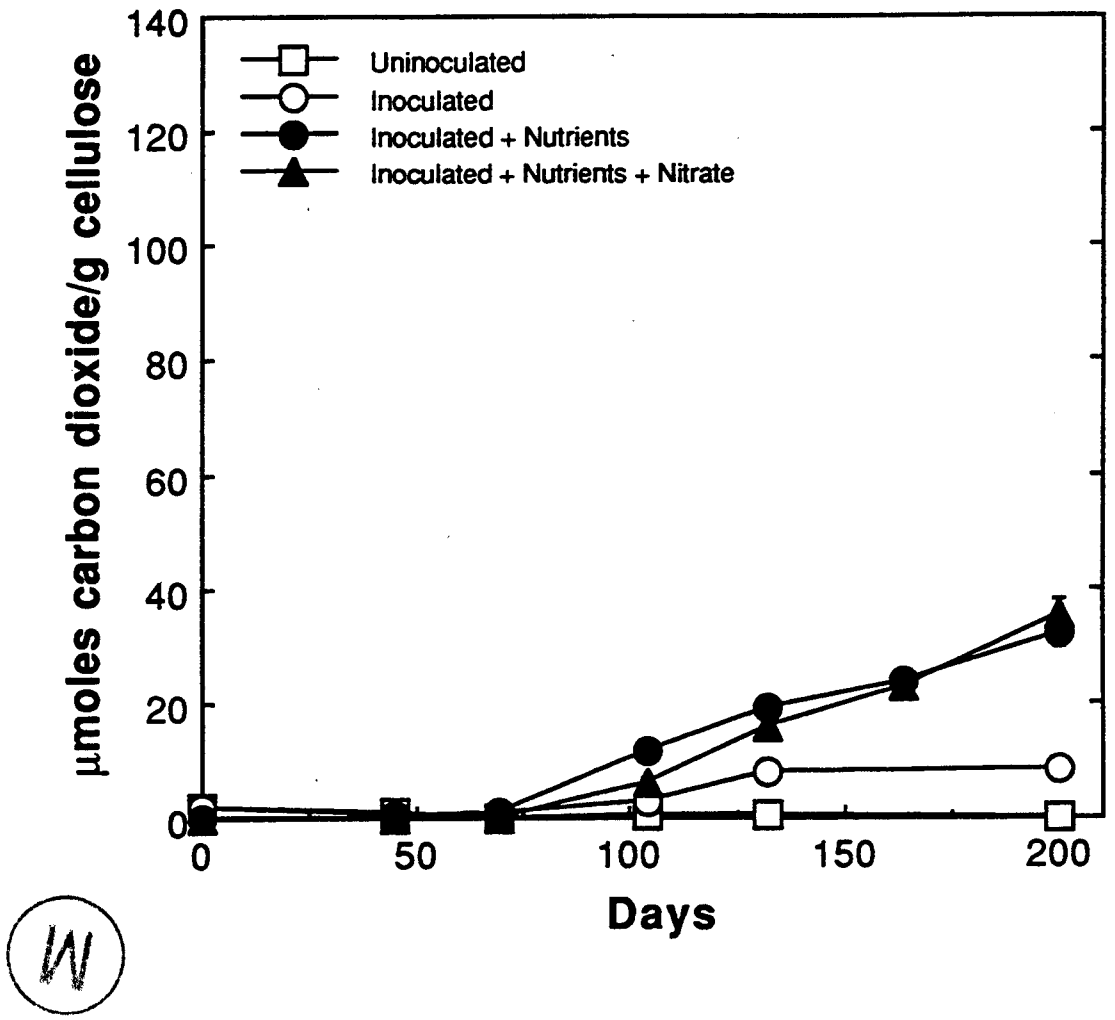

Figure 22. Carbon dioxide produced in anaerobic samples containing bentonite.

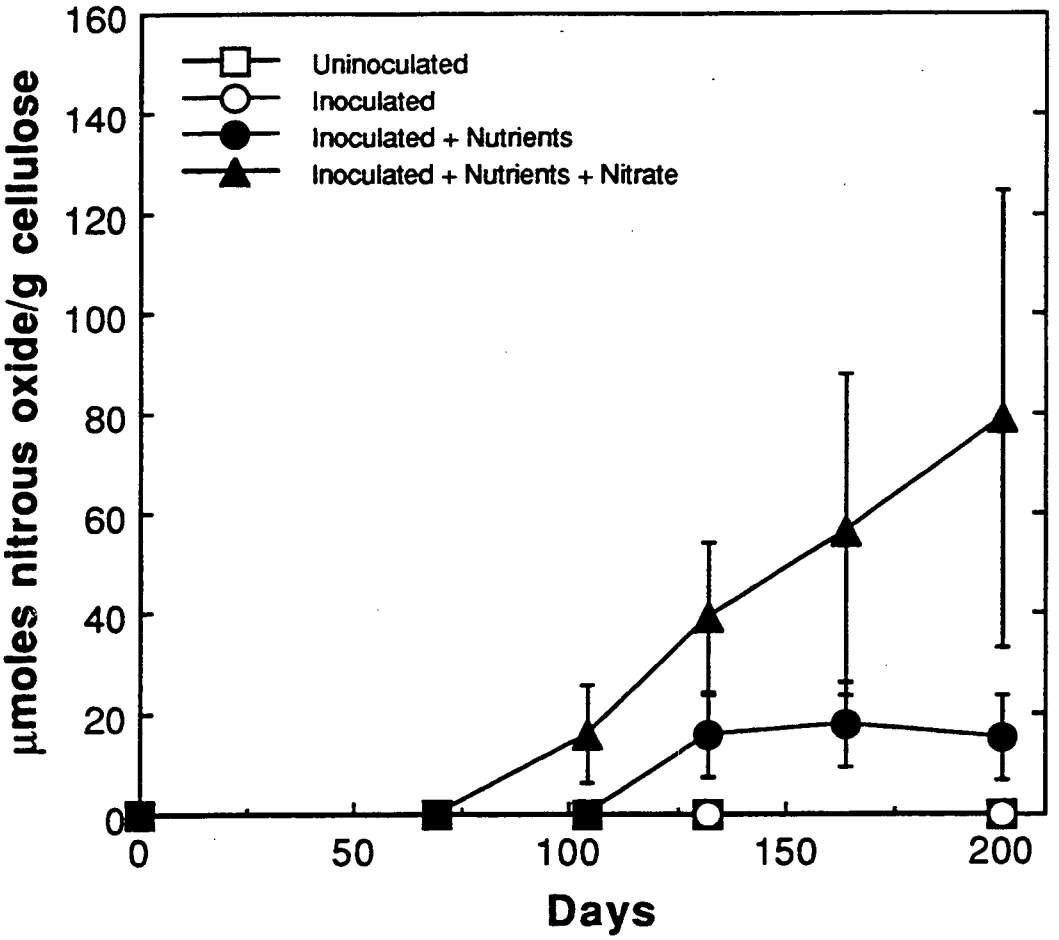

Figure 23. Nitrous oxide produced in anaerobic samples.

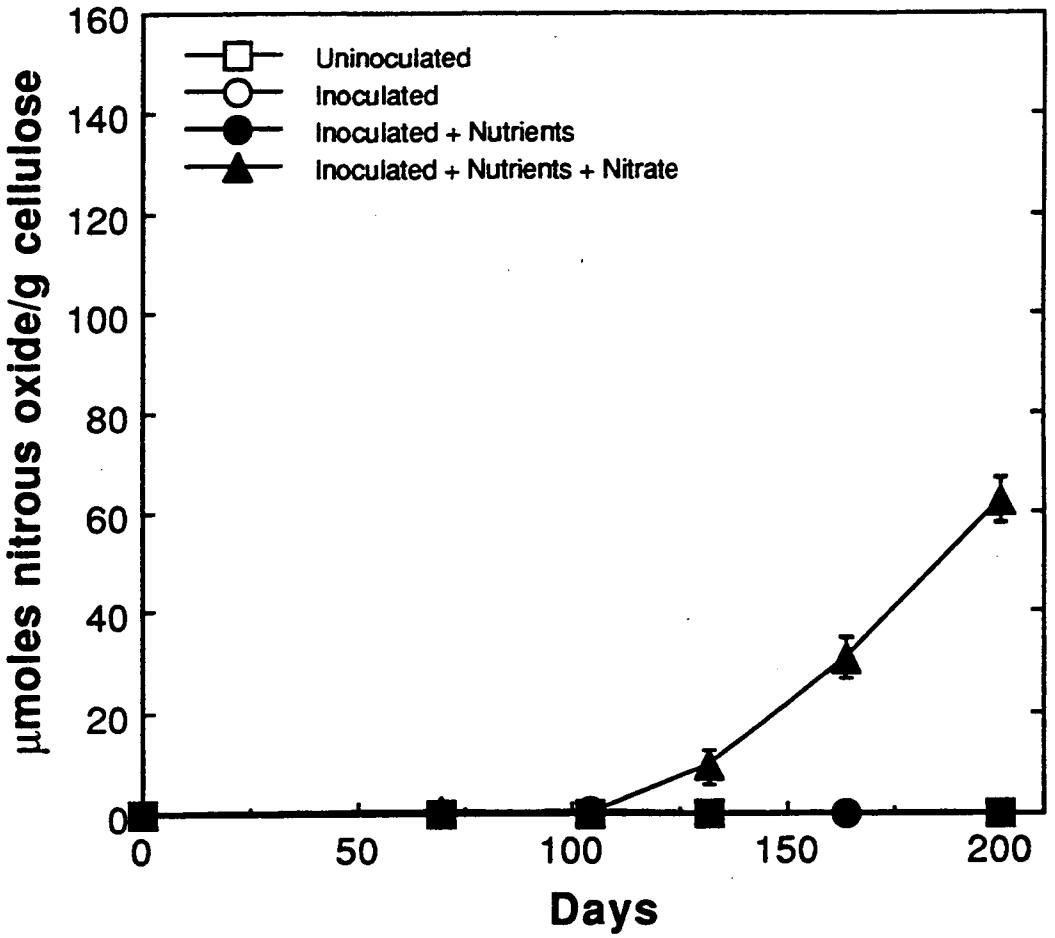

Figure 24. Nitrous oxide produced in anaerobic samples containing bentonite.

6.0 SUMMARY

Gas generation from microbial degradation of a mixture of cellulosic waste was investigated. Cellulosic waste consisting of a mixture of filter paper, paper towels, and Kimwipes® were incubated in the presence of WIPP brine with and without a mixed inoculum, nutrients, or nutrients plus excess nitrate and bentonite. Abiotic (control) samples were treated with formalin and showed no microbial activity. Nitrogen (anaerobic) or air-containing (aerobic) samples with cellulose showed an increase in total gas, CO_2, and N_2O when inoculated with a mixed inoculum without any added nutrients, with nutrients, or nutrients plus excess nitrate and bentonite. In particular, samples which received nutrients plus excess nitrate produced much more gas, CO_2, and N_2O than samples which did not. Bentonite increased the background level of CO_2 concentration due to abiotic reactions and also appears to have a stimulatory effect on aerobic microbial activity.

Table 14 summarizes the rate and extent of gas production due to the presence of cellulose from 69 to 200 days (131 days). Before 69 days, gas production in most treatments was not directly attributable to the presence of cellulose because the samples without cellulose also produced gas due to carry over of nutrients in the mixed inoculum, and metabolism of added nutrients. After 69 days, gas production in samples with cellulose exceeded those without cellulose. Gas production rates were calculated from the linear slope between 69 and 200 days. Negative values in the table denote a loss in gas volume. The negative rate reported for carbon dioxide in uninoculated treatments is the result of inactivity in these samples, and should be interpreted as "zero".

The total volume of gas produced in air-containing (aerobic) samples was highest in the presence of bentonite. Gas was produced at a rate of 0.028 mL g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples, and at 0.034 mL g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples containing excess nitrate. The highest amount of gas was produced in the presence of excess nitrate (6.07 mL g^{-1} cellulose).

Table 14. Summary of Rate and Net Gas Production in Samples Containing Cellulose

Sample	Total Volume of Gas		Carbon Dioxide		Nitrous Oxide	
	Rate* (ml/g cell./day)	Total Produced at 200 Days (ml/g cell.)	Rate* (μmol/g cell./day)	Total Produced at 200 Days (μmol/g cell.)	Rate* (μmol/g cell./day)	Total Produced at 200 Days (μmol/g cell.)
Aerobe						
Uninoculated	0.001	-0.18	-0.001	4.00	--	ND
Inoculated	-0.001	-0.34	0.033	8.30	--	ND
Inoc. + Nutrients	0.008	0.86	0.283	40.8	0.674****	24.4
Inoc. + Nut. + Nitr.	0.023***	4.42	0.484****	95.6	0.835	115
Aerobe + Bentonite						
Uninoculated	0.003	0.00	-0.016	2.32	--	0.048
Inoculated	0.001	-0.08	0.134	21.5	--	ND
Inoc. + Nutrients	0.028	4.38	0.533	69.8	1.00****	31.8****
Inoc. + Nut. + Nitr.	0.034	6.07	0.869	116	0.589	82.7
Anaerobe						
Uninoculated	-0.004	-0.09	-0.003	3.59	--	ND
Inoculated	0.003	0.59	0.016	5.47	--	ND
Inoc. + Nutrients	0.021	2.27	0.198	26.0	0.564*****	15.8*****
Inoc. + Nut. + Nitr.	0.039	5.44	0.422	61.4	0.602	79.0
Anaerobe + Bentonite						
Uninoculated	-0.003	-0.28	-0.005	0.22	--	ND
Inoculated	0.007	0.81	0.057	8.28	--	ND
Inoc. + Nutrients	0.013	1.92	0.236	31.8	--	ND
Inoc. + Nut. + Nitr.	0.025	3.52	0.252	35.0	0.647******	62.1*****

* Rate calculated from 69 days (end of lag phase) to 200 days (131 days) except where noted; rate assumed linear and averaged over available data.

**For an assumed average drum of transuranic waste, with 10 kg of cellulosic material, the following rate conversion factors are applicable:

0.01 ml/g/day = 1.6 moles/drum/year

1.0 μmole/g/day = 3.7 moles/drum/year

*** Lag phase not present, gas production started at T=0

**** Nitrous oxide reached maximum at 104 days, rate is over 35 days

***** Nitrous oxide reached maximum concentration at 132 days, rate is over 32 days.

****** Lag phase lasted 104 days

Negative values denote gas volume loss or decrease in concentration over time.

ND - not detected

In anaerobic samples, gas production was highest in the absence of bentonite. Gas was produced at a rate of 0.021 mL g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples, and 0.039 ml g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples containing excess nitrate.

The concentration of carbon dioxide was highest in aerobic treatments in the presence of bentonite. In samples containing excess nitrate, 116 μmol CO_2 g^{-1} cellulose was produced at a rate of 0.869 μmol g^{-1} cellulose day^{-1}. Inoculated, unamended samples of this treatment also showed the highest amount of carbon dioxide, with 21.5 μmol g^{-1} cellulose produced over 200 days. In the absence of bentonite, aerobic samples that were inoculated with nutrients produced 40.8 μmol CO_2 g^{-1} cellulose, whereas the samples containing excess nitrate produced 95.6 μmol CO_2 g^{-1} cellulose. Aerobic samples produced more carbon dioxide than anaerobic samples. In the absence of bentonite, anaerobic samples produced 0.422 μmol CO_2 g^{-1} cellulose day^{-1} with a total yield 61.4 μmol CO_2 g^{-1} cellulose in the presence of excess nitrate. However, in the presence of bentonite, 35.0 μmol g^{-1} cellulose was produced in anaerobic samples containing excess nitrate, about one third of that produced in aerobic samples. Therefore, initially aerobic processes were more efficient in producing CO_2.

In the presence of cellulose and nutrients, there is significantly greater amount of gas production than in samples without nutrients. In the absence of nutrients, microbial activity was minimal. Aerobic, denitrifying, and anaerobic, primarily fermentative, activities, were the predominant microbial processes noted.

Production of nitrous oxide correlated with the presence of excess nitrate (1240 μmol g^{-1} cellulose), and 115 μmol g^{-1} cellulose was produced in aerobic samples without bentonite. Nitrous oxide did not accumulate in nutrient-amended samples which contained 0.1% nitrate (250 μmol g^{-1} cellulose); it quickly disappeared after about 30 days. Bentonite did not stimulate the accumulation of nitrous-oxide, but instead, was correlated with a lower accumulation of N_2O.

The long-term inundated experiments showed enhanced halophilic bacterial activity in the presence of cellulose under aerobic and anaerobic conditions. Up to 200 days, gas production was highest in nutrient amended samples including excess nitrate treatments containing an initial concentration of oxygen; this was enhanced by the addition of bentonite.

Table 15 presents gas production data scaled up to total gas and carbon dioxide produced per drum of waste per year. Nitrous oxide is not presented because this gas, the production of which is significant as a marker of microbial activity, is converted to nitrogen which affects the production rate. The rates drum^{-1} of waste year^{-1} were calculated on the basis of an assumed average drum of transuranic waste with about 10 Kg of cellulosic material. A total gas generation rate of 0.01 mL of gas g^{-1} cellulose day^{-1} corresponds to a generation rate of 1.6 mol of gas drum^{-1} year^{-1}. A carbon dioxide generation rate of 1.0 μmol CO_2 g^{-1} cellulose day^{-1} corresponds to a generation rate of 1.6 mol gas drum^{-1} year^{-1}.

The data contained in this report is a summarization of work in progress, (a status report) and should not be interpreted as final values. Most of the long-term studies are still in progress. Gas production rates will undoubtedly be modified after long-term data, up to about two years or longer, are obtained and analyzed. The preliminary data included herein, and resultant gas production rates, should only be used for preliminary interpretations and tentative conclusions. Further data and interpretation from this microbial degradation-gas generation study will be documented in the future.

Table 15. Summary of Gas Production Rates Expressed as per g Cellulose/Day and Scaled up to per Drum/Year.

Sample	Total Volume of Gas		Carbon Dioxide	
	Rate* (ml/g cell./day)	Calculated Amount Produced per Waste Drum** (moles/drum/year)	Rate* (μmol/g cell./day)	Calculated Amount Produced per Waste Drum** (moles/drum/year)
Aerobe				
Uninoculated	0.001	0.16	-0.001	--
Inoculated	-0.001	-0.16	0.033	0.12
Inoc. + Nutrients	0.008	1.28	0.283	1.05
Inoc. + Nut. + Nitr.	0.023***	3.68	0.484***	1.79
Aerobe + Bentonite				
Uninoculated	0.003	0.48	-0.016	--
Inoculated	0.001	0.16	0.134	0.5
Inoc. + Nutrients	0.028	4.48	0.533	1.97
Inoc. + Nut. + Nitr.	0.034	5.44	0.869	3.21
Anaerobe				
Uninoculated	-0.004	-0.64	-0.003	--
Inoculated	0.003	0.48	0.016	0.06
Inoc. + Nutrients	0.021	3.36	0.198	0.73
Inoc. + Nut. + Nitr.	0.039	6.24	0.422	1.56
Anaerobe + Bentonite				
Uninoculated	-0.003	-0.48	-0.005	--
Inoculated	0.007	1.12	0.057	0.21
Inoc. + Nutrients	0.013	2.08	0.236	0.87
Inoc. + Nut. + Nitr.	0.025	4.00	0.252	0.93

* Rate calculated from 69 days (end of lag phase) to 200 days (131 days) except where noted; rate assumed linear and averaged over available data.

**For an assumed average drum of transuranic waste, with 10 kg of cellulosic material, the following rate conversion factors were used:

0.01 ml/g/day = 1.6 moles/drum/year

1.0 μmole/g/day = 3.7 moles/drum/year

*** Lag phase not present, gas production started at T=0

Negative values denote gas volume loss or decrease in concentration over time

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APPENDIX A: DETAILS OF THE SHORT-TERM ACTIVITY MEASUREMENTS

APPENDIX A: DETAILS OF THE SHORT-TERM ACTIVITY MEASUREMENTS

The short-term experiments were developed to determine the activity of specific groups of organisms (aerobes, anaerobes, and denitrifiers) by using WIPP salt from the underground and Nash Draw brine as a basal medium and inoculum.

A concentrated stock solution of nutrients (20x) was prepared and 0.5mL dispensed into 20-mL serum bottles. Medium for anaerobes (glucose fermenters) and denitrifiers was dispensed and sealed inside a nitrogen-filled glove box. Medium for aerobes was prepared outside of the glove box in air. The samples were capped with butyl rubber stoppers and aluminum crimps and autoclaved (120°C, 20 psi, 15 minutes).

The nutrient solution was added prior to the addition of inoculum to achieve a final concentration of nutrients in the samples as follows:

Aerobe and Anaerobe Series	
glucose	5.0 g/L
yeast extract	0.5 g/L
potassium phosphate	1.0 g/L
ammonium nitrate	1.0 g/L
inoculum	9.5 mL/bottle
pH=6.8	

Denitrifier Series	
sodium succinate	5.0 g/L
yeast extract	0.5 g/L
potassium phosphate (dibasic)	1.0 g/L
ammonium nitrate	1.0 g/L
potassium nitrate	1.0 g/L
inoculum	9.5 mL/bottle
pH = 6.8	

To determine denitrification, 2 mL of acetylene was injected into the headspace and nitrous oxide production was determined by gas chromatography.

Cellulose degradation was investigated by replacing the carbon source with 0.5 g Whatman #1 filter paper.

A large volume of inoculum was prepared by dissolving 200 g of S2180, W30 muck pile salt from the WIPP underground workings into 1 L of sterile water. A 450 mL aliquot was poured into a sterile beaker and 10 mL of Laguna Cinco mud slurry and 50 mL of Laguna Cinco brine from Nash Draw were added. This was done inside the anaerobic glove box. A total of 510 mL of inoculum was prepared; 9.5 mL of this inoculum was added to each bottle of sterile nutrient medium through a sterile needle and syringe to attain a final volume of 10 mL in each bottle. The pressure was equalized after the addition of inoculum with a sterile syringe and 0.22 μm filter.

A total of 6 samples were prepared per series. Two of the 6 were treated with 1 mL of 10 % formalin to serve as a control. Six samples were also prepared without nutrient additions, 2 treated with formalin.

Samples were incubated at 30°C and analyzed for gas production (total gas, carbon dioxide and nitrous oxide) at specific time periods.

APPENDIX B: GAS ANALYSIS

APPENDIX B: GAS ANALYSIS

Total Gas

Headspace pressure was measured with a Wallace & Tiernan® digital pressure model 661-D/A035 gauge calibrated to National Institute of Standards and Technology (NIST) standard.

Carbon Dioxide

Carbon dioxide analysis was performed on a gas chromatograph equipped with a thermal conductivity detector. Instrument conditions are listed below:

Column	SS 12' x 1/8" Porapak QS
Column temp (°C)	100
Carrier gas	He
Carrier flow (mL/min)	35
Injector temp (°C)	150
Manifold temp (°C)	210
Detector temp (°C)	250
Detector current (mA)	225
Detection limit (nmol/mL)	1

Instrument calibrated with gas standards traceable to NIST.

Nitrous Oxide

Nitrous oxide analysis was performed on a gas chromatograph equipped with an electron capture detector (^{63}Ni). Instrument conditions are listed below:

Column	SS 12' x 1/8" Porapak QS
Column temp (°C)	70
Carrier gas	N_2
Carrier flow (mL/min)	30
Injector temp (°C)	270
Detector temp (°C)	270
Detector current (nA)	2
Detection limit (pmol/mL)	100

Instrument calibrated with gas standards traceable to NIST.

APPENDIX C: DETAILS OF THE LONG-TERM EXPERIMENT

APPENDIX C: DETAILS OF THE LONG-TERM EXPERIMENT

The following is a detailed description of the samples prepared for the long-term inundated experiment, including the number and chemical composition of treatments.

Sample Preparation

Detergent (Alconox®) and acid-washed (10% HCl) 160 mL serum bottles were rinsed with deionized water. They were then dried in a drying oven, covered with aluminum foil and autoclaved, thus completing preparation of the bottles.

Four paper types were used for the experiment:

Whatman #1 filter paper
Brown paper towel
White paper towel
Kimwipes

The papers were reduced to approximately 1 cm by 1 cm squares.

The bottles were filled with the processed paper. The papers were mixed together prior to filling and 1.25 g of each paper type were added to each bottle for a total of 5 grams of paper per bottle.

Anaerobic Samples

Ten liters of G-Seep #9 were removed from storage at 4°C and equilibrated overnight to room temperature. Storage at 4°C was necessary in order to prevent microbial activity in the storage containers; which could possibly pre-enrich the brine with specific microbes.

Sixty filled bottles (w/ paper) were arranged and prepared for treatment as follows:

<u>36 w/paper: unamended (G-Seep w/o additions)</u>
18 w/o bentonite
18 w/ bentonite

<u>12 w/paper: amended (G-Seep w/ nutrients)</u>
6 w/o bentonite
6 w/ bentonite

12 w/paper: amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
6 w/o bentonite
6 w/ bentonite

Thirty-two bottles w/o paper were arranged and prepared for treatment as follows:

16 unamended (G-Seep w/o additions)
8 w/o bentonite
8 w/ bentonite

8 amended (G-Seep w/ nutrients)
4 w/o bentonite
4 w/ bentonite

8 amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
4 w/o bentonite
4 w/ bentonite

A total of 92 bottles were prepared for anaerobic treatment.

Aerobic Samples

Sixty filled bottles (w/ paper) were arranged and prepared for treatment as follows:

36 w/paper: unamended (G-Seep w/o additions)
18 w/o bentonite
18 w/ bentonite

12 w/paper: amended (G-Seep w/ nutrients)
6 w/o bentonite
6 w/ bentonite

12 w/paper: amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
6 w/o bentonite
6 w/ bentonite

Thirty-two bottles w/o paper were arranged and prepared for treatment as follows:

16 unamended (G-Seep w/o additions)
8 w/o bentonite
8 w/ bentonite

8 amended (G-Seep w/ nutrients)
4 w/o bentonite
4 w/ bentonite

8 amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
4 w/o bentonite
4 w/ bentonite

A total of 92 bottles were prepared for aerobic treatment.

Nutrient Additions

The following lists the quantities added and final concentrations of nutrients in the samples. This list applies to both the aerobic and anaerobic samples with and without paper.

(a) Amended: The following quantities of nutrients were used for the amended treatments:

	grams/L	mM
Ammonium nitrate	1	12.5
Potassium phosphate (dibasic)	1	7.35
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contained the following final concentration of nutrients:

	grams/100mL	µmoles
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Yeast extract (0.05%)	0.05	--

(b) Amended and excess nitrate added: Potassium nitrate was added in addition to the ammonium nitrate:

	grams/L	mM
Ammonium nitrate	1	12.5
Potassium phosphate (dibasic)	1	7.35
Potassium nitrate	5	49.5
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contained the following final concentration of nutrients:

	grams/100mL	µmoles
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Potassium nitrate	0.5	4950
Yeast extract (0.05%)	0.05	--

(c) Glucose added (instead of paper): Samples were prepared without paper with a glucose addition to determine the ability of the inoculum to grow in the amended samples. The treatment was composed of the following:

	grams/L	mM
Glucose	5	27.7
Ammonium nitrate	1	12.5
Potassium phospate (dibasic)	1	7.35
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contains the following quantity of nutrients:

	grams/100mL	µmoles
Glucose	0.5	2770
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Yeast extract (0.05%)	0.05	--

(d) Glucose added (instead of paper) and excess nitrate: Samples were prepared without paper with a glucose addition and additional nitrate. The treatment was composed of the following:

	grams/L	mM
Glucose	5	27.7
Ammonium nitrate	1	12.5
Potassium phospate (dibasic)	1	7.35
Potassium nitrate	5	49.5
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contained the following final concentration of nutrients:

	grams/100mL	µmoles
Glucose	0.5	2770
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Potassium nitrate	0.5	4950
Yeast extract (0.05%)	0.05	--

Sample Volumes

The final sample volume (displacement of liquid plus cellulose or liquid w/o cellulose) and the headspace volume of each treatment is as follows:

Cellulose Treatments	sample vol. (mL	hdsp. vol (mL*
U (uninoculated)	110	50
I (inoculated)	114	46
UC (uninoculated control)	113	47
IC (inoculated control)	117	43
"No paper" Treatments	**sample vol. (mL**	**hdsp. vol (mL***
NU (uninoculated)	100	60
NI (inoculated)	104	56
NUC (uninoculated control)	103	57
NIC (inoculated control)	107	53

*Headspace vol. (hdsp. vol) calculated by subtracting sample volume from volume of bottle (160ml).

Acetylene was not injected into the headspace of any of the samples in order to prevent pertubation of the headspace gas.

APPENDIX D: GAS PRODUCTION DATA (GROSS AND NET) FOR THE LONG-TERM INUNDATED EXPERIMENT

APPENDIX D: GAS PRODUCTION DATA (GROSS AND NET) FOR THE LONG-TERM INUNDATED EXPERIMENT

i. Data Reduction

Total gas, carbon dioxide, and nitrous oxide produced by aerobic and anaerobic samples up to 200 days incubation is present in Appendix D, Tables 1-12, on a per sample basis. This data was used to prepare Tables 13-24 in which total gas, carbon dioxide, and nitrous oxide production in aerobic and anaerobic treatments is presented on a per gram cellulose basis. Figures 13-24 are based on the data from Tables 13-24. The data in Tables 13-24 have been corrected for gas production in the absence of cellulose by subtracting the measured gas values in respective treatments prepared without cellulose. As an example, total gas production in aerobic samples was corrected (Table 13) by subtracting total gas production in treatments without cellulose (designated "NC", Appendix D, Table 1) from samples with cellulose (designated "C") at each period. The resultant number was divided by the total amount of cellulose in each sample bottle (5 grams) to arrive at a value that represents the total gas produced per gram of cellulose. Tables 13 to 24 represent the gas produced strictly due to the presence of cellulose in the samples, and are corrected for gas produced due to metabolism of dissolved organic carbon present in the brine or in the nutrient addition as measured in specific control treatments. Carbon dioxide was produced in certain samples in the absence of cellulose, specifically, before 69 days. After this period, gas production reported is that which is above and beyond the control treatments. Significant quantities of NO_2 were not detected in the absence of cellulose. Gas produced at time 0 was not subtracted from later values, as many seem neccessary to normalize the starting values at 0. This was not done because time 0 measurements were taken 3 days after sample preparation; therefore gas present at time 0 is due to evolution of dissolved gases and headspace equilibration. These processes contribute to the overall gas production.

Figures 13 to 24 present data from Table 13 to 24. All data in these figures are presented as gas produced per gram cellulose, and have been corrected for gas production

in the absence of cellulose. The data plotted are the mean values of three samples, and error bars represent the standard error of the mean. In the legend: "uninoculated" refers to samples that have received no mixed inoculum or nutrients; "inoculated" refers to samples that have received mixed inoculum but no nutrients; "inoculated + nutrients" refers to samples that have received both mixed inoculum and nutrients (amended), and; "inoculated + nutrients + nitrate" refers to samples that have received (i) mixed inoculum, (ii) nutrients, and (iii) excess nitrate in the form of potassium nitrate (amended plus excess nitrate).

Data for treatments prepared with glucose to determine activity of the mixed inoculum are persented in Figures 25-30. Data for gas analysis of these samples, along with formalin-treated controls for all cellulose and no-cellulose treatments, are presented in Appendix D, Tables 1(a) to 4(c).

Analysis of the samples will continue at selected intervals (as determined by gas-producing activity) past 200 days and up to 800 days. The analyses then will stop if activity ceases, as indicated by cessation of gas production, or be extended if gas-producing activity continues in the samples. If this occurs in select samples only, then only these samples will be reserved for long-term monitoring, and analyses of inactive samples will stop.

Table 1. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Aerobic Samples.

Treatments* [Brine]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin treated, w/o cellulose	1(NC)-f	4.22 ± 0.13	-0.35 ± 0.13	-0.06 ± 0.45	-0.26 ± 0.06	-0.13 ± 0.13	NA	-1.44 ± 0.00
Formalin treated, with cellulose	1(C)-f	5.44 ± 0.32	4.09 ± 0.16	4.19 ± 0.10	2.08 ± 1.06	1.37 ± 0.93	NA	0.67 ± 0.90
As is, w/o cellulose	1(NC)-a	4.39 ± 0.03	3.71 ± 0.03	3.84 ± 0.03	1.90 ± 0.61	1.33 ± 0.85	NA	-0.61 ± 0.75
As is, with cellulose	1(C)-a	4.63 ± 0.10	2.28 ± 0.95	2.04 ± 0.92	0.34 ± 0.68	0.34 ± 0.61	NA	-1.53 ± 0.51
Unamended/Inoculated (2)								
Formalin treated, w/o cellulose	2(NC)-f	4.96 ± 0.02	2.88 ± 0.04	3.50 ± 0.00	2.49 ± 0.04	2.45 ± 0.14	NA	0.07 ± 0.25
Formalin treated, with cellulose	2(C)-f	4.89 ± 0.06	2.72 ± 0.38	1.76 ± 0.56	0.91 ± 0.41	0.41 ± 0.53	NA	-0.50 ± 0.44
As is, w/o cellulose	2(NC)-a	3.56 ± 0.02	2.90 ± 0.15	2.21 ± 0.30	0.53 ± 0.11	-0.91 ± 0.04	NA	-2.86 ± 0.04
As is, with cellulose	2(C)-a	3.16 ± 0.03	2.97 ± 0.22	1.44 ± 0.16	-0.44 ± 0.22	-1.28 ± 0.25	NA	-4.57 ± 0.34
Amended/Inoculated (3)								
As is, w/o cellulose	3(NC)-a	3.20 ± 0.04	1.37 ± 0.04	0.30 ± 0.00	0.11 ± 0.04	-1.49 ± 0.15	-2.48 ± 0.38	-4.53 ± 0.46
As is, with cellulose	3(C)-a	2.60 ± 0.16	0.03 ± 0.69	-0.94 ± 0.31	1.91 ± 1.53	1.44 ± 1.19	0.34 ± 0.63	-0.22 ± 0.41
As is, with glucose	3(G)-a	3.73 ± 0.08	2.29 ± 0.15	1.83 ± 0.38	-1.79 ± 0.34	-1.22 ± 1.37	1.87 ± 2.63	-1.83 ± 1.30
Excess nitrate, w/o cellulose	3(NC)-x	3.16 ± 0.08	0.84 ± 0.46	-1.30 ± 0.08	-0.78 ± 0.30	-1.14 ± 0.04	-1.80 ± 0.18	-2.82 ± 0.27
Excess nitrate, with cellulose	3(C)-x	3.04 ± 0.06	0.94 ± 0.72	5.66 ± 3.04	11.9 ± 4.4	15.5 ± 5.3	18.3 ± 6.1	19.3 ± 4.0
Excess nitrate, with glucose	3(G)-x	3.52 ± 0.02	2.74 ± 0.50	0.88 ± 0.76	-1.49 ± 0.27	-1.30 ± 0.04	-0.86 ± 0.72	2.90 ± 2.02

NA = not analyzed

Table 2. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Aerobic Samples

Treatments [Brine]	Sample Designation	Carbon Dioxide (μmoles/sample) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin treated, w/o cellulose	1(NC)-f	2.59 ± 0.01	2.50 ± 0.01	3.40 ± 0.40	3.32 ± 0.00	3.61 ± 0.00	NA	3.68 ± 0.01
Formalin treated, with cellulose	1(C)-f	30.5 ± 2.7	40.8 ± 0.1	44.4 ± 0.2	40.6 ± 0.8	41.8 ± 0.3	NA	41.8 ± 0.5
As is, w/o cellulose	1(NC)-a	1.38 ± 0.01	1.49 ± 0.01	0.94 ± 0.00	1.66 ± 0.01	1.83 ± 0.06	NA	2.18 ± 0.04
As is, with cellulose	1(C)-a	13.8 ± 0.5	21.1 ± 0.3	22.0 ± 0.1	21.3 ± 0.1	23.1 ± 0.1	NA	22.2 ± 0.1
Unamended/Inoculated (2)								
Formalin treated, w/o cellulose	2(NC)-f	4.97 ± 0.45	4.38 ± 0.29	4.70 ± 0.11	4.88 ± 0.3	5.02 ± 0.30	NA	4.94 ± 0.27
Formalin treated, with cellulose	2(C)-f	34.5 ± 0.8	35.6 ± 0.0	38.7 ± 0.7	34.3 ± 0.6	35.2 ± 0.1	NA	33.2 ± 1.1
As is, w/o cellulose	2(NC)-a	2.30 ± 0.02	2.97 ± 0.03	2.92 ± 0.09	5.88 ± 0.08	6.56 ± 0.11	NA	7.01 ± 0.11
As is, with cellulose	2(C)-a	12.1 ± 0.3	19.7 ± 0.8	22.6 ± 0.9	30.8 ± 0.9	40.9 ± 1.0	NA	48.5 ± 1.4
Amended/Inoculated (3)								
As is, w/o cellulose	3(NC)-a	2.87 ± 0.03	27.8 ± 1.2	72.9 ± 2.6	113 ± 5	130 ± 2	150 ± 1	142 ± 1
As is, with cellulose	3(C)-a	2.80 ± 0.10	50.9 ± 1.4	91.8 ± 5.9	215 ± 37	278 ± 25	333 ± 21	346 ± 27
As is, with glucose	3(G)-a	2.41 ± 0.03	4.03 ± 0.13	30.8 ± 2.1	94.9 ± 7.5	167 ± 32	325 ± 108	323 ± 95
Excess nitrate, w/o cellulose	3(NC)-x	2.79 ± 0.03	17.2 ± 1.9	48.9 ± 0.2	92.2 ± 0.59	115 ± 3	131 ± 2	126 ± 2
Excess nitrate, with cellulose	3(C)-x	2.60 ± 0.10	51.6 ± 0.0	210 ± 21	399 ± 18	533 ± 13	612 ± 20	604 ± 30
Excess nitrate, with glucose	3(G)-x	2.51 ± 0.01	4.05 ± 0.25	24.1 ± 5.9	72.0 ± 7.7	121 ± 4	211 ± 6	296 ± 20

*Dissolved carbon dioxide concentrations not included.

NA = not analyzed

Table 3. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Aerobic Samples

Treatments [Brine]	Sample Designation	Nitrous Oxide (μmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (1)							
Formalin treated, w/o cellulose	1(NC)-f	0.000 ± 0.000	0.003 ± 0.002	0.000 ± 0.000	0.000 ± 0.000	NA	0.001 ± 0.001
Formalin treated, with cellulose	1(C)-f	0.000 ± 0.000	0.003 ± 0.001	0.003 ± 0.001	0.013 ± 0.001	NA	0.005 ± 0.002
As is, w/o cellulose	1(NC)-a	0.000 ± 0.000	0.162 ± 0.110	0.000 ± 0.000	0.000 ± 0.000	NA	0.051 ± 0.035
As is, with cellulose	1(C)-a	0.000 ± 0.000	0.003 ± 0.001	0.006 ± 0.001	0.015 ± 0.001	NA	0.008 ± 0.000
Unamended/Inoculated (2)							
Formalin treated, w/o cellulose	2(NC)-f	0.000 ± 0.000	0.025 ± 0.018	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	2(C)-f	0.000 ± 0.000	0.001 ± 0.000	0.002 ± 0.000	0.014 ± 0.002	NA	0.004 ± 0.000
As is, w/o cellulose	2(NC)-a	0.003 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.016 ± 0.011	NA	0.062 ± 0.007
As is, with cellulose	2(C)-a	0.014 ± 0.000	0.002 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	NA	0.009 ± 0.006
Amended/Inoculated (3)							
As is, w/o cellulose	3(NC)-a	0.000 ± 0.000	0.061 ± 0.043	0.087 ± 0.061	0.024 ± 0.003	0.000 ± 0.000	0.050 ± 0.033
As is, with cellulose	3(C)-a	0.004 ± 0.000	0.182 ± 0.147	118 ± 48	122 ± 39	8.81 ± 5.98	29.2 ± 25.2
As is, with glucose	3(G)-a	0.000 ± 0.000	0.056 ± 0.010	0.252 ± 0.122	5.64 ± 3.40	114 ± 80	105 ± 74
Excess nitrate, w/o cellulose	3(NC)-x	0.000 ± 0.000	0.001 ± 0.000	0.004 ± 0.002	0.006 ± 0.004	0.006 ± 0.001	0.023 ± 0.006
Excess nitrate, with cellulose	3(C)-x	0.000 ± 0.000	28.2 ± 8.8	245 ± 11	326 ± 18	484 ± 67	577 ± 129
Excess nitrate, with glucose	3(G)-x	0.000 ± 0.000	0.000 ± 0.000	2.97 ± 2.10	2.99 ± 2.08	11.2 ± 7.3	66.0 ± 41.2

*Dissolved nitrous oxide concentrations not included.
NA = not analyzed

Table 4. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Aerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin treated, w/o cellulose	4(NC)-f	5.93 ± 0.04	1.24 ± 2.02	1.43 ± 1.74	1.09 ± 1.05	-0.31 ± 0.00	NA	-2.17 ± 0.00
Formalin treated, with cellulose	4(C)-f	6.59 ± 0.16	4.38 ± 0.13	3.77 ± 0.13	1.82 ± 0.13	0.10 ± 0.03	NA	-1.98 ± 0.03
As is, w/o cellulose	4(NC)-a	5.43 ± 0.04	3.63 ± 0.53	4.78 ± 0.78	2.65 ± 0.45	1.92 ± 0.20	NA	-0.82 ± 0.20
As is, with cellulose	4(C)-a	5.17 ± 0.10	3.74 ± 0.10	2.99 ± 0.20	1.67 ± 0.24	1.26 ± 0.20	NA	-0.82 ± 0.27
Unamended/Inoculated (5)								
Formalin treated, w/o cellulose	5(NC)-f	5.08 ± 0.36	2.56 ± 0.83	1.19 ± 1.73	0.76 ± 0.94	0.54 ± 0.65	NA	-2.02 ± 0.36
Formalin treated, with cellulose	5(C)-f	5.65 ± 0.12	3.63 ± 0.03	2.72 ± 0.00	2.22 ± 0.00	0.88 ± 0.15	NA	-1.23 ± 0.12
As is, w/o cellulose	5(NC)-a	3.66 ± 0.30	3.62 ± 0.04	2.78 ± 0.08	1.64 ± 0.15	1.14 ± 0.11	NA	-2.06 ± 0.34
As is, with cellulose	5(C)-a	3.79 ± 0.06	3.13 ± 0.09	1.88 ± 0.19	0.16 ± 0.66	-1.94 ± 0.47	NA	-2.47 ± 0.78
Amended/Inoculated (6)								
As is, w/o cellulose	6(NC)-a	3.85 ± 0.04	0.84 ± 0.84	1.52 ± 0.84	1.56 ± 0.80	0.11 ± 0.53	-1.49 ± 0.34	-3.47 ± 0.15
As is, with cellulose	6(C)-a	2.60 ± 0.16	3.00 ± 0.06	5.07 ± 0.75	10.7 ± 1.8	14.9 ± 1.5	18.9 ± 1.1	18.4 ± 1.0
As is, with glucose	6(G)-a	1.60 ± 0.04	1.10 ± 0.69	0.69 ± 0.50	-0.34 ± 0.19	-1.07 ± 0.27	-1.62 ± 0.19	-1.52 ± 0.61
Excess nitrate, w/o cellulose	6(NC)-x	1.41 ± 0.08	-1.45 ± 0.04	-0.99 ± 0.08	0.00 ± 0.00	-0.27 ± 0.08	-1.30 ± 0.04	-3.05 ± 0.08
Excess nitrate, with cellulose	6(C)-x	2.91 ± 0.06	2.82 ± 0.09	6.79 ± 0.09	11.2 ± 1.2	18.7 ± 1.5	24.4 ± 0.9	27.3 ± 0.2
Excess nitrate, with glucose	6(G)-x	2.29 ± 0.23	2.51 ± 1.71	0.69 ± 0.57	-0.38 ± 0.5	-0.53 ± 0.11	-1.49 ± 0.15	-1.94 ± 0.69

NA = not analyzed

Table 5. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Aerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Carbon Dioxide (μmoles/sample) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin treated, w/o cellulose	4(NC)-f	50.3 ± 0.4	88.8 ± 1.0	98.8 ± 0.4	101 ± 1	115 ± 2	NA	121 ± 4
Formalin treated, with cellulose	4(C)-f	71.1 ± 1.2	95.3 ± 0.2	110 ± 0	114 ± 0	127 ± 1	NA	137 ± 1
As is, w/o cellulose	4(NC)-a	17.7 ± 0.3	38.8 ± 0.4	44.5 ± 0.4	40.2 ± 0.3	42.7 ± 0.2	NA	40.0 ± 0.1
As is, with cellulose	4(C)-a	25.3 ± 1.5	47.6 ± 0.3	66.9 ± 11.8	49 ± 0.7	51.8 ± 0.5	NA	51.6 ± 0.1
Unamended/Inoculated (5)								
Formalin treated, w/o cellulose	5(NC)-f	37.3 ± 10.1	59.6 ± 15.7	66.1 ± 18.4	77.4 ± 18.1	76.0 ± 26.5	NA	79.0 ± 33.0
Formalin treated, with cellulose	5(C)-f	61.9 ± 0.9	83.5 ± 0.0	94.0 ± 0.2	93.2 ± 0.6	100 ± 0	NA	102 ± 0
As is, w/o cellulose	5(NC)-a	13.5 ± 2.9	36.7 ± 0.7	41.3 ± 0.2	38.7 ± 0.7	41.4 ± 0.7	NA	37.6 ± 0.7
As is, with cellulose	5(C)-a	23.7 ± 0.2	43.6 ± 0.4	61.3 ± 4.0	80.3 ± 2.1	101 ± 3	NA	145 ± 6
Amended/Inoculated (6)								
As is, w/o cellulose	6(NC)-a	11.3 ± 0.1	103 ± 3	169 ± 3	185 ± 2	201 ± 2	203 ± 0	181 ± 1
As is, with cellulose	6(C)-a	8.60 ± 0.00	72.4 ± 1.0	156 ± 5	247 ± 11	358 ± 19	492 ± 6	530 ± 6
As is, with glucose	6(G)-a	8.50 ± 2.80	67.1 ± 0.2	73.1 ± 0.4	72.9 ± 0.2	75.8 ± 0.4	79.5 ± 1.0	75.7 ± 1.7
Excess nitrate, w/o cellulose	6(NC)-x	10.5 ± 0.4	84.6 ± 0.0	153 ± 1	171 ± 3	139 ± 37	184 ± 4	159 ± 4
Excess nitrate, with cellulose	6(C)-x	8.9 ± 0.1	68.0 ± 1.2	164 ± 3	307 ± 23	499 ± 75	711 ± 46	741 ± 30
Excess nitrate, with glucose	6(G)-x	9.40 ± 0.90	65.0 ± 2.0	71.4 ± 1.2	71.2 ± 0.6	76.5 ± 0.2	80.1 ± 1.5	81.1 ± 5.0

*Dissolved carbon dioxide concentrations not included.

NA = not analyzed

Table 6. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Aerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Nitrous Oxide (μmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (4)							
Formalin treated, w/o cellulose	4(NC)-f	0.000 ± 0.000	0.002 ± 0.002	0.213 ± 0.146	0.010 ± 0.007	NA	0.000 ± 0.000
Formalin treated, with cellulose	4(C)-f	0.000 ± 0.000	0.008 ± 0.002	0.001 ± 0.001	0.019 ± 0.000	NA	0.006 ± 0.001
As is, w/o cellulose	4(NC)-a	0.000 ± 0.000	0.006 ± 0.001	0.003 ± 0.002	0.017 ± 0.000	NA	0.005 ± 0.003
As is, with cellulose	4(C)-a	0.000 ± 0.000	0.731 ± 0.489	0.188 ± 0.054	0.222 ± 0.070	NA	0.245 ± 0.101
Unamended/Inoculated (5)							
Formalin treated, w/o cellulose	5(NC)-f	0.000 ± 0.000	0.070 ± 0.049	0.009 ± 0.002	0.166 ± 0.106	NA	0.076 ± 0.049
Formalin treated, with cellulose	5(C)-f	0.000 ± 0.000	0.012 ± 0.001	0.011 ± 0.002	0.025 ± 0.001	NA	0.009 ± 0.002
As is, w/o cellulose	5(NC)-a	0.000 ± 0.000	0.038 ± 0.024	0.195 ± 0.065	0.210 ± 0.066	NA	0.161 ± 0.050
As is, with cellulose	5(C)-a	0.000 ± 0.000	0.010 ± 0.006	0.000 ± 0.000	0.000 ± 0.000	NA	0.064 ± 0.027
Amended/Inoculated (6)							
As is, w/o cellulose	6(NC)-a	0.000 ± 0.000	0.002 ± 0.001	1.21 ± 0.36	6.06 ± 4.21	4.96 ± 3.51	4.27 ± 2.55
As is, with cellulose	6(C)-a	0.000 ± 0.000	31.6 ± 13.2	160 ± 53	132 ± 8	0.528 ± 0.459	0.000 ± 0.000
As is, with glucose	6(G)-a	0.000 ± 0.000	0.003 ± 0.000	0.003 ± 0.000	0.028 ± 0.001	0.007 ± 0.001	0.015 ± 0.004
Excess nitrate, w/o cellulose	6(NC)-x	0.000 ± 0.000	0.000 ± 0.000	14.6 ± 2.7	13.9 ± 5.2	13.8 ± 5.4	11.6 ± 4.9
Excess nitrate, with cellulose	6(C)-x	0.000 ± 0.000	27.1 ± 6.5	142 ± 22	217 ± 41	354 ± 41	425 ± 35
Excess nitrate, with glucose	6(G)-x	0.000 ± 0.000	0.005 ± 0.001	0.010 ± 0.001	0.022 ± 0.003	0.092 ± 0.063	0.011 ± 0.001

*Dissolved nitrous oxide concentrations not included.
NA = not analyzed

Table 7. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Anaerobic Samples

Treatments [Brine]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin treated, w/o cellulose	7(NC)-f	2.99 ± 0.10	2.65 ± 0.10	2.01 ± 0.03	1.09 ± 0.06	1.66 ± 0.00	NA	0.06 ± 0.03
Formalin treated, with cellulose	7(C)-f	4.28 ± 0.06	3.49 ± 0.06	3.10 ± 0.03	1.95 ± 0.03	2.37 ± 0.03	NA	1.37 ± 0.00
As is, w/o cellulose	7(NC)-a	3.20 ± 0.34	2.96 ± 0.07	0.99 ± 0.14	2.24 ± 0.00	2.07 ± 0.10	NA	0.65 ± 0.31
As is, with cellulose	7(C)-a	3.37 ± 0.27	3.47 ± 0.10	2.99 ± 0.07	1.33 ± 0.34	2.28 ± 1.17	NA	0.20 ± 0.17
Unamended/Inoculated (8)								
Formalin treated, w/o cellulose	8(NC)-f	3.79 ± 0.04	2.31 ± 0.07	1.73 ± 0.18	0.76 ± 0.11	1.55 ± 0.11	NA	-0.07 ± 0.11
Formalin treated, with cellulose	8(C)-f	3.89 ± 0.03	3.39 ± 0.09	2.54 ± 0.15	1.58 ± 0.00	2.14 ± 0.06	NA	1.02 ± 0.03
As is, w/o cellulose	8(NC)-a	3.66 ± 0.08	-1.37 ± 0.99	1.41 ± 0.23	1.87 ± 0.08	2.10 ± 0.08	NA	-0.50 ± 0.00
As is, with cellulose	8(C)-a	3.47 ± 0.06	3.63 ± 0.13	2.53 ± 0.16	1.78 ± 0.13	2.22 ± 0.06	NA	2.44 ± 0.63
Amended/Inoculated (9)								
As is, w/o cellulose	9(NC)-a	3.77 ± 0.04	3.35 ± 0.08	6.63 ± 0.30	7.96 ± 1.33	9.07 ± 0.88	8.41 ± 0.48	8.04 ± 0.46
As is, with cellulose	9(C)-a	3.35 ± 0.09	3.44 ± 0.16	4.04 ± 0.03	11.3 ± 0.5	16.7 ± 1.3	19.2 ± 1.2	19.4 ± 0.6
As is, with glucose	9(G)-a	2.97 ± 0.08	2.59 ± 0.15	2.36 ± 0.15	1.64 ± 0.15	1.52 ± 0.27	0.18 ± 0.16	-1.26 ± 0.30
Excess nitrate, w/o cellulose	9(NC)-x	3.24 ± 0.04	2.86 ± 0.08	4.30 ± 0.23	6.59 ± 0.76	9.18 ± 0.23	8.65 ± 0.67	6.93 ± 0.27
Excess nitrate, with cellulose	9(C)-x	3.29 ± 0.13	2.28 ± 0.38	5.76 ± 1.47	16.6 ± 2.9	14.2 ± 3.9	28.9 ± 6.2	34.1 ± 7.1
Excess nitrate, with glucose	9(G)-x	3.01 ± 0.11	0.61 ± 0.15	0.19 ± 0.11	0.46 ± 0.04	0.46 ± 0.61	1.33 ± 2.08	1.14 ± 2.90

NA = not analyzed

Table 8. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Anaerobic Samples

Treatments [Brine]	Sample Designation	Carbon Dioxide (µmoles/sample) Incubation Time (Days)						
		0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin treated, w/o cellulose	7(NC)-f	2.26 ± 0.01	1.92 ± 0.03	2.20 ± 0.20	2.24 ± 0.04	2.33 ± 0.01	NA	2.39 ± 0.01
Formalin treated, with cellulose	7(C)-f	31.7 ± 0.5	38.0 ± 0.1	38.0 ± 0.1	35.0 ± 0.2	36.4 ± 0.1	NA	36.3 ± 0.1
As is, w/o cellulose	7(NC)-a	1.12 ± 0.01	0.58 ± 0.13	0.90 ± 0.00	1.37 ± 0.01	1.35 ± 0.01	NA	1.46 ± 0.03
As is, with cellulose	7(C)-a	13.0 ± 0.4	19.3 ± 0.1	20.5 ± 0.1	19.5 ± 0.1	20.5 ± 0.2	NA	19.4 ± 0.2
Unamended/Inoculated (8)								
Formalin treated, w/o cellulose	8(NC)-f	4.42 ± 0.01	3.88 ± 0.08	3.89 ± 0.13	3.88 ± 0.04	3.99 ± 0.03	NA	3.97 ± 0.03
Formalin treated, with cellulose	8(C)-f	32.1 ± 0.7	34.3 ± 0.4	33.5 ± 0.2	31.2 ± 0.0	32.5 ± 0.5	NA	32.8 ± 0.4
As is, w/o cellulose	8(NC)-a	1.96 ± 0.02	1.37 ± 0.01	2.29 ± 0.02	2.75 ± 0.01	2.86 ± 0.01	NA	2.74 ± 0.01
As is, with cellulose	8(C)-a	12.5 ± 0.2	18.4 ± 0.2	19.0 ± 0.1	17.8 ± 0.7	22.7 ± 0.5	NA	30.1 ± 1.7
Amended/Inoculated (9)								
As is, w/o cellulose	9(NC)-a	3.02 ± 0.00	6.86 ± 0.02	58.9 ± 3.1	95.9 ± 9.5	109 ± 4	119 ± 3	120 ± 1
As is, with cellulose	9(C)-a	2.70 ± 0.00	25.8 ± 0.2	42.5 ± 1.7	132 ± 3	200 ± 7	240 ± 3	250 ± 4
As is, with glucose	9(G)-a	2.25 ± 0.01	3.36 ± 0.04	2.96 ± 0.04	3.50 ± 0.05	3.88 ± 0.06	4.26 ± 0.09	4.31 ± 0.07
Excess nitrate, w/o cellulose	9(NC)-x	3.07 ± 0.03	5.17 ± 0.28	35.3 ± 5.3	94.5 ± 4.4	120 ± 1	125 ± 1	123 ± 1
Excess nitrate, with cellulose	9(C)-x	5.40 ± 0.00	26.6 ± 0.2	65.8 ± 17.1	193 ± 33	249 ± 32	352 ± 40	430 ± 41
Excess nitrate, with glucose	9(G)-x	1.81 ± 0.27	2.88 ± 0.19	2.65 ± 0.25	8.64 ± 3.62	23.6 ± 13.3	53.6 ± 31.4	74.9 ± 40.9

*Dissolved carbon dioxide concentrations not included.
NA = not analyzed

Table 9. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Anaerobic Samples

Treatments [Brine]	Sample Designation	Nitrous Oxide (µmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (7)							
Formalin treated, w/o cellulose	7(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	7(C)-f	0.000 ± 0.000	0.009 ± 0.007	0.004 ± 0.001	0.007 ± 0.005	NA	0.002 ± 0.002
As is, w/o cellulose	7(NC)-a	0.000 ± 0.000	0.003 ± 0.002	0.001 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
As is, with cellulose	7(C)-a	0.000 ± 0.000	0.002 ± 0.002	0.003 ± 0.002	0.000 ± 0.000	NA	0.002 ± 0.002
Unamended/Inoculated (8)							
Formalin treated, w/o cellulose	8(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	8(C)-f	0.000 ± 0.000	0.002 ± 0.001	0.002 ± 0.000	0.014 ± 0.001	NA	0.008 ± 0.000
As is, w/o cellulose	8(NC)-a	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
As is, with cellulose	8(C)-a	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Amended/Inoculated (9)							
As is, w/o cellulose	9(NC)-a	0.000 ± 0.000	0.376 ± 0.262	35.5 ± 25.1	7.55 ± 5.34	0.000 ± 0.000	0.359 ± 0.235
As is, with cellulose	9(C)-a	0.000 ± 0.000	0.359 ± 0.145	13.2 ± 10.1	86.5 ± 41.3	89.3 ± 43.0	77.8 ± 42.2
As is, with glucose	9(G)-a	0.000 ± 0.000	0.002 ± 0.001	0.000 ± 0.000	0.005 ± 0.003	0.005 ± 0.000	0.015 ± 0.010
Excess nitrate, w/o cellulose	9(NC)-x	0.000 ± 0.000	0.081 ± 0.021	5.13 ± 2.48	0.014 ± 0.002	0.000 ± 0.000	0.000 ± 0.000
Excess nitrate, with cellulose	9(C)-x	0.000 ± 0.000	0.870 ± 0.422	85.7 ± 50.2	196 ± 75	280 ± 160	395 ± 228
Excess nitrate, with glucose	9(G)-x	0.000 ± 0.000	0.028 ± 0.020	3.84 ± 2.72	0.523 ± 0.006	0.539 ± 0.381	13.8 ± 0.5

*Dissolved nitrous oxide concentrations not included.

NA = not analyzed

Table 10. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Anaerobic Samples.

Treatments* [Brine/Bentonite]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin treated, w/o cellulose	10(NC)-f	4.65 ± 0.23	4.61 ± 0.47	2.37 ± 1.47	3.41 ± 0.19	4.07 ± 0.04	NA	2.33 ± 0.00
Formalin treated, with cellulose	10(C)-f	4.96 ± 0.06	4.64 ± 0.03	4.22 ± 0.00	2.94 ± 0.16	3.39 ± 0.16	NA	2.05 ± 0.16
As is, w/o cellulose	10(NC)-a	4.24 ± 0.33	4.04 ± 0.04	3.51 ± 0.69	2.86 ± 0.08	3.27 ± 0.20	NA	1.55 ± 0.08
As is, with cellulose	10(C)-a	3.84 ± 0.48	3.84 ± 0.14	3.33 ± 0.27	2.01 ± 0.41	2.18 ± 0.48	NA	0.14 ± 0.44
Unamended/Inoculated (11)								
Formalin treated, w/o cellulose	11(NC)-f	5.16 ± 0.07	5.01 ± 0.14	3.89 ± 0.22	2.85 ± 0.25	3.57 ± 0.25	NA	1.23 ± 0.22
Formalin treated, with cellulose	11(C)-f	4.65 ± 0.03	4.53 ± 0.00	3.66 ± 0.03	1.73 ± 1.14	2.16 ± 1.08	NA	0.94 ± 1.20
As is, w/o cellulose	11(NC)-a	4.23 ± 0.11	3.62 ± 0.08	3.47 ± 0.19	2.06 ± 0.19	2.44 ± 0.30	NA	0.34 ± 0.34
As is, with cellulose	11(C)-a	4.38 ± 0.03	4.19 ± 0.06	3.19 ± 0.16	2.88 ± 0.22	3.88 ± 0.19	NA	4.38 ± 0.38
Amended/Inoculated (12)								
As is, w/o cellulose	12(NC)-a	3.85 ± 0.08	4.53 ± 0.15	6.97 ± 0.15	9.90 ± 0.08	10.9 ± 0.1	11.1 ± 0.3	9.87 ± 0.80
As is, with cellulose	12(C)-a	3.32 ± 0.25	4.29 ± 0.09	7.92 ± 0.44	16.8 ± 0.4	19.8 ± 0.4	18.3 ± 0.3	19.5 ± 0.4
As is, with glucose	12(G)-a	3.50 ± 0.04	5.52 ± 0.34	9.49 ± 2.40	24.7 ± 3.3	33.9 ± 0.6	38.8 ± 1.8	37.8 ± 2.3
Excess nitrate, w/o cellulose	12(NC)-x	3.66 ± 0.00	4.19 ± 0.15	8.19 ± 0.69	11.8 ± 0.3	12.4 ± 0.0	12.8 ± 0.1	11.2 ± 0.1
Excess nitrate, with cellulose	12(C)-x	3.38 ± 0.09	3.76 ± 0.16	9.36 ± 0.31	15.7 ± 0.4	20.8 ± 0.5	23.8 ± 0.7	28.9 ± 1.4
Excess nitrate, with glucose	12(G)-x	3.09 ± 0.08	2.29 ± 0.19	2.21 ± 0.46	23.4 ± 0.6	52.3 ± 6.7	77.4 ± 20.2	80.7 ± 21.1

NA = not analyzed

Table 11. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Anaerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Carbon Dioxide (µmoles/sample) Incubation Time (Days)						
		0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin treated, w/o cellulose	10(NC)-f	55.8 ± 0.6	82.9 ± 1.1	85.5 ± 0.8	86.4 ± 1.7	92.8 ± 2.0	NA	94.9 ± 1.1
Formalin treated, with cellulose	10(C)-f	65.5 ± 1.0	85.5 ± 0.2	88.6 ± 0.4	81.9 ± 0.3	88.7 ± 0.9	NA	90.2 ± 0.3
As is, w/o cellulose	10(NC)-a	16.4 ± 0.4	37.7 ± 0.0	38.4 ± 0.1	38.1 ± 0.3	39.8 ± 0.3	NA	40.0 ± 0.4
As is, with cellulose	10(C)-a	26.6 ± 0.5	42.6 ± 0.2	43.0 ± 0.4	41.3 ± 0.2	43.1 ± 0.5	NA	41.1 ± 0.2
Unamended/Inoculated (11)								
Formalin treated, w/o cellulose	11(NC)-f	53.0 ± 0.2	76.9 ± 0.6	80.2 ± 0.4	76.5 ± 0.0	83.7 ± 0.6	NA	83.5 ± 0.2
Formalin treated, with cellulose	11(C)-f	64.4 ± 1.3	76.3 ± 0.5	78.6 ± 0.2	75.1 ± 1.9	78.6 ± 1.6	NA	80.4 ± 0.8
As is, w/o cellulose	11(NC)-a	20.8 ± 0.0	35.0 ± 0.1	36.3 ± 0.1	35.2 ± 0.2	19.6 ± 11.9	NA	36.2 ± 0.2
As is, with cellulose	11(C)-a	30.1 ± 0.6	38.1 ± 0.2	40.5 ± 0.1	48 ± 2.5	59.9 ± 0.7	NA	77.6 ± 1.0
Amended/Inoculated (12)								
As is, w/o cellulose	12(NC)-a	14.0 ± 0.0	60.2 ± 0.2	99.8 ± 4.7	150 ± 4	16.6 ± 0.4	177 ± 1	179 ± 0
As is, with cellulose	12(C)-a	12.0 ± 0.8	55.0 ± 0.3	104 ± 5	209 ± 2	260 ± 8	295 ± 10	338 ± 10
As is, with glucose	12(G)-a	15.2 ± 0.6	76.0 ± 2.4	144 ± 28	375 ± 36	590 ± 15	691 ± 20	786 ± 25
Excess nitrate, w/o cellulose	12(NC)-x	13.9 ± 0.3	69.2 ± 0.0	121 ± 3	166 ± 1	186 ± 2	196 ± 2	196 ± 2
Excess nitrate, with cellulose	12(C)-x	10.3 ± 0.6	57.4 ± 1.7	122 ± 3	195 ± 5	264 ± 6	309 ± 7	371 ± 14
Excess nitrate, with glucose	12(G)-x	15.1 ± 0.0	69.4 ± 1.2	111 ± 4	422 ± 12	916 ± 35	1370 ± 19	1610 ± 43

*Dissolved carbon dioxide concentrations not included.
NA = not analyzed

Table 12. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Anaerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Nitrous Oxide (μmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (10)							
Formalin treated, w/o cellulose	10(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	10(C)-f	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
As is, w/o cellulose	10(NC)-a	0.000 ± 0.000	0.004 ± 0.003	0.102 ± 0.065	1.040 ± 0.490	NA	1.73 ± 0.10
As is, with cellulose	10(C)-a	0.000 ± 0.000	0.005 ± 0.002	0.008 ± 0.004	0.021 ± 0.009	NA	0.031 ± 0.011
Unamended/Inoculated (11)							
Formalin treated, w/o cellulose	11(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.002 ± 0.001
Formalin treated, with cellulose	11(C)-f	0.000 ± 0.000	0.000 ± 0.000	0.006 ± 0.002	0.024 ± 0.003	NA	0.000 ± 0.000
As is, w/o cellulose	11(NC)-a	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.037 ± 0.026	NA	0.007 ± 0.005
As is, with cellulose	11(C)-a	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Amended/Inoculated (12)							
As is, w/o cellulose	12(NC)-a	0.000 ± 0.000	0.016 ± 0.006	0.534 ± 0.378	0.000 ± 0.000	0.000 ± 0.000	3.35 ± 2.19
As is, with cellulose	12(C)-a	0.000 ± 0.000	0.111 ± 0.056	2.34 ± 1.92	0.000 ± 0.000	0.301 ± 0.246	0.000 ± 0.000
As is, with glucose	12(G)-a	0.000 ± 0.000	1.56 ± 1.10	40.1 ± 28.3	0.782 ± 0.557	0.016 ± 0.011	0.000 ± 0.000
Excess nitrate, w/o cellulose	12(NC)-x	0.000 ± 0.000	0.007 ± 0.001	0.081 ± 0.057	0.000 ± 0.000	0.003 ± 0.002	0.481 ± 0.340
Excess nitrate, with cellulose	12(C)-x	0.004 ± 0.000	3.80 ± 2.39	0.022 ± 0.018	47.1 ± 17.8	154 ± 20	311 ± 23
Excess nitrate, with glucose	12(G)-x	0.005 ± 0.000	0.077 ± 0.049	2.31 ± 1.59	261 ± 184	616 ± 428	585 ± 406

*Dissolved nitrous oxide concentrations not included.
NA = not analyzed

Table 13. Total Volume of Gas Produced in Aerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Milliliters of Gas Produced/Gram Cellulose Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin	1(C)-f	0.24 ± 0.06	0.89 ± 0.03	0.85 ± 0.02	0.42 ± 0.21	0.27 ± 0.19	NA	0.42 ± 0.18
As is	1(C)-a	0.05 ± 0.02	-0.29 ± 0.19	-0.36 ± 0.18	-0.31 ± 0.14	-0.20 ± 0.12	NA	-0.18 ± 0.10
Unamended/Inoculated (2)								
Formalin	2(C)-f	-0.01 ± 0.01	-0.03 ± 0.08	-0.35 ± 0.11	-0.32 ± 0.08	-0.41 ± 0.11	NA	-0.11 ± 0.09
As is	2(C)-a	-0.08 ± 0.01	0.01 ± 0.04	-0.15 ± 0.03	-0.11 ± 0.04	0.00 ± 0.05	NA	-0.34 ± 0.07
Amended/Inoculated (3)								
As is	3(C)-a	-0.12 ± 0.03	-0.27 ± 0.14	-0.25 ± 0.06	0.36 ± 0.31	0.29 ± 0.24	0.07 ± 0.13	0.86 ± 0.08
Exc. nitrate	3(C)-x	-0.02 ± 0.01	0.02 ± 0.14	1.39 ± 0.61	2.38 ± 0.87	3.10 ± 1.06	4.02 ± 1.21	4.42 ± 0.80

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 14. Total Volume of Gas Produced in Aerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Designation	Milliliters of Gas Produced/Gram Cellulose Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin	4(C)-f	0.13 ± 0.03	0.63 ± 0.03	0.47 ± 0.03	0.15 ± 0.03	0.02 ± 0.01	NA	0.04 ± 0.01
As is	4(C)-a	-0.05 ± 0.02	0.02 ± 0.02	-0.36 ± 0.04	-0.20 ± 0.05	-0.13 ± 0.04	NA	0.00 ± 0.05
Unamended/Inoculated (5)								
Formalin	5(C)-f	0.11 ± 0.02	0.21 ± 0.01	0.31 ± 0.00	0.29 ± 0.00	0.07 ± 0.03	NA	0.16 ± 0.02
As is	5(C)-a	0.03 ± 0.01	-0.10 ± 0.02	-0.18 ± 0.04	-0.30 ± 0.13	-0.23 ± 0.09	NA	-0.08 ± 0.16
Amended/Inoculated (6)								
As is	6(C)-a	-0.25 ± 0.03	0.43 ± 0.01	0.71 ± 0.15	1.82 ± 0.35	2.96 ± 0.30	4.07 ± 0.22	4.38 ± 0.20
Exc. nitrate	6(C)-x	0.30 ± 0.01	0.85 ± 0.02	1.56 ± 0.02	2.23 ± 0.24	3.74 ± 0.29	5.15 ± 0.18	6.07 ± 0.04

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 15. Production of Carbon Dioxide in Aerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin	1(C)-f	5.58 ± 0.54	7.66 ± 0.02	8.20 ± 0.04	7.46 ± 0.16	7.64 ± 0.06	NA	7.62 ± 0.10
As is	1(C)-a	2.48 ± 0.10	3.92 ± 0.06	4.21 ± 0.02	3.93 ± 0.02	4.25 ± 0.02	NA	4.00 ± 0.02
Unamended/Inoculated (2)								
Formalin	2(C)-f	5.91 ± 0.16	6.24 ± 0.00	6.80 ± 0.14	5.88 ± 0.12	6.04 ± 0.02	NA	5.65 ± 0.22
As is	2(C)-a	1.96 ± 0.06	3.35 ± 0.16	3.94 ± 0.18	4.98 ± 0.18	6.87 ± 0.20	NA	8.30 ± 0.28
Amended/Inoculated (3)								
As is	3(C)-a	ND	4.62 ± 0.28	3.78 ± 1.18	20.4 ± 7.4	29.6 ± 5	36.6 ± 4.2	40.8 ± 5.4
Exc. nitrate	3(C)-x	ND	6.88 ± 0.00	32.2 ± 4.2	61.4 ± 3.6	83.6 ± 2.6	96.2 ± 4.0	95.6 ± 6.0

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 16. Production of Carbon Dioxide in Aerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin	4(C)-f	4.16 ± 0.24	1.30 ± 0.04	2.24 ± 0.00	2.60 ± 0.00	2.40 ± 0.20	NA	3.20 ± 0.20
As is	4(C)-a	1.52 ± 0.30	1.76 ± 0.06	4.48 ± 2.36	1.76 ± 0.14	1.82 ± 0.10	NA	2.32 ± 0.02
Unamended/Inoculated (5)								
Formalin	5(C)-f	4.92 ± 0.18	4.78 ± 0.00	5.58 ± 0.04	3.16 ± 0.12	4.80 ± 0.00	NA	4.60 ± 0.00
As is	5(C)-a	2.04 ± 0.04	1.38 ± 0.08	4.00 ± 0.80	8.32 ± 0.42	11.9 ± 0.6	NA	21.5 ± 1.2
Amended/Inoculated (6)								
As is	6(C)-a	ND	ND	ND	12.4 ± 2.2	31.4 ± 3.8	57.8 ± 1.2	69.8 ± 1.2
Exc. nitrate	6(C)-x	ND	ND	2.20 ± 0.60	27.2 ± 4.6	72.0 ± 15.0	105 ± 9	116 ± 6

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 17. Production of Nitrous Oxide in Aerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Nitrous Oxide (µmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (1)							
Formalin	1(C)-f	ND	ND	0.001 ± 0.000	0.003 ± 0.000	NA	0.001 ± 0.000
As is	1(C)-a	ND	ND	0.001 ± 0.000	0.003 ± 0.000	NA	ND
Unamended/Inoculated (2)							
Formalin	2(C)-f	ND	ND	ND	0.003 ± 0.000	NA	0.001 ± 0.000
As is	2(C)-a	0.002 ± 0.000	ND	ND	ND	NA	ND
Amended/Inoculated (3)							
As is	3(C)-a	0.001 ± 0.000	0.024 ± 0.029	23.6 ± 9.6	24.4 ± 7.8	1.76 ± 1.20	5.83 ± 5.04
Exc. nitrate	3(C)-x	ND	5.64 ± 1.77	49.0 ± 2.2	65.2 ± 3.6	96.8 ± 13.4	115 ± 26

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

Table 18. Production of Nitrous Oxide in Aerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Desig.	Nitrous Oxide (μmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (4)							
Formalin	4(C)-f	ND	0.001 ± 0.000	ND	0.002 ± 0.000	NA	0.001 ± 0.000
As is	4(C)-a	ND	0.145 ± 0.098	0.037 ± 0.011	0.041 ± 0.014	NA	0.048 ± 0.020
Unamended/Inoculated (5)							
Formalin	5(C)-f	ND	ND	ND	ND	NA	ND
As is	5(C)-a	ND	0.000 ± 0.001	ND	ND	NA	ND
Amended/Inoculated (6)							
As is	6(C)-a	ND	6.32 ± 2.64	31.8 ± 10.6	25.2 ± 1.6	ND	ND
Exc. nitrate	6(C)-x	ND	5.42 ± 1.30	25.5 ± 4.4	40.6 ± 8.2	68.0 ± 8.2	82.7 ± 7.0

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

Table 19. Total Volume of Gas Produced in Anaerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Designation	Milliliters of Gas Produced/Gram Cellulose Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin	7(C)-f	0.26 ± 0.01	0.17 ± 0.01	0.22 ± 0.01	0.17 ± 0.01	0.14 ± 0.01	NA	0.26 ± 0.00
As is	7(C)-a	0.03 ± 0.05	0.10 ± 0.02	0.40 ± 0.01	-0.18 ± 0.07	0.04 ± 0.23	NA	-0.09 ± 0.03
Unamended/Inoculated (8)								
Formalin	8(C)-f	0.02 ± 0.01	0.22 ± 0.02	0.16 ± 0.03	0.16 ± 0.00	0.12 ± 0.01	NA	0.22 ± 0.00
As is	8(C)-a	-0.04 ± 0.01	1.00 ± 0.03	0.22 ± 0.03	-0.02 ± 0.03	0.02 ± 0.01	NA	0.59 ± 0.13
Amended/Inoculated (9)								
As is	9(C)-a	-0.08 ± 0.02	0.02 ± 0.03	-0.52 ± 0.01	0.66 ± 0.09	1.52 ± 0.25	2.15 ± 0.24	2.27 ± 0.12
Exc. nitrate	9(C)-x	0.01 ± 0.03	-0.12 ± 0.08	0.29 ± 0.29	2.00 ± 0.58	2.24 ± 0.78	4.04 ± 1.24	5.44 ± 1.42

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 20. Total Volume of Gas Produced in Anaerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Designation	Milliliters of Gas Produced/Gram Cellulose Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin	10(C)-f	0.06 ± 0.01	0.01 ± 0.01	0.37 ± 0.00	-0.09 ± 0.03	-0.14 ± 0.03	NA	-0.06 ± 0.03
As is	10(C)-a	-0.08 ± 0.10	-0.04 ± 0.03	-0.04 ± 0.05	-0.17 ± 0.08	-0.22 ± 0.10	NA	-0.28 ± 0.09
Unamended/Inoculated (11)								
Formalin	11(C)-f	-0.10 ± 0.01	-0.10 ± 0.00	-0.05 ± 0.01	-0.22 ± 0.23	-0.28 ± 0.22	NA	-0.06 ± 0.24
As is	11(C)-a	0.03 ± 0.01	0.11 ± 0.01	-0.06 ± 0.03	0.16 ± 0.04	0.29 ± 0.04	NA	0.81 ± 0.08
Amended/Inoculated (12)								
As is	12(C)-a	-0.11 ± 0.05	-0.05 ± 0.02	0.19 ± 0.09	1.39 ± 0.09	1.78 ± 0.08	1.44 ± 0.07	1.92 ± 0.08
Exc. nitrate	12(C)-x	-0.06 ± 0.02	-0.09 ± 0.03	0.23 ± 0.06	0.78 ± 0.09	1.68 ± 0.10	2.19 ± 0.14	3.52 ± 0.28

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 21. Production of Carbon Dioxide in Anaerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Carbon Dioxide (µmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin	7(C)-f	5.89 ± 0.10	7.22 ± 0.02	7.16 ± 0.02	6.55 ± 0.04	6.81 ± 0.02	NA	6.78 ± 0.02
As is	7(C)-a	2.38 ± 0.08	3.74 ± 0.02	3.92 ± 0.02	3.63 ± 0.02	3.83 ± 0.04	NA	3.59 ± 0.04
Unamended/Inoculated (8)								
Formalin	8(C)-f	5.54 ± 0.14	6.08 ± 0.08	5.92 ± 0.04	5.46 ± 0.00	5.70 ± 0.10	NA	5.77 ± 0.08
As is	8(C)-a	2.11 ± 0.04	3.41 ± 0.04	3.34 ± 0.02	3.01 ± 0.14	3.97 ± 0.10	NA	5.47 ± 0.34
Amended/Inoculated (9)								
As is	9(C)-a	ND	3.79 ± 0.04	ND	7.22 ± 0.60	18.2 ± 1.4	24.2 ± 0.6	26.0 ± 0.8
Exc. nitrate	9(C)-x	0.47 ± 0.00	4.29 ± 0.04	6.10 ± 3.42	19.7 ± 6.6	25.8 ± 6.4	45.4 ± 8.0	61.4 ± 8.2

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 22. Production of Carbon Dioxide in Anaerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin	10(C)-f	1.94 ± 0.2	0.52 ± 0.04	0.62 ± 0.08	ND	ND	NA	ND
As is	10(C)-a	2.04 ± 0.1	0.98 ± 0.04	0.92 ± 0.08	0.64 ± 0.04	0.66 ± 0.10	NA	0.22 ± 0.04
Unamended/Inoculated (11)								
Formalin	11(C)-f	2.28 ± 0.26	ND	ND	ND	ND	NA	ND
As is	11(C)-a	1.86 ± 0.12	0.62 ± 0.04	0.84 ± 0.02	2.56 ± 0.50	8.06 ± 0.14	NA	8.28 ± 0.20
Amended/Inoculated (12)								
As is	12(C)-a	ND	ND	0.84 ± 1.00	11.8 ± 0.4	48.68 ± 1.6	23.6 ± 2.0	31.8 ± 2.0
Exc. nitrate	12(C)-x	ND	ND	0.20 ± 0.60	5.80 ± 1.00	15.6 ± 1.2	22.6 ± 1.4	35.0 ± 2.8

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 23. Production of Nitrous Oxide in Anaerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Nitrous Oxide (μmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (7)							
Formalin	7(C)-f	ND	0.002 ± 0.001	0.001 ± 0.000	0.001 ± 0.001	NA	ND
As is	7(C)-a	ND	ND	ND	ND	NA	ND
Unamended/Inoculated (8)							
Formalin	8(C)-f	ND	ND	ND	0.003 ± 0.000	NA	0.002 ± 0.000
As is	8(C)-a	ND	ND	ND	ND	NA	ND
Amended/Inoculated (9)							
As is	9(C)-a	ND	ND	ND	15.8 ± 8.3	17.9 ± 8.6	15.5 ± 8.4
Exc. nitrate	9(C)-x	ND	0.158 ± 0.084	16.1 ± 10.0	39.2 ± 15.0	56.0 ± 32.0	79.0 ± 45.6

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

Table 24. Production of Nitrous Oxide* in Anaerobic Samples in the Presence of Cellulose and Bentonite

Treatments [Brine/Bent.]	Sample Desig.	Nitrous Oxide (μmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (10)							
Formalin	10(C)-f	ND	ND	ND	ND	NA	ND
As is	10(C)-a	ND	ND	ND	ND	NA	ND
Unamended/Inoculated (11)							
Formalin	11(C)-f	ND	ND	0.001 ± 0.000	0.005 ± 0.001	NA	ND
As is	11(C)-a	ND	ND	ND	ND	NA	ND
Amended/Inoculated (12)							
As is	12(C)-a	ND	0.019 ± 0.011	0.361 ± 0.384	ND	0.060 ± 0.049	ND
Exc. nitrate	12(C)-x	0.001 ± 0.000	0.759 ± 0.478	0.000 ± 0.000	9.42 ± 3.56	30.8 ± 4.0	62.1 ± 4.6

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

APPENDIX E: MEASUREMENT OF MIXED INOCULUM ACTIVITY

APPENDIX E: MEASUREMENTS OF MIXED INOCULUM ACTIVITY

To determine the activity of the mixed inoculum, brine samples were incubated with glucose with an initial air and N_2 atmosphere. Total gas, CO_2 and N_2O were periodically monitored.

Aerobic Samples

Total Gas Production

Samples containing glucose, nutrients, excess nitrates with and without bentonite did not show an increase in total gas production (Figure 25, Tables 1(a)-2(a) Appendix D).

Carbon Dioxide Production

Production of carbon dioxide was evident after 132 days in amended and in amended plus excess nitrate samples without bentonite. After 200 days, amended samples produced 323 μmol of CO_2, whereas amended plus excess nitrate samples produced 296 μmol CO_2. Samples with bentonite did not produce significant amounts of CO_2 beyond the initial background level (~70-80 μmol) (Figure 26, Tables 1(b)-2(b) Appendix D).

Nitrous Oxide Production

Nitrous oxide was detected at 132 days in aerobic samples without bentonite (Figure 27, Tables 1(c)-2(c) Appendix D). Less N_2O was detected in amended samples with excess nitrate, and in samples containing bentonite, N_2O was not detected.

Anaerobic Samples

Total Gas Production

Amended and amended samples with excess nitrate showed no increase in total gas production. However, in the presence of bentonite, production in amended samples increased after 45 days of incubation and reached to 37.8 mL at 200 days (Figure 28, Tables 3(a)-4(a) Appendix D). Amended samples plus excess nitrate produced more gas (80.65 mL of gas at 200 days) than the other samples.

Carbon Dioxide Production

Production of carbon dioxide was not detected in the amended samples, whereas the amended samples with excess nitrate produced a small amount of CO_2. Carbon dioxide production in samples containing bentonite was significant (Figure 29, Tables 3(b)-4(b) Appendix D). Amended samples containing excess nitrate produced 1610 μmol of CO_2 at 200 days while the basic amended samples produced 786 moles. Carbon dioxide production was much higher in the glucose/bentonite samples than in the cellulose/bentonite samples, indicating the potential of the microorganisms to produce significant amounts of CO_2 under hypersaline conditions when a simple sugar is present. In addition, bentonite seems to enhance the overall gas production.

Nitrous Oxide Production

Accumulation of nitrous oxide was detected only in samples containing bentonite (Figure 30, Tables 3(c)-4(c) Appendix D). With excess nitrate, the N_2O concentration reached 585 μmol and then started to decline.

Summary

We examined glucose metabolism by the mixed inoculum used in the long-term experiments. Total gas production in samples incubated under aerobic conditions was not evident, but anaerobic samples produced significant amounts of gas, especially the samples with bentonite plus excess nitrate. Production of carbon dioxide in the aerobic samples was observed only in the amended and excess-nitrate samples without bentonite. Bentonite enhanced the activity of anaerobes. Carbon-dioxide production in anaerobic samples with excess nitrate reached a higher amount than any of the totals reached thus far in the long-term inundated experiment. Substantial amounts of N_2O also accumulated in the headspace of these samples.

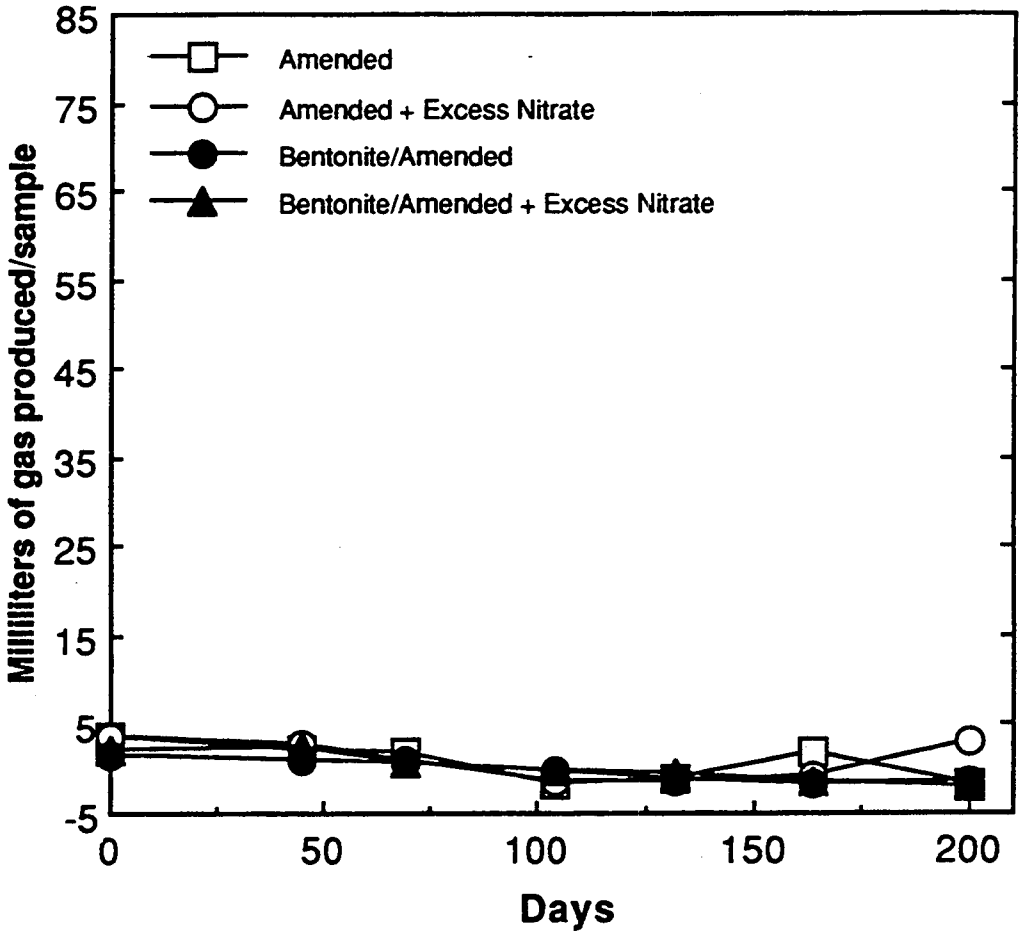

Figure 25. Total gas produced in samples containing glucose incubated with an initial atmosphere of air.

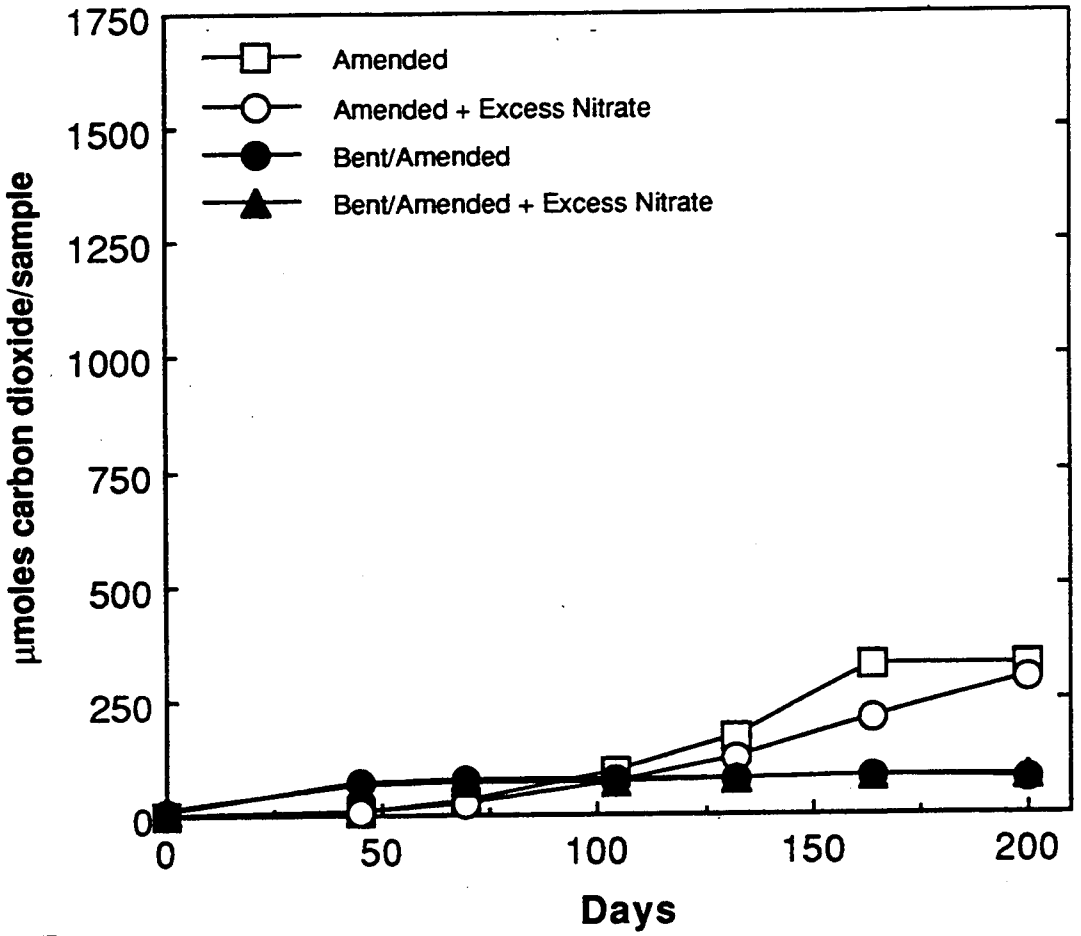

Figure 26. Carbon dioxide produced in samples containing glucose incubated with an initial atmosphere of air.

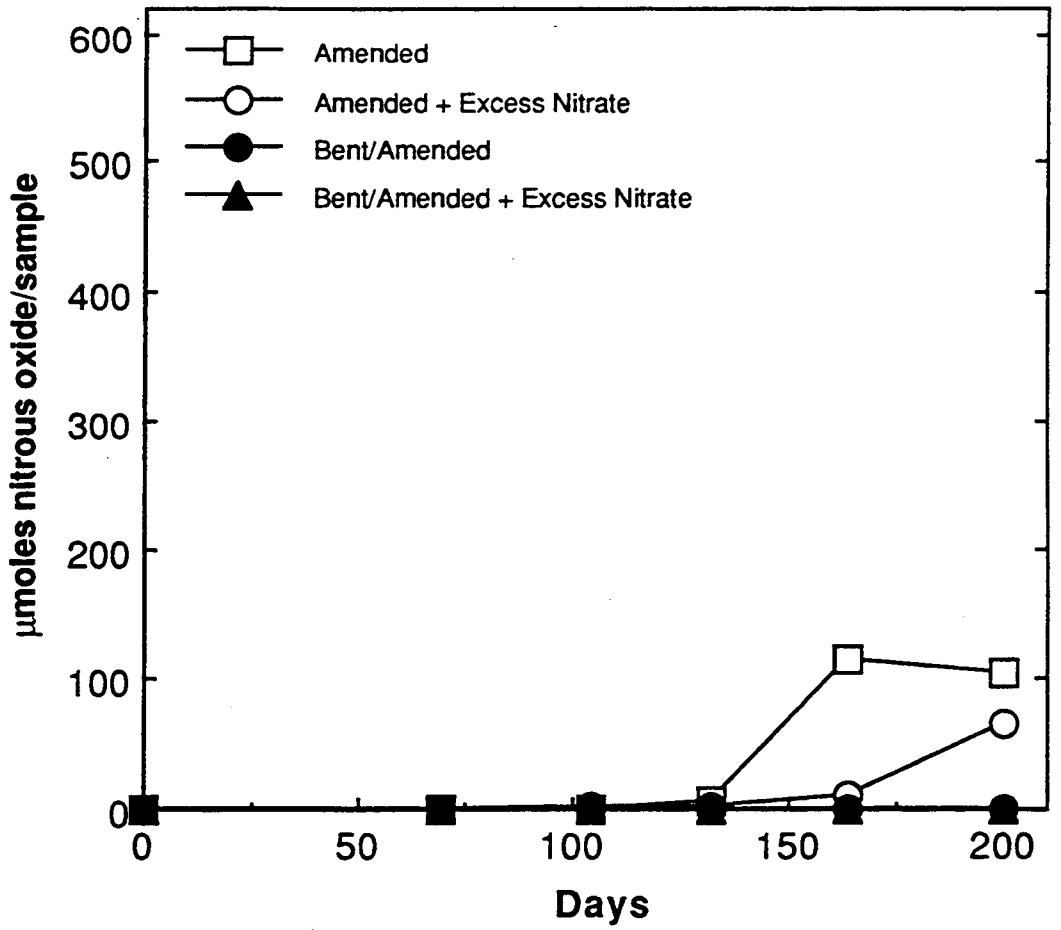

Figure 27. Nitrous oxide produced in samples containing glucose incubated with an initial atmosphere of air.

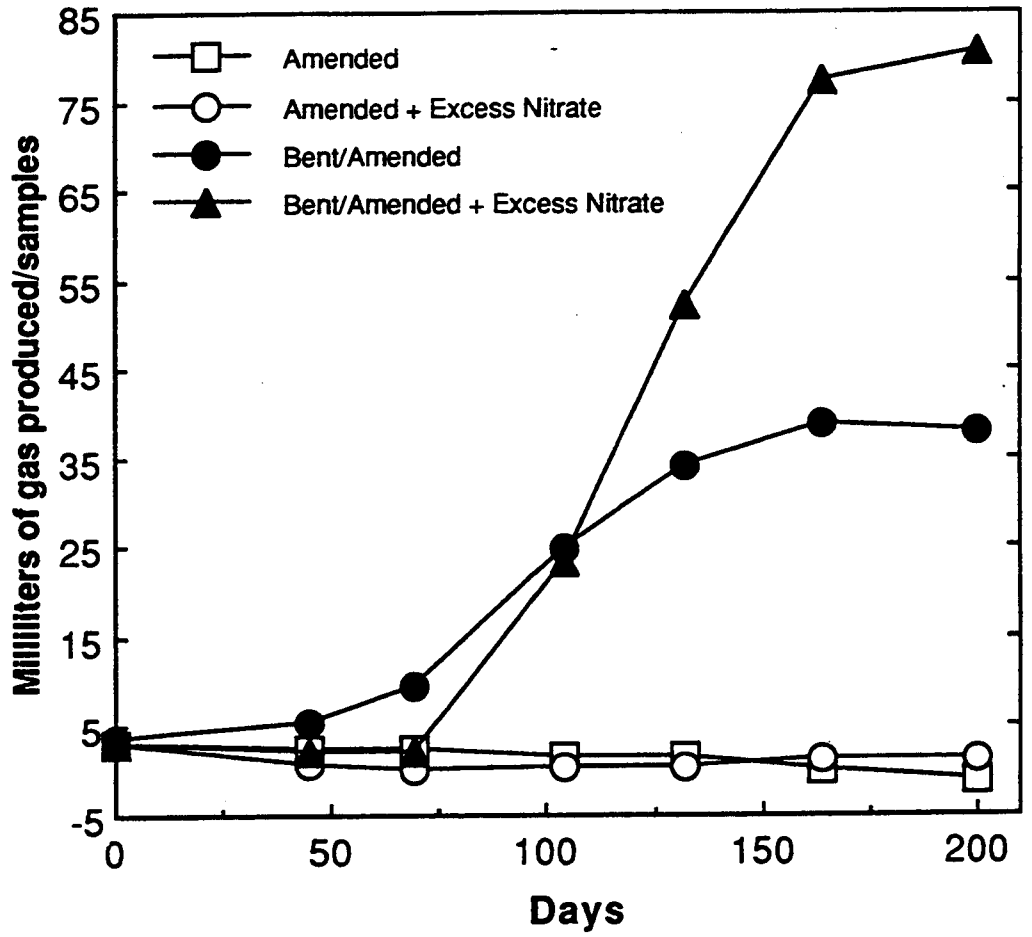

Figure 28. Total gas produced in anaerobic samples containing glucose.

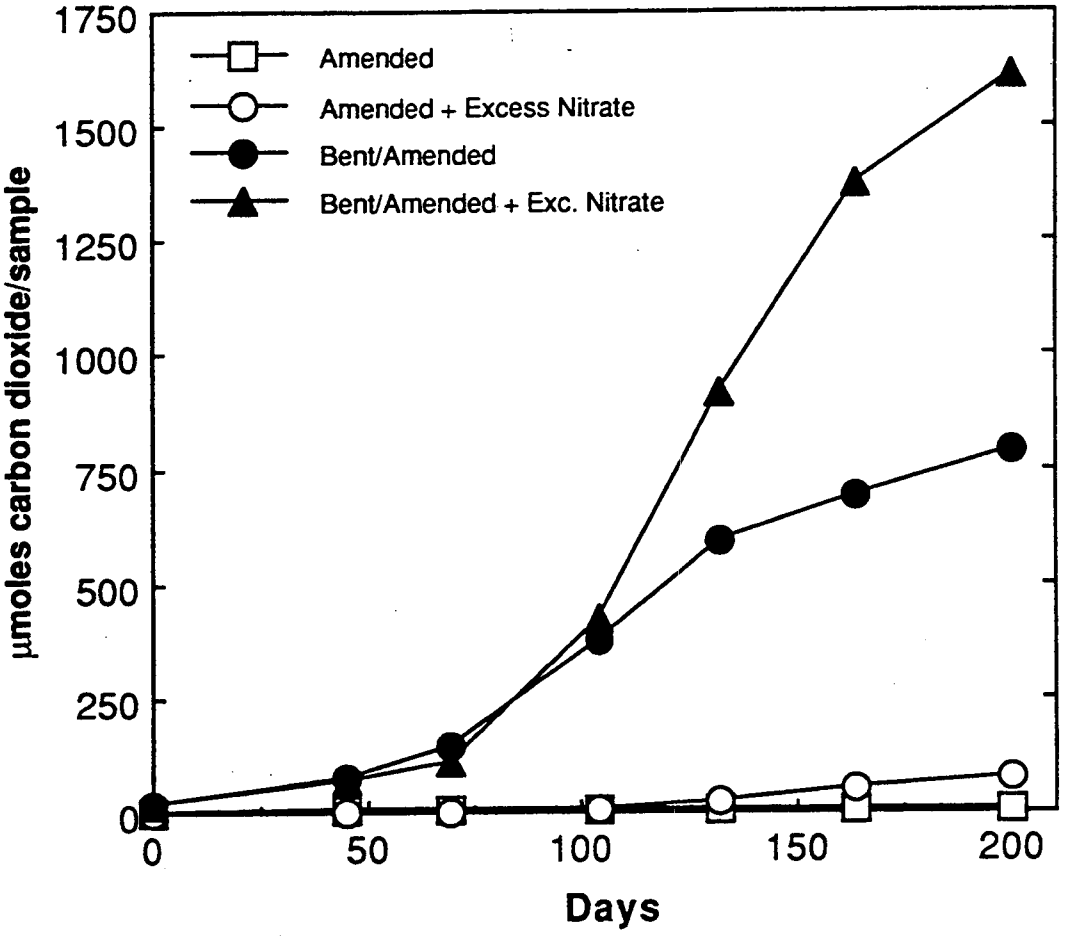

Figure 29. Carbon dioxide produced in anaerobic samples containing glucose.

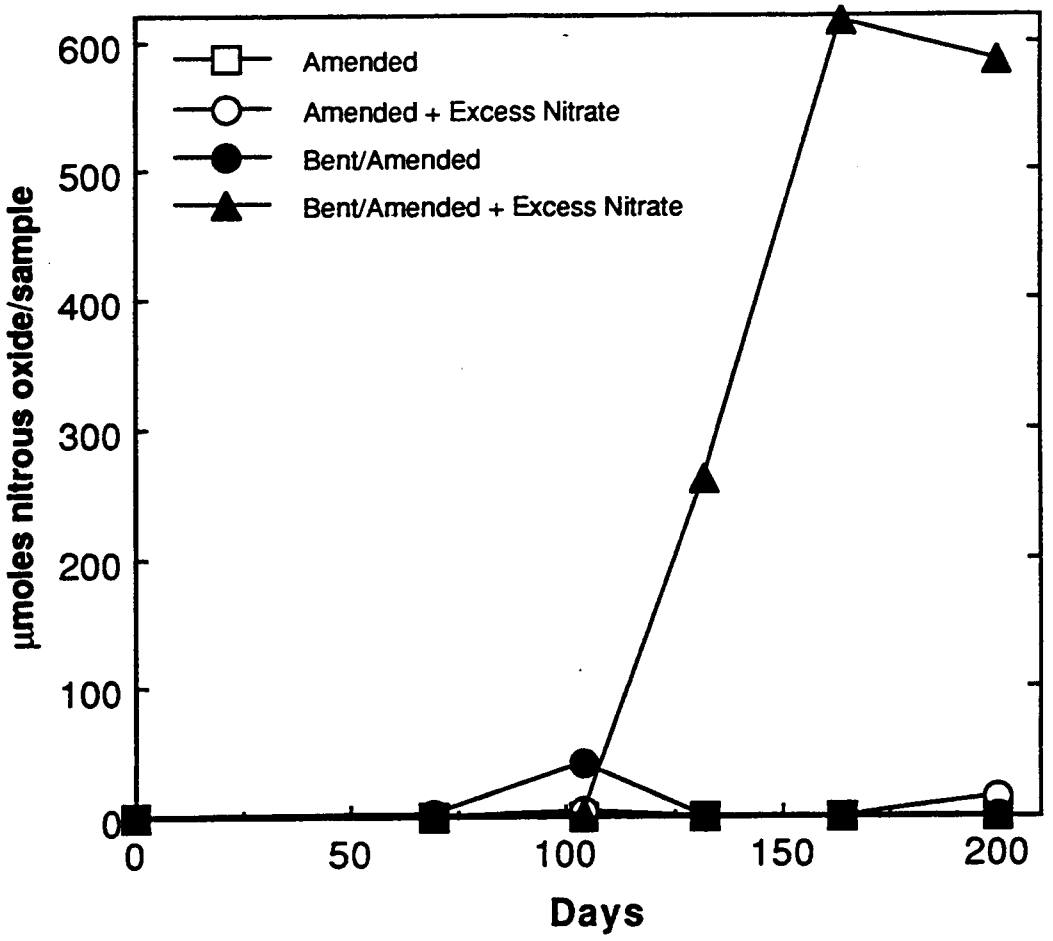

Figure 30. Nitrous oxide produced in anaerobic samples containing glucose.

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APPENDIX GCR

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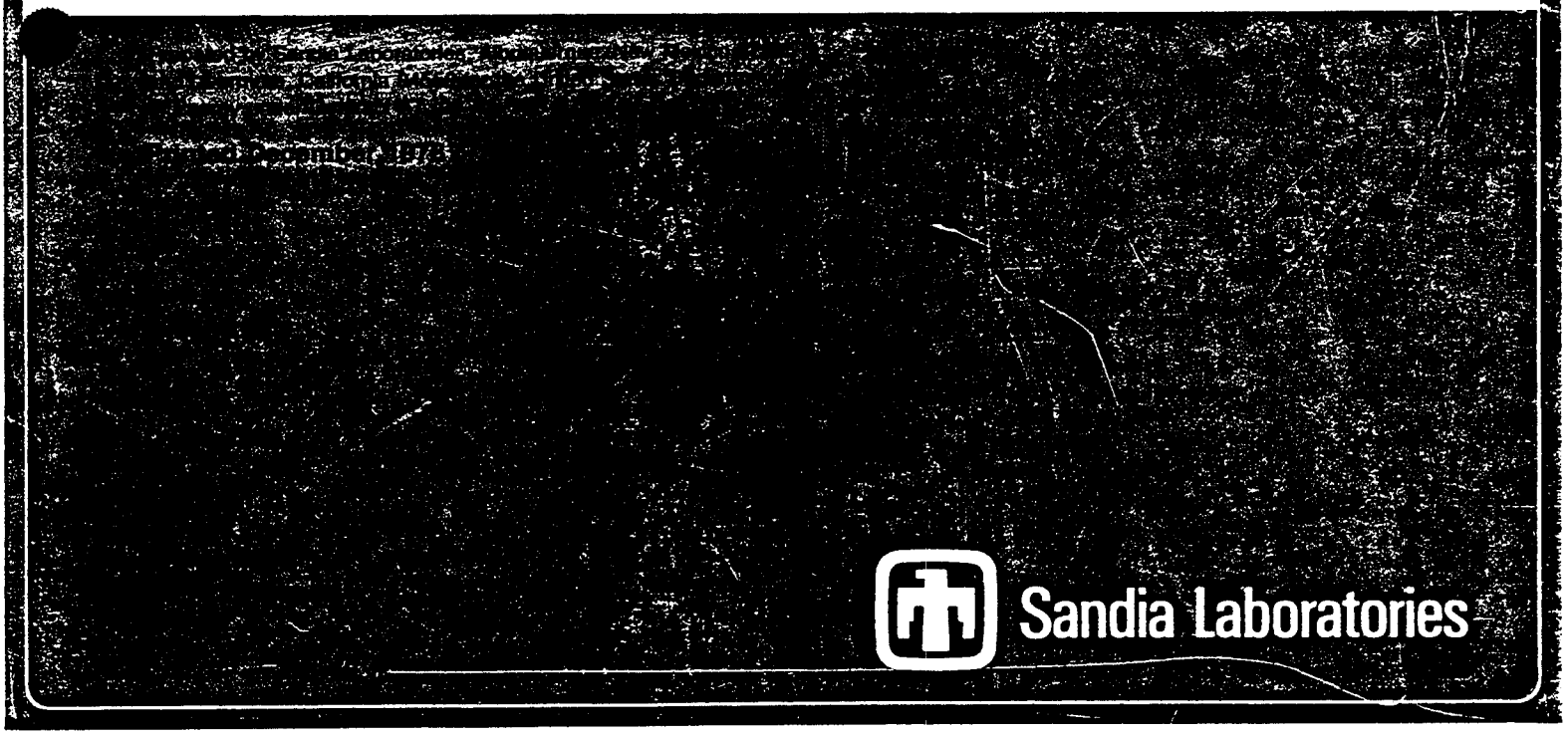
Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico

Volume I

August 1978

Dennis W. Powers, Steven J. Lambert, Sue-Ellen Shaffer, Leslie R. Hill, Wendell D. Weart, Editors



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GEOLOGICAL CHARACTERIZATION REPORT WASTE ISOLATION PILOT PLANT (WIPP) SITE, SOUTHEASTERN NEW MEXICO

SAND78-1596

VOLUME I

Dennis W. Powers, Steven J. Lambert, Sue-Ellen Shaffer,
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PREFACE

The Geological Characterization Report (GCR) for the WIPP site presents, in one document, a compilation of geologic information available to August, 1978, which is judged to be relevant to studies for the WIPP. As such, commonly available documents are summarized as appropriate while other documents may be presented more fully. In some instances, the information presented may be preliminary or may reflect continuing studies not yet complete. The Geological Characterization Report certainly should not be construed as the final word on the WIPP geology. Furthermore, specific judgements of how the geologic information affects the WIPP are restricted since the document is intended as a source of information. However, recommendations may be made on the basis of the document. The Geological Characterization Report for the WIPP site is neither a Preliminary Safety Analysis Report nor an Environmental Impact Statement; these documents, when prepared, should be consulted for appropriate discussion of safety analysis and environmental impact. The Geological Characterization Report of the WIPP site is a unique document and at this time is not required by regulatory process.

The Geological Characterization Report (GCR) for the WIPP has been created through the efforts of many individuals who are to be acknowledged for their contributions; little of the material presented, however, is original material created solely for the Geological Characterization Report. At Sandia Laboratories, principal contributors to the writing of the GCR are, in alphabetical order: G.E. Barr, B.M. Butcher, R.G. Dosch, L.R. Hill, S.J. Lambert, D.W. Powers, S.E. Shaffer, W. Wawersik, and W.D. Weart. Bechtel Corporation provided basic summaries for many chapters; the principal participants were: D. Dale, C. Farrell, V. Howes, J. Litehiser, D. Roberts, R. Sayer. In particular, J. Litehiser provided the analysis of seismic risk in Chapter 5. G.B. Griswold of Tecolote Corporation summarized resources in Chapter 8. F.H. Dove of NUS summarized hydrology in Chapter 6.

Editorial and review comments were solicited on a working copy and received from independent agencies with personnel familiar with the geology of southeastern New Mexico, particularly the New Mexico Bureau of Mines and Mineral Resources. An internal review at Sandia Laboratories of a working copy of the entire document also resulted in detailed comments. Those review comments were incorporated as appropriate into this draft copy. As usual, some of the suggestions were not followed for various reasons. The draft copy received review and comment by the WIPP Panel (Committee on Radioactive Waste Management, National Research Council) of the National Academy of Science, the Office of Nuclear Waste Isolation (ONWI) and various subcontractors, and by Westinghouse as a contractor to DOE. Major parts of the draft were reviewed by members of the Special Projects Branch, USGS. These comments have resulted in some revision of the final copy, as seemed appropriate. The editors assume responsibility for the contents of this report.

The editors and writers acknowledge the enormous volume of accumulated data and interpretations which provide the background for the Geological Characterization Report; referencing of authors is intended to reflect this background and to properly attribute material.

The Report is primarily intended for use by those with a technical background in earth sciences. However, the text should also be generally readable without all of this background by referral to the American Geological Institute Glossary of Geology (1974).

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GCR CHAPTER 1

EXECUTIVE SUMMARY

This Executive Summary presents, in condensed form, geotechnical information relevant to the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. The presentation of material follows the Geological Characterization Report (GCR) chapter organization, beginning with Chapter 2, INTRODUCTION. Figures and a reference list are not included in the Executive Summary; where desired the reader must examine the figure and reference list following each Chapter.

INTRODUCTION (Chapter 2)

The Introduction provides an overview of the purpose of the WIPP, the purpose of the Geological Characterization Report, the site selection criteria, the events leading to studies in New Mexico, status of studies, and the techniques employed during geological characterization.

The purpose of the Waste Isolation Pilot Plant (WIPP) is to demonstrate the technology for the disposal of the transuranic (TRU) waste resulting from this nation's past and current defense programs. It is anticipated that the WIPP will be converted to a repository after successful demonstration of this technology and assessment of safety of a repository for southeastern New Mexico. In addition, the WIPP is to provide a research facility to examine, on a large scale, the interactions between bedded salt and high-level radioactive waste. A Department of Energy (DOE) Task Force (DOE/ER-0004/D, 1978) has recommended that WIPP also be used to demonstrate surface and subsurface methods of handling, storing and disposing of up to 1,000 canisters of spent reactor fuel. A decision on implementing this recommendation has not been made at this time.

If this site is accepted by the DOE, the schedule calls for the initiation of facility construction in early 1981; completion is to be late 1985, and the first waste to be accepted in 1986. The TRU waste would be readily retrievable for a five to ten year period of initial

operation. All HLW for experiments would be retrieved upon completion of the experiments. The conceptual design of WIPP facilities is complete. DOE has expressed an intent to request licensing of the WIPP by the Nuclear Regulatory Commission (NRC), but this issue is not yet resolved.

Interest in disposal of radioactive waste in geologic media may be traced back to a 1957 committee report by the National Academy of Sciences - National Research Council, that recommended guidelines for permanent disposal of radioactive waste in geological media. Recommendations fell into two categories: burial in bedded salt deposits or in deep sedimentary basins (perhaps 4000 - 5000 m deep).

Salt became the leading candidate as a disposal medium, and from 1957 until the 1970's most disposal studies in the U.S. concentrated on bedded salt. In the mid-1960's, Oak Ridge National Laboratories (ORNL) conducted a successful in situ experimental program called "Project Salt Vault" in a salt mine near Lyons, Kansas. A subsequent plan to establish a federal repository near Lyons was withdrawn due to both technical and political objections.

Subsequent evaluation of salt basins in the United States by ORNL and the USGS led in 1974 to field investigations of Permian salt deposits of the Delaware Basin in southeastern New Mexico to determine if the geologic setting was adequate for a radioactive waste repository. Permian evaporite deposits consist of the Castile Formation which is interbedded halite and anhydrite, the Salado Formation which consists principally of halite and the Rustler Formation which is mostly anhydrite but contains halite, dolomite, and siltstone.

In 1975, the AEC (later Energy Research and Development Administration (ERDA) and now Department of Energy (DOE)) assigned responsibility for site evaluation and conceptual design for this project in New Mexico to Sandia Laboratories of Albuquerque, New Mexico. The project in New Mexico is now known as the Waste Isolation Pilot Plant (WIPP).

Preliminary site selection criteria were general in nature. (Most areas are not well enough known to allow application of precise criteria.) After Sandia Laboratories determined in 1975 that the first preliminary study area originally selected by ORNL was geologically unsuitable, site selection factors were refined specifically for and applied to the Delaware Basin in New Mexico to define the present study area. The major siting factors employed in southeastern New Mexico are that the repository salt beds should be: (a) relatively pure; (b) several hundred feet thick; (c) between depths of 1000 and 3000 feet; (d) located where groundwater dissolutioning is relatively limited; (e) at least one mile from boreholes that completely penetrate the evaporite section, (f) generally located to avoid private land; (g) located where strata are relatively flat; and (h) located to minimize conflicts with mineral resources. Data from hundreds of borehole geophysical logs and more than fifteen hundred miles of existing seismic reflection lines from petroleum companies were analyzed and considered along with hydrologic data and available information on natural resources to narrow the area of search. A relatively restrictive criterion was the requirement the repository be one mile or more to the nearest borehole penetrating the complete evaporite section. Existing studies of borehole dissolution indicated one mile is sufficient, though perhaps not necessary, to ensure repository integrity.

Geologic studies for the WIPP fall into three different phases: preliminary site selection activities, geological characterization, and studies of long-range geologic processes affecting a repository. Preliminary site selection activities are complete now, and geological characterization is nearing completion with this report. Studies of long-range processes are becoming the focus of geotechnical programs; some of these latter studies are already underway. These studies, which will be oriented toward geologic processes and rates, will mostly be completed before conversion of the WIPP to a permanent repository for defense waste; these studies plus operation should provide further refinement to criteria for conversion of the WIPP.

Many standard petroleum and mineral industry techniques have been used to characterize the WIPP site. Considerable reliance has been placed on the combination of geophysical techniques corroborated by borehole information. The geophysical techniques most widely used to characterize the WIPP site include seismic reflection and resistivity. By summer, 1978, about 75 line miles of new seismic reflection data were obtained and over 9000 resistivity measurements had been made and analyzed. Twenty-one boreholes were drilled to evaluate potash, 14 hydrologic test holes were drilled and four potash holes were converted for hydrologic studies of the aquifers above the Salado Formation. Ten stratigraphic test boreholes have been drilled on or around the WIPP site as of early August, 1978, and two other holes have been drilled well away from the WIPP site to study dissolution processes. Two of these holes were drilled through the salt to test deep aquifers and to acquire geologic data.

Most of the WIPP geologic studies to date advanced geological characterization. Geologic studies will continue in order to permit a better quantification of the rates of geologic processes in and near the WIPP site and to develop a more thorough understanding of the geologic phenomena of interest (see Chapter 10).

REGIONAL GEOLOGY (Chapter 3)

Regional Geology provides a broad assessment of the surface and subsurface environment of the area within a radius of about 200 miles of the proposed WIPP Site. The discussion comprises a synthesis of the available data pertaining to the physiography and geomorphology, stratigraphy and lithology, structure, tectonic development and geologic history of this region. Such information is necessary to understand the geological processes that need to be understood for assessment of long-term safety of a repository in the Delaware Basin of southeastern New Mexico. The paragraphs below present a brief summary of this information.

The WIPP site is located within the Pecos Valley section of the southern Great Plains physiographic province, a broad highland belt which slopes gently eastward from the Rocky Mountains and Basin and Range province to the Central Lowlands province. The Pecos Valley section itself is dominated by the Pecos River valley, a long north-south trough from 5 to 30 miles wide and as much as 1,000 feet deep, which exhibits an uneven rock and alluvium-covered floor marked by widespread solution subsidence features resulting from dissolution within the underlying Upper Permian Ochoan rocks. The section is bordered on the east by the Llano Estacado, the virtually uneroded fluviatile plain of the High Plains section, and on the west by the Sacramento and Guadalupe Mountains area of the Sacramento section.

The principal geomorphic features with bearing on the site area include the Pecos River drainage system, the Mescalero Plain, karst topography and wind erosion "blow-outs." The Pecos River system has evolved from the south, cutting headward through the Ogallala sediments to capture what is now the upper Pecos and becoming entrenched sometime after the Middle Pleistocene. The system at present receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent, due to the contemporary semi-arid climate. Most of the ground surface east of the Pecos River valley comprises the Mescalero Plain, a poorly drained surface covered by gravels, eolian sand and caliche, which has developed since Early to Middle Pleistocene time. The surface of the region exhibits karst topography containing superficial sinkholes, dolines, solution-subsidence troughs, and related features, formed as a result of both surface erosion and subsurface solutioning activity.

The WIPP site lies on a caliche and sand covered drainage divide separating two major and perhaps still developing solution-erosional features, Nash Draw on the west and San Simon Swale to the east. This prevailing erosional pattern is expected to continue in the future, with most local erosion occurring in the draw and swale areas. The site is located west of the local drainage divide.

The stratigraphic section present in the site region includes Precambrian through Triassic rocks, overlain by outliers of possible Cretaceous age, and widespread Late Tertiary through Holocene sediments.

Metasediments and granitic-volcanic igneous materials constitute the majority of the regional basement, cropping out in isolated areas to the west and north. The granitic rocks range in age from about 1,400 million years in the north to about 1,000 million years in the south and are overlain in places by younger Precanibrain volcanic terrains. The surface of the Precambrian reflects the Late Paleozoic platform and basin structural configuration of the area.

The Paleozoic section comprises up to 20,000 feet of Upper Cambrian sandstones through Upper Permian evaporites and redbeds. The Ordovician, Silurian and Devonian rocks are primarily carbonates with lesser sands, shales and cherts which were deposited in shallow, rather calm shelf areas of broadly subsiding areas of the Tobosa Basin, with some minor influence from uplifted areas such as the ancestral Central Basin Platform. The Mississippian sequence consists of locally cherty limestones overlain by silty and sandy shales, truncated against adjacent emerging uplands. Post-Mississippian orogeny caused uplift, tilting and erosion, producing a massive section of Lower Pennsylvanian continental sediments, interbedded with dark limestones, particularly toward the top of the section. Late in the Pennsylvanian, a basin, basin margin, and shelf configuration, which endured through the Permian, developed, resulting in deposition of dark shales, clastics and some limestones and bioclastics forming a series of reefs along the basin margins, and shallow-water limestones and clastics on the adjacent shelves. Upon filling of the basins in the Late Permian, a sequence of evaporites totalling 4000-5000 feet in thickness was deposited during recurrent retreats of shallow seas restricted by the encircling Guadalupian reefs. The Castile Formation consists of anyhdrite interlaminated with calcite and halite overlain by the Salado Formation, which is primarily halite with lesser clastics, anhydrite and a suite of salts. The Rustler Formation overlying the Salado is composed of anhydrite, gypsum and

lesser salt with carbonates and clastics. The top of the Paleozoic is marked by the thin Dewey Lake Redbeds.

The Mesozoic sequence is represented by only the Upper Triassic Dockum Group of terrigenous redbeds, which in many places are truncated or removed by erosion, and by scattered patches of Cretaceous limestone and sandstones.

The lower Cenozoic section is missing from the region due to erosion and/or non-deposition, and the widespread Late Miocene-Pliocene Ogallala clastics represent the earliest deposition of the section. The Ogallala is capped by a dense, resistant layer of caliche, which probably started to form during the Late Pliocene. Quaternary deposits occur only locally and consist of the Middle Pleistocene to Holocene terrace, channel and playa deposits as well as windblown sands.

The major structural framework of the region is provided by the large-scale basins and platforms of late Paleozoic age and by Cenozoic features primarily associated with Basin and Range tectonics.

The principal late Paleozoic features of the area consisted of the western extent of the Tobosa and later the Permian Basin and its border lands. These elements include the Delaware Basin, Central Basin Platform, Midland Basin, the Northwestern Shelf, Pedernal Uplift, Matador Arch, Val Verde Basin and Diablo Platform.

The site is located in the northern portion of the Delaware Basin, a broad, oval-shaped asymmetrical trough with a northerly trend and southward plunge and a structural relief of more than 20,000 feet on top of the Precambrian. Deformation of the basin rocks is minor, those formations older than Late Permian are only gently downwarped. Deep-seated faults, some reflecting Precambrian faults, occur in the basin, as do folds, joint sets, and a number of smaller, probably solution-related structures originating in the Upper Permian evaporites. The basin was defined by early Pennsylvanian time, and major structural

adjustment occurred from Late Pennsylvanian to Early Permian time. By the Late Permian, this episode of tectonic activity ended in the basin; regional eastward tilting occurred later, in the Cenozoic.

The Central Basin Platform, a northward-trending feature, separated from the Delaware Basin to its west by a zone of major normal faulting, represents a broad uplift of Precambrian to Pennsylvanian rocks, within which movement took place periodically, probably from the Precambrian until the late Paleozoic when the basin became structurally stable.

North and northwest of the Delaware Basin lies the Northwestern Shelf, which was well-developed before Permian time and may have originated in the Early Paleozoic, when it formed the margin of the Tobosa Basin. A number of flexures, arches, and faults which have been identified on the shelf had probably ceased tectonic activity in Tertiary time.

The Diablo Platform, forming the southwestern border of the Delaware Basin, experienced primary deformation in the late Paleozoic in the form of uplift, folding and faulting. Deformation also occurred here during late Tertiary time through block faulting and buckling. Recent uplift along its eastern side suggests continuing tectonic development in the area. The remainder of the previously listed late Paleozoic structural elements of the area are only remotely related to the site area.

Late Tertiary Basin and Range tectonics produced the Sacramento, Guadalupe and Delaware Mountains bordering the region on the west. These uplifts are generally eastward-tilted fault blocks bordered on the west by complex normal fault systems forming short, steep westward slopes and backslopes dipping gently eastward. Tectonic activity began in this area during Mississippian to Early Permian time in the form of fault systems, followed by the major Basin and Range tectonics. Small fault scarps in recent alluvium along the western edge of these ranges, as well as some seismic activity, suggest that structural development here may still be taking place.

Post-Precambrian igneous activity in the region consists of Tertiary intrusives and Tertiary to Quaternary volcanic terrains located on the north, west and south of the site area. Only minor igneous activity, in the form of dikes and possibly sills, is known to have occurred within the Delaware Basin.

The closest such igneous feature to the site is a near-vertical trachyte or lamprophyre dike or series of en echelon dikes trending about N50°E for perhaps 75 miles into New Mexico from near the Texas-New Mexico border southwest of Carlsbad Caverns, passing about 9 miles northwest of the site. Evidence for the dike's existence consists of exposures in two mines, cuttings from several drill holes, aeromagnetic indications and surface exposures some 42 miles southwest of the site in the Yeso Hills. This dike has been dated as mid-Tertiary and intrudes only the Late Permian Salado and underlying formations.

The principal Tertiary igneous features of the area beyond the Delaware Basin include several intrusive bodies within the Delaware Mountains, widespread occurrences further south in the Trans-Pecos region and several areas well to the north of the basin, in the form of the eastward-trending El Camino del Diablo and Railroad Mountain dikes (near Roswell) and the stocks of the Capitan and Sierra Blanca Mountains. Quaternary volcanic and related extrusive terrains are present west of the site region, well within the Basin and Range province.

The geologic history of the region is recorded in igneous and metasedimentary rocks as old as about 1,400 million years which indicate a complex Precambrian history of mountain-building, igneous events, metamorphism and erosional cycles. Probably before Paleozoic time, erosion had reduced the area to a nearly level plain.

The early to middle Paleozoic Era was characterized by generally mild epeirogenic movements and carbonate deposition interrupted by only minor clastic sedimentation. The oldest sediments in the region are the Late Cambrian and perhaps Early Ordovician Bliss sandstones. Following Early

Ordovician time, a broad sag, the Tobosa Basin, formed and began deepening. Shelf depositions of clastics continued, derived partly from the ancestral Central Basin Platform, and carbonates deposited in shallow waters. By Late Ordovician time, the Marathon Ouachita geosyncline to the south of the area began subsiding, but until the Middle Mississippian, only mild tectonic activity continued, with several periods of minor folding and perhaps some faulting, the basin subsiding, the Pedernal landmass to the north emergent and some regional erosion occurring.

From late in Mississippian time through the Pennsylvanian, regional tectonic activity accelerated, folding up the Central Basin Platform, Matador Arch and the Ancestral Rockies, producing massive deposition of clastics. The Tobosa Basin was definitively split into the rapidly subsiding Delaware, Midland and Val Verde Basins. Throughout the Permian, sedimentation was continous in the basins, climaxing in the development of massive reefs, and, following stabilization in the Late Permian, in the deposition of a thick sequence of evaporites. By the end of the period, the area was slightly emergent, and a thin sheet of redbeds covered the evaporites.

Since the close of the Permian, the basin area has been relatively stable tectonically, and the Mesozoic through Cenozoic eras have been characterized by erosion, with only relatively minor deposition of terrestrial materials. During the Triassic, a broad flood plain sediment surface developed, followed late in the period by fluvial clastic deposition and formation of a rolling topography. Sometime during the Cretaceous, submergence occurred, and thin limestone and clastics collected in intermittent, shallow seas. During the Jurassic and perhaps as early as the Triassic, subsurface dissolution of the Upper Permian evaporites began. The close of the Mesozoic was marked by the Laramide orogeny and uplift of the Rocky Mountains, with mild tectonic and igneous activity to the west and north of the site area. Throughout most of the Tertiary, erosion dominated, until deposition of the Ogallala late in the era. Mid to late Tertiary Basin and Range uplift of the Sacramento and

Guadalupe-Delaware Mountains was accompanied by regional uplift and east-southeastward tilting. Upon this gently sloping surface the Miocene-Pliocene Ogallala fan deposits accumulated, and a resistant caliche caprock began to form. During Quaternary time, the present landscape has developed through processes of surface erosion and dissolution of the Upper Permian evaporites, accompanied by terrace and stream valley deposition and eolian activity.

The regional geology shows that the northern Delaware Basin has been a part of large structures reacting slowly to tectonic and climatic processes. About 300 million years of Paleozoic geologic history indicate a downwarping basin on a grand scale. The last 200 million years are characterized by slow uplift relative to surroundings resulting in some erosion and dissolution of rocks in the Delaware Basin. Dramatic geologic events such as faults and volcanic activity have not occurred in the northern Delaware Basin where the WIPP site is located. The nearest events of this type are occurring west of the Guadalupe Mountains about 70 miles southwest of the WIPP site. The regional geology does not indicate that any dramatic changes in geologic processes or rates have recently occurred at the WIPP site.

SITE GEOLOGY (Chapter 4)

Much investigative effort has been expended to define subsurface geologic conditions at the WIPP site. These studies not only provide detailed information regarding mining conditions at the repository levels, but also furnish a basis for an assessment of the level of protection or safeguard against possible modes of containment failure at the site, in the context of the long-term isolation requirements of radioactive waste. Information for geologic investigations conducted by the U.S. Geological Survey and reported in several open-file reports by that agency, as well as details of salt deformation investigated by other consultants, have done much to define the general geologic conditions in the vicinity of the WIPP site and have been freely utilized in assembling Chapter 4 of the GCR. Detailed site-specific exploration techniques include seismic

reflection, resistivity, gravity and magnetic surveys, borehole exploration including coring, geophysical logging and hydrologic testing, and reconnaissance geologic mapping. From data thus obtained a series of structure contour and isopach maps were constructed which are presented and discussed in section 4.3 and 4.4 A continuously cored stratigraphic test hole, ERDA-9, has been drilled to a depth of 2,875 feet below ground surface near the center of the WIPP site and provides much detail on geologic properties at and above the WIPP repository levels.

The surface of the WIPP site is a slightly hummocky plain sloping gently southwest at about 50 feet per mile; elevations range at the site from about 3300 to 3600 feet above sea level. There are no permanent drainage courses in the site area. Any intermittent runoff drains west into Nash Draw, a broad swale of about 150 feet of relief leading southwest toward the Pecos River. A declivity marking the east edge of Nash Draw in the site area, known as Livingston Ridge, is located about 4 miles west of the center of the site. Nash Draw, now partly filled with Pleistocene sediments, has evolved both by surface erosion and by subsurface dissolution of salt, presumably during wetter intervals in the geologic past.

Recent windblown sand and partly stabilized sand dunes blanket most of the site area. A hard, resistant duricrust or caliche (Mescalero caliche) is typically present beneath the sand blanket and has developed upon the surface of the underlying Pleistocene fluvial (Gatuna) deposits. The fluvial deposits are tentatively assigned a Kansan age and the caliche formed upon them a Yarmouth (interglacial) age; that is, the caliche formed starting approximately 500,000 years ago. At some places, the caliche is fractured and drapes into Nash Draw along Livingston Ridge, indicating that some erosion and dissolution has taken place in Nash Draw since the caliche was formed, presumably during wetter climatic intervals associated with Illinoian and Wisconsin glaciations. Increased erosion from runoff, should the climate of the region become more humid in the future, would be expected to occur in the existing drainage courses, leaving the drainage patterns relatively unaltered.

The proposed WIPP underground storage facilities are to be placed near the middle of a 3,600-foot-thick sequence of relatively pure evaporite strata containing primarily rock salt and anhydrite, lying between depths of about 500 and 4,100 feet beneath ground surface. The formation richest in rock salt, the Salado Formation, is nearly 2,000 feet thick and contains the relatively pure salt layers in which the two proposed underground storage levels are to be constructed, at a depth near 2,120 feet for the upper level and near 2,670 feet for the lower. The storage horizons are well isolated from the hydrologic environment by adjacent evaporite strata. A thickness of at least 1,300 feet of undisturbed evaporite rock, primarily rock salt, overlies the upper storage horizon and about an equivalent thickness of anhydrite and rock salt intervenes between the lower storage horizon and the next adjacent underlying non-evaporite formation. The salt deposits of the Castile and Salado Formations at the WIPP site were formed about 225 million years ago and have remained isolated from dissolution since about that time.

The total thickness of the sedimentary pile resting on top of Precambrian basement beneath the WIPP site is about 18,000 feet of Ordovician to Recent strata. Following is a brief summary of the stratigraphy, proceeding from the surface down to the basement. Beneath a thin but persistent veneer of windblown sand at the site are sediments representing Pleistocene, Upper Triassic, and uppermost Permian strata, all of which occur above the evaporite sequence. Sandstone of the Pleistocene Gatuna Formation, capped by Mescalero caliche also developed in Pleistocene time, is only a few tens of feet thick at the site and is of interest primarily for the geochronologic and paleoclimatic implications of its presence. Between the Pleistocene deposits and the evaporite sequence is a 500-foot-thick succession of nonmarine redbeds of Late Triassic Age (Santa Rosa sandstone) and marine redbeds of latest Permian age (Dewey Lake Redbeds). This redbed sequence thins westward and thickens eastward, having been beveled westward by several post-Late Triassic erosional episodes; the thickness of redbed deposits remaining above the evaporite sequence is crudely proportional to the degree to which the underlying salt horizons have been protected from surficial processes leading to erosion and dissolution.

At the center of the site all but the uppermost 50 feet of the 18,000 feet of strata are of Paleozoic age, the marine Dewey Lake Redbeds being the topmost Paleozoic rocks. The Permian section alone, about 12,800 feet thick, constitutes over two-thirds of the sedimentary pile. The Permian section is divided into four series, the three lowest of which (Wolfcampian, Leonardian and Guadalupian) contain thick clastic sequences, and the uppermost of which (Ochoan) is represented by the Castile, Salado, Rustler, and Dewey Lake (in ascending order).

The Rustler, which lies over the Salado, contains the largest percentage of clastic material of the three evaporite formations, yet where its original thickness of around 450 feet has been protected from salt dissolution, about 70 percent of the formation is composed of evaporite minerals, more than half of which is halides. Beneath the Los Medanos site the Rustler has been leached of most of its rock salt, with the result that 310 feet of the formation was encountered at ERDA-9 at the center of the site. This implies that up to 140 feet of rock salt have been removed and that the overlying strata have subsided accordingly; it does not, however, imply that dissolution and subsidence is presently active or even that it has recently occurred. The uppermost occurrence of halite in the Rustler Formation was encountered at a depth of about 760 feet (about 100 feet above the base of the formation). Between this level and the upper level storage zone of the proposed WIPP facility over 1,300 feet of undisturbed evaporite rock, primarily Salado rock salt, intervene.

The 2,000-foot thickness of the salt-rich Salado Formation is divided into three members by the recognition of a middle member referred to as the McNutt potash zone, which is the interval within the Salado that contains all of the potential reserves of potash, or potassium minerals commercially mined in the Carlsbad district west of the site. The lowest member of the Salado, beneath the McNutt potash member, is the member that contains the nearly pure halite chosen for the proposed facility. The Castile Formation beneath the Salado contains highly pure beds of halite but, unlike the Salado, also contains much massive anhydrite.

The rest of the Permian section beneath the evaporite sequence, together with the subjacent Pennsylvanian and possibly Late Mississippian sections, contain dominantly clastic rocks that represent deposition during the time in which the Delaware Basin existed as a distinct structural entity. Much of these pre-evaporite, basinal sediments, which total about 11,000 feet in thickness beneath the site, have been targeted for petroleum exploration at one point or another in the Delaware Basin and contain nearly all of the region's known potential reserve of hydrocarbons.

The remainder of the Paleozoic section (Mississippian down through the Ordovician) consists of about 3,000 feet of mainly carbonate strata deposited in shallow-water or shelf conditions over a period of long-sustained crustal stability.

The underlying crystalline basement is believed to be a granitic terrane, formed about 1,300 million years ago. The only other igneous rocks that are known in the site area are known only in the subsurface and occur as lamprophyre (basaltic) dike rock intruded into evaporite beds along a single northeast dike trend that approaches no closer than about 9 miles northwest of the center of the proposed WIPP site.

With regard to subsurface geologic structure at the site, all of the Permian and older strata exhibit a gentle, regional homoclinal dip to the east or southeast, reflecting the presence of the Delaware Basin tectonic structure. No surface faulting is known. A general summary and assessment of structure in the site area was provided by C.L. Jones in an open-file report issued by the U.S. Geological Survey in 1973. Jones stated,

> "The structure of the Los Medanos area is basically simple and the rocks are, for the most part, only slightly deformed. Nevertheless, the rocks have been tilted, warped, eroded, and subroded, (ed. note: subjected to subsurface removal by dissolution), and discrete structural features can be recognized. These include: (1) structural features of regional extent related to Permian sedimentation, (2) intraformational folds of limited extent related

> to "down-the-dip" movement of salt under the influence of gravity and weight of overburden and (3) subsidence folds related to warping and settling of rocks to conform with the general shape and topography of the surface of salt in areas of subrosion...
>
> "On the basis of available geological information, the salt deposits of Los Medanos area seem in many ways to constitute a suitable receptacle for use in a pilot-plant repository for radioactive wastes. The deposits have thick seams of rock salt at moderate depths, they have a substantial cover of well-consolidated rocks, and they have escaped almost completely undamaged long periods of erosion. The deposits are only slightly structurally deformed, and they are located in an area that has had a long history of tectonic stability."

Information developed in the succeeding five years of investigations do not significantly alter that assessment relative to the structural and tectonic conditions present at the Los Medanos site. Based on exploration accomplished to date, a series of structure contour and isopach maps are presented for rocks ranging in age from Devonian to Pleistocene. This and other information indicate that active tectonic faulting and warping of rocks in the site vicinity seems to have predated Permian evaporite deposition; certain minor faulting within the thick Permian section appears to have occurred contemporaneously with sedimentation and may be ascribed to compaction. Deformation related to salt flowage has occurred primarily in the Castile Formation beneath the Salado, and has locally modified the regional easterly gradient to 80 to 100 feet per mile at the level of the storage horizons near the base of the Salado. Areas in the vicinity of the site in which artesian brine reservoirs have been encountered are associated with thickened salt sections and salt-flow anticlines in the Castile, but no such major structural features are recognizable within the limits of the WIPP storage facility on any of the Salado horizons contoured. The site appears to be in a slight structural saddle, a condition considered to be favorable for site selection. Dissolution of bedded salt at the site has been restricted to horizons within the Rustler Formation; there is no evidence that the resulting settlement produced any significant

structural irregularities or collapse features in the overlying strata within the area of the Los Medanos site. Investigations are continuing to further define the extent to which salt deformation in the Castile may have affected the structural configuration within the lower part of the Salado where excavation of the remote handling (RH) and contact handling (CH) levels is presently planned. These investigations will permit a more detailed assessment of the optimum layout, design and construction method of the storage facility.

The geologic history of the Los Medanos site may be organized into three main phases occurring subsequent to the original establishment of a granitic basement intrusive complex between about one billion and 1.4 billion years ago, forming the cratonic crust beneath the site. The first phase, of at least 500 million years duration, was a time of uplift and erosion of all pre-existing Precambrian sedimentary and metamorphic rocks which may have once been deposited or formed in the site area, eventually exposing the deep-seated igneous rocks.

The second phase, which corresponds to the Paleozoic Era, was characterized by an almost continuous marine submergence lasting about 225 million years, wherein shelf and shallow basin sediments slowly accumulated. It culminated in a comparatively rapid accumulation of over 13,000 feet of Permian sediment within a relatively brief period lasting 50 to 55 million years, toward the end of which time thick evaporite beds, mainly rock salt, were deposited. This rapid Permian deposition was presaged in Late Mississippian time by tectonic activity that differentially upwarped elements of the craton, such as the Central Basin Platform, thereby defining the Delaware Basin as a tectonic feature for the first time. During Pennsylvanian time, repeated marginal faulting caused periodic uplift of bordering platforms and some warping within the basin. By early Permian time, this tectonic activity apparently died out as basin subsidence and sedimentation accelerated. Eventually the Permian sea became shallow and briny, at first characterized by extensive reef development, but eventually in Ochoan time by a vast brine flat in

which thick evaporite deposits formed, burying the earlier reef masses. The final event of the long, nearly continuous accumulation of marine sediment of the second phase was deposition of a blanket of marine or brackish tidal flat redbeds over the evaporite strata.

Uplift and subaerial conditions next occurred at the site in the third and final phase, and persisted some 225 million years to the present, with the exception of a brief marine inundation in about the middle of that span of time. Periods of terrestrial deposition alternated with erosional episodes, so that a series of nonmarine deposits separated by angular unconformities blanket the evaporite beds at the site. These angular unconformities represent intervals during which the salt beds at the WIPP site were tilted and subjected to potential dissolution. At least four erosional episodes separated by depositional intervals are recognized: (1) Early Triassic time in which the Dewey Lake Redbeds were tilted and eroded to a slight angular unconformity before deposition of the Upper Triassic Dockum Group; (2) Jurassic-Early Cretaceous time in which the Dockum Group was tilted and eroded to a wedge before marine inundation in Washitan time (latest Early Cretaceous); (3) a Late Cretaceous through mid-Tertiary erosional interval when the region was again tilted and the Triassic Dockum Group of sediments was bevelled for a second time; and (4) a post-Ogallala (post-Pliocene) uplift and erosion in early Pleistocene time, prior to deposition of the (Kansan?) Gatuna Formation took place. Subsequent to deposition of the Gatuna, there probably were intervals corresponding to the later Illinoisian and Wisconsin glaciations during which accelerated erosion in these wetter times occurred in the area of the WIPP site.

Each period of tilting, which accompanied renewed erosion as outlined above, afforded an opportunity for salt flow by plastic deformation along the imposed gradient and salt deformation as the salt impinged against reef abutments or responded to uneven, differential sediment loading or erosional unloading; therefore there may have been several episodes of salt deformation of this type. To the extent that some "deep dissolution" features are recognized today in salt at depths of several

thousand feet below the surface, it seems likely that subsurface dissolution of salt could have been initiated at comparable depths beneath the surface as soon as Early Triassic time. It is reasonable to assume that episodes of active dissolution occurred during the Jurassic and Late Cretaceous-mid Tertiary erosional intervals, as well as during the several pluvial periods corresponding to Pleistocene glacial stages. Any attempt at reconstructing past history of salt dissolution in the Los Medanos area as an approach to predicting the future course of salt erosion must contend with the likelihood of the existence of times of greatly accelerated dissolution of salt in the geologic past interspersed with intervals of much lesser activity. The evidence available today indicates little if any change in erosion rates at the WIPP site in the recent geologic past. Detailed mapping studies are underway which will contribute to information on dissolution rates at various times in the geologic history of the site.

The discussion of the site geology defines the present conditions of the site which must be known to establish the WIPP. These conditions relate mostly to physical characteristics such as thickness, depth, extent, purity, and structure of the evaporites (as well as some of the surrounding beds). In addition, baseline conditions regarding the processes of dissolution and erosion as they affect the immediate site have been determined. Thus the baseline geological conditions at the site are presented so that judgement of the site relative to the present criteria may be undertaken and so that continuing studies will focus on geologic processes important to assessment of repository safety.

The site geomorphology indicates tectonic stability at the site for the last 500,000 years or more. The local stratigraphy is continuous with the regional stratigraphy. Local minor structures exist within the evaporite beds, but no severe displacements or brine or gas have been encountered. Potential repository zones at depths of 2730-2620 feet and 2176-2074 feet have been chosen on the combined basis of purity, depth, thickness, mutual separation, and depth below the potash zone.

SEISMOLOGY (Chapter 5)

Regional seismicity of the Los Medanos site is discussed in two separate time intervals suggested by the type and quality of information available for each interval. These intervals are before 1962 (non-instrumental) and from 1962 to the present (instrumental).

Before 1962 almost all data on earthquakes within 300 kilometers of the site are based on collection, cataloging, and consideration of non-instrumental reports. These data indicate that twenty earthquakes with maximum reported intensities between III and VIII on the Modified Mercalli Scale have occurred within a 300 kilometer radius of the site region from 1923 to 1960. There have been no earthquakes of epicentral intensity V or greater within about 200 kilometers of the site in this period. The closest reported shocks are two intensity IV events at Carlsbad in 1923 and 1949. The strongest reported earthquake to occur within 300 kilometers is the intensity VIII Valentine, Texas event of lugust 16, 1931 at a distance of approximately 210 kilometers.

Between 1962 and 1972 inclusive, a general instrumental survey of the site region shows 38 earthquakes with magnitudes ranging from 1.2 to 4.6 (Richter scale). The seismicity pattern of these instrumentally located events is very similar to pre-instrumental data except that a number of earthquakes occur on the Central Basin Platform in the later data set. The closest reported shock between 1962 and 1972 was a magnitude 2.8 event on July 26, 1972 about 40 kilometers northwest of the site. The largest event in this period is the magnitude 4.6 earthquake almost 300 kilometers to the southwest.

Three investigations of a more local and temporally restricted nature have impact on the Los Medanos site. These involve earthquakes recorded at a seismographic station installed near the site itself, events recorded at an array of seismographic stations installed on the Central Basin Platform near Kermit, Texas, and three earthquakes recorded regionally and found to have occurred near the site.

At the beginning of April, 1974 a vertical, single-component, continuously recording seismograph station (with letter designation CLN) was installed very near the site. During the latest available reporting period, April, 1974 to October, 1977, 291 events identifiable as local and regional earthquakes have been recorded and locations for 75 of the 291 events have been obtained. The seismicity pattern suggested is very similar to that of the general 1962-1972 instrumental survey. Approximately one-half of all located events in the CLN data set occur on the Central Basin Platform while most of the rest occur to the west and southwest of the site in the Rio Grande Rift Zone. There is also a scattering of earthquakes in the High Plains physiographic province of the site. Included is a magnitude 3.6 event on November 28, 1974 at about 40 kilometers to the northwest, which was close to the July 26, 1972 earthquake mentioned above.

Instrumental studies show earthquake activity in the Central Basin Platform at a higher level than expected. Primarily for this reason, the Kermit, Texas seismographic station array was established in late 1975 to more closely monitor this activity. During the latest available reporting period for this array (November, 1975 to July, 1977), 407 local events have been detected and 135 located with array data. Of the located events 56 were in the interior of the array while the rest have been peripheral to it. Earthquakes with magnitudes calculated both using Kermit array data and regional seismographic station and CLN data show that Kermit magnitudes are almost one unit higher. This inconsistency remains unresolved at this time.

As a result of general survey and specialized seismic instrumental studies in the Los Medanos site region there is little doubt that the Central Basin Platform has been seismically active since at least mid-1964, and that during this time it has been the most active seismic area within 300 kilometers of the site in terms of number of events. The basic conclusion from all instrumental data is that seismic activity is equally likely to occur anywhere along the Central Basin Platform structure without particular regard to small scale structural details

such as pre-Permian buried faults. Attempts have been made to relate this seismicity to secondary oil recovery operations in the area. Although both spatial and temporal coincidences of Central Basin Platform seismicity with secondary recovery projects are highly suggestive of a close relationship, this has not been satisfactorily established at this time.

Questions of the tectonism and seismic activity very near or at the site are of great interest. For this reason the most important seismic events instrumentally recorded are those closest to the site: July 26, 1972, and November 28, 1974, magnitudes 2.8 and 3.6, respectively; and a later shock on January 28, 1978, with only preliminary data yet available. If these events are an indication of normal background seismicity in the immediate site area, they might cause a re-evaluation of previous estimates of seismic risk at the Los Medanos site (Sanford and Toppozada, 1974). At the time of the first two events rockfalls and surface ground cracking were reported at the National Potash Company Eddy Co. Mine. To see if mine collapse at this mine was responsible for both events, an analysis was run to see if both epicenters could be made coincident with each other. Such a coincidence would be a strong indication of a rock fall origin for both events. At this time the best available analysis indicates that these small events did not both occur at the Eddy Co. Mine and thus they cannot both have been caused by a very localized non-tectonic source there. The third shock is located, in a very preliminary fashion, north of the station an estimated 17 km.

Using all the information developed above on regional seismicity and some additional simple assumptions about regional tectonism a preliminary analysis of risk from vibratory ground motion at the surface is derived in a way useful to seismic design characterization at the site during its active phase of development and use. The results of this analysis are that the 1000 year acceleration is less than or equal to 0.06 g and the 10,000-year acceleration is less than or equal to 0.1 g for all models tried. Probabilities at which higher acceleration levels occur depend almost exclusively on the assumptions made about the seismic potential of the immediate site area.

In addition to its use to determine risk as a function of vibratory ground motion level, regional seismicity is also considered as an indicator of longer-term tectonic processes. Natural regional seismicity should be consistent with the geologic indicators of tectonic processes unless the tectonic setting is changing. Regional stress patterns, as implied by focal mechanism solutions for regional earthquakes and in site measurements, and regional tectonism, as implied by earthquake recurrence statistics, are both considered. Although other explanations cannot be precluded, it seems that the most reasonable interpretation of the seismic implications to tectonism at this time are: (1) Observed geologic and seismic data are in general agreement in the Rio Grande rift zone to the west and southwest of the site where the largest historic earthquakes within 300 kilometers of the site have occurred. Future significant earthquakes can be expected there. (2) The current level of seismic activity on the Central Basin Platform is probably related to fluid injection for secondary recovery of oil. (3) The lack of geologic indications of natural recent tectonic activity for the High Plains province of the site can probably be reconciled with the seismic data by assuming a maximum magnitude limit of the earthquakes that have occurred here.

The importance of seismicity information over the immediate future is to provide a data base for design of facilities for the operational time of the WIPP. Seismicity information also serves as an indicator of the tectonic situation in assessing the WIPP site for a repository.

HYDROLOGY (Chapter 6)

Chapter 6 contains an assessment of surface and groundwater resources in and surrounding the proposed WIPP site and a status report of current hydrogeologic investigations in the local site area. The water resource assessment incorporates the published results of regional and local hydrologic studies supported by universities and state and federal agencies since the late 1930's. Present studies of the proposed site and

adjacent area are directed toward a more quantitative evaluation of the salt dissolution process, the hydrogeologic parameters affecting groundwater movement, and the major elements of surface and groundwater quality as related to water resource use and local ecology. The collection of hydrologic data is projected to continue for several years to provide site-specific information for a detailed safety analysis of the WIPP. Because of the relationship to hydrologic processes, dissolution activity is also summarized within this chapter.

The only major stream near the site is the Pecos River which flows southeasterly through Carlsbad. At its closest point, the river is approximately 14 miles southwest of the WIPP site. Several reservoirs, located on the Pecos upstream of the site, regulate river flow. The maximum recorded flood on the Pecos River occurred on August 23, 1966, with a discharge of 120,000 cfs and a maximum water surface elevation near Malaga of approximately 2938 feet. The minimum surface elevation of the site is more than 310 feet above this historic flood level.

Climatological records show that mean annual precipitation at the site is approximately 12 inches per year. The maximum daily precipitation recorded at Carlsbad was 5.12 inches in August 1916, and the maximum daily snowfall was 10 inches in December 1923. Winter storms in the area occur as a result of fronts moving from the west while summer storms, generally the most severe, occur as thunderstorms from moist air moving northwest from the Gulf of Mexico.

Surface drainage patterns at the site are undeveloped. Infiltration rates are high because of the sandy, gravelly soils that cover the region. However, the nearest groundwater is more than 50 feet below the land surface. Aided by the low relative humidity (typically 36% during daylight hours) and high mean annual temperature (61°F), most infiltration escapes the soil through evaporation and transpiration.

Important aquifers of the region include the San Andres Formation, a major source for irrigation waters in the Roswell Basin and other areas

to the north and northwest of the site region. Potable water is present in the Capitan aquifer southwest of the community of Carlsbad and is the primary source of municipal water in the local area. Other important aquifers of the region include the Ogallala Formation to the east of the proposed site, and unconsolidated alluvium along the Pecos River.

Groundwater within the Delaware Basin is predominantly of poor quality with total dissolved solids concentrations typically in excess of 3,000 ppm. The only large quantities of potable groundwater are found in aquifers west of and along the Pecos River. To the west, the formations of the basin crop out, and the soluble salts have been leached from the Ochoan evaporites. From recharge areas west of the Pecos River, groundwater in the Delaware Basin moves eastward. From the site area, water in hydrologic units above the salt moves generally southwest to the Pecos. These shallow units, or those cut by the Pecos River, discharge to the river, either directly or to alluvium of the river channel. Although a local hydraulic connection between the river and the Capitan aquifer may occur near Carlsbad, groundwater flow in the reef formation is severely restricted near the Eddy-Lea county line. Groundwater in formations older than the Capitan is not directly affected by the river, is present under confined conditions, and flows eastward. The aquifer of most significance to the proposed site in these older formations is the Bell Canyon Formation.

Water-bearing strata in the local site area at elevations above the proposed repository include the Santa Rosa Sandstone and the Culebra and Magenta members of the Rustler Formation. Hydrologic units below the repository elevation include the Bell Canyon Formation of the Delaware Mountain Group. Hydrologic test results to date show the average head elevations of the potentiometric surfaces from these aquifers are 3200 feet for the Santa Rosa Sandstone, 3150 feet for the composite Rustler Formation, and 3350 feet for the Delaware Mountain Group (equivalent "fresh-water" elevation). The thick halite beds of the Salado Formation are isolated from circulating groundwaters by confining layers of low hydraulic conductivity, directly above and below the salt formation.

In the vicinity of the proposed site, potable groundwater is not present, except in small, isolated, near-surface perched pockets. Thus, it would appear that the proposed repository is favorably situated in relation to groundwater circulation and occurrence. Detailed investigations of groundwater hydrology at the proposed site have been conducted and are continuing. The data will provide a basis for more quantitative determinations regarding the continued isolation of the proposed repository from groundwater circulation.

A shallow salt dissolution zone occurs in Nash Draw at the contact between the Salado and Rustler Formations. The dissolution area ranges in width from 2 to 10 miles and has a length of approximately 30 miles. The brine solution flows southwesterly and discharges into the Pecos River at Malaga Bend. The average rate of vertical dissolution has been estimated to be between 0.33 and 0.5 feet per 1,000 years, and the average rate for lateral dissolution has been estimated to be between 6 and 8 miles per million years. Dissolution of salt at the top of the Salado occurs about 2 miles west of the center of the site. Eastward across the site salt is present in the Rustler at progressively higher levels, indicating that the salt has not been dissolved out of the Rustler and that the Salado has not been attacked by dissolution.

Future measurements obtained from the hydrologic test programs and analyses of the test data will be used to refine bounding calculations, such as estimates of groundwater travel times, and to provide a more detailed description of the physical system and system dynamics. The use of computer models as predictive tools is expected to be closely coordinated with timely observations from an established monitoring network. The predictive results and the real time measurements will aid in the continued assessment of repository isolation from dissolution and groundwater circulation. The retardation of radioisotopes within the hydrologic system (Chapter 9.3), when coupled with the hydrologic model,

will allow realistic calculations of radioisotope transport for postulated failure scenarios.

GEOCHEMISTRY (Chapter 7)

Chapter 7 of this WIPP Geological Characterization Report discusses geochemical properties of geologic materials from Southeastern New Mexico. Geochemistry includes accounts of mineralogy and petrology of evaporites and the associated non-evaporites, volatile constituents of the Salado Formation, fluid inclusions in evaporite minerals, ground water chemistry, and age-dating of evaporites and ground waters.

Megascopic, microscopic and x-ray diffraction examination of the Permian (Ochoan) evaporite section showed the three most common minerals of the Salado Formation to be halite, anhydrite and polyhalite. In addition, there are the potassic and magnesic minerals sylvite, kainite, kieserite, langbeinite, loeweite and bloedite in the McNutt Potash Zone of the Salado Formation. Marker beds throughout the Salado Formation (mostly anhydrite and polyhalite) occur at intervals of a few tens of meters, are on the order of 10 to 100 cm thick, and are laterally traceable in core holes adjacent to the center of this investigation. The McNutt Potash Zone varies laterally in mineralogy, and contains "clay partings" typically at the top of each individual ore zone. Silicate minerals in the Salado Formation are quartz, illite, feldspar, chlorite, talc, serpentine, and several varieties of expandable clay, including saponite, illite-saponite and chlorite-saponite. In rock salt, the contribution of silicates is 0.004 to 2.5 weight percent in the lower part of the Salado (>2400 ft. depth in ERDA No. 9), 0.009 to 5 weight percent in the middle Salado (2000 - 2400 ft. depth), and 0.003 to 21% in the McNutt Potash Zone (above 1,650 ft. depth).

Petrographic textures reveal that significant portions of the evaporites have preserved their original depositional textures, indicating no

post-depositional recrystallization or other sorts of alteration. Other portions have undergone extensive recrystallization to non-primary evaporite minerals such as sylvite and polyhalite, which do not precipitate from sea water in normal evaporation. Textures of bedded anhydrite in the Castile Formation below the Salado Formation show a finely laminated arrangement of evaporite and detrital materials in alternating laminae, implying an original depositional form. Petrographic relationships of minerals in the McNutt Potash Zone show that at no time were these minerals in equilibrium with a solution only of sodium chloride, also precluding the possibility of large incursions of surface-derived water in the geologic past.

Amounts and compositions of volatile constituents in the evaporite minerals were determined by heating rock samples to 600°C, recording mass loss, and in some cases analyzing the effluent in a gas chromatograph/mass spectrometer. Except for samples rich in hydrous minerals (polyhalites, clay partings, potash zones), the vast majority of rock salt contains less than 0.5 weight percent total volatiles.

The most abundant volatile constituent in that 0.5% or less is water. Next most abundant is nitrogen, followed by CO_2. Traces of hydrocarbons and fluorides from drilling operations were detected as contaminants in the core.

In addition to fluid inclusions in halite, (see below), the minerals thought to be sources of volatiles in the Salado Formation include clays and polyhalite, and traces of gypsum, magnesite, carnallite, celestite, glauconite, and kainite. The typical volatile content in Salado salt is 3 to 30 times less than that in the Hutchinson (Kansas) rock salt. An additional contributor to the less than 0.5 total weight percent may be traces of hydrated iron oxides, which account for the red-orange to red-violet colors in some accumulations of polyhalite, sylvite, carnallite and halite in the evaporite section.

Fluid inclusions have been studied in core samples from nineteen horizons above and below the levels of the proposed repository in Salado salt beds. The techniques used include mainly petrography, freezing stage, heating stage, crushing stage and decrepitation tests. The purpose was to determine those inclusion parameters that might be pertinent to an understanding of the origin and geological history of these salt beds.

Four general types of inclusions were found in these samples: type A - extremely abundant but minute primary liquid inclusions, with or without a tiny vacuum bubble, outlining primary growth features; type B - much larger liquid inclusions, trapped during several stages of recrystallization of the primary salt, some with a small vacuum bubble and/or unidentified daughter crystals; type C - scarce large liquid inclusions with large and variable gas bubbles under pressure, presumably from fracturing and refilling of type B inclusions; and type D - empty (i.e., gas) inclusions, found principally along grain boundaries, that have leaked and hence have lost their liquid contents.

The total weight percent of liquid as fluid inclusions in these 19 samples, as measured, ranged from 0.1 to 1.7%, mostly as type B inclusions; the amount of liquid in these same samples in situ was larger, since many of the largest inclusions, that are the major contributors to the total percentage, and the intergranular fluids, have been drained during the boring and sample preparation. The temperatures at which these inclusions were trapped were generally in the range of 25-45°C. The brines in them are never simple saturated NaCl solutions, or even NaCl-KCl solutions; freezing temperatures indicate that they must contain considerable amounts of other ions such as Mg and Ca.

When the host crystal is uniaxially stressed, the geometries of the inclusion walls show visible changes within several minutes, possibly due to solution and redeposition, as well as deformation. Internal fracturing of the inclusion walls, but generally without leakage, occurs on freezing.

The distribution of primary type A inclusions provides evidence that they have not moved visibly (i.e., less than a few micrometers at most) in that fraction of the 225 million years between original deposition and the present that these samples have been in the small but finite normal-geothermal gradient.

Subsurface samples of water from various rock types in the Delaware Basin of Southeastern New Mexico and West Texas have been analyzed for their solute contents and $^{18}O/^{16}O$ and D/H ratios. Saturated brines (total dissolved solids greater than 300,000 mg/l) were found in one well in the Bell Canyon Formation, two wells in the Castile and in potash mine seeps in the Salado. According to Cl/Br ratios (between 430 and 900), all the waters have derived their dominant solute (NaCl) from nearby rocks. Potash mine seeps and saline Capitan waters contain solutes corresponding to common primary evaporite mineral assemblages, (halite-anhydrite-kainite-carnallite-bischofite) indicative of simple uptake of dissolved solids. Bell Canyon and Morrow brines contain less magnesium but more calcium than primary evaporite assemblages, and have participated in ion exchange reactions. Stable isotope measurements indicate that Santa Rosa, Rustler and Capitan waters are meteoric, while Salado, Bell Canyon, Morrow and one of the Castile waters (ERDA No. 6) have undergone episodes of low-temperature isotopic exchange with oxygen- and hydrogen-bearing minerals. Isotopically the Carlsbad Caverns hydrologic system is unique to the Guadalupe Mountains, unrelated to the Delaware Basin as a whole.

The ERDA No. 6 occurrence of saturated NaCl-Na_2SO_4 brine and H_2S-rich gas (55% CO_2, 28% H_2S, 15% CH_4, 1.5% N_2 and 0.5% C_2H_6 by weight) in the Castile represents a biogenically-produced sulfide-sulfate disequilibrium. The brine's Na_2SO_4 content may have arisen by rock/fluid ion exchange involving a replacement of magnesium by sodium in the solution. None of the saline groundwaters were found to be original evaporite mother-liquors or products of partial evaporation.

Rb-Sr geochronologic study of the bedded salt deposits from the Salado Formation has been undertaken to age date the last episode of evaporite

crystallization or recrystallization, and to test their feasibility for alkali and alkaline earth retention.

Whole rock samples (i.e., water soluble plus insoluble material) are typically unsuited for Rb-Sr isochron work due to the low Rb/Sr ratio; however, several of these samples do indicate the R_o (i.e., $^{87}Sr/^{86}Sr$ at T=0) value to be about 0.708, thus indicating that large amounts of brine, typically enriched in ^{87}Sr, have not been generated in the sample area since evaporite formation some 235 $\pm$ 10 m.y. ago.

The water soluble fraction of evaporite samples yields an apparent isochron date of 206 m.y. with R_o = 0.7084 while clay minerals (less than two micron size) yield 325 m.y. with R_o = 0.7123. A composite of the water soluble fractions and clay minerals yields a date of 204 m.y. with R_o = 0.7137. This 204 m.y. date is interpreted as a minimum date due to the high R_o value; but it does suffice to indicate that the evaporite-clay mineral assemblages apparently have remained closed to widespread alkali-alkaline earth migration since about the time the evaporites were formed.

Regional exploration of bedded salt for a radioactive waste repository in the Delaware Basin included boreholes into the evaporites and associated rocks. One such hole, ERDA No. 6, encountered an accumulation of saturated $NaCl-Na_2SO_4$ brine accompanied by H_2S-rich gas. This fluid and fluids from other boreholes elsewhere in the area have been characterized geochemically according to solute content, $^{18}O/^{16}O$ and D/H ratios and natural actinide content. Deviations from the equilibrium $^{234}U/^{238}U$ activity ratio (α) of 1.0 were found in all water samples. These deviations are used to affirm the isolation of ERDA No. 6 and to establish bounds on the age of the ERDA No. 6 fluid.

A mathematical model for the age of ERDA No. 6 water intrusion was formulated in terms of the following variables: initial α -value (α_0) of the brine precursor waters, zero order kinetic rate constants of leaching of ^{234}Th and ^{238}U from the rocks, and degree of leaching of

^{234}Th from the rocks. The model allows calculation of α-values of brines as a function of time, leach rate and α_0. Various combinations of α_0's, leach fractions and leach rates indicate that the leach rate must be low. If no leaching is assumed and the α_0 is the highest known α from the nearby Capitan Reef (α_0 = 5.2 at present), the fluid is older than 880,000 years. ERDA No. 6 brine has undergone more profound rock/fluid interactions, reflected in its solutes and stable isotopes, compared with younger meteoric Capitan waters.

The geochemistry of the proposed WIPP site shows that the mineralogy of most of the rock salt is relatively simple. The evaporites have been recrystallized, resulting in some mineral assemblages different from those precipitated from original sea-water-like solutions at one time present in the Delaware Basin. The last episode of such recrystallization took place more than 204 million years ago. The recrystallization resulted in evaporite mineral assemblages which apparently have reached thermodynamic equilibrium. The nature, distribution, geochronology and composition of fluid inclusions, clay minerals, and isolated accumulations of aqueous solutions in the evaporites show no evidence of movement of surface-derived water through the WIPP evaporites (at depths greater than 1000 feet) since their deposition in the Permian Period.

RESOURCES (Chapter 8)

Potash salts and natural gas are the two resources of economic significance under the WIPP site. Other minerals present are halite (salt), gypsum, and caliche, but deposits of similar (if not better) quality exist in the surrounding areas. Other economic minerals and elements, including lithium, uranium, sulfur and metalliferous deposits, could exist in a geologic setting like that of the WIPP, but none appears to be present.

Potassium salts occur in a variety of mineral types, but only sylvite (KCl) and langbeinite ($K_2Mg_2(SO_4)_3$) are mined in the Carlsbad

Potash Mining District, which is the largest domestic source of potash, accounting for approximately 80% of U.S. production. The U.S. is a net importer of potassic fertilizers. The U.S. Bureau of Mines has judged that a langbeinite deposit located in the northeast quadrant of the WIPP site could be profitably mined using today's technology at the current market price for the refined product. The deposit extends beyond the bounds of the WIPP site, but about 49 million tons of langbeinite averaging on the order of 9% K_2O, lie inside the WIPP withdrawal area. Several deposits of sylvite are present, but none meet today's economic conditions; to meet them would require the market price for refined sylvite to increase from $43 to $52 or more per ton.

Natural gas accompanied with some distillate and oil with associated gas are being produced from various beds in the Delaware Basin. One particular formation, the Morrow of Pennsylvanian age, is a consistent producer in this region, and the exploration risk ("wildcatting") is justifiable in much of the western half of the site. About 37 billion cubic feet of natural gas accompanied by about 0.5 million barrels of distillate are estimated to be economically recoverable from beneath the WIPP site.

The studies also included estimation of total resources under the site, not just the resources that could be considered economic today. The U.S. Geological Survey estimates that there are 353.3 million tons of sylvite and langbeinite mineralization under the WIPP site of sufficient quality to require competitive bidding for mineral rights. The WIPP site accounts for about 7% of the potash resources that the USGS believes to be present in the Carlsbad area. Langbeinite is probably the most significant mineral resource under the WIPP site. It is a specialized agricultural fertilizer that finds its use on crops that need potassium but cannot tolerate additional chlorine. Langbeinite adds potassium but is a sulfate. Southeast New Mexico is the only economic source for this particular mineral in the free world. Langbeinite equivalent is produced from potassium and magnesium sulfates from brine lakes. A report is in preparation for DOE which will estimate the fraction of the Carlsbad district's langbeinite resources within the WIPP site.

The New Mexico Bureau of Mines and Mineral Resources studied a large area surrounding the site area, and in its judgement the total hydrocarbon resource in that area is 37.5 million barrels of crude oil, 490 billion cubic feet of natural gas, and 7.33 million barrels of distillate. While these are large quantities, they represent only about 1% of the hydrocarbon resources for southeast New Mexico.

SPECIAL STUDIES OF REPOSITORY ROCKS (Chapter 9)

Special studies are being conducted to address issues of particular interest because the site is being evaluated for the isolation of radioactive wastes. Rocks from the WIPP site were tested in four broad areas: (1) petrography (2) physical properties (density, moisture content, resistivity), (3) thermo-mechanical properties (quasi-static and creep parameters), and 4) radionuclide sorption. Because of a scarcity of core, only those tests deemed necessary for early design were conducted. Testing at specified temperature and creep rates is continuing.

Physical properties representative of rock salt found in the WIPP horizons are summarized in the following table:

Property	Average Value* (Range)
Density	2.18 grams/cm^3
Porosity	0.5 percent (0.1-0.8)
Moisture Loss to 300°C	0.4 weight per cent (0-1.0)
Resistivity	58,100 ohm-meters (4,900-230,000)
Gas Permeability	$< 0.05 \times 10^{-6}$ darcy
Compressional Wave Velocity	4.5 km/sec (4.42-4.62)
Thermal Conductivity	5.75 w/m°K

*Except for moisture loss, values are given at 25°C

Rock salt properties are both time and temperature dependent; as a result, mechanical properties must be generated at a specific loading rate and temperature. Parameters defining the mechanical behavior at different load conditions must be inferred with considerable caution and with proper regard for the time dependent nature of the material. Quasi-static experiments were carried out at particular loading rates, e.g. 30 psi/min.

Quasi-static Properties of WIPP Rock Salt at 23 $^{o}_{C}$

Unconfined Strength	2,450 to 3,700 psi
Secant Modulus	2 X 10^{6} psi
Principal Strain Ratio	0.25-0.35

Strain at failure:

confining pressure	strain at failure
0 psi	2.5-6.0%
500 psi	17-20%
3,000 psi	> 20%

Tensile Strength	220 psi
Initial Yield Stress	$(\sigma_1 - \sigma_3) \approx$ 100 psi

Preliminary Creep Properties

Steady State Creep Rate ($\dot{\varepsilon}$)

At 23°C:	$(\sigma_1 - \sigma_3)$=1000psi	$\dot{\varepsilon} = 10^{-10}$ sec^{-1}
At 130°C:	$(\sigma_1 - \sigma_3)$=2000psi	$\dot{\varepsilon} = 10^{-7}$ sec^{-1}

Results analyzed to date indicate that WIPP salt may undergo both transient and steady-state creep. However the latter is a tentative observation as occurrence of steady-state creep is uncommon. Indeed, if steady state creep occurs under loading conditions expected in the WIPP,

design calculations should consider creep in detail. This most likely will be of concern if elevated temperatures are involved. Although present considerations of steady-state creep are incomplete, it appears that steady-state creep rates range from 10^{-10} to 10^{-7} /sec. The transient creep results indicate that pressure, principal stress difference and temperatures are strongly coupled. Furthermore, of these three, temperature appears to have the most dramatic effect on the creep rate.

Data from the petrographic and physical properties studies show the WIPP horizon rock salt has low moisture content (less than 0.5%), is essentially impermeable (less than 5×10^{-8} darcy) and has a high thermal conductivity (about 5.75 watts/m^{o}K). These properties, along with the studies of fabric and fracture, indicate that this rock salt is ideally suited from a physical standpoint for the storage of heat producing radioactive wastes.

It has been shown that rock salt can experience large creep strains (greater than 25%) prior to loss of load bearing capacity. Gradual creep is an acceptable feature in the design of underground openings in rock salt as it allows the structure to close without a reduction in bearing strength. As long as allowances for creep are incorporated into design and the shape of the opening does not create large shear stresses, the WIPP rock salt can be expected to sustain stable openings.

A survey of the potential of geological media from the vicinity of the WIPP site in southeastern New Mexico for retardation of radionuclide migration in an aqueous carrier was conducted. The survey included the measurement of sorption coefficients (Kd) for twelve radionuclides between three natural water simulants and ten samples from various geological strata.

The nuclides included ^{137}Cs, ^{85}Sr, ^{131}I, ^{99}Tc, ^{125}Sb, ^{144}Ce, ^{152}Eu, ^{153}Gd, ^{106}Ru, ^{243}Am, ^{244}Cm, and ^{238}Pu. The compositions of the simulant solutions were those expected of water in contact with halite

deposits in the area and in a typical groundwater found in the Delaware Basin. The geological samples were obtained from potential aquifers above and below the proposed repository horizons and from bedded salt deposits in the repository horizons.

In brine solutions, Tc and I were not significantly adsorbed by any of the minerals and Cs and Sr showed minimal adsorption (Kd's < 1). The lanthanide and actinide Kd's were typically > 10^3 and Ru and Sb Kd's varied in the range of 25 to > 10^3. In the groundwater simulant, Tc and I showed the same behavior, but the Kd's of the other nuclides were generally higher.

Some initial parametric studies involving pH, trace organic constituents in the simulant solutions, and radionuclide concentrations were carried out. Differences in the observed Kd's can result from varying one or more of these solution parameters.

The WIPP site rocks, including rock salt, show an affinity for radionuclide sorption ($K_d > 0$). Even small values of K_d ($0<K_d<1$) are effective in retarding the movement of radionuclides in groundwaters.

It is not anticipated that results of these special studies will be pivotal in site selection; rather, they are being performed to provide additional confidence in geologic isolation in bedded salt.

CONTINUING STUDIES (Chapter 10)

Although much detailed information has been reported here as a result of site selection and characterization, there remain a number of programs which have not come to completion, or in some cases, have not begun. These pending programs are aimed at refining and supplementing information gathered to increase the confidence to be placed in factors relating to site selection. Furthermore, some kinds of information remain to be gathered to support laboratory and in-situ experiments and long-term safety assessment.

In regional geology, paleoclimatic studies based on detailed geologic mapping, geomorphology studies, microfossils, and age-dating are planned to provide a history of past climatic changes and to help assess the possible effects of future changes. Tectonic studies, involving examination of LANDSAT photos and accompanying field evaluation, first-order levelling surveys, and seismic monitoring of structural features adjacent to the Delaware Basin will continue to provide an account of the dynamic forces which might affect the Basin.

Continuing studies in site geology are aimed at expanding the details of site characterization for the purpose of refining site-specific safety assessment modeling scenarios for the repository. Geologic mapping is being undertaken to establish the local geomorphologic stability. High resolution aeromagnetic surveys will be implemented to provide greater confidence that possible geologic anomalies such as breccia pipes and igneous dikes have been identified and may be examined and sampled in detail.

Seismological studies will continue to document and evaluate the seismicity of the region due to various sources (mining, secondary hydrocarbon recovery, tectonic activity). The data will assure the appropriate seismic risk has been assumed in facility design and will further the safety assessment in general.

Hydrological studies will continue to expand the area around the site for which the groundwater behavior is characterized. In addition to hydrologic monitoring points near site center and periphery, a system of points will be established in nearby Nash Draw to evaluate the relationships among groundwater movement, evaporite dissolution and resulting subsidence. Also, investigations of "breccia pipes" will be undertaken to improve our understanding of why, how and when these features developed. The hydrologic monitoring system will provide the basis for development of a regional groundwater model to be used in safety assessment, and will be evaluated as a monitoring tool for repository-induced changes in the groundwater system.

Continuing studies in geochemistry are designed to support other investigations (such as the examination of dissolution products), provide detailed characterization of geologic materials to be used in in-situ and laboratory experimental programs (such as waste-rock interactions) and to contribute towards our understanding of the nature of Ochoan evaporites in general. These studies include mineralogy, petrology, volatile and fluid inclusion analyses, major, minor and trace element analyses in rocks and fluids, age-dating, stable isotopes, and examination of dike-evaporite interactions as a partial analogue of waste-evaporite interactions.

There are no continuing studies of resources planned at the WIPP site.

Continuing special studies of rock properties include long-term creep analyses in various temperature regimes, micromechanics of rock deformation, migration of volatiles, and mechanistic studies of radionuclide sorption on rocks. Some of these special studies are designed to provide an understanding about differences in mineralogy, grain size, volatile content and rock fabric which are to be found at different in-situ test horizons. The physical properties of the various horizons will be examined with these variations in mind. Non-salt horizons, which may be significant in the development of refined models for calculation of repository effects, will also be tested.

Continuing studies of radionuclide sorption include measurements of dynamic sorption from fluids flowing through columns of WIPP rocks in laboratory environments. In addition, parametric studies will continue to determine changes in sorption which accompany changes in mineralogy, pH, oxidation state, radionuclide concentration, and concentrations of organic contaminants. The rates at which sorption takes place and the differences between the processes of sorption and desorption will be investigated.

GCR CHAPTER 2

INTRODUCTION

The purpose of this chapter is to provide introductory information concerning the function of the WIPP and to discuss the site selection criteria and factors affecting the criteria; the criteria and factors are specific to the WIPP and to the Delaware Basin of southeastern New Mexico. In addition, some of the site exploration techniques are briefly mentioned here as background to further discussion of geological characterization.

2.1 THE PURPOSE OF WIPP

The purpose of the WIPP should be understood clearly as it is distinct from that of several other projects for the disposal of radioactive waste. The WIPP will demonstrate disposal technology for the transuranic (TRU) waste resulting from this nation's defense programs of over 30 years. After a period (5-10 years) of limited (pilot) operation it is anticipated that the WIPP will be converted to a full-scale repository for permanent disposal of defense TRU waste. Secondly, the WIPP is to provide a research facility to examine, on a large scale, the interactions between bedded salt and high-level radioactive waste. These interactions will involve physical and chemical phenomena resulting from thermal and radiation fluxes. A DOE Task Force (DOE/ER-0004/D, 1978) has recommended that WIPP also be used to demonstrate surface and subsurface methods of handling, storing and disposing of up to 1,000 canisters of spent reactor fuel; however, a decision on this recommendation has not been made at this time.

If the site is accepted by the DOE, the schedule calls for the initiation of facility construction in 1981; completion is to be about 1985, and the first waste to be accepted in 1986. The conceptual design of facilities is complete. The Draft Environmental Impact Statement and this Geological Characterization Report for DOE are presently scheduled for completion in late 1978. DOE has expressed an intent to request

licensing of the WIPP by the Nuclear Regulatory Commission (NRC), but this policy is presently under discussion between the DOE and Congress.

2.2 PURPOSE OF GEOLOGICAL CHARACTERIZATION REPORT (GCR)

The purpose of the GCR is to provide an account of the known geotechnical information considered relevant to site selection (see Section 2.3) for the proposed WIPP site. The GCR presents background information as well as information regarding factors related to selection criteria; for the most part, specific judgements regarding the suitability of the site are not made. Those judgements and recommendations are the function of other processes and documents. The GCR is neither a Preliminary Safety Analysis Report nor an Environmental Impact Statement; these documents, when prepared, should be consulted for appropriate discussion of safety analysis and environmental impact. The GCR is intended as a source document on the geology of the WIPP site for individuals, groups, or agencies seeking basic information. Therefore, rather extensive reference lists of reports and documents are provided at the end of chapters for the reader who may desire extended detail concerning particular geotechnical subjects discussed in this report. The GCR is not intended to present primary source material, and the instances of reporting original data or information in this document have been limited.

2.3 SITE SELECTION

Within this document, "site selection" primarily refers to the activities whereby the Los Medanos (or other) area is evaluated, on geotechnical grounds, as to whether it is an acceptable location for the WIPP. "Preliminary site selection" may be used here or elsewhere as a description of the activities which result in selecting a site for characterization; the characterization of such a site establishes technical grounds for the more specific site location of the WIPP. "Site selection" has also been described as that action which results when all technical aspects of establishing a repository site have been satisfied. For the WIPP studies, this latter action is termed "site confirmation";

the criteria for "site confirmation," which means conversion to a repository, will in part be developed through operation of the WIPP as a demonstration facility. Because of unforeseen geological occurrences or enhanced understanding of geological processes, final satisfaction regarding the geological suitability of the site for a repository may not develop until significant portions of the underground workings are explored and studies of geological processes finished. Site selection here refers to the position that most, if not all, of the extant geological characteristics are favorable to the WIPP; the rates of some geological processes may require further examination to reduce that uncertainty with regard to specific detailed effects on a repository. Site selection for the WIPP is not to be interpreted as a guarantee that a repository will be established.

2.3.1 History of WIPP Site Selection Effort

The sequence of events which has culminated in the WIPP site selection activities in the Delaware Basin of southeast New Mexico began in 1955 when the Atomic Energy Commission (AEC) requested the National Academy of Science (NAS) to examine the issue of permanent disposal of radioactive wastes. The Academy's Committee on Waste Management issued a report (NAS/NRC Report) in 1957 in which they stated, "The most promising method of disposal of high-level waste at the present time seems to be in salt deposits." This recommendation initiated several years of research, directed by Oak Ridge National Laboratory (ORNL), on the phenomena associated with disposal of radioactive waste in salt. In 1961 (NAS/NRC Meeting Minutes, December, 1961), the NAS waste management committee reaffirmed its position on the use of salt beds for disposal commenting that "Experience both in the field and in the laboratory on the disposal of wastes in salt have been very productive and well conceived; plans for the future are very promising." Pierce and Rich (1962) reported on salt deposits in the United States that might be suitable for disposal of radioactive wastes. The Delaware Basin was one of these areas discussed. The ORNL research was expanded to include a large-scale field program in which simulated waste (irradiated fuel elements), supplemented

by electric heaters, was placed in salt beds for observation of the resulting phenomena. This experiment, called Project Salt Vault (Bradshaw and McClain, 1971), was conducted in an existing salt mine at Lyons, Kansas, from 1963 to 1967. Results from this program were favorable, and no unacceptable phenomena occurred which would rule out salt as a repository medium. The NAS committee again reviewed and endorsed the NAS position regarding disposal in salt (NAS/NRC Report, 1966). In June, 1970, the Lyons site was tentatively selected by the AEC as the location for a radioactive waste repository. The concept and location were conditionally endorsed by the NAS committee in November, 1970 (NAS/NRC, 1970). Conceptual design for a facility accommodating both transuranic (TRU) and high-level waste (HLW) was completed in 1971. During 1971, as plans for the repository proceeded, two technical problems arose. The first involved the presence of a large number of existing boreholes in the vicinity of the repository which penetrated through the salt beds into underlying aquifers. There was concern that not all these holes could be adequately plugged and that not all such drill holes were on record and identified. This prospect meant that borehole dissolutioning and eventual breaching of the repository could not be ruled out. The second concern related to the solution mining being carried on by the American Salt Mining Company about three miles from the proposed repository but only 1700 feet from an extension of the Carey Salt Mine which was to contain the repository. The revelation that large volumes of water were unaccountably "lost" in the hydraulic fracturing and solution mining was regarded as illustrating a mechanism threatening to the repository site. This site was opposed by the Director of the Kansas Geologic Survey and political opposition within the state increased. By early 1972, the proposal for a repository at Lyons was abandoned and a much expanded search for a suitable repository site was commenced. Other potential sites in the state were identified by the Kansas Geological Survey, and the United States Geological Survey (USGS) examined potential salt sites in other areas of the United States.

After a nationwide search for a suitable repository site (Pierce and Rich, 1962; Anderson et al., 1973; Bachman and Johnson, 1973; Hite and

Lohman, 1973; Jones et al., 1973; Mytton, 1973; Ekren et al., 1974), the USGS and ORNL selected the Permian Basin in New Mexico as best satisfying their site selection guidelines. Four locations within this area were examined in more detail (Brokaw et al, 1972; Jones et al, 1973; Jones, 1974a; Jones, 1974b), and a location in the Los Medanos area, about 30 miles east of Carlsbad, New Mexico, was chosen for exploratory work. One of the most restrictive site selection criteria, primarily because of the Lyons experience, was avoidance of drill holes penetrating through the salt within two miles of the repository border. This criterion caused the potential site to be shifted twice within the Los Medanos area as oil/gas wells were drilled in the vicinity. The eventual site selected by ORNL was located on the Eddy-Lea county line, 30 miles due east of Carlsbad, New Mexico.

Field investigations began at this site in March, 1974, with the drilling of core holes AEC 7 (3,918 feet deep) and AEC 8 (3,028 feet deep) at the northeast and southwest corners of the 1 1/2 by 2 mile rectangular site. The data from these holes was considered satisfactory by ORNL, but further work at the site was suspended in May, 1974. This suspension was due in part to a shift in AEC waste management emphasis to retrievable surface storage facilities (RSSF) and in part to a reluctance at the commission level to ask for land withdrawal to set aside the necessary area for the repository and its protective "buffer" zones.

Sandia received program funding to continue field investigations in southeastern New Mexico on March 31, 1975. Geologic investigations resumed at the ORNL site in May, 1975. Extensive review sessions with ORNL and the USGS covered past efforts in site selection. Studies conducted by the USGS and ORNL consultants on regional geology, seismicity, hydrology and solutioning of salt were re-evaluated. Sandia concurred that the northern Delaware Basin seemed appropriate for siting a waste repository.

In the opinions of both ORNL and USGS, the two core holes, AEC 7 and 8, indicated acceptable subsurface geology at the ORNL site. The first

Sandia task, therefore, was to confirm this by additional drilling and geophysical investigations. Core hole ERDA 6 was initiated in May, 1975, at the northwest corner of the ORNL site. ERDA 6 encountered unexpected subsurface geology. Formation contacts were much higher than anticipated, and salt and anhydrite beds exhibited severe distortion with dips up to 75 degrees. Sections of the upper Castile Formation were missing, and the fractured anhydrite encountered at a depth of 2710 feet contained a pocket of pressurized brine. The unpredictability of the detailed geology at this site was not compatible with Sandia requirements for the pilot plant; therefore, site selection activities were expanded. Reconsideration of site selection guidelines in light of the results of continuing studies and exploration in southeast New Mexico led to the adoption of additional guidelines and some modification of the original guidelines. Evaluation of oil company seismic and drilling data and the resultant structural contours on the Castile Formation confirmed deformation of Castile salt beds in a band about five miles wide paralleling the Capitan Reef front. Since this deformation and the distortion of the geologic units encountered in ERDA 6 was believed due to gravity-induced buckling of salt beds abutting against the Capitan Reef, an additional site selection factor was established requiring a site area to be at least six miles from the reef front.

The proximity of boreholes penetrating the salt formations, another site selection criterion, was re-evaluated during this period. Analytical studies and field research conducted for ORNL after the Lyons, Kansas, borehole problems allowed a more quantitative judgement (Snow and Chang, 1975; Walters, 1975). In the Los Medanos area, a requirement to separate the repository from boreholes penetrating through the salt by one mile seemed quite conservative and was adopted. This buffer would assure more than a quarter million years of isolation using very conservative flow assumptions. While improved borehole plugging and study of the consequences of an unplugged hole may make such holes acceptable even closer to the repository, neither has yet been demonstrated.

The New Mexico portion of the Delaware Basin was re-examined by both the USGS and Sandia in late 1975. On November 14, 1975, the USGS recommended an area about seven miles southwest of the ORNL site for further examination. Sandia had independently selected the same area as showing the most promise for a repository site. Considerable geologic data were available in this region from oil/gas wells and from shallow drill holes used to explore for potash. In a regional study, the USGS found that initial dissolution of Salado salt, the formation of interest, was sufficiently distant from the proposed site that dissolution would pose little, if any, threat to the WIPP. The three-square mile repository could be located to avoid the known potash area (KPA) and to be at least one mile from all boreholes penetrating through the salt. No private (fee) land and less than three sections of state land were present in the potential withdrawal area. A stratigraphic core hole, ERDA 9, was started in parallel with geophysical studies of the area. ERDA 9, drilled in the center of the area under study, revealed the expected geology and indicated the desired flat bedding (dips are about 75 feet/mile). Physical properties of the salt beds were found to be satisfactory; beds at depths of about 2100 and 2600 feet were selected as appropriate for TRU and heat-generating wastes respectively. Consequently, an extensive program of site evaluation and laboratory investigation was begun and is continuing as of the date of this report (August, 1978). Sufficient information has now been developed to allow the site to be adequately characterized for site selection purposes.

2.3.2 General Location and Land Requirements of WIPP Facility

Figure 2-1 shows the general location of the Los Medanos site within the regional geographic setting. The nearest town is Loving, New Mexico, (population about 1100) 18 miles west-southwest of the site. Carlsbad, New Mexico, (population about 25,000) is 26 miles west of the site, and Carlsbad Caverns National Park is about 40 miles to the southwest.

Figure 2-2 is a diagram of the WIPP site showing proposed land use controls around the limits of the underground facilities (Zone II).

Engineering studies had indicated that approximately 3 square miles were desired for ultimate development of underground facilities at the WIPP site, necessitating the restriction of land use within an equivalent area of land at ground surface. Administrative control of additional land (Table 2-1) will also be required beyond the boundary of the excavated area to protect the repository: a mile-wide restricted zone around the repository in which, for the present, no underground mining, excavation, or through-going boreholes will be considered (Zone III); and an additional mile-wide buffer zone in which limited (i.e. subject to control and regulation by DOE) underground mining and deep drilling will be allowed (Zone IV). "Hydrofracing" and other injection methods of hydrocarbon recovery, and any kind of solution mining, would be prohibited. This zonation is shown in Figure 2-2, (which also indicates the corresponding total acreage of restricted land needed for the WIPP site). On the surface, only the plant site itself (Zone I) will exclude land access.

The irregular pattern of the outer boundary of the WIPP site (Figure 2-2) originated from a desire to conform to the Bureau of Land Management's (BLM) land subdivision system and to exclude private land and producing wells. The WIPP program plan calls for the entire area within this boundary to be brought under control of the DOE. The inner boundaries that define restricted areas are polygonal, designed to minimize the area to be withdrawn while achieving optimum conformance to the siting criteria.

2.3.3 General Considerations and Requirements of Underground Storage Facilities for Radioactive Waste

Neglecting consideration of surface restrictions and land use conflicts for the purposes of this report, geotechnical siting requirements for an underground radioactive waste repository are ultimately determined by: 1) the physical (including thermal), chemical and radioactive interactions between the waste and the surrounding media, 2) the type of rock chosen in which to place the repository, and 3) the level of

assurance desired against failure of the containment. While WIPP is anticipated to be a repository for defense transuranic waste, Sandia was also requested to consider possible future options for high-level waste in its site selection studies of bedded salt in the Delaware Basin. For WIPP, the desired goal is complete isolation of waste with negligible consequence in the event of containment failure for the total duration of time in which the radioactivity of the waste could constitute a potential hazard to the biosphere or humans in general.

These unprecedented long storage requirements, which embrace a small but significant interval of geologic time, call for a careful characterization of long-term hydrologic, geologic and climatic processes, potentially affecting stability and survival of the underground facility, in order that appropriate siting criteria may be specified. These and other considerations in the long-term management of radioactive wastes have been defined and discussed in ORNL reports by Gera and Jacobs (1972) where they identify geologic processes relevant to waste disposal and discuss the suitability of various geologic media for radioactive waste storage. Claiborne and Gera (1974) describe and evaluate potential mechanisms of containment failure and of hydrologic release of contaminants from the bedded salt deposits in the southeastern New Mexico area. The conclusions and recommendation of these studies, which are not repeated here, have been utilized as guidelines in formulating siting criteria employed in the selection of candidate site locations in the Delaware Basin area of southeastern New Mexico. Regarding the overall danger of contamination from properly sited underground waste storage facilities, however, it is appropriate for proper perspective to repeat the observation of Claiborne and Gera (1974, p.4) that

> "the conditions required for a serious release of activity to the biosphere from a repository in bedded salt tend to approach the bizarre and have considerably less credibility than the 'maximum credible accident' assumed for nuclear power plant safety analyses."

2.3.4 Initial Screening Criteria and Selection of the Original (ORNL) Site in the Delaware Basin

Preliminary site screening studies for an underground waste isolation storage facility in the Delaware Basin were initiated jointly in 1972 by ORNL and the USGS for the AEC. Guidelines developed at that time were mostly contained in the ORNL report by Gera and Jacobs (1972) and in ORNL-TM-4219, which, however, did not address conditions in the southeastern New Mexico area specifically. Geologic information was assembled by the USGS for use in evaluating the suitability of various areas in the Delaware Basin for disposal of radioactive wastes; this information appeared in open-file form in the report by Brokaw, et al. (1972). Additional data by Bachman, et al. (1972) appeared as an ORNL report.

Large-scale (Stage I) site screening criteria (ORNL-TM-4219) were developed and were employed in an initial selection of a site at the Lea-Eddy County boundary, about 7 miles northeast of the present WIPP site. In addition to the usual geologic standards some technical criteria which were applied by ORNL were as follows (Griswold, 1977, p.12):

A two-mile radius from any boring through the Ochoan evaporites down into the Delaware, or deeper formations.
No active mining within five miles.
Salt of high purity at depths of less than 3,000 ft.
A minimum depth to suitable salt of 1,000 ft.
Avoidance of obvious mineral resources to the extent possible.

The maximum depth indicated was solely a mine engineering criterion dictated by the viscous flow potential of salt at pressures exerted by the lithostatic loading and at temperatures imposed by the expected geothermal gradient coupled with the maximum thermal flux of the stored waste; the minimum depth was that considered adequate to insure against disinterment by erosion.

Figure 2-3 shows the results of this initial screening process. A two-mile radius from deep wells proved to be the most restrictive criterion; on the figure the shaded areas indicate land, more than two miles from deep wells, also satisfying the depth and mineral resource exclusion criteria. The site initially selected by this method is also indicated.

Cores from AEC Nos. 7 and 8 intercepted leasable grades of potash; ERDA No. 6 cores did not. However, at ERDA No. 6, evidence of complex evaporite structure and the encounter of an artesian flow of brine were sufficient evidence that this original site was unsuitable and that more information would be needed to define additional criteria to be used in selection of acceptable alternate sites.

2.3.5 Site Selection and Evaluation Criteria for the Los Medanos Site

When the initial Delaware Basin repository study area was shown to be unacceptable, Sandia undertook the task of locating a satisfactory site in the New Mexico portion of the Delaware Basin. By late 1975 a more complete understanding of the geology of the basin and of potential repository failure mechanisms permitted a reformulation of siting criteria and site selection factors. These criteria and factors were developed rather specifically for the Delaware Basin in southeastern New Mexico, and are neither generic criteria for bedded salt nor generic criteria for all rock types.

Some of the specific studies contributing to this effort include the following: Claiborne and Gera (1974) considered potential failure modes of bedded salt containment in the Delaware Basin; Bachman and Johnson (1973), Jones (1973), Bachman (1974) and Piper (1973) reported on geologic and hydrologic conditions in the Permian Basin region and in the Delaware Basin in particular; Jones (1975) discussed potash deposits; and Foster (1974) and Netherland, Sewell and Associates (1975) investigated hydrocarbon resources. Reports on dissolutioning associated with unplugged boreholes (Snow and Chang, 1975; Walters, 1975; Fader, 1973)

were also available. The selection of additional alternate sites made in November, 1975, utilized this information. Two factors which received careful attention because of the experience gained in locating and evaluating the original site were the existence of salt flow structures and associated brine pockets and the dissolution potential of man-made penetrations through the evaporites.

Siting factors were formulated to eliminate from further consideration areas of possible severe structural deformation or complexity of the salt beds. Geologic evidence (Jones, 1973) indicated the tendency for greater structural complexity to occur in salt beds adjacent to the Capitan reef front. Substantial salt deformation resulting in displacement and fracturing of anyhdrite beds was encountered in ERDA-6. Structural contouring of the Castile Formation, based on petroleum drilling and seismic reflection data, indicate this distortion of salt is most severe in a belt, about five miles wide, paralleling the reef front. Accordingly, a belt with a width of six miles basinward from the Capitan reef was eliminated from eligible areas. This also served to avoid any possible dissolution hazards which might be associated with the reef. Known locations of artesian brine flow appeared to be related to anticlinal features in the subsurface; therefore, the avoidance of pronounced anticlinal structures in salt was adopted as a selection factor.

The extent of deep drilling, resulting from hydrocarbon exploration in the Delaware Basin, indicated that a careful evaluation of the required separation from boreholes be performed. Desirable regions could be excluded from consideration if this factor was unduly restrictive. The two mile separation distance established after the Lyons, Kansas, experiences, was modified to one mile based on studies by Snow and Chang (1975), Walters (1975), and Fader (1973). These studies improved prospects for assuring plugging of boreholes, and the hydrologic conditions expected in the acceptable portions of the Delaware Basin all indicate that a one-mile buffer zone is amply conservative against potential borehole dissolution (Griswold, 1977, p. 12). Figure 2-4 shows

areas that are more than one mile from boreholes penetrating into the Delaware Mountain Group. Avoiding these boreholes would also result in avoiding existing oil or gas fields.

In addition to the salt anticline and borehole restrictions already mentioned as assuming a primary role in narrowing the choice of acceptable sites, several other aspects proved to be significant for the northern portion of the Delaware Basin. Proximity to the dissolution front at the top of the Salado Formation and the existence of local solution features were prime considerations.

Although open joints, fractures or faults are not expected to occur in salt, intrusions in the form of igneous dikes which pass through the salt beds are known to exist locally in the Delaware Basin. The proximity of such a feature might be cause for rejection of a site for geologic, hydrologic and engineering reasons. Shown in Figure 2-5 are areas where undesirable structure, such as salt deformation, brine-flow anticlines, or dike trends, are known or presumed to occur; the dike trend is magnetically expressed and is defined by magnetic survey methods.

Candidate sites should be located in areas affording adequate long-term protection against encroachment of salt dissolution. Surface dissolution was assumed to be related to downward percolation of meteoric water and removal through Nash Draw and the Pecos drainage system. In addition, evidence of possible dissolution in salt over the Capitan reef aquifer is known in such places as San Simon Sink. Dissolution fronts, or boundaries at which salt has been or is being dissolved from the enclosing rock material, had been recognized at various horizons in the evaporite sequence of the Delaware Basin. Rates of dissolution were estimated by Bachman (1974), and longevity of Salado salt was diagrammed by Jones (1973, Figure 7). These observations were translated into appropriate avoidance criteria. Dissolution of salt in the Rustler Formation was not considered to be a significant hazard to a repository located in the lower part of the Salado; however, areas that exhibit extensive salt dissolution at the top of the Salado would be rejected.

For conservatism, sites that would be in, or within a mile of, areas of known dissolution at the top of the Salado were considered less desirable. Figure 2-6 displays areas where dissolution at the top of Salado was indicated to occur, based on studies current at that time.

The interception of commercial grades of potash by holes AEC-7 and AEC-8 and the known occurrences of potash nearby highlighted the necessity of evaluating the potential of this resource to assess possible resource conflict. Areas of potash mineralization meeting minimum grade and thickness criteria, termed the "potash enclave" by Aguilar et al. (1976), would be avoided to the extent possible by the three square mile core of the site. Regarding possible conflict with hydrocarbon reserves, the avoidance of deep drill holes automatically insures that a potential site would not be located over an existing oil or gas field. To minimize the possibility of siting over areas having favorable potential for discovery of additional hydrocarbon reserves, oil and gas trends in the subsurface beneath a possible site location would be considered in siting the repository. The locations of such trends are shown in Figure 2-7.

Finally, with regard to land ownership, the land withdrawn should be federally owned to the extent possible to expedite site exploration and land withdrawal. Potash lease rights would be avoided by Zones I and II to the extent feasible.

2.3.6 Site Selection: Criteria and Factors

Two principal stages are involved in establishing a nuclear waste repository. The first stage, outlined mainly in the previous section (2.3.5), involves preliminary site selection of the most desirable site from among the potentially acceptable study areas. This selection is based on application of criteria and selection factors to the existing knowledge and general reconnaissance information available for the areas. Specific and detailed studies are not conducted at this stage. The second stage is to determine the characteristics and processes affecting a site or sites sufficiently well to allow confirmation of a

site for a repository. It is possible that this detailed study will reveal that some factors are less than ideal. It is unlikely (and unnecessary) that a site will be ideal with respect to all selection factors. Similarly, it is unnecessary and, indeed, impossible to prove that the "best" site has been selected. The extent of investigation in stage two is such that all prospective sites cannot be examined in this detail. Rather it is sufficient to establish that an adequate, safe, and acceptable site has been identified. This knowledge requires that potential failure modes and hazards be recognized and that siting factors take them into consideration.

For the WIPP, the facility demonstration and additional studies of processes and underground geology will lead to further development of criteria for a repository and subsequent assessment of the safety of the WIPP site as a repository. Thus, at least for WIPP, it is necessary to refine criteria, through operation and continued study, sufficient for confirmation as a repository.

For site selection of the Los Medanos site the following criteria and the factors which address those criteria are listed. In most cases, the nature of the factor desired can be indicated but not quantitatively specified a priori since the acceptable combinations of factors under the multiple barrier concept is so large. Many of the desired factors are just that - desired. They are sufficient but may not be necessary for long-term repository safety. The general relationship of factors to WIPP studies is indicated by referring to principal chapters containing information about particular factors.

Geology Criterion: The geology of the site will be such that the repository will not be breached by natural phenomena while the waste poses a significant hazard to man. The geology must also permit safe operation of the WIPP.

Factors: Topography - Must permit access for transportation. Effect on inducing salt flow during excavation must be considered. Surface water flow and future inundation must be evaluated. (See 3.2, 4.2)

Depth - Repository horizons should be deeper than 1000 feet to assure erosion and consequences of surficial phenomena are not a major concern. Depth of suitable horizons will not exceed 3000 feet to limit rate of salt deformation around the excavations. (See 3.3, 4.3, 9.2)

Thickness - Total thickness of the salt deposits should be several hundred feet to buffer thermal and mechanical effects. The desired thickness for the repository bed is 20 feet or more to mitigate the thermal and mechanical effects at non-halite units. (See 4.3.2, 9.2)

Lateral Extent - The distance to structural or dissolution boundaries must be adequate to provide for future site integrity. For the Los Medanos area a distance of five miles to the Capitan reef and one mile to regional Salado dissolution have been established. (See 3.3, 4.3, 6.3)

Lithology - Purity of the salt beds is desirable to reduce the brine content of the salt. Pending further investigations, three percent brine is established as a desirable upper limit for the heat-producing waste horizon. Additional geochemical interactions must be considered if significant chemical or mineralogical impurities are present. (See 4.3, 7.2, 7.3, 7.4, 7.5, 7.6)

Stratigraphy - Continuity of beds, character of inter-bedding and nature of beds over- and underlying the salt are important considerations in construction of the facility and in assessment of possible failure scenarios. (See 3.3, 3.4, 4.3, 4.4)

Structure - Relatively flat bedding ($< 3^{o}$) is desirable for operational purposes. Steep anticlines and major faults are to be avoided. (See 3.4, 4.4)

Erosion - While the depth factor reduces concern for erosion it is desirable to avoid features which would tend to localize and/or accelerate erosion. (See 3.2.3, 3.6, 4.2, 4.5, 6.2)

Hydrology Criterion: The hydrology of the site must provide high confidence that natural dissolution will not breach the site while the waste poses a significant hazard to man. Accidental penetrations should not result in undue hazards to mankind.

Factors: Surface Water - Present and future run-off patterns, flooding potential, etc., should not endanger the penetrations into the repository while these openings are unplugged. (See 6.2)

Aquifers - For WIPP, the over- and underlying aquifers represent a secondary barrier if the salt is breached. Consequently low permeability and transmissivity are desirable but not mandatory. Accurate knowledge of aquifer parameters is important to construction, decommissioning and realistic calculation of the consequences of failure scenarios. (See 6.3)

Dissolution - Regional and/or local dissolution must not breach the repository while the wastes represent a significant hazard to man. While there are various suggestions for the time a repository should remain isolated from the biosphere, 250,000 years (ten half-lives of ^{239}Pu) is one period which may be sufficient for evaluating the WIPP site. (See 6.3.6)

Subsidence - Subsidence due to dissolution of salt will be avoided when the subsidence adversely affects the repository beds or unduly accelerates the rate of

dissolution to the jeopardy of long-term integrity of the repository. (See 6.3.6, 10.6)

Hydrologic Transport - For the WIPP, this is a secondary factor which must be evaluated to allow quantitative calculations of the consequences of various failure scenarios. Slow transport of isotopes is acceptable if more critical factors have been satisfied. (See 6.3, 9.3. 10.6)

Climatic Fluctuations - Possible pluvial cycles must be considered when estimating the effects of the above factors. (See 3.6, 4.5, Chapter 6, 10.3)

Man-made Penetrations - The effect of drill-holes and mining operations on the site selection must be evaluated in considerations of dissolution.

Tectonic Stability Criterion: Natural tectonic processes must not result in a breach of the site while the wastes represent a significant hazard to man and should not require extreme precautions during the operational period of the repository.

Factors: Seismic Activity - The frequency and magnitude of seismic activity impacts facility design and safety of operation. Low levels of seismicity are desirable but facility design can accommodate higher levels as well. (See Chapter 5, 10.5)

Faulting/Fracturing - While open faults, fractures or joints are not expected in salt, the more brittle units within and surrounding the salt may support such features which can enhance dissolution and hydrologic transport. Major faults and pronounced linear structural trends should be avoided. (See 3.4, 4.4)

Salt Flow/Anticlines - Major deformation of salt beds by flow can fracture brittle rock and create porosity for brine accumulations. Major anticlines resulting from salt flow should be avoided or evaluated to check on brine presence and anhydrite fracturing. (See 4.4)

Diapirism - An extreme result of salt flow, this feature will be avoided for WIPP siting. (See 4.4)

Regional Stability - Areas of pronounced regional uplift or subsidence should be avoided since such behavior makes anticipation of future dissolution, erosion and salt flow more uncertain. (See 3.4, 4.4, 10.3.2)

Igneous Activity - Areas of active or recent volcanism or igneous intrusion should be avoided to minimize these hazards to the repository. (See 3.5)

Geothermal Gradient - Abnormally high geothermal gradients should be avoided to allow construction in salt at 3000 feet. High gradients may also be indicative of recent igneous or tectonic activity. (See 4.4.1)

Physico-chemical Compatibility: The repository medium must not interact with the waste in ways which create unacceptable operational or long term hazards.

Factors: Fluid Content - The repository bed containing high level waste should not contain more than three percent brine. The limit for TRU waste has not been established, but the same value used for HLW is acceptable. (See 7.5, 10.7.8)

Thermal Properties - No major natural thermal barriers should exist closer than 20 feet to avoid undesirable temperature rises. (See 4.3, 9.2.3)

Mechanical Properties - The medium must safely support excavation of openings even while thermally loaded. Clay seams and zones of unusual structural weakness should be avoided in selection of the repository horizon. (See 9.2.4)

Chemical Properties/Mineralogy - Beds of unusual composition and/or containing minerals with bound water should not occur within 20 feet of the waste horizon. This will lessen the uncertainties with regard to thermally driven geochemical interactions. (See 4.3, 7.2, 7.3, 7.4, 7.5)

Radiation Effects - While no unacceptably deleterious effects are postulated, these phenomena are best quantified in halite and thus the purer rock salt beds are desired for high- level waste. (See 9.3)

Permeability - Salt has very low permeability and only the inter-beds and surrounding media are considered for siting with respect to this factor. Low permeability is desirable, but quantitative limits need not be specified for site selection. (Salt permeability to gases may be important in establishing waste acceptance criteria.) (See 9.2.3)

Nuclide Mobility - This is a secondary factor in siting since confinement by the salt and isolation from water is the basic isolation premise. Ion sorption must be determined to allow quantification of safety analyses and to indicate whether engineered barriers (clay) would be beneficial. (See 9.3)

Economic/Social Compatibility Criterion - The site must be operable at reasonable economic cost and should not create unacceptable impact on natural resources or the biological/sociological environment.

Factors: Natural Resources - Unavoidable conflict of the repository with actual or potential resources will be minimized to the extent possible. (See Chapter 8)

Man-made Penetrations - Boreholes or shafts which penetrate through the salt into underlying aquifers shall be avoided within one mile of the repository. Existing mining activity, unrelated to the repository, should not be present within two miles of the repository. Future, controlled mining, will be allowable up to one mile from the repository. Future studies may permit still closer mining and drilling if properly controlled. (See 2.3, Chapter 4)

Transportation - Transportation should be capable of ready development. Avoidance of population centers by transportation routes is not a factor in WIPP siting. (Not addressed in GCR)

Accessibility - The site should be readily accessible for transportation and utilities. (Not specifically addressed in GCR; see Chapter 2 figures)

Land Jurisdiction - Siting will be on federally controlled land to the extent possible. (Not specifically addressed in GCR; see Chapter 2 and 8 figures)

Population Density - Proximity to population centers and rural habitats will be considered in siting. Low population density in the immediate site area is desirable. (Not addressed in GCR)

Ecological Effects - Major impacts on ecology due to construction and operation should not occur. Archaeological and historical features of significance should be preserved. (Not addressed in GCR)

Sociological Impacts - Demographic and economic effects should not result in unacceptable sociological impacts. (Not addressed in GCR)

One may summarize the WIPP siting criteria having the greatest impact as follows:

Avoidance of land within one mile of any boring through the Ochoan evaporites and into the Delaware or deeper formations.

Salt of high purity at a depth between 1000 and 3,000 ft.

Avoidance of areas where dissolution had advanced to the top of Salado or deeper levels, by establishing a distance of one mile or more from dissolution fronts at the top of Salado.

Avoidance of possible salt deformation in a belt 6 miles wide basinward from the Capitan reef.

Avoidance of pronounced known anticlinal structures.

Avoidance of known oil and gas trends.

Avoidance of the known potash enclave above the repository and minimizing conflict with the known enclave in the buffer zone.

Minimize existing potash lease rights in Zones I and II.

Minimize state and private land in Zones I through IV.

These criteria were applied to all areas within the Delaware Basin in New Mexico. Figure 2-8 illustrates result of application of the expanded set of criteria. Two alternate sites survived the constraints imposed by the site selection criteria.

2.3.7 Preferred Preliminary Site Selection

Since only two alternate sites in the New Mexico part of the Delaware Basin withstood the set of revised Stage II siting criteria, the preliminary selection of a preferred site was fairly straightforward. Alternate I, now known as the Los Medanos site, appeared to be the preferred site. Alternate II was considered less desirable because it was restricted in size, the acceptable salt zones were deeper, and the high-purity salt lying between the Cowden anhydrite (in the lower Salado Formation) and the Castile was thought to be absent. The top of the Salado was about 800 feet deep at Los Medanos versus 1500 feet at Alternate II. Other factors that favored the selection were:

Structural interpretation of what seismic data was then available to Sandia indicated the Los Medanos site would be in a synclinal area unfavorable for oil and gas acccumulation.

Similarly, if the site were in a syncline, geopressured brine reservoirs would be less likely.

The Alternate II area lay adjacent to the Double X and Triple X shallow oil fields where water flooding for secondary recovery could occur.

No seismic exploration data whatsoever was available to Sandia on the Alternate II area, and only partial coverage at Los Medanos.

Sandia Laboratories selected the Los Medanos alternate as the best candidate area in early December, 1975. Figure 2-9 illustrates how the siting criteria apply to the Los Medanos site.

Geological characterization activities were then expanded to focus on obtaining subsurface data at the Los Medanos site. A descriptive summary of these programs is given in Section 2.5.

2.4 STATUS OF STUDIES

In review, geologic studies for the WIPP fall naturally into three different phases: preliminary site selection activities, geological characterization, and studies of long-range geologic processes affecting a repository. Preliminary site selection activities are complete now; these consisted primarily of national and regional studies over the past fifteen years, and resulted in selection of the WIPP study area for geological characterization. The work of geological characterization should be considered to have begun with the drilling of ERDA 9 and the initiation of seismic reflection work on the site. That geological characterization, which is primarily oriented to provide specific data concerning the present geology of the site, will be virtually complete in 1978 when this Geological Characterization Report is submitted to DOE; much basic information has been gathered indicating no major technical problems with the site as it is now understood. Studies of long-term

processes which might affect a repository or have an effect on safety analyses will be the major geotechnical activity for the WIPP project after 1978, although some of these activities are already underway. These studies will concern the age of significant features and the rates and processes which produce those features. The information so gained will be useful in increasing the confidence in evaluation of the safety of a repository when a decision is necessary regarding conversion of the WIPP to a repository.

2.5 EXPLORATION TECHNIQUES

Much of the geological characterization of the WIPP study area is done using exploration geophysics and boreholes. About 75 line miles of new seismic reflection data and 9000 resistivity measurements were collected and 47 drillholes completed to support WIPP geological characterization to date (August, 1978). For convenience, the boreholes are listed in Table 2-2 according to primary objective. Twelve geologic exploratory holes (two by ORNL and ten by Sandia Labs) have been drilled to date in support of this program (Table 2-2A); three holes were drilled at the old study area, two are located off the WIPP site, and seven were drilled on the WIPP site. ERDA 9 is located at the center of the present study area (Figure 2-10). These boreholes were extensively logged, cored, and drill-stem tested in the evaporite section. The cores form the basis for several continuing laboratory studies that are important to an understanding of the physical and chemical phemomena associated with the WIPP and contribute to general knowledge about the formation of evaporites. Two of the exploratory boreholes have been drilled well outside the immediate site to obtain dissolution and paleoclimate data. Twenty-one holes (Table 2-2B) were drilled in conformance with industry standards to obtain core from the potash zones to supplement more than 30 existing industry holes for evaluation of potash resources within the WIPP study area by the USGS and the U.S. Bureau of Mines (Figure 2-11). When that evaluation is complete, others may use the core for studies of potash ore formation. Fourteen hydrologic holes (Table 2-2C) have been drilled and four potash holes converted to hydrologic monitoring to

provide a total of eighteen holes now dedicated to hydrologic studies. Hydrologic tests of the Bell Canyon Formation underlying the evaporites have also been conducted in two of the exploratory boreholes, one northeast and one south of the site. Except for ERDA 9, none of the boreholes within Zones I, II, or III penetrate as deep as the repository horizons. Future holes will sample repository horizons within these zones.

Seismic reflection data available from petroleum companies and 26 line miles initially obtained strictly for the study area (Figure 2-12), were collected using standard techniques for the petroleum industry. The data are excellent for interpreting deeper structure, but are not as useful for showing reflectors in the upper 3000 feet. In 1977, about 48 line miles of new data (Figure 2-13) were collected using shorter spacings for geophones, higher frequencies from vibroseis units, and higher rates of data sampling. These data show much improved reflections from, and better resolution in, the shallow section of interest. Resistivity has also been extensively used as a characterization tool. Field tests indicated that resistivity could detect certain types of solution features; more than 9,000 measurements have been taken in the study area to search for such features (Figure 2-14). Additional measurements of resistivity using expander arrays have been made to study resistivity changes with depth and to help interpret the detailed measurements (Figure 2-15). Analysis of geophysical data for the geological characterization was nearly complete by Summer, 1978. One resistivity anomaly was drilled to determine the cause of the anomaly and consequences, if any, for the WIPP. This anomaly did not result from dissolution phenomena. Further detailed geophysical investigation of the site, using techniques previously described for better resolution of shallow horizons, is now underway (Summer, 1978) for the primary purpose of providing detailed engineering information.

A variety of studies to continue geological characterization and contribute to long-range assessments are under way. Studies directed primarily toward geochemistry include water chemistry and stable isotope

studies of surface and subsurface water of the Delaware Basin; fluid inclusion studies of the evaporite beds; chemical and mineralogic effects of an igneous intrusion into the evaporite section; Rb/Sr dating of potash ores; and sorptive capacities of evaporites and associated rocks for various radionuclides. The dissolution history for the area and the local paleoclimate are being investigated through analysis of a core taken from a sink in nearby San Simon Swale. Field investigations of the climatic history and stability of the Pecos River drainage are beginning, and caliche studies will form a significant part of this effort. Studies of LANDSAT images will conclude in 1979. In addition, the first 200 km of the first-order level line from Carlsbad to El Paso, Texas, has been resurveyed to examine regional tectonic movements associated with the West Texas salt flats graben and trans-Pecos volcanic area. A first-order level line has also been established from Carlsbad east to the WIPP site through Nash Draw for future assessment of tectonic, erosion, solutioning, and subsidence phenomena. Further assessment of basin tectonics may be derived through measurements of in situ stress. These long-range studies will continue until sufficient data are available to permit reasonable and confident assessment of the risks involved in having a repository in bedded salt in southeastern New Mexico. These studies, plus the successful operation of the WIPP as a demonstration facility, are essential for the development of criteria for the conversion of the WIPP to a repository.

2.6 SUMMARY

Bedded salt has been a leading candidate as a rock type for the storage of radioactive waste; a combination of technical factors has led to the examination of the Delaware Basin in southeastern New Mexico as a location for the WIPP. Through preliminary site selection and partial site characterization of an early site near the WIPP, site selection criteria and factors which are rather specific to southeastern New Mexico were refined, and a new preliminary site was selected. Chapter 2 contains the description of the criteria and factors used in this process as an introduction to the geological characterization of the WIPP site

which is presented in the following chapters. The geological techniques used in the characterization of the WIPP site are a combination of well-tested conventional techniques supported by state of the art tools. Multiple, supporting techniques are used where appropriate. Continuing geological studies will increase the data base for assessment of the WIPP as a repository and allow refinement of criteria for conversion to a repository.

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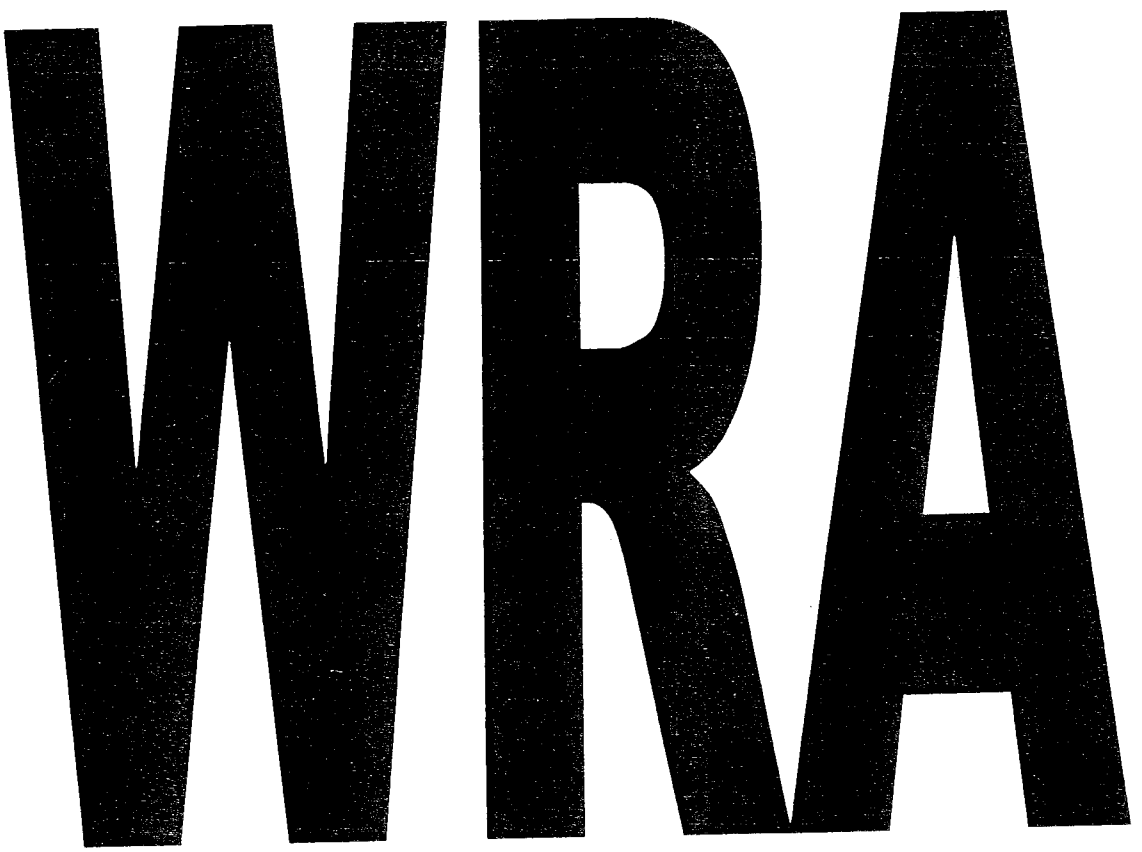

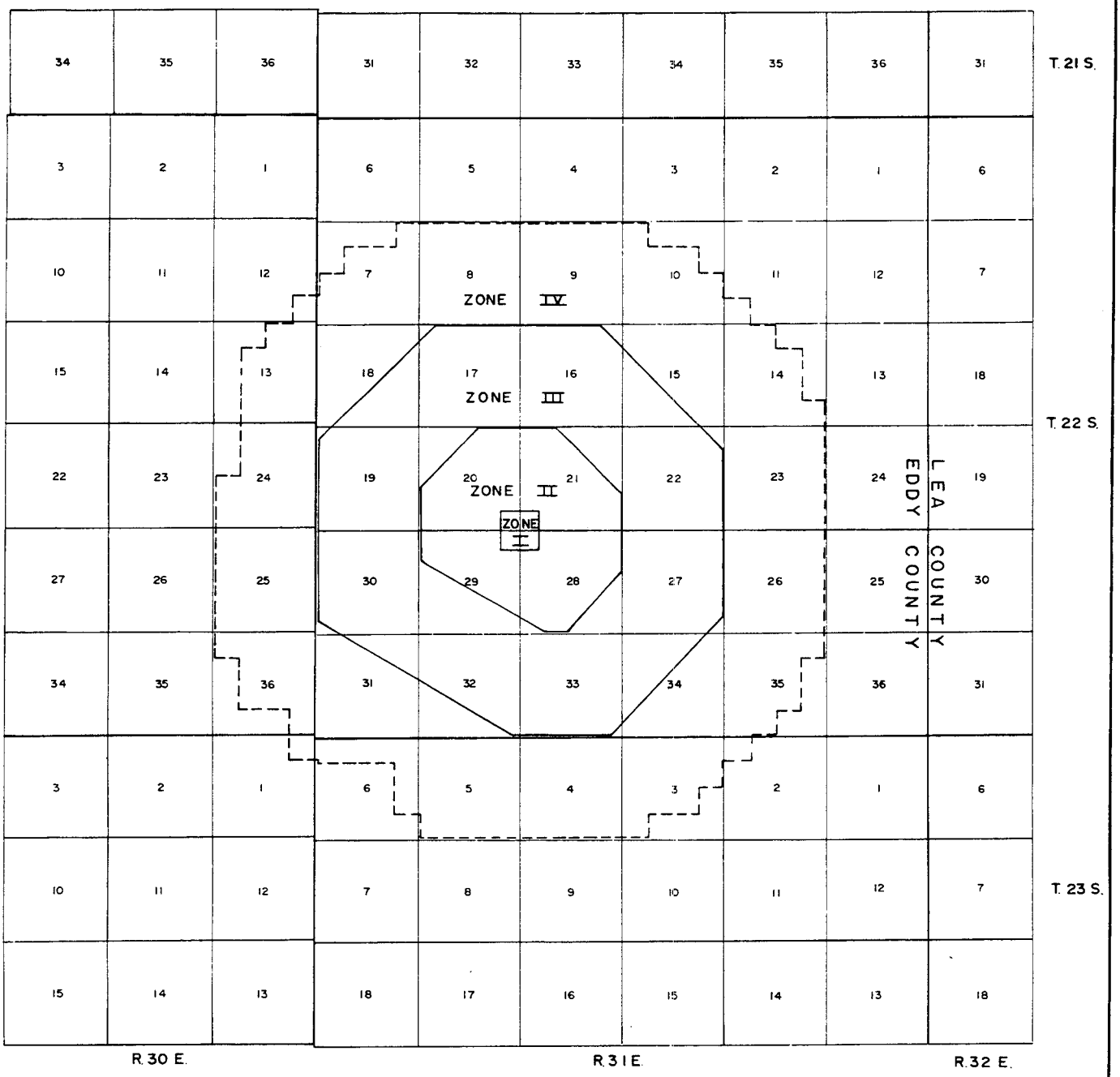

ZONE ACREAGE

ZONE I - 60-100 (surface facilities)

ZONE II - 1860 (underground repository)

ZONE III - 6230 (no mining or drilling)

ZONE IV - 10,810 (DOE-controlled mining and drilling)

1 0 1 2 3

SCALE IN MILES

N

WIPP SITE ZONATION

FIGURE 2-2

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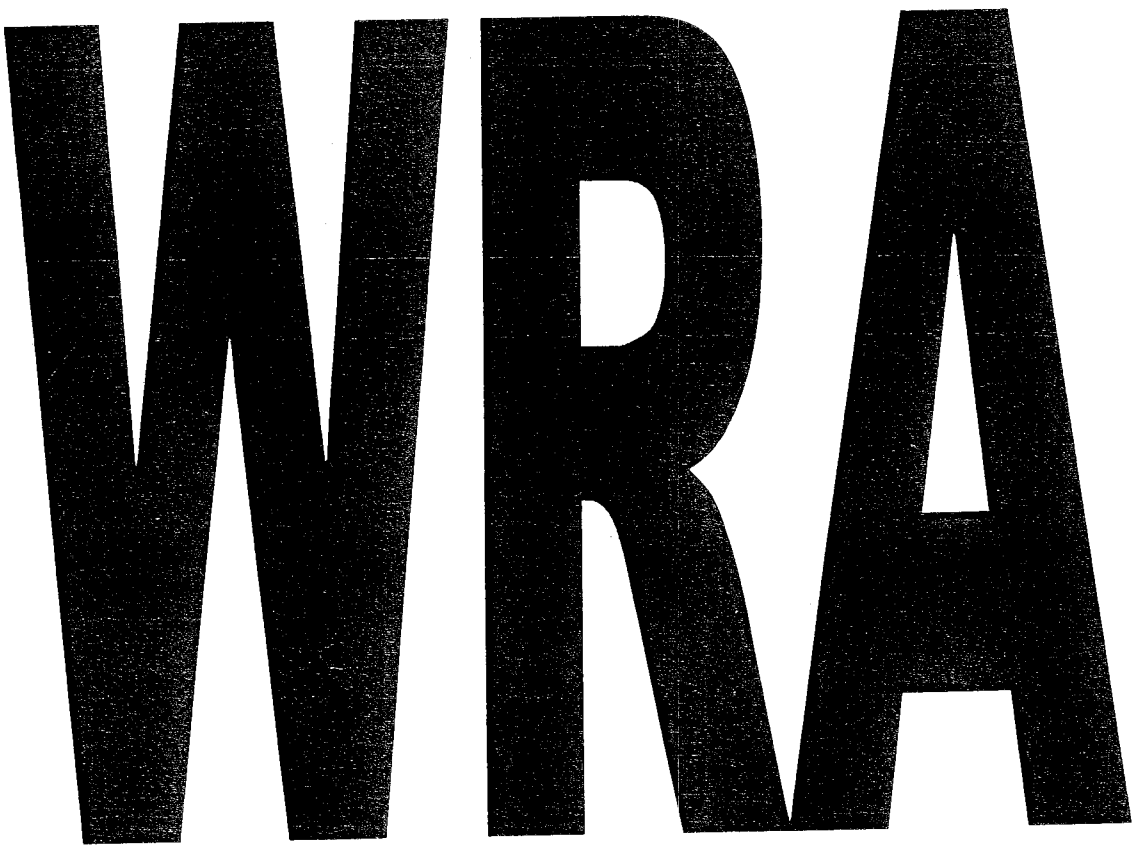

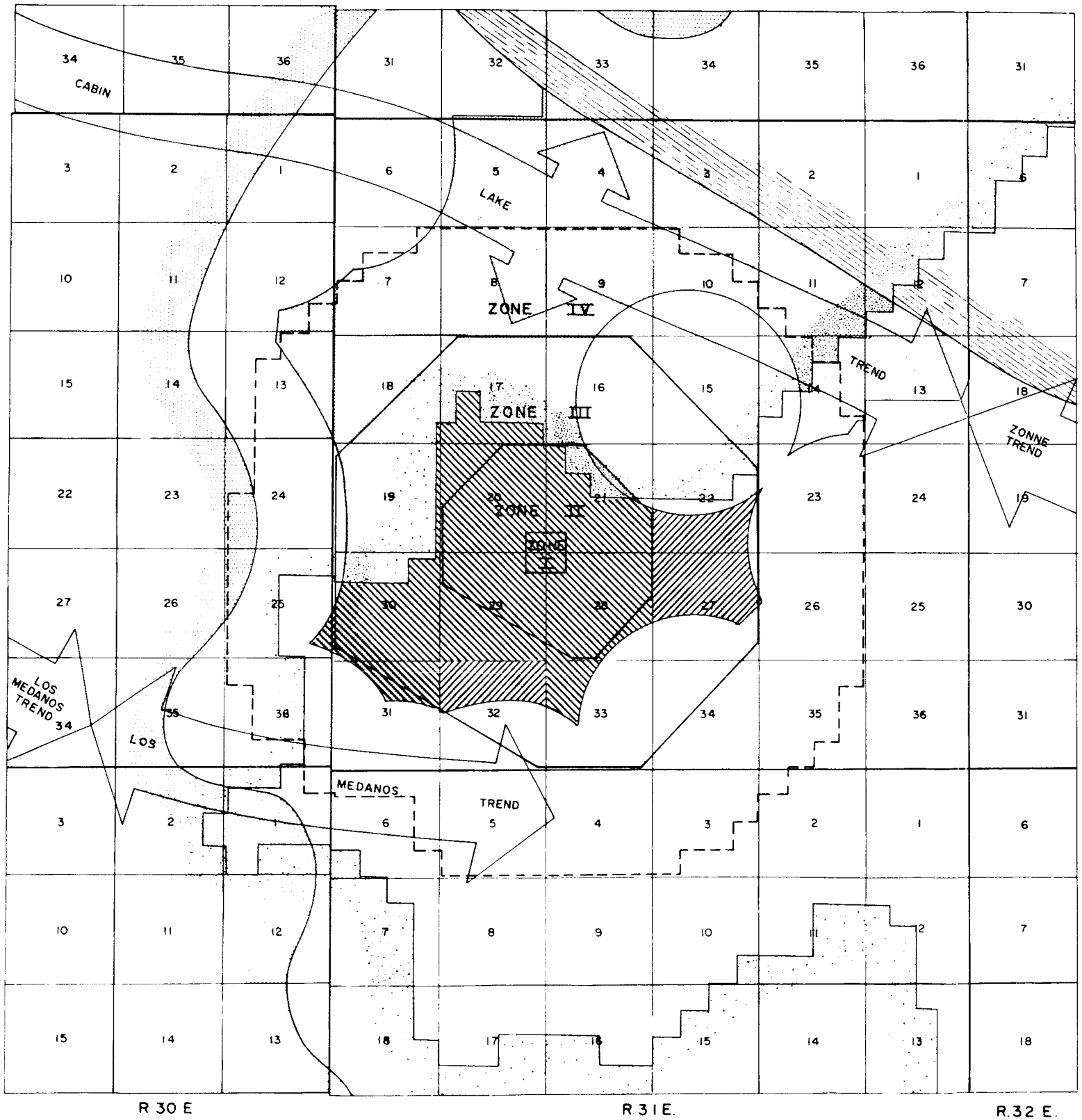

EXPLANATION

- OIL OR GAS TREND
- DISSOLUTION FRONT
- BUFFER FROM DEEP HOLE (1 MI)
- KNOWN POTASH ENCLAVE
- DEFORMATION BELT
- STATE LAND
- ACCEPTABLE FOR WIPP

REFERENCE:

GRISWOLD, 1977, FIGURE 2

0 1 2
SCALE IN MILES

N

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SELECTION OF PREFERRED SITE

FIGURE 2-9

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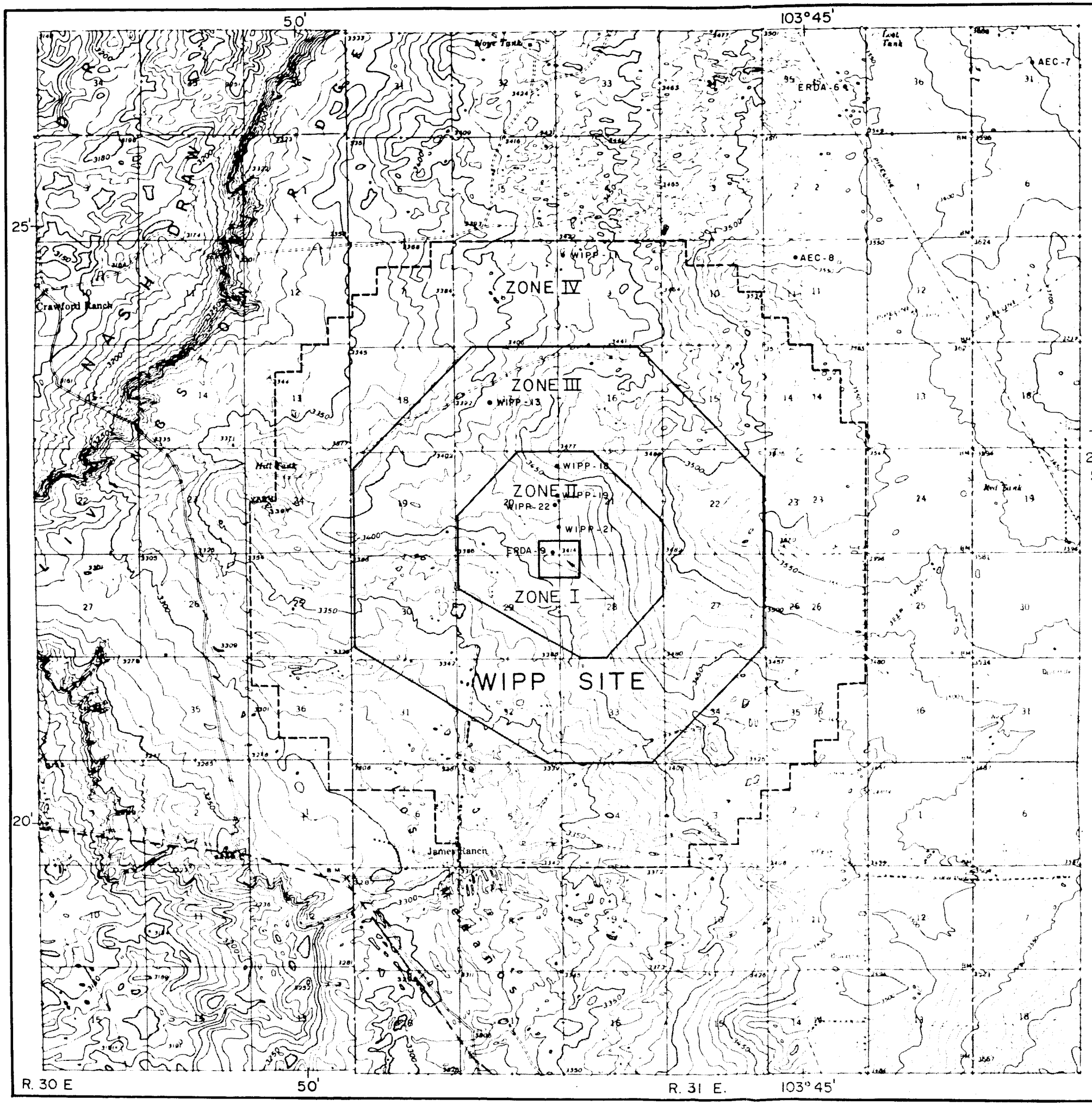

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REFERENCE:

U.S.G.S. 15 minute quadrangles: Nash Draw, N.Mex., 1965 and Hat Mesa, N.Mex., 1972.

0 1 2 3 MILES
0 1 2 3 KM.
SCALE

WIPP SITE STRATIGRAPHIC HOLES

FIGURE 2-10

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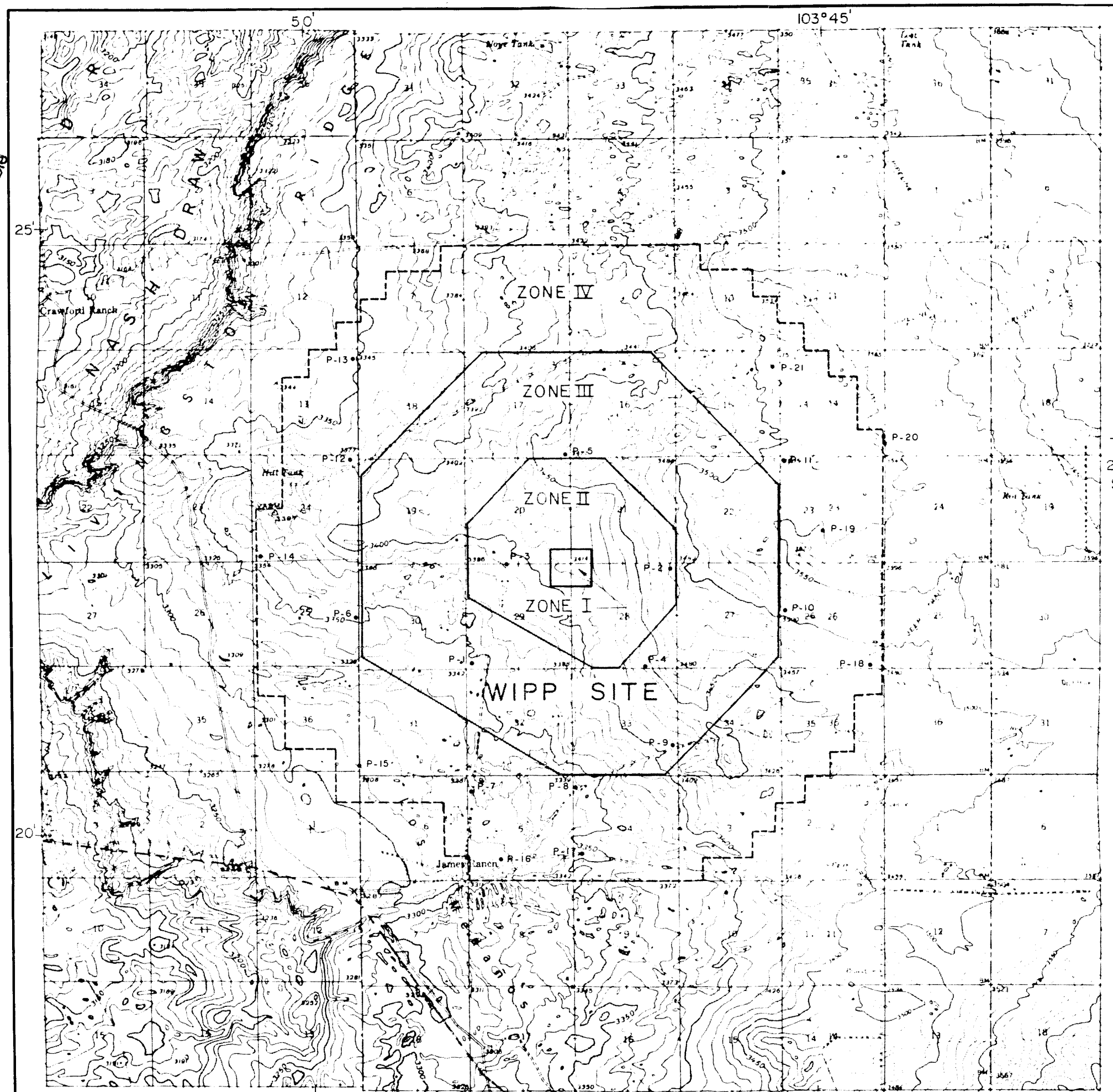

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W

REFERENCE:

U.S.G.S. 15 minute quadrangles: Nash Draw, N.Mex., 1965 and Hat Mesa, N.Mex., 1972.

0 1 2 3 MILES

0 1 2 3 KM.

SCALE

WIPP SITE POTASH DRILLING BY ERDA, 1976

FIGURE 2-11

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R 30 E | R 31 E | R 32 E

T 21 S

T 22 S

T 23 S

ZONE IV

ZONE III

ZONE II

ZONE I

WIPP SITE

CABIN LAKE 1

CABIN LAKE 2

CABIN LAKE 3

CABIN LAKE 4

CABIN LAKE 5

SAND DUNES 2

SAND DUNES S. E. 2

SSC N VIB

SSC P VIB

SSC O VIB

SSC R VIB

SSC M VIB

SSC K VIB

SSC AH VIB

GL-16 GL-18 GL-19 GL-21 GL-22 GL-23 GL-24 GL-27 GL-28 GL-39 GL-40 GL-14 GL-58 GL-55 GL-65 GL-64 GL-170 GL-346

SAN-1 SAN-2 SAN-3

S-36 S-32 S-694 S-708 S-687 S-998 S-1139 S-985 S-994 S-55

0020 0017 0016 9964 9962 9963 9965 9994 5098 5002 9980A

FNR

INDUSTRY SEISMIC REFLECTION LINES
PLUS SANDIA REFLECTION LINES
(SAN. – 1, 2, 3) FROM 1976

FIGURE 2-12

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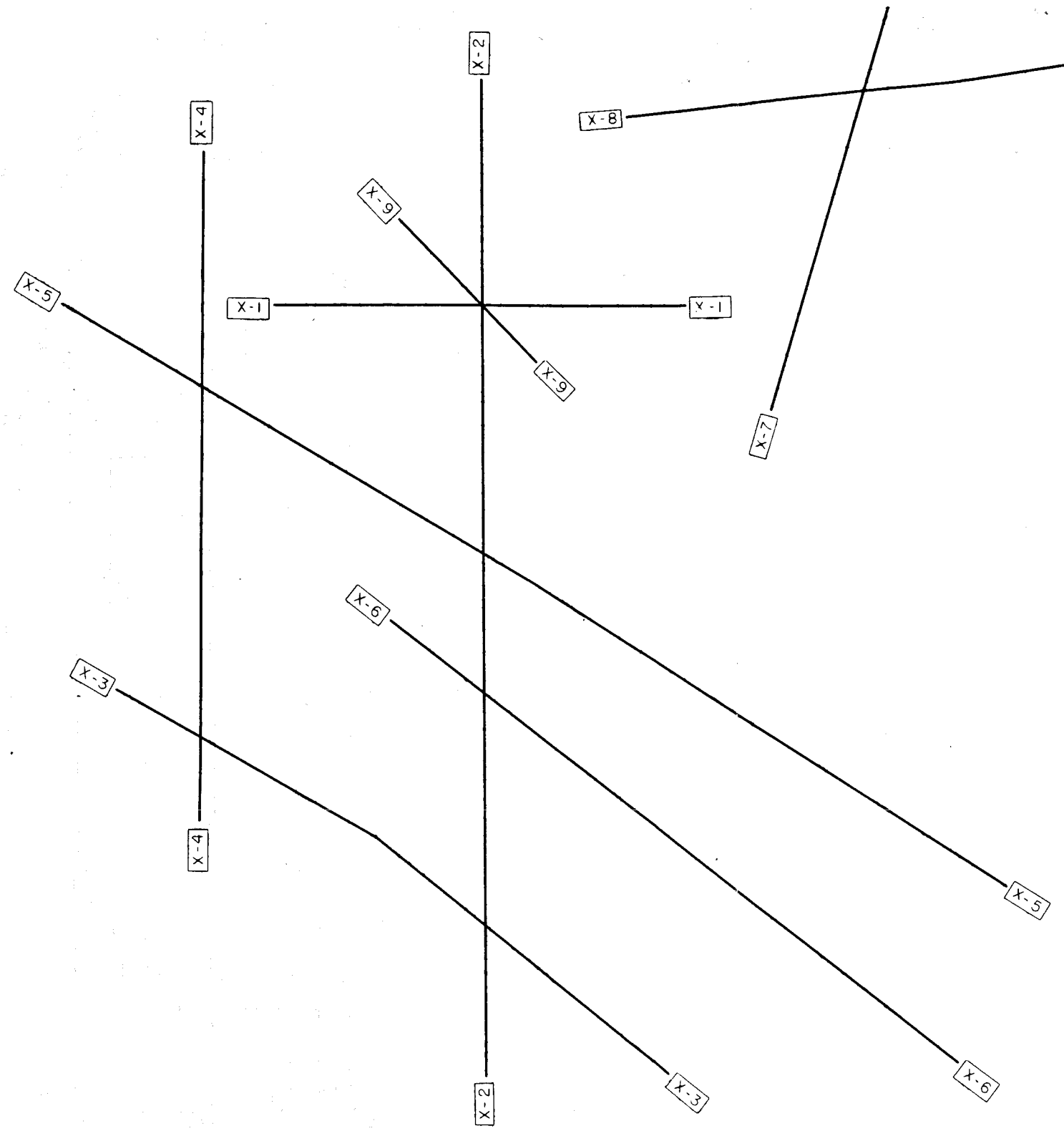

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REFERENCE:

U.S.G.S. 15 minute quadrangles: Nash Draw, N.Mex., 1965 and Hat Mesa, N.Mex., 1972.

0 1 2 3 MILES

0 1 2 3 KM.

SCALE

SEISMIC REFECTION LINES FOR

SEISMIC PROGRAM, 1977

FIGURE 2-13

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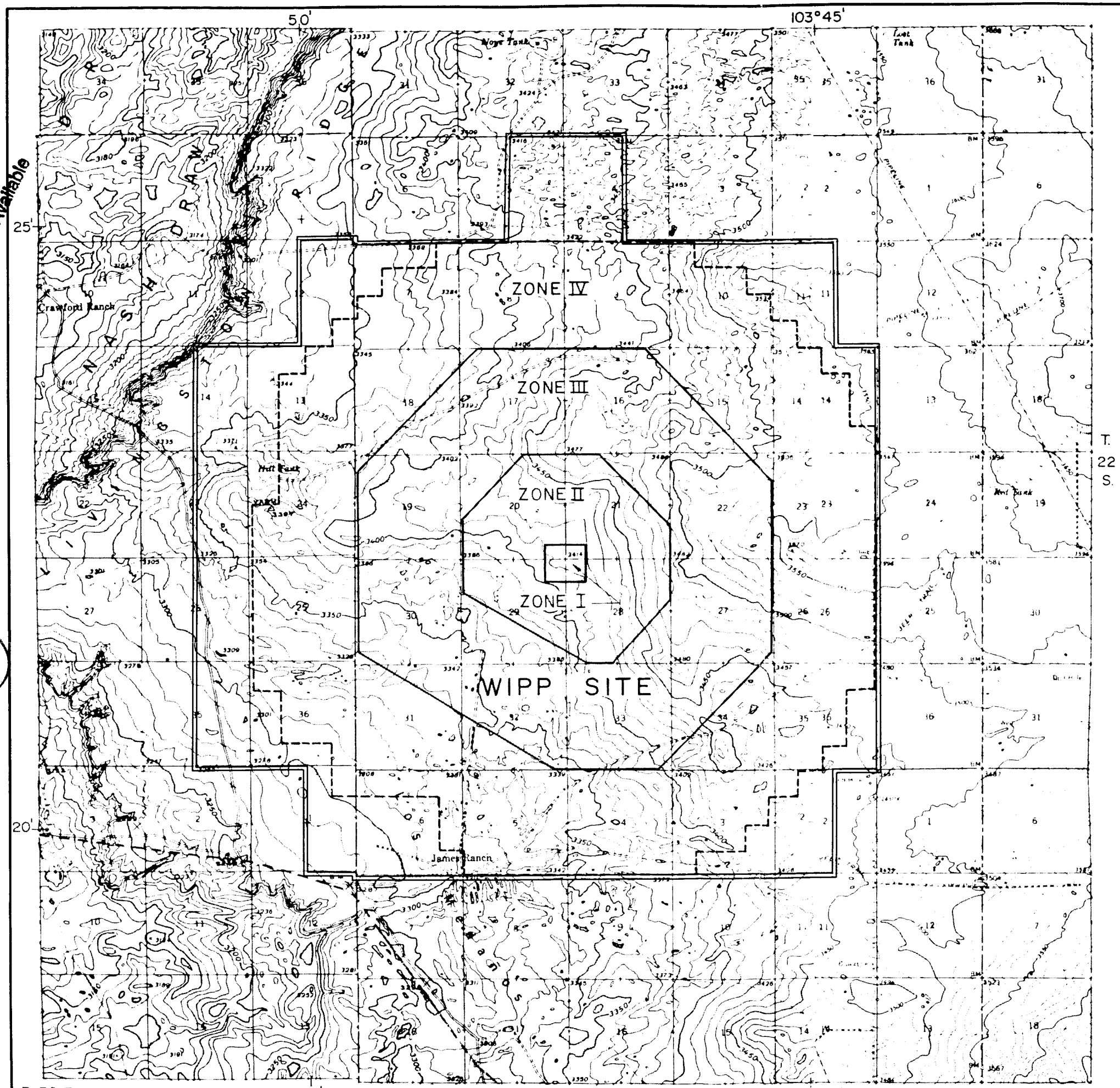

N

EXPLANATION:

═══ Outer Boundary of Resistivity Measurement Area

REFERENCE:

U.S.G.S. 15 minute quadrangles: Nash Draw, N.Mex., 1965 and Hat Mesa, N.Mex., 1972.

0 1 2 3 MILES
0 1 2 3 KM.
SCALE

PROFILE LOCATION MAP
OF
GRADIENT ARRAY RESISTIVITY

FIGURE 2-14

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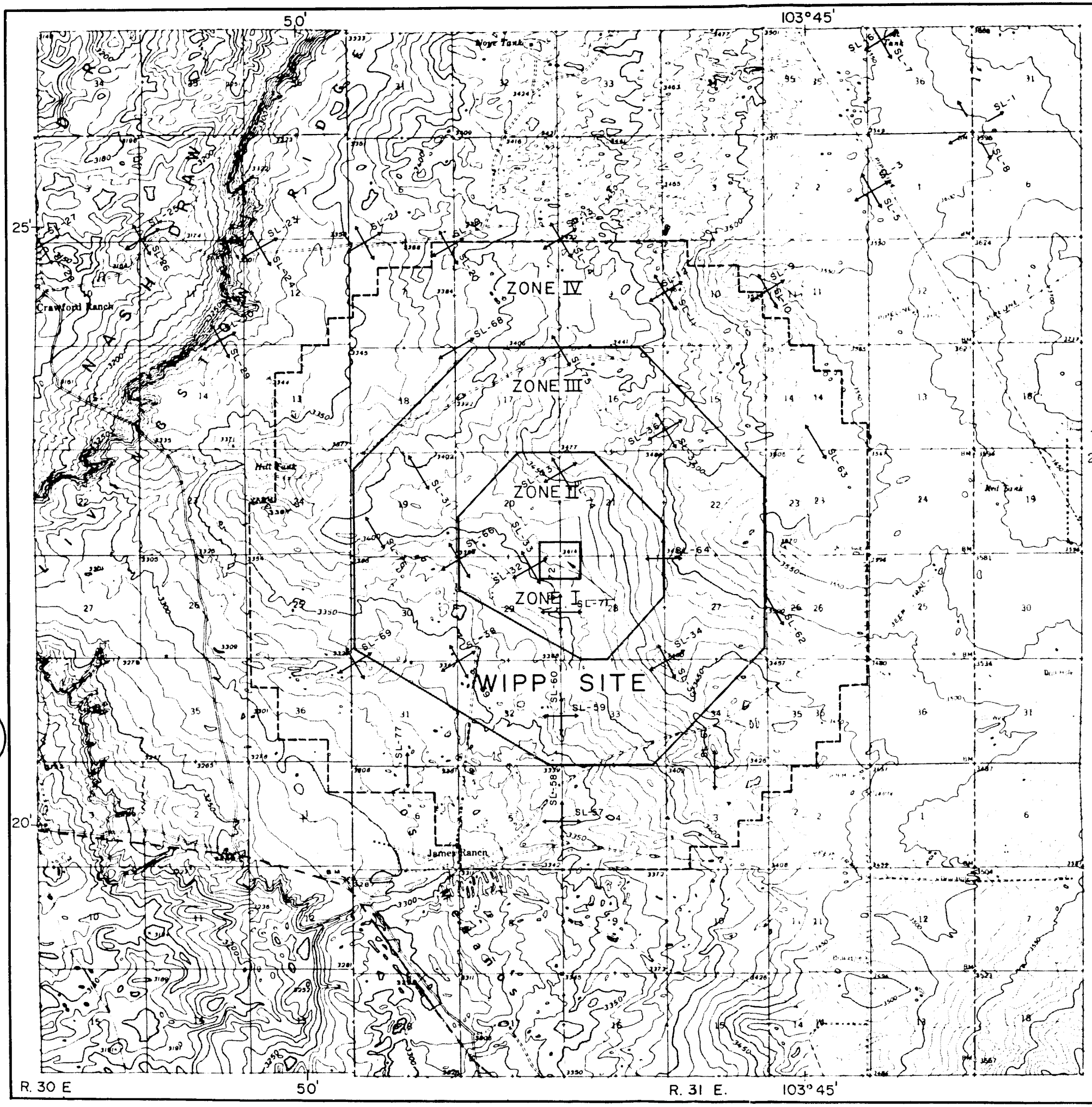


SL-29 SL-30

Schlumberger Array Soundings with Line No. and Direction

N

W

REFERENCE:

U.S.G.S. 15 minute quadrangles: Nash Draw, N.Mex., 1965 and Hat Mesa, N.Mex., 1972.

0 1 2 3 MILES

0 1 2 3 KM.

SCALE

LOCATION MAP
FOR
RESISTIVITY SOUNDINGS

FIGURE 2-15

TABLE 2-1

WIPP SITE CONTROL ZONES

Zone	Area Description	Surface Use and Activity Control	Approximate Acreage
I	Surface Exclusion Area	All non-WIPP activities excluded (security fenced area).	60(to 100)
II	Underground Storage Limits	Restricted; land use same as Zone III. Must be free of prior lease rights.	1,860
III	Restricted Buffer Zone	Drilling & mining operations prohibited. Current livestock grazing activities permitted. Other future activities subject to approval and regulation under ERDA authority.	6,230
IV	Controlled Use Buffer Zone	Drilling and mining operations permitted but restricted in conformance with ERDA specifications. Solution mining, well injection recovery methods prohibited. Other activities as specified for Zone III.	10,810
		TOTALS	18,960

TABLE 2-2

A. GEOLOGIC EXPLORATORY HOLES
(Figure 2-10)

Designation	Location	Date	Purpose
AEC 7	21/32/31	3/74	ORNL Stratigraphic--Old Site
AEC 8	22/31/11	4/74, 6/76	ORNL Stratigraphic--Old Site Sandia--Deep Hydrology--Old Site
ERDA 6	21/31/35	6/75	Stratigraphic--Old Site
ERDA 9	22/31/20	4/76	Stratigraphic--WIPP Site
ERDA 10*	23/30/34	8/77	Deep Dissolution--Off Site
WIPP 11	22/31/9	2/78	Stratigraphic--WIPP Site
WIPP 13	22/31/17	7/78	Stratigraphic--WIPP Site
WIPP 15*	23/35/18	3/78	Paleoclimate--Off Site
WIPP 18	22/31/20	2/78	Stratigraphic--WIPP Site
WIPP 19	22/31/20	4/78	Stratigraphic--WIPP Site
WIPP 21	22/31/20	5/78	Stratigraphic--WIPP Site
WIPP 22	22/31/20	5/78	Stratigraphic--WIPP Site

* not shown on Figure 2-10

B. ERDA POTASH HOLES
(Figure 2-11)

Designation	Location	Date
P1	22/31/29	8/76
P2	22/31/21	8/76
P3	22/31/20	8/76
P4	22/31/28	8/76
P5	22/31/17	9/76
P6	22/31/30	9/76
P7	23/31/5	9/76
P8	23/31/4	9/76
P10	22/31/26	9/76
P11	22/31/23	9/76
P12	22/30/24	9/76
P13	22/31/18	9/76
P14	22/30/24	9/76
P15	22/31/21	8/76
P16	23/31/5	9/76
P17	23/31/4	10/76
P18	22/31/26	10/76
P19	22/31/23	10/76
P20	22/31/14	10/76
P21	22/31/15	10/76

TABLE 2-2 (Continued)

C. HYDROLOGIC TEST HOLES
(See Figure 6.3-5)

Designation	Location	Date	Purpose
H1	22/31/29	5/76	Rustler, Top Salado Hydro
H2a	22/31/29	2/77	Magenta
H2b	22/31/29	2/77	Culebra
H2c	22/31/29	2/77	Top Salado
H3	22/31/29	7/76	Rustler, Top Salado Hydro
H4a*	22/31/5	5/78	Magenta
H4b*	22/31/5	5/78	Culebra
H4c*	22/31/5	4/78	Top Salado
H5a*	22/31/15	6/78	Magenta
H5b*	22/31/15	6/78	Culebra
H5c*	22/31/15	5/78	Top Salado
H6a*	22/31/18	7/78	Magenta
H6b*	22/31/18	6/78	Culebra
H6c*	22/31/18	6/78	Top Salado

* Holes being drilled at time of report

GCR CHAPTER 3

REGIONAL GEOLOGY

3.1 INTRODUCTION

This chapter considers the physiography and geomorphology, stratigraphy and lithology, structure and tectonics, igneous activity, and geologic history of the southeast New Mexico-west Texas area within a radius of about 200 miles of the proposed WIPP site. The information presented in the discussion below has been derived from previously available published and unpublished sources, including well-known reference texts, U.S. Geological Survey publications and open-file reports, Roswell Geological Society and New Mexico State Bureau of Mines and Mineral Resources materials, journal articles, and reports prepared under contract to Sandia Labs. A study of LANDSAT imagery was also conducted to examine lineaments as well as physiographic and structural features.

Section 3.2 presents a general description of the physiographic divisions, illustrated in Figure 3.2-1, which lie within approximately 200 miles of the site, followed by a more detailed study of the origin and development of those geomorphic features having significance to the site and by a consideration of relative erosion rates estimated for the future in the area surrounding the site.

Section 3.3 summarizes the major rock types and stratigraphic nomenclature by which the Precambrian basement and overlying sedimentary section are characterized within an area roughly bounded by the Sacramento Mountains on the northwest, and by Texas' Midland and Val Verde basins on the south and southeast. Generalized cross sections, depicting the entire stratigraphic section present in the area (Figure 3.3-2) and a study of Permian reef relationships (Figure 3.3-4) as well as correlations of the Precambrian rocks, (Figure 3.3-1) and Permian section (Figure 3.3-3) supplement the discussion.

Section 3.4 describes the major structural elements comprising the southeast New Mexico-west Texas region and summarizes the history of their tectonic development. The features discussed include the major subsurface basins and platforms of Late Paleozoic origin, which together have produced the essential structural framework of the area, and large-scale Cenozoic features, which generally possess surficial structural expression, as well as the more important smaller structures occurring within the boundaries of these elements. The structures considered in this section are displayed in Figure 3.4-1, and a basement contour structure map (Figure 3.4-2) demonstrates the basic structural configuration of the region.

The major occurrences of igneous activity within the site region are described in Section 3.5. As demonstrated in Figure 3.5-1, this igneous activity has been generally limited to the area west and south of the proposed WIPP site, in the form of Tertiary intrusive bodies and volcanic terrains. The igneous feature nearest to the site, a northeast-trending dike located about nine miles northwest of the site, is discussed separately in this section and is illustrated in Figure 3.5-2.

Section 3.6 presents a synthesis of the major events which have affected the site region, as these have been determined from lithologic and structural data available in the area. A schematic visualization of the regional geologic history, as correlated with the geologic time scale, is provided in Figure 3.6-1.

3.2 REGIONAL PHYSIOGRAPHY AND GEOMORPHOLOGY

Figure 3.2-1 presents the major physiographic units which encompass the southeast New Mexico-west Texas region. The discussion below includes a general description of the physiographic sections, as defined by Fenneman (1931), which lie within a radius of about 200 miles of the proposed WIPP site. This is followed by a more detailed description of the development of the major nearer site landforms.

3.2.1 Physiographic Setting

The proposed WIPP site is located within the eastern part of the Pecos Valley section of the southern Great Plains physiographic province. The Great Plains physiographic province comprises a broad highland belt sloping gradually eastward from the Rocky Mountains and Basin and Range province to the Central Lowlands province. The Great Plains province in turn represents the western extent of the Interior Plains major physiographic division (Fenneman, 1931).

Pecos Valley Physiographic Section The Pecos Valley section consists of the Pecos and upper Canadian valleys, which together form a long north-south trough carved from what was once part of the High Plains section on the east, but whose axis now lies 500 to 1,000 feet below the High Plains surface -- the Llano Estacado. The Guadalupe and Sacramento mountains of the Basin and Range physiographic province flank the Pecos Valley section to the west.

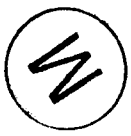
The topography of the Pecos Valley section varies from flat plains and lowlands to rugged canyon lands. Except where covered by alluvium, much of the land surface has an uneven rock floor, which results from the erosion of the moderately resistant limestones, sandstones, shales and gypsum to form scarps, cuestas, terraces, side canyons and some mesas of limited extent. The valleys of the Pecos River in the vicinity of the Delaware Basin exhibit a characteristic lowland topography marked by widespread solution-subsidence features, which have resulted from dissolution within the Upper Permian Ochoan rocks (see the karst topography discussion below).

The land surface generally slopes gently eastward, reflecting the attitude of the underlying rock strata. The average elevations within the section range from over 6,000 feet above sea level in the northwest and about 5,000 feet in the north to 4,000 feet on the east and 2,000 feet to the south (Fenneman, 1931).

The Pecos Valley section is drained primarily by the Pecos River which lies slightly to the west of the center of the Pecos trough and flows in a southeast to southward direction through most of the length of the section. The extreme northeastern portion of the section is also drained by a short segment of the generally eastward-flowing Canadian River. Owing to the desert character of the area, most of the tributaries of these major streams flow only intermittently, and some creeks drain into local depressions, where the water evaporates or percolates into the underlying sediments.

The Canadian River has cut much more deeply into the surrounding land than has the Pecos River, thereby producing a much greater relief in the far nothern portion of the section than is present to the south.

The northern portion of the Pecos River, north of Roswell, has cut a valley in places as deep as 1,000 feet below the surrounding land surface and from 5 to 30 miles wide. The central portion of the river, from about 50 miles north of Roswell to near the New Mexico-Texas border, flows through an alluvial valley of comparable width but much reduced relief and is underlain by as much as 250 feet of alluvium near Carlsbad. The southern part of the Pecos, just north of the Edwards Plateau, flows across an alluvial plain, called the Toyah Basin, which is similar to that further north and comprises most of the west Texas portion of the Pecos Valley section (Fenneman, 1931). The genesis and development of the Pecos River system are discussed in Section 3.2.2, below.



The immediate valley of the Pecos River is bordered on the east by almost continuous bluffs, beyond which the eastward-dipping rock strata lie at or near the surface for a distance of several miles. A sloping alluvium-mantled plain extends eastward from this rocky belt to the westward face of the Llano Estacado (Fenneman, 1931).

<u>High Plains Physiographic Section</u> East of the Pecos Valley section lies the High Plains section of the Great Plains physiographic province,

extending from South Dakota on the north to near the Rio Grande (river) in Texas. The High Plains are remnants of a former great fluviatile plain, which stretched from the mountains on the west to the Central Lowlands on the east. The portion of the High Plains east of the Pecos valley is known as the Llano Estacado and comprises approximately 20,000 mi^2 of almost completely flat plain, which has undergone very little dissection. Northward, the land is more dissected, and the original flat surface is still preserved only along stream divides.

The High Plains originated through deposition of the Late Tertiary Ogallala Formation, resulting in more than 500 feet of silts with lesser gravels and sand. The deposits were laid down in alluvial fans by overloaded streams flowing eastward from the Rocky Mountain area over an irregular erosional surface. By the end of the time of formation of the Ogallala, the High Plains surface was probably continous across the area of the present Pecos River drainage to the back slope of the Sacramento Mountains (Bachman, 1976) (also see Section 3.6.5). In many areas, the nearly flat surface which resulted was later cemented by a hard caliche layer. The almost perfect preservation of the orginal topography in the Llano Estacado area is due to a combination of the porous nature of the sediments, the protection afforded by the caliche, and the relatively arid climate of the region (Fenneman, 1931).

The few, generally insignificant topographic features present in the High Plains section consist mainly of depressions derived from a variety of origins, such as dissolution with subsidence, blowout activity, buffalo wallowing or differential compaction of the Tertiary sediments. Ponding of water occurs in these depressions following rain storms, and a few maintain permanent pools (Thornbury, 1965). Sand dunes also occur in scattered locations throughout the section, generally fringing the leeward sides of streams (Fenneman, 1931).

Edwards Plateau Physiographic Section The Llano Estacado merges southward into the Edwards Plateau section of the Great Plains province by the gradual thinning and disappearance of the Ogallala Formation. It

comprises a wedge-shaped portion of west Texas, and then extends across the Rio Grande into Mexico. The Edwards Plateau is bounded on all sides by an escarpment, except for two small areas, where it merges with the Llano Estacado on the northwest and where it terminates against the mountains of the Mexican Highlands on the west. The northern edge of the plateau, bounding the Central Texas Section, is formed by an eroded and deeply notched southward-retreating escarpment, and the southern boundary is marked by a line of faulting and local folds, which produces an escarpment up to 1,000 feet high (Fenneman, 1931).

The Edwards Plateau ranges in elevation from 3,000 feet on the north at its border with the Llano Estacado and 4,000 feet at the foot of the mountains on the west to 2,200 feet along its southern margin and 1,000 feet at the southeast corner.

The surface of the Edwards Plateau is underlain by a single resistant layer of limestone dipping gently to the south and east, which has encouraged the development of rather flat-lying terrain and bold escarpments. In the eastern part of the plateau, where rainfall is greatest, the plateau is narrow and highly cut by the dissection moving inward from the margins. West of the 100th meridian, the plateau becomes a drier, broad area covered by a plain much like the Llano Estacado. The wide, shallow valleys that have formed in this part of the section generally carry runoff only during rain storms. However, the Pecos River and Rio Grande have cut canyons across the section as deep as 1,000 feet. And on all sides where escarpments exist, the dissected edges carry outflowing streams.

Other surface features on the plateau are limited and generally restricted to erosion or dissolution-type structures. Some shallow sinkholes exist in areas where dissolution of the underlying limestone has caused a collapse of the land surface (Fenneman, 1931).

Sacramento Physiographic Section West of the Pecos section lies the Sacramento section of the Basin and Range physiographic province,

comprising a narrow, north-south strip approximately 300 miles long and less than 70 miles wide (Fenneman, 1931). The section is bordered on the west and south by the Rio Grande depression (Thornbury, 1965) and Mexican Highlands and on the east by the Great Plains province. The northeastern boundary of the Sacramento section is formed by the eastward escarpment of the Glorieta mesa, an intricately carved divide of horizontal strata. Farther south, the Capitan escarpment marks the boundary of the two provinces along the southeast side of the Guadalupe Mountains and is exposed for a distance of some 45 miles between Carlsbad and El Capitan Peak (Thornbury, 1965).

Topographically, the section is characterized by two major basinal areas, called bolsons, located at the north and south ends of the section, and by a series of intervening mountain ranges (Thornbury, 1965).

The Estancia Valley, or Sandoval Bolson, forms the central feature of the north part of the section, and is bordered on the east by the Glorieta Mesa and Pedernal Hills, on the west by the Sandia and Manzano Mountains, and on the south by the elevated Chupadera Mesa. The Estancia Valley, primarily composed of a group of salt basins and dunes or low hills, was the site of an extensive lake during Pleistocene time (Thornbury, 1965), which is now reduced to several small salt lakes.

Southeastward from the Estancia Valley and Pedernal Hills lie a series of mountain ranges, many of which are bordered on the west by bold scarps and on the east by gently dipping slopes extending toward the Pecos Valley. Sierra Blanca, the highest of the mountain ranges, reaches an elevation of approximately 12,000 feet above sea level. The other ranges attain maximum elevations of from 8,000 to 10,000 feet (Fenneman, 1931).

At the south end of the Sacramento section is a second large bolson known as the Salt Basin, situated west of the Guadalupe and Delaware Mountains and east of the Sierra Diablo or Diablo Plateau. The Salt Basin is a large down-faulted block with an average floor elevation of about 3,600 feet above sea level. The floor lies some 800 feet below the basin rim

(Thornbury, 1965). The basin covers an area approximately 150 miles long and from 8 to 20 miles wide, rising on both north and south ends to merge into rocky plateaus (Fenneman, 1931). The floor of the basin is covered almost entirely by unconsolidated Cenozoic sediments, with rocky outcrops limited primarily to the margins of the basin (Thornbury, 1965). The LANDSAT color composite of this vicinity shows that the surface sediments are sandy, with a series of salt lakes present in the center of the Salt Basin. Evidence of two Pleistocene lake phases in the basin have been described by King (1948), but their time of formation during the Pleistocene is uncertain.

Mexican Highland Physiographic Section West and south of the Sacramento section lies the vast Mexican Highland section of the Basin and Range physiographic province. This section extends southeastward from Nevada and the Colorado Plateau far into Mexico, where it has its maximum development. The eastern boundary in New Mexio is unclear but is defined as extending east of the Rio Grande to about longitude 106°W, where alternating basins and ranges give way to the faulted and sloping plateaus of the Sacramento section (Fenneman, 1931).

The Mexican Highland section consists of almost equal areas of mountains and plains or basins. In the eastern portion of the section, the mountains generally trend north-south, while in the west they trend northwestward. Of the intermountain area, about half is bolson, and the rest drains or slopes toward the major rivers, such as the Rio Grande. The following discussion considers further only the large-scale features within the eastern part of the section.

The Mexico Highlands mountain ranges of Texas and New Mexico can be grouped into three or more north-south lines from 10 to 50 miles apart and are dominantly Great Basin type, in common with those of the western half of the section. Faulting and related deformation as well as volcanic activity have formed these ranges since Late Tertiary times.

Between the eastern mountain ranges lie generally continuous, flat-floored troughs separated by divides into bolsons or drainage basins (Fenneman, 1931). The two major basins here are the Hueco and Tularosa, on the north, which together mark the eastern border of the section in New Mexico and Texas. They form a trough about 30 to 40 miles wide and 125 miles long, interrupted at the Texas border by a low divide separating the two basins. These basins are grabens in general configuration, bordered on both east and west by fault-bounded mountain ranges. The floors of the basins are relatively flat and slope southward from an elevation of about 4,500 feet at the north end of the Tularosa Basin to 3,500 feet at the south end of the Hueco Basin. The Tularosa Basin exhibits centripetal drainage marked by arroyos and a great salt marsh flanked by the gypsum dunes of White Sands monument.

The northern end of the Tularosa Basin is bordered by Chupadera Mesa averaging 7,000 feet elevation and underlain by gently eastward-dipping Permian strata, which have been dissected almost to maturity (Fenneman, 1931).

3.2.2 Major Geomorphic Features in the Site Vicinity The geomorphic development of the major land forms which constitute the near-site setting are discussed in this section. These features include the Pecos River drainage system, the Mescalero Plain and associated deposits, karst topography and blowouts. In general, these geomorphic features as considered below are located within the Pecos Valley physiographic section.

Pecos River Drainage System The Pecos River, 20 miles west of the site, is the only major, perennial stream in the Eddy and Lea Counties area of southeastern New Mexico. It receives almost all of the surface drainage in this region and a large part of the subsurface drainage. The Pecos originates in the southern Rocky Mountains of north-central New Mexico and flows south and southeastward to join the Rio Grande in west Texas (Kottlowski, et al., 1965). The dimensions of the contemporary river valley are stated above in Section 3.2.1 under the Pecos Valley section.

According to King (1948), the Pecos River apparently had its origin to the south, in the Edwards Plateau, as a short tributary of the Rio Grande River. As the Pecos worked its way northward, eroding the Ogallala sediments in the process, it captured the westward-flowing streams of the present upper Pecos valley, thereby reversing their drainage direction. This stream piracy was facilitated by the underlying poorly resistant Permian rocks (Thornbury, 1965).

Bachman (1973, 1974) has expressed the opinion, in accordance with Lee (1925) and Morgan (1942), that the present course of the Pecos was formed, at least in part, through the coalesence of trains of solution sinks (see Karst Topography below, for discussion of solution-sink development). Bachman cites as evidence for this theory many places along the course of the river in southeast New Mexico where the river follows broad meanders, although the floodplain as a whole is unusually narrow or nonexistent, as well as locations adjacent to the Pecos where intermittant tributaries follow seimcircular collapse valleys. Bachman concludes that the river became entrenched in its present position by a combination of this solution-subsidence, headward cutting, and piracy.

The age of entrenchment of the Pecos River is somewhat uncertain. Thornbury (1965) has stated that the age of the piracy which constituted part of the entrenchment process is rather definitely dated as post-Pliocene and is assumed to have taken place in the early Pleistocene. Bachman (1974) has stated that it is not possible to precisely date the entrenchment of the ancestral Pecos River in southern New Mexico. But Bachman has observed (1976) that the Pecos entrenched itself near its present channel along the toes of pediments east of the Sacramento Mountains sometime after middle Pleistocene, which would place the establishment of the present course at a later date.

Since entrenchment, the river has carved a valley in which a variety of subsidence features have developed through dissolution processes which are probably still active in the valley today.

Mescalero Plain East of the Pecos River to about longitude 104°W lies an extensive, gently sloping pediment surface known as the Mescalero Plain (Thornbury, 1965), which extends from the vicinity of Fort Sumner in northern New Mexico to south of the Mexico-Texas border (Bachman, 1974). The surface of the plain rises eastward from about 150 feet above the Pecos River to as much as 400 feet above the river at the base of the Llano Estacado (Bachman, 1973; Kelley, 1971). The average elevations range from about 3,800 to 4,100 feet above sea level in northwestern Lea County near Mescalero Ridge to about 3,100 feet in southeastern Eddy County, south of Big Sinks (Bachman, 1973).

Although termed a "plain", the area includes many low mesas, bluffs and wide draws. Locally the surface has been dissected by intermittent streams, but in general the area is poorly drained and contains numerous playa pans and smaller sinks (Brokaw, et al., 1972; Kelley, 1971). The surface of the plain is covered widely with gravels and sands, often cemented with caliche. As much as 5 to 10 feet, and locally more, of these materials are exposed along the edges of the long irregular mesas of the area (Kelley, 1971).

The Mescalero Plain is very obvious on LANDSAT imagery. The surface materials of the plain are generally darker in color and exhibit more vegetation and higher moisture content than sandy areas.

The Mescalero Plain probably formed during a period of tectonic stability after deposition of the Gatuna Formation in the Early to Middle Pleistocene and has been modified both during and after its formation by solution-subsidence features, discussed below (Bachman, 1976). The widely distributed gravel deposits have probably been derived from erosion of the Ogallala Formation in the Llano Estacado, to the east (Kelley, 1971). The development and distribution of caliche and sand dune deposits, both of which overlie extensive portions of the pre-caliche Mescalero surface in southeast New Mexico, are discussed separately in the following paragraphs.

1) Mescalero Caliche

The deposits of the Mescalero Plain are generally covered by the calcareous, cemented remnant of an extensive soil profile known as the Mescalero caliche (see Section 3.3.4). The caliche forms a resistant caprock which averages 3 to 5 feet thick and is generally less than 10 feet thick. It consists of a basal earthy to firm, nodular calcareous deposit and an upper well-cemented laminar caprock (Bachman, 1976). In places, the caliche has weathered to a ledge that overhangs less resistant deposits. The caliche is generally thin; it is locally absent over the solution depressions of the plain, and in areas of collapse may be nearly vertical. Caliche may also be locally absent due to erosion on nondeposition. Because of the generally uniform covering by the erosion-resistant caliche, it is probable that these irregular surfaces result from subsurface solutioning and subsidence of the underlying sediments, primarily after the caliche caprock formed.

Although the genesis of the Mescalero caliche is uncertain, it is thought to be a process dependent upon climatic conditions involving certain ranges of both temperature and rainfall, in which carbonate movement is produced within the soil profile, resulting in the reworking and cementing of the soil constituents into a cohesive, calcareous mass. This caliche formed during a period of stable, semiarid climatic conditions which have been tentatively correlated with the Yarmouthian interglacial stage of the middle Pleistocene (Bachman, 1974, 1976).

2) Eolian Sand

Eolian sand covers much of the Mescalero Plain in southeastern New Mexico and is known locally as the Mescalero sand (Vine, 1963). This sand generally forms two distinct types of deposits - sheetlike stretches of surficial sand, which vary in thickness from about 5 to 15 feet (Bachman, 1973; Vine, 1963), and dunes, having a maximum thickness of about 60 feet (Hendrickson & Jones, 1952).

The eolian sand deposits of the Mescalero Plain have probably been derived from a widespread source of fine-grained sediments. Bachman (1974) suggests that most of this sand originated from the Ogallala Formation, although local sources, such as blowouts, have also been a source of some dune materials. There is litle evidence to indicate that much sand has been derived from the Pecos River (Bachman, 1973, 1974, 1976).

Except where the sand is stabilized by vegetation, it is continually blown about to form transverse dune ridges and barchan dune areas separated by broad flats. The orientation of the dune ridges is not uniform throughout the area, with the long dimension of the ridges apparently reflecting the direction of the strongest prevailing winds at the time of their formation (Vine, 1963) (also see Section 3.6.5).

At least two periods of eolian sand emplacement have occurred since the formation of the Mescalero Plain in Pleistocene time and are evidenced in some places by two distinct layers of sand. The lower deposit consists of a semiconsolidated somewhat clayey sand, as much as 1.5 feet thick, overlain by as much as 20 to 25 feet of loose surficial sand forming the contemporary sheet and dune formations (Bachman, 1976).

Karst Topography The land surface in southeastern New Mexico locally exhibits a karst topography, characterized by geomorphic features such as sinkholes, linear depressions (called solution-subsidence troughs by Olive, 1957), domes (including one known "breccia pipe"), "castiles" and collapsed outliers (Anderson, 1978). Many of these features show up on LANDSAT imagery as ponds and other water-filled depressions concentrated particularly near Roswell and also between the Pecos River and Mescalero Ridge. These features have resulted from the dissolution of salts and other soluble materials within the upper Permian Ochoan Series (see Section 3.3.2), particularly in the Rustler and the Upper Salado. The water required for the dissolution process has come into contact with the soluble materials either by surface exposure, following erosional removal of the protective mantle of younger sediments such as the Ogallala and

caliche, or at depth, by means of the downward percolation of local surface water or by contact by means of fracture systems between the Ochoan rocks and underlying regional aquifers, which have been exposed along basin margins by the Cenozoic regional uplift, tilting and erosion. These solution processes have been followed by collapse of the insoluble strata into the voids left behind by the dissolution (Bachman, 1974).

Development of karst features may have occurred in southeastern New Mexico as early as Triassic or Jurassic time, when the area was above sea level and probably undergoing extensive erosion which exposed the soluble materials. Bachman (1976) surmised that some dissolution of Permian salts and gypsum probably took place in the western part of the Delaware Basin during Jurassic time, before resubmergence in the Cretaceous. Extensive regional erosion also took place during the early Tertiary, presumably with accompanying renewed dissolution activity, although no sedimentary records of that period are preserved today. The earliest and most widespread basis for relative dating of solution-collapse features in the area is the Mescalero caliche, of Middle Pleistocene time. If, as is generally believed the caliche was derived from a soil profile, it could not have formed on the irregular and, in places, very steep slopes of today. Additionally, the fracturing and slumping of the Mescalero caliche along the widely occurring depressions of the area indicates collapse after Mescalero time. Some of the major collapse features here, such as Nash Draw, Clayton Basin and Crow Flats, exhibit evidence of several intervals of dissolution and subsidence activity. For example, Crow Flats, a large feature 15 miles east of Artesia, contains evidence for at least 3 such episodes, ranging in time from after Triassic and before Pleistocene Gatuna deposition, during or after Gatuna time and after Mescalero time (Bachman, 1976). Notwithstanding this evidence of long term dissolution history, Anderson (1978) believes that many of the deep-seated dissolution features formed during the most recent and most extensive period of salt removal following the Cenozoic erosion and exposure of the evaporites. Much of this activity is suggested to have occurred during the past few million years; dissolution has apparently progressed from west to east and from south to north across the Delaware Basin.

1) Principal Types of Solution - Subsidence Features

a) Sinkholes

Sinkholes form a category of features represented by thin or missing sections of halite in the Castile or by surficial depressions. Thin or missing halite in the Castile may be determined on the basis of borehole geophysical logs (see Anderson, 1978); the data may not assuredly represent dissolution at depth. Sinkholes designated on the basis of one borehole should also be viewed with caution. Similar data might be obtained in an area with some salt deformation. For the purposes of building a working hypothesis of deep dissolution, Anderson (1978) took these data as possible indications of deep dissolution.

Many of the sinkholes present in the northern Delaware Basin area developed as deep-seated features originating in the Castile Formation. These sinks are often expressed as thin or missing sections of the "Halite I" and "Halite II" salt of the Castile, and to a lesser extent of smaller salt beds above these units, and resulting structural depression of the overlying stratigraphic units. At least 100 deep-seated sinks are estimated to exist presently in the New Mexico portion of the basin. Around the margin of the basin, a number of these deep-seated sinks appear to be associated with anticlinal structures in the salt; in the mid-basin area, these sinks occur as both isolated features and in association with salt anticlines (Anderson, 1978). In addition to these deep-seated features, there are many sinks present in the area which are associated with active near-surface dissolution, such as those along the Pecos River and in Nash Draw (Anderson, 1978).

Compound sinkholes, resulting from coalescing collapse sinks, are common along the Pecos River valley south of Roswell. Many of these sinks have collapsed within historic time (Bachman, 1974). As discussed above, Bachman (1974) has suggested that the course of the Pecos River southward from Carlsbad to near the New Mexico-Texas border lies within a major belt of such collapse sinks. Bachman has also described similar

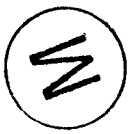
developments along the east side of the Pecos River southeast of Carlsbad, where a linear scarp is believed to have formed as the result of a collapse structure which is now occupied by the river.

b) Dolines

Dolines are very common features in southeastern New Mexico, forming on limestone bedrock and caliche surfaces. Dolines are defined as relatively shallow solution sinks that develop on the surface beneath the soil mantle without physically disturbing the underlying rocks or being underlain by subsurface solution cavities (Bachman, 1974).

c) Solution-Subsidence Troughs

Narrow, linear, generally northeast-trending depressions that vary in width from a few hundred feet to a mile and in length from one-half mile to 10 miles in southeastern New Mexico have been termed solution-subsidence troughs by Olive (1957), who proposes that these troughs result from the subsidence of near-surface material which fills voids dissolved by water flowing in underground channels. According to Thornbury (1965), these troughs are particularly common west of the Pecos in areas underlain by the Castile Formation and extend eastward, parallel to the regional dip as a result of dissolution along eastward-trending joint systems that parallel the regional dip.



Bachman and Johnson (1973) also describe linear features occurring in areas generally underlain by the Ogallala, to the north and northeast of the site, and suggest that at least some of these depressions may be the result of alternate leaching and wind deflation (Judson, 1950; Price, 1958). These features appear on LANDSAT imagery as alternating linear strips of vegetation and white to gray soil, trending NW-SE. They are most prominent north of Hobbs, north of San Simon Sink, and at scattered locations on the Mescalero Plain. The leaching may have been produced by the chemical action of plant growth on the caliche surface between longitudinal sand dunes where small amounts of ground water were able to

collect during periods of eolian quiescence; later periods of eolian activity removed these leached sediments from between the dunes. The swales left behind by this leaching activity mark the location of former longitudinal dune fields which have been displaced or removed by continued eolian activity. The effect of these linear features has been to provide depressions in which surface runoff collects and serves as sources of ground water recharge. Solutioning and erosion along these lineaments may have also opened conduits to the subsurface and contributed to a more rapid dissolution of the underlying soluble rocks (Bachman and Johnson, 1973).

d) Breccia Pipes and Domes

Various domal structures, having diameters of from several hundred to several thousand feet, occur in southeastern New Mexico, particularly along and east of the Pecos River, and are associated with areas of relatively recent surface salt dissolution (Anderson, 1978). Although they have been termed "breccia pipes," these features have no relationship whatsoever to volcanic activity. Many of the domes have been breached by erosion to reveal brecciated cores of stratigraphically displaced Gatuna, Rustler, and Triassic beds. These features are also characterized by doming-related deformation of rocks as young as the Mescalero caliche (Vine, 1960). The depth to which these breccia pipes extend is not known; one pipe is known to reach as deep as the McNutt member of the Salado Formation, as evidenced by underground exposures in the Mississippi Chemical Company potash mine (Griswold, 1977).

Anderson (1978) hypothesized that breccia pipes originate from the dissolution of salt at depth by waters circulating along intersecting joint sets in adjacent brittle rocks. Subsequent collapse of insolubles into the cavity forms a rubble breccia chimney, which sometimes penetrates to the ground surface. The only known breccia pipe (located in the Mississippi Chemical Corporation mine in Nash Draw) is observed to be well-cemented by fine-grained material with no perceptible open space. There is no evidence of removal of soluble material from the

evaporites adjacent to the feature in the mine. This particular feature is expressed at the surface by a dome with a collapsed center. The doming of this brecciated core takes place at a later time. Vine (1960) has suggested three possible mechanisms for this later deformation: the erosion of the rock surrounding the core of the sink; the upward flow of salt into the sink; an increase in volume of rock as anhydrite is altered to gypsum in the brecciated core. Anderson (1978) expressed the opinion that the doming has been produced by regional near-surface dissolution removing the salt from around the pipes and producing a sagging of the beds around the pipes. As a result of the doming process, the rock strata surrounding the dome at the surface generally dip away from the breccia pipe core (Vine, 1960). Underground, in the Mississippi Chemical mine, beds adjacent to the breccia pipe dip down toward the breccia pipe at about 10-20°.

The age of the breccia pipe formation in this area has not been determined. Mescalero caliche, of Middle Pleistocene age, is present on the flanks of breccia pipes and lying at steeper angles than those at which the caliche probably originally formed. This may indicate that the breccia pipes are younger than the Mid-Pleistocene. It is also possible, however, that the breccia pipes predate the caliche and that later subsurface removal of salt by dissolution produced greater amounts of downdrop away from the more resistant breccia pipes, resulting in the slopes present today. (Continuing studies of these features are addressed in Chapter 10.)

Despite the fact that the breccia pipes which have been recognized are generally expressed topographically as domes, it has been surmised that others may have no surficial expression and have therefore gone undetected to the present time. Geophysical exploration has been used to explore for pipes without surficial expression. Electrical resistivity surveys have shown that the breccia core of the known pipe has a much lower resistivity than does the surrounding undisturbed strata (Elliot, 1976). Continuity of seismic reflections are lost when similar geomorphic features are crossed by survey lines (Griswold, 1977).

e) Collapsed Outliers and "Castiles"

Outliers of the Rustler Formation, separated from the main outcrop area through erosional processes, as described by Anderson (1978), are circular to elongate or irregular collapse features consisting mostly of the Culebra dolomite. They occur where the salt has been completely dissolved from the evaporites.

Limestone buttes, called Castiles, occur west and south of the collapsed outliers, primarily in Texas, in the lower part of the Castile Formation outcrop area. These features consist of biogenic calcite which has replaced the gypsum or anhydrite of the Castile Formation, and some exhibit collapse structures with brecciated cores. These buttes are similar in size and distribution to the collapsed outliers (Anderson, 1978).

2) Major Near-Site Features

Major geomorphic features which have formed in the area of the proposed WIPP site as a result of sinkhole formation and related solution-subsidence mechanisms include Nash Draw and San Simon Swale (see Figure 2-1 for their location and topographic configurations). These features and their specific development are discussed separately, below.

a) Nash Draw

Approximately 5 miles northwest of the proposed WIPP site is a prominent geomorphic feature, known as Nash Draw, which Vine (1960) described as "a sinuous depression about 4 miles wide and 18 miles long." Its surface structural expression is similar to that of a breached anticline plunging gently northward, with the older Rustler Formation exposed in its center and the younger Dewey Lake redbeds and Santa Rosa Sandstone exposed along its flanks. However, well records in the area indicate that the bedrock underlying the draw exhibits a gentle homoclinal configuration. Accordingly, Nash Draw has been identified as an undrained physiographic

depression, which has probably developed as a result of regional and differential dissolution of the anhydrite, gypsum and halite beds of the Rustler and upper Salado Formations (Vine, 1963).

According to Vine (1963), dissolution on top of the massive salt in the Salado has produced a rather uniform lowering of the land surface in Nash Draw, but its surficial structural features have been produced and greatly modified by differential solution of the more soluble portions of the Rustler Formation. While the bedrock in the northern part of Nash Draw is generally covered by eolian sand, caliche and alluvium, the central and southern portions of the draw contain exposures of Rustler that has been highly deformed primarily as a result of large-scale collapse following solution of the Rustler and Salado. This dissolution activity has also produced numerous individual sinkholes in Nash Draw, which vary in configuration from circular features a few tens or hundreds of feet across to irregular or arcuate features up to more than a mile across. Many of the larger depressions in the area of Nash Draw, including the basin at its southwestern extent which contains Salt Lake, have probably formed through the coalescing of several smaller solution depressions or sinks. Some such places, where several depressions tend to line up may also indicate the location of subterranean cavernous water courses (Vine, 1963).

The age of the earliest solution activity that produced Nash Draw is uncertain. It is thought that some of the deep-seated solution in the Delaware Basin area had occurred by the middle part of the Mesozic, but that a substantial amount of this process has taken place since the Late Tertiary regional tilting of this area. Within Nash Draw, the formation of a large number of the individual solution features has resulted in the deformation of rock units as young as the Pleistocene Mescalero caliche, which indicates that Quaternary dissolution of the Salado and Rustler Formations is of primary importance in the geomorphic history of Nash Draw. Assuming that this disturbed caliche originally lay at an elevation corresponding to that of the adjacent Mescalero Plain, then at least 100 to 150 feet of local warping and depression has occurred in

Nash Draw within relatively recent time (Vine, 1963). Bachman (1974) estimated that at one place in Nash Draw a surface lowering of approximately 180 feet, almost wholly the result of solutioning and subsidence, has occurred in the past 600,000 years.

b) San Simon Swale

San Simon Swale is one of a series of large deep-dissolution depressions filled with Cenozoic sediments, lying above the inner margin of the Capitan reef along the eastern side of the Delaware Basin (Anderson, 1978). Situated approximately 20 miles east of the proposed WIPP site, San Simon Swale forms a southeasterly-trending depression approximately 25 miles long and from 2 to 6 miles in width. Much of the surface of the swale is at present covered by eolian sand, which masks the relief. Of particular interest within San Simon Swale is a compound collapse feature called San Simon Sink, which occupies an area about 2 miles long and 1 mile wide at the southeastern end of the swale (Bachman and Johnson, 1973).

San Simon Swale originated from a combination of surface stream erosion and solution-subsidence (Bachman & Johnson, 1973). During the Pleistocene, a major tributary of the Pecos River is thought to have flowed southeastward through what is now San Simon Swale to join the Pecos in western Texas. The initial course of this tributary was determined as it eroded its way through the caliche caprock of the Ogallala Formation (Bachman and Johnson, 1973). The dissolution and subsequent removal of these beds resulted in the formation of numerous sinkholes, some of which coalesced to form, at least in part, the depression now known as San Simon Swale (Bachman and Johnson, 1973). The swale has been lowered at least 180 to 200 feet below its original surface, in view of lake deposits in the sink encountered during preliminary WIPP studies. Current drilling operations reveal a thickness of over 600 feet of post-Ogallala sediments underlying the present floor of the swale.

Within San Simon Swale, the San Simon Sink formed as a secondary collapse structure, probably during the Pleistocene. Numerous ring fractures around the sink indicate that it has had a long history of successive collapse events since its initial formation (Bachman and Johnson, 1973). The most recent of these events is reported to have occurred in the 1930's (Nicholson and Clebsch, 1961). It is therefore assumed that salt dissolution in the underlying formation is continuing here and it is thought by some that the resulting brine is being carried in a southeasterly direction toward Texas (Bachman and Johnson, 1973).

On the basis of written communication from C.L. Jones of the U.S. Geological Survey, Bachman (1973) reported that over 500 feet of Cenozoic sediments have thus far been deposited in San Simon Sink. Nicholson and Clebsch (1961) have estimated that alluvium is presently being deposited in the sink at a rate of about 1 foot in 5 years. Recently acquired core (WIPP 15) from San Simon Sink has been analyzed in a preliminary way (Anderson, 1978) showing about 545 feet of fill on top of Triassic sediments. Dates on the fill have not yet been obtained.

Blowouts Some of the basins which are present in southeastern New Mexico have been formed by processes other than the previously described mechanisms of dissolution and collapse. The most conspicuous of these basins in the area of the proposed WIPP site are named Williams Sink, Laguna Gatuna and Laguna Plata, all of which are situated approximately 15 miles to the north of the site.

These features, termed blowouts, have formed through the removal of loose sand deposits by wind erosion. During the rainy season, many of the depressions which have resulted are partially filled with water. The floors of the blowouts are mantled with clay and saline deposits, and many blowouts are surrounded by eolian sand. Dune fields commonly develop along the northeastern and eastern leeward margins of these depressions (Bachman, 1974).

3.2.3 Erosion Rate- Significance of Geomorphic Developments to Site

This section provides a short review of the degree to which the major surface and subsurface processes discussed in the previous section have affected the land surface in the vicinity of the site and discusses to what extent these activities may be predictive of future geomorphic modifications in this area.

The resistant Mescalero caliche covers most of the land surface in the vicinity of the site and underlies the site itself. Where present, the caliche provides an indication that no significant erosion of the surface in these areas has occurred since the formation of the caliche in Mid-Pleistocene time.

The major areas of relief which have developed since this time have probably been produced to a large extent from subsurface dissolution and subsidence. The two major features of significance to the site, originating from these processes, are Nash Draw and San Simon Swale. In Nash Draw the surface has been lowered at least 100 feet by dissolution, and locally as much as 180 feet, within approximately the past half million years. Bachman (1974) also cited one location within the draw where the lowering of the ground surface appears to have exceeeded the rate of salt removal, indicating a surface erosion of about 40 feet in addition to solution activities. San Simon Swale, a product of surface erosion as well as solution-subsidence, lies at its lowest point some 180 to 200 feet below the surrounding land surface (Claiborne and Gera, 1974), and may have undergone a total subsidence of about 750 feet. No age has yet been obtained from the sediments obtained during recent drilling. (See Chapter 10, Continuing Studies.)

Wind erosion has produced other depressions in the area, with a resultant buildup of material in the same vicinity. However, these features are generally of only minor dimensions and are local in extent (Claiborne and Gera, 1974).

These observations should not be considered as constants for rates of erosion which would hold true for the future. But in providing a general indication of the surface modification in the vicinity of the WIPP site, they do indicate the pattern of continuing geomorphic development of the area. Variations in climatic conditions give rise to variations in rates of denudation and also in rates of subsurface dissolution. The nature of the ground surface is also of major importance in terms of its vulnerability to erosional processes.

The site is located west of and near a drainage divide between Nash Draw and San Simon Swale, where it appears that very little dissolution or surface erosion has occurred since Early Pleistocene time, as evidenced by the relatively undisturbed nature of the Mescalero caliche there, which has also served as a protective layer for the underlying soluble rock units. Contouring studies, too, indicate that this area has been a drainage divide between San Simon Swale and Nash Draw at least since Mid-Pleistocene time (Bachman, 1976). Although erosion here has been minimal under the present semiarid climatic conditions, if more humid conditions should develop in the future, an accelerated erosion of the caliche is reasonable to expect. However, with increased rainfall, it is also expected that Nash Draw and San Simon Swale will be exposed to more erosive stress, since most of the runoff will probably flow out of the immediate area along these depressions.

3.3 REGIONAL STRATIGRAPHY AND LITHOLOGY

3.3.1 Precambrian Rocks

Metasediments and granitic igneous materials consititute the majority of the basement rock of the southeast New Mexico - west Texas region. These Precambrian rocks crop out in only a few localities, in the western part of the region, such as the Nigger Ed Canyon area of the Sacramento Mountains (Pray, 1954), in the core of the Pajarito Mountain dome (Kelley, 1971) and in the Bent Dome, east of Tularosa (Bachman, 1960). Data on the Precambrian underlying the Delaware Basin and further east

and south across the Central Basin Platform into southwest Texas have been obtained principally through oil company records; hundreds of wells have been drilled in this area, particularly on the Central Basin Platform. Little data are available from the basin areas, where most wells penetrate only to the Upper and Middle Paleozoic sections.

The configuration of the Precambrian basement surface reflects the late Paleozoic structural framework of the region (see Figure 3.4-2). The surface is deepest along the northern axial portion of the Delaware Basin, where it reaches a depth of about 20,000 feet below sea level. The basement surface rises to the east, north and west of the Delaware Basin. On the northeast, into Otero and Chaves Counties, the basement rises fairly uniformly to more than 4,000 feet above sea level; on the east, the surface rises rapidly on the Central Basin Platform to elevations of between -5,000 and -4,000 feet (Cohee, et al., 1962; Foster and Stipp, 1961). Well data suggest that a number of post-Precambrian faults break the profile of the basement surface throughout the region. A notable example of this occurs along the west margin of the uplifted Central Basin Platform, where a vertical offset of perhaps more than 5,000 feet is present along the south portion of a large normal fault system.

The Precambrian sections which have been examined display a complex association of metasedimentary, sedimentary, metavolcanic, volcanic and plutonic rock types, suggesting a history of repeated orogenic activity interspersed with erosional episodes. Muehlberger, et al. (1967) have classified the Precambrian rocks of the region into a number of terranes of various age and lithology. A modified version of their geological map, Figure 3.3-1, presents the distribution of the major Precambrian rock types of the area.

Outcrops of probably Late Precambrian age slightly metamorphosed siltstones, shales and fine-grained quartz sandstone with associated intrusive sills are found in the vicinity of Nigger Ed Canyon in the Sacramento Mountains. The majority of the sills are diabase, and some are markedly porphyritic (Pray, 1954, 1961).

In the subsurface, similar Precambrian diabase and incipiently metamorphased clastics, including quartzite, siltstone and impure limestone, comprise a broad band which extends from southern Otero County northward for over 200 miles to southeastern Guadalupe Country. Muehlberger, et al. (1967) have termed these rocks the DeBaca terrane. In the Franklin Mountains at the extreme western tip of Texas, these metasediments attain a known thickness of almost 4,000 feet (Harbour, 1960). The rocks are underlain, at least in part, by rhyolites of the Panhandle volcanic terrane, discussed below, and are overlain in the Franklin Mountains by up to 1,000 feet of rhyolite (Harbour, 1960) dated at 900 million years.

To the east of the Sacramento Mountains on the Northwestern Shelf, an approximately 2-square-mile outcrop of Precambrian rock is exposed in the core of Pajarito Mountain dome. These rocks, radiometrically dated as 1,270 million years old, consist of hornblende, syenite, hornblende syenite gneiss, and some diabase, locally intruded by leucocratic syenite and hornblende syenite pegmatite (Kelley, 1971). Granitics apparently underlie most of the south-central parts of New Mexico and large areas in Eddy and Lea Counties (Foster & Stipp, 1961), extending at least as far west as the Guadalupe Mountains as well as south and southeastward into Texas (Flawn 1954: Muehlberger et al. 1967). These rocks, named the Chaves granitic terrane, are largely granite, granodiorite, compositionally equivalent gneiss and lesser amounts of metasedimentary and metaigneous rocks. Granite comprises about 80 percent of the samples studied. Foliation in these rocks is generally faint, but is enhanced by some shearing (Muehlberger et al., 1967). Wasserberg et al. (1962) dated the granitics in this area as between 1,250 and 1,400 million years in the north and as young as 1,090 million years to the south. These granitics appear to predate the sedimentary Precambrian rocks to the west (Foster & Stipp, 1961).

Younger volcanics, which appear to have been extruded and deposited as a relatively thin layer above the granitics, are present in at least parts of Chaves, Lea, Roosevelt, Curry and Quay counties as well as near the

south border of New Mexico west of the Brokeoff Mountains and eastward in the Texas Panhandle (Foster & Stipp, 1961; Muehlberger, 1967). These rocks, known as the Panhandle volcanics, are primarily rhyolitic flows and tuffs and pyroclastics with subordinate trachytic and andesitic types. The volcanics are mostly undeformed and unmetamorphosed. Rb-Sr dating of these rocks yields an average age of 1,140 ± 50 million years (Muehlberger et al., 1967).

Gabbro and diabase or basalt, commonly showing intergranular ophitic to subophitic textures, underlies parts of Roosevelt and southern Curry Counties and extends eastward into Texas. These rocks, termed the Swisher diabasic terrane, intrude the volcanics, and, although their age is uncertain, are considered Precambrian (Muehlberger et al., 1967; Flawn, 1954). According to Flawn (1954, 1956), these rocks appear to be a great stratiform body occupying a major basement syncline, although no large positive gravity or magnetic anomaly is present over this region.

Clastics of Late Precambrian age crop out near Van Horn, Texas. These deposits are part of an alluvial fan which is overlain by the Bliss sandstone (McGowan and Groat, 1971). Elsewhere, including the Guadalupe Mountains, these rocks have been studied through well cuttings.

3.3.2 Paleozoic Rocks

Cambrian Rocks

Very little is known about the existence or nature of any Cambrian sediments underlying the Delaware and Val Verde Basins area of southeast New Mexico-west Texas, partly because the great thickness of the overlying section in this region and partly because the belief that the Ordovician Ellenburger is the deepest potential reservoir formation has discouraged deeper drilling (Vertrees et al., 1959).

Basal Paleozoic clastics were named the Bliss Sandstone by Richardson (1904) for exposures in the Franklin Mountains. They range in thickness from 0 feet to the north to about 375 feet toward the south. The Bliss unconformably overlies the Precambrian and in most places is conformably overlain by the El Paso Group (Hayes, 1964). According to Harbour (1960), the Bliss is probably a beach or near-shore deposit of the sea in which the overlying El Paso Limestone accumulated.

In its type locality and in most areas east of longitude 107°W, the Bliss generally consists of over 90% sandstone that is thin-bedded and jointed. Subordinate, thin interbeds of siltstone or shale and rare thin beds of sandy limestone or dolomite are present. Dark siltstone grains, cemented by glauconite and hematite, combine to produce a dark color (Hayes, 1975; Harbour, 1972).

In the Sacramento Mountains of southeastern New Mexico, the Bliss Sandstone is exposed in the vicinity of Nigger Ed Canyon. A 10° angular unconformity separates it from the underlying Precambrian. The Bliss in this area contains 110 feet of quartz sandstone, minor dolomitic sandstone, sandy dolomite, brown-weathering sandstone interbeds in the upper third of the section. Abundant glauconite is present in some of the strata. In general, this section is similar to that at the type locality near El Paso (Pray 1954, 1961). Farther southeast in the subsurface at the Guadalupe Mountains area, the Bliss consists of less than 30 feet of light gray to white, poorly sorted, coarse-grained quartz sandstone at the base and top, separated by gray, fine-to-medium grained, sandy dolomite (Hayes, 1964).

Most investigators consider the Bliss Sandstone to be diachronous, ranging in age from Late Cambrian through Early Ordovician, becoming younger from west to east, as determined from faunal evidence and lithologic correlations (Hayes, 1975). The Bliss of the Sacramento Mountain area has been dated as Cambrian by the Residue Research Laboratory of Midland (Roswell Geological Society, 1953). However, Flower (1953) has indicated that the formation is time-transgressive and

contains both Late Cambrian and Early Ordovician fauna in New Mexico (Harbour, 1972). The evidence indicates that in its easternmost localities, the entire Bliss is of Early Ordovician age (Hayes, 1975). Hayes reported in 1964 that it is very likely that the Bliss in the subsurface of the Guadalupe Mountains area is entirely Ordovician. Foster (1974) also considers that the Bliss sediments of the southeastern New Mexico Delaware Basin area probably correlates only with the Ordovician part of the unit as defined in Texas.

Ordovician Rocks The Lower Ordovician section is composed mainly of carbonates deposited in a shallow sea with a relatively calm shelf environment (see Figure 3.3-2). In 1904 Richardson named exposures in the Franklin Mountains the El Paso Limestone (Hayes, 1975). Cloud and Barnes (1948) named exposures in western and central Texas the Ellenburger Group, and this name is commonly applied to subsurface rocks in the Permian Basin. Some workers have subdivided these rocks into formational groupings that are recognizable over much of the region. For discussion of nomenclature and detailed stratigraphy, refer to Hayes (1975).

Where the El Paso crops out in the Sacramento Mountains escarpment, it is composed of up to about 420 feet of light-to-olive-gray, very fine-to medium-grained dolomite. Thin to medium beds predominate, chert nodules occur sporadically, and interbeds of dolomitic quartz sandstone are common toward the base, derived from erosion of rocks to the east. In the Sacramento Mountain area, at least, the El Paso appears to be either time-transitional with the Bliss Sandstone or separated from it by a minor disconformity (Pray, 1961). To the southeast, in the subsurface of the Guadalupe Mountains, the El Paso comprises from 520 to 550 feet of gray, fine-to medium-grained, crystalline, siliceous dolomite with some sand near the base and top and some light-colored aphanitic chert. Eastward in the Delaware Basin over 700 feet of El Paso or Ellenburger has been encountered. In the New Mexico portion of the basin, the formation is almost entirely a light-gray to gray crystalline dolomite with small amounts of sandstone; much chert is present in some localities

near the top of the section (Haigler, 1962). South and southeastward in the west Texas Delaware-Val Verde Basin area, the Ellenburger reaches a maximum thickness of at least 1,600 feet and is composed almost entirely of limestone and dolomite (Vertrees et al., 1959). Its limestones are light-gray and dominantly sublithographic, becoming purer upward; the dolomites range from coarse-grained pale rocks, generally near the bottom to finer-grained, more brightly colored ones above (Cloud and Barnes, 1946).

Middle Ordovician sediments comprising the Simpson Group are recognized in the subsurface from the Guadalupe Mountains area through the Delaware Basin and east into Texas. The Simpson thins rapidly to the west at an average rate of about 10 feet per mile (Hayes, 1964), wedging out near Artesia, New Mexico. To the north, it extends to the latitude of Roswell and elsewhere is truncated by erosional unconformities. Where the Simpson, or equivalent, is encountered within the New Mexico portion of the Delaware Basin, it ranges in thickness from less than 200 feet to 1,850 feet in southern Lea County (Nicholson & Clebsch, 1961). In the basin, the Simpson consists of 3 main layers of limestone, alternating with thinner green, brown and black shale, black shale with rounded quartz grain inclusions, and sandstone (Haigler, 1962). Towards the south and southeast, the formation thickens considerably, reaching a maximum of at least 2,250 feet before wedging out in the Marathon Mountains region. Shaly facies predominate towards the south. In the Delaware-Val Verde region, the sandstones and some of the carbonate members are potential oil and gas reservoirs (Vertrees et al., 1959).

In the subsurface of the Permian Basin, the Simpson is overlain conformably by carbonates of the Montoya Group, assigned to the Middle and Late Ordovician by Hayes (1975). At the type locality in the Franklin Mountains, the Montoya ranges in thickness from about 140 to 250 feet, averaging about 200 to 225 feet, and consists of a lower olive gray to dark gray cliff-forming dolomite with a thin, very coarse-grained quartz sandstone at the base and an upper, lighter colored cherty and finer-grained, slope-forming dolomite. The top of the group is marked by

a zone of bedded chert (Bachman and Myers, 1969). Eastward in the north part of the Delaware Basin, the Montoya ranges from about 280 to 440 feet in thickness and consists of medium-to dark-gray dolomite with minor amounts of dark gray limestone and chert (Haigler, 1962). Where it occurs on the Central Basin Platform, the Montoya is a cherty limestone about 150 feet thick. To the south, the Montoya is composed of primarily chert and dolomite, reaching a maximum thickness of 600 feet (Vertrees et al., 1959).

The uppermost rocks of Ordovician age in the area consist of a generally light-gray, thin-bedded dolomite with some marl. It had been included by Darton (1917, 1928) as the lower part of the Fusselman, but having been recognized by Kelley and Silver (1952) as Ordovician, it was removed from the Fusselman and renamed the Cutter Formation. Pray (1954) called it the Valmont, where he encountered it in the Sacramento Mountains. Now, however, these beds have been established as the Cutter Member of the Montoya Dolomite (Harbour, 1972; Bachman and Myers, 1969).

Silurian Rocks The Silurian of the southeast New Mexico - west Texas areas consists of the Fusselman limestone and the carbonates and shales of an "Upper Silurian" unit, both of which were deposited in a broad subsiding area named the Tobosa Basin.

The Fusselman rests unconformably on the Late Ordovician Montoya and ranges in thickness from 0 to 1,000 feet in part of southern New Mexico and west Texas, and thins westward and northward into an erosional wedge (Hayes, 1975). It is composed of a massively-bedded, clean, light-colored dolomite and locally limestone. The limestone facies is dominant to the southeast; a thicker dolomite facies is dominant to the north and west. The Fusselman has been dated as Middle Silurian and possibly also Early Silurian in age (McGlasson, 1968; Hayes, 1975; Pray 1958).

In the Sacramento Mountain area, the sequence overlying the Montoya has been divided by Pray (1953, 1954, 1961) into two units. The lower member, which he termed the Valmont, is composed mostly of light gray, very finely textured dolomite ranging in thickness from 150 to 225 feet. The upper part of the sequence in the Sacramento area, recognized by Pray (1954) as Silurian, comprises a medium to finely crystalline, light to medium gray, cherty dolomite not exceeding 100 feet. As identified in the subsurface of the Guadalupe Mountains, the Fusselman ranges from 580 feet to about 740 feet of white to light gray, coarse to medium crystalline dolomite, which contrasts sharply with the darker, fine-grained underlying Montoya (Hayes, 1964). In the Delaware Basin, the Fusselman is a light-colored dolomite containing abundant chert and two thick limestone intervals. It reaches its maximum thickness in southern Lea Country. Eastward across the Central Basin Platform, the Fusselman is represented by a coarse-grained crystalline glauconitic limestone and dolomite 180 to 200 feet thick (Nicholson & Clebsch, 1961).

The subsurface unit informally called the "Upper Silurian" consists of a shaly facies to the southeast and much thicker carbonate facies to the north and west. The unit is more restricted areally than is the underlying Fusselman, pinching out northward and westward across north-central Eddy and Lea Counties. The carbonate facies predominates in the New Mexico portion of the Delaware Basin and includes both limestones and dolomites, reaching over 1,500 feet in thickness (McGlasson, 1969). On the Central Basin Platform, it consists of 180 feet of green, gray, and black shales interbedded with dense limestones (Nicholson & Clebsch, 1961). Southward into Texas, the shaly facies is composed of bright green to dark brown shales and white to brown calcilutites with a maximum thickness of 300 feet (McGlasson, 1968).

Devonian Rocks Lower to Middle Devonian rocks are known only from subsurface exploration, and only in the southeastern corner of Lea County, New Mexico. Called the "Devonian" rock unit by McGlasson (1965), these rocks are more restricted in area than the "Upper Silurian" and range in thickness from zero to 1,000 feet in the vicinity of Crane

County, Texas. The unit is composed primarily of chert in the southwest, grading northeastward into dark siliceous micrite and light-colored calcarenite. After deposition, the unit underwent considerable diagenetic alteration.

In the western part of the region, along the Sacramento Mountain escarpment, a unit dated as upper Middle Devonian, the Onate, has been recognized (Pray, 1954, 1961). It consists largely of dark gray to olive gray, very fine-grained dolomite mixed with coarse silt to very fine quartz sand, with minor shale, increasing to the south. Small, irregular chert or silicified dolomite nodules several inches long are distinctive lithologic features of the upper part of the formation in the central and northern parts of the escarpment. To the west the Onate forms beds generally less than 1 foot thick and rarely thicker than 2 feet but is as much as 60 feet thick in the central escarpment area, thinning northward and southward.

Upper Devonian rocks in the subsurface of the southeast New Mexico area constitute the Woodford shale, portions of which are also variously known as the Percha shale and Canutillo Formation. These rocks are described by McGlasson (1968) as extending from eastern Chaves and southern Roosevelt Counties in New Mexico, southward and eastward through western Texas and ranging in thickness from zero to approximately 700 feet near the southeast corner of Lea County, with an average of 200 feet elsewhere (Vertrees et al., 1959). The Woodford is a dark brown to black, fissile, bituminous, spore-bearing shale which becomes arenaceous northward and contains black chert to the south and west (McGlasson, 1968).

Across the Central Basin Platform, the rocks correlative to the Woodford in age consist of interbedded, calcareous chert and siliceous limestone, reaching a maximum thickness of 980 feet (Nicholson & Clebsch, 1961). Westward in the northern Delaware Basin, the unit decreases to less than about 200 feet thick and is an organic pyritic shale. In the Guadalupe Mountain area, the unit comprises less than 100 feet of dark gray, locally silty shale, with a few feet of dark or medium gray chert at its

base (Hayes, 1964). At the northwestern limit of the unit in the Sacramento Mountains, the lower Upper Devonian section has been called the Sly Gap Formation and consists of up to 50 feet of calcareous, yellow-gray to dark gray shale with irregular nodular limestone becoming predominant upward. This unit is absent in the south half of the escarpment, where the Upper Devonian is represented by a dark gray noncalcareous shale, considered equivalent of the Percha shale and recognized southward as the Woodford (Pray, 1954).

The Woodford and equivalent units are transgressive and lie unconformably on an erosional surface formed on the rocks of the older Devonian section through the Ordovician Montoya Group. According to McGlasson (1968), the upper portion of the Woodford deposition probably was deposited in Early Mississippian time. At its upper limit, the Woodford is conformably overlain by limestones and sandstones of the Early Mississippian.

Mississippian Rocks Mississippian rocks throughout most of the southeast New Mexico-west Texas area consist of limestones overlain by shales, which together attain a maximum thickness of some 2,400 feet, truncated by erosional unconformities (Vertrees et al., 1959). Rocks of definite Mississippian age appear to be absent across the Central Basin Platform (Nicholson & Chelbsch, 1961).

The Lower Mississippian Kinderhookian-Osagian series is represented in southeast New Mexico and west Texas by a limestone unit (Roswell Geol. Soc. 1958). It is 365 feet thick in the Guadalupe Mountains and 220 to 320 feet in the northern Delaware Basin, thickening to the southeast and thinning to the west (Haigler, 1961). The limestone is light gray to brown, finely crystalline and commonly cherty, with a basal dark gray organic-rich shale unit. The limestone partially grades to shale southeastward from the northern margin of the Delaware Basin (Brokaw et al., 1972; Haigler, 1962). The northwestern face of the Sacramento Mountains contains exposed units of equivalent age, but detailed correlation with the foregoing surface data from the rest of the area is unreliable (Haigler, 1962). The Kinderhookian here is represented by up

to 60 feet of Caballero limestone and calcareous shales. The overlying Osagian series Lake Valley Formation, which attains a thickness of about 400 feet in the northern and central Sacramento Mountains, is composed of 6 members whose dominant lithology is limestone containing various amounts of chert and argillaceous and biohermal materials (Pray, 1954).

The Upper Mississippian rocks in the subsurface of southeast New Mexico, apart from the Sacramento area, consist of black, brown and gray shale much of which is silty, variously named the Barnett, Chester or Meramec (Brokaw et al., 1972; Haigler, 1962). Near the north and west edges of the Delaware Basin, and in the Guadalupe Mountains, gray limestone beds occur at the top of the Mississippian shale, with some interspersed thin sandstone beds. To the east and south, in the central portion of the Delaware Basin, the unit consists of between 250 and 320 feet of primarily a black argillaceous shale with a dark gray to black calcareous shale of shaly limestone comprising approximately the lower 100 feet of section (Haigler, 1962). Equivalent age rocks in the western part of the region have been defined as the Rancheria and Helms Formations of Meramacian and Chesterian age, respectively. The Rancheria, whose type locality is north of El Paso, Texas, closely resembles the Lower Mississippian limestones of the southeast New Mexico area. (For detailed description, refer to Harbour, 1972). The Rancheria is up to 400 feet thick in the Franklin Mountains and 300 feet at the south end of the Sacramento Mountains, thinning northward, and is composed of gray argillaceous and silty thin-bedded limestone with minor shales and massive crinoidal limestone strata. Its basal contact is an angular unconformity with the underlying Lake Valley and Caballero. The Helms, of latest Mississippian age, which reaches a maximum of 230 feet in the Franklin Mountains and only 60 feet northward in the Sacramento Mountains, consists of thin-bedded, argillaceous limestone and yellow to gray calcareous interbedded shales with lesser limestones (Harbour, 1972; Pray, 1954).

Pennsylvanian Rocks Post-Mississippian orogeny uplifted and tilted much of the southeast New Mexico-west Texas basinal areas, eroding the exposed rocks and, upon subsequent Pennsylvanian deposition, producing a major angular unconformity called the Springer hiatus (McGlasson, 1968). Relatively rapid, almost continual deposition in most of the region resulted in a thick Pennsylvanian carbonate section, with large volumes of terrigenous clastics in some places. The Pennsylvanian in places is thicker than the entire underlying Paleozoic section (Pray, 1954). Total thickness of the Pennsylvanian section varies from about 3,000 feet in the Sacramento Mountains, near 2,500 feet in the northern Delaware Basin, and between 1,650 and 2,700 feet in southern Lea County along the Central Basin Platform.

The rocks of Pennsylvanian age were derived from a variety of different sources and deposited in increasingly active structural settings. As a result, the lithology of the section is highly variable, both horizontally and vertically, and correlations on the basis of mappable rock units are difficult to make (Pray, 1961; Oriel et al., 1967). Although a variety of schemes have thus been utilized to subdivide the Pennsylvanian section of the area, the following discussion employs the common usage of Morrowan through Virgilian stages as a framework for consideration of the dominant lithologies and several formations identified in this region.

1) Morrowan Series Of the stages present in New Mexico, the basal Pennsylvanian Morrowan rocks occupy the smallest area and contain, in the central and northern portions of the Delaware Basin, the largest proportion of clastic material. These rocks, which mark the initiation of a major transgression climaxing in the Virgilian, attain a thickness of about 1,250 feet in the Permian Basin area and wedge out northward in southeast New Mexico (Meyer, 1968). The Morrowan rocks in New Mexico consist largely of limestone and shaly limestone; fine-grained sediments predominate (Bachman, 1975).

In the Sacramento Mountains, at the northwest extent of the area, the basal Pennsylvanian strata were deposited on a surface of at least 100 feet of local relief, the lowest parts of which were filled with coarse sandstone or cobble conglomerates derived from Mississippian cherts. The percentage of shales and dark limestones increase upwards into the Atokan. These rocks have been called the basal part of the Gobbler formation by Pray (1954). Southward across the Guadalupe Mountains area of the Northwest Shelf, the Morrowan consists of from 230 to over 400 feet of fine to coarse-grained, poorly sorted, locally conglomeratic quartz sandstone, mottled medium gray oolitic limestone and medium to dark gray shale, which resemble the lower Gobbler as well as the rocks of central to northern New Mexico, called the Sandia Formation (Hayes, 1964). Fine-grained detrital sediments trend southeasterly from the Pedernal Uplift into the western Delaware Basin. Within the Delaware Basin, the Morrowan is composed primarily of brown to gray argillaceous limestones and gray quartzose sandstones with dark gray to black shale. Across the Central Basin Platform into Texas, the basal Pennsylvanian unit is a black shale (Nicholson & Clebsch, 1961; Bachman, 1975).

2) Atokan Series The Early-Middle Pennsylvanian rocks, assigned to the Atokan or Derryan Stage, consist of dark-colored sandstones, shales and limestones, which attain a maximum thickness of about 1,000 feet. These rocks were deposited over the entire area, with the exception of the Pedernal Uplift to the north (Meyer, 1968).

Interbedded shales and dark limestone constitute the top of the 200 to 500 foot section of the lower Pennsylvanian Atokan deposition to the northwest in the Sacramento Mountains (Pray, 1954). Southward into the northern Delaware Basin, the unit consists of gray to brown and black, fine-grained to dense limestone and chert and dark gray to black shale with minor sandstone. In the southern Delaware and Val Verde Basins region, the Atokan rocks consist mainly of sandstones and shales in the lower part and carbonate rocks in the upper part, reaching about 1,000 feet in thickness (Vertrees et al., 1959). The top of the Atokan section is transitional, and is placed at the change from dominantly terrigenous, detrital rocks below to predominantly carbonates above (Bachman, 1975).

3) Desmoinesian Series Upper-Middle Pennsylvanian Desmoinesian rocks are predominantly carbonates, and attain a maximum thickness of about 1,000 feet in the Delaware and Lucero Basins and in northwestern New Mexico (Bachman, 1975). Sedimentation during this time was primarily influenced by reef and adjacent shelf and basinal deposition within the areas of the Permian Basin and Orogrande Basin to the west. Also known as the Strawn, the unit is the only readily identifiable Pennsylvanian rock found widespread over the southeast New Mexico-west Texas area (Vertrees et al., 1959).

The Desmoinesian rocks of the Sacramento Mountain area constitute up to 1,000 feet of contrasting facies: a shelf limestone or reef, consisting almost entirely of cherty calcilutites, and a deltaic facies of equal thickness but smaller lateral extent, composed of quartz sandstones, subgraywackes, shales and minor limestones (Pray, 1954). Southward and eastward, in the Permian Basin area, the Desmoinesian strata were deposited in a variety of environments from back-reef lagoon, to reef, to deep marine basin - a spectrum which lasted from this time through most of the Permian (Meyer, 1968). Within the Delaware Basin, these rocks are typically dark brown, fine-grained cherty limestones, the lower part of which may contain interbeds of gray shale and gray to white, medium-grained angular quartz sandstone (Meyer, 1966). Reef facies of the Desmoinesian also extend south and eastward into the Val Verde Basin. The limestones of the Desmoinesian within both the Delaware and Val Verde Basins are known for their numerous stratigraphic traps, and have been attractive for oil and gas exploration (Vertrees et al., 1959). Desmoinesian limestones also occur across the Central Basin Platform into Texas.

4) Missourian Series The Missourian rocks of the late Lower Pennsylvanian age constitute up to 1,000 feet of mostly clastic sediments, such as interbedded arkose and arkosic sandstone, as well as mudstone and limestone, deposited in environments similar to those of Desmoinesian time (Meyer, 1968; Bachman, 1975).

On the northwest, as much as 500 feet of thin-bedded, argillaceous limestone and shale of the Missourian overlie the shelf limestone and deltaic deposits of the Desmoinesian. Most of these rocks reflect basinal deposition, but locally there was cyclic deposition in turbulent shallow waters (Pray, 1954). To the south, Missourian rocks are identified generally only in the deeper parts of the Permian Basin area. Within the New Mexico portion of the Delaware Basin, the Missourian rocks consist of dark gray shales and limestones, quartz sandstone, and some chert, ranging in thickness from zero to 1,250 feet (Meyer, 1966). Toward the Val Verde Basin near the Texas-New Mexico border and across the Central Basin Platform, the unit grades into a dark gray, non-fossiliferous shale (Vertrees et al., 1959). The absence of datable materials in this unit has made its correlation as Upper Pennsylvanian difficult to verify.

5) Virgilian Series The uppermost Pennsylvania section is similar to that of the Missourian but contains, in addition to carbonates, some continental shales, coarser clastics and evaporites.

Over most of the area to the northwest, algal reefs up to 100 feet thick formed. The Virgilian deposition grades upwards into more uniformly bedded, light-colored limestone with interbedded shale and minor sandstones. At the top of the section, red shales and limestone conglomerates repeat cyclically with nonred shales and massive nodular limestone, indicating fluctuations in depth and gradual transition to final emergence of the northwestern area. The Upper Pennsylvanian units of this area were named the Holder Formation by Pray (1959). Within the Permian Basin proper, over 1,000 feet of Virgilian limestones and shales were concurrently deposited. Southward over the Northwestern Shelf and eastern side of the Central Basin Platform and northeastward of the Horseshoe Atoll, the series is represented by limestone. Toward the Eastern shelf, the unit consists of both mudstone and limestone with some interbedded sand (Oriel et al., 1967). Reefs formed along the northern margin of the Delaware Basin (Meyer, 1968), while within the basin up to 1,000 feet of brown to tan, fine-grained limestone, black to brown shale and white, fine-to coarse-grained subangular quartz sandstone were

deposited (Meyer, 1966). Southward in the deeper part of the basin, dark nonfossiliferous shale, similar to the underlying Missourian, continued to be deposited.

Permian Rocks. In many parts of the southeast New Mexico area, the lower boundary of the Permian is difficult to determine except on the basis of fusilinids, because the Permian rocks are underlain by lithologically similar Pennsylvanian rocks. In the Delaware and Val Verde Basins, the boundary is located below several hundred feet of dark gray mudstone unit. No lithologic basis of recognizing the boundary is apparent on the Northwestern Shelf, along the east margin of the Central Basin Platform, or in the area of the Horseshoe Atoll (in the northern Midland Basin). Only in the structurally positive areas where Pennsylvanian rocks are missing, as in many locations on the Central Basin Platform, is the base of the Permian clear. In other places, such as the Sierra Diablo, an angular unconformity separates the Permian from underlying units. Ages of basin rocks to the base of the Permian are usually assigned through fusilinids interpretation but it is sometimes difficult because of the scarcity of fossils (Oriel et al., 1967). The thickness of the Permian sediments equals or exceeds the total thickness of the underlying Paleozoic systems. Details are presented in the discussions of each series below. Figure 3.3-2 provides a schematic illustration of the subsurface distribution and relative thicknesses of the Permian.

Most of the major structural elements that influenced Permian sedimentation in the area were well developed late in Pennsylvanian to very early in the Permian; thus, marked differences in lithology occur from the Northwestern shelf region, through the Delaware Basin and across the Central Basin Platform into the Midland Basin, and the stratigraphic nomenclature differs from place to place. In general, the units of the basins contain a much higher proportion of clastics than do the adjacent shelf areas, and the basin carbonates are much less dolomitized than are the shelf carbonates. The rock units along the basin margins are partially dolomitized, and contain less clastics than equivalent shelf units. In common practice, the different facies of the region have been

related to each other by time-stratigraphic units. The provincial series names used in New Mexico and Texas are, from oldest to youngest, the Wolfcampian, Leonardian, Guadalupian and Ochoan (Oriel et al., 1967). Figure 3.3-3 presents a summary and correlation of the major Permian formations of the region which are discussed below.

1) Wolfcampian Series The Wolfcampian series consists primarily of limestones and dolomites. A few reefs are present on the shelves; dark gray shales, sandstones, and conglomerates are present in the basins. The basinal sediments of the Delaware, Midland and Val Verde were probably deposited under stagnant, reducing, deep-water conditions, while the limestone on the Northwestern and Eastern shelf and Central Basin Platform were deposited in relatively shallow and well-aerated water. The series thickens southward from generally less than 1,000 feet over the shelf areas and 1,500 feet in the subsurface of the Guadalupe Mountains area of the Northwestern Shelf, to somewhat less than 5,000 feet in the Midland Basin, 7,500 feet in the central Delaware Basin, and over 15,000 feet southward in the eastern half of the Val Verde Basin (Oriel et al., 1967). The name Hueco limestone has been applied to the rocks of the basal Permian in the region; however, some workers prefer to restrict this term to the Northwestern shelf and northernmost Delaware Basin (Hayes, 1964).

On the Northwestern Shelf, the Wolfcampian is subdivided into two cherty limestone units separated by interbedded limestones and red, green and gray mudstones, which thicken northward and become sandy. Along the shelf margins, medium to dark-gray mudstone layers intertongue with the limestone (Oriel et al., 1967).

Within the northern Delaware Basin, the Wolfcamp consists of about equal parts of gray, black or brown shale and fine, crystalline, rarely cherty, brown limestone with a few thin beds of micaceous and calcareous sandstone (Hayes, 1964). Southward, in the deeper parts of the basin, it consists primarily of dark shale with brown sand and some coarser clastics. Here the absence of index fossils precludes satisfactory lower

time boundary detection. Within the Delaware Basin, both the sandstone and carbonate facies have been recognized as potential oil and gas reservoirs. Southward, in the Val Verde Basin, sandstones interbedded within the shales of the Wolfcampian are established as a commercial gas reservoir (Vertrees et al., 1959).

Eastward, over the Central Basin Platform, the Wolfcampian consists chiefly of limestone with a basal unit of as much as 440 feet of red and green shale and conglomerate (Nicholson & Clebsch, 1961). The Wolfcampian within the Midland Basin is similar to that of the Delaware Basin, except for the presence of an upper zone of dark argillaceous, locally cherty limestone and interbedded dark mudstone. The lower part of the section consists of dark mudstone with thin units of fine-grained, argillaceous sandstone and fossiliferous limestone, which increase in thickness north and west along the basin periphery (Oriel et al., 1967).

2) Leonardian Series The Leonardian series of the Lower Permian is represented by a highly variable group of facies consisting of limestone and dolomite, with mudstones, sandstones and some chert. Clastics are dominant in the lower parts of the basins, while calcareous deposits dominate the margin and shelf areas. The series was deposited under mostly marine conditions, but some strata formed in restricted or marginal environments. The Leonardian rocks are over 4,000 feet thick in two north-trending belts along the east and west margins of the Delaware Basin and in the south-central part of the Midland Basin. In the Val Verde Basin, thicknesses average 2,000 to 3,000 feet. On the shelf north and west of the Delaware Basin along the oil-producing Abo reef trend, thicknesses are over 3,500 feet. On the Eastern Shelf, the Leonardian is less than 2,000 feet. Minimum thicknesses in the area are about 800 feet (Vertrees et al., 1959; Oriel et al., 1967).

The Bone Spring Limestone represents the basin facies of the Leonardian in the Delaware Basin and northwest end of the Val Verde Basin, and consists of a dominantly dark-gray, thin-bedded, argillaceous limestone, a gray to buff, very fine-grained sandstone in three separate zones, and

a black shale with some chert nodules and beds. The base is a sandstone member which may be Wolfcampian, and the top is placed above a black shale with dark gray limestone. Deep water conditions with poor circulation probably characterized these basin settings (Oriel et al., 1967).

Eastward, in the Midland Basin, the Leonardian rocks have been assigned to formations different from those in the Delaware, but the rock types, dominantly black shales and limestones, are similar. The section--known as the upper Wichita Group, the Clear Fork Group and the lower part of the Pease River Group at the top--consists of mudstone with lesser sandstone and limestone at the base, two fine-grained sandstone members divided by dark calcareous mudstone and a muddy limestone, that may be time-correlative with two of the three sandstone layers of the Bone Spring. Above this zone, limestone and dolomite predominate, with lenses of mudstone and sandstone; the top of the unit is primarily carbonate.

At the margins of the basins, these basin units grade laterally into limestones. Around the perimeter of the Delaware Basin, the lower part of the Bone Spring Limestone grades into thick-bedded gray limestone overlapping unconformably on the Hueco Limestone (King, 1965). The middle and upper part of the Bone Spring grades into the shelf-margin dolomite of the Victorio Peak, which is correlative with the Yeso of the shelf. The Victorio Peak is a light-gray, thick-bedded fossiliferous limestone containing some chert and sandstone and made up of small, discontinuous or patch reefs and a limestone bank. Unconformably overlying the Victorio Peak of Leonardian to Guadalupian age, is the Cutoff shale consisting of as much as 150 feet of a thin-bedded, platy gray to black limestone, black siliceous or sandy mudstone, and thin-bedded, fine-grained sandstone (Hayes, 1964). In the Midland Basin, the unit grades laterally north and westward into almost pure limestone and dolomite along the peripheries of the Central Basin Platform and Northern Shelf (Oriel et al., 1967).

Away from the Delaware Basin onto the shelves and Central Basin Platform areas, the Leonardian series grades laterally from the Bone Spring and Victorio Peak a into light-colored dolomite, almost 3,000 feet thick, with a few sandstone units. The lower portion of the dolomite has been called the Wichita Group on the Central Basin Platform and the Abo Formation in central eastern New Mexico, which grades northward into red mudstone, sandstone and anhydrite. The Yeso overlies the Abo in central eastern New Mexico, and consists of medium to light gray, fine-crystalline dolomite with lesser sandstones and siltstones (Hayes, 1964). Somewhat below the middle of the Leonardian shelf dolomite on the Central Basin Platform, is a thin but extensive sandstone bed called the Tubb, Fullerton or Drinkard, which serves as a regional marker. The name "Clear Fork Group" is sometimes applied to the section of dolomite encompassing this bed on the Central Basin Platform, and is roughly age-equivalent with the Yeso. The upper limit of the Leonardian on the shelves is formed by a unit consisting of two sandstone layers separated by dolomite. On the northwest shelf, this unit is called the Glorieta; on the Central Basin Platform, it is called the San Angelo (Oriel et al., 1967; King, 1948; Hayes, 1964).

3) Guadalupian Series

The Guadalupian Series in the southeastern New Mexico region encompasses three distinct depositional settings, closely related to structural elements: clastic sedimentation in the Delaware Basin and on the Eastern shelf, carbonate reefs along the margins, and mixed carbonate and evaporite deposition on platforms and shelves other than the Eastern Shelf. The series is over 5,500 feet thick in the Delaware Basin, and gradually thins northward on the Northwestern Shelf to less than 3,000 feet. It thins southeastward from less than 2,000 feet to 1,400 feet at the south end of the Central Basin Platform. Maximum thicknesses in the Midland and Val Verde Basins are about 3,500 feet (Oriel et al., 1967).

a) Basin Facies

The basin facies of the Guadalupian, known as the Delaware Mountain Group, is composed mainly of light gray, very fine-grained sandstone and

siltstone separated by gray shale and a few thin light gray to gray limestone and dolomite members with minor evaporites, indicating frequent relative sea level changes. The Delaware Mountain sandstones produce oil and gas and are important exploration objectives (Vertrees et al., 1959). The Group has been subdivided into three formations from oldest to youngest--the Brushy Canyon, the Cherry Canyon, and Bell Canyon--each of which are up to 1,000 feet in thickness. The Brushy Canyon differs from the upper two formations in that its sandstones are coarser grained with minimal amounts of sediments other than sandstone, and its structural features are indicative of deposition in agitated water. Harms (1974) discusses the Brushy Canyon and proposes density currents as the origin of the formation rather than turbidity currents. This formation terminates northward against the Bone Spring flexure at the basin margin. The Cherry Canyon and Bell Canyon are fine-grained sandstone to siltstone and very finely laminated. The sandstone tongue of the Cherry Canyon disconformably overlies the Cutoff Shale as a shelfward extension of the lower fourth of the Cherry Canyon Formation. Along the reef facies area, the tongue averages 200 to 300 feet thick and, where described in Last Chance Canyon of the Guadalupe Mountains, consists of moderately resistant, indistinctively bedded, grayish-orange, very fine-grained, well-sorted quartz sandstone with scattered chert nodules and silicified megafossils. The upper 25 to 30 feet of the unit is transitional shelfward into an overlying dolomite tongue of the San Andres Limestone (Hayes, 1964) (Also see Figure 3.3-3). The upper Cherry Canyon and the Bell Canyon grade into reef facies at the margin of the basin.

b) Reef Facies

The Guadalupian reef facies consists of the Goat Seep Dolomite and the overlying Capitan Limestone. A generalized cross-section through the reef facies, Figure 3.3-4, demonstrates the relationships between the various Guadalupian units along the reef margins.

Gradationally overlying the sandstone tongue of the Cherry Canyon Formation is the Goat Seep Dolomite. The Goat Seep was a reef, which grew primarily upward and formed a barrier around a considerable portion of the western side of the Delaware Basin. King (1948) originally extended the name Goat Seep to include the shelfward-lying thin-bedded limestones and interbedded sandstones, but Newell et al., (1953) restricted the formation to the massive "reef and forereef talus facies" of the basin margin, a designation maintained by Hayes (1964). The lowerportion of the Goat Seep is thick-bedded, and the upper portion is a massive light gray, fine-crystalline to saccharoidal, in places very porous, dolomite.

The overlying Capitan Limestone is a light colored, fossiliferous and vuggy limestone and breccia which reaches a maximum vertical thickness of about 2,000 feet in McKittrick Canyon of the Guadalupe Mountains, and is at least 6 times as broad as thick, reaching a width of from 10 to 14 miles along the Northwestern Shelf. It apparently formed primarily by oblique or horizontal basinward growth (Newell, et al., 1972; Hayes, 1964; Hiss, 1976). The Capitan virtually encircles the Delaware Basin. It extends from the west side of the Guadalupe Mountains northward and eastward as a bold escarpment which gradually descends to the hills in the vicinity of Carlsbad, where it is overlain by younger rocks (Dunham, 1972). The buried reef front trends northeastward to eastward from there across the Eddy-Lea County line, turns southward to parallel the length of the Central Basin Platform, and then turns west and crops out in the Glass Mountains (Hiss, 1976; Kelley, 1971). The Capitan grades laterally basinward into the Bell Canyon Formation and possibly into the lowermost beds of the Castile; onto the Northwestern Shelf the Capitan grades laterally into the Seven Rivers, Yates, and Tansill Formations of the Artesia Group (Hayes, 1964) (Also see Figure 3.3-3).

The limits of the Capitan described by Crandall (1929) and Lang (1937) have been used by most of the more recent workers, including King (1948), Adams and Frenzell (1950), Newell, et al., (1957), Hayes (1964), and Kelley (1971) and are followed in this report. For a different interpretation, see Dunham (1972).

Hayes (1964) recognizes two units as comprising the Capitan Limestone, a massive member and a breccia member, which grade into each other both laterally and vertically. The massive member forms nearly vertical, smooth-weathering cliffs and ranges in thickness from about 250 to 270 feet averaging 400 feet along its Guadalupe Mountains portion. This member is composed primarily of light to yellowish gray, fine-textured, fossiliferous limestone with virtually no discernible bedding planes. Isolated aggregates of coarsely crystalline calcite are common, and some dolomite, sandstone dikes, and isolated sandstone pockets occur. Solution and recrystallization, weathering, and the very small size of the fossils have made the organic content difficult to recognize in the field. Newell, et al., (1953), however, have identified 115 species of fossils within the formation, including fusulinids, sponges, corals, crinoids, bryozoans, brachiopods, and mollusks; in total volume, stromatolites are probably most important in the construction of this rock unit (Hayes, 1964).

The breccia member, which generally forms more easily eroded uneven slopes, consists of thick beds dipping basinward at 20 to 30 degrees or more on the west side of the Delaware Basin. Most of this member is composed of microbreccia derived from the massive member and from the Artesia Group and also contains coarse, angular cobbles and boulders of limestone and dolomite from these sources. The breccia attains a maximum vertical thickness of about 1,750 feet and averages 1,250 feet and as such comprises about two-thirds of the bulk of the Capitan (Hayes, 1964).

Although it has been generally agreed that the Capitan Formation represents a "geologic reef," (a thick, laterally restricted mass of pure or largely pure carbonate, according to Dunham, 1972), investigators of the Capitan have over the years proposed different interpretations as to its genesis and environment of formation.

Crandall et al. (1929) published the barrier reef hypothesis, according to which reef-building, sediment-binding organisms grew practically at sea level on a reef which developed rapidly enough, despite erosion, to

maintain a nearly vertical front, overriding its own debris. Newell, et al., (1953) concurred with Crandall, based on their detailed petrological work on the reef constituents, and a number of recent investigators, such as Hayes (1964), Boyd (1955), Adams (1944), and Adams and Rhodes (1960) have generally followed this interpretation.

A second alternative was advocated by King (1948) and named by Dunham (1972) the "uninterrupted slope hypothesis." King used it to explain his findings in the southern Guadalupe Mountains which seemed to indicate facies change due to change in slope as the shelf descended to the Delaware Basin. Dunham (1972) pointed out, however, that King studied only portions of the structure. Had he gone farther northwestward, his findings would have corroborated Lang (1937), who proposed a third hypothesis, that of the marginal mound.

According to the marginal mound alternative, supported elaborately by Dunham (1972), organisms produced carbonate particulate sediment upon a broad topographic high which was at different times a sandy shoal or an island bordered by sand and mud flats. The sediment was cemented during the island stages of development. Achauer (1969) has advocated a somewhat similar view that the Capitan represents an ancestral organic bank, rather than a classical barrier reef.

c) Back-Reef or Shelf Facies

The thick massively-bedded limestones along the margins of the basins grade shelfward into thin-bedded dolomites. On the Northwestern and Eastern Shelves and southward along the Central Basin Platform, the Guadalupian includes the San Andres Limestone and overlying Artesia Group (also identified eastward on the Central Basin Platform as the Whitehorse Group by Nicholson and Clebsch, 1961). This group includes from base to top the Grayburg, Queen, Seven Rivers, Yates and Tansill Formations (Hayes, 1964). These shelf units are also recognized in the Midland Basin area. There is some disagreement as to whether the Lower Guadalupian there is missing or greatly resembles the upper Leonardian (Hendrickson & Jones, 1952; Oriel et al., 1967).

In the western part of the Delaware Basin, parallel to the reef front, facies encountered in a shelfward direction are: 1) dolomitized coquin and calcarenite, 2) pisolites, 3) fine-grained dolomite, 4) evaporites, and 5) terrigenous red detritus (Newell et al., 1953). This general succession of facies is also described by Dunham (1972) in the vicinity of the Capitan Escarpment. Hayes (1964) presents a comprehensive discussion of the Guadalupian shelf rocks.

The San Andres is partly time-correlative with the basinal Brushy Canyon; at its base it may be upper Leonardian, and at its top it interfingers with the base of the Cherry Canyon. The San Andres is mainly dolomite with minor limestone near its base and some chert, sandstone and reddish mudstone (Oriel et al., 1967; Kelley, 1971). It extends shelfward much farther than the Artesia Group before grading into evaporites and detrital materials. The San Andres thins eastward across the Midland Basin, and detrital and evaporite contents increase progressively to the east.

The Artesia Group ranges in thickness from about 880 feet to over 1,500 feet. In the shelf and Central Basin Platform areas, it is separated from the underlying San Andres by an unconformity, according to Nicholson and Clebsch (1961). The basal Grayburg and Queen Formations are time-correlative with the marginal Goat Seep Reef and basinal Cherry Canyon Formation. To the south, they consist of dolomites and sandstone; they grade northward into gypsum, mudstones and dolomite (Kelley, 1971). The Queen Formation is distinguished from the underlying Grayburg by its much greater abundance of clastics and red mudstones. The Seven Rivers, Yates and Tansill Formations are all correlative with the Capitan Limestone at the margin, and with the Bell Canyon in the Delaware Basin. To the south, they all resemble the lower two formations of the Group, except for the presence of gypsum and limestone in the Yates. Toward the north, gypsum and anhydrite increase in the Tansill, and siltstone and dolomite increase in both the Yates and Tansill.

Ochoan Series

The Late Permian Ochoan series consists primarily of evaporites that were deposited during recurrent retreats of a shallow sea restricted by the Guadalupian reefs. The lower three formations in the series, the Castile, Salado and Rustler, comprise what is perhaps the thickest and most extensive evaporite rock sequence in North America (Oriel et al. 1967). They are overlain by the Dewey Lake Redbeds, which may be either Permian or Triassic in age. Within the Ochoan, halite is dominant on the shelf north of the Delaware Basin, where the Salado Formation makes up the bulk of the unit; total thickness of salt is greatest, however, in the Delaware Basin, but the presence of the Castile Formation in the basin reduces the proportion of halite there. The proportion of carbonates to other rock types increases southwestward and southward, and the proportion of detrital rocks increases eastward and northeastward (Oriel et al., 1967). The total thickness of the Ochoan ranges from slightly more than 5,000 feet in the center of the Delaware Basin and 4,000 feet in a north trending belt through the basin, to about 1,500 feet in the Midland Basin and 1,000 feet on the shelves. Irregular thinning occurs near the basin margins as a result of erosion and leaching of the more soluble beds (Oriel et al., 1967; Nicholson & Clebsch, 1961).

The Castile Formation is confined to the Delaware Basin and was deposited upon the Bell Canyon, in "apparent conformity," according to Kelley (1971), but unconformably, according to Nicholson and Clebsch (1961), and is laterally bounded by the Capitan limestone reef. The Castile is generally of uniform thickness, up to about 2,000 feet, throughout the basin. The formation consists primarily of massive anhydrite, limestone interlaminated with anhydrite, and halite in beds as thick as several hundred feet (Vine, 1963). In the lower to middle portion of the sequence, banded light gray anhydrite is interlaminated with brown bituminous limestone on a scale of millimeters. Two very extensive layers of fairly pure halite averaging 200 to 350 feet thick persist throughout the northern Delaware Basin. Several smaller tongues of halite are also present through the unit. Towards the basin margins, the

Castile thins abruptly. The basal part of the banded portion grades reefward into laminated limestone and the upper part into massive anhydrite. The top of the Castile is light-gray massive anhydrite, grading into the basal part of the overlying Salado by wedging of thin anhydrite tongues northeastward into salt (Jones, 1954; Brokaw et al., 1972).

The Salado Formation extends from the Delaware Basin area beyond the limits of the Castile and across most of the Permian basin, including the Midland Basin, the Northwestern Shelf and the Central Basin Platform. The complete Salado is present only in the subsurface of this area, and is represented at the surface only by a solution residue. Its thickness varies because of leaching, but it is generally up to 2,000 feet near the northern Delaware Basin, thinning northward over the Capitan reef to 700 to 1,200 feet and thinner farther north and east. In the shelf and platform areas, it rests unconformably on the Artesia, or Whitehorse, Group (Brokaw et al., 1972; Nicholson & Clebsch, 1961).

The Salado is mainly halite, some of which is argillaceous, red mudstones, sandstone, siltstone, abundant anhydrite and a suite of salts including polyhalite, kieserite, glauberite, sylvite, carnallite, langbeinite, kainite and leonite. Beds locally rich in sylvite, KCl, and other soluble potassium minerals constitute valuable potash ores (Vine, 1963). The principle lithologic materials occur in cyclic sequences 2 to 30 feet thick consisting of a detrital layer, a relatively thin sulfate layer chiefly composed of anhydrite and polyhalite, and a thicker halite zone, overlain by a mixed halite-detrital layer, all with gradational contacts. The potash ores occur near the middle of the formation in irregularly lenticular to tabular bodies (Brokaw et al., 1972; Oriel et al., 1967). The upper part of the Salado is locally characterized by a leached zone from which the halite has been removed, and is largely unconsolidated reddish-gray to brown silt and clay with varying amounts of brecciated gray or red gypsum (Vine, 1963).

The Rustler Formation ranges in thickness from 90 to about 400 feet, and overlies the Salado in the Permian Basin area. In the central part of the Permian Basin, the Rustler conformably overlies the Salado, but in other places, as along the west and north margins of the Delaware Basin, it truncates the Salado by a marked unconformity (J. A. Adams, 1944; Nicholson and Clebsch, 1961). In outcrop, the Rustler appears as calcareous sandstone, fine grained dolomites and gypsum. The subsurface Rustler consists primarily of anhydrite or gypsum and subordinate salt, with lesser amounts of dolomite, limestone, siltstone and sandstone. Within the Delaware Basin, the limestone and dolomite increase to the south and southeast.

Vine (1963) has described the Rustler in the northern part of the Delaware Basin. Here, the lower part of the Rustler consists of over 100 feet of siltstone and very fine-grained sandstone with interbeds of gypsum or anhydrite. Next above is the Culebra dolomite, about 30 feet of uniformly microcystalline gray dolomite or dolomitic limestone with numerous small, generally unconnected, nearly spherical cavities. Overlying the Culebra is the Tamarisk member, about 115 feet of anhydrite with local gypsum and a 5 foot thick siltstone bed some 20 feet from its base. The Magenta member, above the Tamarisk, consists of about 20 feet of thin, wavy, lenticular laminae of dolomite and anhydrite (or gypsum). The uppermost member of the formation is the Forty-niner, consisting of up to 65 feet of anhydrite (or broken gypsum in outcrops) with a bed of massive siltstone near the base. According to Jones et al., (1960), the siltstone represents insoluble residue from a bed of halite present in the subsurface to the east.

The top of the Rustler has been placed at the top of the first persistent anhydrite bed penetrated by oil and gas tests and provides a clear marker for structural correlations (Oriel et al., 1967).

Overlying the Rustler in apparent conformable relationship is a sequence of redbeds, up to about 600 feet thick, which represents deposition of terrigenous materials in shallow water remaining in the basin areas over

the older evaporate sequence (Mercer & Orr, 1977; Oriel et al., 1967). On the basis of physical stratigraphy, the unit has been traditionally assigned a Permian age (Oriel et al., 1967). No fossils have been found. Although several names (e.g. the Pierce Canyon) have been proposed for this unit, the term Dewey Lake Redbeds, as defined in west Texas (Page and Adams, 1940), is generally used throughout the area (Nicholson & Clebsch, 1961).

The Dewey Lake consists of a series of micaceous, orange to red sandy siltstones, sandstones and some mudstone. Gypsum commonly forms cement, secondary crystals and veins. The lower 10 feet of the sequence contains a widely distributed zone of coarse, frosted quartz grains.

The top of the redbed unit is marked by an erosion surface, upon which younger units were deposited with a slight angular discordance. In some places, the Dewey Lake has been removed by later erosion, and rocks of Cretaceous or Cenozoic age rest on the Rustler or Salado (Oriel et al., 1967).

3.3.3 Mesozoic Rocks

Triassic Rocks Unconformably overlying the rocks of Late Permian age is the Upper Triassic Dockum Group of red beds, composed of up to 1,500 feet of moderate-reddish-brown to yellow-brown conglomeratic sandstones, siltstones and shales (Brokaw et al., 1972). The sediments of this group display characteristics of rapid deposition from a local source, in their poorly rounded sand grains and micaceous minor constituents. This group has been subdivided into two formations, the Santa Rosa Sandstone and overlying Chinle Formation; however, because of poor exposures and lithologic similarities between the sandstones of the two units, the distinction cannot be made throughout the entire southeast New Mexico area (Nicholson & Clebsch, 1961).

The Santa Rosa is a fine-to-coarse-grained sandstone, generally red but containing white, gray, and greenish to lavender sands and some minor reddish-brown mudstones and conglomerate. The unit is commonly cross-stratified and ranges in thickness from about 140 to over 300 feet (Kelley, 1971; Nicholson & Clebsch, 1961).

The upper portion of the Dockum Group, the Chinle Formation, ranges in thickness from zero to almost 1,300 feet, thickest to the east, near the Texas-New Mexico border, and entirely absent in the west, where it has been removed by post-Mesozoic erosion. The Chinle is a reddish-brown to greenish-gray shaly mudstone with interbedded lenses of conglomerate and thin, gray to reddish-brown sandstone and siltstone (Mercer & Orr, 1977; Nicholson & Clebsch, 1961).

Jurassic Rocks No record of Jurassic deposition has been shown to exist in the southeast New Mexico region.

Cretaceous Rocks Kelley (1971) described three formations, identified as Cretaceous, which crop out to the north and northwest, in the Sierra Blanca and Capitan area, named the Dakota Sandstone, Mancos Shale and Mesaverde formation. The Dakota is comprised of up to 150 feet of sandstone, conglomerate, and beach shale. The overlying Mancos is up to 700 feet of dark shales, siltstone and local thin sandstone and limestone. The Mesaverde Formation comprises from 500 to 1,500 feet of light-colored to maroon coarse clastics and mudstones, and coal. These deposits reflect subsidence of the area during the Cretaceous to a shallow marine and floodplain environment. An outlier of Cretaceous rocks is also present on the crest of the Sacramento Mountains. Here, a pebble-bearing quartz sandstone 150 feet thick is overlain by a shale containing fossils of late Early to early Late Cretaceous age (Pray & Allen, 1956).

Further south on the Northwestern Shelf, there are no definite Cretaceous age outcrops, but solution cavities on the surface of the Castile southeast of the Guadalupe Mountains contain pebbles of limestone and

sandstone with fossils of early Washita age. At several places along the top of the Reef Escarpment, low areas on the ridge and joints in the Permian Tansill formation contain conglomeratic quartz sandstone which closely resembles the Cretaceous deposits in the Sacamento Mountains (Hayes, 1964).

To the southeast, in the Lea County area, only several exposures of Cretaceous rocks are known. A gravel pit east of Eunice contains large slump blocks, up to 5 feet thick and 20 feet long, of massive, highly fossiliferous, white to buff sandstone containing some sand and shaly partings along the bedding planes (Nicholson and Clebsch, 1961; Ash and Clebsch, 1961). This rock and the Comanche limestone of Early Cretaceous age are strikingly similar, so are believed by Ash and Clebsch (1961) to be equivalent. Another outcrop of Cretaceous rocks at North Lake consists of dark gray siltstone and thin interbedded stringers of light brown crystalline to light gray, fine-grained limestone. According to fossil and lithologic similarities, the rocks at North Lake are correlated with the Early Cretaceous Tucumcari shale (Ash & Clebsch, 1961). In the subsurface of Lea County, 5 feet or more of yellow, blue, or gray clay or shale encountered by drilling and consistent with the description of the rock at North Lake constitute the major evidence for the subsurface presence of Cretaceous outliers in the area. Based on some 8,000 water-well logs and seismic shotholes, Ash and Clebsch (1961) have determined that in the subsurface Cretaceous rocks are generally continuous in the northeastern portion of Lea County, but further west and south, only scattered, discontinuous occurrences have been encountered.

Rocks of Cretaceous age were deposited over the southeast New Mexico area but have been almost entirely removed by erosion. Now only scattered patches or reworked pockets of limestone and sandstones of probable Early and Mid-Cretaceous age are present in the area; Cretaceous rocks have also been identified here in the subsurface through drilling (Bachman, 1976; Hayes, 1964; Nicholson and Clebsch, 1961).

3.3.4 Cenozoic Rocks

Tertiary Rocks. Following Cretaceous deposition, widespread uplift and erosion occurred throughout the region, and the earliest Cenozoic deposits for which there is record, the Ogallala, were depositied in Late Tertiary Miocene to Pliocene time.

The Ogallala Formation underlies the High Plains of eastern New Mexico and west Texas. Although there are no confirmed remnants of the Ogallala west of easternmost Eddy County, isolated gravels to the west in the Pecos Valley and Guadalupe Mountains have been interpreted as belonging to this formation (Mercer and Orr, 1977). The Ogallala was deposited on an irregular, broadly sloping pediment or complex alluvial fan surface by southeastward flowing streams under rapidly changing conditions (Bachman, 1976).

The Ogallala in the region is up to 400 feet thick (Bachman, 1976) and consists of a yellowish-gray semi-consolidated, fine-to medium-grained, calcarous sand containing some silt, clay, and gravel. In many places, a basal gravel deposited within stream beds is also encountered. Some beds of well consolidated silica-cemented conglomeratic sandstone from one to three feet thick also occur within the formation. As a result of intertonguing, lensing and pinching out of the beds caused by the varying depositional conditions there are no consistent marker beds within the Ogalalla (Nicholson and Clebsch, 1961; Bachman, 1973).

The Ogallala is capped by a dense layer of brecciated and pisolitic caliche ranging in thickness from a few feet to as much as 60 feet. At the surface it is a well indurated calcium carbonate, but below the surface, it becomes softer and more porous and grades into the underlying sands. This capping was formed in post-Ogallala time and before the extensive Pleistocene erosion of the area, probably during the Late Pliocene. The caliche accumulated within the zone of illuviation of a pedocal "climax soil," which developed on the depositional surface of the

Ogallala (Nicholson and Clebsch, 1961; Bachman, 1976). (Pedogenic caliche formation in southern New Mexico is described in detail by Gile, et al., (1966).)

Quaternary Rocks Following Pliocene time, erosion removed much of the Ogallala as well as some of the older materials, and stream systems became entrenched. Periodic deposition also occurred in the southeastern New Mexico area during the Pleistocene and Holocene, leaving behind the Gatuna Formation, caliche, terrace, channel and playa deposits and windblown sand.

The Gatuna, of Pleistocene age, unconformably overlies rocks as old as Permian and Triassic and consists of up to several hundred feet of reddish-brown friable sandstone, siltstone and cherty and siliceous conglomerate, but locally also includes gypsum, gray shale and claystone. Remnants of the formation are discontinuous and may have been deposited in local depressions such as stream channels and solution subsidence areas (Bachman, 1973; Vine, 1963).

Unconformably above the Gatuna and older deposits throughout southeastern New Mexico, there formed a fairly continuous mantle of caliche called the Mescalero. It is a sandy light gray to white deposit composed of a lower nodular calcareous zone and upper dense laminar caprock and ranges in thickness from 3 to 10 feet. According to Bachman (1973), the caliche is the remnant of an extensive soil profile.

Late Pleistocene to Holocene terrace and channel deposits are preserved in the western part of the area, particularly along the Pecos River and the Guadalupe Mountains area. Channel deposits consist of silt and sand to boulders. Within the Guadalupe Mountains area, deposits are generally limestone cobbles and boulders. Three terraces are commonly recognized in the area: the Blackdom, Orchard Park and Lakewood. The Blackdom and Orchard Park have been dated as Pleistocene while the Lakewood may be of Holocene age. The deposits of the Blackdom terrace are generally coarser than those of the younger terraces, but the two Pleistocene terraces are

similar in composition, consisting of limestone-porphyry conglomerates capped by caliche. The younger Lakewood terrace contains river conglomerates and pond, marsh, and lake silts (Bachman, 1973; Hendrickson and Jones, 1952).

Playa and shallow lake deposits are present in the area in many small shallow depressions, particularly east of the Pecos River. In most of these depressions, lakes formed after heavy runoff and evaporated rapidly, but some contain generally perennial lakes, the largest of which is Laguna Grande de la Sal, in Nash Draw. The playa deposits consist of alluvium, reworked eolian sands, silt and clay. Around some of the standing lakes, gypsum, carbonate minerals, and some halite have been deposited. These deposits date from the Late Pleistocene to Holocene time (Hendrickson and Jones, 1952, Vine, 1963).

Windblown sands mantle much of the surface east of the Pecos River for 20 to 30 miles eastward to the Mescalero ridge and south to the Texas border. The sand is very erratic in both thickness and distribution, and appears to be fairly uniform, fine-grained light brown to pale reddish-brown quartz. Many of the grains are rounded and frosted. Some of the sand rests in coppice dune fields where the sand is as thick as 25 feet. Most of the sand has been stablized by mesquite, bunchgrass and other vegetation.

3.4 REGIONAL STRUCTURE AND TECTONICS

The major tectonic structures of the region are displayed in Figure 3.4-1. Most of the large-scale elements that provide the structural framework of the area were developed in the Late Paleozoic, principally from Late Pennsylvanian to Early Permian time. These include the Delaware Basin, the Central Basin Platform, the Midland Basin, and the Northwestern Shelf of the western extent of the Permian Basin, the Pedernal Uplift, the Matador Arch, the Val Verde Basin, and the Diablo Platform, as well as secondary features such as the Huapache Monocline and Artesia-Vacuum Arch and the northeast-trending buckles and smaller

fold systems believed to be expressions of basement faulting. Middle to Late Tertiary Basin and Range-related doming and faulting produced the remainder of the major tectonic features in the area, including the Guadalupe, Delaware, and Sacramento Mountains, and associated west-bounding faults, as well as a gentle regional east to southeastward tilt which affected the entire region under consideration.

The WIPP site lies near the western margin of the region of the Western Interior known as the Permian Basin, which comprises a series of sedimentary basins in which halite and associated salts accumulated during Permian time and where Permian rocks have reached their maximum development. The region extends about 520 miles from the Amarillo uplift on the north to the Marathon thrust belt on the south and some 300 miles westward, from west-central Texas to the Diablo Platform and the present Sacramento and Guadalupe Mountains (Hills, 1963).

The formation of a depositional basin in the west Texas-southeast New Mexico area began following Lower Ordovician Canadian time, when a broad sag, named the Tobosa Basin by Galley (1958), developed. Several periods of minor folding and perhaps some faulting occurred in the Tobosa Basin area prior to Pennsylvanian time. There was some erosion, but a general tectonic stability prevailed until the Late Mississippian to Late Pennsylvanian-Early Permian time. Tectonic activity accelerated in the area coincident with the Marathon disturbance, and the sag was split into two rapidly subsiding basins--Midland to the east, and Delaware on the west--by the final uplift of the median ridge, the Central Basin Platform (Foster, 1974). Continuing basin and platform development occurred throughout the Permian Basin through Permian time. Stabilization of the basins followed, during which time evaporites were deposited. Since Permian time, the Permian Salt Basin has been relatively stable tectonically (Bachman & Johnson, 1973); thus, the large structural features of the Permian Basin are reflected only indirectly in the Mesozoic and Cenozoic rocks (Nicholson & Clebsch, 1961).

The structure of each of the major tectonic units of the Permian Basin in the site region is described below, followed by discussion of the larger secondary features and younger Tertiary Basin and Range-related structures.

3.4.1. Delaware Basin

The site is located within the northern portion of the Delaware Basin, which, during most of Permian time, was a deep-water embayment extending into what is now southeastern New Mexico and western Texas. The Delaware Basin is a broad, oval-shaped asymmetrical trough with a northerly trend and southward plunge, as reflected on the top of the Precambrian (Figure 3.4-2). Its axis lies in central Lea County, New Mexico, roughly paralleling the Central Basin Platform. The eastern slope of the trough rises rapidly to the platform, while the western slope is much gentler (Figure 3.3-2). The basin comprises an area of about 12,000 mi^2 and measures roughly 75 to 100 miles east to west and 135 to 160 miles north to south. The Delaware Basin is nearly surrounded by the large horseshoe-shaped Capitan limestone that extends from Carlsbad on the northwest and opens to the south in Texas, between the Davis and Glass Mountains. However, the structural boundaries of the basin encompass a larger area to the north, beyond the Capitan reef front, into which the older and deeper lying basin sediments (e.g. the Delaware Mountain Group and Bone Spring) extend. The Delaware Basin represents the area of maximum subsidence of the Permian Basin, with more than 20,000 feet of structural relief, on the Precambrian (See Figure 3.4-2), and it is also here that the Permian section is thickest, with some 13,000 feet of Permian strata present in southeast New Mexico (Oriel, et al., 1967)

Regional structural deformation of the Delaware Basin rocks is relatively minor. The sediments older than Late Permian are gently downwarped as a result of concurrent basinal development. The Late Permian Ochoan rocks and Triassic rocks do not reflect this basinwide warping; their major structural feature is the regional eastward slope (Brokaw, et al., 1972).

There are no known active faults within the northern Delaware Basin study area of the WIPP site. Deep-seated faults, which may be partly of tectonic origin, do occur within the older sediments of the Delaware Basin. Some of these faults probably originated from the rapid Pennsylvanian-Early Permian subsidence of the basin, during which widespread block faulting occurred within the basin (Adams, 1965). Others are pre-Permian and basement structures which are reflected in the overlying beds. An example of this type of intrabasin feature is the Bell Lake fault, recognized by Haigler (1962, 1972), which has a displacement of about 500 feet in the Precambrian. The structure is reflected upwards through the Pennsylvanian Section and Foster's (1974) map. It shows as a north-south high with closure on the south. Closure is also indicated on the Bone Springs map. Whether this structural representation results from continued movement of the Bell Lake fault system up to that time or is only an effect of compaction is not known (Foster, 1974). A complex series of faults with several thousand feet of offset marks the boundary between the Delaware Basin and Central Basin Platform. These faults were involved in the development of the basin and are considered to have been inactive after Permian time. They are discussed in more detail in the following section.

Two sets of joints, with strikes to the northwest and northeast, have been recognized within the basin. The northeasterly set appears to be better developed and penetrates the lower anhydrite of the Castile Formation along the western margin of the basin, where the formation is exposed. This set also controlled the emplacement of replacement limestone within the evaporites (Anderson, 1978).

Other structures within the Delaware Basin include flexures, some of which formed during Early to Mid-Permian basinal downwarping and deposition of the Bone Spring and Delaware Mountain Groups (Pray, 1954), and minor scattered folding of the younger beds (U.S. Bureau of Mines, 1977). Evidence of anticlinal structures as well as an unusual type of fracturing and microfolding within the Castile anhydrite has been cited by Anderson and Powers (1978) and Anderson, et al., (1972), as evidence

of salt movement. C. L. Jones (unpub.) has described a deformation zone encircling the inner margin of the basin and extending inward about 5 miles, as well as a number of similar structures in the interior of the basin, which, according to Anderson and Powers (1978), may be salt anticlines. These features may have formed as a result of differential stress from unloading related to salt dissolution (Anderson, 1978). Scattered small domes, various collapse structures due to salt and/or gypsum dissolution (including domal structures with collapsed centers, known colloquially as breccia pipes), limestone buttes (Castiles), collapsed outliers, and deep-seated sinks can be found in the evaporite sections (Vine, 1960; Anderson, 1978). Stipp (1954) also identified brecciation in the beds of the Wolfcampian and Leonardian rocks, which he attributed to adjustment in the basin in response to sedimentation and structural forces.

The tectonic development of the Delaware Basin, as reflected in the structures discussed in this section, may be summarized as follows. The Delaware Basin was defined by early Pennsylvanian time and major structural adjustment took place in Late Pennsylvanian to Early Permian time. Regional subsidence in conjunction with broad arching, folding, and faulting occurred until Late Permian time, when the basin's history as an active structural feature ended (Brokaw, et al., 1972). Regional uplift and deposition of continental red beds in Triassic time was followed by continued emergent conditions, resulting in erosion or nondeposition. Mid-Cenozoic to Late Cenozoic regional eastward tilting of the basin much later shifted the deepest part of the Basin to its present position close to and paralleling the Central Basin Platform (Stipp, 1954). Since then, the only structural developments in the basin have been related to hydration and solutioning of the Late Paleozoic sediments.

3.4.2 Central Basin Platform

The Central Basin Platform is a subsurface feature (see Figure 3.3-2) which represents an ancient broad uplift of Precambrian and Cambrian to

Pennsylvanian rocks separating the Delaware and Midland Basins at the southern extreme of the Permian Basin in southeastern New Mexico and southwest Texas. The platform extends in a north-northwest trend for about 200 miles to the south flank of the Matador Arch (Bachman and Johnson, 1973). The Central Basin Platform may represent a zone of structural weakness along which movements took place periodically at least into Late Paleozoic time. Displacement within and along the margins of the platform appears to have been along large, high-angle normal or reverse faults, which trend north to northwest and break Early Permian and older rocks; all faults predate the salt deposits of the adjacent basins (Bachman and Johnson, 1973). According to Hills (1970), these faults may have been involved in considerable lateral as well as vertical movement.

The platform itself is a horst. In the structurally higher parts of the platform identified by Foster (1974) as the Hobbs and Eunice blocks, the Precambrian surface is from 4,000 to 7,000 feet below sea level, while the adjacent Monument-Jal block stands at 6,500 to 11,500 feet below sea level. The fault system separating the Hobbs and Eunice blocks from the Monument-Jal block has a displacement of about 1,000 feet in the north to possibly 4,000 feet west of Eunice. The fault bounding the Monument-Jal block extends about 50 miles southward, into Texas, with an inferred displacement of 1,500 feet at the north to over 6,000 feet west of Jal. The aeromagnetic map of the Carlsbad area (U.S.G.S., 1973) provides fairly good definition of the trend of the major features of the Central Basin Platform (Foster, 1974).

The maximum structural relief east-west between the Central Basin Platform and the Delaware Basin is remarkably uniform, at about 9,000 feet (Foster, 1974). Complex fault systems form the boundary between these two structural units. Hills (1970) indicated a fault in approximately this location and termed it the West Platform fault. According to Haigler (1962), this fault system has a relief about equivalent to that of the Huapache monocline bordering the west side of the Delaware Basin.

The Central Basin Platform has been more intensely deformed than has the Delaware Basin or shelf areas (Brokaw, et al., 1972). The tectonic development of the Central Basin Platform may have begun in Precambrian time, and it appears to have been a high during Early Ordovician time. The platform was unstable during late Devonian time but was generally an area of stability thoughout early to Mid-Paleozoic time. In latest Mississippian or early Pennsylvanian time, the area was deformed to an elevated emergent fold belt, trending north-northwest. After submergence and deposition in Middle and part of Late Pennsylvanian time, renewed orogeny further elevated the area and sharpened, compressed, and faulted the folds (Hills, 1963). The complex fault system bordering the platform on the west formed either in Late Pennsylvanian or Early Permian time, according to Haigler (1962), and contributed as well to the structural development of the Delaware Basin. Claiborne and Gera (1974) also identify the subsurface faults outlying the Central Basin Platform as no younger than Permian age, since the Permian and younger beds in the area are unfaulted. Over the faulted platforms, the sedimentary formations were broadly arched, and concurrently eroded, in places to the Precambrian basement. Subsidence followed, and upper Wolfcampian- through Guadalupian-age carbonates were deposited on the roots of the earlier mountain ranges. Since filling of the Midland and Delaware Basins in Late Permian time, the platform has been structurally stable (Brokaw, et al., 1972). Recent seismic activity there is being studied to determine its relationship to secondary oil recovery operations (see Section 5.). The Central Basin Platform is probably not naturally active at the present time, in view of the lack of fault scarps to match the seismic activity (Sanford, 1978).

3.4.3 Midland Basin

The Midland Basin, situated to the east of the Central Basin Platform, is similar in most respects to the Delaware Basin but shallower, having experienced less structural development. The Midland Basin extends some 200 miles along a north to northwest trend to the Matador Arch vicinity. Its shape is much more symmetric than is the Delaware Basin, and its

relief is only 4,000 to 5,000 feet. Extensive major faulting occurred before the deposition of Late Permian salt in the southern part of the basin and on its west flank in proximity to the Central Basin Platform (Bachman & Johnson, 1973). As is the case with the Delaware Basin, general tectonic stability has prevailed in the Midland Basin since Permian time.

3.4.4 Matador Arch

The Matador Arch is a narrow east-west trending Paleozoic highland of irregular relief and outline underlain by Precambrian granitic rocks. The uplift extends for some 300 miles across the Permian Basin, from west of Wichita Falls, continuing westward, north of Lubbock and entering New Mexico in southern Roosevelt County. Its western limits are uncertain, but some have supposed a connection with the Capitan Mountains to the west, by way of the intrusive igneous Railroad Mountain and Camino del Diablo dikes that parallel the trend of the Matador arch in eastern New Mexico (Stipp, 1960). The Matador Arch provides structural division between the Delaware and Midland Basins to the south and the Hardeman, Palo Duro, and Tucumcari Basins in the northern part of the Permian Basin.

The Precambrian structural framework of the Matador Arch itself is probably not a continuous ridge, but a series of prominences which may be the roots of a chain of islands or hills existent during Precambrian and Early Paleozoic times. The only large tectonic structures on the Matador Arch consist of strong faults and folds that trend obliquely across the uplift in a northwest direction (Eardley, 1962). These faults are present only on the southern flank of the arch, near its western extremity and break only the Precambrian basement rocks (Bachman and Johnson, 1973). The history of the major tectonic development and activity of the Matador can thus be considered to have ended by early Paleozoic time.

3.4.5 Pedernal Uplift

The Pedernal Uplift represents a southward extension of the Rocky Mountains in south-central New Mexico about midway between the Rio Grande and Pecos Rivers. The boundaries of the uplift are not very well defined but in general trend north-south from the eastern side of the Sacramento Mountains in Otero County, apparently continuously to northern Torrance County (Eardley, 1962). The uplift is named for Pedernal Mountain in Torrance County, which is considered to be a remnant and the southernmost exposure of the Ancestral Rockies.

Together with the Permian Basin, the Pedernal landmass strongly influenced the depositional and structural patterns of the region. The Pedernal Uplift appears to have been a wide and not particularly emergent area connecting southward with the Diablo Uplift, and existed, according to Thompson (1942), and Pray (1961), from Early Pennsylvanian time until well after the beginning of Permian time. Within the confines of the Uplift, red shales, sandstones, variegated shales, and limestones of Permian age rest directly on igneous and metamorphic rocks of Precambrian age (Eardley, 1962). In structure, the uplift may have been a broad upwarp in some places and fault-bounded blocks in others. The uplift was probably sharpest on the west with the possible exception of the southeastern edge along the buried Huapache zone (Kelley, 1971).

There is some disagreement as to the time of initial uplift of the Pedernal. According to Stipp (1960), the uplift apparently rose in Late Mississippian or Early Pennsylvanian concurrently with the Central Basin Platform, and was subsequently eroded down to its Precambrian core. Kelley (1971) states that the Pedernal began its rise in Late Pennsylvanian time. According to Bachman (1975), the earliest indication of Ancestral Rocky Mountain building in New Mexico occurred during the Middle Pennsylvanian Desmoinesian time but the Ancestral Rocky Mountain-Pedernal Uplift activity accelerated and was extended southward into New Mexico during Late Pennsylvanian Missourian time, and the uplift reached its maximum in New Mexico during the Virgilian, with accompanying

major faulting occurring along the west side of the Pedernal Uplift. Acceleration of uplift continued through Wolfcampian time, denuding the rocks well into the Precambrian core. Some broad arching and erosion had taken place before the basal Artesia was deposited, followed by renewed rise during and following Salado deposition. Post-Triassic to pre-Dakota time saw renewed rise of the Pedernal Uplift. Structural development ended with a slight uplift and tilting of the Pedernal towards the north during Late Jurassic to Early Cretaceous time (Kelley, 1971).

3.4.6 Diablo Platform

The Diablo Platform is a northwest-trending, structurally positive area southwest of the Delaware Basin, extending southeastward from the Cornudas Mountains at the New Mexico-Texas border and terminating with the Marathon Uplift area and Ouachita tectonic belt to the southeast. The platform is a horst with an average elevation of 1,200 meters above sea level and is bounded on the east, south, and west by grabens. At its northern extent and closest approach to the site, the platform is bordered on the east by the Salt Flat graben (Barker, et al., 1977). (See Figure 3.4-1).

The Diablo Platform experienced primary deformation in Late Pennsylvanian or Early Permian time, but topographic relief and the presence of coarse detritus favor Early Permian for the major portion of the activity. Deformation consisted of uplift, folding, and faulting. The uplift was greater on the south than the north, in the Carrizo Mountain-Van Horn area, where subsequent erosion exposed Precambrian rocks. Faulting is also known to have occurred in post-Permian rocks along the northeast margin of the platform. The Late Cenozoic Basin and Range activity affected the Diablo platform through prominent block faulting and buckling. Major movement in this area was on northwest-trending faults along the northeast margin of the Diablo Platform. Late Cenozoic regional uplift concurrently affected the platform (Oriel, et al., 1967). Oliver (1977) reports several centimeters of relative uplift of the eastern Diablo Plateau and western Salt Basin between 1934 and 1958.

Releveling of this first-order line by the National Geodetic Survey in 1977 for the WIPP indicates only millimeters of relative uplift during the period 1934-1958 and about 5 centimeters of downwarping from 1958-1977 relative to the 1958 line. Further studies of this area are indicated in Chapter 10.

3.4.7 Val Verde Basin

The Val Verde Basin was a deep Early Permian depositional basin at the southwestern extent of the Permian Basin area. The Val Verde Basin trends east-southeast towards the Delaware Basin, adjacent to the north rim of the Ouachita tectonic belt.

The Val Verde Basin attained its major structural definition in Late Paleozoic time. The southeastern part of the south margin of the trough may have been established early in Pennsylvanian time. During Upper-Middle Pennsylvanian Desmoinesian time, the Val Verde area was a fairly stable foreland. But near the beginning of Permian time, the Val Verde trough was abruptly deepened and its north side irregularly steepened opposite the Marathon salient of the south rimming structural belt. Large-scale faulting believed to be of Pennsylvanian age has been recognized, through drilling, along the north flank of the trough; sagging along these zones of weakness during the Early Permian deepening of the trough is probable, according to Vinson (1959), Hester and Holland (1959) and Oriel et al., (1967). The large-scale rapid downwarping that occurred in earliest Permian time caused Permian rocks to accumulate here to a thickness exceeding 17,000 feet, the greatest accumulation of Permian rocks to be found in the Permian Basin. By the Mid-Permian there was a marked decrease in deformation, and a shelf formed across part of the area. Permian rocks here were later warped, possibly in Early Triassic time and eroded (Oriel et al., 1967).

3.4.8 Huapache Flexure

The Huapache Flexure is a long, narrow, northwest-trending monoclinal structure along the eastern slope of the Guadalupe Mountains on the west border of the Delaware Basin. The monocline extends from parallel to the Guadalupe Ridge anticline on the south, northward across the Capitan Reef escarpment, where it is offset to the west. Similar offset occurs farther north as it crosses the folds along the shelf margin. The monocline terminates at the north end of the Guadalupe uplift.

The Huapache flexure is marked by tonal and textured differences on LANDSAT imagery. On the southwest side of the mapped flexure line, the terrain is more dissected, has more vegetation, and from the visible shadows appears to be topographically much higher than the area to the northeast.

The width of the flexure ranges from 0.5 to 2.5 miles. The Precambrian structural relief ranges from 300 to 400 feet in the north to as much as 1,000 feet in the south, just north of Guadalupe Ridge. In the Delaware Basin, the structural relief on the Precambrian along the monocline is from 300 to 600 feet. The maximum dip along the flexure is about 15 degrees to the east, and above and below the structure, dips are from 3 to 5 degrees (Kelley, 1971).

Although the Huapache structure has the configuration of a monocline at the surface, there is evidence that it overlies a thrust fault or series of faults in the Precambrian basement and Paleozoic sedimentary section, and so represents the draping of sediments over a fault or fault zone (Stipp, 1960; Hayes, 1964). Haigler (1962) interpreted the results of drilling as indicating a displacement of as much as 5,400 feet along an underlying fault.

According to Claiborne and Gera (1974), the age of inception of the Huapache was Pennsylvanian; according to Haigler (1962), it was late Pennsylvanian to Permian, contributing to the final structural

development of the Delaware Basin. Hayes (1964) has indicated that the Huapache thrust faulting must have been post-Mississippian in age, since Mississippian rocks show no lithologic change across the zone but are vertically displaced as much as 4,000 to 6,000 feet, with a much higher Pennsylvanian section east of the zone (also see Meyer, 1966). According to Hayes, the zone was apparently intermittently active through all or most of Pennsylvanian time, into Early Permian. The Guadalupian San Andres Limestone, however, is not ruptured; thus, the faulting must have been pre-Guadalupian. According to Kelley (1971), too, movement ceased in Leonardian time. Since then, deposition of sediments above the fault trace has produced the low eastward-dipping flexure configuration exposed today. Although no major activity has occurred here since the Mid-Permian, Hayes (1964) believes that inasmuch as the monocline affects rocks of Late Guadalupian age, it appears that minor post-Guadalupian, probably Tertiary, movement has taken place along the old zone of weakness.

3.4.9 The Northwestern Shelf

North and northwestward of the Delaware Basin is a large platform area. Some investigators have taken the southward front of the platform to be delineated by the Capitan Reef Escarpment. Here the dips of the beds average about 20° to the southeast (Hendrickson & Jones, 1952).

The Northwestern Shelf was well developed before the onset of Permian time, as shown by the abundance of shelf limestones, including numerous reefs of Virgilian age, along its present trend. This tectonic element may have originated in early Paleozoic time, when it formed the margin of the early Tobosa Basin (Galley, 1958, Oriel, et al., 1967).

A number of flexures, arches, and buried fault systems have been identified in this area, several of the largest and best known of which are discussed below. The consensus is that tectonic activity along the individual structures had ceased in Tertiary time, and since then, only broad regional monoclinal flexing has occurred. Other than minor

surficial effects due to solution and hydration of evaporates, the entire southern part of the shelf appears to have been stable in Quaternary time (Brokaw, et al., 1972).

Folds A belt from 6 to 9 miles wide of sharply flexured folds lies just back of the Capitan Reef front, extending in long arcs convex to the west and parallel to the shelf margin for a distance of about 65 miles eastward to the Central Basin Platform. These symmetrical and parallel folds termed the Carlsbad folds by Kelley (1971), average about 1.5 miles apart from crest to crest and have an average fold amplitude of about 100 feet (Motts, 1972). Kelley (1971) describes their shape as "domical uplifts," circular to elliptical, with average dimensions of 1.5 by 3 miles. These folds are partly expressed in the present topography. Shelf domes, consisting of biohermal cores covered by shelf beds, are superimposed on the folds, which suggests to Motts (1972) that the folds may have been topographically positive features during the time of Capitan Reef. Brokaw, et al., (1972) dates these folds as of early Tertiary or perhaps older age. According to Hayes (1964), they are presumed to be Laramide in age, since they post date the Permian rocks and antedate the development of Carlsbad Cavern in early and middle Tertiary.

Another arcuate fold belt, called the Waterhole Anticlinorium, is present about 12 miles west of Carlsbad and extends for about 20 miles with a width of 1 to 2 miles. The feature consists of a narrow, closely spaced set of 3 synclines alternating with 3 anticlines. Structural relief on the folds is from 200 to 400 feet. The axes of the anticlines are sharper than those of the synclines, and locally, their axial planes appear to be faults (Kelley, 1971). Like the Carlsbad folds, this system has been dated as early Tertiary or older (Brokaw et al., 1972).

The Cenozoic folds that parallel the reef escarpment on its northwest may be indirectly related to the older Bone Spring Monocline, which formed a broad southeast-dipping fold along the basinward edge of the Victorio Peak Limestone in the Late Leonardian-Early Guadalupian time. The

monocline is exposed only in the south end of the Guadalupe Mountains in Texas but is presumed to continue northeastward into New Mexico, forming the southeast flank of the 15 to 20 mile-wide Bone Springs Arch. The arch was virtually buried in Brushy Canyon time, but near the end of San Andres time the flexure was rejuvenated and produced an accentuated northwest margin for the Delaware Basin. This had a great effect on later Permian deposition and may have controlled the position of the Capitan limestone (Hayes, 1964).

Numerous other local fold structures have been identified on the shelf area, a good number of which are described by Kelley (1971), by Motts (1972), and by Hayes (1964). Many of these folds have north to northwesterly curving axes and structural closure of up to 100 feet or more. According to Motts (1972), the size of some of these features, such as the McKittrick anticline and adjacent Dark Canyon syncline, as well as their possible influence upon the orientation of the Capitan reef, suggests that they may reflect deeper flexures or faults in the basement. Some of these features have been dated: Motts (1972) has found evidence that the McKittrick anticline and Dark Canyon syncline were a topographic high and low, respectively, during Guadalupian time.

Faults The most prominent area of fault-like structures on the shelf north of the Delaware Basin is the zone of straight northeast-trending shears extending from several miles north of Artesia northwestward toward the Sacramento Uplift and Capitan Mountains. The major structures of this group, such as the Y-O, Six-Mile Hill, and Border Hills Buckles, are exposed for from 35 to 80 miles along strike and spaced at distances of 8 to 20 miles. Movement along these features has involved folding, faulting along strike, and overthrusting, and along the strike of these buckles the nature of deformation may change markedly over a short distance. These features are visible on LANDSAT imagery to varying degrees. The Border Hills Buckle appears as a very obvious scarp and adjacent depression which is visible along its entire length, whereas there are no obvious scarps or depressions along the mapped trace of the Six-Mile Hill Buckle, although some stream offsets are aligned along its

trend, and the Y-O fault is marked only by portions of 3 streams which follow the fault line a short distance. Evidence exists that movement on these zones was initiated in Carboniferous or earlier times and may have been basically right lateral (Brokaw et al., 1972 and Kelley, 1971).

Kelley (1971) has described two faults, named the Barrera and Carlsbad, fronting the reef escarpment 32 kilometers and 16 kilometers southwest of Carlsbad and having "late Tertiary with possible Quarternary movement." However, many other geologists who have investigated the area are not convinced that the linear features seen on aerial photos are actually faults. (Claiborne and Gera, 1974).

Artesia-Vacuum Trend The Artesia-Vacuum trend is a long, low, east-trending arch in Permian rocks, which extends eastward from a little south of the town of Artesia, in Eddy County, New Mexico, for a distance of about 75 miles, roughly paralleling the Carlsbad folds. The trend represents slightly warped Permian strata in an eastward-plunging anticline (Stipp, 1960). The arch is almost completely covered by post-Permian beds, except for a short stretch near Chalk Bluff Draw where the plunging south limb is seen dipping southeastward at about 4 degrees. This feature has been dated as either Early Permian or pre-Permian, and, according to Brokaw et al. (1972), is largely or wholly the product of differential compaction over the Abo reef of Early Permian age.

3.4.10 Sacramento Mountains

The Sacramento Mountains constitute an uplift area to the west of the Northwestern Shelf and form the local eastern border of the Basin and Range province. The uplift extends for a distance of over 45 miles in a north to slightly northeast direction, and most of the structures within the range also exhibit a northerly trend. The overall structure of the Sacramento Mountains is a tilted fault block, with a regional dip to the east of about 1 degree. The eastern flank of the mountains is characterized by its simple, undeformed eastward dip of 100 to 140 ft/mi. Greater

uplift along the central crestal zone has produced dips of several degrees in the strata on the north and south ends of the range. The Sacramento uplift is separated from the Tularosa Basin on the west by one or more normal faults involving several thousand feet of displacement (Stipp, 1960).

The Sacramento Mountains have developed through several periods of tectonic activity, probably beginning in Late Pennsylvanian and early Wolfcampian time. Pre-Permian strata of the range are deformed by folding and faulting during this time, and many of the internal structures of the Sacramento Mountains formed then. Some further deformation occurred during Mesozoic or early Cenozoic time (Pray, 1959).Cretaceous strata, strongly folded and faulted and intruded by dikes and sills, occur extensively in the northern Sacramento Mountains, especially between the towns of Capitan and Carrizozo. Here the structure suggests a depressed synclinal block greatly affected by igneous activity (Stipp, 1960).

Late Cenozoic Basin and Range faulting, which produced uplift and tilting, gave the Sacramento Mountains their present configuration. The dominant location of this activity has been the large fault zone at the western base of the uplift in the Tularosa Basin, and the uplift appears to be still in progress (Pray, 1959).

3.4.11 Guadalupe-Delaware Mountains Uplift

The Guadalupe-Delaware Uplift is a gently northeastward-tilting fault block extending northwestward for some 110 miles, from the Diablo Platform area near Van Horn, Texas, to east of Pinon, New Mexico. In New Mexico, the western boundary of the uplift is a great fault scarp produced by a system of nearly en echelon, normal faults of Late Cenozoic age, along which the displacement ranges from 2,000 to 4,000 feet (Kelley, 1971; Hayes, 1964). The eastern margin is formed largely by erosional conformance to the Late Paleozic to Tertiary Huapache Monocline, and the southeast margin of the range coincides with the Reef

Escarpment, which, according to Hayes (1964) may have resulted partly from Cenozoic rejuvenation of the Late Paleozoic Bone Spring Monocline. Using the Huapache Monocline as the east boundary, the uplift is about 11 miles wide in its southern part, tapering northward to about 3 miles (Kelley, 1971). The Guadalupe Mountains lie within the Sacramento section of the Basin and Range province and are structurally part of the Northwestern Shelf (Brokaw, et al., 1972).

In cross section, the mountains have a cuesta-like or asymmetric profile, with the fault scarp forming a short, steep western slope and a backslope dipping gently eastward at generally less than 3° or about 200 ft/mi. The beds usually dip more steeply than the land surface, thus exposing progressively younger rocks to the east and southeast (Hendrickson & Jones, 1952).

The principal structural elements within the Guadalupe Mountains area have been described in detail by Hayes (1964), Boyd (1958), and King (1948). These include the Huapache and Bone Springs Flexures and the folds which parallel the Reef Escarpment (refer to Section 3.4.8). The only faults along the eastern periphery of the uplift, paralleling the reef, are short normal faults of very small displacement, which probably originated as tension joints (Hayes, 1964). The major faulting in the area is located to the west of the Guadalupe Mountains Uplift, where many closely spaced faults trend north to northwest. Hayes (1964) describes those in the New Mexico portion of the area in three groups: those along the Guadalupe Mountains scarp north of Stone Canyon, those parallel to the Shattuck Valley scarp south of Stone Canyon, and those in and north of the Brokeoff Mountains. Along the Guadalupe Escarpment are numerous, closely spaced, high-angle normal faults paralleling the scarp and generally downthrown on the west. From high on the scarp westward into Big Dog Canyon, the faults decrease in dip to as low as 60 degrees and increase in displacement from rarely over 100 feet on the east to about 800 feet in the canyon, low on the scarp. The faults south of Stone Canyon are separated from those to the north by an unfaulted monocline some 1 1/2 miles wide. Most of the displacement on the scarp here is

along a large fault high on the scarp having a displacement of as much as 800 feet, and an arcuarte trace convex to the east; adjacent to its trace are a number of small strike faults (Hayes, 1964; see also King, 1948; Boyd, 1958). West of the Guadalupe Mountains is a graben area occupied by a complex north-northwestward trending zone of Late Cenozoic faults in and adjacent to the Brokeoff Mountains. Most of the faults are high angle and normal and are downthrown to the east, except for several in the north that form grabens and horsts. Stratigraphic displacements here range from a few feet to about 600 feet (Hayes, 1964).

Evidence has been presented by King (1948) that tectonic deformation was occurring in the southern Guadalupe area before Middle Permian time and produced the Bone Spring Flexure, which possibly governed the location of the Delaware Basin. Hayes (1964) describes a fault zone in the Guadalupe Mountains that may have trended southeastward into the western edge of the Delaware Basin and may have been active during Mississippian to Early Permian time. Like the Sacramento Uplift, though, the Guadalupe-Delaware Mountains are primarily a Late Cenozoic structural feature, uplifted and tilted eastward by the Basin and Range tectonic activity.

King (1948) dated most of the major normal faulting of the Guadalupe Mountains area as Late Pliocene to Early Pleistocene. He did note, however, that some renewed movement along pre-existent faults probably took place in the Early Pleistocene, as evidenced by dissection of probable early Pleistocene deposits due to change in base level. But he found no evidence for younger movements in the Delaware or Guadalupe Mountains.

There is evidence, though, that development of the uplift may still be continuing at a reduced rate today. Kelley (1971) reports that during his work a small scarp in the alluvial fans along the northeastern end of the Guadalupe Fault Scarp, in T20S, R17E was found, indicating some slight Holocene uplift. More recent field investigations in the Salt Basin graben region adjacent to the Guadalupe Mountains in Texas have identified over 100 Quaternary-age normal, en echelan, and discontinuous

fault scarps and photolineaments with displacments of as much as 18 feet, which appear to be controlled by preexisting structural zones of weakness. The orientation of the scarps, the proximity of recurring seismic activity, and the youthfulness of offset surfaces suggest that these scarps have a tectonic origin and are maintained by intermittent activity which is in some places younger than 1,000 years old and probably continuing (Goetz, 1977). Such data would thus indicate some ongoing Holocene structural development of the eastern extent of the Basin and Range elements in the Southeast New Mexico west-Texas region.

3.5 REGIONAL IGNEOUS ACTIVITY

Large-scale post-Precambrian igneous activity in the southeast New Mexico-west Texas area consists of Early to mid-Tertiary intrusive bodies and Tertiary to Quaternary volcanic terrains located well to the north, west, and south of the site area. Figure 3.5-1 presents the regional distribution of known igneous features. Within the northern Delaware Basin, only minor igneous activity, in the form of one or more Tertiary dikes and possibly associated sills, is known to have occurred. This section discusses the igneous features known to exist within about 100 miles of the WIPP site and considers in particular detail the near-site intrusives within the northern Delaware Basin.

3.5.1 Near-site Activity

The outcrops of igneous dike-related material nearest to the WIPP site are located about 42 miles southwest of the site, in the Yeso Hills. Subsurface samples of intrusive igneous rock within about 9 miles of the site have also been obtained from drill holes and from two underground potash mining operations, located some 10 miles apart in the Salado Formation. Aeromagnetic investigations have also indicated the presence of magnetically responsive, perhaps igneous, materials in this area. Whether all these occurrences represent parts of one dike or en enchelon dikes, they together produce a very linear trend striking approximately N50^{o} E for a distance in excess of 75 miles. This trend extends from a

point near the Texas-New Mexico border southeast of Carlsbad Caverns at least to the northeasterly most well intercept, some 30 miles northeast of the site (Elliot, 1976b; Claiborne and Gera, 1974). The location of the intercepts and magnetic indications and the dike trace they suggest are plotted on Figure 3.5-2.

The outcrops in the Yeso Hills consist of rectilinear patches of rust-colored, earthy material studded with occasional sharp, small fragments of a dark, fine-grained igneous rock that represent the surface expression of three parallel, en enchelon dikes within the outcropping Castile gypsum. The dikes trend east northeast and vary in width up to about 20 feet and in length up to about one-half mile (Pratt, 1954). These outcrops are separated by a distance of about 27 miles from the nearest subsurface dike intercepts or definite magnetic response along strike to the northeast.

Intercepts of intrusive igneous material have been reported from at least 9 drill holes within the northern Delaware Basin along the trend indicated above (See Table 3.5-I). These intercepts have generally been multiple in each well or drill hole. For instance, the Stanolind U.S. Duncan #1 is reported to have 8 intercepts which range in depth of location from 470 to 13,300 feet. Several petroleum exploration geologists have interpreted the occurrences to represent a series of sill-like intrusions (Elliot, 1976b), a theory which may be supported by magnetic data discussed below.

Dike exposures have also been observed in the underground workings of the International Minerals and Chemical Corporation mine, located approximately 9-1/2 miles northwest of the proposed WIPP site, and in the Hobbs Plant mine of the Kerr-McGee Chemical Corporation, some 10-1/2 miles north of the site (See Table 3.5-1). The dike exposures in these mines are intruded into the Upper Permian Salado Formation. These intrusives are nearly vertical and usually only a few inches to a foot thick, but thicken to approximately 15 feet wide at their widest observed point, in the Kerr McGee mine. No displacement exists between the salt

beds on the two sides of the dike and, in one of the mines, the end of the dike can be observed (Claiborne & Gera, 1974), indicating a discontinuous, segmented character.

Airborne magnetic surveys of the region, performed by the U.S. Geological Survey, have been utilized to help determine the position of the dike material and its genetic relationship to the surrounding rock strata. These surveys show magnetic indications of a dike-like structure extending southwestward from a point approximately 30 miles northeast of the WIPP site to near the Pecos River. The width of the magnetic anomaly so indicated varies from several miles at its base, at a depth of about 12,000 to 13,000 feet, near the Precambrian basement to a very thin trace at its upper extremity near the ground surface. Elliot (1976b) noted that an aeromagnetic response indicating such an apparent single, broad anomaly may be produced by a series of dikes which have a broad base and pinch out vertically. The feature under consideration may thus represent "a multiplicity of en echelon dikes forming a swarm, which rise generally vertically from the basement and pinch out in an upward direction (Elliot, 1976b)". According to this interpretation, one of these dikes extends upward above the other dikes, penetrating units as young as the Salado Formation, and is encountered in the outcrops and subsurface intercepts. The multiple showings from one drill hole are, according to this interpretation, thought to represent small sill-like projections which extend outward horizontally from the main vertical dike source.

The dike or series of dike-related features indicated by the above lines of evidence has a similar appearance, composition, and structure wherever it has been encountered in the subsurface. The dike rock is a medium-gray to grayish-black, fine-grained porphyritic material identified as lamprophyre by Jones (1973). The groundmass of the rock consists of orthoclase with accessory biotite, which is partially altered to vermiculite, and minor amounts of ilmenite, apatite, anatase and pyrite. The rock also contains corroded andesine phenocrysts and pseudomorphs of siderite and antigorite after pyroxene. Amygdules as large as 2 mm in diameter, filled with halite, siderite, calcite, and natrolite are dispersed through the dike rock.

Nearly vertical and subhorizontal fissures are present throughout the dike and are usually filled with halite, with local polyhalite, anhydrite and minor amounts of pyrite, dolomite, quartz and crystalline hydrocarbons. The dike has a rather poorly-developed flow structure and a chilled border. The halite of the adjacent intruded beds has been recrystallized as much as 3/4 inch along the dike contact, and, in places, contains methane and other gases under pressure. Where the termination of the intrusive mass is observed, a vein of polyhalite, also containing minor amounts of pyrite, dolomite, and crystalline hydrocarbons, extends upward into the adjacent salt, indicating that some migration of fluids along the dike must have taken place following intrusion. Later recrystallization and plastic flowage have, however, healed any permeable zones which may have formed at the time of the intrusion and flowing water is not now present where the dike is observable (Claiborne & Gera, 1974).

Specimens of the dike material from the Yeso Hills were classified by Peter H. Masson (reported in Pratt, 1954) as an alkali trachyte and as a soda trachyte of porphyritic texture with principal minerals of anorthoclase, albite, chlorite, ilmenite, and magnetite. The rocks are severely altered, and the walls of the dikes are not clearly defined. Both specimens examined were vesicular, indicating a surface environment of cooling and crystallization. Calcite and gypsum often line the vesicles as secondary deposits (Pratt, 1954).

The emplacement of the lamprophyre dikes probably occurred during mid-Tertiary time, approximately 30 million years ago. Urry (1936) dated the intrusives at 30 +1.5 m.y., from drill hole cuttings of the Texas Co. No. 1 Moore well, located about 12 miles north of the WIPP site. More recent K/Ar whole-rock dating by the U.S. Geological Survey, Denver, has determined an age for a sample (#J-1-71(M75)) of this dike of about 34.8±0.8 million years (recalculated for recent change in measured decay constant) (C. L. Jones, personal communication).

The span of time thus indicated since intrusion has been ample to provide for complete cooling of even the largest of these intrusive bodies, and at the present time there is no evidence of magnetic masses unusually close to the surface in the area.

These dike indications may represent part of an en echelon dike arrays extending northeastward for almost 80 miles from the Gypsum Hills in southern Eddy County, near the New Mexico-Texas state line, to the Vacuum oil field south of Buckeye in central Lea County, New Mexico.

The northeast trend of all these dikes generally coincides with the orientation of several tectonic lineaments in the area and also parallels the trend of crevasses and joints in the carbonate rock of the Capitan and Tansill Formation near Carlsbad Caverns. These fractures are filled with Early Cretaceous sandstones and conglomerates. Thus, the emplacement of the magmatic material may have been facilitated by earlier patterns of structural weakness, which developed in response to regional stresses operative previous to Cenozoic time. The date of the dikes, however, suggests that their development may have been related events which were precursors to the later Basin and Range tectonism of Mid-to-late Tertiary time.

3.5.2 Guadalupe-Delaware Mountains Area Activity

King (1948) described several occurrences of igneous material in the Guadalupe-Delaware Mountain area. He identified one small intrusive plug, about 15 miles southwest of the Yeso Hills dikes, located within the Delaware Mountains in a ravine one-half mile north of Lamar Canyon, 1-1/2 miles east of its junction with Cherry Canyon. This plug forms a low ridge several hundred feet long and cuts sandstones within the Guadalupian-age Bell Canyon Formation. These sandstones have been tilted, baked, and silicified, according to King, for about 10 feet from the edge of the plug. The intrusive rock itself he described as "light gray and aphanitic, probably a trachyte." Pratt (1954) later examined this reported plug and similar outcrops in the area. He found no igneous

rock or any tilted or baked sandstones, only evidence of intense silicification of the sandstones within low parallel ridges oriented north northwest. Pratt, however, interpreted these features to be evidence of underlying intrusive dikes, as did King. Pratt futher stated that the dikes formed part of the siliceous mantle of an underlying igneous intrusion.

Seven miles to the east southeast of these chalcedony-like ridges, within the Magnolia Petroleum Company's Homer Cowden No. 1 well, a body of igneous rock has been intercepted at depths from 8,730 feet to 9,140 feet (Pratt, 1954). The feature is oriented parallel to the trend of the hypothesized dikes of Lamar Canyon and is interpreted as a sill. Pratt (1954) suggests that "the source of this intrusion may also be the source of the solutions which so intensely silicified the conspicuous outcrops" in the Delaware Mountains, described above. The "sill" is composed of extremely porous, light gray and holocrystalline rock with prominent black needles of a ferromagnesian mineral, which has been analyzed by Peter T. Flawn as a "lenco syendiorite," otherwise possibly termed a monzonite (Pratt, 1954).

King (1948) has postulated the existence of a third buried intrusive, located in the Guadalupe Mountains of Texas, approximately 1-1/2 miles south of the Otero-Eddy county line, on the northeast slope of Lost Peak. His hypothesis is based on the observation that the Carlsbad limestone here, at the Calumet and Texas mine, "has been replaced by copper, lead, zinc, and iron minerals, which probably emanated from an igneous source beneath (King, 1948)."

The age of the igneous intrusive activity in the Guadalupe-Delaware Mountains region has been conjectured by King (1948) as Early Tertiary or somewhat younger, representing the northern extension of a vast number of intrusives related to the intense Trans-Pecos Davis Mountain activity. Unlike the region further south, however, little remains of these records in the Guadalupe Mountains area, and only minor igneous activity occurred here (King, 1948). Pratt (1954), in agreement with King's dating work,

has stated that the Delaware Mountain materials he investigated "may reasonably be presumed to be of Tertiary age." He based this judgement on the assumption that these rocks are similar in composition to the generally alkalic igneous rocks identified by Flawn (1952) as comprising the Tertiary intrusives of the west Texas-eastern New Mexico area.

3.5.3 Trans-Pecos Magmatic Province

The Trans-Pecos "magmatic province" comprises a vast area of both intrusive and extrusive igneous outcrop terrains of Tertiary age situated east of the Rio Grande River and west and south of the Guadalupe-Delaware Mountains, approaching within about 90 miles of the WIPP site at the northern extent of the province. The magmatic province extends a distance of about 225 miles from the Diablo Plateau-Cornudas Mountains outcrops near the New Mexico-Texas border, southeastward through the Davis Mountains volcanic area and associated intrusives to the southern tip of Texas (see Figure 3.5-I). The entire province contains in excess of 200 intrusive bodies having outcrops exceeding about 1/2 square mile each in surface area (Barker, 1977) in addition to the approximately 6,000 square-mile region of volcanic outcrop terrain of the Davis Mountains area (from Cohee, et al., 1962). According to King (1948), this magmatic province was developed during Early Tertiary time, when great sheets of lava spread over the Davis Mountains and adjacent areas, across a surface of Cretaceous and older rocks. Both the lavas and sedimentary rocks were then intruded by a host of small to large intrusive masses, some of which were far removed from the Davis Mountains region. Barker (1977) has determined that the magmatic activity in the Trans-Pecos province occurred during the interval from 43 to 16 million years before present. Those intrusives which lie closest to the site are discussed further, below.

Within the northern portion of the Diablo Plateau, some 22 intrusive igneous bodies are exposed along a north northwest trending belt. The northernmost of these igneous outcrops occurs within the Cornudas Mountains, which are centered approximately 105 miles west-southwest of the proposed WIPP site, on the Texas-New Mexico border.

These intrusions, known collectively as the Cornudas Group, generally consist of a central group of plugs, surrounded by sills and laccoliths. The materials composing these intrusions have been classified as nepheline syenites, phonolites, or quartz-bearing syenites. The older rocks are generally fine to coarse-grained, equigranular to porphyritic, with only weakly and locally developed flow structure. The younger rocks of the group are fine-grained, microporphyritic and vesicular, with strongly developed flow structure. Abundant autoliths of alkalic igneous material are contained within several of the intrusions of the Cornudas Mountains (Barker, et al., 1977).

K-Ar dating of biotite in igneous rock samples from the Cornudas Group yields an age of approximately 31 to 37 m.y. for the time of intrusion. The intrusives were emplaced in sedimentary rocks which range in age from Early Permian to Cretaceous (Barker, et al., 1977).

3.5.4 El Camino del Diablo and Railroad Mountain Dikes

The east-west trending El Camino del Diablo and Railroad Mountain dikes are the igneous features nearest to the WIPP site on the north, beyond the limits of the Delaware Basin. The outcrop areas of both dikes are covered by a thin veneer of gravel, caliche, and alluvium (Kelley, 1971), and neither have much expression on LANDSAT imagery.

The southernmost of the two dikes, El Camino del Diablo, is located approximately 67 miles north of the WIPP site. The dike can be traced on the surface for about 25 miles (Kelley, 1971) from the caliche-capped plains east of the Pecos River eastward until it disappears under the Mescalero sands. The dike varies in width from some 32 feet on the west to about 47 feet at its easternmost outcrop. Although it exhibits very little topographic expression, in places along its trace the dike is marked by a slight depression produced by a greater erosion of the dike than of the surrounding country rock. The intrusive material is an extensively altered, fine-grained, slightly porphyritic, bluish-gray rock displaying typical diabasic texture and is composed of augite and

magnetite in a matrix of lath-shaped feldspar crystals. Since the composition is intermediate between an andesite and basalt, the rock has been classified as an "augite-andesite" (Semmes, 1920). Bordering the dike are contact zones from one to 12 feet wide, which consist primarily of a mere baking of the country rock with no appreciable mineralization.

The Railroad Mountain Dike parallels the Camino del Diablo Dike 13 miles 6o the north and extends a distance of about 30 miles from the eastern side of the Pecos River eastward into the Mescalero sands. The width of the dike is remarkably constant, measuring at most about 100 feet, which suggested to Semmes (1920) that the exposed portion represents only a fraction of the entire intrusion (Kelley, 1971; Semmes, 1920). In contrast with the Camino del Diablo Dike, this dike forms a ridge, which in places reaches as high as 60 to 80 feet. On LANDSAT imagery, it has its most pronounced expression as it approaches the Matador uplift region to the east. The dike material is a massive, dense, dark-blue, medium-grained granitoid rock composed of pyroxene and olivine with considerable magnetite in a felt-like mass of interlocking lath-shaped plagioclase crystals. The rock may thus be classified as an olivine gabbro, of more basic nature than most of the other intrusives of the region. Almost no secondary alteration has occurred, which accounts for the dike's prominent ridge-like expression (Semmes, 1920). The contact zone between the dike and host rock displays a slight baking but little mineralization and is, at most, several feet wide.

Both the Railroad Mountain and El Camino del Diablo Dikes have been classified as Tertiary in age by Cohee (1962) and have intruded rocks as young as the Triassic Santa Rosa Sandstone (Kelley, 1971). Semmes (1920) considered the dikes to have been Eocene or younger in age and possibly as young as Middle to Late Tertiary, representing later stages in Tertiary igneous activity, when the basaltic intrusives and extrusives of the area originated. The generic relationship of the dikes to other features in the region is unclear, but airborne magnetic surveys indicate that both of the dikes "nose out" to both east and west (Elliot, 1976b).

This would seem to preclude the dikes being direct extensions of either the Capitan stock activity, to the west (see section 3.5.5, below), or of the Matador Arch (section 3.4.4) to the east.

3.5.5 Capitan and Sierra Blanca Mountains Region

The Capitan intrusive is located within the Capitan Mountains region approximately 117 miles northwest of the WIPP site. The feature is about 21 miles long and from 3.5 to 5 miles wide, with an above ground volume of about 20 cubic miles (Kelley, 1971; Semmes, 1920). There is some controversy regarding the nature of the intrusion, due to the fact that it has characteristics of both a laccolith and a stock. Typical of a laccolith, there is evidence of a concordant roof along most of the summit, but the structural and stratigraphic discordances, including observed uplift and structural nosing, favor its designation as a stock. In any case, the intrusion has penetrated units as young as the Rio Bonito member of the San Andres Formation and the Yeso Formation, of Middle Permian Leonardian age. Along the eastern end of the mountain, the Yeso beds stand almost vertically near the contact (Kelley, 1971). "Mesaverde beds" of Cretaceous age show thermal alteration as well according to Kelley (1971).

The Capitan intrusive is remarkably uniform for its size in both composition and texture. It is a medium- to fine-grained, slightly porphyritic rock, classified by Kelley (1971) as a leucoratic quartz syenite. The Capitan intrusive has been designated as Tertiary in age by Cohee (1962); Semmes (1920) suggested that it may be of Early Tertiary age, in concurrence with Lindgren, et al. (1910), who considered all of the quartz-bearing monzonitic and dioritic intrusives of this area to be Early Tertiary. Semmes (1920) considered these acidic intrusives to represent an early stage in igneous activity, preceeding the more basic, less extrusive diorities and gabbros of later Tertiary time.

Immediately west and southwest of the Capitan intrusive, underlying and cropping out in the Sierra Blanca Mountains, are the Sierra Blanca volcanics, dikes, and stocks.

The Sierra Blanca volcanics crop out in an area of some 200 square miles; Thompson (1966) believes that the field was once as large as 750 square miles prior to intrusion by the stocks and Late Tertiary erosion. The volcanics consist of massive, purplish-brown, andesitic breccias, flow, and tuffs overlain by trachtye breccia and have a recorded thickness of as much as 3,340 feet. These volcanics are thought to be of Early to Mid-Tertiary age (Kelley, 1971; Thompson, 1966).

Some 200 dikes occur in swarms oriented generally radially with respect to the Sierra Blanca stocks and in a great swarm 7 miles wide and 22 miles long, trending north northeastward from Ruidoso to east of Patos Mountain. The dikes are generally traceable for less than one mile and range in thickness from one foot to 60 or 70 feet. They vary in composition from a few occurrences of syenite porphyry to diabasic, although 60 to 70 percent of the dikes are basic (Kelley, 1971). Since the dikes intrude the Sierra Blanca volcanics, they post-date them, and may be Mid-Tertiary in age.

3.5.6 Conclusions

The data presented above indicate that, within some 100 miles of the WIPP site, no igneous activity has taken place since the early part of Basin and Range tectonism, which began in the mid-Tertiary. In the near-site vicinity, the closest igneous feature to the site is a lamprophyre dike or series of en echelon dikes, which approaches no nearer than about nine miles from the site; no associated igneous bodies have been found to approach or underlie the site itself. The dike has been dated as approximately 35 m.y. old and has long since completely solidified and cooled. Younger intrusive and extrusive features are situated far to the west of the site, beyond the area of discussion, and are associated with the regions of more recent Basin and Range tectonism. Thus, judging from the pattern of the structural development of the northern Delaware Basin area, further igneous activity is not expected in the near-site region.

3.6 REGIONAL GEOLOGIC HISTORY

Figure 3.6-1 presents a summary of the major geologic events which have affected the southeast New Mexico-west Texas area as have been determined from the rock types and structural relationships for which evidence remains and has been uncovered.

3.6.1 Precambrian

Very little is known about the Precambrian history of the southeast New Mexico-west Texas area. The Precambrian rocks penetrated in the Guadalupe Mountain and Sacramento uplift regions in southern Lea County and in west Texas, consist of plutonic granitics and metamorphics, which suggest that the region has a complex Precambrian history of mountain building, metamorphism, and erosional cycles (Nicholson & Clebsch, 1961; Hayes, 1964; Kelley, 1971). According to Flawn (1956), the Precambrian granitics encountered in the southern part of this area comprise a generally stable mass, called the Texas Craton, which extended northward from Texas into southeastern New Mexico. Muehlberger, et al. (1967), however, have demonstrated that these materials comprise part of a much more complicated basement surface representing a variety of environments involving intrusive and extrusive igneous activity as well as metamorphism of sediments.

The ages suggested for the Precambrian rocks encountered in this region are all fairly ancient. In the core of the Pajarito Mountain dome, southeast of the Sacramento uplift, the metamorphics have a radiometric date of 1,270 million years (Kelley, 1971). The granitics and metamorphics of the Guadalupe Mountain area are probably somewhat less than one billion years old (Hayes, 1964), while slightly greater ages have been indicated for the Precambrian rocks of the Texas Craton. Wasserberg, et al. (1962) determined ages of 1,250 to 1,400 million years in the northern part of the area and a younger 1,090 million years terrain to the south, suggesting progressively younger metamorphic events from north to south in this region during the Precambrian.

There is no record of the latest Precambrian or of most of the Cambrian time in this region; however, about one billion years before present the area was reduced to a nearly level plain upon which the Paleozoic rocks were later deposited (Hayes, 1964).

3.6.2 Early and Middle Paleozoic

During most of the Paleozoic Era, from at least Late Cambrian until near the close of the Mississippian Period, the eastern New Mexico-western Texas area was part of a broad, low-lying, generally stable region named the Tobosa Basin by Galley (1958). The shallow basins of the area formed northern arms of the Ouachita trough, which shoaled on the north in south-central New Mexico and merged southward with the Ouachita-Marathon geosyncline, connecting with the open sea in the vicinity of the present Gulf Coast or coast of southern California (Brokaw, et al., 1972; Hills, 1972). During the early Paleozoic there seem to have been no well-marked platforms within the basin. However, lines of weakness along strike-slip faults in the basement probably were present (Hills, 1970). Along these faults later vertical movement took place (Hills, 1972).

For a span of about 180 million years, until Late Mississippian time, almost continuous deposition occurred in this area under conditions of general tectonic stability in shallow seas periodically transgressing from the south. Shelf-type carbonate deposition predominated but was interrupted by shale sedimentation during Middle Ordovician, Late Devonian, and Early Mississippian. The total section of these sediments is about 2,500 feet, from the base of the Bliss Sandstone to the top of the Helms Shale, in the Guadalupe Uplift-southeastern New Mexico area (Hayes, 1964).

The chief events which characterized each period of the Early through Middle Paleozoic are summarized below.

Cambrian-Ordovician. No rock record older than Late Cambrian age has been uncovered in the southeastern New Mexico area (Hayes, 1964). The Bliss

Sandstone near El Paso, Texas, provides evidence of clastic sedimentation in that area during part of the Late Cambrian. After the Precambrian rocks had been uplifted and deeply eroded, a sea advanced over the region from the west or southwest and the Bliss sandstone was deposited; the abundant quartz grains in the Bliss were probably derived from reworking of sedimentary debris on the eroded Precambrian surface (Harbour, 1972; Bachman and Meyers, 1969).

During Early Ordovician time, the sea in which the Bliss was deposited continued to transgress eastward and extended at least as far north as Roswell. During this time, the carbonates and clastics known as the El Paso Formation in New Mexico and the Ellenburger in west Texas were deposited in shallow seas containing abundant marine life (Bachman, 1969). These sediments thickened southeastward from a thin layer lapping onto a positive area of Precambrian basement then present in northern New Mexico and Colorado to a massive deposit over 2,000 feet thick in Texas, at the edge of what may have been the continental shelf (Eardley, 1962). At this time, the ancestral Central Basin Platform was a granitic upland or island chain which provided clastics to the early Ordovician shelf and adjacent shallow basin deposits.

During the Ordovician, the Marathon-Ouachita geosyncline bounding the Tobosa Basin area on the south began subsiding (McGlasson, 1968). In Mid-Ordovician time, a broad and gently emergent peninsula, extending southeastward through Texas, rose, and the region was also tilted southward. To the north, the shales, sandstones, and sandy limestones of the Simpson Group were deposited above the El Paso--Ellenburger, wedging out north at the latitude of Roswell, west around Artesia and east around the Central Basin Platform. Southward, toward the deepening basin regions, the deposits thickened and became predominantly shaly. In Middle to Late Ordovician time, fewer clastics were provided to the area, and the carbonates, and fine-grained calcareous muds of the Montoya Group were deposited in shallower, calmer seas than earlier, that moved northward over the tilted surface of the El Paso Formation. At the close of Montoya time, a gentle southward tilting occurred (Bachman, 1969).

Silurian-Devonian. During Silurian and Devonian time, the Pedernal Landmass, to the northwest, and the Texas Peninsula, to the south, were land areas of low relief. The Tobosa Basin between these two areas, joined southward with the Marathon-Ouachita geosyncline. There is no evidence of major tectonic activity during this time in west Texas or southeast New Mexico. However, mild epeirogenic movements did occur, and the Tobosa Basin was gently subsiding throughout the period, becoming also more restricted areally. To the south, the Ouachita-Marathon geosyncline reached its maximum depth.

During Early Silurian time, most of the Tobosa Basin was emergent but low-lying. By the Middle Silurian, the sea returned, perhaps transgressing from the south and southeast, and broad, shallow areas developed around the northern, eastern, and western margins of the Tobosa Basin, upon which the thick Fusselman dolomites and limestones were deposited conformably in a marine environment atop the Montoya Group in clear, well-circulating water (McGlasson, 1968; Harbour, 1972; Bachman, 1969). At this time, the basin waters reached their furthest extent into New Mexico. Minor fluctuations of sea level within this shallow area of deposition produced a karst topography on the surface of the periodically exposed carbonates. During Late Silurian time, southward tilting occurred once more, and the sea regressed. Within the deeper areas to the south into Texas, a sediment-starved condition developed, resulting in deposition of micrites and green shales. Around the Tobosa Basin rim, carbonates continued to form (McGlasson, 1968).

The shallow sea continued to retreat from the New Mexico area through Early and Middle Devonian time. In Early Devonian, the shoreline had retreated, producing a carbonate plain of low relief. The depositional basin had an asymmetrical shape, with the deepest water to the west, in which cherts and silicious limestones were deposited. By the late Middle Devonian, mild uplift and southward tilting had occurred, and most of the Tobosa Basin was exposed to erosional processes; the only deep water lay to the south, where the basin plunged into the Marathon-Ouachita geosyncline. In Late Devonian time, the area was again submerged as

shallow seas spread across southern New Mexico, and the dark heavily clastic Woodford shales were deposited in a nearshore environment (Bachman 1969), overlapping all of the previous Devonian and Silurian deposits (McGlasson, 1968). Woodford deposition continued into Mississippian time.

Mississippian. Subsidence of the Tobosa Basin continued into Mississippian time. The Texas peninsula to the south and the Pedernal landmass to the northwest were mildly positive features and remained so until the Middle Mississippian (McGlasson, 1968).

In Early Mississippian time, a new paleogeographic regime began to develop in this region. The ancient Tobosa Basin began deepening on either side of a medial zone, later to become the Central Basin Platform, that was bounded by Precambrian basement faults. Shelf deposition continued along the margins of the basinal areas.

Toward Late Mississippian time, regional tectonic activity accelerated in the Tobosa Basin area, folding up the medial zone along its ancient lines of weakness. By the end of the period, erosion had probably exposed Precambrian rocks in the cores of the larger anticlines (Hills, 1963). Meanwhile, deep, broad basins, the forerunners of the Delaware and Midland Basins, formed to the east and west of the median upland area. Broad carbonate shelves developed around the margins of these basins, while black shale sedimentation occurred in their deep central portions. The black shale deposition was probably slow, much of it taking place during times of slight sea level sinking (Hills, 1972). Toward the south end of the basins, deposition of the shale and sandstone of the Tesnus Formation continued from Late Mississippian into the beginning of Pennsylvanian time, the clastics apparently being derived from highlands on the southeast which were rising in the earliest activity of the Ouachita orogeny (Flawn, 1961).

To the north of the basins, the Matador Arch was upfolded in the latest Mississippian and rapidly eroded to expose its Precambrian core. At the same time, orogenic forces raised the Ancestral Rocky Mountains to the

west, in a general north-south trend through central New Mexico (Stipp, 1960), producing a regional southward tilt which resulted in widespread erosion, exposing progressively older rocks toward the north.

By the close of the Mississippian Period, most of northeast New Mexico formed a low hilly area of Precambrian rocks, rimmed on the north and east by outcrops of Lower Ordovician dolomites and on the south by the uplifted former site of the Tobosa basin.

3.6.3 Late Paleozoic

Pennsylvanian. Following Mississippian time, the entire region was invaded by the sea from the south and east, and, particularly near the uplifted areas, tremendous thicknesses of Pennsylvanian rocks were deposited unconformably over the tilted bedrock strata, which ranged in age from Mississippian in the south to Precambrian northward in central New Mexico (Hills, 1963; Meyer, 1968). The tectonic processes initiated near the close of the Mississippian, including uplift and erosion of mountains in the Ouachita-Marathon area, of the mountain range separating the early Delaware and Midland Basin areas, and of the Matador Arch and Ancestral Rockies, continued into early Pennsylvanian, providing clastic materials to the adjacent basins. This tectonic activity also involved vertical movement along the ancient strike slip faults, with some new faulting taking place in the recently deposited early Pennsylvanian rocks (Hills, 1972; Stipp, 1960).

The basal Pennsylvanian rocks, the Morrowan, occupied the smallest area, wedging out northward, and contained the greatest proportion of coarse clastic material of the Pennsylvanian section. Along the edges of the platforms, especially in the eastern basin, strong reef and bank growth also occurred during the beginning of the Pennsylvanian. At the same time, submarine tectonism began in the Guadalupe Mountains area, continuing intermittently through the period, elevating the southeastern part of the area relative to the northeast along the northwest-trending Huapache thrust zone (Hayes, 1964).

Lower Middle Pennsylvanian Atokan strata were deposited over most of the southeastern New Mexico area except for the then-positive Pedernal uplift. During this time, anticlinal folds developed north of the Delaware Basin area on the Northwestern Shelf, and the Central Basin Platform range was uplifted as a fault block and eroded. By Desmoinesian time in upper Middle Pennsylvanian, deposition in the Permian basin region consisted primarily of limestones. The environmental setting consisted of a back-reef (lagoon), reef, and basin or open sea, a situation which persisted from this time through Late Pennsylvanian and much of Permian time (Meyer, 1968).

During most of the Late Pennsylvanian, depositional conditions in the Permian Basin were similar to those of Desmoinesian time. The sea encroached farther than before onto the rising Pedernal landmass, followed by a regression beginning in the northwest. To the northeast, the land was intermittently emergent. And southward, in Texas, the Ouachita-Marathon disturbance folding and uplift was being followed by strong northward thrusting, which continued into early Permian time (Hills, 1963). Ensuing erosion from these areas provided an abundance of clastics to the Late Pennsylvanian deposits. The Central Basin Platform, emergent throughout most of the Pennsylvanian, began to subside and received a sequence of Late Pennsylvanian sediments (Nicholson & Clebsch, 1961). Meanwhile, reef banks continued to form, especially along the northwestern edge of the Delaware Basin.

Toward the close of Pennsylvanian time, tectonic activity had virtually ceased, and mixed continental and marine sediments were deposited in the lower areas, nearly obscuring the irregular sea bottom caused by the earlier tectonism (Hayes, 1964).

At the end of Pennsylvanian time the entire region subsided, and the major features of the Permian Basin became firmly established. The rapidly eroding range of the Central Basin Platform separated the Delaware and Midland Basins which were rimmed to the north by a broad shelf area. By this time, the Delaware and Midland Basins were probably both

topographically and structurally deep; only the northern part of the Midland Basin remained a relatively shallow platform, upon which the Horseshoe Atoll grew (Oriel et al., 1967). The Central Basin Platform and shelf areas were subsiding more slowly than was the Delaware Basin and consequently received a lesser thickness of sediments, which were lithologically distinct from the deeper water deposits of the basin (Nicholson & Clebsch, 1961).

Permian. Through Early Permian Wolfcampian time, sedimentation was continuous in most of the basin areas of southeast New Mexico and west Texas, with shales deposited in the low areas and limestone on the shelves (Hills, 1972). The regression in the northwest which had commenced in the Late Pennsylvanian became pronounced, and the acceleration of the rise of the Pedernal uplift through Early Permian resulted in its denudation well into the Precambrian basement rocks. Southward, the Delaware and Midland Basins and the Val Verde Trough were rapidly sinking, at a rate exceeding that of deposition, a situation which favored shales and other stagnant-water deposits to form there (Oriel et al., 1967). The deepening of these basins, as well as uplift elsewhere, was encouraged by the development of major normal fault zones towards late Wolfcampian time (Meyer, 1968), along the north and west sides of the Diablo Platform, on the southeast side of the Pedernal Uplift, and along the periodically emergent Central Basin Platform, where strong submarine relief was produced. Around the perimeter of the Delaware Basin, the Abo reef developed, along with back-reef lagoons into which muds and carbonates accumulated. Along the south border of the Permian Basin region, the final northward thrusting of the Ouchita-Marathon structural belt occurred, causing Late Pennsylvanian and Early Permian strata to be overridden and a large volume of detritus to pour into the Val Verde trough (Hills, 1963; Oriel, et al, 1967). Following the close of this activity, the rest of Permian time was marked by regional tectonic stability in which depositional basins separated by platform areas passed through maturity.

Through Middle Permian time, restriction of marine circulation, coupled with eustatic withdrawal of the sea in a southwest direction, resulted in the development of high reefs and carbonate banks, behind which evaporites, ranging from dolomites, sulfates, and chlorides to potash minerals, were deposited in highly saline, shallow lagoons (Hills, 1972).

Early in lower Middle Permian Leonardian time, movement on a line along the Delaware Basin margin, the later Bone Spring monoclinal structure, accompanied by continued subsidence of the basin, produced a more definite northwest margin of the basin, the development of which resulted in deposition of a great submarine bank that formed a barrier to free circulation of the sea water. The gray carbonates of the Victorio Peak formation represent patch reefs which built upward and southwards across earlier deposits as the basin margin regressed. Similar carbonate reefs and banks formed along the margins of the Midland Basin as well as on the Central Basin Platform, overlying the old medial mountain range (Hills, 1972). Within the deep basin areas the black limestones and shales of the Bone Spring were deposited, and on the broad back-reef lagoonal shelf north and northeast of the basin, the Yeso gypsum and limestone or dolomite and clastics were laid down. Northwestward, the entire area including the Pedernal was gradually overlapped by sediments, and, by latest Leonardian time, all but a few of the highest Precambrian peaks were buried (Kelley, 1971).

At the end of Leonardian time and into the Guadalupian, pronounced differential movement occurred along the Delaware Basin margin, and a broad, southeastward-dipping fold, the Bone Spring Arch, was elevated, forming a barrier 15 to 20 miles wide between the basin and the Northwestern Shelf area (Hayes, 1964). In a marked regression, the seas withdrew, and were nearly restricted to the Delaware Basin (King, 1942).

As Guadalupian time opened, the arching and limited evaporitic conditions resulted in deposition of clastics in the basins and limestone on the shelf areas (Kelley, 1971; Hayes, 1964).

By the mid-Guadalupian, slight rejuvenation of the Bone Spring arch led to growth of lime-bank deposits upon the arch, which provided the foundation for a barrier reef, the Goat Seep. As the Delaware Basin continued to deepen, the reef grew primarily upwards, in consequence, restricting circulation, thus producing sediment-starved conditions within the basin and leading to the precipitation of calcium sulfate shelfward for a distance of 15 to 25 miles. (Oriel et al., 1967; Hayes, 1964). Eastward, the Midland Basin gradually filled and became favorable for evaporite deposition, in common with the adjacent shelves and Central Basin Platform.

Late Guadalupian time brought gradual subsidence of the shelf and even greater downwarping of the Delaware Basin, while renewed reef growth occurred at great pace around the periphery of the Delaware Basin. The Capitan Limestone began to grow upward and basinward in oblique fashion from the top of the Goat Seep dolomite, resulting in a wide barrier which even at its narrowest point was six times as wide as it was high (Hayes, 1964; Newell et al., 1972). Most investigators consider the Capitan to have been a true barrier reef. Achauer (1969), however, believes that it originated as a linear organic belt, instead, since he finds no coincidence between the topographic and lithologic break produced by it, and Dunham (1972) hypothesizes that the structure represents a marginal mound. In any case, as the structure grew, deposition in the basin proceeded more slowly than on the shelf and did not keep pace with the sinking of the basin, so that by the close of the period, the sea bottom in the Delaware Basin was about 1,500 feet below the adjacent reef and lagoon floor to the northwest. The reefs and banks eventually grew almost continually around the periphery of the Delaware Basin, and by the close of Guadalupian time, access of water to and from the open ocean was sharply restricted, the seas of the shelf area evaporated, and the water of the Delaware Basin itself became highly saline, thus halting the reef growth.

The Delaware Basin was essentially an evaporating pan by the beginning of Late Permian Ochoan time. Many hundreds of feet of Castile evaporites, containing anhydrite and limestone laminae at the bottom and a few beds of

halite, were deposited in the basin, with apparently little in the reef and back-reef areas. By the latest Castile time, the basin had filled such that a thin tongue of anhydrite extended northward across the reef to the shelf. Saline waters then spread from the Delaware Basin over the shelf, the Central Basin Platform and Midland Basin areas, and extensive salt deposition occurred, resulting in the predominantly halite Salado Formation. From this time on, the old Permian Basin structures, notably the Central Basin Platform, became progressively more deeply buried by Late Permian sediments and no longer constituted depositional barriers. Periodically, clastics swept into the area from the north and northwest, increasing towards the end of Salado time, as the Pedernal Landmass underwent renewed uplift. At the same time, the sea freshened somewhat, probably from the south, judging from the presence of more soluble salts northward, in New Mexico. Halite deposition decreased while anhydrite became dominant, along with an increase in carbonate muds during Rustler Formation deposition (Hayes, 1964; Brokaw et al., 1972). Broad epeirogenic uplift at the close of Permian time caused the seas to withdraw, and the continental fine sands and silts of the Dewey Lake Redbeds were deposited in a thin layer on broad mudflats over the former seabed (Brokaw et al., 1972; Kelley, 1971). As terrestrial conditions developed across the New Mexico-west Texas area, erosion became the dominant geologic process.

3.6.4 Mesozoic Rocks

Triassic. During most of Triassic time, the southeast New Mexico area was emergent and subject to erosion, and by late Triassic the entire area, including the Pedernal, must have been reduced to a great peneplain (Kelley, 1971). In Late Triassic time, a broad floodplain basin formed on the site of the Permian Basin over a large area and beyond the borders of the Delaware Basin. This was an interior basin draining toward the northwest into other interior basins (Hills, 1963, Brokaw, et al., 1972). Source areas to the north provided fluvial sands, muds, and gravels to the basin, forming the Dockum Group red beds that included the Santa Rosa Sandstone and finer-grained Chinle Formation.

The nearly conformable relationship which exists between these Upper Triassic strata and the Permian Dewey Lake Redbeds indicates continued regional tectonic stability through Triassic time (Oriel, et al., 1967). It is possible that some dissolution of soluble Permian rocks occurred during the general emergence of Triassic time. Bachman and Johnson (1973) state that during this period, sinkholes may have formed in parts of the Pecos Valley due to removal of salts (Gorman & Robeck, 1946). And Bachman (1974) describes a Late Triassic karst topography in the vicinity of Santa Rosa, New Mexico. However, direct evidence for this Triassic dissolution and collapse has not been found in southeastern New Mexico (Bachman, 1974).

Jurassic. During Jurassic time, the southeast New Mexico area was uplifted above sea level so that the Triassic and perhaps Permian rocks in the western part of the Delaware Basin and westward were eroded away. Some dissolution of Permian salt deposits probably occurred here at this time. The period of exposure, which generally affected the entire Permian Basin, may have been 50 million years; however, the surface relief was probably low, and erosion was not deep. This is the first of three erosional cycles which have incised the Triassic rocks of the area (Nicholson & Clebsch, 1961; Bachman, 1974).

During Jurassic time, continental rocks were laid down to the north, in central and northern New Mexico, derived from the sediments being stripped from the eroding basin area in southeastern New Mexico. South of the basins, in western Texas and northern Mexico, marine conditions prevailed during at least part of the time (Bachman, 1974). By Late Jurassic Entrada and Morrison time, seas again encroached on the north, covering southeast Colorado and northeastern New Mexico. And from the Late Jurassic into the Early Cretaceous, a slight tilt involving uplift took place in the northern part of the former basins region, accompanied by widespread erosional stripping across the area (Hills, 1963; Kelley, 1971).

Cretaceous. By the early part of Cretaceous time, the west Texas-southeast New Mexico area comprised a rolling topography of Triassic rocks with beds from Precambrian to Permian exposed on the uplifts and on

the Diablo Platform. The geography evolved from that of interior basins with highlands in the north and east to a general gulfward slope with highlands in the west and evidence of only slight tectonic activity (Hills, 1963; Kelley, 1971).

During Cretaceous time, a large part of the western interior of North America became submerged beneath epicontinental seas. By late in the Early Cretaceous, the southeast New Mexico area had subsided slightly, and shallow shelf seas advanced over the area from the south and remained until early in Late Cretaceous time, when the seas probably withdrew for the last time, leaving behind a thin deposit of fossiliferous limestone and coarse sandstone and conglomerate (Hayes, 1964; Nicholson & Clebsch, 1961). Isolated slump blocks of limestone and shale in Lea County east of Eunice, in the Pecos River drainage, in the Sacramento and Guadalupe Mountains and perhaps on the crest of the reef escarpment are the only remaining evidence of the sea's advance in the southeast New Mexico area (Hayes, 1964; Bachman, 1973).

There is no record of most of the Late Cretaceous in the area. The land surface was probably slightly above sea level, and the region was dry land by the close of Cretaceous time (Bachman & Johnson, 1973).

3.6.5 Cenozoic

Early Tertiary. The Mesozoic Era came to a close with the Laramide revolution and uplift of the Rocky Mountains. Late in the Cretaceous or very early in the Tertiary Period, the entire region from north of the Guadalupe Mountains through southeast New Mexico was elevated by broad epeirogenic uplift and tilted slightly to the northeast. Mild tectonism affected the Guadalupe area of the Northwestern Shelf, producing small igneous dikes, fold systems, and setting the stage for the ancestral northeast flowing drainage system (Hayes, 1964). Igneous activity also occurred to the northwest in the Sierra Blanca and Capitan Mountains (Bachman, 1974). In general, however, most of the area southwest of the Pedernal Uplift and Matador Arch was not subject to such tectonic forces.

According to Hills (1963), these ancient positive elements formed buttresses which transmitted and distributed the orogenic forces on the east, and this protected the basins on the southeast from folding.

The dominant process in southeast New Mexico from Late Cretaceous until Late Tertiary, notwithstanding the minor tectonism, was erosion. No Early or Middle Tertiary rocks are represented in the Permian Basin. The Cretaceous and Triassic rocks of the area underwent intense erosion to form a surface of low relief, sloping gently east and southeast (Bachman, 1974; Brokaw, et al., 1972). In the Lea County area of southeast New Mexico, the entire sequence of Cretaceous rocks, particularly to the west, was stripped off, except for small remnants, and the Triassic rocks were subjected to a second cycle of erosion (Nicholson & Clebsch, 1961). By Late Tertiary Miocene time, erosion had again exposed the Permian rocks to dissolution, notably in the vicinity of San Simon Swale (Bachman, 1974).

Late Tertiary (Miocene-Pliocene). In Late Tertiary time, regional uplift and east-to-southeastward tilting occurred throughout southeastern New Mexico into Texas, as Basin and Range tectonic activity commenced to the west, producing the western escarpments of the Delaware, Guadalupe, and Sacramento Mountains. The western section of the Permian evaporites was elevated, and exposed to dissolution and subsidence, particularly in the vicinity of the Pecos River divide, which created new patterns of groundwater movement (Bachman, 1973; Mercer & Orr, 1977). Erosional forces carved a pediment-like surface, down which streams flowing eastward from the Rocky Mountains deposited an extensive blanket of gravel, sand, and related deposits in coalescing fans, which comprise the Ogallala Formation. Deposition of the Ogallala began about 12 million years ago, in Miocene time. The Ogallala represents the first preserved sedimentary record in the vicinity of the Delaware Basin since Cretaceous deposition (Bachman, 1974). The Ogallala formed a thick mantle throughout the Permian Basin, producing the even surface of the High Plains, called the Llano Estacado in western Texas and eastern New Mexico. Locally, eolian activity played a part in deposition, and periodically, widespread soils formed (Frye, 1970).

Ogallala deposition ended about 4 million years ago, in Pliocene time, with regional warping and uplift. Eolian activity reworked the sediments, producing a widespread soil profile across the Great Plains. A caliche zone formed within the soil complex and constitutes the carbonate "caprock" of today (Mercer & Orr, 1977; Bachman & Johnson, 1973). The caliche caprock has since undergone a complex history of brecciation, solution, and recementation (Bachman, 1973).

Pleistocene-Holocene. During the Late Pliocene and Early Pleistocene, the major part of the faulting and uplift of the Guadalupe Mountains occurred (Hayes, 1964). Concurrently to the east, fields of great longitudinal dunes formed atop the Ogallala surface of the southern Great Plains as a result of desert conditions with westerly to northwesterly prevailing winds. Since this time, erosion has exceeded deposition in the Permian salt basin area. Etching and thinning of the caliche caprock between the dunes created series of parallel swales. Erosion and coalescence of subsided areas removed Ogallala sediments, and in places also eroded the Triassic rocks a third time and entrenched the Pecos and San Simon drainages (Nicholson Clebsch, 1961; Mercer & Orr, 1977). Also during early to Middle Pleistocene time, Nash Draw, Clayton Basin, and probably San Simon Swale underwent extensive subsidence and partial filling (Bachman, 1973). Local sink holes and other solution features began to form at this time.

The most humid climate and the greatest erosion occurred during the Middle Pleistocene. The western escarpment of the High Plains underwent severe erosion, followed by a period of aggradation in the valley areas, during which the mostly locally-derived pebbles and other coarse debris of the Gatuna Formation filled the depressions and mantled the slopes (Brokaw, et al., 1972). During this time of heavy precipitation and stream flow, major salt dissolution is assumed to have occurred within the Delaware basin (Bachman, 1974). After Gatuna time, but still during the Middle Pleistocene, the region became more stable and semi-arid, and the Mescalero caliche formed on the ground surface.

During the Late Pleistocene, there were intermittent episodes of caliche formation and renewed periods of high rainfall accompanied by erosion and salt dissolution, which produced local subsidence and deposition of fluvial and lacustrine sediments.

From Late Pleistocene through Holocene time, the climate has remained variable although becoming more arid. The detrital materials have been reworked by winds from the west and southwest, giving rise to the vast deposits of dune sand that now cover large parts of southeast New Mexico east of the Pecos River (Nicholson & Clebsch, 1961; Bachman, 1973). Some slight uplift is also probably still occurring along the western escarpments of the Basin and Range structures, such as the Guadalupe Mountains. Renewed periodic downcutting by streams and subsurface solution with resultant subsidence, have continued to the present, accompanied by intermittant local accumulations of pediment and terrace alluvium and playa deposits. Most of the recent erosion has been confined to the Pecos Valley, and solution and subsidence have occurred at a slower rate than during the earlier Pleistocene time (Bachman, 1973).

3.7 SUMMARY

The regional geology of SENM is the source of much information germane to long-term safety; knowledge of the regional geology also permits preliminary site selection and general evaluation of the consistency of site geology with regional geology.

The regional geology and geological history may first be divided into three major intervals of about .5 billion years each. This period from about 1.5 to 1.0 billion years ago is represented by metamorphosed rocks of various sedimentary to igneous origins. The time from about 1.0 to .5 billion years ago is not known to be represented by rocks through most of the region; erosion is assumed to be the dominant geological process during this time. The last interval, from about .5 billion years ago to the present, shows more complexity in the rock record. From about 500 to

100 million years ago, SENM shows a rock record of mostly marine sediments deposited in a basin that became shallower as time passed. About 225 million years ago the marine environment became quite restricted, resulting in deposition of about 4000 feet of evaporites in which it is proposed to dispose of radioactive waste. The lack of rock record in much of the region from about 100 million years to about 4 million years ago imply that erosion has been dominant. Fluvial sediments and caliche developed within the last 4 million years suggest some change in base level but considerable stability.

The list of important structural events in the region include metamonolusm and relative uplift during the Precambrian, downwarping through much of the Paleozoic, some downwarping and uplift during the Mesozoic, and some uplift during the Cenozoic. Specific structural features include basin and range type faulting more than 70 miles west of the site and about 1o eastward tilting of the Delaware Basin; both of these features are believed to be about mid-Cenozoic in age. The Central Basin Platform to the east of the site has probably not been active since the Permian (see also Chapter 5).

Thus the regional geology furnishes evidence of tectonic and geologic stability that will be used for assessing the safety of a repository at the WIPP site.

3.8 REFERENCES

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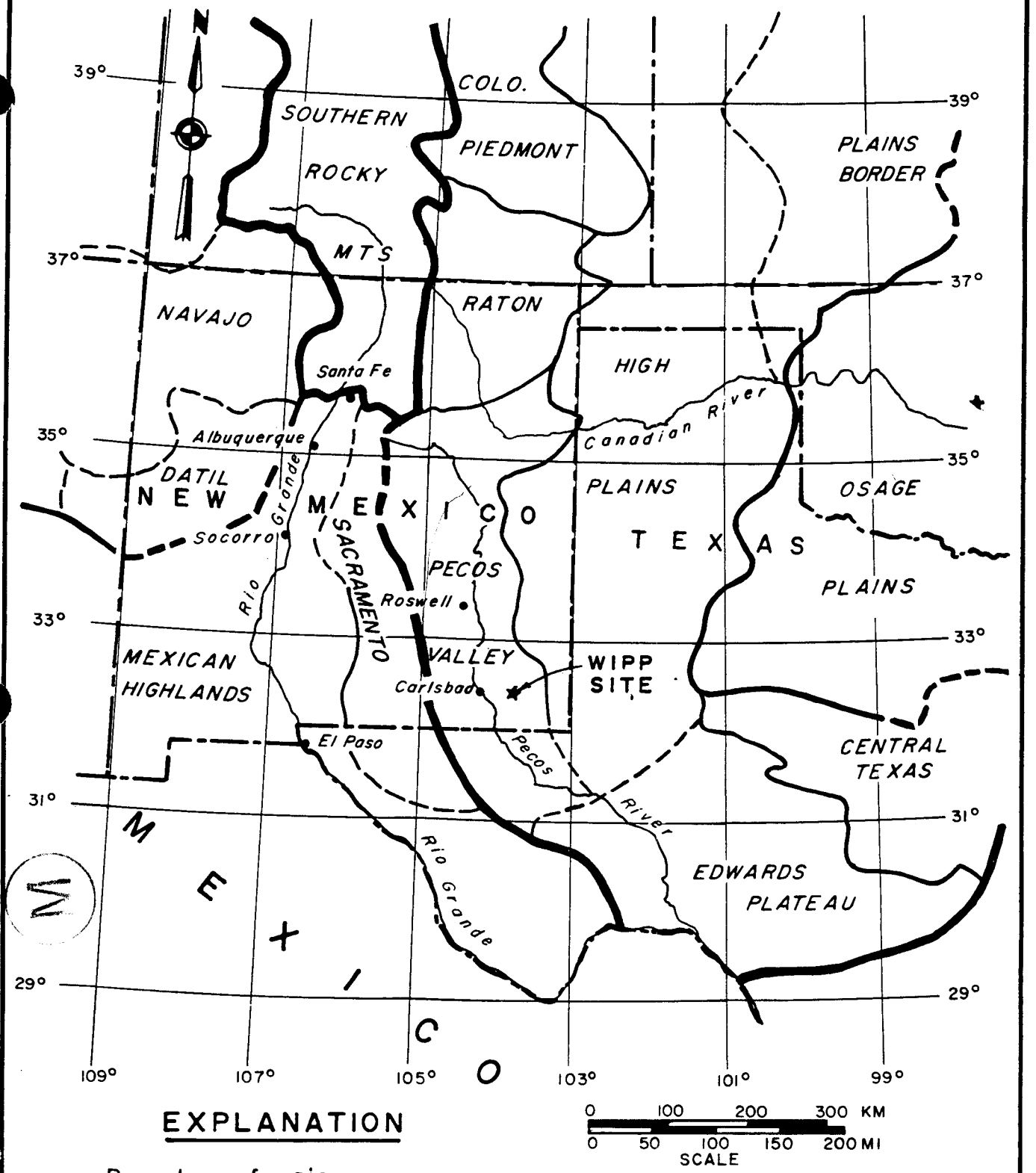

PHYSIOGRAPHIC SECTIONS

REFERENCE:

Fenneman, N.M., and D.W. Johnson, 1946.

FIGURE 3.2-1

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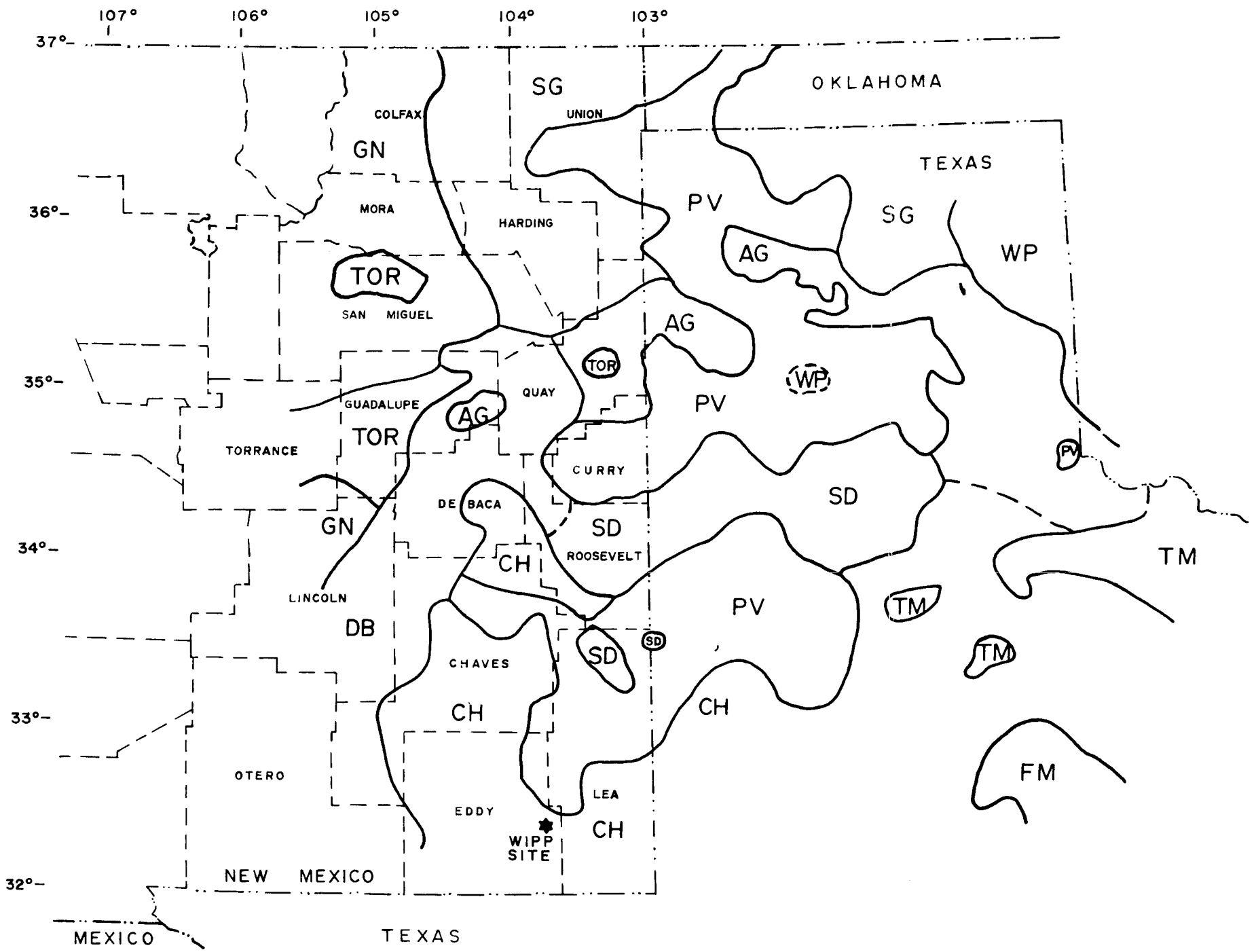

EXPLANATION

CH: Chaves granitic terrane

PV: Panhandle volcanic terrane

SD: Swisher diabasic terrane

DB: De Baca terrane

TM: Tillman metasedimentary group

GN: Older gneiss and granite

AG: Amarillo granite terrane

TOR: Older metasedimentary and meta-igneous rocks

SG: Sierra Grande granite terrane

WP: Cambrian igneous rocks: Wichita Province

FM: Fisher metasedimentary terrane

_ _ _ _ County boundary

_ · _ · _ State boundary

_ · · _ · · _ International boundary

REFERENCE:

Muehlberger, et al. (1967)

25 0 25 50 75miles

PRECAMBRIAN ROCKS OF TEXAS PANHANDLE AND EASTERN NEW MEXICO

FIGURE 3.3-1

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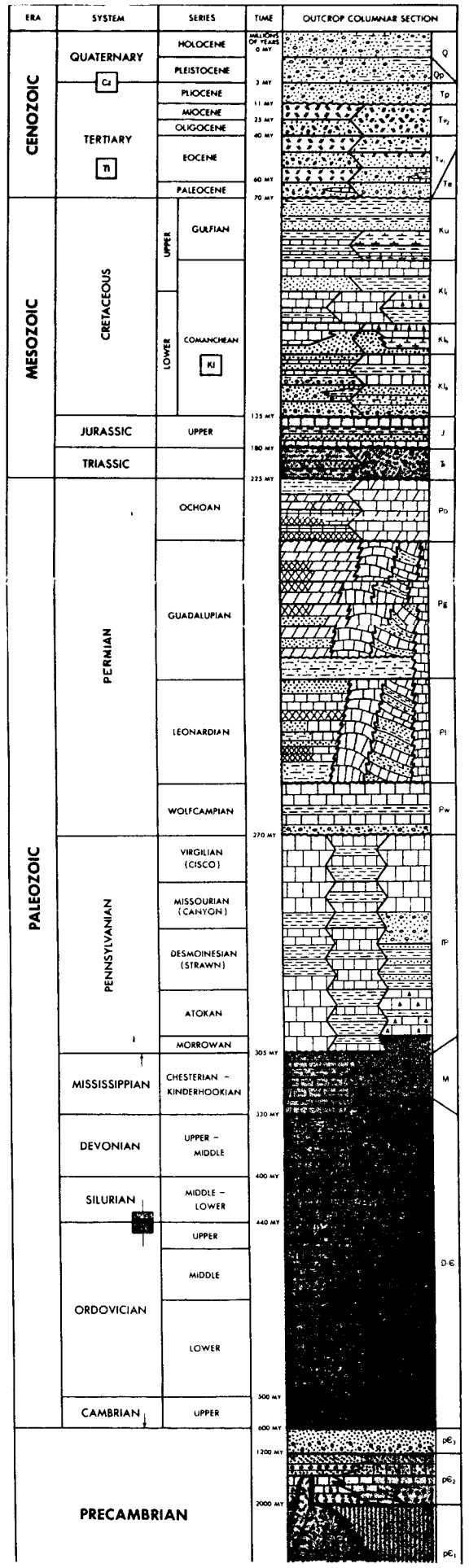

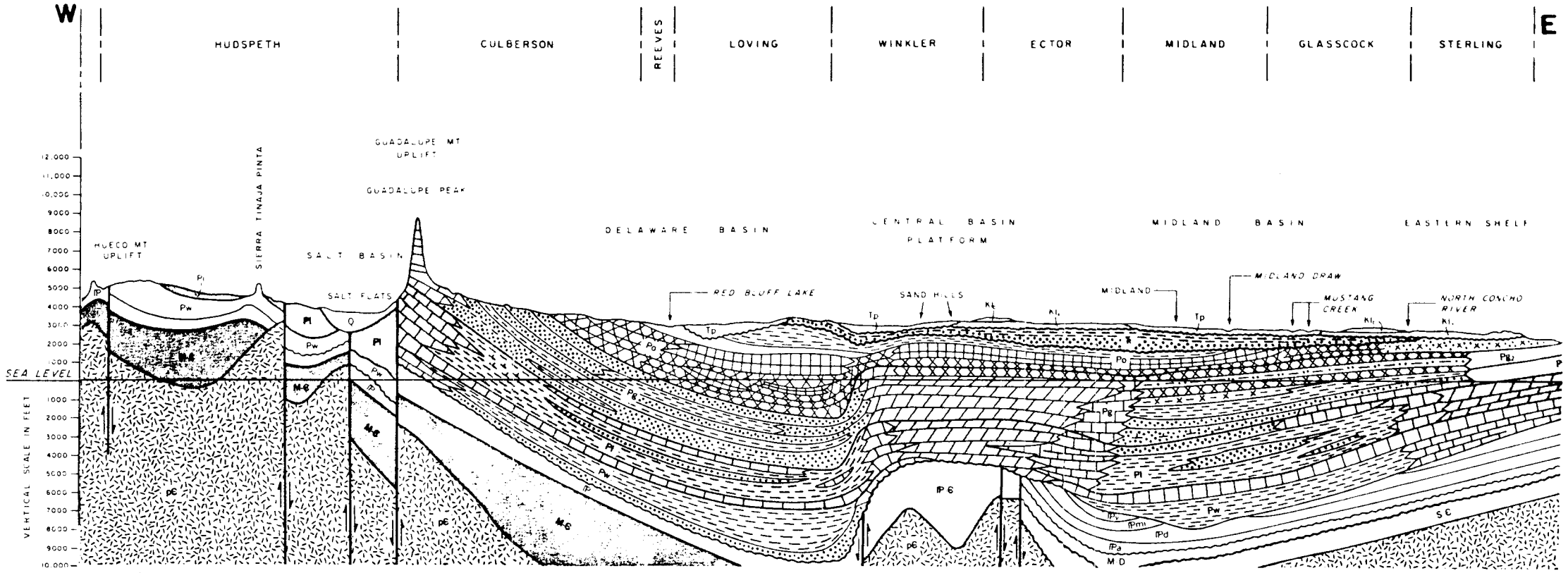

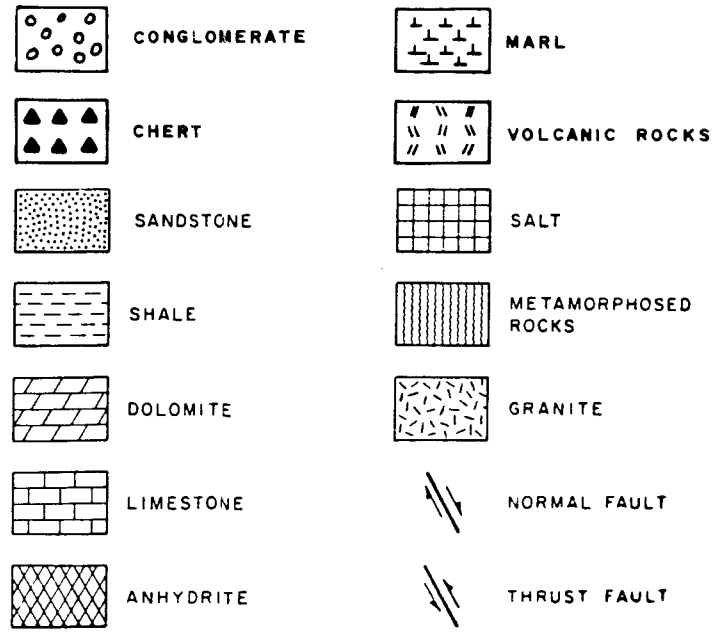

WEST–EAST CROSS SECTION
NEW MEXICO – TEXAS BORDER

REFERENCE: From Geological Highway Map of Texas, 1973

FIGURE 3.3-2

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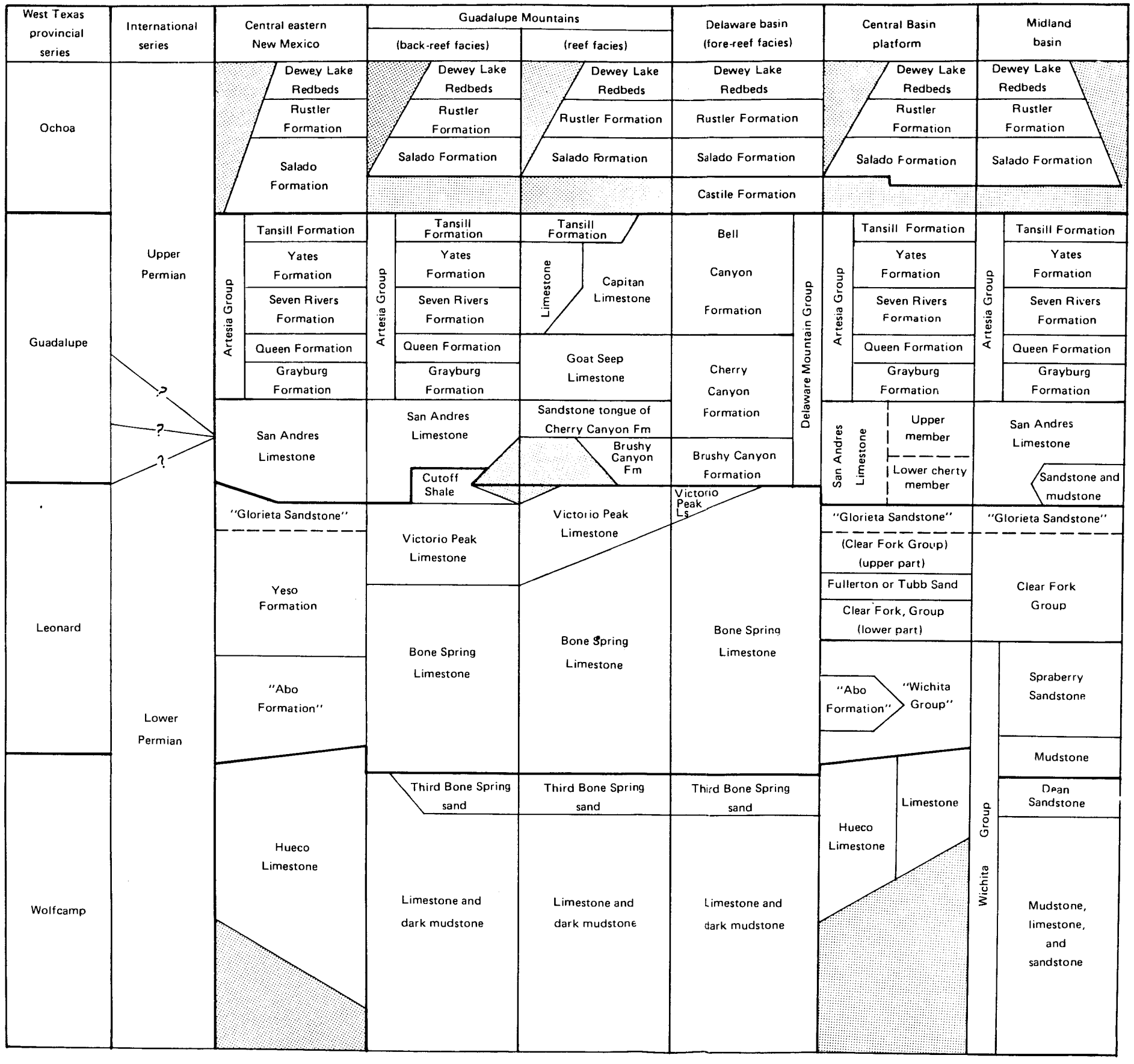

MISSING SECTION

STRATIGRAPHIC CORRELATIONS
PERMIAN SYSTEM
SOUTHEAST NEW MEXICO

FIGURE 3.3-3

REFERENCE:

U.S.G.S. Prof. Paper 515, Table 1, 1967.

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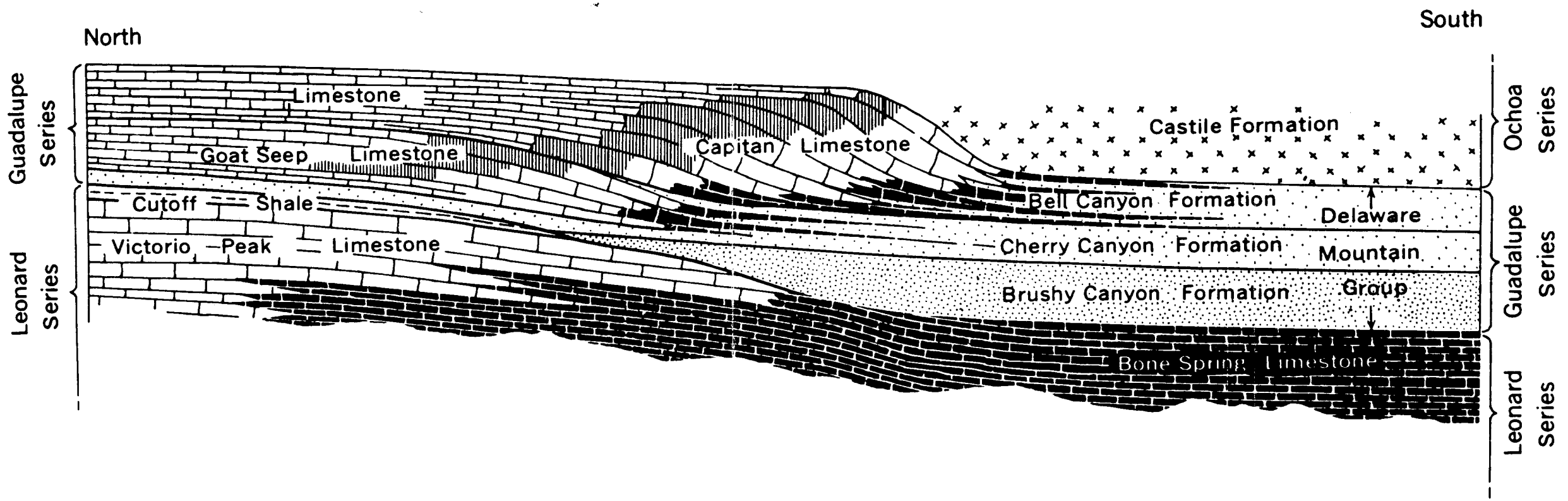

EXPLANATION

BACK-REEF OR SHELF DEPOSITS

- Hueco Limestone, of various facies, but without known reef deposits
- Thin-bedded gray limestone
- Cutoff shale
- Sandstone, locally conglomeratic

DEPOSITS OF REEF ZONE

- Massive gray or white limestone; forms reef crest
- Gray detrital limestone in thick inclined layers; forms reef face
- Thick-bedded gray limestone; forms bank deposits

FORE-REEF OR BASIN DEPOSITS

- Coarse-grained massive sandstone (in Brushy Canyon Formation)
- Fine-grained thin-bedded sandstone (in Cherry Canyon and Bell Canyon Formations)
- Dark-gray or black thin-bedded limestone

OTHER ROCK UNITS

- Pre-Permian rocks
- Evaporitic rocks chiefly anhydrite with limestone laminae

Horizontal scale

0 1 2 miles

Vertical scale

0 5000 feet

Stratigraphic summary of the Guadalupe, Leonard, and adjacent series of the Permian System in the Southern Guadalupe Mountains. The Delaware basin area is to the right and the shelf or platform area is to to the left. Rock facies are greatly generalized.

REFERENCE:

Adapted from E.D. McKee, et al. (1967).

(Originally compiled from P.B. King (1942, 1948)).

CROSS SECTION OF

CAPITAN REEF AREA

FIGURE 3.3-4

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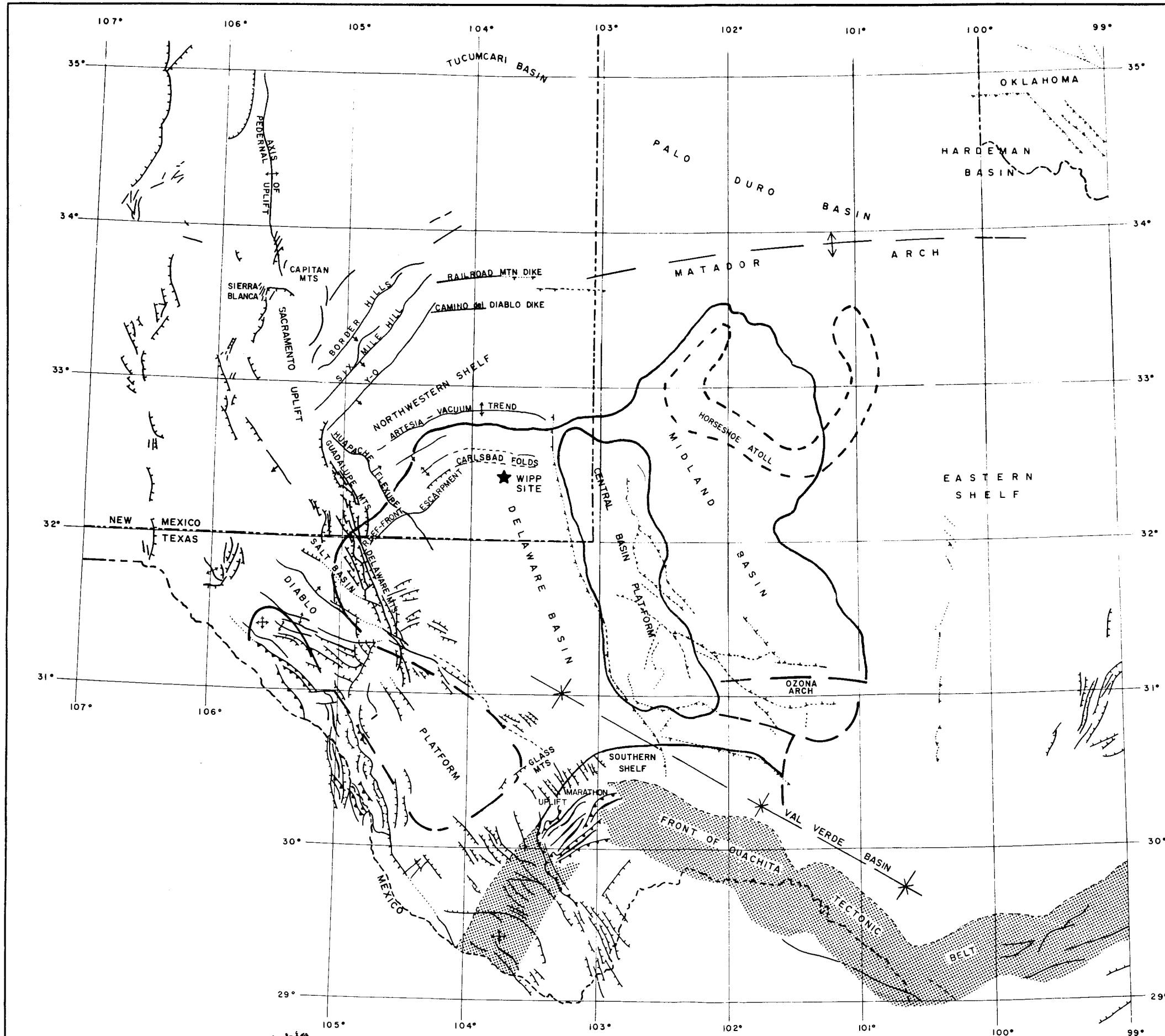

EXPLANATION

Fault, type unspecified; dashed where inferred, dotted where concealed.

Thrust fault; saw teeth on upthrown side, dashed where inferred, dotted where concealed.

Normal fault; hachures on downthrown side, dashed where inferred, dotted where concealed.

Elongate, closely compressed anticline; width suggests height, steepness or size of fold.

Axis of major anticline.

Axis of major syncline.

Dome.

Boundaries of major structural elements. (From Steven S. Oriel, et al., 1967)

Ouachita Tectonic Belt.

REFERENCES:

1. Cohee, G.V., et al, 1962
2. Kelley, V. C., 1971.
3. Claiborne, H.C., and F. Gera, 1974.
4. Oriel, S. S., et al., 1967.

SCALE 0 50 100 150 KM. / 0 25 50 75 100 MI.

MAJOR REGIONAL STRUCTURES

FIGURE 3.4-1

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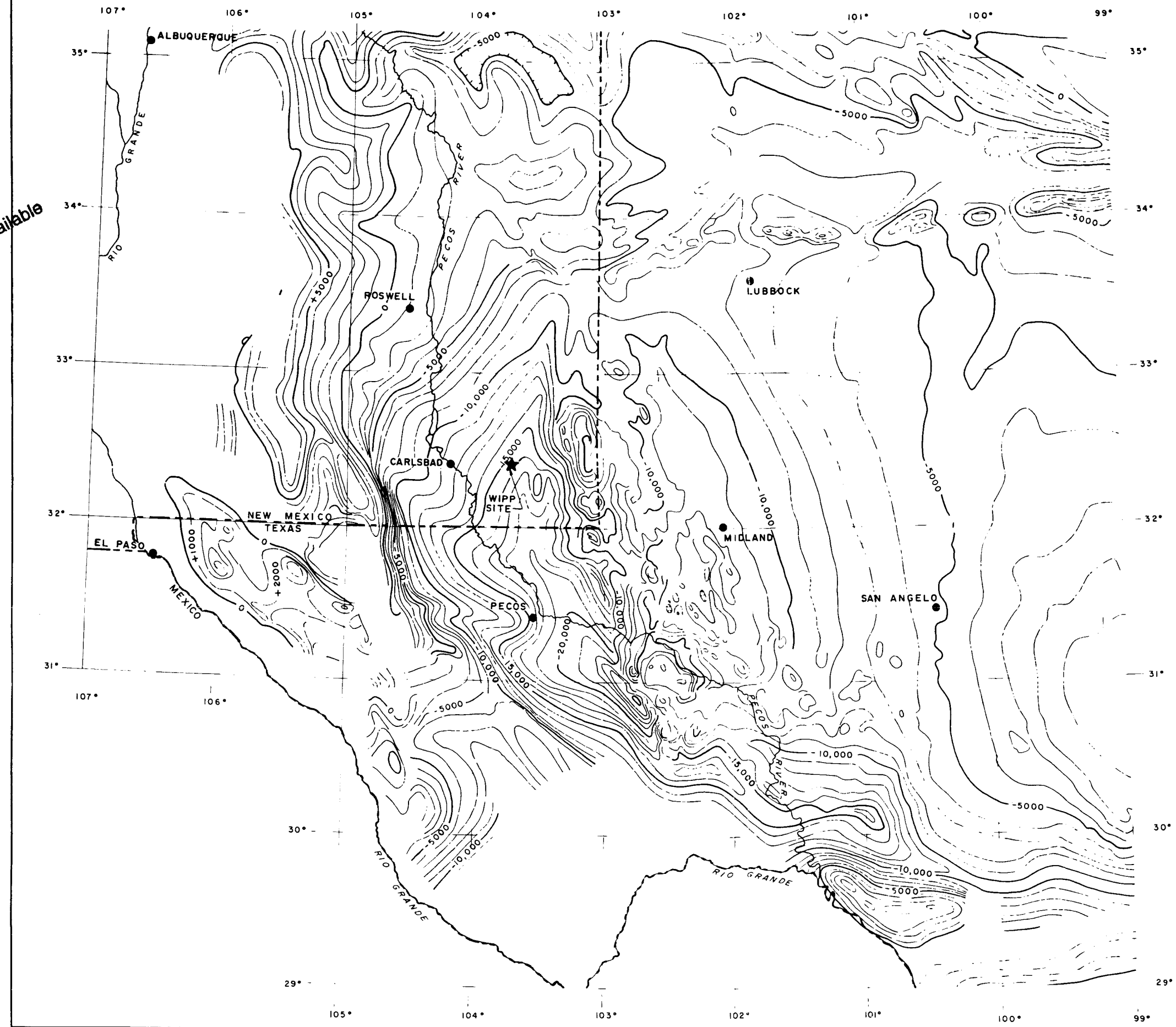

EXPLANATION

-7500 — Structure contours, in feet, at top of Precambrian section. Contour interval is 1000 feet, datum is sea level.

REFERENCE:

Cohee, G. V., et al, 1962

N

0 50 100 150 KM.
0 25 50 75 100 MI.
SCALE

STRUCTURE CONTOURS
ON TOP OF PRECAMBRIAN ROCKS

FIGURE 3.4-2

N

2v

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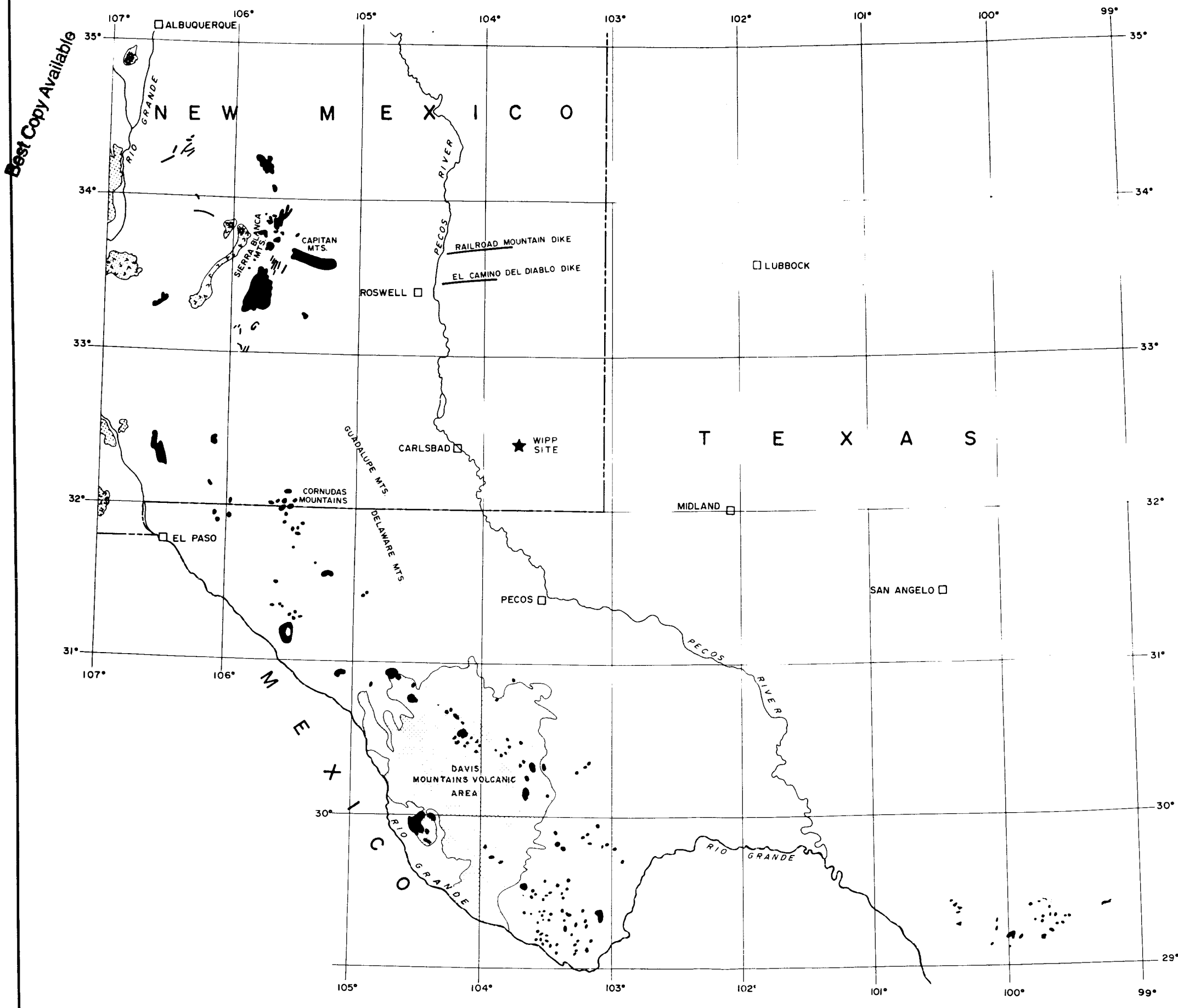

EXPLANATION

INTRUSIVE IGNEOUS ROCKS

Tertiary intrusive bodies, dikes, plugs, stocks, laccoliths

VOLCANIC ROCKS AND FEATURES

Volcanoes and volcanic cones of Quaternary and Late Tertiary age

Tertiary and Quaternary volcanic rocks. Only larger areas or areas of tectonic significance are shown. Mainly of various Tertiary ages. Volcanic rocks of Quaternary distinguished in places by v pattern

REFERENCE:

Cohee, G.V., et al., 1962

N

0 50 100 150 KM
0 25 50 75 100 MI
SCALE

REGIONAL DISTRIBUTION OF EXPOSED IGNEOUS FEATURES

FIGURE 3.5-1

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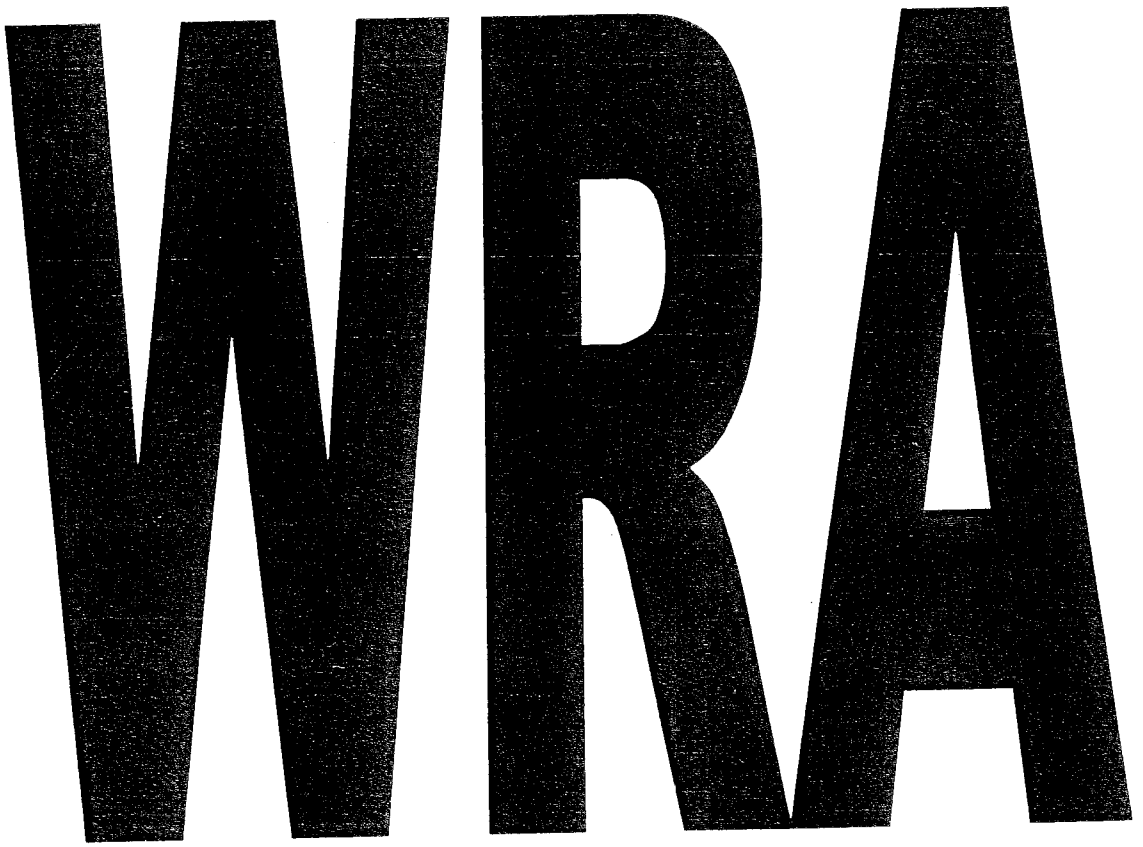

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MAJOR GEOLOGIC EVENTS – SOUTHEAST NEW MEXICO REGION

ERAS	PERIODS	EPOCHS	MILLIONS OF YEARS DURATION	MILLIONS OF YEARS BEFORE THE PRESENT	
CENOZOIC	Quaternary	Holocene	To Present	1,000,000	– Eolian and erosional/solution activity. Development of present landscape.
		Pleistocene	1,000,000		
	Tertiary	Pliocene	12,000,000		– Deposition of Ogallala fan sediments. Formation of caliche caprock.
		Miocene	12,000,000		– Regional uplift and east-southeastward tilting; Basin-Range uplift of Sacramento and Guadalupe - Delaware Mountains.
		Oligocene	11,000,000		
		Eocene	22,000,000		– Erosion dominant. No Early to Mid-Tertiary rocks present.
		Paleocene	5,000,000	63,000,000	– Laramide "revolution." Uplift of Rocky Mountains. Mild tectonism and igneous activity to west and north.
MESOZOIC	Cretaceous		72,000,000		– Submergence. Intermittant shallow seas. Thin limestone and clastics deposited.
	Jurassic		46,000,000		– Emergent conditions. Erosion. Formation of rolling topography.
					– Deposition of fluvial clastics.
	Triassic		49,000,000		– Erosion. Broad flood plain pediment surface develops.
				230,000,000	
PALEOZOIC	Permian		50,000,000		– Deposition of evaporite sequence followed by continental redbeds.
					– Sedimentation continuous in Delaware, Midland, Val Verde basins and shelf areas.
	Pennsylvanian		30,000,000		– Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
	Mississippian		35,000,000		– Regional tectonic activity accelerates, folding up Central Basin platform, Matador arch, Ancestral Rockies.
					Regional Erosion. Deep, broad basins to east and west of platform develop.
	Devonian		60,000,000		– Renewed submergence.
					– Shallow sea retreats from New Mexico. Erosion.
	Silurian		20,000,000		– Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas peninsula emergent, until Middle Mississippian.
	Ordovician		75,000,000		– Marathon – Ouachita geosyncline, to south, begins subsiding.
					– Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform, and carbonates.
	Cambrian		100,000,000		– Clastic sedimentation – Bliss sandstone.
				600,000,000	– Erosion to a nearly level plain.
PRECAMBRIAN					– Mountain - building, igneous activity, metamorphism, erosional cycles.

MAJOR GEOLOGIC EVENTS – SOUTHEAST NEW MEXICO

FIGURE 3.6-1

TABLE 3.5-I

REPORTED DIKE INTERCEPTS OR SURFACE EXPOSURES

WELL OR DRILL HOLE NAME	LOCATION	INTERCEPT DEPTHS IN FEET
Humble Oil & Refining; State "BO"#3	SE 1/4 Sec. 12, T18S-R34E	8745
Continental; Forest #1	Sec. 22, T18S-R34E	7210-8640
International Minerals Corp.; ConcDale #95	NW 1/4 Sec. 12, T20S-R32E	2239
Noranda; HB-10	SW 1/4 Sec. 14, T20S-R32E	1700
Texaco; Moore #1	SW 1/4 Sec. 21, T20S-R32E	2115
Kerr-McGee; Mine	Sec. 31, T20S-R32E	1530
Perry R. Bass; Big Eddy #44	SE 1/4 Sec. 25, T22S-R28E	12120-13330
Stanolind; U.S. Duncan #1	SW 1/4 Sec. 30, T21S-R30E	470-2710(8 Intercepts)
International Minerals Corp.; Mine	Sec. 36, T21S-R29E	790
H & W Drilling; Danford #1	SE 1/4 Sec. 9, T22S-R29E	2210
Perry R. Bass; Big Eddy #43	SE 1/4 Sec. 25, T22S-R28E	940-2050
Outcrop	Sec. 31, T25S-R25E	Surface
Outcrop	Sec. 11, T26S-R24E	Surface
Amoco; Teledyne Gas #1	Sec. 13, T23S-R28E	Rumor?
Unknown	Sec. 25, T22S-R28E	1880-1900 (γ Ray Response)

Reference: C. L. Elliot (1976 b), Table I.

GCR CHAPTER 4

SITE GEOLOGY

4.1 INTRODUCTION

This chapter is a detailed review of the geologic characteristics of the Waste Isolation Pilot Plant (WIPP) repository site and its environs, including discussions of geomorphology, stratigraphy, structure, and tectonics. In keeping with the concept of underground placement of the radioactive wastes, subsurface geologic conditions are emphasized. Structure contour and isopach maps are presented and discussed. Particular effort has been made throughout the text to relate site-specific aspects to regional geologic conditions. A final section on geologic history reviews the geologic origin and development of the WIPP site.

The available literature, including maps and reports on file with federal and state agencies, has been consulted. Results of field and research investigations carried out specifically to define site geologic conditions have been integrated into the discussion and the investigative reports referenced. Detailed descriptions of the various exploration programs and investigations may be found in Chapter 2.

4.1.1 Area of Study

The area to be considered in detail in this chapter on site geology is shown in Figure 4.1-1. It represents a 10-by-10-mile square area centered on the site, including all of Township 22 South, Range 31 East and parts of the adjacent townships in eastern Eddy and western Lea Counties in the southeastern corner of New Mexico. In many instances, however, the topics under discussion were judged to require consideration of areas more distantly removed or to benefit from a somewhat broader focus, so that Figure 4.1-1 should not be construed as a limitation of the area considered or discussed.

Also shown in Figure 4.1-1 is the outline of the WIPP site itself, locating land-use restriction zones. Zone I is the area of the surface facilities. The roughly octagonal Zone II represents the underground area which would be mined if a fully developed (3 square miles) repository were developed here. No drill hole extending through the salt beds to deeper strata occurs within one mile of the Zone II boundary. Other zones represent levels of land-use restriction and are discussed elsewhere in this report (for example, see Table 2-1). The outer boundary of Zone IV defines the area of the WIPP site. The term "Los Medanos" is also frequently used to refer to the WIPP site area, as for instance in the site selection process to distinguish the WIPP site from other alternate sites in the same region (see Chapter 2). Griswold (1977) defined the 10-by-10-mile square of Figure 4.1-1 as the "Los Medanos site"; however, for the purpose of this report, it seems more appropriate to use the term "Los Medanos" to refer to the general vicinity of the WIPP site, roughly corresponding to the sand- and dune-mantled area bearing that name and within which the site occurs.

4.2.1 Sources of Data

Much of the information specific to the Los Medanos area and to the WIPP site is available from various agencies commissioned to carry out special technical studies. In assembling these descriptions, free recourse has been made to what is available in the open literature, particularly to the numerous open-file reports released by the U.S. Geological Survey. Much useful information on surficial stratigraphy of the Los Medanos area is provided by Vine (1963) and by Bachman (1974; also in Jones, 1973); both have provided surficial geologic maps of parts of the area. Valuable compilations of stratigraphy and structure of the Ochoan evaporite sequence have been assembled by Jones (1972, 1973, 1975), by Brokaw et al. (1972), by Anderson et al. (1972), and by Anderson (1978). Permian Basin geology in general is extensively discussed in King (1948) and in McKee et al. (1967a, 1967b). Pennsylvanian studies are presented for the Los Medanos area by Foster (1974) and regionally by Meyer (1966). Much of the available information regarding pre-Pennsylvanian

stratigraphy is reviewed in Foster (1974), who presents numerous reference sections and isopach and structure contour maps for these deeply buried strata.

A series of subsurface structure contour and isopach maps has been prepared specifically for the WIPP site by Griswold (1977) and most are incorporated into this chapter. The data base for these maps is furnished by available well and borehole information supplemented by specially contracted seismic reflection surveys. The location of all boreholes and seismic reflection profiles used in the subsurface studies reported herein are shown in Figure 4.1-2 and listed in Table 4.1-1.

A glance at the depths of holes listed in Table 4.1-1 shows the paucity of data available for horizons deeper than about two thousand feet. With the possible exception of oil or gas fields where deep holes are clustered, well spacing is typically such that minor faulting probably would not be delineated; only the smoothed trend of local depressions and arches is outlined. The detection of minor faulting and other local structural detail is generally possible only through the use of deep seismic reflection techniques, supplemented by deep well control where available. Horizons which most efficiently reflect seismic wave energy are the most logical targets for detailed study of deep structures. Beneath the site, horizons which are found to be good reflectors include top of the Silurian carbonate sequence, top of Morrow limestone (lower part of Pennsylvanian rocks), and top of Delaware sand (below base of Castile). Although many hundreds of miles of seismic reflection profiling have been carried out in the Delaware Basin, nearly all of it is privately owned by industry sources and the record profiles are not subject to disclosure. Accordingly, Sandia Laboratories engaged the services of G.J. Long and Associates, Inc., of Houston, Texas and Permian Exploration Company of Roswell, New Mexico, to carry out a program of seismic reflection profiling across the WIPP site, supplemented by any oil industry data which was made accessible for examination. Over 1,500 miles of private seismic data were examined and about 70 miles of new

seismic data have been obtained by Sandia. (For further information on seismic reflection profiling and well data control used in the exploration for deep structure at the site, refer to Section 2.5).

Data regarding structural detail of bedded salt in the Delaware Basin, in contrast to deeper horizons, are not generally available in the form of seismic reflection surveys of the type normally used in subsurface exploration, nor do petroleum exploration companies generally pick stratigraphic markers above the Delaware, as there is no commercial hydrocarbon interest in these relatively shallow strata. Perhaps the lack of early recognition of the character of deformation within the bedded salt sequence is accounted for by the petroleum industry's disinterest in non-petroliferous strata. The intensive exploration drilling for potash deposits by commercial mining interests, however, has provided a means of obtaining at least some general outline of deformation features within the evaporite sequence down through the McNutt potash zone of the Salado that would not otherwise have been available. In addition, mine workings have provided supplementary detail in localized areas. Within the site exclusion area, additional potash exploratory holes have been drilled under contract to Sandia Laboratories. Because commercial potash exploration is targeted to the McNutt member of the Salado Formation, shallower strata have generally not been extensively logged and sampled, with the result that details of structure in the Rustler Formation and Dewey Lake Redbeds were not well recorded. The holes drilled under contract to Sandia Laboratories to determine the extent of potash reserves in the site area were logged through these upper formations by wireline geophysical methods and are the source of much of the shallow subsurface data near the WIPP site. Figures 4.4-11 through 4.4-15 are constructed from these data.

Nothwithstanding the apparent wealth of drill hole data in the area, it should be emphasized that well data necessarily represent an incomplete sampling and extrapolation from such data will be imprecise to an extent dependent on the well spacing, the complexity of the subsurface structure, and the level of detail desired. Well picks probably will not

record absolute maxima or minima of sharper crests and troughs, and certain smaller features could remain undetected. Other techniques such as seismic reflection aid in finding smaller structures.

4.2 SITE PHYSIOGRAPHY AND SURFICIAL GEOLOGY

4.2.1 Site Physiography

The proposed WIPP site is located on the eastern edge of the Pecos Valley section of the southern Great Plains physiographic province (Figure 3.2-1). The land surface within the area of the site is a monotonous, semi-arid, eolian plain sloping gently to the west and southwest (Figure 4.2-1a), its surface made somewhat hummocky by an abundance of sand ridges and dunes. Figure 4.2-2 is a topographic map of the area in the vicinity of the site (from Nash Draw and Hat Mesa 15-minute topographic quadrangle maps). Also shown on this figure are the boundary zones of the WIPP site as discussed in Section 4.1, extending a maximum distance of about 3 miles from the geographic center of the site. Within these boundaries, elevations range from 3,570 feet in the east to 3,250 feet in the western part of the site. The average slope from east to west is 50 feet per mile (Griswold, 1977).

In the vicinity of the site, Livingston Ridge is perhaps the most prominent physiographic feature. Located about a mile beyond the northwestern border of the WIPP site, it is a northeast-southwest trending, west facing escarpment about 75 feet high marking the east edge of Nash Draw. Nash Draw, the nearest drainage course of any significance in the vicinity of the site, is a shallow, 5-mile-wide valley open to the southwest. Elevations within Nash Draw, which descend from about 3,300 feet at its northeast head to 2,945 feet at Salt Lake, near the Pecos River, are generally 200 to 300 feet lower than the surrounding terrain and may reflect substantial subsurface dissolution of salt from the Rustler and Salado Formations and accompanying subsidence of overlying materials. Livingston Ridge marks the approximate boundary, therefore, between terrain that has undergone erosion and/or solution collapse and

terrain that has not been so affected, and may be considered to indicate the approximate position east of which significant dissolution of the underlying Salado Formation has not occurred (refer to Chapter 6 and Section 3.2 for further discussion).

East of the site, the nearest major drainage course is the southeast-trending San Simon Swale, some 15 miles or more distant (a more regional topographic map is shown in Figure 2-1). It, too, most likely owes part of its decreased elevation to subsurface dissolution. Between Sam Simon Swale and the WIPP site, a broad, low mesa named "The Divide" occurs about 6 miles east of the site, rising about 100 feet above the surrounding terrain and attaining an elevation of about 3,800 feet, and, as such, marks a local boundary between general southwest drainage toward Nash Draw and general southeast drainage toward San Simon Swale. The Divide is capped by the Ogallala Formation, and overlying caprock caliche upon which have formed small, elongate depressions similar to those found developed on the Ogallala of the High Plains, proper, farther east (refer to Regional Geomorphology, Section 3.2, for additional discussion of these features).

Surface drainage in the site area is intermittent; the nearest perennial stream is the Pecos River, more than 15 miles south-west of the center of the site. Surface runoff in the site area finds its way to the Pecos River via Nash Draw; discharge of shallow groundwater is likewise believed to be controlled by the Pecos River (refer to hydrology sections 6.2.5 and 6.3). Although basins like Nash Draw may have evolved partly through active subsurface dissolution of thick, buried salt deposits, there is no evidence available at present to evaluate differences in rates of dissolution which may have prevailed under different climatic conditions. That the site is in a natural divide between drainage basins indicates that it is protected from serious flooding and erosion from heavy runoff. Should the climate of the region become more humid in the future, any perennial streams which might then arise would be expected to follow the present basins, and Nash Draw and San Simon Swale would undergo the greatest amount of erosion from this increased humidity, leaving the divide area relatively intact (Bachman, 1974).

Because of the presence in Nash Draw and elsewhere in the Delaware Basin of extensive subsidence which appears to be caused by subsurface dissolution of salt, much attention has been focused on the search for geomorphic indications of possible subsidence features in the vicinity of the site. One feature that has attracted some attention is described by Griswold (1977) as a shallow sink about 8 miles north of the site in the southeast part of Section 9, T. 21 S., R. 31 E. (pictured in Figure 4.2-1b). The feature is very subdued, about 1,000 feet in diameter and 30 feet deep. Resistivity studies conducted by Elliot (1976) indicate very shallow surficial fill within the feature and no disturbance of underlying beds, indicating a probable surface rather than subsurface origin. This type of feature is common in southeastern New Mexico and is not necessarily indicative of an origin tied to subsurface subsidence. On the other hand, recent resistivity surveys conducted over the surficial sand cover within the WIPP site area (Elliot, 1977e) have disclosed a resistivity anomaly in section 17, T. 22 S., R. 31 E., within the limits of the Zone II exclusion area. The anomaly bears some resemblance in character to the pattern observed over a known sink, a so-called salt "breccia pipe" (Elliot 1977a). Recent drilling (WIPP 13) has shown this resistivity anomaly is not caused by dissolutioning but by lower than average resistivity in the Dewey Lake Redbeds.

4.2.2 Site Surficial Geology

Most of the site area is covered by blanket eolian sand or, especially on the north, east, and southeast, by partially stabilized sand dunes. Active sand dunes are located in the southern portion of the site (Figure 4.2-3). The sand, of Holocene age ("Mescalero sand"), forms a thin, persistent veneer no more than a few meters thick (except where dunes occur) that is believed to have been swept westward from the High Plains, where the inferred source material, the sandy Ogallala Formation, is abundant. The widespread sand cover is readily apparent on the surficial geologic map of the site area, Figure 4.2-4, which is compiled from maps prepared by Vine (1963) and Bachman (1974).

Not at all apparent from the map, however, is the general occurrence of a hard, caliche layer up to 10 feet thick immediately beneath the eolian sand blanket. The relatively high resistance of the caliche to erosion has protected the more erodable underlying strata from dissection and exposure. It is recognized over a regionally broad area and has been termed the "Mescalero caliche". Caliche may form pedogenically over geologic time at or near the surface through capillary rise of carbonate-laden water in the vadose zone followed by precipitation of solute upon evaporation of pore water (Brown, 1956). The youngest formation on which the Mescalero caliche has formed is the Pleistocene Gatuna Formation, of presumed Kansan age (Bachman, 1974). Bachman (1974) indicates that the formation of the Mescalero caliche probably dates back to the Yarmouth interglacial stage, or approximately 500,000 years ago. That such a thick, areally extensive, and continuous caliche had accreted implies past stable climatic and geomorphic conditions over the considerable time period required for its formation. The relevance of this type of paleoenvironmental indicator to the stability of present climatic conditions and to possible future climatic variablility, and the implications regarding the long-term integrity of the WIPP repository, are presently being pursued by Bachman (see Chapter 10).

On the surficial geologic map (Figure 4.2-4) exposures of the Mescalero caliche are indicated. These occur where the eolian cover is very thin or removed entirely, mostly near the edge of Nash Draw, into which much of the nearby loose sand may have been swept. Along Livingston Ridge, the Mescalero caliche is draped inward into Nash Draw and is present over much of the north half of the valley, indicating that at least some subsidence or lateral backwasting along Nash Draw has occurred subsequent to the formation of the caliche, presumably during the more humid glacial stages (Illinoian or Wisconsin) of Pleistocene time.

Within Nash Draw, and the WIPP site area, the Triassic Santa Rosa Sandstone, the Ochoan Dewey Lake Redbeds, and more than half of the Rustler Formation are sporadically exposed. Field descriptions of these formations are included in Section 4.3.

The overall geology and structure of the WIPP site is quite simple. It is characterized by a persistent, gentle homoclinal dip toward the east of 50 to 200 feet per mile (2 degrees or less), depending upon depth. Successively older rocks are seen to occur toward the west, the result of erosional bevelling of the gently eastward-dipping strata. Additional information regarding erosional history of the WIPP site is presented in section 4.5; details of the site structure and stratigraphy are discussed in the following sections.

4.3 SITE STRATIGRAPHY AND LITHOLOGY

The following paragraphs briefly summarize the stratigraphic sequence at the WIPP site; systematic description of the various lithologic units commences in Section 4.3.1.

The proposed WIPP underground storage facilities are to be placed near the middle of a 3,600-foot-thick sequence of relatively pure evaporite strata containing primarily rock salt and anhydrite, lying between depths of about 500 and 4,100 feet beneath ground surface. The formation richest in rock salt, the Salado Formation, is nearly 2,000 feet thick. The Salado contains the relatively pure salt layers in which the two proposed underground storage levels are to be constructed, at a depth near 2,120 feet for the upper level and near 2,670 feet for the lower. The storage horizons are well isolated from the enviroment by adjacent evaporite strata. A thickness of at least 1,300 feet of undisturbed evaporite, primarily rock salt, overlies the upper storage horizon, and about an equivalent thickness of anhydrite and rock salt intervenes between the lower storage horizon and the next adjacent underlying non-evaporite formation. The salt deposits were formed at least 225 million years ago and have apparently remained isolated since that time.

The total thickness of the sediments resting on Precambrian basement beneath the surface of the proposed WIPP facility is about 18,000 feet of Ordovician to Recent strata. Depicted in Figure 4.3-1 is a generalized stratigraphic section of the site, showing the vertical sequence of major

units and their relative thicknesses. More detail, but still of a generalized nature, is provided in Figure 4.3-2, Site Geologic Column, which shows simplified graphic and descriptive lithologies of the major units known or inferred to occur beneath the site and gives the geologic classification of rock units used in this report. Following is a brief summary of the stratigraphy, proceeding from the surface down to basement.

Beneath a thin but persistent veneer of windblown sand at the site are sediments representing Pleistocene, Upper Triassic, and uppermost Permian strata, all of which occur above the evaporite sequence. Sandstone of the Pleistocene Gatuna Formation, capped by Mescalero caliche, also developed in Pleistocene time, is only a few tens of feet thick at the site and is of interest primarily for the geochronologic and paleoclimatic implications of its presence; it was deposited, and much of the caliche on its surface believed to have developed, half a million years ago (Kansan-Yarmouth time) (Bachman, 1974). Between the Pleistocene sandstone and the evaporite sequence is a 500-foot-thick succession of nonmarine redbeds of Late Triassic age (Santa Rosa Sandstone) and marine redbeds of latest Permian age (Dewey Lake Redbeds). This redbed sequence thins westward and thickens eastward, having been beveled to the west by one or more post-Late Triassic erosional episodes; the thickness of redbed deposits remaining above the evaporite sequence is crudely proportional to the degree to which the underlying salt horizons have been protected from surficial processes leading to erosion and dissolution.

At the center of the site, all but the uppermost 50 feet of the 18,000 feet of strata are of Paleozoic age, the marine Dewey Lake Redbeds being the topmost of the Paleozoic rocks. The Permian section alone, about 12,800 feet thick, constitutes over two-thirds of the sedimentary column. The Permian section is divided into four series, the three lowest of which (Wolfcampian, Leonardian, and Guadalupian) contain thick clastic sequences, and the uppermost of which, the Ochoan Series, contains the evaporite formations, which are in descending order the

Rustler, Salado, and Castile Formations. (The topmost Ochoan formation, the Dewey Lake Redbeds, is not part of the evaporite sequence but represents a return of clastic, normal marine deposition.)

The Rustler, which overlies the Salado, contains the largest percentage of clastic material of the three evaporite formations. However, where its original thickness of around 450 feet has been protected from salt dissolution, about 70 percent of the formation is composed of evaporite beds, including about 40 percent rock salt. Beneath the WIPP site, the Rustler has been leached of most of its rock salt in the geologic past. At ERDA-9, 310 feet of the formation was encountered, which implies that up to 150 feet of rock salt has been removed and that the overlying strata have subsided accordingly. It does not, however, imply that dissolution and subsidence is necessarily presently active or even that it has recently occurred. At ERDA 9 halite was logged in the lower 100 feet of the Rustler. Over 1,300 feet of undisturbed evaporite rock, primarily Salado rock salt, occur above the upper level storage zone of the proposed WIPP facility.

The 2,000-foot thickness of the salt-rich Salado Formation is divided into three members by the recognition of a middle member referred to as the McNutt potash zone, which is the interval within the Salado that contains the potential reserves of potash minerals mined in the Carlsbad District west of the site. The lowest member of the Salado, beneath the McNutt potash member, is the member that contains the nearly pure halite which is proposed for the WIPP facility. The Castile Formation beneath the Salado also contains nearly pure beds of halite but, unlike the Salado, also contains massive anhydrite beds.

The rest of the Permian section beneath the evaporite sequence, together with the subjacent Pennsylvanian and possibly Late Mississippian sections, contain dominantly clastic rocks that represent deposition during the time in which the Delaware Basin existed as a distinct structural entity. These pre-evaporite, basinal sediments, which total about 11,000 feet in thickness beneath the site, have been targeted for

petroleum exploration at one point or another throughout the Delaware Basin. They contain nearly all of the region's known potential reserve of hydrocarbons.

The remainder of the Paleozoic section (Mississippian down through the Ordovician) consists of about 3,000 feet of mainly carbonate strata deposited in shallow-water or shelf conditions over a period of long-sustained crustal stability.

The underlying crystalline basement is believed to be a granitic terrane, formed about 1,300 million years ago. The only other igneous rocks known in the area occur as a lamprophyre dike rock intruded into the evaporite beds along a single northeast dike trend that approaches no closer than about 8 miles northwest of the center of the proposed WIPP site.

Brief descriptions of the various stratigraphic units are provided in the following sections, in order of deposition from oldest to youngest, with emphasis on the evaporite beds, particularly the Salado Formation.

4.3.1 Precambrian Eonothem

Few holes in the near vicinity of the WIPP site have penetrated entirely through the Paleozoic section. The nearest such holes are the Richardson and Bass No. 1 Cobb-Federal, approximately 13 miles north-northwest of the center of the site, and the Texas No. 1 Richards, 12-1/2 miles to the north-northeast. Inferences about the nature of basement rock lying beneath the site have been gleaned from these wells and others more distantly removed.

Crystalline basement rocks beneath the Mesozoic and Paleozic sedimentary pile near the proposed site are believed to be either granitic igneous rock or metamorphosed granites and rhyolites. The basement surface here is at a depth of approximately 17,900 feet (Foster and Stipp, 1961); a slightly greater depth (approximately 18,200 feet) has been inferred by independent consultants (Sipes et al., 1976). The basement rocks occur

within what has been considered by Flawn (1954, 1956) to be part of a regional Precambrian granitic terrane constituting the Texas craton. A later investigation (Muehlberger et al., 1967), which reclassified the rocks within the Texas foreland or craton, among other areas, suggests that the basement rocks in the area near the site belong to the Chaves granitic terrane, composed largely of granite, granodiorite, and equivalent gneisses, with a minor amount of other metamorphic rocks included. Measured radiometric dates for basement rocks in the area range between 1,140 to 1,350 million years (Foster, 1974; Muehlberger et al., 1967); the Chaves terrane is defined to include the 1,350 m.y.-old granitic basement rocks.

4.3.2 Paleozoic Erathem

Cambrian System. No Cambrian strata are recognized in the subsurface in the vicinity of the WIPP site. Basal conglomerate and sandstone resting on the Precambrian of southeastern New Mexico are sometimes called Bliss sandstone, which is partly Late Cambrian and partly Early Ordovician in age, but such rocks in this area probably correlate only with the Ordovician part of the Bliss (Foster, 1974) and are here considered a member of the Ellenburger Group.

Ordovician System. In the Los Medanos area, the Paleozoic section begins with an estimated 1,290 feet of Ordovician rocks beneath the center of the site (Foster, 1974), assuming an even gradient between widely spaced well control points. In ascending order the sequence includes the Ellenburger, Simpson, and Montoya Groups, representing Lower, Middle, and Upper Ordovician strata, respectively.

Detail of the local stratigraphy of the Ordovician is based on samples and a radioactivity log from the Texas No. 1 Richards well, 12-1/2 miles north-northeast of the site. The Ellenburger Group there consists of at least 300 feet of dolomite with some chert; included is a basal member of sandstone and conglomerate about 75 feet thick. The top of the Ellenburger may be at a depth of as much as 17,800 feet beneath the

center of the site (Netherland, Sewell, 1974). Overlying the Ellenburger dolomite is a sequence of alternating limestone and green or gray shale members, with several sandstone units occurring in the upper half of the sequence. The Upper Ordovician Montoya Group is almost entirely carbonate rock. At the Texas 1 Richards well, the lower half of the Montoya is limestone and the upper half dolomite, chert being fairly common, particularly in the middle of the section; whereas 14 miles south of the site the Montoya has been logged as mostly limestone and sandy limestone. Some intermediate lithology is therefore to be expected beneath the WIPP site.

In the Texas 1 Richards reference section the Ordovician rocks total 975 feet in thickness; however, the section thickens in a south to southeast direction at a rate estimated to be 25 to 40 feet per mile (Foster, 1974), most of which is due to the thickening of the Ellenburger and Simpson groups in that direction. It is likely that the Ellenburger and Simpson are each between 400 and 500 feet thick in the site area.

Silurian System. Lying above the dolomite of the Ordovician Montoya Group is additional carbonate rock of Silurian, or perhaps Siluro-Devonian age. Near the site it consists entirely of light-colored dolomite with appreciable chert, except for two prominent intervals of limestone, one about 100 feet thick near the middle of the section and one about 200 feet thick near the top (Foster, 1974). The basal contact is apparently disconformable in this area.

The relatively homogenous lithology of the Silurian carbonate sequence in the subsurface of southeastern New Mexico has thus far precluded its formal separation into formational units. McGlasson (1968), however, has suggested that the lower part is correlative with the Fusselman Formation of Early and Middle Silurian age, and that the upper part, generally referred to as "Upper Silurian" strata, may be correlative with the Henryhouse Formation of partly late Middle and partly Late Silurian age. McGlasson (1968) also shows that no Devonian carbonate rocks were deposited in New Mexico, except in the extreme southwest corner of Lea

County. Nevertheless, common oil-field usage refers to these carbonates as "Siluro-Devonian" carbonates (Foster, 1974). Probably most if not all of the post-Montoya, pre-Woodford carbonate strata beneath the WIPP site is Silurian in age, according to McGlasson's studies. Isopach maps (Foster, 1974) indicate the total thickness of the Silurian or "Siluro-Devonian" carbonates at the site to be about 1,140 feet. The sequence thins westward relatively uniformly at a rate of about 25-50 feet per mile toward a landmass emergent during Silurian time.

The marked contrast in lithology between the Silurian carbonate and the overlying Devonian shale is believed to provide a good seismic reflecting horizon. Structure contour maps on top of "Siluro-Devonian lime" indicate that the top of Silurian, equivalent to base of Devonian, is at a depth of about 15,850 feet beneath the center of the WIPP site (elev. minus 12,450 feet) (Netherland, Sewell, 1974).

Devonian System. The Devonian system is represented by a distinctive unit of organic, pyritic black shale which unconformably overlies the Silurian carbonate sequence. McGlasson (1968) correlates it with the Upper Devonian Woodford Shale of Oklahoma and describes it as a "dark brown to black, fissile, bituminous, spore-bearing shale". He shows that it is a transgressive unit which overlaps successively older units to the northwest (McGlasson, 1968). Beneath the center of the site it is indicated to be about 175 feet thick, thickening gradually southeastward (Foster, 1974). Haigler and Cunningham (1972) show the top of undifferentiated Silurian and Devonian rocks at an elevation of slightly above minus 12,300 feet MSL at the center of the WIPP site. The uppermost portion of the Woodford Shale in the Delaware Basin is reported to be actually of earliest Mississippian age (McGlasson, 1968).

Mississippian System. Rocks of the Mississippian System at the site include a series of limestones referred to simply as "Mississippian limestone," and an overlying shale interval called the Barnett shale. At the Texas 1 Richards locality, the limestone is light-yellowish brown, locally cherty, with some minor gray shale, contrasting with brown,

locally silty shale of the Barnett. Like the top of Silurian carbonate, the top of Mississippian carbonate most likely affords a good reflecting horizon; structure contour maps indicate that it is about 15,150 feet below Zone I at the site (elev. minus 11,750 feet) (Netherland, Sewell, 1974). Total thickness of the carbonate appears to be about 480 feet at the site, gradually thickening northward. The overlying black shale is about 175 feet thick.

Stratigraphic relations between subsurface Mississippian strata in southeastern New Mexico and formational units defined in other areas are unclear. On the basis of the local fauna, the carbonate sequence in the Delaware Basin is assigned to the Lower Mississippian (Foster, 1974). Lithologically it is similar to the Rancheria Formation in the Franklin Mountains. At or near the site, deposition of the Barnett Shale corresponds for the most part to Late Mississippian time.

Pennsylvanian System. Approximately 2,200 feet of Pennsylvanian strata occur in the subsurface at the WIPP site (Foster, 1974). The section consists of alternating members of sandstone, shale, and limestone, and rests unconformably on the underlying Barnett Shale.

Unlike most of the earlier Paleozoic strata, the Pennsylvanian strata in the Delaware Basin, and some of the Lower Permian strata as well, are characterized by relatively numerous changes in lithology vertically in the section and by an abundance of lateral facies changes along time-equivalent horizons. Lithologic units traceable over broad areas in the subsurface generally cannot be assumed to represent time-stratigraphic units under these conditions. Attempts to construct a basin-wide geologic history for Pennsylvanian time and to develop regional correlations based on time equivalence are greatly complicated by these lithologic changes. These complexities have spawned efforts such as those of Meyer (1966) to develop a method for placing surface outcrop and subsurface strata into a formal Pennsylvanian time-stratigraphic framework. As defined by this approach, the Lower Pennsylvanian Series includes rocks assigned to the Morrowan Stage, the

Middle Pennsylvanian Series to rocks assigned to the Atokan (or Derryan) and Desmoinesian Stages, and the Upper Pennsylvanian Series to rocks assigned to the Missourian and Virgilian Stages.

In the Delaware Basin, local subsurface stratigraphic units have sometimes been informally defined, or extended on the basis of lithology and are therefore, strictly speaking, lithostratigraphic and not time-stratigraphic units. Thus, rocks considered part of, for example, the "Morrow" or the Morrow Series on the basis of subsurface lithologies may not necessarily all be encompassed within or represent all of the time of the Morrowan Stage as formally defined. Although the Pennsylvanian section is herein described by reference to lithologies recorded in nearby wells, for the reasons stated the section at the site cannot from the nature of data available be positively correlated with formal stage names or with Lower, Middle, or Upper Pennsylvanian Series. Nevertheless, the designations of Morrowan, Atokan, Desmoinesian, and Missourian-Virgilian rocks for the respective Bend, Strawn, and Canyon-Cisco rock units have frequently been used with modifications for some time (Thompson, 1942; Haigler, 1962, p. 7-8, Netherland-Sewell, 1974, exbt. G-2; see also Meyer, 1966, p. 11). The bipartite classification of Lower Pennsylvanian for Morrowan and Atoka and Upper Pennsylvanian for Strawn has also been employed (e.g., Sipes et al., 1976).

Foster (1974), in his description of Pennsylvanian subsurface lithologies in the vicinity of the site, adopted the usage of Morrow, Atoka and Strawn, which denote from deepest to shallowest the respective principal oil and gas producing zones in Pennsylvanian rocks of the Delaware Basin. He noted that the "overlying rocks of Missourian and Virgilian ages are present... but following the common oil-field usage (they) are included in the Wolfcamp sequence". Hence, "... it appears that the top of (Meyer's) Desmoinesian Stage is the same as the top of the Strawn..." (Foster, 1974). This usage is followed in this chapter in the interest of its adaptability to existing commercial exploratory data. Reference sections are provided by Foster for Pennsylvanian strata some distance

north and south of the site (his Figures 12 and 36, respectively). Sipes, et al. (1976) show "picks" on Pennsylvanian units in the Clayton W. Williams Jr., Badger Unit Federal well about 2 miles northeast of the center of the site, and they present down-hole logs on this and other exploration holes in the vicinity of the site as well.

Morrowan rocks near the site consist mostly of fine- to coarse-grained sandstone with varying amounts of dark gray shale. Some limestone, generally as a series of relatively thin beds with shale and sandstone, typically occurs in the upper part of the sequence and is often separately identified. The Morrow sand is a known hydrocarbon producer of oil and gas in this part of the Delaware Basin, particularly from fields in the area north of the site (refer to Section 8.3.2). Foster (1974) shows areal distribution of sand lithologies in this zone.

The Atoka rocks are principally limestone, becoming cherty toward the middle of the section, and alternating with varying amounts of medium- to dark-gray shale. Sandstones are subordinate. The Atoka is considered to have locally significant hydrocarbon potential in this part of the Delaware Basin, as in the Los Medanos field which is southwest of and nearest to the WIPP site.

The lower part of the Strawn (regionally the Desmoinesian) is dominated by light gray to white, medium- to coarse-grained sandstone, locally conglomeratic in the site area. In its upper part, the Strawn is dominantly limestone, apparently with a minor amount of chert but becoming more abundant northeastward in the immediate vicinity of the site (Foster, 1974). Thin beds of dark gray and brown shale are present throughout the section.

Records of the apparent thickness of the Morrow, Atoka and Strawn vary considerably from area to area simply because there is no completely agreed-upon way of selecting "picks" on down-hole logs and seismic reflection data. In some oil fields, "picks" above the Morrow include

Atoka (or Bend), Strawn, Missourian, and Virgilian. According to Foster (1974), "in well completion reports the top of the Strawn is picked fairly consistently," but selections for the top of Morrow and Atoka may differ significantly, and generally the Canyon and Cisco are not distinguished in this part of basin. Sipes et al. (1976) show the top of Strawn at elevation minus 9,400 feet msl beneath the center of the WIPP site. The "picks" they show in the C.W. Williams Jr., Badger Unit Federal well two miles northeast of ERDA 9 yield thicknesses of 1,224, 607, and 257 feet for the Morrow, Atoka, and Strawn rocks, respectively, for a total thickness of 2,088 feet for the Pennsylvanian. Presumably, one or more units thicken southwestward slightly to attain the 2,200-foot value that Foster shows at the center of the site, a value which specifically excludes at least some Missourian-Virgilian strata. Probably the value of approximately 2,500 feet shown by Meyer (1966, Figure 48) is more truly representative of the total accumulation of strata beneath the site during Pennsylvanian time.

Permian Rocks. As much as 13,000 feet of Permian strata were deposited within the area of the Delaware Basin, which constitutes the most complete succession of the Permian in North America (Brokaw et al., 1972). The entire Permian section beneath the WIPP site averages about 12,800 feet in thickness, over two-thirds that of the entire sedimentary column, or over twice as thick as all of the earlier Paleozoic formations combined (about 5,200 feet). Of this total, about 3,600 to 3,800 feet of thick, relatively pure evaporite beds (primarily salt and anhydrite) occur in the upper part of the sequence, in which the proposed waste isolation facility is to be constructed.

Because the Permian in the Delaware Basin and surrounding region has long been the subject of intensive exploration and study by both commercial and non-commercial interests, its subsurface and surface stratigraphy have become a relatively well understood aspect of a classic study area (e.g., King, 1942, 1948; Adams, 1944, Newell et al., 1953; McKee et al., 1967a, 1967b; Anderson et al., 1972; Brokaw et al., 1972; Jones, 1973).

Even so, problems in stratigraphic nomenclature still abound, particularly with regard to the more deeply buried basin sediments of the Lower Permian within the Delaware Basin.

Permian rocks are divided into four series (Adams et al., 1939), two of which (Wolfcampian and Leonardian) are equated with Lower Permian time and two (Guadalupian and Ochoan) with Upper Permian. The well-known massive reef deposits bordering the Delaware Basin were built up mainly during Guadalupian time; massive evaporite deposits were formed only during Ochoan time, between 225 and 250 million years b.p. (before present). Regional correlations of the Permian are shown in Figure 3.3-3.

1) Wolfcampian Series

"Apparently sedimentation in the Permian Basin was continuous from Pennsylvanian time throughout Wolfcampian" (Meyer, 1966, p. 1); "major tectonic elements of Early Permian time in west Texas and southeastern New Mexico were inherited from the Pennsylvanian and continued to grow" (Oriel et al., 1967, p. 37). These regional generalities suggest the difficulty that has been experienced, at least basinward from shelves, in identifying the base of the Wolfcamp strata. An arbitrary convention in exploration practice in the Delaware Basin is to use the top of the Strawn to mark the top of the Pennsylvanian. If any Pennsylvanian strata are present above the Strawn, they are very similar to the overlying Wolfcampian Series and attempts have not normally been made to distinguish the two in the subsurface.

In the site area, the Strawn is overlain by a thick sequence of interbedded, dark-colored limestone and shale, including considerable dolomite. Sandstone is insignificant. No formational status has yet been designated for this interval; informally the sequence is sometimes called "Wolfcamp formation". It is known to markedly thicken southward with increasing shale and sand content toward the Val Verde trough, where extremely thick Wolfcampian strata are known. Toward the north, it thins and gains limestone content, suggesting a shelf margin facies. Foster (1974) indicates that at the WIPP site the shale content probably nearly

equals that of the carbonate. Isopachs presented in Foster (1974) indicate slightly less than 1,400 feet of Wolfcampian strata beneath the site, whereas Meyer (1966) shows between 1,000 and 1,100 feet; the latter value excludes some rocks above the Strawn. A regional map by McKee et al., (1967a) appears to indicate nearly 2,000 feet. The nearest "pick", in the Badger Unit Federal Well, indicates 1,493 feet of Wolfcampian strata, 2 miles northeast of the center of site (Sipes et al., 1976). These differing values reflect the uncertainties in identifying lower and upper limits of subsurface Wolfcampian strata in the Delaware Basin.

2) Leonardian Series.

The Leonardian series of the Lower Permian Series is represented by basinal sandy equivalents of the Bone Springs Limestone, which was originally defined for a shelf and bank facies of the unit at the margin of the Delaware Basin. Both the name "Bone Spring" and "Bone Springs" have been used in the past, and both usages are found in the current literature. Originally defined as Bone Springs by Blanchard and Davis (1929), King (1948, p. 13) changed it to Bone Spring "to agree with the geographic term" of the type locality, which "is in the lower course of Bone Canyon below Bone Spring..." The U.S.G.S. Lexicon (Keroher et al., 1966) also gives Bone Spring Limestone, but states that it is "named for Bone Springs Canyon...," citing Blanchard and Davis (1929).

Conditions favoring significant buildup of reef and bank limestone at the edge of the Delaware Basin existed in Leonardian time (Victorio Peak Limestone), but development of by far the most extensive of these limestones occurred subsequently in Guadalupian time. Within the basin in the vicinity of the WIPP site, the Bone Springs interval thickens markedly and consists of alternating units of sandstone and dark-colored limestone, with a thick, slightly cherty limestone at the top. Three laterally persistent, very fine to fine-grained sandstone units are recognized as the first, second, and third Bone Springs sands. Shale is a minor constituent of the Bone Springs strata, but the limestone beds are commonly argillaceous.

Foster (1974) shows the WIPP site to be near a local center of maximum thickness of Bone Springs strata, about 3,500 feet. The unit becomes thinner to the east and northeast. The Badger Unit Federal well is indicated to have penetrated 3,427 feet of Bone Springs rocks.

3) Guadalupian Series.

The Delaware Mountain Group includes all basin facies rocks of Guadalupian age in the Delaware Basin, which at the site are composed mostly of sandstones interbedded with some dark shales and a few thin-bedded limestones. A dramatic facies change takes place about 10 miles north of the site, where the basin facies terminates abruptly against massive reef limestones. Because these reef limestones almost completely encircle the Delaware Basin, they seem to conveniently demark the structural limits of the basin, although earlier basin sediments of the Delaware Group extend some distance beneath, or behind, the latest and most massive of the reefs, represented by the Capitan Limestone. North of the site, these reefs are buried by later sediments but become progressively less deeply buried toward the west; west of Carlsbad they surface and form a bold escarpment that defines the eastern boundary of the Guadalupe Mountains, for which the Guadalupian Series was named.

During their earlier development, the reefs at first built upward at the margin of the basin, but during later development progressed outward into the basin as well. Thus, successively older formations of the basin facies of the Delaware Mountain Group have greater areal extent beyond the Delaware Basin as defined by the uppermost part of the Capitan reef. Like modern reefs, the lateral development of these Guadalupian reefs was accompanied by an appreciable vertical buildup of material, in some cases exceeding 1,000 feet, such that sediments being contemporaneously deposited in the basin now appear structurally to be correspondingly lower in the section, where in actuality they are time-stratigraphic equivalents. By the same token, the evaporitic materials (Ochoan evaporites) that later filled the basin now appear to some extent to be laterally equivalent to the reef masses. These stratigraphic relationships are especially well portrayed by Haigler (1962) and King (1948).

A thickness of 3,944 feet of Delaware Mountain Group strata is recorded 2 miles northeast of the center of the WIPP site. Surface mapping at the margins of the basin led to the recognition there of three formations; namely, in ascending order, the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations. Generally, petroleum exploration practice in the Delaware Basin has been not to attempt to define these formations in the subsurface. However, Foster (1974) provides a reference section showing stratigraphic positions of the formations of the Delaware Mountain Group in the Shell No. 1 James Ranch well about 3 miles southwest of the site, and Sipes et al. (1976) give similar "picks" in the Clayton W. Williams, Jr., well to the northeast of the area. Foster shows 3,970 feet of Delaware Mountain strata.

The Shell No. 1 James Ranch well lithologies indicate that the Brushy Canyon Formation is 1,540 feet thick and consists of mostly fine-grained, gray to brown sandstone with minor brown shale and dolomite. The Cherry Canyon Formation consists of 1,070 feet of sandstone similar to that in the Brushy Canyon Formation, interbedded with shale, dolomite, and some limestone. The Bell Canyon Formation, 1,180 feet thick, also consists mostly of fine-grained sandstone, but has a greater percentage of limestone, the result of closer proximity to the shelf-margin carbonates. A limestone member at the top of the Bell Canyon Formation, known as the Lamar limestone, is recognizable over a considerable part of the Delaware Basin. Basinwide the sands of all three formations are targets for hydrocarbon exploration. The top of the Delaware beneath the center of the site is contoured by Sipes et al. (1976) at minus 650 feet (depth 4,065 feet). It is overlain by evaporites of the Castile Formation.

4) Ochoan Series.

The Ochoan Series "includes perhaps the thickest and most extensive evaporite rock sequence in North America" (Oriel et al., 1967). It also contains, within the Salado Formation east of Carlsbad, extensive potash evaporite deposits which contain 65 percent of presently exploitable potash resources available within the United States (Jones, 1975).

All of the salt deposits and other evaporites of the Los Medanos area are restricted to the Ochoan rocks, of Late Permian age. The Ochoan rocks are entirely of marine origin, but have two unlike parts--a thick lower section of evaporite and a thin upper section of red beds (Jones, 1973). The lower section includes, in ascending order, the Castile, Salado, and Rustler Formations; the upper section is made up of the Dewey Lake Redbeds. Together the four formations have a maximum thickness of 3,600 feet, slightly more than 3,000 feet of which are evaporite beds of the lower three formations, which are composed dominantly of anhydrite and rock salt with minor amounts of gypsum, potassium evaporite minerals, carbonate rock, and fine-grained clastic material.

At the WIPP site, the Ochoan rocks are about 3,900 to 4,000 feet thick, of which 3,600 to 3,800 feet, or about 90 percent, are the evaporite sequence. Of the three evaporite formations, roughly one-half the total thickness belongs to the Salado. Both the underlying Castile and overlying Rustler are richer in anhydrite and poorer in rock salt than the Salado, and they provide this salt-rich formation with considerable protection from fluids which might be present in adjacent rocks (Jones, 1973). Jones (1972) provides lithologic percentages of the complete Ochoan evaporite sequence (Castile-Rustler), obtained from exploratory potash drilling, as follows: 59 percent halite and associated potash deposits; 33 percent anhydrite and gypsum, with glauberite and polyhalite; 6 percent carbonate rock (limestone, dolomite, magnesite) and 2 percent clastic rock (clays and silts).

Considered broadly, the evaporites represent a transitional zone between underlying reef and normal marine limestones (Guadalupian beds) and the overlying Dewey Lake which was deposited under brackish or restricted marine conditions (Jones, 1968). The floor of the Delaware Basin in early Ochoan time is generally estimated to have been at least 1,200 feet below the top of the Capitan reef, which almost completely encircled it, restricting southern access to the open sea and setting the stage for deposition of evaporites within the basin (Brokaw, et al., 1972).

Castile Formation

The Castile Formation is almost completely confined within the limits of the Delaware Basin (Oriel et al., 1967), the only evaporite formation so restricted. It gradationally overlies the Bell Canyon Formation (Brokaw et al., 1972).

Lithologically, the Castile is the least complex of the evaporite formations, being composed chiefly of anhydrite with a few interbeds of rock salt. Limestone is present in secondary amounts; clastic materials (siltstone, shale, sandstone) are notably absent. A lithologic summary by Jones (1972) lists 59 percent anhydrite and other sulfates, 30 percent halite and other chlorides, 11 percent limestone, dolomite, and magnesite, and no clastic rock for the Castile Formation, based on data from exploratory drilling. The rock is sparingly bituminous and yields a fetid odor. It has a faint to conspicuous lamination or banded structure involving a color change, a difference in texture, or a rhythmic alternation of bituminous calcite and anhydrite, bitumen and anhydrite, or anhydrite and halite in layers a fraction of a millimeter to a few centimeters thick. The color of the rock ranges from white to dark gray, becoming darker with increasing depth below the top of the formation (Jones, 1975).

In the subsurface, the Castile Formation, to use Jones' description, is readily divisible into three informal members by a salt-rich zone 200-400 feet above the base: a lower member composed chiefly of anhydrite, a middle member composed chiefly of rock salt, and an upper member composed chiefly of anhydrite. The three members are discrete, readily distinguished lithologic units that are laterally persistent over wide sections of the Delaware Basin. Near the margin of the basin, however, they merge into a single wedge-like mass of anhydrite that rapidly thins to a narrow tongue and extends across the basin margin for a few miles before thinning out in the southern part of the Northwestern Shelf.

As described by Jones (1973), the lower member of the Castile Formation is a well-stratified evaporite consisting of laminae of gray anhydrite and brownish-gray limestone in regular, rhythmic alternation. Some beds of laminated dark-gray and brownish-gray limestones, a few inches to several feet thick, are present at wide intervals in the lower and middle parts of the member, and there are a few thicker beds of massive gray anhydrite at long intervals. The member is 200-240 feet thick south of the site, but it thickens northward and reaches a thickness of at least 400 feet before merging with other members of the Castile to form a single unbroken mass of anhydrite adjacent to the Capitan reef mass.

The middle member of the Castile Formation, a salt-rich, tabular zone that forms a widespread, lithologically distinct stratigraphic marker, is 500-700 feet thick in the southern part of the Carlsbad potash area, but thickens northward and attains thicknesses of 800-1000 feet along a broad 2 to 3-mile-wide belt of deformation within the evaporite sequence paralleling the margin of the Delaware Basin (refer to Section 4.3.2.7). The member is predominantly rock salt, but it contains thin to thick layers of interlaminated anhydrite-limestone rock. The thickest of these layers averages about 100 feet, and it divides the member into two almost equally thick salt beds. The upper bed includes several interlaminated anhydrite-limestone layers, some of which are 2-5 feet thick, whereas the lower bed has none. This member terminates northward by grading laterally into, and intertonguing with, anhydrite.

The upper member of the Castile Formation exhibits greater lithologic complexity and is composed chiefly of anhydrite interlaminated and interbedded with calcitic limestone and, to a lesser extent, with massive anhydrite, rock salt, and carbonate rock, including both magnesite and dolomite. It contains a northward-thinning tongue of magnesitic anhydrite that overlaps the Capitan Limestone along the margin of the Delaware Basin and extends a few miles into the northwest shelf. Though 600-700 feet thick some distance south of the site, the upper member thins rapidly northward to as little as 170 feet near the margin of the basin. The nature of this northward reduction in thickness is, as

subsurface studies in the Carlsbad potash area and elsewhere in the Delaware Basin have shown, due both to a lateral gradation and to an intertonguing, or pinching out, of individual anhydrite beds at the top of the Castile into the rock-salt beds of the overlying Salado Formation, resulting in a northward stratigraphic descent of identifiable Castile anhydrite. These relationships demonstrate that the contact between the Castile Formation and the overlying Salado Formation is conformable and gradational; nevertheless, the contact at any particular location is generally rather sharply definable as the horizon at which dominant anhydrite below gives way to rock salt above.

A somewhat different classification scheme of the Castile Formation has been established by R.Y. Anderson and his co-workers. Working in the central and southern part of the basin with thin sections of cores obtained through special drilling arrangements made with industry operators, Anderson et al. (1972) divided the Castile into three separate halite members and four anhydrite members across the width of the Delaware Basin. Furthermore, they traced individual laminae in the anhydrite members over distances as great as 113 km. Each anhydrite-calcite couplet is believed to represent an annual varve, the nature of the evaporite precipitation being controlled by changes in the partial pressure of carbon dioxide in the Castile brine sea as the growth of brine algae waxed and waned with the seasons. Some 250,000 varve couplets are inferred, by representative counts, beginning below the Lamar limestone in the Bell Canyon and ending in the lower part of the Salado (Anderson et al., 1972).

Toward the northern part of the Delaware Basin, the upper halite and anhydrite units appear to converge and cannot be traced basinwide as major units. In the site area two lower anhydrite members (AI, AII) and two halite members (HI, HII) are recognized as basinwide equivalents of units identified elsewhere; a more heterogeneous upper unit, principally anhydrite, corresponds to the position of Anhydrite IV but may not be stratigraphically equivalent to it (Anderson et al., 1972; Anderson and Powers, 1978; Anderson, 1978). These anhydrite and halite members are

identified on Figure 4.3-2. Thicknesses are taken from isopach maps which appear in Anderson et al. (1972) and Anderson, (1978). Thus, the lower anhydrite (Anhydrite-I) member is indicated to be nearly 250 feet thick in the vicinity of the WIPP site; Halite-I, about 330 feet thick; Anhydrite-II, 100 feet thick; and Halite-II, 210 feet thick. The remainder of the total thickness of the formation is occupied by the upper anhydrite described by Jones (1973), as quoted above. Jones' middle halite unit is equivalent to Anderson's Halite-I plus Anhydrite-II plus Halite-II sequence; Anderson has simply subdivided the sequence based on the presence of a middle anhydrite member (Anhydrite-II) that Jones also recognized (see above). Both Jones and Anderson recognize that here the upper anhydrite unit does not display the varved interlaminations comparable to those observed in the lower anhydrite units.

The only major disagreement between Anderson and Jones appears to center around the nature of the Castile-Salado contact. Jones asserts that the contact is conformable and laterally intertongues (see discussion above), whereas Anderson believes an unconformity exists. Anderson (1978) cites as evidence for this the presence of some dissolution breccia near the top of the Castile, suggesting a period of non-deposition or even subaerial erosion. Furthermore, Halite-III is missing over the northern part of the basin, which could be explained by a local erosional episode there. Anderson also notes that the basal infra-Cowden salt of the Salado Formation (see below) does not occur to the south and is thickest wherever the Halite-III member is absent. This controversy has not been resolved to date; whether or not significant dissolution took place during deposition of the Castile and Salado evaporite sequence could have important implications regarding models invoked to estimate past and present rates of salt dissolution in the Delaware Basin.

Because no drill hole within Zones I-III of the WIPP site has made a complete penetration of the Castile, the thickness of the Castile beneath the repository must be estimated. Beneath the site, the base of the Castile is indicated by structure contours in Figure 10 of Jones (1972)

to be at an elevation of about minus 680 feet MSL at the center of the site; Sipes, et al. (1976) show it at minus 650 feet MSL. Since ERDA-9 intersected the top of Castile at elevation 579 feet above sea level, the Castile is indicated to be about 1,230-1,260 feet thick at the site, or approximately 1,250 feet thick. Drill hole AEC-8 encountered 1,333 feet of Castile in section 11, about 4 miles northeast of ERDA-9 (Griswold, 1977, Table III).

b) Salado Formation. The Salado Formation contains the thick salt beds in which the contemplated WIPP repository would be constructed. It is one of the principal deposits of halite on the North American continent (Brokaw, et al., 1972, p. 21), and it contains the Carlsbad potash enclave, the principal producer of potash in the United States.

As of the date of this report, one core hole, ERDA No. 9, has been drilled through the Salado at the location of the proposed repository. A schematic section of that hole, including general lithology, location of marker beds, position of halite zones in which the repository will be located, and well construction data, is given in Figure 4.3-3a. The detailed lithologic log is included as Figure 4.3-3b of this report. Details of the numerous down-hole logs performed, mineralogical and geochemical determinations made, and rock mechanics tests conducted are not discussed here but are given in Chapters 7 and 9 of this report, to which the reader is referred.

At the ERDA-9 location at the center of the site, the base of the Salado is 2824 feet and the top 848 feet below ground surface (elevations 590 and 2,566 feet above sea level, respectively), for a total thickness of 1,976 feet. The proposed contact handling (CH) zone halite interval, containing halite of relatively high purity, is between elevations 1,250 and 1,352 feet, and the remote handling (RH) zone, high-purity halite interval between elevations 696 and 806 feet. (Ground surface elevation at the ERDA-9 hole location is given as 3414.70 feet MSL).

Variations in the thickness of the Salado in the vicinity of the WIPP site are on the order of 300 feet (1,700 to 2,000 feet), based on results of the AEC and ERDA test holes (Griswold, 1977, Table III). Thicker sections of the Salado (over 2,300 feet) are known where it may have been affected by deformation due to salt flow. West of the site in the Nash Draw area the thickness of the formation locally and erratically decreases owing to local solution and removal of rock salt in the upper part of the formation (Vine, 1963; Jones, 1973). These variations are illustrated by a subregional isopach map of the Salado Formation presented by Brokaw et al. (1972).

As discussed by Brokaw et al. (1972),

> "In exposures of the Salado Formation along the west side of the Carlsbad potash area (10 or more miles west of the site), all the salt has been removed by solution and the anhydrite and polyhalite have been altered to gypsum. The alternation of the evaporite rocks extends to depths ranging from 260 feet to almost 1,600 feet below the surface and is responsible for a fourfold to sixfold reduction in the thickness of that part of the Salado and for a change in composition from dominantly rock salt in the subsurface to dominantly gypsum in the outcrop. The contact between the two highly dissimilar parts of the formation, known locally as the 'base of leached zone' and also as the 'top of salt', is highly irregular, with many closed depressions and isolated pinnacles. The contact dips generally eastward but rises in stratigraphic position from the base of the Salado near the west side of the potash area to the top of the formation near the Eddy-Lea County line at the east side of the area."

Figure 8 of Brokaw, et al. (1972) shows the location of the contact at the top of the Salado, or in other words the easternmost extent of dissolution in the Salado, to be located about 1 mile from the east edge of Range 30 E.; that is, about 2 miles west of the center of the WIPP. Additional discussion of solutioning is discussed in Section 6.3.7 of this report.

Broadly considered, the Salado is characterized by a predominance of rock salt compared to a predominance of anhydrite in the Castile and by typically thinner bedding or interbedding of lithologic units. Unlike the Castile, the Salado as well as the overlying Rustler extends over and beyond the confining Capitan reef masses to the north and east, in effect

overfilling the ancient basin formed by the reefs. The Salado sea was, in general, even more saline than the sea of Castile time. Lacking a shield of carbonate reefs, it received, however, considerable fine clastic sediment. Consequently, its halite deposits are generally less pure than those of the Castile (Brokaw et al., 1972), although thick intervals of highly pure halite are known in the lower half of the Salado Formation.

A detailed description of the overall lithology and member units has been provided by Jones (1973), who studied data from the numerous potash exploratory holes drilled in the Los Medanos area. The remainder of this section incorporates Jones' description, modified where appropriate by discussion of more recent data from ERDA-9.

The Salado Formation is composed of rock salt, anhydrite, and potassium rocks with varying amounts of other evaporites and fine-grained rocks. Rock salt constitutes about 85-90 percent of the formation except in the western part of the area where percolating ground water has dissolved and removed some of it. The next most abundant rock in the formation is anhydrite. The remainder of the formation is chiefly polyhalite and other potassium and magnesium-bearing minerals with minor amounts of sandstone, and claystone.

The rock salt in the Salado is composed of halite and clayey halite in discrete layers ranging from an inch to several feet in thickness. The two rock types differ primarily in that the halite is free of detrital debris and the clayey halite characteristically contains this debris in significant but typically small amounts. The detritus is chiefly quartz and clay, including illite, chlorite, and a corrensite-type of swelling, regular mixed-layered clay mineral (Grim et al., 1960). In general, the detritus-bearing clayey halite is mostly brown and tan; it is moderately crystalline but somewhat porous with a scattering of small cavities or vugs filled with clay and other detritus, and it either lies between seams of claystone or has a layer of halite below and a seam of claystone

above. The halite is typically reddish orange but its color grades to amber, gray, and white. It is generally somewhat more coarsely crystalline than the clayey halite.

Common to both the halite and the clayey halite in the rock salt of the Salado are traces to very minor amounts of polyhalite and anhydrite. Locally, glauberite is present in small amounts, and there are several potassium and magnesium minerals, including sylvite, carnallite, kieserite, and several other exotic evaporite minerals that occur in small to large amounts in seams of rock salt in the middle and upper parts of the formation. Other constituents of the halite and clayey halite include traces to very minor amounts of brine and gas that fill microscopic to very small cubic and rectangular cavities in grains of halite and other evaporite minerals. Less common, but more notable in other respects, are much larger cavities or pockets that contain halite-saturated brine and nitrogenous gas confined under presure sufficient to produce "blow-outs" when encountered during drilling operations.

The seams of anhydrite and polyhalite, which alternate with rock salt in all sections of the Salado, are very persistent but highly variable in composition (Jones, 1954; Jones, 1972). Lateral replacement of anhydrite by polyhalite is common, and nearly all seams show one or more stages of replacement between an initial slight development of polyhalite in the lower and upper parts of the seam to complete replacement of anhydrite by polyhalite. Locally, anhydrite and polyhalite give way laterally to glauberite, and polyhalite in the middle and upper parts of the Salado is replaced by hartsalz consisting of a coarsely crystalline mixture of anhydrite, kieserite, and carnallite.

Close examination of the Salado in drill cores and geophysical logs of boreholes in the Los Medanos area and vicinity reveals that rock sequences show a regular order of succession. A typical sequence, repeated many times between the base and top of the formation, involves a change from claystone upward through anhydrite or polyhalite and halite

to clayey halite capped by claystone. In other sequences the change is from halite to clayey halite capped by claystone. Boundaries between individual members of a rock sequence are gradational, but those along the lower and upper sides of the individual sequences are corrosion surfaces that form sharp, clear-cut breaks in the evaporite section but, nevertheless, are laterally persistent and convergent northward. The rock sequences represent a fundamental sedimentation unit or evaporite cycle, and they are believed to record discrete periods of influx and subsequent precipitation of calcium sulfate and soldium chloride during evaporation of sea water or an initially dilute brine. The ubiquitous claystone is thought to be a residue concentrated during dissolution of clayey halite by inflowing sea water or dilute brine.

The Salado Formation is divided into three members (Figure 4.3-3), but more subtle divisions can be made, for the beds are very persistent. In fact, the persistence of individual beds is the prime basis for the system of numbering individual seams of anhydrite and polyhalite which was introduced by geologists of the United States Geological Survey (USGS), such as Jones (1960) and is widely used by mining companies in the Carlsbad potash field. The numbers used in the USGS system to designate some seams of anhydrite and polyhalite in selected parts of the three members of the Salado are shown on Figure 4.3-3, and on Figures 4 and 6 of Jones (1973).

The threefold division of the Salado used herein includes: an unnamed lower member, a middle member known locally as the McNutt potash zone, and an unnamed upper member. The three members are about equally rich in rock salt, anhydrite, polyhalite, and fine-grained clastic rocks, and they are generally similar in all but one major respect. The lower and upper members are generally lacking or poor in sylvite, carnallite, and other potassium- and magnesium-bearing minerals, while the McNutt potash zone is generally rich in these minerals and accounts for the large and extensive deposits in the potash field.

Lower Member. Located below Marker Bed 126, the lower member of the Salado is the rock unit in which it is proposed to place both levels of the repository. As shown in Figure 4.3-3, the CH-zone is defined as the interval between Marker Beds 137 and 139 near the middle of the lower member, 560 feet above the base of the Salado. The RH-zone is in a zone devoid of nearby polyhalite marker beds, beneath a prominent anhydrite bed known as the "Cowden anhydrite." The top of the RH-zone is 344 feet below the base of the CH-zone; its base is 106 feet above the base of the Salado. The choice of zone intervals was made on the basis of combined purity, depth, thickness, mutual separation, and depth below the potash zone (Griswold, 1977).

The Cowden anhydrite identified above forms a distinctive, areally extensive bed of anhydrite about 20 feet thick below which is a salt bed of exceptional purity. This thick salt bed lying below the Cowden and above the Castile-Salado contact is sometimes referred to as the "Infra-Cowden", a sub-member located at the base of the Salado as shown in Figure 4.3-3. It is 296 feet thick at ERDA-9.

Lithologic details of each of the three members in the site area are provided by Jones (1973). The lower member of the Salado Formation is almost entirely made up of alternating thick seams of rock salt and thinner seams of anhydrite and polyhalite. Magnesite in thin bands, laminae, and ragged knots form a carbonate-rich zone in the lower part of most anhydrite and polyhalite seams. Seams and partings of claystone underlie the anhydrite and polyhalite seams, and claystone caps layers of clayey halite in the rock salt. There are also a few beds of very-fine-grained halitic sandstone, a few inches to a foot or so thick, near the base and top of the member. Insofar as has been determined by drilling, the member is completely free of carnallite and other hydrous potassium and magnesium evaporite minerals in all parts of the Los Medanos area, but the upper part contains traces to small amounts of these minerals several miles to the north of the area.

The lower member is 1,195 feet thick as recorded in ERDA-9. The member thins to 430 feet near the northeast corner of the area; in this instance the decrease of thickness seems to be due to beds missing at the corrosion surfaces that truncate individual rock sequences, as well as to thinning of all beds northeastward. Southward, the lower 240-300 feet of the member (that is, the Infra-Cowden) grades, according to Jones (1973), by intertonguing into the upper part of the Castile Formation, and the thickness of the member decreases to between 785 and 950. Anderson (1978) disagrees with the concept of an intertonguing lithofacies relationship between the Infra-Cowden salt and Castile anhydrite. He asserts that the Infra-Cowden wedges out southward and that the top of the Castile is unconformable with the Salado because of dissolution at or near the top of Castile prior to Salado deposition (refer to discussion above). Anderson (1978) presents an isopach map showing distribution of Infra-Cowden salt across the northern part of the Delaware Basin.

McNutt Potash Zone. The McNutt potash zone, located between the Vaca Triste halitic sandstone and the 126-marker bed, is another salt-rich member of the Salado Formation. However, unlike other members of the Salado, the McNutt may contain potassic rocks rich in sylvite, langbeinite, and hydrous evaporite minerals. The potassic rocks occur at short to long intervals in seams of rock salt scattered through nearly all parts of the McNutt zone. They are the obvious lithologic feature by which the NcNutt is distinguished, yet they are absent locally and, at best, probably comprise only 3 to 5 percent of the member in the most potassium-rich sections of the Los Medanos area.

Apart from the potassic rocks, the McNutt presents virtually the same aspect as other members of the Salado. Thick seams of rock salt alternate with thinner seams of anhydrite and polyhalite. There are partings of claystone beneath most anhydrite and

polyhalite seams and above layers of clayey halite. A bed of very-fine-grained halitic sandstone, the Vaca Triste, a foot or so thick, occurs in clayey halite at the top of the member.

The McNutt potash zone is 369 feet thick at ERDA-9, decreasing in thickness to the northeast. This decrease is similar in nature to that observed for the lower member. As a rule, where the member is thinnest it seems to be more thinly bedded and to have fewer beds.

Upper member. The upper member of the Salado, located above the Vaca Triste marker, consists of rock salt, minor anhydrite and polyhalite, and two persistent beds of very-fine-grained halitic sandstone, which are, respectively, 30-40 feet and 110-115 feet below the top of the unit. Claystone underlies seams of anhydrite and polyhalite, and coats the upper surfaces of clayey halite layers in the rock salt. Most parts of the upper member are generally free of hydrous evaporite minerals, but, nevertheless, some intervals of rock salt and other rocks in the upper 130 to 180 feet of the unit commonly contain traces to very small amounts of carnallite and kieserite.

Of particular interest is the occurrence of carnallite at the top of the upper member. The carnallite forms a major deposit of potassic rock that extends over a wide section in the northern part of the Los Medanos area and much of the region immediately to the north. The deposit is the only one known to occur in the upper member of the Salado, but is not restricted to the unit. It extends irregularly upward into sandstone of the overlying Rustler Formation.

At the WIPP site, the upper member of the Salado Formation is 512 feet thick (ERDA-9), becoming thinner (between 430 to 480 feet) farther north. This thinning northward seems to be partly depositional and partly erosional, for the member is more thinly bedded in the north and contains fewer beds. Many seams of anhydrite, polyhalite, and other evaporites are only about

three-fourths as thick as at the south end of the area. Beds of halite and clayey halite are missing beneath many of the corrosion surfaces that separate rock sequences in the unit.

Several miles west of the site in the Nash Draw area, variations in thickness of the upper member are fairly complex and large. The complexity and thickness of the member are believed to reflect a combination of geologic factors involving mostly (1) gradual thinning northward in response to changes in deposition patterns during the Ochoan Epoch, and (2) rapid thinning westward in response to change in dissolution patterns during the Pleistocene and earlier parts of the Cenozoic Era. In contrast to the modest northward thinning, the westward thinning of the member toward Nash Draw involves as much as a fourfold reduction in thickness in a distance of 4 to 6 miles, and the member is as thin as 150 to 170 feet at places along the west side of the area. This small thickness is considered to include the residue or remnants of at least a 450- to 500-foot-thick section of rock from which soluble salts have been leached by percolating ground water. The section of rock from which salts have been leached decreases in thickness eastward and feathers out in the area immediately east of Nash Draw. Insofar as can be determined from drilling records, the feather-edge of the residual materials marks the easternmost extent of dissolution of the upper member of the Salado Formation at any time. Apparently the regime here is highly stabilized and of long duration, with very little or practically no dissolution since the Pleistocene, or perhaps earlier. Estimates prepared by Bachman and Johnson (1973) indicate that the rate of salt removal during dissolution may amount to as much as 0.5 foot per 1,000 years. This rate suggests that roughly 1 million years would be required to reduce 450 to 500 feet of the upper member to an insoluble residual debris, and that dissolution in the western part of Los Medanos area has a long history extending back at least as far as mid-Pleistocene time. Other considerations, however, suggest that its history is even longer and may have begun by the mid-Tertiary (Bachman, 1976).

In all parts of the Los Medanos area, where the upper member of the Salado is thinned by dissolution, the section of rock between the upper surface of salt and the upper surface of the formation is composed of clay with crudely interlayered seams of broken and shattered gypsum and fine-grained sandstone. The clay is considered to be a subsurface residue concentrated through dissolution of clayey halite and other clay-bearing evaporites by percolating ground water. The gypsum is clearly the hydrated remnant of anhydrite and polyhalite seams, for it commonly contains ragged and embayed masses of anhydrite and polyhalite, and also grades laterally into anhydrite and polyhalite. The clay, gypsum, and sandstone comprise a fairly distinct residual unit that thins out eastward by grading into, and intertonguing with, rock salt and the other precursory rocks from which it originated. The residual unit thickens westward and crops out locally along the Pecos River west of the Los Medanos area. The unit is generally assigned by geologists mapping areas along the Pecos River to the lower member of the Rustler Formation, but this practice should be discontinued, for the clayey residue is clearly part of the Salado Formation.

Isopach maps of intervals in the upper member and in the McNutt potash zone are shown in Figures 4.3-4 through 4.3-7 referenced to the marker beds indicated. The same gradual northward decrease in thickness at the rate of about 10 to 15 feet per mile is exhibited by all four intervals contoured. It is significant that pronounced westward thinning of the Salado, which would be related to dissolution of salt from the Salado toward the Nash Draw area, is evidenced only in the uppermost interval (figure 4.3-7), and then only in Range 31 E., a mile or more west of the proposed WIPP repository boundary. The onset of westward thinning of the Salado Formation as defined by these isopach countours delimits a "suberosion" front at the top of the Salado (Griswold, 1977; Brokaw, et al., 1972; Jones, 1973) or the leading edge of a wedge of dissolution in the Salado progressing from west to east. This indicates that, insofar as can be detected by isopach patterns,

leaching of salt at the top of the Salado Formation by dissolution activity centered in the Nash Draw area has not occurred closer than approximately 1 mile west of the proposed WIPP repository.

In the Los Medanos area, the Salado Formation is overlain conformably by the Rustler Formation. The contact between the two formations is rather sharply defined as the horizon at which dominant rock salt below gives way to a 35- to 55-foot-thick unit of fine-grained sandstone that is generally dolomitic in the basal few feet.

Rustler Formation. The Rustler Formation, the uppermost or last of the three Ochoan evaporite formations, contains the least quantity of rock salt and the largest proportion of clastic material in this evaporite sequence. It was deposited in the last stages of the saline Permian sea that inundated the Delaware Basin, and is very largely coextensive with the Salado in this area (Brokaw et al., 1972). Jones (1972) lists lithologic percentages in the Rustler, presumably from areas in the Delaware Basin where Rustler salt has not been leached, as follows: 43 percent rock salt and other halides, 30 percent anhydrite, polyhalite, gypsum, and other sulfates, 17 percent clastic rocks, and 10 percent dolomite, limestone, and magnesite.

Shallowest of the evaporites to be exposed in the site area, the Rustler Formation crops out locally about 5 miles west of the center of the site, beyond the Livingston Ridge escarpment which forms the east edge of Nash Draw (refer to Figure 4.2-4, Surficial Geologic Map) Generally it is covered by alluvial material, sand dunes, or collapse debris.

The following descriptions of the Rustler are given by Jones (1973). As typically exposed in outcrop, the Rustler is a broken and somewhat jumbled mass of gypsum with minor dolomite and a few crude seams of virtually unconsolidated sands and clays. The outcrops in Nash Draw are decidedly poor for any study that requires precise information on the lithology, thickness, or specific chemical or physical properties of the

formation, and, as previously noted by Vine (1963), it is impossible to piece together a meaningful stratigraphic section from study or mapping of outcrops. Exposed rocks are porous, friable, and loose-textured, and all are strongly jointed, cavernous, and locally brecciated. Stratification is obscured or completely obliterated, and the attitude of bedding can rarely be determined with any degreee of confidence. The considerable deformation attests to the removal of much soluble material by percolating ground water and to the altered nature of the debris exposed in outcrop.

Two areally persistent beds of dolomite in the Rustler serve as important marker beds. The lowermost of the two dolomite beds, normally 100-150 feet above the base of the formation, is known as the Culebra Dolomite member. The upper bed, 200-250 feet above the base, is the Magenta Dolomite member. They were named and described by Adams (1944). Clastic rocks, consisting of thin to thick beds of sandstone and claystone, make up the remainder of the less soluble part of the formation.

In the subsurface, proceeding eastward across the WIPP site and into Lea County, all the gypsum in the Rustler gives way to anhydrite and minor polyhalite, and the sands and clays grade into sandy and clayey rock salt. In western Lea County at depths of 900-1,000 feet, the Rustler is largely an alternation of thick seams of rock salt and anydrite. A persistent seam of polyhalite occurs near the middle of the formation, and, insofar as has been determined, it is the only hydrous evaporite rock of any great extent or major importance in the stratigraphy of the formation.

With the eastward, down-dip change in composition from gypsum to anhydrite and rock salt, the thickness of the Rustler also changes rather significantly. The thickness ranges between 280 and 300 feet near the Nash Draw outcrop , but increases eastward to 490 feet about 10 miles southeast of the site and to 385 feet about 10 miles to the northeast. The increase ranges in amount between 105 and 160 feet and provides a crude measure of the minimum thickness of rock salt that is missing in

the area of outcrop. The difference in formation thickness between the southeast and northeast corners of the area is probably depositional in origin, for the formation is more thickly bedded in the southeast where it is thickest (Jones, 1973). These relationships are shown on a Rustler isopach map in Brokaw, et al. (1972).

In the immediate site area, the Rustler is lithologically divisible into a sandy lower part and an anhydritic upper part (Jones, 1975). The sandy lower part, 92 to 125 feet thick, is dominantly very fine-grained, silty sandstone, with less abundant anhydrite and rock salt; the sandstone is halitic and light to dark gray in its lower section and reddish brown and salt-free in its upper section. The anhydritic upper part of the formation, 200 to 227 feet thick, is largely gray anhydrite, with a few interbeds of reddish-brown clay and gray dolomite. The anhydrite is in fairly massive beds which have gypsiferous rinds along their lower and upper sides.

At the proposed WIPP site, ERDA-9 encountered 310 feet of Rustler commencing at a depth of 550 feet (refer to Figure 4.3-3). The Culebra and Magenta members were both encountered and measured at 26 and 24 feet thick, respectively. The thickness of the formation as a whole would indicate that much of the halite originally contained in the formation has been leached away, particularly in the upper part of the formation. The detailed well record of ERDA-9 (Griswold, 1977) shows that clayey halite was encountered in the Rustler below the Culebra dolomite, about 100 feet above the base of the formation. Between this position downward to the proposed upper level CH-storage zone, over 1300 feet of undisturbed evaporite rock, primarily Salado rock salt, intervene.

An isopach map of the Rustler Formation is shown in Figure 4.3-8. The closely spaced contours at the east edge of the site are a measure of the increasing amount of salt remaining in the Rustler in the eastward direction. The formation increases in thickness eastward and southeastward by about 180 feet over a distance of about 2.7 miles, or over 65 feet per mile. As with the Salado Formation, these contours can be used to postulate a dissolution front in the Rustler.

The Rustler Formation is separated from the overlying Dewey Lake Redbeds by a sharp lithologic break, an abrupt change from gray anhydrite to reddish-brown mudstone. The anhydrite below the break is free of sand and clay, and it ranges erratically in thickness from 18 to 32 feet. There is no indication of northward thinning, such as that common to most, if not all, rock units in the Rustler and underlying Salado Formations, and it would appear that the contact between the Rustler and Dewey Lake is an unconformity. The discordance and hiatus is probably not very great.

Dewey Lake Redbeds. The Dewey Lake Redbeds are the uppermost of the Late Permian Ochoan Series of formations and represent as well the top of the Paleozoic in the Delaware Basin. The term "Dewey Lake" is synonymous with the term "Pierce Canyon" originally proposed by Lang (1935) and applied to the redbeds in the Nash Draw area by Vine (1963). Actually the assignment of the Dewey Lake to the Permian Ochoan sequence is somewhat arbitrary, being based on certain lithologic details and stratigraphic aspects, rather than any definitely demonstrable affinity. Like the underlying Ochoan evaporites, the Dewey Lake appears to lack fossils despite its marine origin. Bachman (in Jones, 1973), while acknowledging the customary age assignment of the formation, nevertheless feels "that the Dewey Lake of southeastern New Mexico may actually be Triassic in age." He does not state, however, whether he believes it might be of Early or Late Triassic age.

The Dewey Lake crops out in places along the west edge of Nash Draw where partial thicknesses are exposed (refer to Surficial Geologic Map, Figure 4.2-4), but generally the formation is mantled by dune sand and caliche. Beneath the surficial cover, however, the Dewey Lake occupies a broad band between the center of the WIPP site and Nash Draw. It is bounded on the west by gypsiferous residue of the uppermost anhydrite seam in the Rustler Formation and on the east by coarse-grained clastic rocks of the Santa Rosa Sandstone of Late Triassic age. The latter contact occurs approximately across the center of the WIPP site.

The Dewey Lake is differentiated from other formations by its lithology, distinctive reddish-orange to reddish-brown color, and sedimentary structures. The formation consists almost entirely of an alternation of siltstone and very-fine-grained sandstone beds a few inches to several feet thick, but there are a few beds of claystone in its lower and upper parts. Individual beds are persistent, and the formation is readily separable on well log records into several sequences alternately richer or poorer in sandstone. Surficially, most rock is evenly and thinly bedded, liberally sprinkled with greenish-gray spots, and irregularly intruded by horizontal and criss-crossing veins of fibrous selenite. Some beds are structureless, whereas others are either horizontally laminated or cross-laminated. Many bedding surfaces carry shallow current or oscillation ripple marks. Silt-filled mud cracks occur at the top of many mudstone layers, and there are small chips and flattened pellets of mudstone in the basal part of many siltstone and sandstone layers (Jones, 1975).

According to Vine (1963), the Dewey Lake Redbeds represent the beginning of continuous deposition of detrital sediment following the long period of predominantly evaporite deposition in the Delaware Basin and adjacent shelf areas of southeastern New Mexico. However, the abrupt change in lithology does not necessarily signify a sudden tectonic or eustatic movement, but only a gradual decrease in the salinity or depth of the water plus a new source for the detrital sediments which were deposited.

Certain general features of the Dewey Lake are especially noteworthy. The lithology and color appear to be remarkably uniform. Viewed from the distance of a few feet, the stratification nearly always appears to be parallel, even though small-scale cross-lamination may be seen on close inspection. The small grain size, together with the minute scale of primary sedimentary structures, such as cross-lamination in sets less than 1 cm thick and oscillation ripple marks less than 1 inch from crest to crest, suggests that the silt was deposited in extremely shallow water extending over a broad flat. Lenses of medium-scale, cross-laminated, fine-grained sandstone or siltstone in the upper part of the Dewey Lake

probably indicate a gradual change toward fluvial deposition near the end of Dewey Lake time. The deposit undoubtedly blanketed the Delaware Basin and part of the shelf area to the north, but the source of the sediment is unknown.

The ERDA-9 well records a thickness of 487 feet of Dewey Lake strata. The thickness varies greatly across the area, however, from about 550 feet a few miles southeast of the site to 100 feet a few miles to the southwest (refer to isopach map, Figure 4.3-9). Normally in this area, the Dewey Lake ranges betwen 500 and 560 feet in thickness, thinning to the northwest. This northwestward thinning is attributed to pre-Late Triassic erosion after the redbeds had been tilted southeastward (Jones, 1973, p. 25). Locally, however, where the Dewey Lake forms the surface of either pre-late Tertiary terrain or Quaternary terrain, erosion later than Triassic has cut through the Dewey Lake, producing the steepened isopach gradients. In Figure 4.3-9 the gradients of 20 to 40 feet per mile observable in the eastern half of the map reflect pre-Late Triassic erosional thinning, while the steeper dips of up to 150 feet per mile to the west represent later dissection, apparently related to the origin and development of Nash Draw. A geologic section given by Jones (1973, Figure 3) illustrates the effect of this later dissection on the Dewey Lake surface.

4.3.3 Mesozoic Erathem

Triassic System. Triassic rocks in the northern part of the Delaware Basin are all Late Triassic in age and are included in the Dockum Group. The Dockum is entirely of continental origin and consists of the dominantly fine sediments of broad flood plains and coarse alluvial debris deposited over a very broad area extended beyond the borders of the Delaware Basin. It surfaces the pre-Tertiary terrane at and east of the WIPP site. Local subdivisions of the Dockum Group are the Santa Rosa Sandstone (Darton, 1922) and the Chinle Formation.

1) Santa Rosa Sandstone

The Santa Rosa Sandstone rests unconformably with sharp lithologic contact on the underlying Dewey Lake Redbeds. Vine (1963), based on outcrop observation, called this contact a disconformity (that is, parallel beds on either side of the contact representing a time-rock gap), but Jones (1973) considers it "an angular unconformity of low angle." Corresponding to an interval between the end of Permian time and the start of Late Triassic time, this unconformity represents a break in deposition perhaps longer than had previously occurred in the region since Mississippian time or even earlier, assuming the assignment of the Dewey Lake Redbeds to the Permian is valid.

At the site, the Santa Rosa occurs as an erosional wedge pinching out westward just beyond the center of the site; a thickness of only 9 feet of Santa Rosa Sandstone was recorded at ERDA-9. Eastward the formation forms the pre-Gatuna surface (See Figure 2 in Jones, 1973) but is blanketed by such an extensive veneer of Upper Tertiary alluvial deposits and caliche, and Recent dune sand, that the nearest extensive outcrops occur about 7 miles to the north (Vine, 1963).

The wedge of Santa Rosa thickens relatively rapidly eastward at the rate of up to 150 feet per mile, attaining a maximum thickness of 250 feet over a distance of only two or three miles, thereafter maintaining a more uniform profile (refer to isopach map of the Santa Rosa, Figure 4.3-10). Sections compiled by Jones (1973) indicate a relatively uniform thickness of the Santa Rosa on the order of 250 feet at least as far as several miles east of the Lea County boundary. The steepened wedge effect of the Santa Rosa across the site area is undoubtedly due to the post-Late Triassic, pre-Gatuna erosion that cut downward into the Dewey Lake surface, which is discussed above (compare Figure 4.3-9).

The Santa Rosa Sandstone consists, for the most part, of cross-stratified, medium- to coarse-grained, gray to yellow-brown sandstone, but includes both conglomerate and reddish-brown mudstone. In

outcrop it has been observed by Vine (1963) to consist of large-scale, trough-type, cross-bedded, pale-red sandstone and conglomerate lenses, 3 to 15 feet thick, separated by thin partings of moderate reddish-brown siltstone and silty claystone. The conglomerate lenses contain both silty dolomite pebbles and chert or quartz pebbles. The sandstone is characteristically poorly sorted. The formation differs from the underlying Dewey Lake Redbeds by being coarser grained, less well sorted, and by having beds that are thicker and more lenticular. Fossil plant impressions, carbonaceous plant fragments, and fossil reptile bones and teeth thought to be from phytosaurs characterize some of the beds. Clay is a relatively minor constitutent in most of the Santa Rosa Sandstone. Secondary dolomite is the most abundant cement, and it probably constitutes at least 10 percent of the rock.

The Santa Rosa Sandstone represents a change in the environment of deposition as compared with the Dewey Lake Redbeds. The large-scale trough-type crossbedding probably indicates a fluvial environment. The lack of sorting, arkosic composition, and angularity of the grains suggests rapid deposition by streams descending from a predominantly crystalline terrain (Vine, 1963).

2) Chinle Formation

The Chinle Formation, though not present at the WIPP site itself, occurs at about the Lea County line 5 miles to the east, where it forms the subcrop surface of pre-Tertiary rock, as shown by Jones (1973). Like the Santa Rosa Sandstone at the site, in profile the Chinle is seen to wedge out from the east at the Lea County line, beveled by pre-Gatuna erosion. Farther east, the Chinle appears not to attain a thickness in excess of 100 feet as shown by Jones (1973). Northward, however, it achieves a thickness of about 800 feet near the Hat Mesa gas field, about 11 miles northeast of the site, where the Chinle is blanketed by Late Tertiary Ogallala Formation (Jones, 1973). These relationships plus the areal distribution of Ogallala remnants indicate that post-Chinle, pre-Ogallala erosion occurred subsequent to an eastward to northward tilting of at

least the northern part of the Delaware Basin, resulting in a greater amount of Chinle sediments removed progressively southward and eastward. Later, one or more erosional episodes beveled a westward-sloping surface on post-Ogallala terrain.

In lithology, the Chinle is dominantly reddish-brown shaly mudstone interspersed with some greenish-gray mudstone and minor lenses of sandstone and conglomerate, deposited in a floodplain or alluvial environment basically similar to that of the Santa Rosa. Its contact with the underlying Santa Rosa Sandstone is conformable and is at the change from sandstone of the Santa Rosa to shaly mudstone of the Chinle. It is overlain unconformably by the Ogallala Formation of Late Tertiary age.

Post-Triassic Rocks of Mesozoic Age. No Mesozoic rocks later than the Chinle strata are known to exist in the WIPP site area. According to Jones (1973), there are good reasons to infer from paleogeology and other considerations that the Jurassic Period was a time of erosion and removal of the Dockum. Some rocks of Cretaceous age, though absent from the site area, almost certainly were deposited by Early Cretaceous seas which advanced northward across southeastern New Mexico. Small outliers, crevasse deposits, and other remnants of Lower Cretaceous rocks are found lying unconformably on the Capitan, Tansill, and Castile Formations near Carlsbad Caverns (Hayes, 1964; Lang, 1937), on the Salado Formation near Black River Village, on the Rustler Formation a few miles northeast of Carlsbad, New Mexico, and on the Chinle Formation at many places to the north and east of the WIPP site area (Ash and Clebsch, 1961).

4.3.4 Cenozoic Erathem

Tertiary System. No Early or Middle Tertiary sedimentary rocks are known to be present in the region. A lamprophyre dike, the only igneous rock later than Precambrian age known in the region, is observed to intrude the Salado Formation at the Kerr-McGee potash mine, about ten miles north of the center of the WIPP site (refer to Figure 3.5-2). Part of a

northeast-southwest dike trend of regional extent, the closest approach of which is at least eight miles northwest of the center of the site, the dike is not exposed at the surface east of the Pecos River. A radiometric date of 30 million years for the lamprophyre has been in the record for some time (Urry, 1936); an Oligocene or mid-Tertiary age for emplacement is therefore indicated. Further discussion of this dike trend, including an account of more recent investigations conducted, is included in Regional Geology, Section 3.5.1.

In Late Tertiary time extensive alluvial fans carried sandy and gravelly material eastward over a broad erosional plain that had developed in the region by Late Miocene time. The sediments accumulated during this alluviation, which lasted until Late Pliocene time, constitute the Ogallala Formation. The youngest fauna present in the Ogallala Formation is of Kimball age. This fauna may be as old as 4.6 million years (Bachman, 1974).

Only one area occupied by the Ogallala is present within 10 miles of the site, namely, a relatively thin erosional remnant capping The Divide located between 6 and 9 miles east-northeast of the center of the site (refer to Figure 4.2-4, Surficial Geologic Map). A geologic map by Bachman (in Jones, 1973) indicates that the Ogallala at the Divide is restricted to elevations above 3750 feet, where it is about 25 feet thick and includes about 10 feet of conglomeratic sandstone at the base overlain by about 15 feet of caliche. Pebbles of rounded quartzite and chert as much as 1-1/2 inches in diameter are present in lenticular beds (Bachman, 1974).

Special attention has been given to the caliche developed on the Ogallala by Bachman (in Jones, 1973), who suggests that it may be distinct in origin from caliche observed elsewhere in the area. Based on field examination, he finds that

> "Caliche of the Ogallala Formation is a distinctive travertine-like calcium carbonate. It is dense, light gray to white, and composed of concentrically laminated fragments that range from less than one-half inch to more than 2 inches in diameter. Space between

> these fragments is filled with structureless or, in places, laminated limestone. The weathered surface appears algal or pisolitic in places. However, these concentric laminae probably are not the result of organic activity but indicate repeated generations of inorganic solution and reprecipitation. The caliche is sandy and has been precipitated in porous spaces between sand grains; therefore, individual sand grains appear to float in the caliche. The Ogallala caliche probably formed as a part of a soil profile that developed on the High Plains surface either during or after deposition of the Ogallala Formation."

In the High Plains to the east of The Divide, longitudinal depressions in the Ogallala caliche are interpreted to be interdunal swales caused by solution etching of Ogallala caliche where it was not protected by Pleistocene sand dunes (Bachman, 1976).

Quaternary System

1) Pleistocene Series

a) Gatuna Formation

The only Pleistocene deposit at the proposed WIPP site which has been assigned a formal stratigraphic name is the Gatuna Formation. In the immediate area, the Gatuna forms a thin blanket, locally absent, ranging in thickness from zero to slightly more than 30 feet (refer to Figure 4.3-11, Gatuna Isopach Map); at ERDA-9, 27 feet of Gatuna were recognized. In spite of its shallow depth below the surface, however, the Gatuna crops out only rarely, being for the most part obscured by a thin but persistent veneer of caliche and surficial sand. The nearest mapped outcrops occur along the west-facing slope of Livingston Ridge at the edge of Nash Draw (about four miles northwest of the center of the site; see Figure 4.2-4, Surficial Geologic Map) where they were mapped by Vine (1963), and to the southeast of the site as mapped by Bachman (1974). In Nash Draw itself the Gatuna locally exceeds 100 feet in thickness and fills sinkholes previously formed by dissolution of salt and other evaporites. It has alluviated most drainage valleys of an ancient Pecos system, of which Nash Draw was a part. Though the Gatuna is predominantly a fine-grained, reddish or brownish friable sandstone,

conglomerate lenses and blankets are common regionally. It is the pebbles in the conglomerate which have proved most useful in providing evidence relating to geologic history, age, and provenance of the formation.

Bachman (1974) discusses age, lithology, and paleoclimatic implications of the Gatuna at some length. Generally, the Gatuna was stream-laid under pluvial conditions. In some areas having fine-grained materials in the lower part of thicker sections, the Gatuna first filled collapsed basins and extensive sinks; in other areas, such as in the southern part of Nash Draw, gypsum-rich clays and silts in the section suggest deposition in areas then undergoing sinking and collapse. Based on examination of pebble clasts in Gatuna gravels of the Pecos River northwest of the site in Chaves and northern Eddy Counties (refer to Regional Geology and Regional Geomorphology sections for additional discussion of these gravels), Bachman concludes that the Gatuna was deposited in a much wetter climate than present. There is no indication that modern drainage is carrying clasts of the size and quantity preserved in Gatuna stream deposits. The discovery of Ogallala pisolitic debris (i.e., pebbles of Ogallala caprock caliche) in the Gatuna demonstrates that the Gatuna is Pleistocene rather than Pliocene in age. Futhermore, on the basis of the many stream and pond deposits in the Gatuna and the evidence for widespread solution and collapse, Gatuna time represents the most humid Pleistocene stage in southeastern New Mexico. Regional considerations lead Bachman to assign a tentative Kansan age to the Gatuna, or approximately an age of 600,000 years (Bachman, 1974).

b) Mescalero Caliche

Beneath an obscuring cover of wind-blown sand, much if not all of the site area, excluding some depressions and drainages such as Nash Draw, are covered by a hard, resistant caliche crust. It is very extensive to the north in Chaves County on the Mescalero plain between the Pecos River and the Llano Estacado and is informally called the Mescalero caliche. Though generally less than 10 feet thick in the site area, its resistance to weathering in the dry climate has effectively prevented natural

exposure of older strata and has allowed it to form extensive surfaces that can themselves be mapped in definite stratigraphic sequence with other deposits.

Vine (1963) provides a detailed account of caliche as he observed its occurrence in the Nash Draw quadrangle. He states,

> "Caliche is a near-surface accumulation of calcareous and clastic material that forms a resistant mantle. It is characterized by an excess of calcareous material over that required to cement the clastic grains, with the result that the grains appear to float in the matrix. In many areas the caliche is characteristically brecciated and recemented. In addition to sand and calcareous material, pebbles are locally abundant, and silica in the form of chalcedony or opal also forms part of the cementing matrix. Other soluble minerals, including gypsum, are probably locally present. Where the top surface of caliche has long been exposed to weathering, it almost invariably has a very hard dense limestone surface that could easily be misinterpreted as an outcrop of massive limestone similar to those in some older formations. Close inspection, however, generally reveals sand grains, chalcedony, and brecciation. Commonly the dense layer at the top is only 1 or 2 feet thick, and the rock becomes more friable and shows a greater proportion of sand grains to matrix within a few feet of the surface. The less calcareous zone in turn grades downward within 5 or 10 feet into the underlying bedrock, which generally is broken into angular fragments recemented with calcareous material. (Note: five feet of caliche were encountered at ERDA-9.) In many areas caliche has concentric lamination or colloform structure resembling calcareous algal structures. The widespread mantle of caliche has much the same composition throughout the area regardless of whether the underlying bedrock is red sandstone and siltstone from the Gatuna Formation, Santa Rosa Sandstone, and Pierce Canyon (=Dewey Lake) Redbeds, or gypsum from the Rustler Formation."

Bachman (1974) shows a regional structure contour map of the Mescalero caliche. He confirms Vine's recognition of an upper dense zone over an earthy-to-firm nodular calcareous deposit, and notes that it is the upper dense caprock that is prominently laminated. The character of the laminae indicates that the Mescalero caliche arose through successive cycles of dissolution and reprecipitation of the matrix, and that this occurred during an interval of tectonic stability that followed deposition of the Gatuna Formation--that is, in the semiarid environment that followed the moist conditions of Gatuna time. Based on regional geomorphic considerations, Bachman correlates the formation of the

Mescalero caliche with the Yarmouthian interglacial stage, or mid-Pleistocene time, about 500,000 years ago. Brown (1956) reached generally similar conclusions on the origin of caliche he studied on the Llano Estacado of the Texas panhandle, where he found that "the caliche, with interruptions, apparently has been forming continuously since its inception in the Pliocene, and its multiple occurrence is a reflection of climatic variations in the Pliocene and Pleistocene". Noting that the Mescalero caliche dips abruptly into Nash Draw along Livingston Ridge, Bachman (1974; also in Jones, 1973) concludes that Nash Draw was subjected to subsidence after the formation of the caliche, presumably during the more pluvial conditions of the subsequent Illinoian or Wisconsin glaciations.

2) Recent Deposits

Deposits of Recent age in the vicinity of the WIPP site include windblown sand, alluvium, and playa lake deposits.

The most prevalent deposit by far is the windblown sand which covers nearly all of the area of the WIPP site itself. The sand, locally known as the Mescalero sand (Vine, 1963), occurs either as a sheet deposit resting on caliche or as tracts of conspicuous dune fields (Los Medanos). In the former case, the sand is probably no more than 10 to 15 feet thick on the average; in the latter, the sand may attain 100 feet in thickness locally. At many places the sand consists of two parts: a compacted, slightly clayey moderate-brown eolian sand up to 1-1/2 feet thick, overlain by loose, windblown light-brown to light yellowish-gray sand. The sand dunes appear to be relatively inactive at present, partly stabilized by sparse plant cover. The widespread deposits of windblown sand are indicative of a large source of fine sand as well as of the extreme fluctuations of climate that have occurred during Pleistocene time. There is very little evidence that much sand has been derived from the Pecos River. Bachman (1974) suggests that most sand has been derived from deposits of the Ogallala Formation. During humid intervals in Pleistocene time the sand has been eroded from the Ogallala, and during arid intervals the wind has moved this sand across the Mescalero plain.

Deposits of alluvium are mapped by Vine (1963) generally in belts 1/4 to 3/4 of a mile wide along the base of declivities into Nash Draw, as along the base of Livingston Ridge, and locally in smaller depressions (refer to Figure 4.2-4, Surficial Geologic Map). These deposits are similar to sheet wash or small alluvial fans, and Vine considers them analogous to pediment or bolson deposits.

Playa deposits occur in mudflats, and consist of eolian sand and alluvium reworked by shallow-lake waters. Vine (1963) shows these areas clustered mostly within Nash Draw, where the occasional runoff accumulates. The nearest playas are mostly small, circular areas about 5 miles west of the center of the site filling in the bottoms of sinkhole depressions adjacent to Nash Draw.

4.4 SITE STRUCTURE AND TECTONICS

4.4.1 Tectonic and Structural Setting of Los Medanos Site

Relation of Site Structure to Regional Tectonics. The single dominating tectonic feature in the region around the proposed WIPP site is the Delaware Basin, the locus of unusually thick and rapid sedimentation in Permian time. Beneath the site, for example, about 15,000 feet of Pennsylvanian and Permian clastics, limy clastics, and evaporites accumulated. The basin was marginal to an orogenic belt located farther southwest (the Diablo Platform) which was tectonically active in Late Pennsylvanian and Permian time. The basin evolved by downwarp of Precambrian basement terrane of the Texas foreland, a granitic craton. South of the New Mexico border in Texas, the Delaware Basin in Late Pennsylvanian time was trough-like and received much of its sediment from a bordering mobile orogenic belt (Marathon system), in the manner of a molasse trough or exogeosyncline; in New Mexico, however, the northern part of the Delaware Basin received sediment from intracratonic highs located both to the west (Huapache flexure) and to the east (Central Basin Platform) and assumed more the character of an intracratonic basin in which subsidence was accomplished mainly by downwarping of the craton

without major marginal faulting and without subsequent folding or compressive tectonic deformation, although buried normal faults of fairly large displacement are known at the margins of the Central Basin Platform. The Central Basin Platform, located approximately along the New Mexico-Texas border east of the site, may be viewed as a medial, arched horst, now deeply buried by later sedimentary deposits, which separated and partly isolated the Delaware Basin from its eastern counterpart, the Midland Basin, during Late Pennsylvanian and Early Permian time; later in Permian time these basins constituted part of the broad Permian Basin (refer to Sections 3.4 and 3.6; see Figure 1 of Bachman and Johnson (1973) for the extent of the Permian salt basin).

In the Delaware Basin toward the close of Permian time, as much as 4,000 feet of evaporite beds, dominantly rock salt, accumulated, during which time differential subsidence ceased and stable cratonic conditions returned to the area. Later, Triassic redbeds mantled the region. In mid to late Tertiary time, rifting and tensional faulting occurred in the Basin and Range region of New Mexico as far east as the Sacramento and Delaware Mountain anticlinal structures west of the Delaware Basin, and southeast along the Diablo Platform to the Big Bend area of Texas, but did not occur within the Delaware Basin itself. The basin was, however, tilted gently one or more times between Late Triassic and Pliocene time, producing a general net eastward tilt of about 2 degrees. The Late Permian Ochoan rocks and the Triassic rocks exposed in the basin today do not reflect basinwide warping; the major structual feature of these deposits is merely the regional eastward slope produced after Triassic time (Bachman and Johnson, 1973).

Tectonic and Nontectonic Mechanisms at the Site. At the site, stresses associated with the origin and development of the Permian Delaware Basin have deformed the pre-existing rocks or contemporaneous sediments in different ways. Specifically, these stresses included the nontectonic downward pressure imposed by the weight of rapidly deposited sediment and the tectonic stress arising from within the earth's crust and transmitted through the basement rocks to the sedimentary pile. The tectonic stress

would have been most effectively imposed upon those rocks of the sedimentary pile that had already undergone lithification and were therefore mechanically coupled with the basement rocks. Stress imposed by sedimentary loading would have been most effectively absorbed by subjacent materials that were the least lithified and therefore the most compressible and capable of adjusting to differential sediment loads. Each mechanism would have produced different kinds of structures and caused different types of faulting in the rocks beneath the basin. The temperatures measured and heat flow calculated for AEC 8 (Mansure and Reiter, 1977) show evidence of normal geothermal gradients.

The presence of thick salt beds profoundly affects the type of deformation which occurs in the salt itself and which is imposed upon rocks and sediment lying above the salt, inasmuch as thick salt is known to deform plastically and to behave as a viscous medium over extended periods of time. This behavior is promoted by high overburden pressures and increased temperatures. Under favorable conditions, even slight tilting of the beds or lateral differences in lithostatic pressure are sufficient to initiate long-term viscous flow of salt. Salt deformation is therefore quite different in mechanism and manifestation than the deformation of the enclosing rock materials. As a result, deformational features exhibited by rocks and sediments lying above thick salt would normally be expected to have little or no mechanical relationship to structures in rocks occurring beneath the salt, because the intervening salt effectively decouples the two rock masses. Rocks overlying salt would be expected to display local structures that are generated by mass flow of salt. In addition, because shallow salt is susceptible to dissolution by unsaturated ground water, sediments above shallow salt where active solutioning had occurred could be expected to exhibit karst and collapse features, or to have internal irregularity and chaotic structure brought about by uneven subsidence or upward stoping following removal of significant thicknesses of salt in the subsurface. It should be emphasized, however, that at the WIPP site, evaporite dissolution has been restricted to salt beds of the Rustler Formation. No evidence has been obtained to date to indicate that this relatively small amount of dissolution of Rustler salt has resulted in significant differential

subsidence in the site area. In contrast, the potential for subsidence structures to occur has been realized in areas such as Nash Draw, where partial dissolution of Salado evaporite beds has taken place.

It is concluded on the basis of the preceding discussion that the nature of the origin and development of possible structural features in the rocks which occur in the Los Medanos area is spatially related to the position of these rocks in the geologic column relative to the position of thick bedded salt. Accordingly, the following description of geologic structure at the WIPP site is organized into separate discussions of deep structure (i.e., structure in rocks underlying Ochoan salt), salt deformation, and shallow structure.

4.4.2 Deep Structures

Subregional Structure of Pre-Evaporite Rocks. A variety of structure contour maps covering an area within about a 25-mile radius of the WIPP site has been prepared, generally from well data. Foster (1974) provides seven such subregional maps from top of Precambrian to top of Bell Canyon (base of Castile); Sipes et al. (1976) show somewhat more structural detail on top of Devonian, Morrow, Atokan, Strawn, and Delaware strata (their exhibits 11,10, 9, and 8, respectively, the first two of which incorporate seismic reflection profile interpretations). Netherland, Sewell and Associates (1974) present generalized structure contour maps of a slightly different area on eleven horizons, from Ellenburger to top of Bell Canyon (their Figures G-6 through G-16).

Structure contour maps express a homoclinal regional dip toward the southeast to east on all pre-Ochoan Paleozoic strata, reflecting the presence of the Delaware Basin downwarp. Gradients on all pre-Permian horizons are similar in magnitude and direction, decreasing from about 150 feet per mile southeasterly in the lower Paleozoic to about 100 feet per mile at the top of the Pennsylvanian. The nearest fault large enough to be indicated by subsurface well control is a north-trending fault shown by Foster (1974) about 15-20 miles east and southeast of the WIPP

site, and referred to as the "Bell Lake fault." It has a length of about 15 miles and a displacement of about 500 feet. Located west of the central axis of the Delaware Basin, it nevertheless appears to be structurally related by orientation and displacement (upthrown to the east) to the west-bounding fault of the Central Basin Platform farther east, as is shown on the regional structure contour map of Haigler and Cunningham (1972). The fault is not indicated to offset Permian strata (Foster, 1974), but contours of Wolfcamp and Bone Springs strata in the lower part of the Permian section are deflected in the area of the fault. Permian structure contour maps indicate a difference in gradient and direction of horizons compared to earlier strata. This indicates significant tectonic activity in the basin in Late Pennsylvanian and Early Permian time, which was the major period of structural adjustment in the Delaware Basin (Foster, 1974). Permian strata beneath the Ochoan Series slope east-southeast at about 50 feet per mile (Foster, 1974), markedly less than pre-Permian strata.

Site-Specific Interpretations. In the immediate site area seismic reflection data can be utilized as an adjunct to well control in preparing more detailed structure contour interpretations. Figures 4.4-1 thru 4.4-3 contour horizons at, respectively, the top of the Silurian (Siluro-Devonian carbonate, refer to Section 4.3.2), top of Morrow, and near the top of the Delaware. Seismic profile lines are indicated and well control points are shown. Structural interpretation of seismic reflection profiles has been furnished by G.J. Long and Associates, Inc. (1977). (Additional seismic profiling has been performed (G.J. Long, 1977b) or is presently being undertaken as part of a continuing program by Sandia Laboratories to delineate subsurface structures at the WIPP site. These additional data will be presented and discussed when the analyses are completed.)

In general, Figures 4.4-1 through 4.4-3 reveal the existence of minor faulting and secondary warping (swells and saddles) in Paleozoic strata below the evaporite beds. Comparing Figure 4.4-1 with 4.4-2, a pattern of generally north-northeast-trending faults has been interpreted,

oriented roughly parallel to regional strike and typically upthrown to the east. Small, subdued dome-like features and complementary saddles spaced several miles apart and with crest-to-trough amplitude of several hundred feet are superimposed on the regional gradient and appear to persist in position through both horizons. In the Silurian, for example, several small arches of up to 300 feet of relief are aligned in an east-southeast or west-northwest anticlinal trend passing just north of the Zone II exclusion area (Figure 4.4-1). In the Morrow a similar east-west trend in about the same location is defined by more subdued structural gradients and highs of lower amplitude (Figure 4.4-2). This trend is identified as the "Cabin Lake" trend by Netherland, Sewell and Assoc. (1974); see also Figure 2-7 of this report. On both horizons a domal feature is evident beyond the southwest edge of the site. This feature, which Netherland, Sewell (1974) indicate is at the east edge of the "Los Medanos" trend, is presumably responsible for the gas production of the Los Medanos field, the nearest hydrocarbon field to the site. Between these two anticlinal trends, a northwest-trending saddle is defined, located beneath the southwestern edge of the site.

The north-northeast-trending faults inferred in Figures 4.4-1 and 4.4-2 are, as interpreted from seismic reflection records, of greater intensity in the Devonian, being traceable over distances exceeding ten miles and having displacements of up to 400 feet (Figure 4.4-1). Faulting of the Morrow (Figure 4.4-2), some 2,500 feet higher stratigraphically, is roughly correlative with the deeper displacements, but seems to dissipate into discontinuous segments of generally smaller displacement.

Small-scale structures interpreted on the Delaware Mountain Group, roughly 9,500 feet above the Morrow horizon, show little or no correlation with deeper features (refer to Figure 4.4-3). The north-northeast-trending faulting is no longer apparent; instead, seismic reflection studies (G.J. Long, 1977a) indicate short (less than 5 miles in length), discontinuous northwest-trending offsets of small displacement (less than 50 feet) passing beneath the northeast half of the site; refer to Figure 4.4-3. The fact that the faults are not

detected at greater depths suggests a shallow-seated origin. Warping in the Delaware Mountain Group appears to be much more subdued than in the Morrow; structure contours lack closure around irregularities, and trends in the Delaware Mountain Group appear to be unrelated to Morrow and deeper trends. One feature of note shown (Figure 4.4-3) is a shallow, northwest-trending saddle of not more than 100 feet of structural relief, located beneath the center of the site; the presence of such structural lows is considered to be a favorable site selection criterion (refer to Section 2).

The contrasting structural characteristics between the Delaware and pre-Permian horizons suggest different origins. All strata from the Pennsylvanian on down have been deformed in continuity, with intensity of deformation increasing with depth. Tectonic deformation apparently occurred in Late Pennsylvanian or Early Permian time and established the local structural elements of all pre-Permian rocks. The "rootless" character of at least some of the normal faulting in the Permian suggests that these are shallow-seated features. Considering the unusually rapid rate of accumulation of material in Permian time (about 13,000 feet), it seems reasonable to presume a predisposition for the occurrence of contemporaneous sedimentary deformation brought about by such factors as gravity creep, compaction during diagenesis, differential sedimentary loading and rates of dewatering, and differential subsidence. Such deformation has been documented along "growth faults" in the Gulf Coast basin (Murray, 1961, p. 137; Fisher and McGowen, 1967, Figure 3; Bishop, 1973; Bruce, 1973). Contemporaneous faults of this type may have been initiated during deposition of thick pre-Ochoan clastic sequences. Conceivably, further movement might have been promoted by mass movement of salt subsequent to evaporite deposition, which shifted overburden loads over possibly still compressible sedimentary material.

Figures 4.4-4 and 4.4-5 show southwest-northeast and northwest-southeast sections, respectively, across the proposed WIPP site area, adapted from Griswold (1977). The overwhelming thickness of Permian pre-evaporite strata relative to earlier deposition is graphically displayed. Faults

arising in the basement offset Pennsylvanian strata but do not propagate through the lowest Permian series, the Wolfcampian. The regional dip of the Delaware Basin is most evident in Figure 4.4-5.

4.4.3 Salt Deformation

For the purpose of this discussion, detailed description of deformational features within the salt beneath the site and in the northern part of the Delaware Basin is restricted to consideration of structure displayed by the Castile and Salado Formations even though the Rustler is normally considered part of the evaporite sequence. At the site and in the vicinity of the site, the Rustler has been leached of much of its salt with the result that most of its structure is surficial in origin and is included in the discussion of site surficial structure, Section 4.4.4.

Of previous studies available in the literature on the northern part of the Delaware Basin, the papers by Brokaw et al. (1972), Anderson et al. (1972), Jones (1973) and Anderson (1978) are most relevant to salt deformation in the area of the proposed WIPP site.

Subregional Structure of Evaporite Beds. Throughout the northern Delaware Basin, the general uniformity in direction and amount of the gentle southeastward homoclinal dip is practically the only structural feature that is common to all levels of the evaporite section (Jones, 1973). Superimposed on this homocline is a rather complex system of flow features variably developed relative to both areal location and stratigraphic position, features attributable to mass migration of salt.

Features that are of subregional significance, and that appear to have a fundamental role in the development of salt deformation, include the Capitan reef front. It formed a steep, submarine prominence or wall 1,000 to 1,500 feet high isolating the deep water of the early Castile brine sea from the rest of the Permian inland sea (refer to Sections 4.3.2 and 3.6). Figure 10 of Jones (1973), a structure contour map on the base of the Castile Formation, graphically depicts the structural

relationship of reef and basin in the site area. Immediately basinward of these buried reef masses, which are located 8 miles north of the WIPP site, is a northwest-southeast-trending structural trough paralleling the base of the reef and descending in elevation, or plunging, southeastward. The most intense deformation in the evaporite sequence seems to be spatially related to this trough; not only is the trough expressed within the salt layers, but the top of the clastic Delaware Mountain Group (Bell Canyon Formation) is also depressed. Subregional geologic sections constructed by Jones across Nash Draw and Livingston Ridge (Brokaw, et al., 1972, Jones, 1973,) illustrate the general configuration of reef, trough, and deformation within the evaporite sequence in the site area. Jones' (1973) assessment of these particular features is pertinent:

> "At intermediate and other levels in the (evaporite) section, the structure is generally more uneven than at the base of the Castile Formation, and minor folds are somewhat more prominent. Salt and anhydrite in the middle member of the Castile are crumpled in sharp intraformational folds that appear to die out northwestward up the dip and to become more pronounced southeastward down the dip. Spatially the intraformational folding of the salt and anhydrite appears to be confined to a single long northwestwardly-trending belt, about 3-4 miles wide, that more or less coincides in trend and extent with the prominent southeastwardly plunging trough at the base of the Castile. The folding has resulted in some buckling and downwarping of rocks in the Salado Formation, and it has uplifted the Salado and other rocks as young as the Chinle Formation in a fairly broad arch that trends northwestward across the area. The exact age of the deformation is unknown; it can be dated only very broadly as post-Late Triassic to pre-Pliocene. Specific considerations concerning minimum thickness of overburden required to initiate salt movement suggest that the deformation may have occurred during or shortly after the period of regional tilting that followed the deposition of Cretaceous rocks. The deformation almost certainly had to occur before any great thickness of Cretaceous rocks was removed by erosion."

Subsequent studies by Anderson (1978) and Anderson and Powers (1978) have supplied some detail on the character of the salt deformation recognized by Jones. Apparently the only part of the Castile that has not been

involved in significant plastic flow deformation is the lower or basal anhydrite, Anhydrite I (refer to site stratigraphy, section 4.3.2 for discussion of Castile stratigraphy). On the other hand, the lowest thick Castile salt member, Halite I, has undergone severalfold increases in thickness in some areas. Anderson (1978) presents a basinwide isopach map of the lower Castile Halite-I unit which shows an increase of thickness from a normal value of about 300-350 feet, as occurs in the area of the proposed WIPP site, to a value of 1,200 feet at the ERDA-6 location 5 miles north-northeast of the site. The isopach lines at this location define an elongate, sharply thickened bulge of the Halite-I unit, the long axis of which is about 12 miles long and is oriented parallel to, and on the basin side of, the buried Capitan reef front. Anderson's isopach map also shows numerous similar, slightly smaller elongate bulges, their long axes all about 3-1/2 times the length of their shorter ones, contained within a belt about 5 miles wide paralleling the basin side of the reef front. Since the anhydrite unit (Anhydrite I) underlying this deformed salt is not significantly deformed and does not itself rest on deformed rocks (Jones, 1973), the tops of these large salt mounds or bulges define what may be termed salt anticlines. These are not anticlines in the usual sense of the term because the top and base of the unit have totally dissimilar profiles; piercement associated with the term salt anticline is not generally present. This belt of salt anticlines, then, is the northwestward-trending belt of intraformational salt deformation recognized by Jones as occurring within the Castile and affecting strata above the Castile.

Structural detail within the large salt anticline located about 5 miles northeast of the center of the proposed WIPP site has been provided by cores recovered from the ERDA-6 hole drilled near the center of the anticline (Anderson and Powers, 1978). Stratigraphic interpretation made by Anderson and Powers from study of the core indicates that the middle anhydrite bed which overlies the salt has indeed been pushed up by the rising salt but has apparently acted as a semirigid confining blanket that was stretched upward like a flexible sheath; whether the anhydrite bed everywhere remained intact or was in places fully ruptured and

detached by extension is not known. What is displayed in the core is that most of the anhydrite, which actually consists of finely interlaminated calcite and anhydrite, was stretched by extensional microfracturing of the calcite laminae and in-filling of the fractures by mobilized calcium sulfate, which presumably was derived by diffusion or creep from adjacent anhydrite laminate. The process seems closely analogous to boudinage in metamorphic rocks, and could be viewed as a microboudinage structure brought about by the properties of finely laminated calcite and anhydrite when subjected to high shear stress under sufficient confining pressure.

Anderson and Powers (1978) find that Halite-I salt, together with streched Anhydrite II or middle anhydrite, have in their upward migration pushed aside both the overlying upper salt (Halite II) and upper anhydrite (Anhydrite III) beds in the manner of an intrusion, since the stratigraphy in the ERDA-6 hole passes directly from Infra-Cowden salt to Anhydrite II. The authors show that the overlying Salado beds, though not breached by the intrusion, are arched over it. It is therefore evident that the arching effect in beds of the Salado and even younger rocks referred to by Jones (1973) along the belt of deformation is in at least some cases due to the presence beneath these anticlines of a salt core which arose from the lower part of the Castile and partly intruded the overlying rocks.

In addition to revealing the cores of many of the salt anticlines in the northwest-southeast belt of deformation described above, the subregional Halite-I isopach map (Anderson, 1978) shows numerous, sharply defined localized depressions at locations where the Halite-I salt is entirely missing from the section. In the central part of the basin, these "deep-seated sinks", as Anderson calls them, do not have obvious surface expression, and are not clearly related to shallower dissolution features--such as collapsed and uncollapsed domes, dissolution fronts, castiles, and collapsed outliers--which have been described and

documented elsewhere in the Delaware Basin region. Many of these isopachous depressions, some of which are defined by a single data point, may possibly be attributed to "deep dissolution" processes (Anderson, 1978), presumably acting from near, or perhaps below, the base of the salt section. A few appear, however, to originate within the Castile in salt zones above the lower halite. Anderson (1978) has proposed that some of them may have propagated vertically upward in the evaporite section to form known cylinders or chimneys of dissolved and collapsed debris. Alternatively, halite flow from adjacent regions into anticlines may account for these paired features as illustrated in Anderson and Powers (1978). (For description of these features in the Delaware Basin subregion and a discussion of their origin and development, refer to regional geomorphology, regional structure, and subsurface hydrology, Sections 3.2, 3.4, and 6.3).

Unlike the belt of salt anticlines having cores of Halite-I salt, the distribution of the localized pockets of missing, or greatly reduced thickness of, Halite I and higher Castile or Infra-Cowden halite that Anderson classifies as "deep sinks" is not confined to a belt above or adjacent to the Capitan reef but includes mid-basin areas as well, as illustrated by Figure 16 of Anderson (1978). The nearest of these deep mid-basin features to the proposed WIPP site as disclosed by the various halite isopach maps of Anderson (1978) occurs about 5 miles southeast of the site at the Eddy-Lea County line. This particular feature is not indicated to originate within the Halite-I zone of the Castile; rather, it appears to be a feature in the infra-Cowden salt (Anderson, 1978, Figure 7); compare this report, Figure 4.4-7, and refer to the section immediately following for additonal detail on the near-site structure.

It is not yet clear whether all or even some of these deeply buried mid-basin "sinks" identified by Anderson have a hydrologic origin subsequent to diagenesis and salt deformation. If they do, they may well be related to other collapse features in the Delaware Basin region as simply one manifestation of the same general process being seen at different levels of exhumation by erosion (Anderson, 1978, p. 58-59).

The concept that these diverse solution structures are being exhumed by present-day erosion suggests that the conditions of their formation in the geologic past may not be present today in kind or to the same degree.

The nature of the deformation in the middle and upper part of the salt sequence above the Halite-I zone is recorded by the subregional halite isopach and structure contour maps of Anderson (1978) and Brokaw et al. (1972). The salt isopachs of Anderson (1978, Figures 4 through 10) clearly show that no other salt member of the evaporite sequence has experienced local flow deformation as severe as the Halite-I zone, nor are the "deep sinks" apparently as prevalent in the middle and upper part as they are near the base of the Castile. The Halite-II member of the Castile mirrors the same thickness trends exhibited by the Halite-I bed, but in a much muted manner. The infra-Cowden salt is the highest salt of the Castile-Salado sequence to exhibit marked thickening along the trend of the buried Capitan reef; it is also the lowest, or first, major salt bed to overtop and extend beyond the confines of the reef margin in this part of the basin. Even though no appreciable thickening of Salado salt above the infra-Cowden is apparent over the Capitan reef margin (Anderson, 1978), structure contours at the base of the Salado Formation (= top of Castile) (Jones, 1973) and on the 124-marker bed within the McNutt potash zone (Anderson, 1978) document that the Salado is indeed arched along the basinward edge of the reef and confirm that the salt deformation which occurs at depth around this margin had imposed an anticlinal structure on overlying strata, much as Jones (1973) described (also compare Brokaw et al., 1972 with Jones, 1973).

The evidence presented in this section regarding the subsurface structure of Castile and Salado halite beds and the spatial relationship of deformation structures with the bounding Capitan reef margin suggests that viscous flow of salt was initiated by post-depositional regional tilting and that the Capitan reef acted as a dam or abutment obstructing the eastward subsurface viscous flow of the lower part of the salt section which impinged against it. The salt piled up slightly, as a rug might when gently pushed against a wall, until lithostatic equilibrium

was attained with the superjacent rock mass. That larger, more dramatic salt plumes were not formed in the Delaware Basin, as they are known to occur in the Gulf Coast basin, for example, may be attributed to several factors. Two of these factors are the gentleness of the regional tilt and perhaps a relatively shallow depth of burial of salt. This would have resulted in lower lithostatic pressures and relatively higher viscosity of salt and hence greater resistance to migration. Evidence from structures nearer the site (e.g., WIPP 11, as discussed in the next section) indicates that the redbeds overlying the Salado are not always involved in the structure. This implies that some of the structures may be Permian in age.

No conclusive evidence establishing the exact time of regional tilting of the Delaware Basin has yet been found, except that it occurred after Chinle deposition (Late Triassic time) and before Ogallala time (uppermost Miocene). King (1948) has proposed that regional tilting took place in early to mid-Tertiary, concomitant with known Basin and Range faulting that occurred in the region west of the Delaware Basin, with relative upthrow of the Guadalupe and Delaware Mountains. Certain relations of Cretaceous strata, as described and discussed in section 4.5 on geologic history, and the long time span between Triassic and Late Cenozoic, suggest that there may have been earlier episodes of moderate regional tilting, of which the present eastward tilt is merely the resultant vector summation.

Geologic Structure of Salt at the Site. Within the context of the subregional relationships of deformation in the Castile-Salado evaporite sequence described and discussed in the previous sub-section, geologic structural features in the salt lying beneath the WIPP site may now be reviewed. Figures 4.4-6 through 4.4-10 show, respectively, structure contours on top of Castile, on the 124-marker bed of the Salado (within the McNutt potash zone in the middle part of the Salado), on top of the Vaca Triste member (top of NcNutt), on the 103-marker bed, and on top of the Salado. Geological sections across the site area are shown on Figures 4.4-4 and 4.4-5. Gross structure of all evaporite horizons

reflects the regional easterly homoclinal dip of 50 to 100 feet per mile. Salt deformation has modified this homocline to a variable extent, generally more so in the Castile than in the Salado, inasmuch as the lower halite beds of the Castile appear to have been the most mobile (refer to subsection 4.3.3).

Seismic reflection surveys performed at the site (G.J. Long, 1977a, 1977b) were designed in part to record the relatively shallow Castile horizons (for description of the seismic survey programs refer to Section 2.4); survey lines are shown on Figure 4.4-6 along with the well control points. A reflecting horizon tentatively identified on the seismic records as the top of Castile (located about 100 feet below the base of the RH-zone) is contoured on Figure 4.4-6, which also shows preliminary structural interpretations made from the seismic records. The contours of Figure 4.4-6 indicate that the easterly regional dip of the Castile is modified by a broad, northwesterly-trending ridge and saddle configuration, with crest-to-trough separation of 2 to 3 miles and total structural relief of up to 400 feet. According to this interpretation, the normal gradient of bedding in this part of the Delaware Basin (about 100 feet per mile or 1 to 2 degrees to the east/southeast) may be significantly greater and different in direction locally at the top of Castile, directly beneath the proposed WIPP underground Facility. Specifically, Figure 4.4-6, G.J. Long's preliminary interpretation of structure on the presumed top of Castile about 100 feet beneath the proposed RH-Zone level, indicates as drawn that local gradients may be as great as 400 feet per mile (about 4 1/2 degrees) to the south and southwest.

Northeast of the site, G.J. Long (December, 1977) shows a domal feature in section 36, T. 31 S., R. 22 E of about 500 feet of structural relief (Figure 4.4-6). ERDA-6, which was drilled in section 35 just west of the crest of this feature, encountered a geopressured (artesian) brine reservoir in the Castile. Studies of the ERDA-6 core establish that the doming in this area is due to a salt anticline with a core of mobilized Halite-I salt (Anderson and Powers, 1978); refer to Figure 4.4-4. This

dome is located within the belt of salt deformation flanking the Capitan reef (refer to Section 4.4.3.1 and Chapter 2, Figure 2-4) where such occurrences are to be expected. Artesian brine flow was also encountered by Belco No. 1 Hudson-Federal over a similar domal feature southwest of the site in the Los Medanos gas field area (Section 1, T. 23 S., R. 30 E)., although no salt-cored anticline of the type encountered at ERDA-6 is known to occur there.

The origin of the inferred northwest-trending structural ridge at the top of the Castile at the northeast edge of the Zone-II exclusion area has not yet been determined; it may be a depositional structure, or it may reflect possible past deformation by salt in underlying halite units. The steepness of the southward gradient suggests possible offset of one or more anhydrite beds as G.J. Long (1977b) has proposed. By contrast, a deep seismic reflection profile running southwest-northeast across the center of the site (Sandia Line 2, G.J. Long, 1977a; compare Figure 4.4-4) detected no anomalies at and below the lower part of the Castile across the trend of the ridge, whereas a significant anomaly is apparent in the same profile at the lower Castile-upper Delaware levels across the Los Medanos gas field southwest of the site (refer to Figure 4.4-4).

The more recent seismic investigation (G.J. Long, 1977b) also defined an area of poor data quality to the north of the site. From the ERDA-6 anomaly westward into Range 30 E. and southward into section 17 at the north edge of the the site, the quality and continuity of data as viewed on the seismic records deteriorate. This suggests the possibility of increased structural disturbance in this area, presumably caused, if real, by some form of previous salt deformation. Deterioration of the seismic record can also be brought about by anomalous or irregular transmission characteristics of the overlying medium. For example, near-surface structural disturbance, such as might be caused by dissolution in the Rustler, or the presence of an anomalously rigid near-surface layer such as caliche could change the quality of the seismic record (Dobrin, et al., 1954). A salt anticline at the northwest corner of Section 9, T22S, R31E, was suspected on the basis of seismic reflection data; drilling (WIPP 11) confirmed the structure was present

in the Castile. WIPP 11 did not show any brine or gas though drilled to the lower anhydrite of the Castile Formation. This confirms that anticlinal structures within the evaporites are not always associated with brine and gas. The apparent non-involvement of the redbeds in the structure may be interpreted, as noted in the previous section, as indicating a Permian age for this structure.

At the present time, while these seismic reflection records are undergoing further study and review, additional seismic reflection surveys are being undertaken in conjunction with exploratory drilling at critical locations. The results of these further investigations are to be reported at a later date.

Figure 4.4-7 presents 10-foot structural contours on the base of the 124-marker bed of the Salado, which is the deepest and most consistently reported horizon in the potash exploration grid. Figure 4.3-3 provides a stratigraphic orientation for the 124 bed, which is in the lower part of the McNutt, or middle Salado; at ERDA-9, the 124 marker is 470 and 1,020 feet, respectively, above the CH- and RH-level mining horizons selected for waste disposal. A uniform, gentle eastward regional gradient of 80 to 100 feet per mile across the repository is evident; there is no suggestion of a northwest-southeast ridge for the Castile (Figure 4.4-6). Two anticlines, or domal structures, are present, one centered near the ERDA-6 locality and the other at the Los Medanos gas field. At both structures, and only at these structures in the map area, exploratory drilling encountered artesian brine reservoirs in the Castile. No such structures are indicated by the 124-marker bed contours to be present within the site exclusion area.

The comparison of Figures 4.4-6 through 4.4-8 to each other indicates that structural disturbance is present within the Castile that is not reflected upward to any great extent. Structural relief on the upper beds is a fraction of that of the Castile. The inferred faulting at depth has not been confirmed by drilling, seismic data and drilling in the area indicates salt remains in the Castile rather than disappearing as any consequence of the faulting.

Two depressions in the 124-marker bed are indicated to occur near the site (Figure 4.4-7). In Lea County in section 31 at the east edge of the map there is a depression with probably less than 100 feet of closure; this is the same feature identified by Anderson (1978) as a possible "deep sink", and apparently is related to a greatly reduced or missing section of the Infra-Cowden (Anderson, 1978, Figure 7). It is nearly 4 miles from the edge of the Zone-II exclusion area. A second depression of the 124-marker bed horizon is centered about a mile north of Zone-II exclusion area, at the southwest corner of section 9. A single-hole anomaly with 50 feet structural closure, it is not reflected by any isopach anomalies in the Salado (Figures 4.3-4 through 4.3-7), nor does it correspond to any evident structural feature higher in the Salado (compare figures 4.4-8 thru 4-4-10). Salt isopach maps of Anderson (1978) indicate no anomaly at this location, nor does the recent seismic reflection work by Long (1977b) show subsurface disturbance of horizons near this point. These negative indications suggest the feature might have developed contemporaneously with depostion and is not significant to the WIPP site. Nevertheless, results obtained from exploratory drilling will be noted and applied if relevant. Higher levels within the Salado are contoured in Figures 4.4-8 and 4.4-9 (refer to Figure 4.3-3 for location in section). Within the area contoured on these Figures, which is somewhat less than the area covered by Figures 4.4-7 and 4.4-10, the two maps are virtually identical in configuration and gradient and exhibit no significant structural features other than the regional gradient.

Structure contours on top of the Salado, or at the contact between the Salado and the Rustler, are displayed in Figure 4.4-10. It should be recalled (Section 4.1) that there is less data control for the top of the Salado than for deeper horizons in the Salado, because potash industry exploration practice normally includes coring and geophysical wireline logging only for horizons below the top of the Salado. Reliable control for top of the Salado is therefore provided mainly by those potash exploratory holes commissioned by DOE. Outlined by contours on Figure 4.4-10, the same domal feature associated with the salt-cored anticline

and brine reservoir encountered by ERDA-6 is still in evidence. The change from regular contours in Range 31 E. to a more irregular configuration in Range 30 E. is due to dissolution at the top of Salado, and is also reflected in the upper Salado isopach map (Figure 4.3-7). (Refer to Section 6.3 for a discussion of dissolution processes in the site area.). A 70-foot depression is apparently recorded by an industrial potash hole (Hole F-91) a mile northeast of the Zone-II exclusion boundary; two similar but smaller features occur a couple of miles farther northwest. Since there is no geophysical or core record available for hole F-91 at the top of the Salado, it may well be that the first encounter of Salado salt is simply not recognizable in the record for this particular hole.

Assuming the record is accurate, however, it is not known at this time whether the apparent depression is a feature of sedimentary origin, although the horizon is a contact zone between two formations, or whether the feature is related to post-depositional solution processes. It should be noted that this apparent depression is about a mile east of, and structurally about 700 feet higher than, a similar depression contoured on the 124-marker bed (Figure 4.4-7, discussed above). However, no such anomalies have been detected on intervening horizons in the Salado (Figures 4.4-8 and 4.4-9). Furthermore, a line connecting the two apparent depressions would have a maximum slope of less than 8 degrees. The available evidence therefore indicates that it is unlikely that there is a physical continuation of this assumed depression at the top of the Salado to horizons lower in the evaporite sequence. On the other hand, there is an approximate spatial coincidence of this depression with a shallow (less than 30 feet of relief) topographic depression at ground surface containing mapped playa deposits (Figure 4.2-4). Resistivity profiles (Elliot, 1977) indicate only minor surficial disturbance attributable to shallow basin fill with no indication of probable subsurface collapse structure.

Preliminary interpretation of seismic reflection data (Long, 1977b) near the top of the Salado indicated the possibility of faulting, with a possible displacement of 100-250 feet, less than one mile north of ERDA 9. Consequently four holes (WIPP 18, 19, 21, 22) were drilled bracketing the possible location of the faulting (see Figure 2-10) to validate the interpretation. The resulting borehole data shows no apparent faulting in this region. The data collected by seismic reflection for that particular seismic program are not apparently useful for primary interpretation of the stratigraphy at the top of the Salado. Revision of field parameters in future surveys may permit more secure interpretation of data for such shallow reflectors.

A preliminary assessment of the proposed WIPP site relative to structural features presently indicated in the Salado and Castile salt formation enclosing the selected CH- and RH-storage levels can now be stated. Structure contour maps of various horizons in the Salado Formation indicate a uniform easterly regional structural gradient of about 80 to 100 feet per mile across the limits of the proposed storage facility, with little indication of the presence of any significant structural anomalies. Plastic deformation and buckling associated with salt migration or flowage has apparently not occurred in the Salado in the geologic past to the extent that it has in the lower levels of the underlying Castile Formation. Areas in the region in which artesian brine reservoirs have been encountered are associated with thickened salt sections and salt-cored anticlines in the Castile. However, a thickened salt section and salt cored anticline was drilled in WIPP 11 (Sec. 9, T. 22 S. R. 31 E.) without encountering fluids. Further, the occurrence of these reservoirs appears to be correlative with consistent structural highs, delimited by structure contours of successive horizons in the overlying Salado Formation. No such structural features are recognizable within the limits of the WIPP storage facility on any of the Salado horizons contoured; in fact, the site, if anything, appears to be in a slight structural saddle.

Among aspects needing further investigation, perhaps the most significant is a determination of the extent to which the upper levels of the Castile closest to the repository levels have been deformed by any salt deformation that may have taken place in the lower halite units of the Castile. There is no suggestion here of deformation of the type associated with artesian brine reservoirs. Seismic reflection techniques suggest, however, that a certain amount of flexure occurs in the upper levels of the Castile beneath the proposed limits of the repository, which could possibly affect local structural gradients in the lower part of the Salado. Faulting on the Castile reflector has also been inferred. Investigations are in progress to further define and delimit structural configurations near the top of the Castile and the extent to which these structures may be reflected within the lower part of the Salado where excavation of the RH- and CH-levels is presently planned. This knowledge will permit a more detailed assessment relative to the location, design and construction of the storage facility but is not believed necessary for a general qualification of the site area.

4.4.4 Shallow Structure

As discussed in Section 4.4.1, in the Los Medanos area a distinction may conveniently be made between structural features exhibited by rocks occurring above unleached salt beds and structural features of all other strata. The distinction may be made because rocks above the Salado at the site have at one time or another in the geologic past been subject to weathering processes and hence might display secondary structures related to surficial dissolution and subsidence that would not have been imposed upon deeper strata. Accordingly, shallow structures at the WIPP site have a potential for greater irregularity and complexity than those which occur at depth. "Shallow structure" is here defined to include the Rustler Formation which extends to a depth of about 850 feet beneath the center of the site (refer to Figure 4.3-3). Figures 4.4-11 through 4.4-15 are structure contour maps on Rustler and higher strata, constructed from the data obtained from wireline geophysical logging of holes drilled at the WIPP site to assess potash reserve potential.

Shallow Subsurface Structure. Structure contours on top of the Culebra Dolomite member of the Rustler Formation are shown on Figure 4.4-11 (refer to Figure 4.3-3 for location in site geologic column). The Culebra is the most productive aquifer in the Rustler Formation. The closely spaced contours in the southwestern quadrant of the map define a slope of about 80 feet per mile eastward (compare Figure 4.4-9). The wider spacing of contours in the eastern half of the map is anomalous with respect to regional structure and marks the increasing amount of halite preserved progressively eastward in the Rustler below the Culebra member. A similar configuration is evident on top of the Rustler, Figure 4.4-12: again the regional gradient appears in the southwestern quadrant, while an anomalously gentle eastward gradient, in some places even reversed, signifies thickening due to an increasing content of salt preserved from dissolution (see Figure 6.3-7). Virtually the same pattern is observed with respect to the structure contours of the Magenta Dolomite member (Griswold, 1977). Isopachs of the Rustler (Figure 4.3-8) show the gradient and amount of eastward thickening. A broad, shallow depression with 30 to 40 feet of closure near hole P-11 appears near the northeast corner of the site on both the Magenta and the top of Rustler levels, but not on the Culebra. Possibly it represents an area of greater dissolution in the upper part of the Rustler, since Rustler isopachs show the Rustler is not thickening eastward at this particular location (Figure 4.3-8)

The area in Figures 4.4-11 and 4.4.-12 wherein the regional gradient is reflected by the Rustler structure contours identifies the area where the Rustler has been leached of most of its salt, and hence presumably where maximum settlement of overlying rocks has occurred, assuming, of course, that no dissolution took place prior to deposition of overlying Dewey Lake strata. Jones (1973) supplies a subregional structure contour map of the Dewey Lake-Rustler contact and recognizes that the unevenness it shows is due to the added complexities of subsidence (Jones, 1973). A low resolution seismic reflection survey conducted at the site (C.B. Reynolds, 1976) suggests the presence in the Rustler of more localized and higher amplitude irregularities than would necessarily be defined by

data points in Figure 4.4-12. However, the known top-of-Rustler data points from potash exploration shown on Figure 4.4-12 are in nearly complete disagreement with elevations of this horizon interpreted from the shallow seismic data (Reynolds, 1976). It would appear that the reflections of horizons in the Rustler obtained by this shallow survey method are not of sufficient quality to provide a basis for making structural interpretations. The subsurface data collected to date indicate that the dissolution of salt in the Rustler has not been accompanied by the development of highly irregular subsidence structures in the overlying strata at the WIPP site.

Proceeding higher in the section, the top of Dewey Lake Redbeds (Figure 4.4-13) is the first horizon that does not reveal the eastward gradient of the Delaware Basin that all lower horizons show. The Dewey Lake surface across the site area is undulatory, possibly reflecting to some extent original undulations in the uncomformable Dewey Lake-Santa Rosa contact mentioned by Jones (1973). A broad depression near hole P-11 with about 50 feet of closure is in the same location as a similar depression on the underlying Rustler surface (Figure 4.4-12). Subregional structure contours of Jones (1973) indicate considerable irregularity of the Dewey Lake surface as is also suggested by Figure 4.4-13, but overall the surface slopes northeastward. Isopachs of the Dewey Lake Redbeds (Figure 4.3-9) disclose that the west-trending slope of the Dewey Lake surface at the west edge of Figure 4.4-13 is the result of the Late Tertiary erosion which is associated with the development of Nash Draw and which completely truncates the Dewey Lake in Nash Draw itself (Brokaw, et al., 1972). Continuation of this erosion surface to the east across higher strata is quite obvious in Figure 4.4-14, contoured on the surface of the Santa Rosa Sandstone. Structure contours of the Gatuna surface (below Mescalero caliche) (refer to Figure 4.4-15) show virtually the same configuration as does the Santa Rosa surface on the east and the Dewey Lake surface on the west, indicating that the thin Gatuna veneer was deposited over these surfaces after erosion occurred.

Surficial Structures. Extensive surficial deposits of dense sand all but preclude the observation of surface geologic structure at the WIPP site (Figure 4.2-4; refer to maps by Bachman in Jones, 1973, and by Vine, 1963). The nearest measurements of bedding orientation appearing on Bachman's map are at the edge of The Divide, some 6 miles northeast of the center of the proposed WIPP site. The Nash Draw geologic quadrangle map by Vine (1963) shows no such measurements, for Vine recognized that dissolution of salt in rocks beneath Nash Draw had caused widespread slumping of the surface rocks. Thus, they are not indicative of original structures. He documents places where not only salt but considerable gypsum has been dissolved. In Nash Draw the Magenta and Culebra dolomite members of the Rustler are observed in contact, whereas normally, when leached of salt only, they are separated by 120 feet of gypsum (Vine, 1963). In mapping the overlying Dewey Lake Redbeds, he noted that,

> "exposures of the redbeds are commonly tilted or draped into simple structures as a result of the collapse and swelling that accompanies solution and hydration of the underlying evaporite rocks. Some exposures...along the margin of Nash Draw show a downwarping into the topographic depression that is presumably the result of removal of soluble rocks. For this reason, strike and dip readings, even on the very apparent parallel stratification of the redbeds, do not necessarily reflect the structure of older rocks" (Vine, 1963).

Jones (1973) affirms that "it is impossible to piece together a meaningful stratigraphic section from study or mapping of outcrops" in Nash Draw. "The (exposed) rocks are porous, friable, and loose-textured, and all are strongly jointed, cavernous, and locally brecciated. Stratification is obscured or completely obliterated, and the attitude of bedding can rarely be determined with any degree of confidence" (Jones, 1973, refer also to discussion of Rustler stratigraphy, Section 4.3.2). It should be emphasized that this surface evidence of jumbled structure is restricted to Nash Draw and has not been described for the area between Livingston Ridge and the WIPP site.

No surface faults have been mapped within 5 miles of the center of the WIPP site; faults that are mapped at the surface are distant and are plainly related to collapse features. Bachman's (1976) mapping east of the WIPP site shows no surface faults. The nearest faults mapped by Vine (1963) involve Rustler offsets in Nash Draw about 9 miles southwest of the site in section 18, T. 23 S., R. 30 E. Although he recognized these faults as being produced by karst processes, involving areas of circular or semicircular rock deformation up to a few thousand feet in diameter, he was unsure of how to account for the fact that some were positive

topographic features or domes (Vine, 1960; Vine, 1963). Anderson (1978) believes that they may be the eroded remnants of former caverns in salt whose roofs had collapsed; the collapsed debris then remained as the upper part of the surrounding salt was partially dissolved and carried away (refer to regional geomorphology, Section 3.2).

Livingston Ridge, 4 miles northwest of the site, marks the edge of Nash Draw, a broad swale developed by a combination of erosional and dissolution processes. Bachman (1974) mapped occurrences of caliche in the region around the WIPP site, and noted the structural relationship of the caliche to depressions such as Nash Draw (refer to structure contour map of the Mescalero caliche in Bachman, 1976). He concludes that,

> "major solution and collapse preceded and followed the accumulation of the Mescalero caliche in Nash Draw..." (Bachman,1976). "The Mescalero caliche probably formed on an undulatory stable surface. ...Along Livingston, Quehada, and Nimenim Ridges...the caliche dips abruptly into the adjacent depressions. The crowding of contours, the presence of fractures, and the uniform thickness of the caliche along these ridges indicate that Nash Draw Draw and Clayton Basin were subjected to collapse after the formation of the Mescalero caliche. On the other hand... the uniform spacing of the contours in the area of the Divide between Livingston and Antelope Ridges suggest that this surface...approaches its original slope" (Bachman, 1974).

Thus, surface mapping and structural interpretations have found no evidence of any anomalous structure in the vicinity of the WIPP site east of Nash Draw that might be indicative of significant differential subsidence of underlying strata. Such surface features and structural relationships that are exposed in the area reveal no indication of any surface faulting at the WIPP site.

In summary, surface and shallow subsurface structure in the vicinity of the WIPP site has presumably been modified to some extent by loss from dissolution of 100-200 feet of salt originally present in the Rustler Formation. The resulting subsidence and settlement would not be expected to have progressed in a perfectly constant and uniform manner over an area of several square miles. On the other hand, there is no indication of the presence of the types of chaotic structure encountered in the Rustler in Nash Draw, as described by Jones (1973) and by Vine (1963).

In the Nash Draw area, the widespread collapse structures observed are due to extensive dissolution in the Salado rather than in the Rustler alone. Further, the successive erosional stripping of Santa Rosa, Dewey, and Rustler strata westward into Nash Draw, coupled with the general eastward regional dip of the evaporite strata, indicates that the amount of overburden above the level of dissolution actually was much less in Nash Draw than it presently is east of Livingston Ridge. Thus the potential for significant differential subsidence to have occurred beneath the Los Medanos site seems to have been minimized by the restriction of salt dissolution to beds within the Rustler and by the relatively high overburden pressure which would have tended to provide more uniform settlement as salt was being removed. Stratigraphic data from potash holes drilled in the site area indicate no major irregularities in horizons above the Salado (Figures 4.4-10 through 4.4-15).

4.4.5 Summary and Conclusions

Jones (1973) concludes that:

> "The structure of the Los Medanos area is basically simple and the rocks are, for the most part, only slightly deformed. Nevertheless, the rocks have been tilted, warped, eroded, and subroded (i.e., subjected to subsurface solution), and discrete structural features can be recognized. These include: (1) structural features of regional extent related to Permian sedimentation, (2) intra-formational folds of limited extent related to "down-the-dip" movement of salt under the influence of gravity and weight of overburden, and (3) subsidence folds related to warping and settling of rocks to comform with the general shape and topography of the surface of salt in areas of subrosion...
>
> "On the basis of available geological information, the salt deposits of (the) Los Medanos area seem in many ways to constitute a suitable receptacle for use in a pilot-plant repository for radioactive wastes. The deposits have thick seams of rock salt at moderate depths, they have escaped almost completely undamaged from long periods of erosion. The deposits are only slightly structurally deformed, and they are located in an area that has had a long history of tectonic stability."

Information that has been developed in the succeeding five years of investigations has little altered that assessment relative to the

structural and tectonic conditions present at the WIPP site. Based on exploration accomplished to date, a series of structure contour and isopach maps is presented for rocks ranging in age from Devonian to Pleistocene. This and other information indicates that tectonic faulting and warping of rocks in the site vicinity seems to be restricted to Pennsylvanian and older rocks and to have predated Permian evaporite deposition; certain minor faulting within the thick Permian section appears to have occurred contemporaneously with sedimentation. Deformation related to salt flowage has occurred primarily in the Castile Formation beneath the Salado, and has perhaps modified the regional easterly gradient to 80 to 100 feet per mile to some extent at the level of the storage horizons near the base of the Salado. Areas in the vicinity of the site in which artesian brine reservoirs have been encountered are associated with thickened salt sections and salt-cored anticlines in the Castile, but no such structural features are recognizable within the limits of the WIPP storage facility on any of the Salado horizons contoured. The site, if anything, appears to be in a slight structural saddle, a condition considered to be a favorable criterion for site selection. Dissolution of bedded salt beneath the site has been resticted to horizons within the Rustler Formation; there is no evidence that the resulting settlement produced any significant structural irregularities or collapse features in the overlying strata within the area of the WIPP site. Investigations are continuing to further define the extent to which salt deformation in the Castile may have affected the structural configuration within the lower part of the Salado where excavation of the RH- and CH- levels is presently planned. These investigations will permit a more detailed assessment of the optimum location, design, and construction method of the storage facility.

4.5 Site Geologic History

Three main phases characterize the geologic history of the WIPP site subsequent to the original establishment of a granitic basement intrusive complex between a billion and a half-billion years ago, forming the cratonic crust beneath the site. The first phase, of at least 500

million years' duration, was a time of uplift and erosion of all pre-existing Precambrian sedimentary and metamorphic rocks which may have once been deposited or formed in the site area, eventually exposing the deep-seated igneous rocks. The second phase was characterized by an almost continuous marine submergence lasting about 225 million years, wherein shelf and shallow basin sediments slowly accumulated. This depositional phase culminated in a comparatively rapid accumulation of over 13,000 feet of sediment within a relatively brief period lasting 50 to 75 million years, toward the end of which time thick evaporite beds, mainly rock salt, were deposited. Uplift and subaerial conditions next returned to the site in the third and final phase, and have persisted some 225 million years to the present, with the exception of a brief marine inundation in the middle of that span of time. Periods of terrestrial deposition alternated with erosional episodes, so that a series of nonmarine deposits separated by unconformities blanket the evaporite beds at the site.

Since the first phase mentioned above really reflects the absence of any evidence in the geologic record at the site for specific events which may have occurred during the latter part of Precambrian time, the following review of site geologic history considers only post-Precambrian events. Additional discussion of geologic history in a regional context is contained in Section 3.6. The reader is referred to Figure 4.3-2 for stratigraphic orientation.

The Precambrian basement terrane, exhumed during the vast erosional regime of late Precambrian time, was first submerged at the start of Ordovician time, with deposition of the basal Bliss Sandstone. From Ordovician time through Pennsylvanian time in the southeastern part of New Mexico where the site is located, marine sediments accumulated slowly but continuously. Shelf and shallow basin deposition progressed marginally to or within broad, nearly flat subsiding basin areas of the Tobosa Basin that formed northern arms of the Ouachita trough (Brokaw et al., 1972).

The dominantly carbonate section (dolomite and limestone) from Ordovician through Mississippian time (a span of roughly 180 million years) indicates stable shelf and gently subsiding shallow basin environments. A sandy clastic sequence in mid-Ordovician time (Simpson Group) may perhaps signify mild uplift of a landmass ancestral to the Central Basin Platform. Although an Ordovician-Silurian unconformity has been recognized elsewhere in the region (refer to Section 3.5), none is evident in the site area. The first significant post-Cambrian emergence or marine regression occurred during the Early and Middle Devonian, but the area apparently was a broad plain never elevated much above sea level. Marine waters reinvaded the area in Late Devonian time, accompanied by unconformable deposition of distinctive black shale (Woodford Shale), followed by a return to carbonate accumulation in Early Mississippian time. Continued subsidence of the area was accompanied by deep-water deposition of dark, silty shale (Barnett).

The end of Mississipian time heralded significant regional warping and tectonic activity. Major faulting accompanied upwarp of positive tectonic elements in the region, including the Central Basin Platform area (refer to Section 3.6). These positive land masses provided a more abundant supply of clastic detritus which was carried into adjacent marine basins and deposited on moderately warped, tilted surfaces. At about this time, the tectonic framework of the Delaware Basin began development. The site area received sandy Lower Pennsylvanian Morrowan sediment and more or less continuously accumulated sediment over the remainder of the period as repeated basin margin faulting caused periodic, strong uplift of the bordering platforms and some warping within the basin. By the end of Pennsylvanian time, differential tectonic upwarp had ceased (refer to Section 3.6).

At the WIPP site, sedimentation was continuous from Pennsylvanian into Early Permian time. In contrast to Pennsylvanian deposition, however, the Delaware Basin subsided at a greatly accelerated pace during Permian time, partly by downwarp and partly by downfaulting along pre-existing basin margin faults. Perhaps the previous Pennsylvanian tectonic

activity had predisposed the Delaware Basin to more rapid downwarping; at any rate, a thickness of about 9,000 feet of Wolfcampian, Leonardian, and Guadalupian sediment was deposited over little more time than had been required for about 2,500 feet of Pennsylvanian strata to accumulate. The sequence tended to progress from shale to basin limestone to sand, possibly related to encroachment of the basin margin reef deposits, as the central part of the basin continued to subside more rapidly than the shelf areas. Although basin margin reef buildup was active in both Leonardian (Bone Springs) and Guadalupian (Delaware Mountain) time, it was not until the latter part of Guadalupian time that continuous, massive reefs, accreting rapidly to keep pace with continued basin subsidence, virtually encircled the basin. This process culminated with the formation of the massive Capitan reef limestone, which approaches to within 9 miles of the site and delimited the Delaware Basin at that time. Although for many millions of years previous to this time, various lesser reef deposits had been encroaching inward upon the basin, the Capitan reef defined a more restricted area of the Delaware Basin than was ever the case previously. At the WIPP site, the basin facies equivalent to the Capitan reef is the Bell Canyon Formation, mostly siliceous sandstone in lithology. When the Capitan reef eventually encircled the basin at the close of Guadalupian time, the top of Bell Canyon was 1,000 to 1,500 feet lower in elevation than its facies equivalent high on top of the reef only a few miles away. At this time the reef had closed off free access of the open sea to the Delaware Basin, setting the stage for the ensuing precipitation of the Ochoan evaporites.

As the seawater in the salt basin of Castile time evaporated to brine, precipitation of anhydrite and limestone, followed by anhydrite and finally salt (halite) occurred. Several major incursions of seawater must have refilled the basin, for there are a number of thick, laminated anhydrite-calcite beds separated by thick salt members. Because this salt basin was shielded from clastic sediment deposition by high bounding reefs, the Castile evaporites tend to be the most chemically pure of the Ochoan evaporites. Eventually the Castile evaporites filled the basin

enclave to the level of the top of the sheltering reef masses. The Salado salt then extended over the top of the still subsiding reefs, burying them and extending outward into the Permian Basin. Although the region continued to subside, reef organisms could not survive in the briny environment, and burial of the reefs by the Salado resulted in the final disappearance of the Delaware Basin as a paleogeomorphic entity.

The Salado, inasmuch as it formed in a broad, regionally extensive brine basin not bounded by protective reefs, was more susceptible to clastic influx, and therefore its halite deposits are generally somewhat less pure than those of the Castile. Nearly 2,000 feet of mostly rock salt accumulated before an increase of clastic influx accompanied by a decrease in salinity caused deposition of Rustler lithologies to occur (anhydrite more dominant with significant thicknesses of clastic rocks). Finally in a shallowing sea or on marginal mudflats, the Dewey Lake Redbeds were deposited as subsidence gradually ended, covering the salt beds with a thick clastic blanket. This was the final episode, about 225 million years ago, of a remarkable accumulation of marine deposits which had been first laid down in Ordovician time.

No Lower Triassic strata occur at the WIPP site, nor are they known in the region (refer to Section 3.6.4). It was a time of general regional epeirogenic uplift and erosion; only a slight angular unconformity is present between Dewey Lake strata and overlying strata (Jones, 1973). According to Bachman (1974), "it is possible that some dissolution of Permian soluble rocks occurred in the periods of uplift during Triassic time", but direct evidence of this has not been found in southeastern New Mexico. Isopachs of the Dewey Lake where it is covered by Upper Triassic rocks indicate a thickness of about 500 feet. Furthermore, Jones (1973) indicates the pre-Upper Triassic Dewey Lake thickness decreases northwestward. Although the actual original protective thickness of the Dewey Lake westward across Nash Draw and over to the Pecos is now indeterminate due to later removal by erosion, it is interesting to speculate whether some dissolution features and processes presently observed there may not have had their beginning in Early Triassic time, over 200 million years ago.

In Late Triassic time inland basin streams laid down floodplain deposits of the Santa Rosa and Chinle Formations, the first record of non-marine deposition in the area. The total original thickness of Late Triassic deposition is not known, because of an erosional surface on the Triassic of the region. The first erosion to have acted upon the Triassic rocks lasted from the close of Triassic time to Late Early Cretaceous, a period which may have lasted as long as 90 million years. In latest Early Cretaceous time (Washita, about 100 m.y.b.p), a shallow sea transgressed across the site area and deposited an unknown thickness of marine sediments. Later erosion removed all but slumped or sunken residual fragments of a presumably once extensive Cretaceous cover.

These Late Triassic-Early Cretaceous relationships hold important implications for the history of both salt dissolution and salt deformation in the Delaware Basin. As Bachman (1974), has stated,

> "In central and southeastern New Mexico where Triassic rocks are preserved they are overstepped by rocks of Cretaceous age. In general, these Cretaceous rocks rest on progressively older rocks toward the south and southwest. After cutting across the wedge edge of Triassic rocks, the Cretaceous rocks rest on Permian or older strata at many places in southern New Mexico."

By plotting locations of these small Cretaceous outliers and noting the age of rocks on which they occur, Bachman (1976) reconstructed an approximation of the Jurassic erosion surface, showing where Permian rocks were unprotected by Triassic cover and exposed to erosion sometime during the Jurassic-Early Cretaceous erosional interval. The sketch shows that Permian rocks along the western edge of the Delaware Basin were exposed to the atmosphere and presumably eroded during Jurassic time. "Probably some dissolution of Permian salt and gypsum occurred in the western part of the Delaware Basin at this time" (Bachman, 1976). To the extent that "deep dissolution" features are recognized today in salt at depths of several thousand feet below the surface (Anderson, 1978), it seems quite likely that similar features would have been present and developing at comparable depths during the Jurassic erosion 100-190 million years ago. Further, considerable dissolution effects could have been initiated or accelerated during the Cretaceous at times preceding or

subsequent to Washitan submergence, particularly in view of the humid or even tropical conditions known to have characterized the Cretaceous in North America.

A second aspect of the above-described Triassic-Early Cretaceous relationships relates to the history of salt deformation at the WIPP site. Prior to Cretaceous submergence, Jurassic erosion had bevelled the blanket of Upper Triassic Dockum sediments to a wedge that pinched out westward across the Delaware Basin. Evidently, eastward regional tilting had occurred, at least by the end of Jurassic erosion. Since this tilt would have involved the underlying salt beds, some salt flow and deformation may have occurred at this time. Deformation may even have continued during the time in which the region was submerged by the Cretaceous marine incursion and was later covered by an unknown thickness of marine strata.

Although the duration of the Cretaceous epicontinental marine transgression is not precisely known for this area, probably early in late Cretaceous time the sea withdrew; during the remainder of Late Cretaceous time the area was probably of low relief and only slightly above sea level (Hayes, 1964). No early or middle Tertiary deposits are known in the site area, so that geologic events near the site over the 60 million years after the end of Cretaceous time and the beginning of Pliocene time are poorly known. Major uplift probably took place concurrent with the Laramide orogeny that occurred farther north and west. "Probably late in the Cretaceous Period or very early in the Tertiary Period the entire region was elevated by broad epirogenic uplift and was tilted slightly to the northeast" (Hayes, 1964). The Cretaceous rocks were eroded to expose Triassic rocks in the eastern half of the Delaware Basin and Permian rocks in the western half of the basin. This erosion again subjected Permian salt to further dissolution (Bachman, 1974), and produced a second erosional truncation of Late Triassic Dockum sediments (Jones, 1973). In Oligocene time (35 m.y.b.p.), lamprophyre

(basaltic) dikes were intruded in the subsurface along a northeast-southwest dike trend which occurs about 8 miles northwest of the site; this is the only post-Precambrian igneous rock known in the New Mexico part of the Delaware basin.

By Late Miocene time conditions became less arid and eastward-flowing alluvial distributories began to deposit sandy and gravelly sediment over an irregular erosion surface. Deposition of these sediments, referred to as the Ogallala Formation, began as early as 12 million years ago and ended before the close of Pliocene time, perhaps as early as 4 million years ago (Bachman and Johnson, 1973). The nearest Ogallala occurrence is at The Divide, 6 or more miles northeast of the site, where its maximum thickness is only 27 feet, which is considered to represent an original, or depositional, thickness (Bachman, 1974).

It is not known whether any Ogallala sediments were ever deposited at or west of the site, or to what extent dissolution subsidence features were geomorphically expressed in Nash Draw and southwestward within the Delaware Basin by the time the erosional plain associated with Ogallala deposition had developed. Bachman (1976) states that, "by the end of Ogallala time the High Plains surface was probably continuous westward across the present Pecos River drainage to the backslope of the Sacramento Mountains" in the region north of the Delaware Basin but that "the Ogallala Formation may not have been deposited in the Pecos depression southward from Carlsbad.... Although some form of major drainage may have been present in the vicinity of the modern Pecos River during pre-Ogallala time, (Bachman's) work does not support an interpretation of thick Ogallala fill southwest of The Divide" (Bachman, 1974). Nevertheless, Bachman (1976) believes "much of the lowering of the Pecos River Valley has occurred as a result of dissolution of evaporites in the underlying Permian rocks since Ogallala time."

When Ogallala deposition ceased in Late Pliocene time, the region around the site was tectonically stable and the climate was arid to semiarid: during this time a caliche caprock developed on the Ogallala surface.

Renewed erosion took place during early Pleistocene time following Basin-and-Range tectonic activity and rejuvenation of the Rocky Mountains. At the site the effect of this uplift and increased rainfall was to cause a renewal of erosional and dissolutional activity. Active stream erosion in the site area caused a third erosional surface to be incised into the Late Triassic sediments; in Nash Draw, this erosion cut deep into the Dewey Lake Redbeds at the same time that Nash Draw was actively collapsing due to subsurface dissolution. Eventually these channels and sinks were filled with the Gatuna Formation, which was derived from reworked Ogallala and older sediments, and a veneer of Gatuna material was deposited across the Los Medanos Mid-Pleistocene surface. Bachman considers that this erosion and deposition occurred "during the most humid climatic conditions that have existed in the area since Ogallala time" (Bachman, 1974), and tentatively correlates the Gatuna deposition with Kansan time, which ended approximately 600,000 years ago.

After deposition of the Gatuna Formation, a caliche (Mescalero caliche) caprock formed on the Gatuna surface in a semiarid environment during an interval of climatic and tectonic stability (Bachman, 1974). Regional climatic considerations lead Bachman to assign a mid-Pleistocene age for the Mescalero caliche, which he tentatively correlates with the Yarmouth interglacial stage, or about 600,000 years before the present (refer to Section 4.3.2).

Since the formation of the Mescalero caliche some half a million years ago, little geological activity has occurred at the WIPP site. In the Pecos Valley a number of Pleistocene surfaces can be identified which provide some clue to the evolution of the regional drainage system (refer to Regional Geomorphology, section 3.2.2.1). At the edge of Nash Draw along Livingston Ridge, the Mescalero caliche is fractured and draped into the draw, indicating that Nash Draw was subjected to some dissolution and subsidence in the half million years subsequent to formation of the caliche, presumably during the more pluvial periods of Illinoian or Wisconsinan glaciations. Similar evidence exists along

other slopes and in sinks within and adjacent to Nash Draw, but is not observed away from Nash Draw in the direction of the site. Perhaps the most obvious activity at the site has been the formation of a nearly continuous cover of windblown sand and sand dunes in Late Pleistocene and Recent time, believed to have been supplied from the east rather than from the Pecos area to the west. The sand apparently was eroded from the Ogallala in wet climatic intervals and was blown westward across the area during dry intervals.

4.6 SUMMARY

Investigations of the site geology for the WIPP define the geology as it is presently known for determination of the general suitability of the site. Many of the factors in Chapter 2 are addressed here in Chapter 4. The ultimate acceptability of the site for a repository may only come after the detailed geology of the site is known from underground workings.

The site physiography and geomorphology shows the site to have been relatively stable through the last 500,000 years or more. The development of the Mescalero caliche, and the lack of developed drainage are indicative. Localized sinks or basins are surficial.

Site stratigraphy and lithology including the evaporites shows continuity from the regional setting. The evaporites at the site are about 3500' thick, and include the Castile Formation, Salado Formation and Rustler Formation from bottom to top. The subsurface structure at the WIPP site within the evaporites is salt deformation three miles north of the site center and possibly also one mile north. The structure three miles north involves deformation of the Castile and lower Salado; drilling (WIPP 11) showed the deformation to be upward bulging of salt, but no severe displacements and no brine or gas were encountered. The structure one mile north appears to be smaller, and is of concern mainly for design of underground workings. It is being investigated further for this purpose. Within the site structure contours on evaporite horizons show areas with slight closure; the range of precision of data from industry

sources and natural variability can probably account for these features though slight deformation or dissolution could also be invoked. No surficial faults are known at the WIPP site.

The potential repository zones are located in the Salado Formation at depths from 2730' to 2620' (remote handling) and 2176' to 2074' (contact handling). These beds are chosen on the combined basis of purity, depth, thickness, mutual separation, and depth below the potash zone.

The geological history of the site is encompassed in the geological history of the region.

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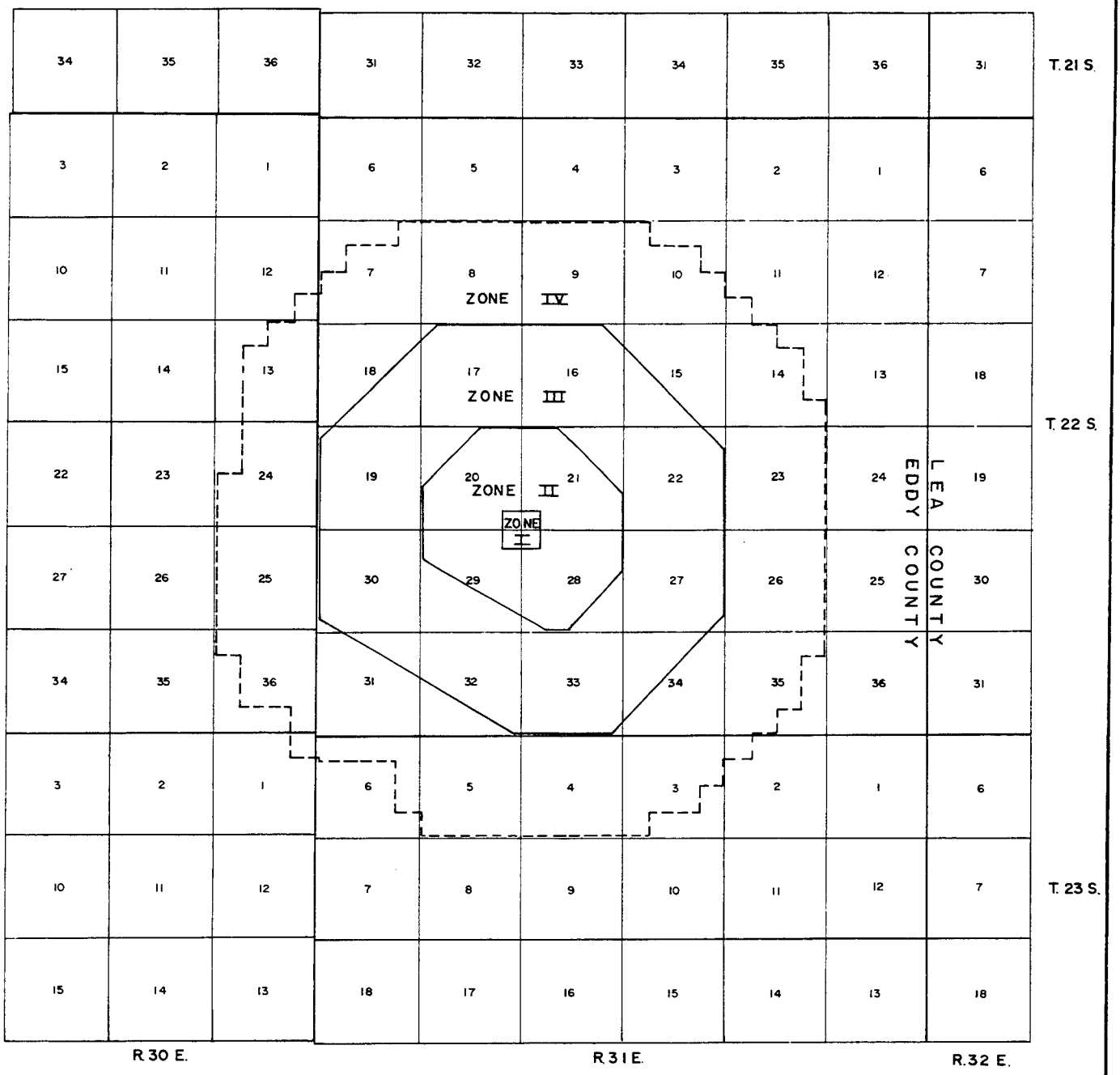


ZONE ACREAGE

ZONE I - 60-100 (surface facilities)

ZONE II - 1860 (underground repository)

ZONE III - 6230 (no mining or drilling)

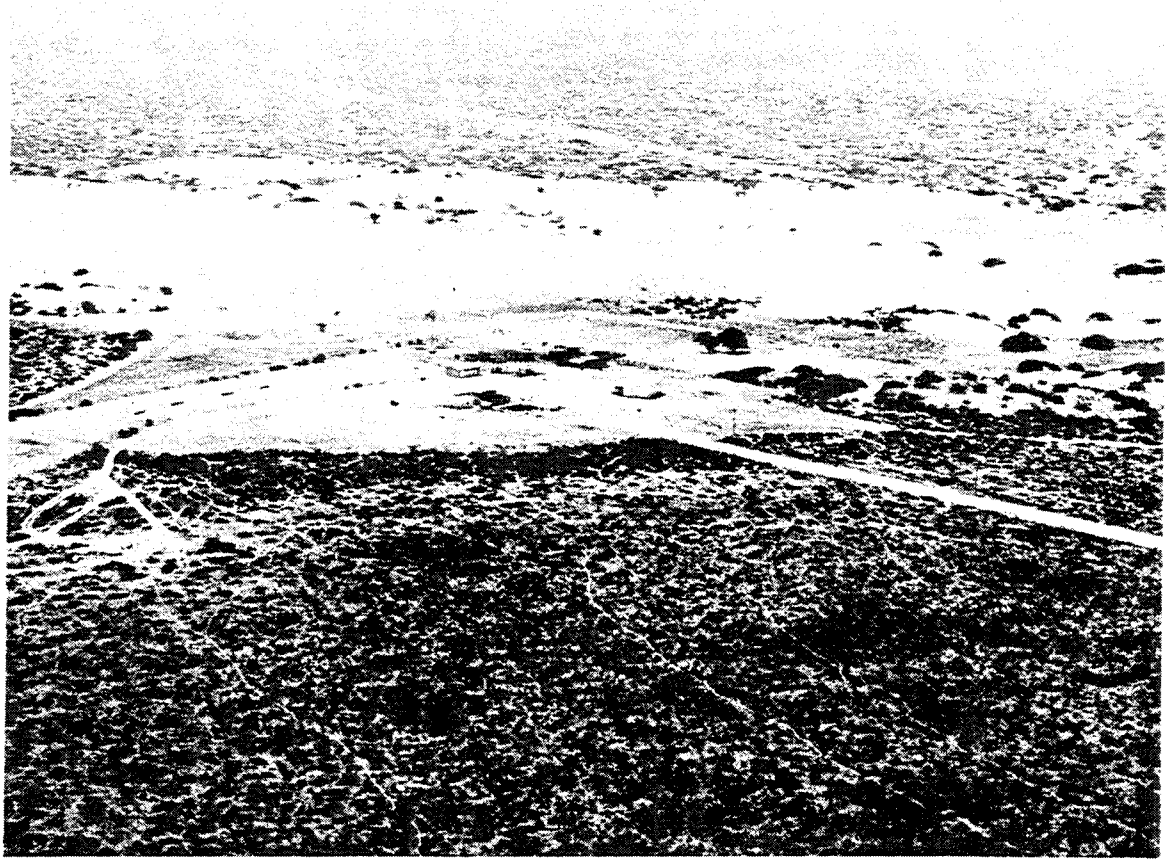
ZONE IV - 10,810 (DOE-controlled mining and drilling)

1 0 1 2 3

SCALE IN MILES

WIPP SITE ZONATION

FIGURE 4.1-1



Active sand dunes at James Ranch. Location is 3 miles south of center of site. Viewed southeast.

N

ACTIVE DUNES NEAR SITE

FIGURE 4.2-3

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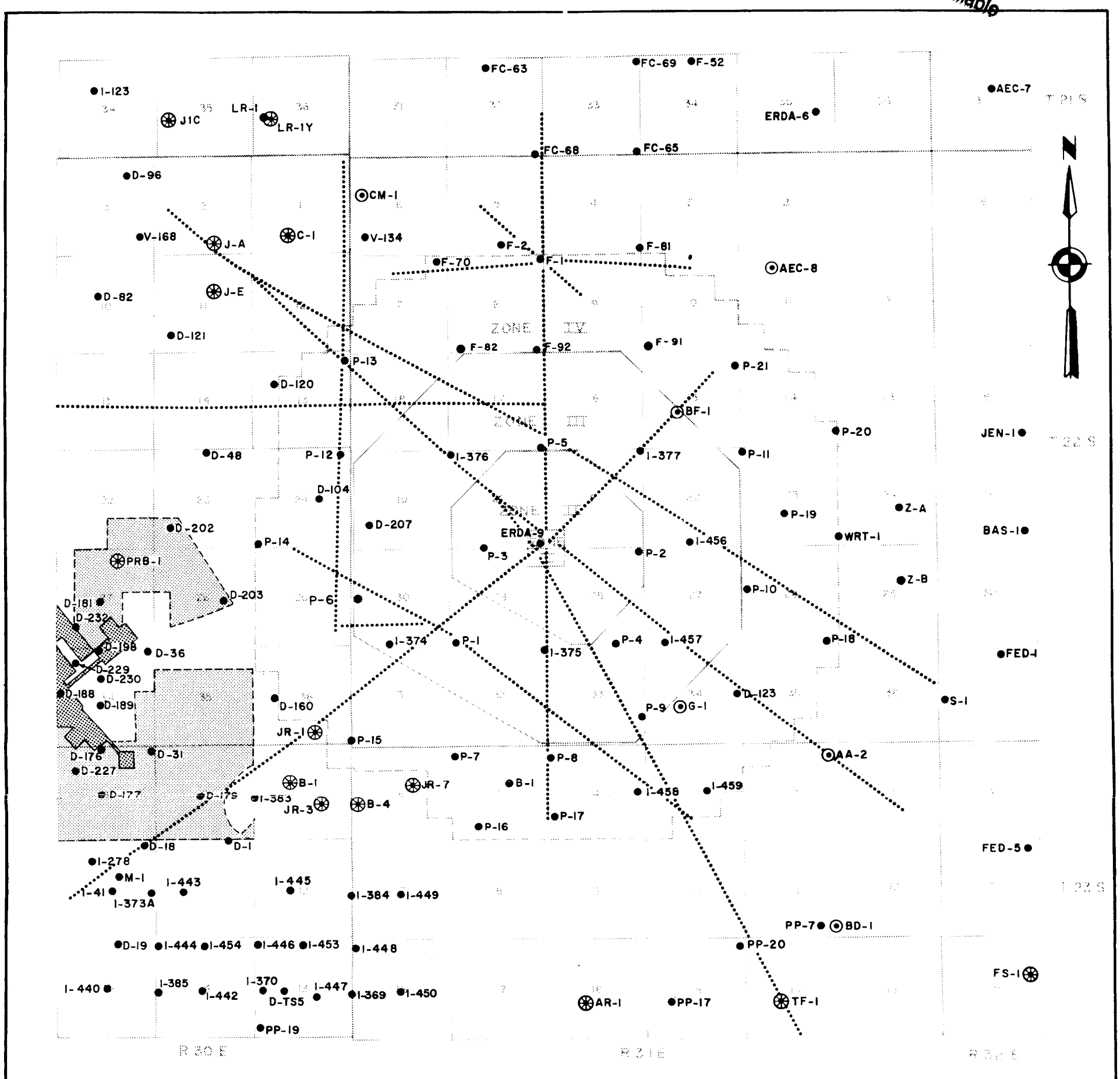

EXPLANATION

- ● Shallow drill holes (bottoming above the Delaware)
- ⊙ Drill holes penetrating Delaware and deeper horizons
- ✳ Hydrocarbon producer (past or present)
- ····· Seismic reflection survey lines
- Location of underground potash mines
- Area of planned underground potash mining

NOTE:

1. Additional drill hole data are listed in Table 4.1-1
2. All seismic profiling shown was performed under contract to Sandia Laboratories for the WIPP Site.

0 1 2 3

SCALE IN MILES

REFERENCES:

Griswold, 1977, figure 4.
G. J. Long & Associates, May, 1977
G. J. Long & Associates, Dec., 1977

SITE EXPLORATION
DRILL HOLES AND SEISMIC REFLECTION LINES

FIGURE 4.1-2

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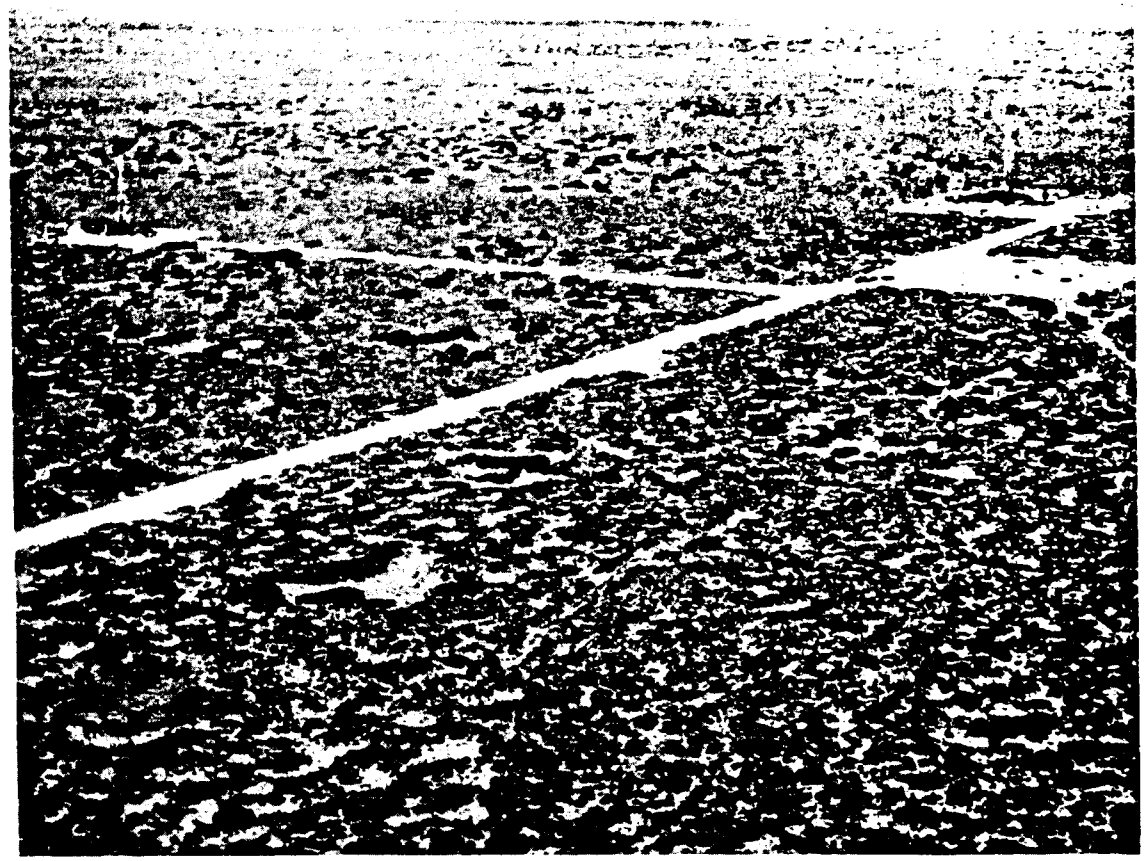
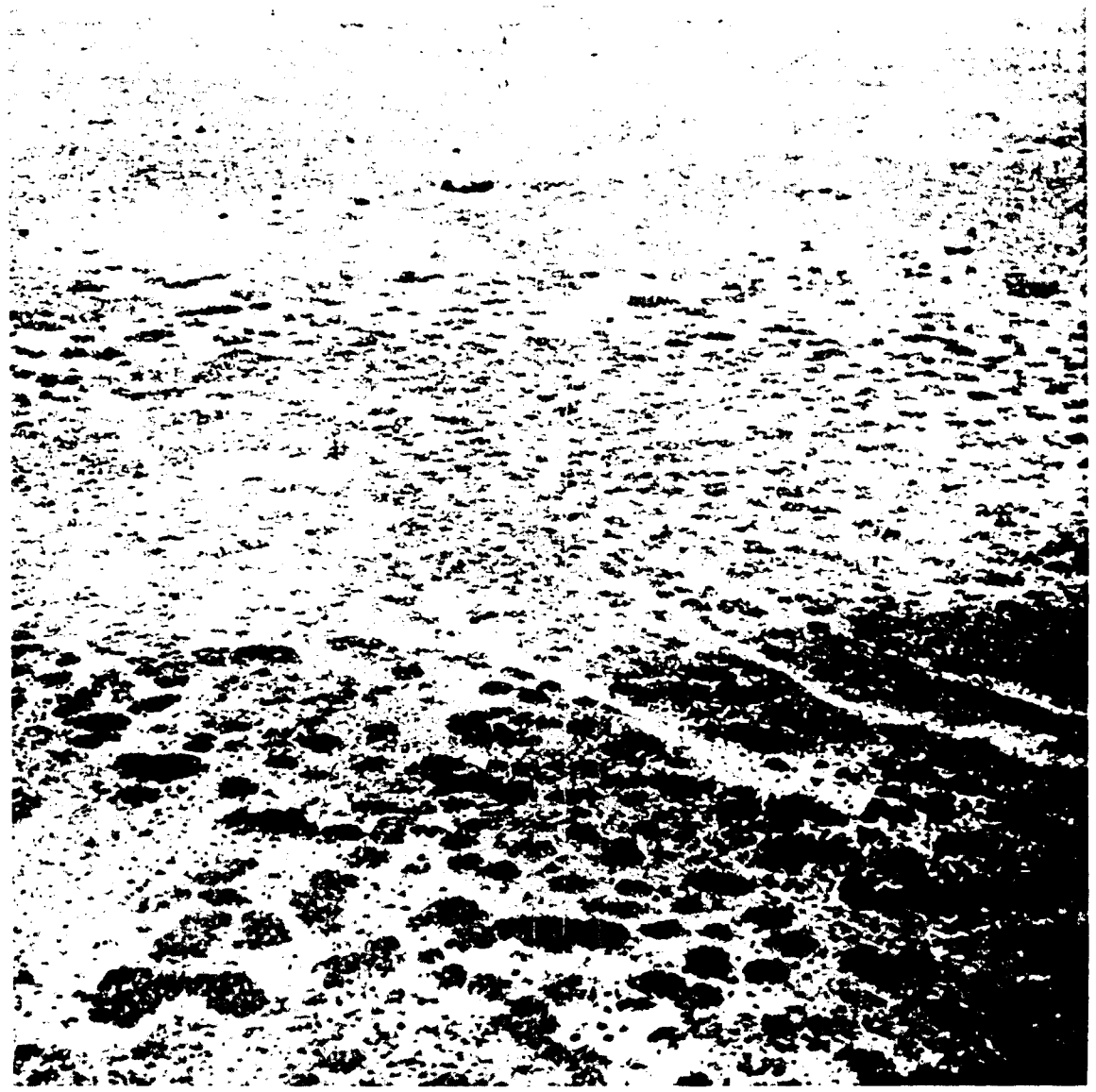


A) Air view northwest across WIPP Site, showing general terrain. Drill rig at right is near center of site, working on ERDA-9. Rig at left is set up on hole H-1.



B) Shallow depression eight miles north of site. Diameter about 1000 feet and relief about 30 feet. Investigation of this feature has found no indication of subsurface subsidence or collapse.

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SITE PHYSIOGRAPHIC FEATURES

FIGURE 4.2-1

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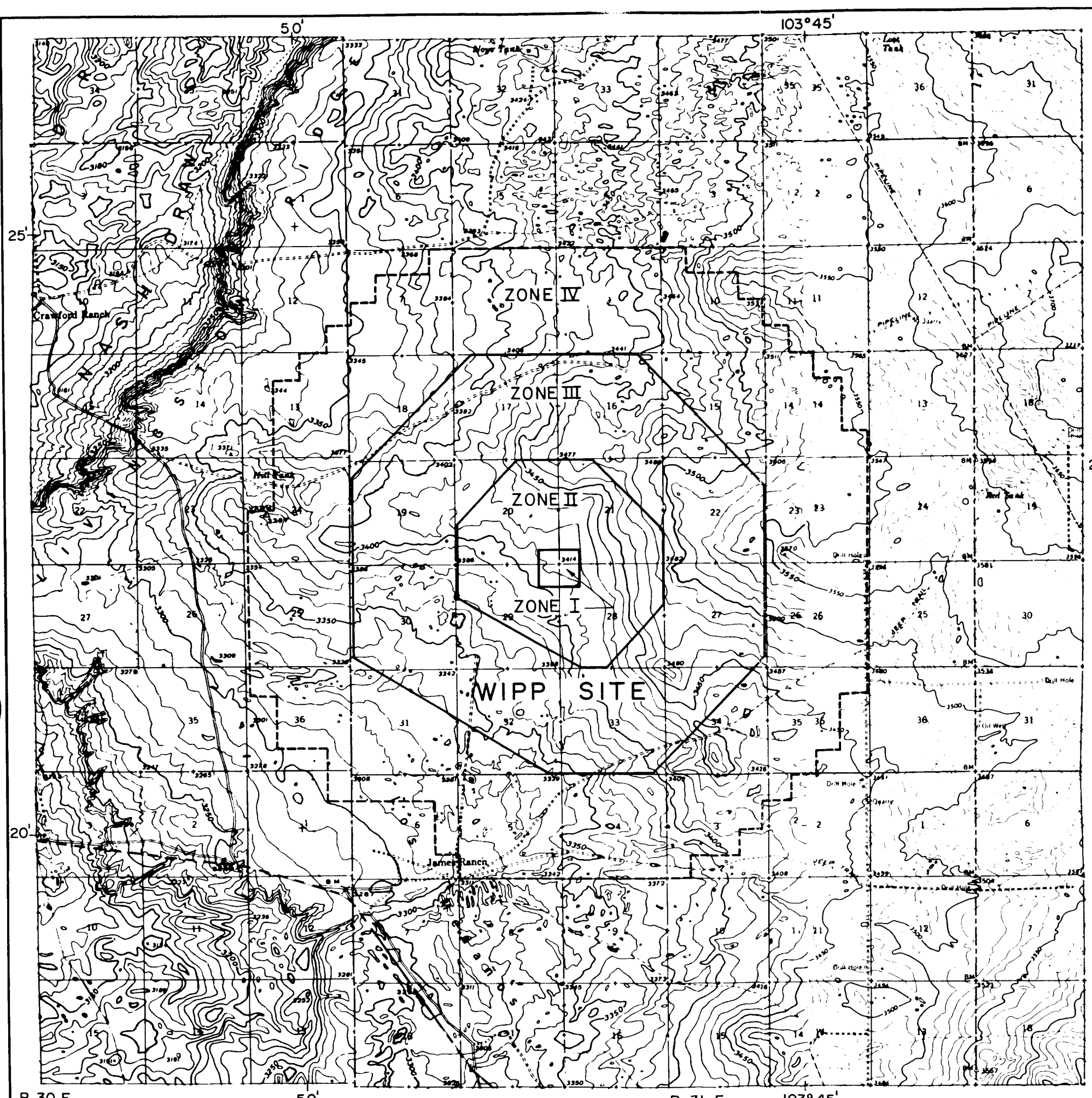

N

REFERENCE:

U.S.G.S. 15 minute quadrangles: Nash Draw, N.Mex., 1965 and Hat Mesa, N.Mex., 1972.

0 1 2 3 MILES
0 1 2 3 KM.
SCALE

SITE TOPOGRAPHIC MAP

FIGURE 4.2-2

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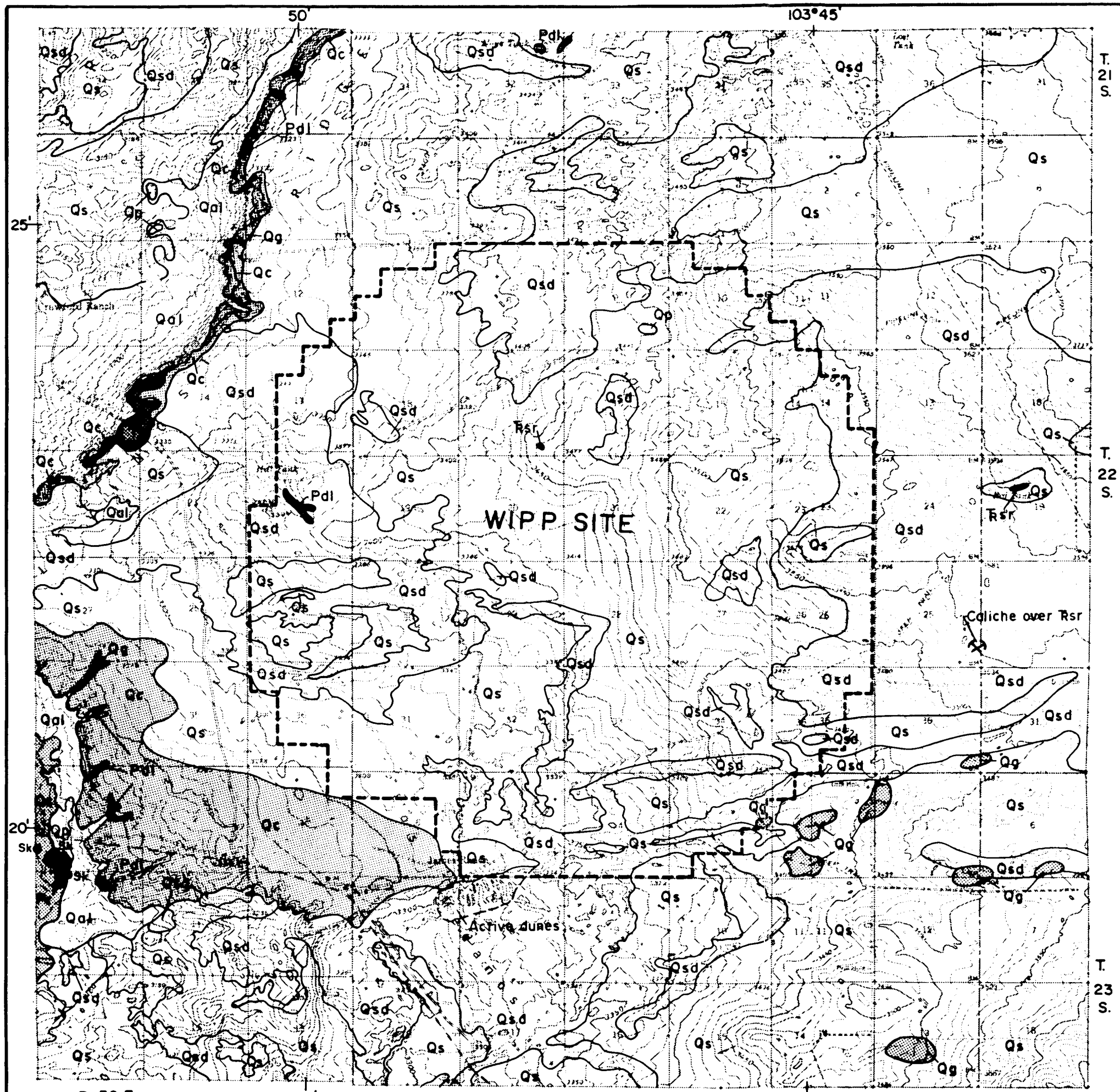

EXPLANATION

QUATERNARY — RECENT

Qs Qsd — SAND – Eolian sand plains (Mescalero sand); Qsd, conspicuous dunes, generally stabilized or partly stabilized.

Qal Qp — ALLUVIUM – Sand and silt, locally conglomeratic, deposited on gentle slopes and depressions; Qp, playa deposits of sand and silt in shallow intermittent ponds or lakes.

QUATERNARY — PLEISTOCENE

Qc — CALICHE – Limestone (Mescalero caliche), dense to travertine-like, with included sand grains and rock fragments. Has been assigned to Yarmouth interglacial stage.

Qg — GATUNA FORMATION – Gravel, sand, silt and clay deposited as alluvium; dominantly reddish-orange, grading to pink, gray or yellow. Has been assigned to Kansan glacial stage.

TRIASSIC — UPPER TRIASSIC

Trsr — SANTA ROSA SANDSTONE – Conglomeratic sandstone, moderate reddish-brown to light brown, poorly sorted, cross-bedded; interbedded locally with moderate reddish-brown claystone and siltstone.

PERMIAN — OCHOAN

Pdl — DEWEY LAKE REDBEDS – Fine sandstone and siltstone, moderate reddish-orange to reddish-brown, conspicuous thin laminae generally less than 1/4 inch thick, locally clayey and with light greenish-gray partings.

Pr — RUSTLER FORMATION – White, massive gypsum.

SK — Sinkhole

Quarry

Best Copy Available

REFERENCES: Compiled from geologic maps by Vine (1963) and Bachman (1974).

0 1 2 3 MILES
0 1 2 3 KM.
SCALE

SURFICIAL GEOLOGIC MAP

FIGURE 4.2-4

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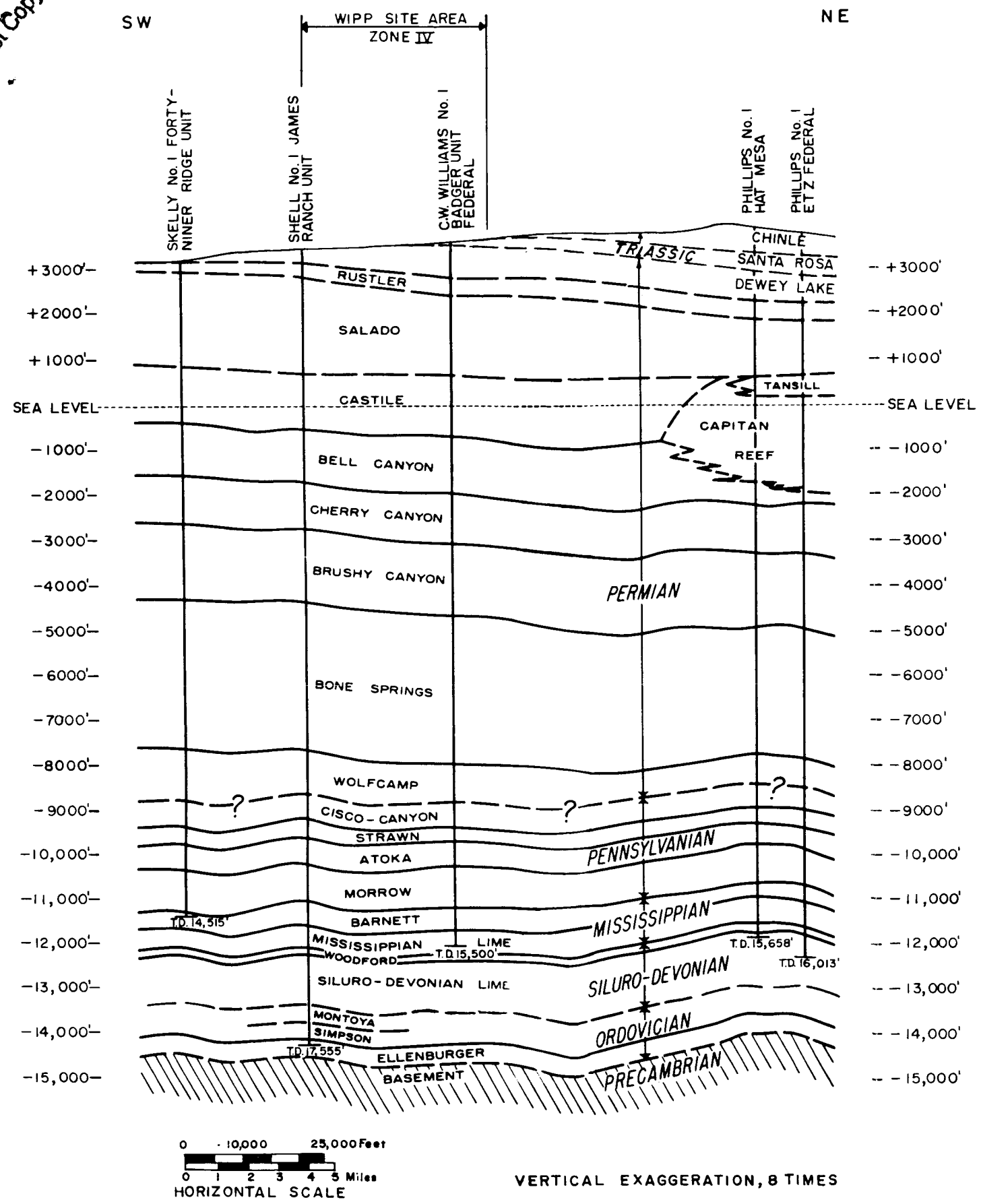

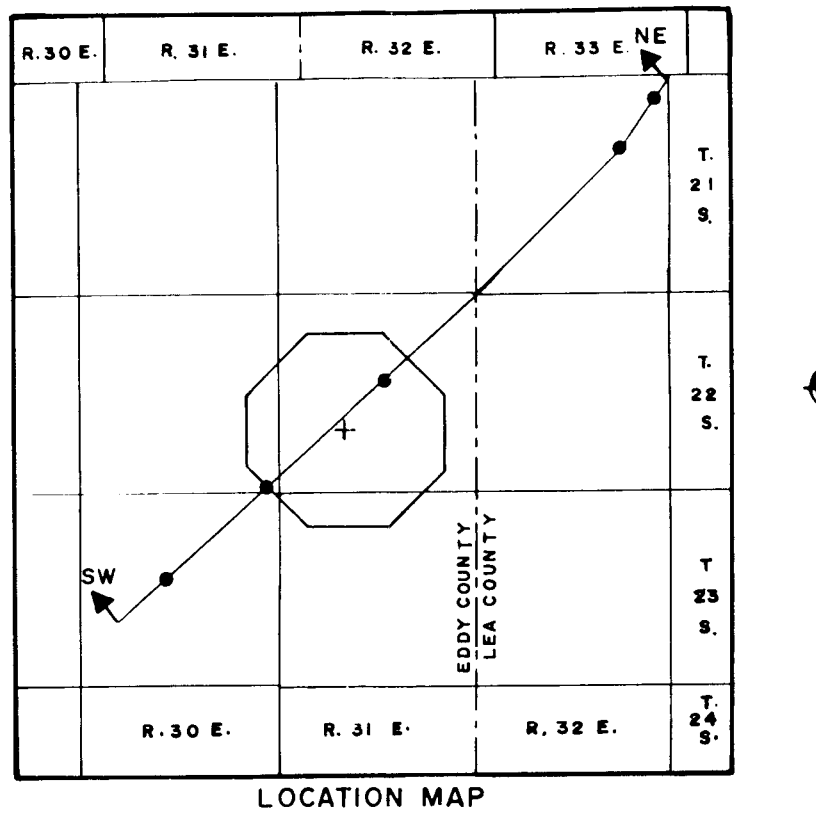

LOCATION MAP

REFERENCE:
Netherland, Sewell & Associates, 1974, Exbt. G-18

GENERALIZED SITE STRATIGRAPHIC SECTION

FIGURE 4.3-1

DOE/CAO-96-2160

Final
No-Migration
Variance Petition

June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume V of VIII

Appendix GCR

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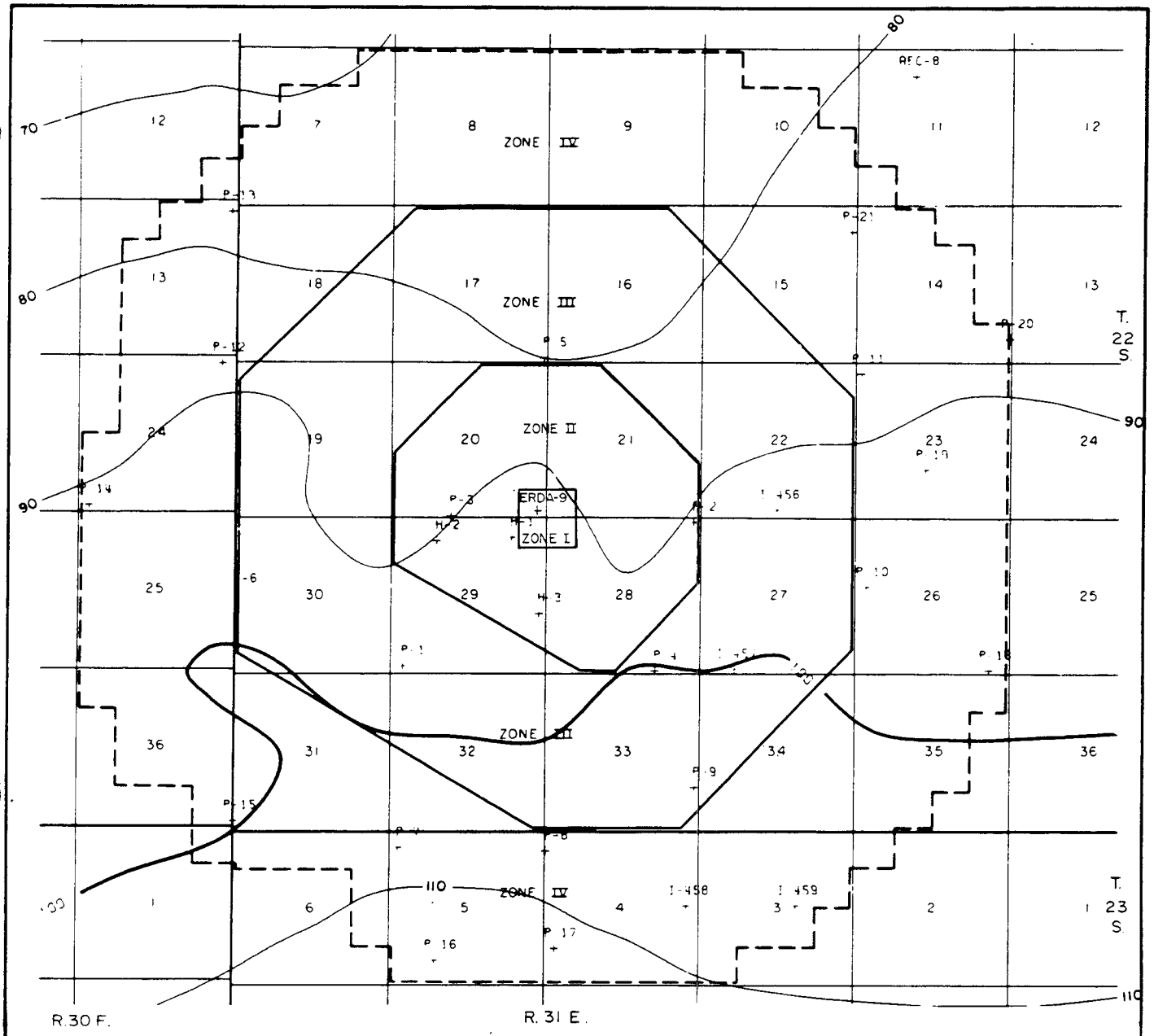


0 1 2 3

SCALE IN MILES

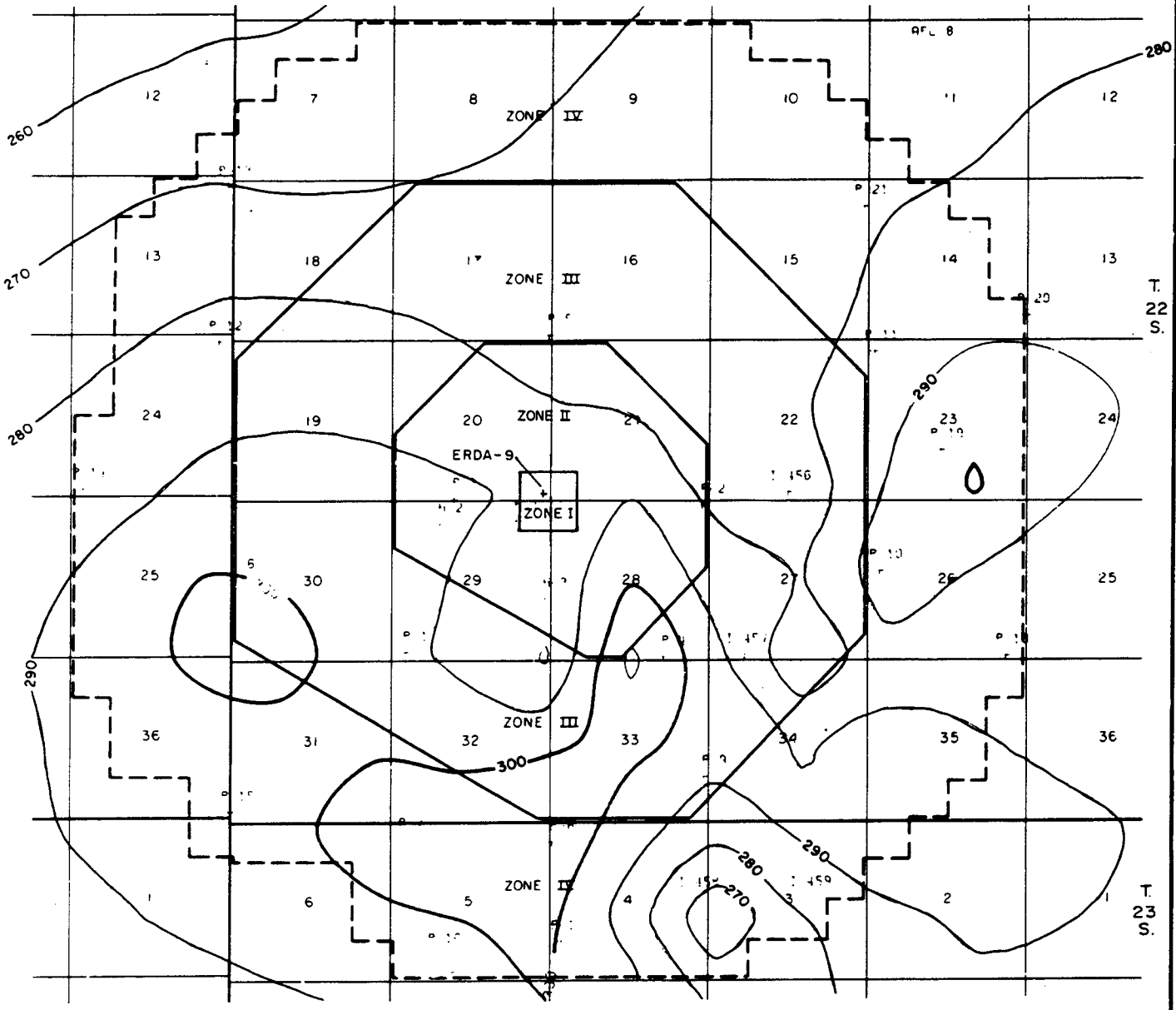
CONTOUR INTERVAL - 10 FEET

REFERENCE:

Griswold, 1977, figure 11

ISOPACH MAP
124 TO 126 MARKER BEDS

FIGURE 4.3-4



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SCALE IN MILES

CONTOUR INTERVAL - 10 FEET

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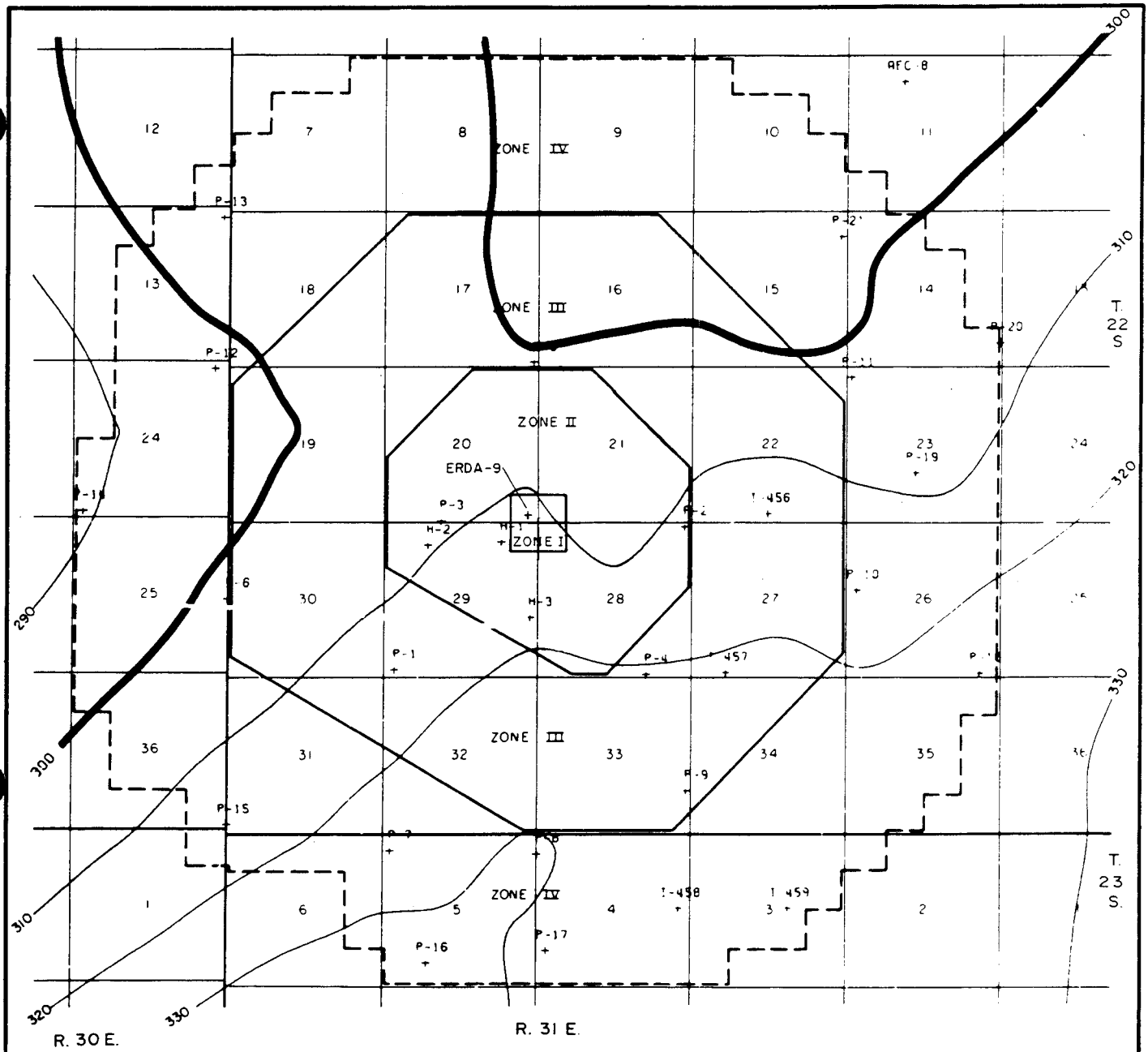
ISOPACH MAP VACA TRISTE TO 124-MARKER BEDS

REFERENCE:

Griswold, 1977, figure 11

FIGURE 4.3-5



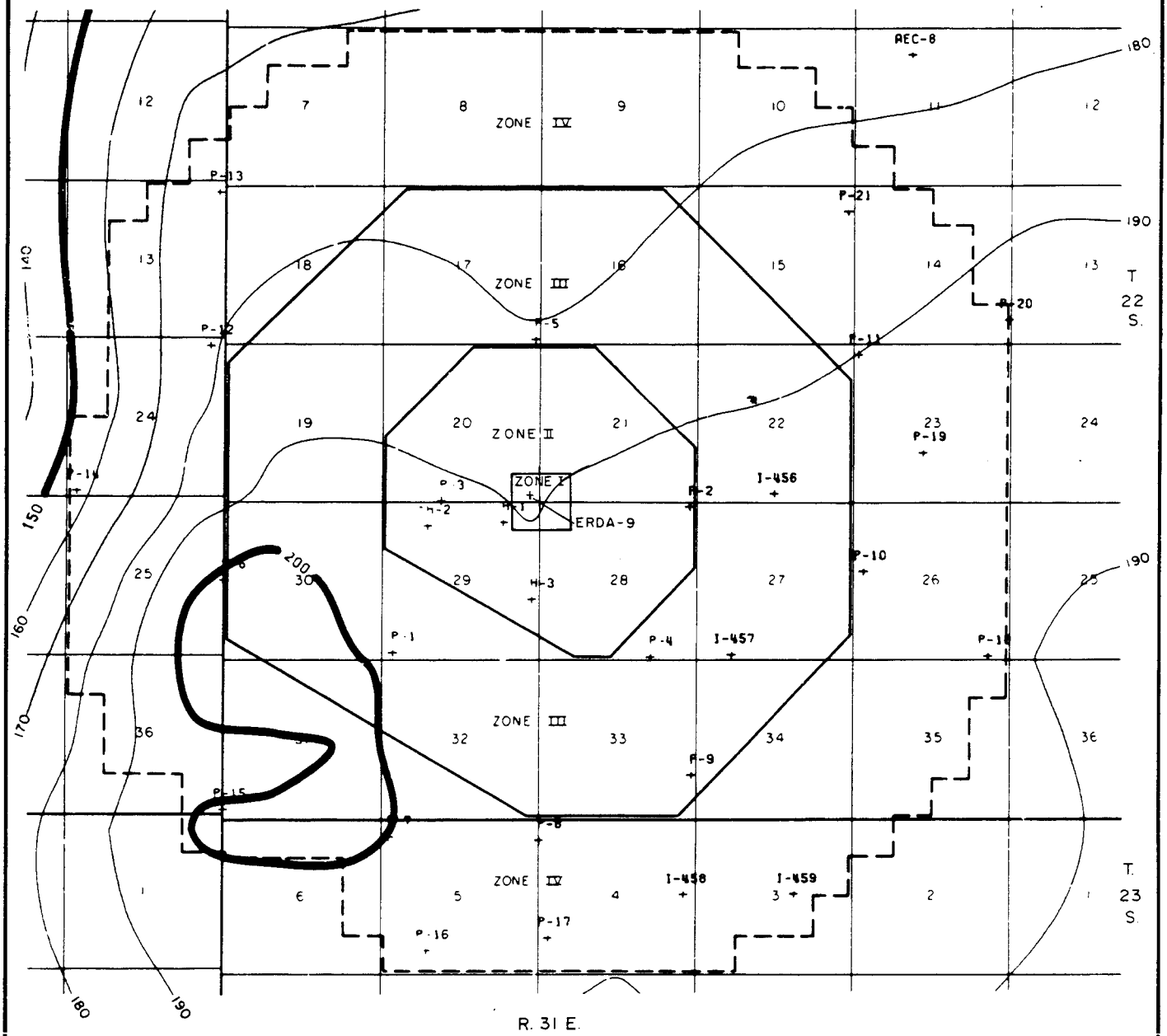
CONTOUR INTERVAL - 10 FEET

REFERENCE:

Griswold, 1977, figure II

ISOPACH MAP 103 TO VACA TRISTE MARKER BEDS

FIGURE 4.3-6



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SCALE IN MILES

CONTOUR INTERVAL - 10 FEET

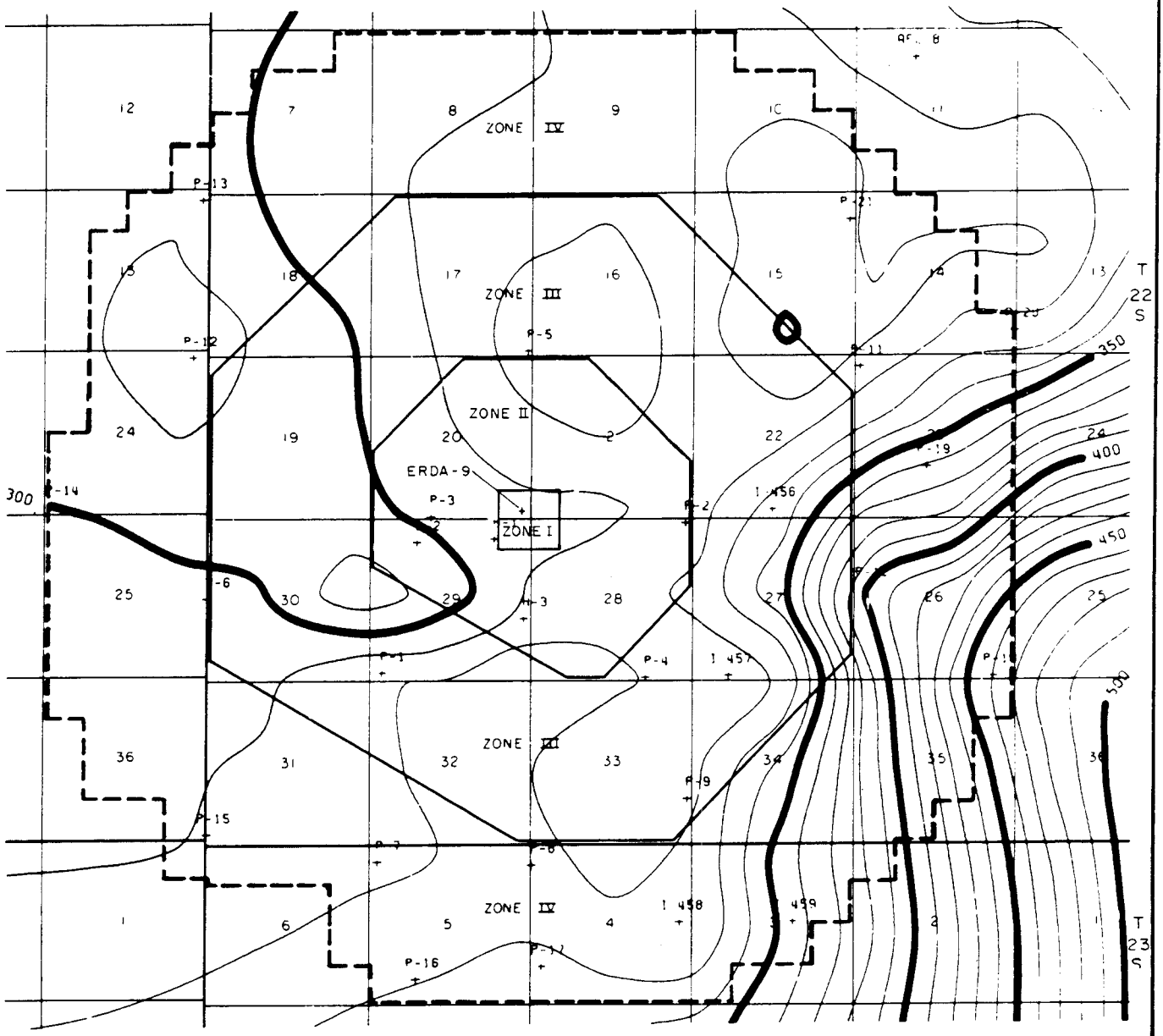
N

ISOPACH MAP TOP OF SALADO TO 103-MARKER BED

REFERENCE:

Griswold, 1977, figure II

FIGURE 4.3-7

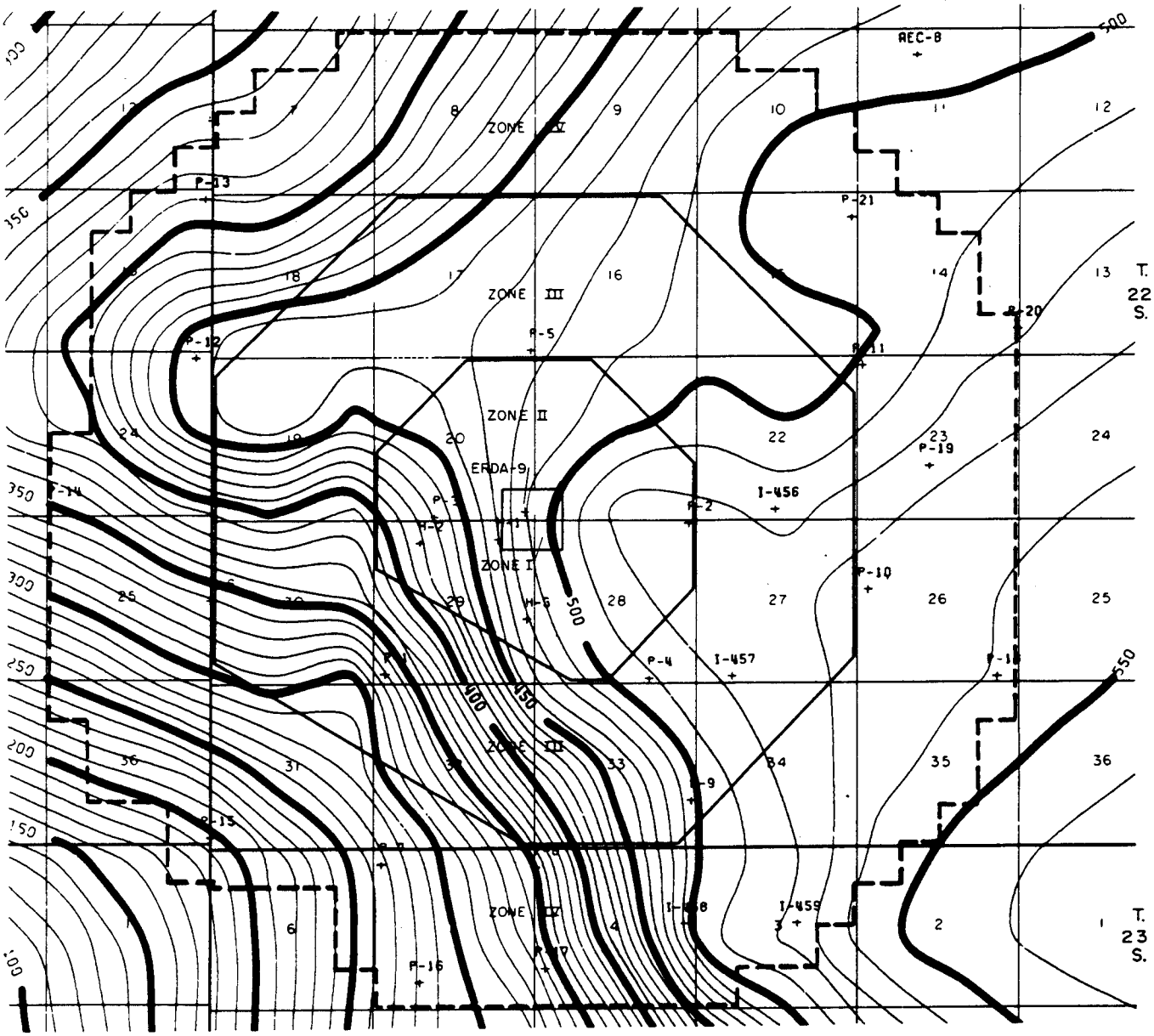


REFERENCE:

Griswold, 1977, figure 10

ISOPACH MAP
RUSTLER FORMATION

FIGURE 4.3-8



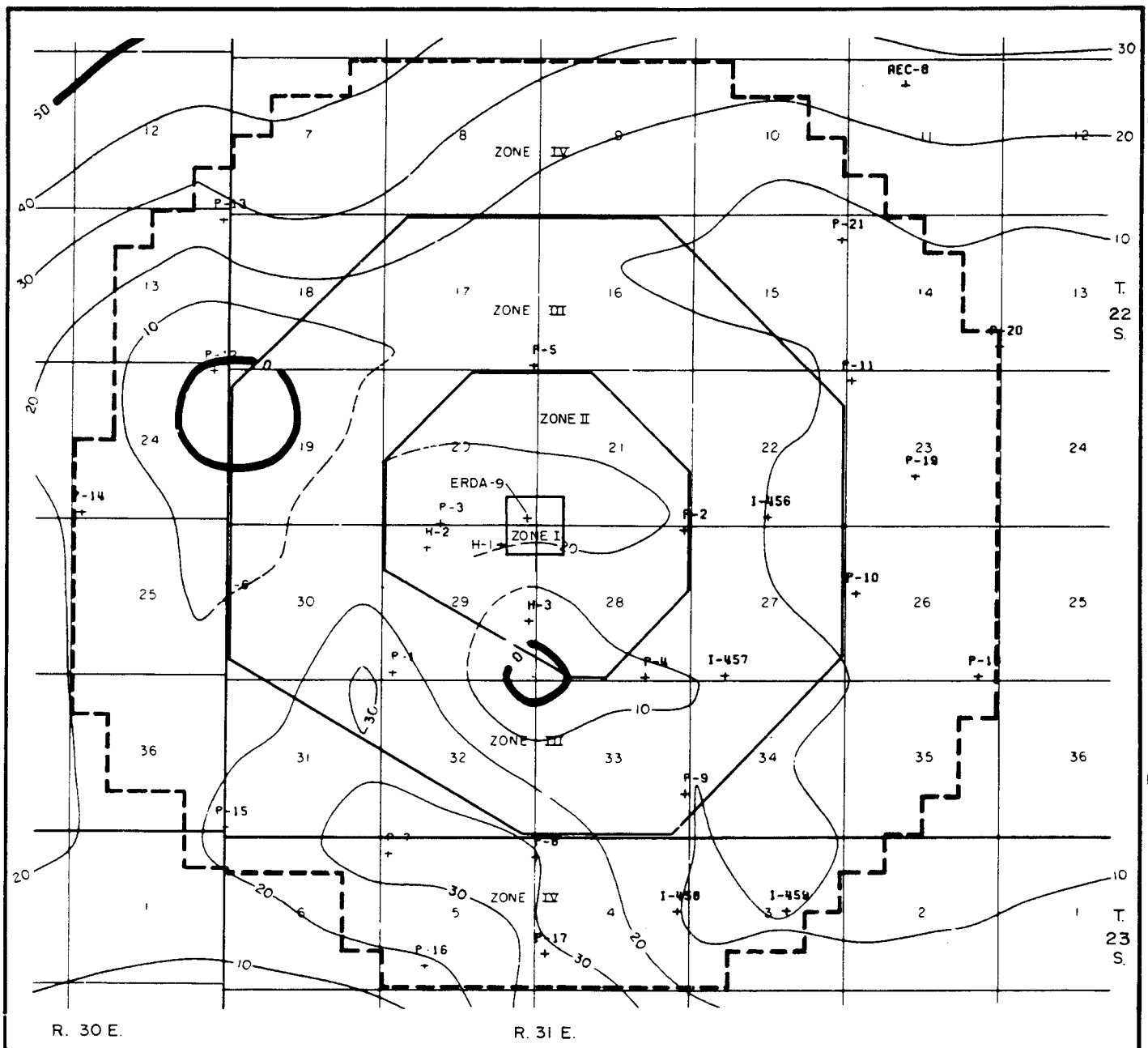
REFERENCE:

Griswold, 1977, figure 10

ISOPACH MAP

DEWEY LAKE REDBEDS

FIGURE 4.3-9



CONTOUR INTERVAL - 10 FEET

0 1 2 3

SCALE IN MILES

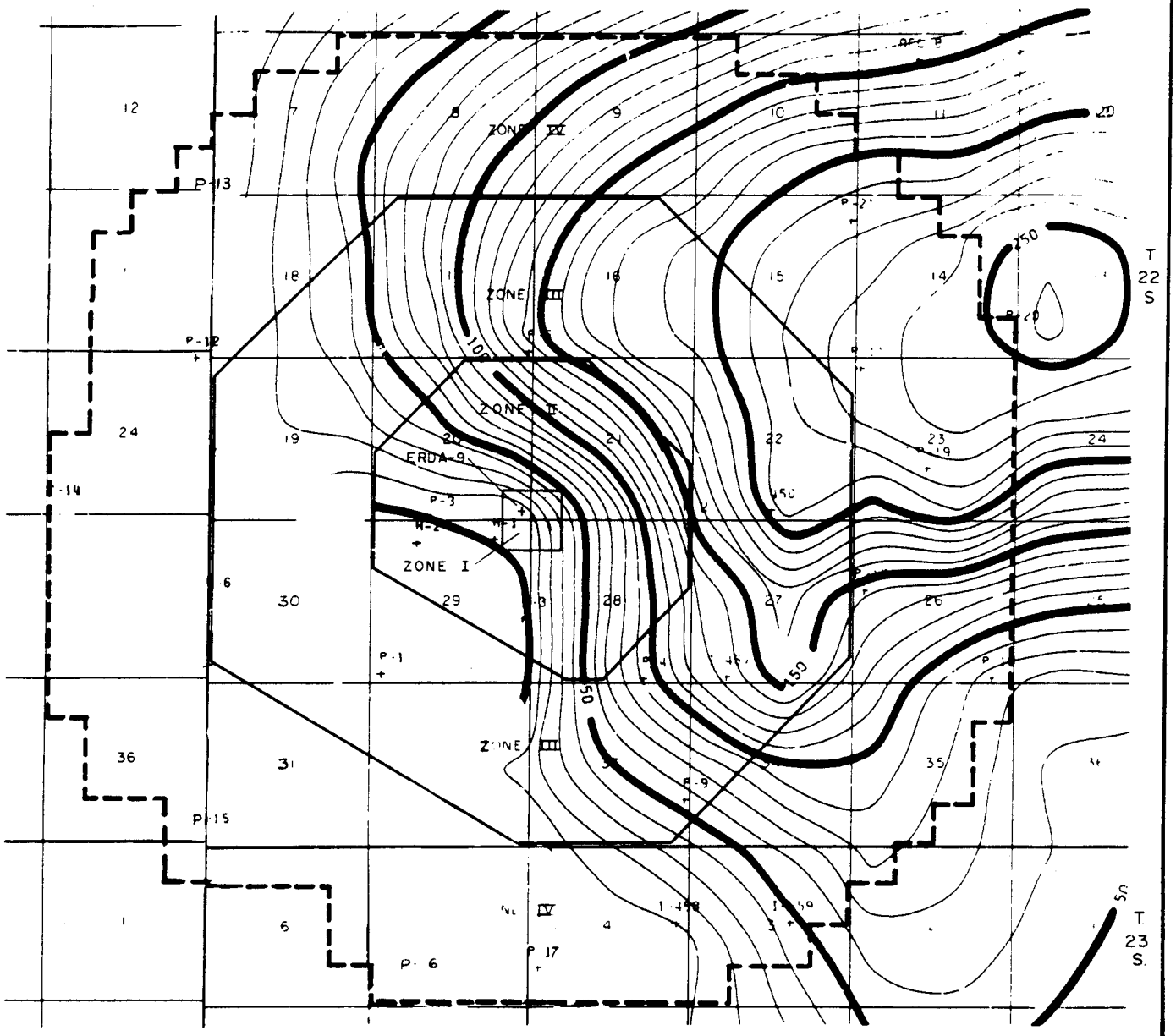
N

ISOPACH MAP
GATUNA FORMATION

FIGURE 4.3-11

REFERENCE:

Griswold, 1977, figure 10



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SCALE IN MILES

CONTOUR INTERVAL - 10 FEET

N

REFERENCE:

Griswold, 1977, figure 10

ISOPACH MAP
SANTA ROSA SANDSTONE

FIGURE 4.3-10

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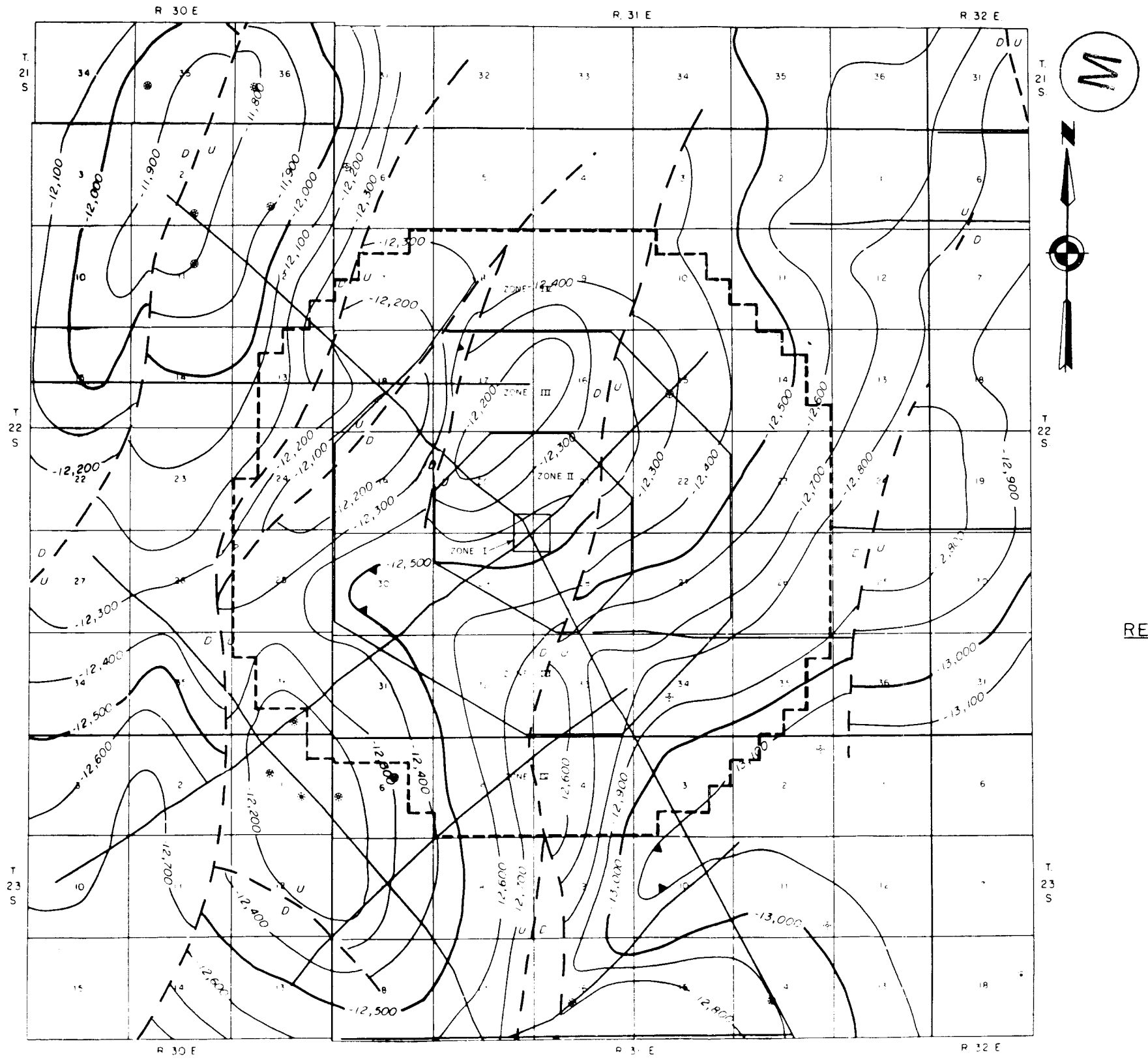

EXPLANATION

Seismic reflection profile lines.

Inferred faults
U – Upthrown side
D – Downthrown side

- Well - Dry and Abandoned
- Completed Well - Producing Gas
- Completed Well - Producing Oil

Contour interval - 100 feet
Datum is mean sea level

REFERENCE:
Griswold, 1977, figure 17

0 1 2 3
SCALE IN MILES

STRUCTURE CONTOURS
ON TOP OF SILURIAN

FIGURE 4.4-1

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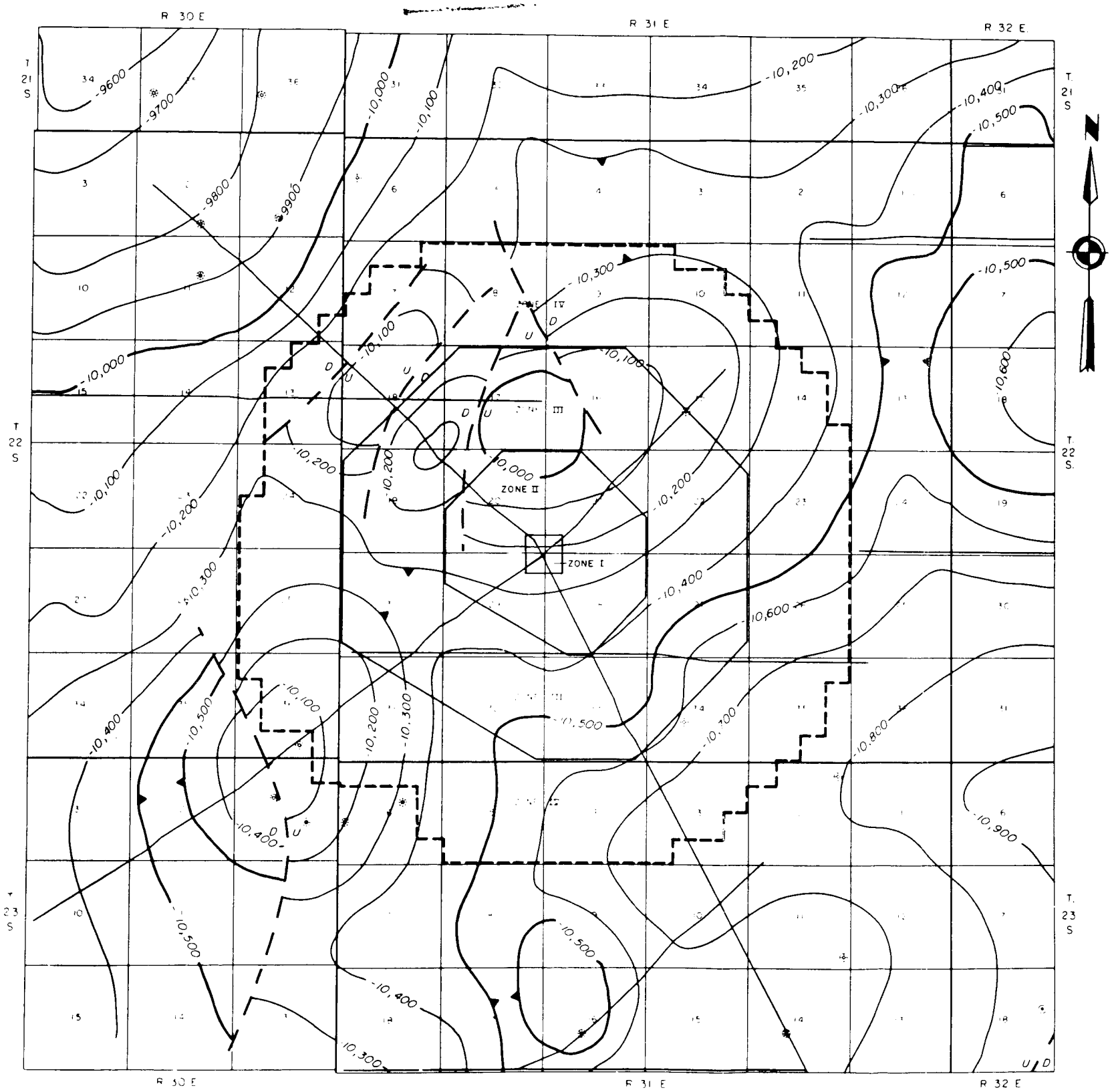

EXPLANATION

Seismic reflection profile lines.

Inferred faults.
U–Upthrown side
D–Downthrown side

- Well - Dry and Abandoned
- Completed Well - Producing Gas
- Completed Well - Producing Oil

Contour interval - 100 feet
Datum is mean sea level

REFERENCE:

Griswold, 1977, figure 16.

SCALE IN MILES

STRUCTURE CONTOURS
ON TOP OF
MORROW LIMESTONE

FIGURE 4.4-2

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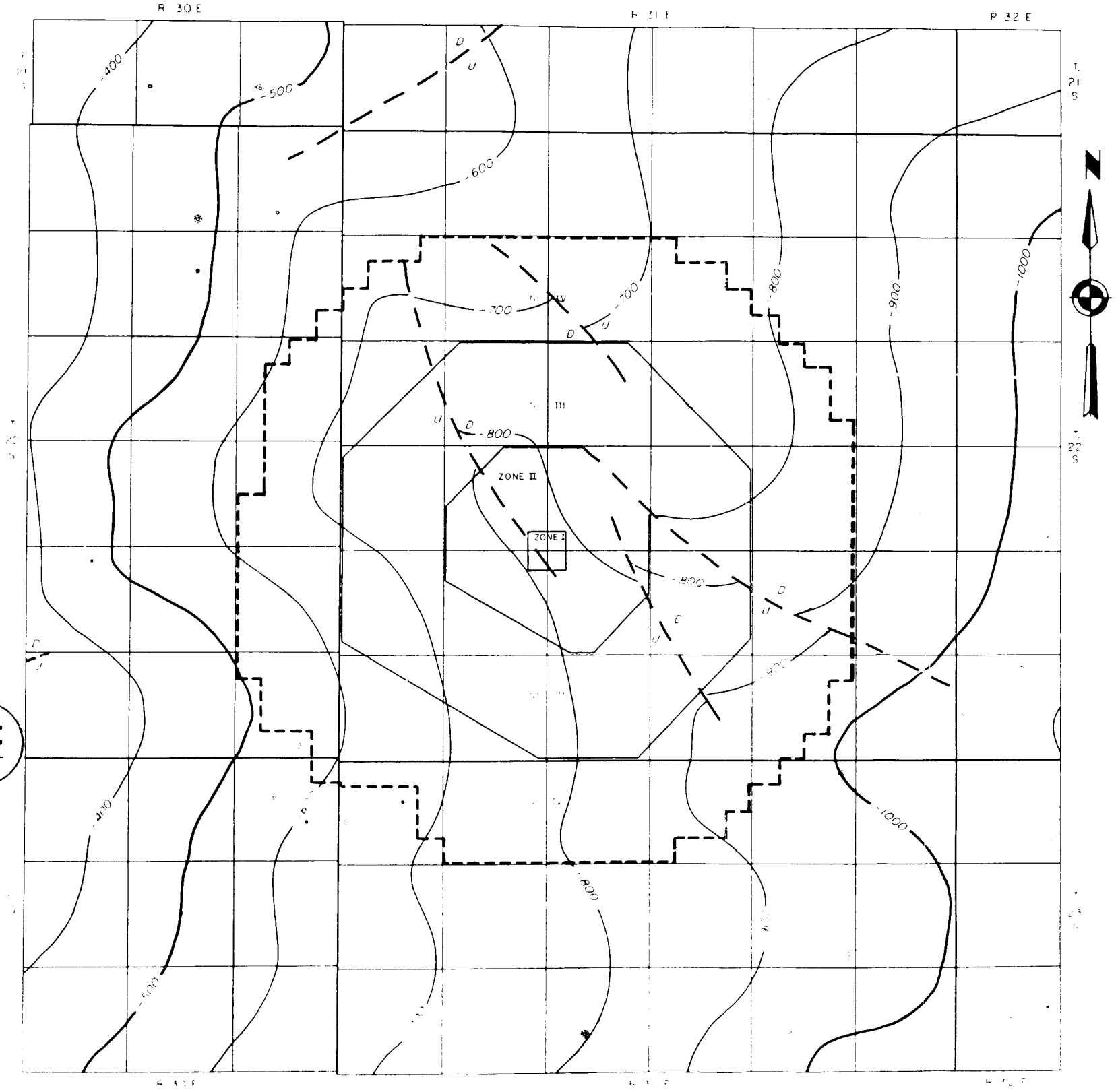

EXPLANATION

Possible faults.
U – Upthrown side
D – Downthrown side

- Well - Dry and Abandoned
- Completed Well - Producing Gas
- Completed Well - Producing Oil

Contour interval - 100 feet
Datum is mean sea level

REFERENCE:

Griswold, 1977, figure 15

0 1 2 3

SCALE IN MILES

STRUCTURE CONTOURS ON TOP OF DELAWARE SANDSTONE

FIGURE 4.4-3

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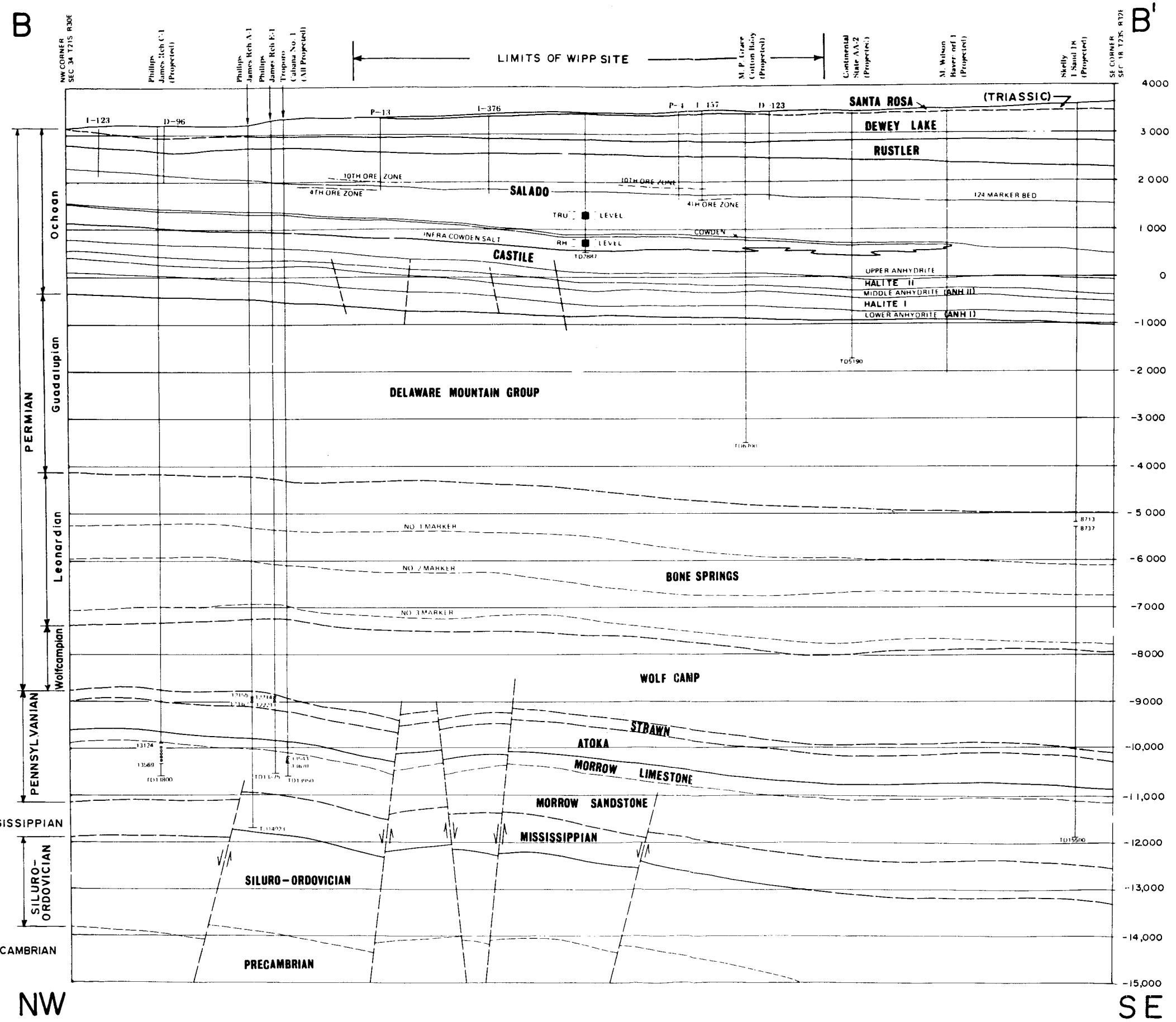

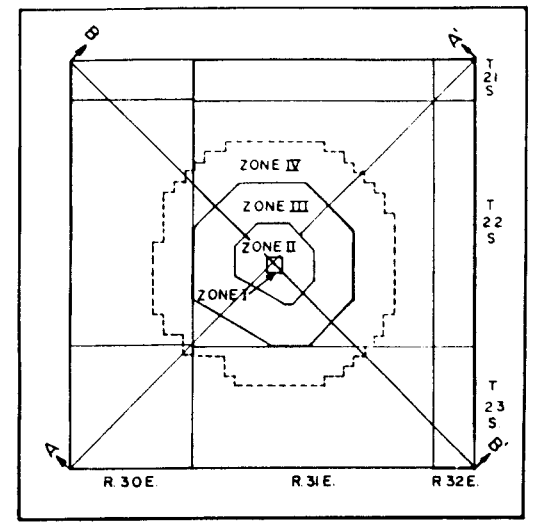

LOCATION MAP

0 1 2 3 4
SCALE IN MILES

REFERENCE:
Griswold, 1977, figure 7

0 1 2 3
HORIZONTAL SCALE IN MILES
VERTICAL EXAGGERATION, APPROX. 3 1/2 TIMES
DATUM IS MEAN SEA LEVEL

SITE GEOLOGIC SECTION B-B'

FIGURE 4.4-5

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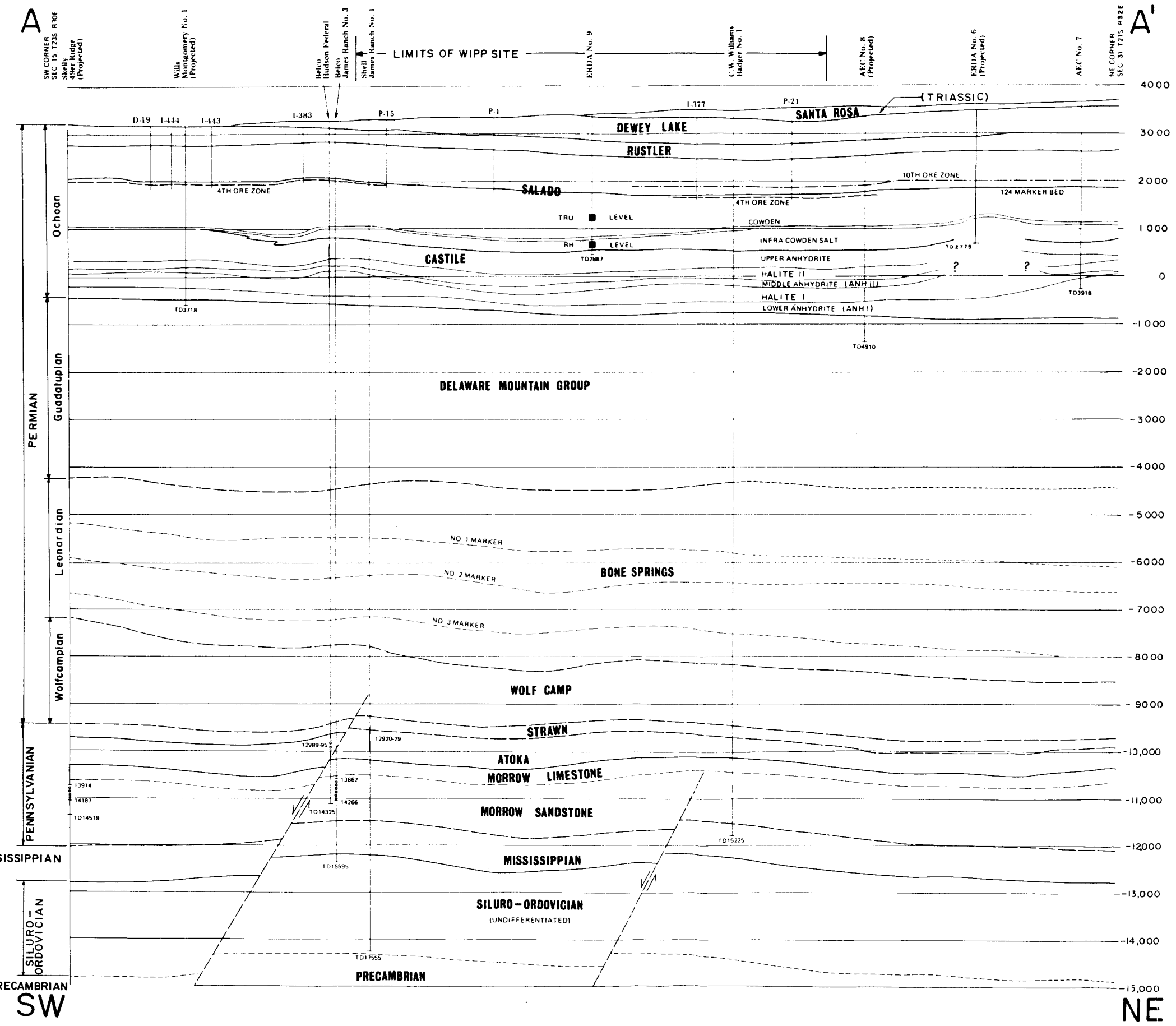

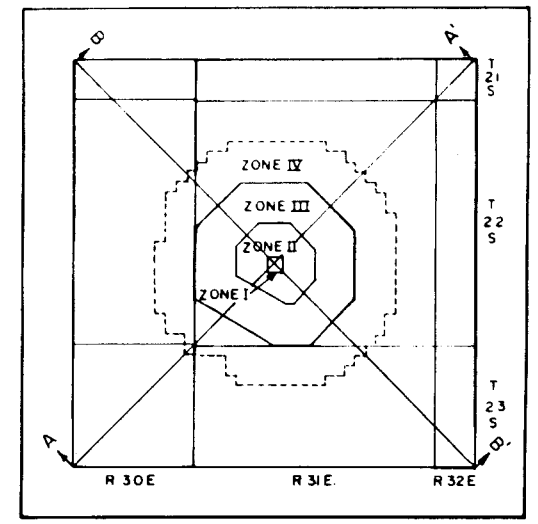

LOCATION MAP

0 1 2 3 4
SCALE IN MILES

REFERENCE
Griswold, 1977, figure 6

0 1 2 3
HORIZONTAL SCALE IN MILES
VERTICAL EXAGGERATION, APPROX. 3 1/2 TIMES
DATUM IS MEAN SEA LEVEL

SITE GEOLOGIC SECTION A-A'

FIGURE 4.4-4

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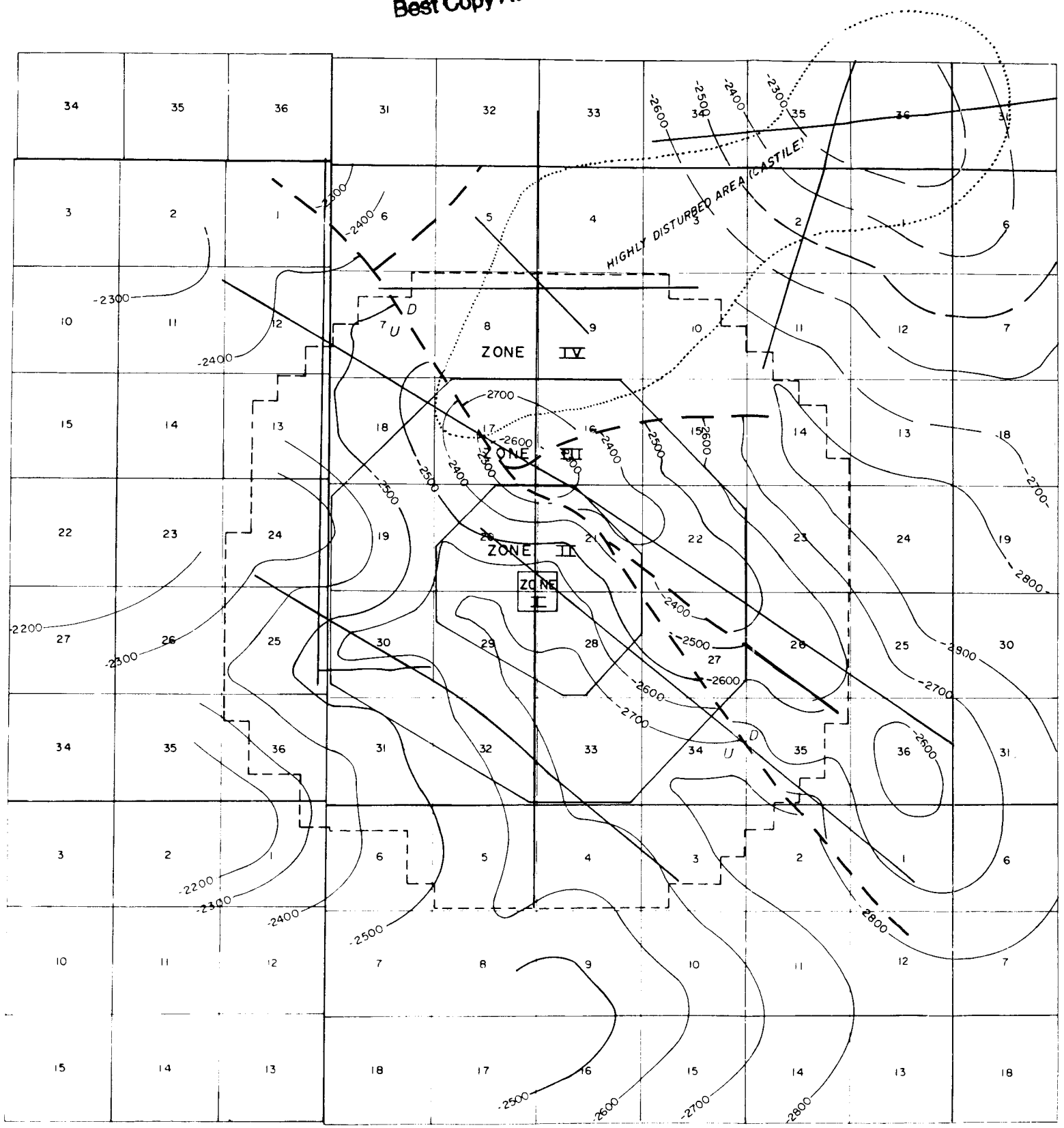

EXPLANATION

Seismic reflection profile lines

U
D

Inferred faults
U-Upthrown side
D-Downthrown side

Contour interval, 100 ft.

N

0 1 2 3

SCALE IN MILES

DATUM IS 3400' ABOVE MEAN SEA LEVEL

REFERENCE:
G.J. LONG & ASSOC., DEC. 1977

STRUCTURE CONTOURS ON TOP OF CASTILE

FIGURE 4.4-6

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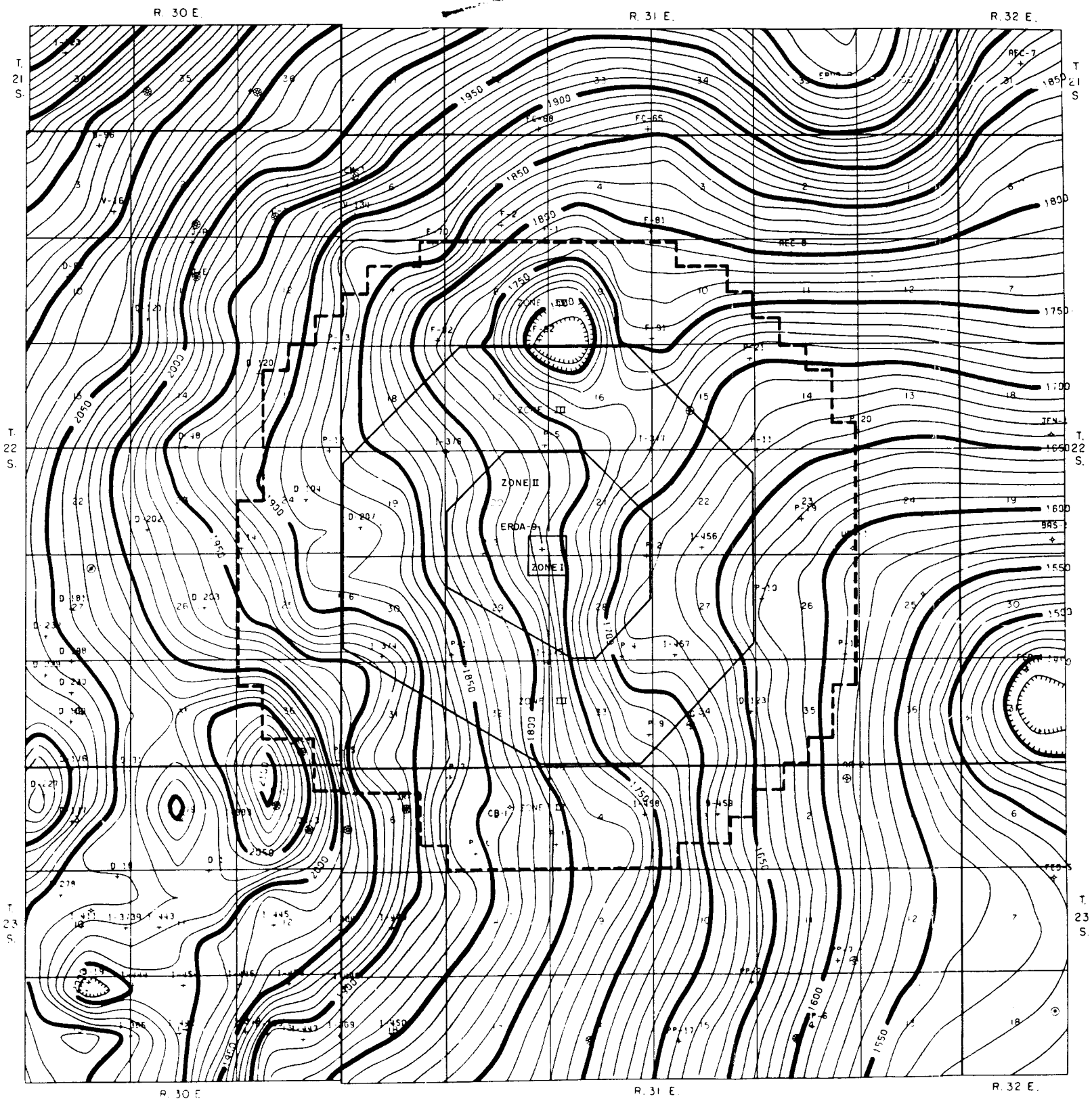
Best Copy Available



Note:
Borehole sources of data are shown.

N

REFERENCE
Griswold, 1977, figure 13

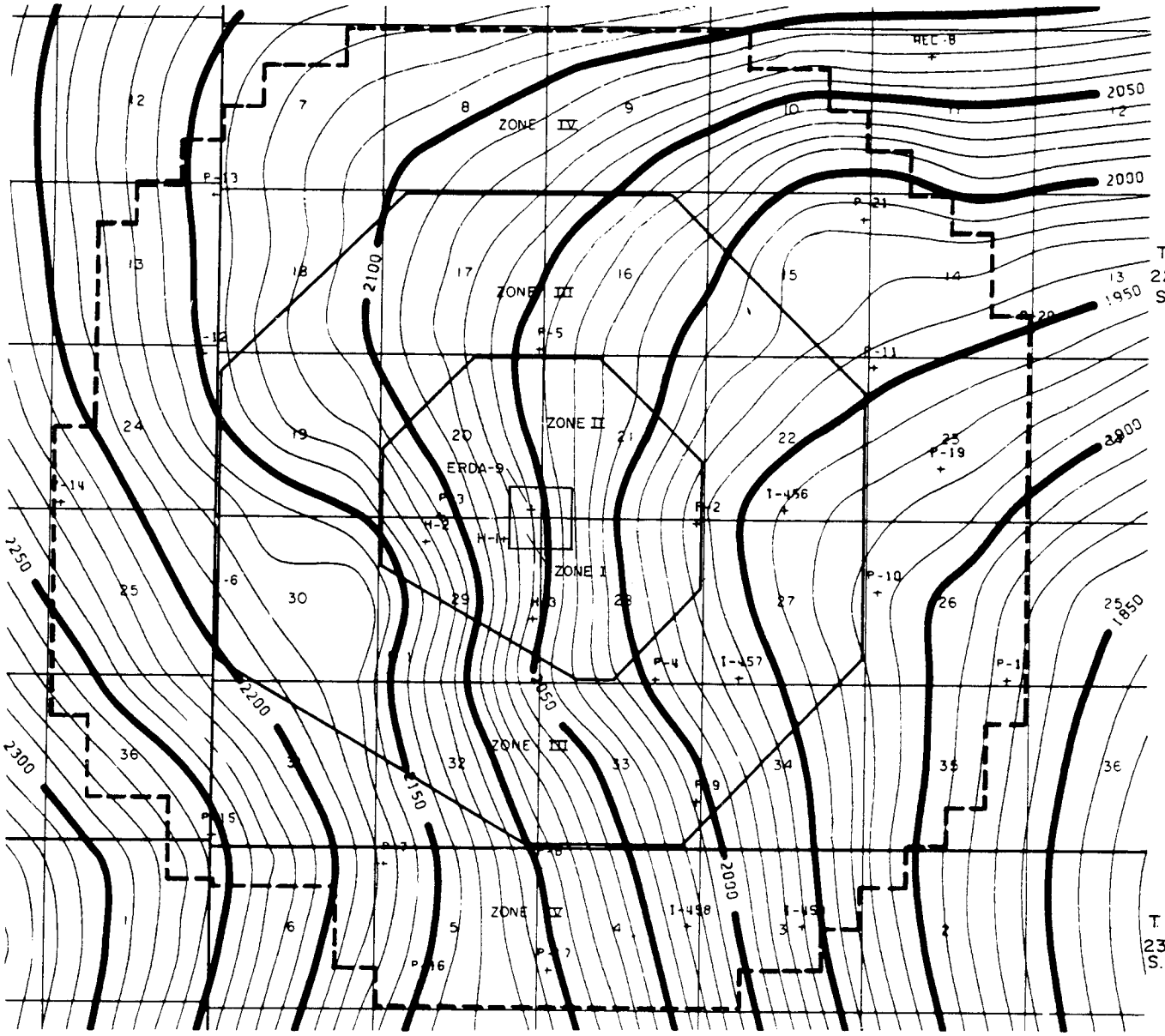
Contour interval, 10 feet

0 1 2 3
SCALE IN MILES

STRUCTURE CONTOURS ON 124-MARKER BED

FIGURE 4.4-7

4c



Contour interval, 10 feet

Note:
Borehole sources of data are shown.

0 2 3

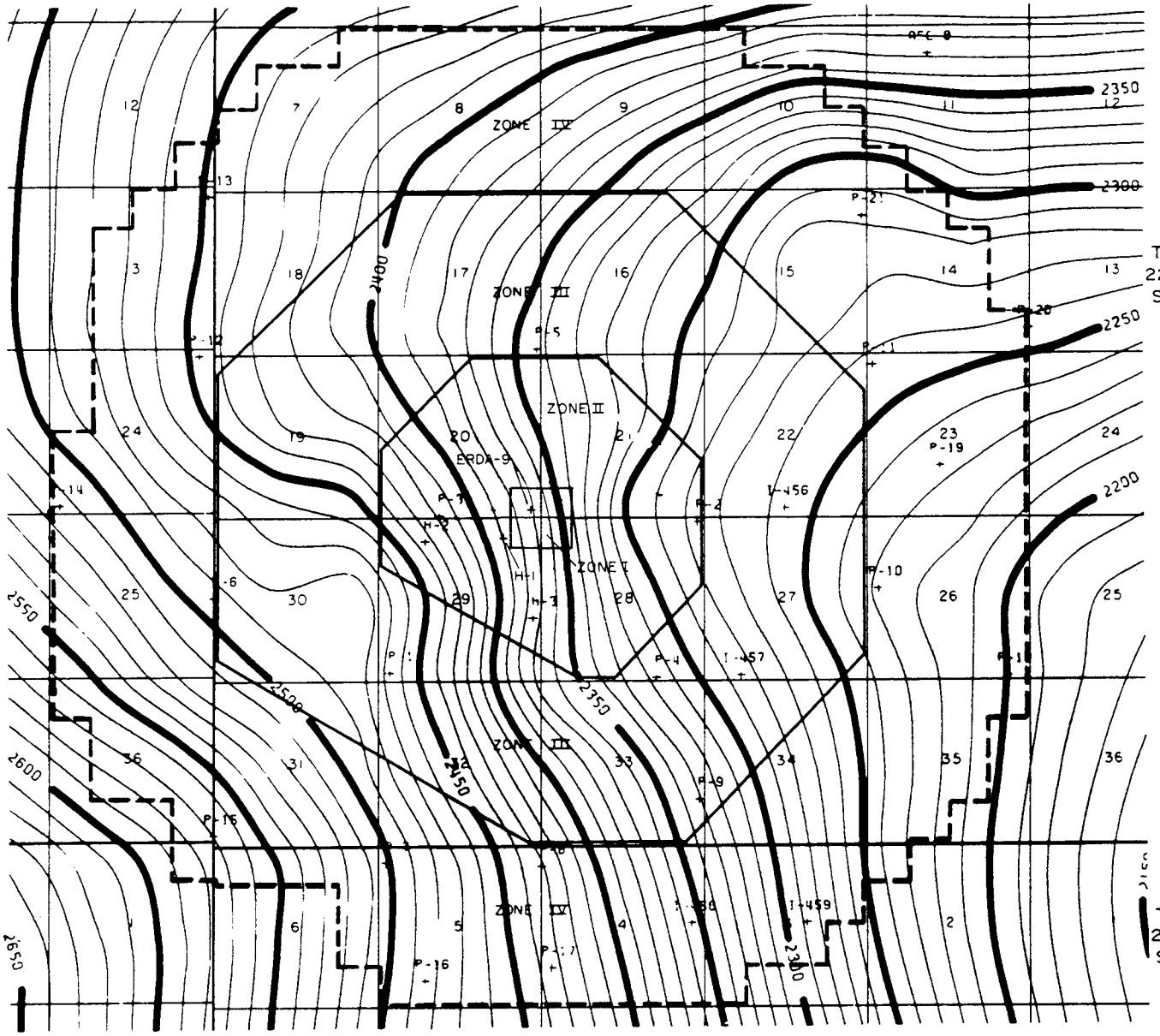
SCALE IN MILES

REFERENCE:

Griswold, 1977, figure 9

STRUCTURE CONTOURS ON TOP OF VACA TRISTE MARKER BED

FIGURE 4.4-8



0 1 2 3

SCALE IN MILES

Contour interval, 10 feet

Note:
Borehole sources of data are shown.

REFERENCE:

Griswold, 1977, figure 9

STRUCTURE CONTOURS ON 103 MARKER BED

FIGURE 4.4-9

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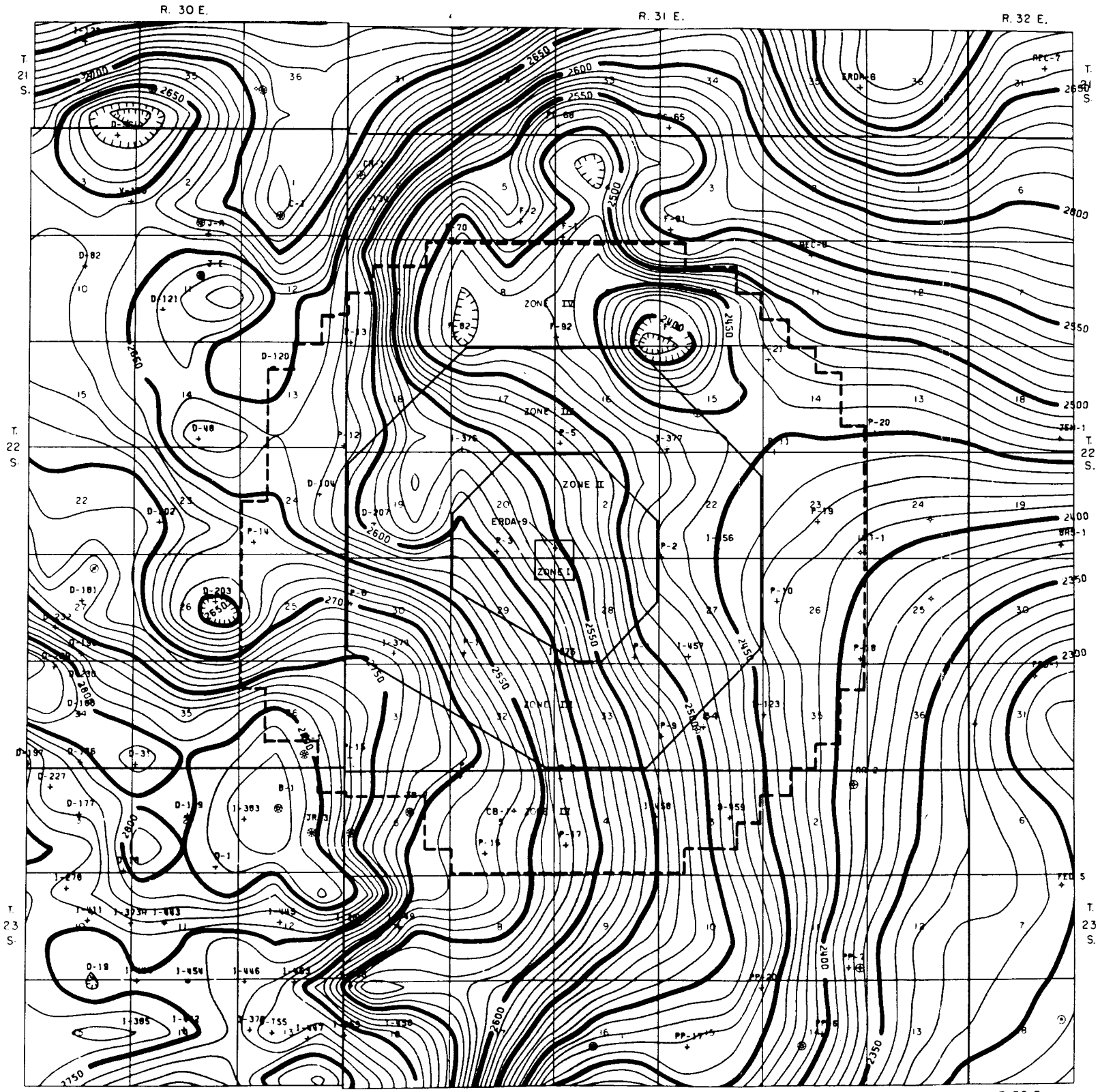
Best Copy Available



EXPLANATION

Contours based on geologic logs of ERDA and industry potash exploration logs. In the site area i.e., within Zones I–IV, the contours are considered accurate within 10 feet in elevation. Outside Zone IV they are approximate, and the error may exceed 50 feet in some areas. The Top of Salado may be higher in the west because drill records report only "top of salt". Datum is sea level.

N

Note:
Borehole sources of data are shown.

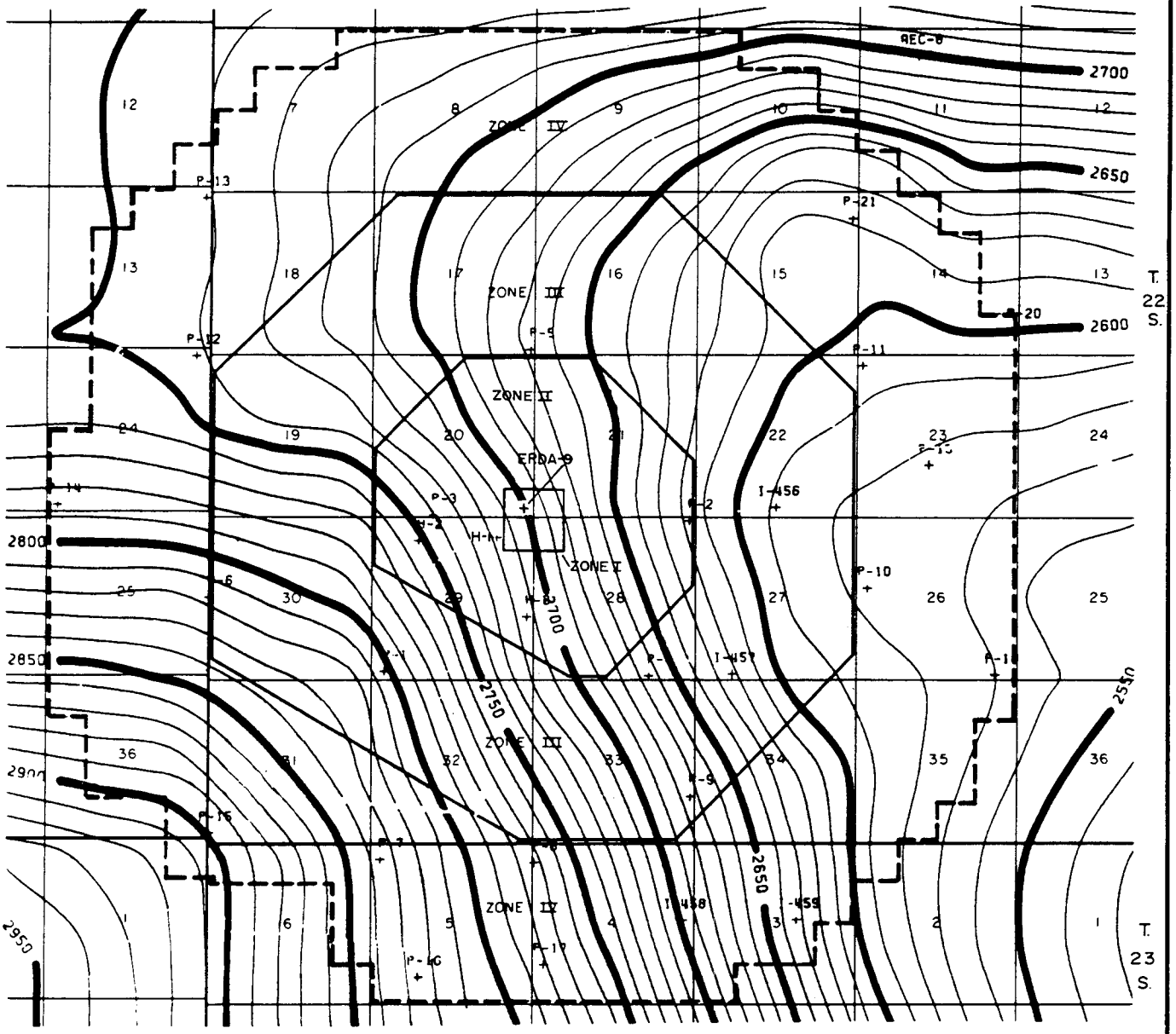
REFERENCE:
Griswold, 1977, figure 12

Contour interval, 10 feet

0 1 2 3
SCALE IN MILES

STRUCTURE CONTOURS ON TOP OF SALADO FORMATION

FIGURE 4.4-10



Contour interval, 10 feet

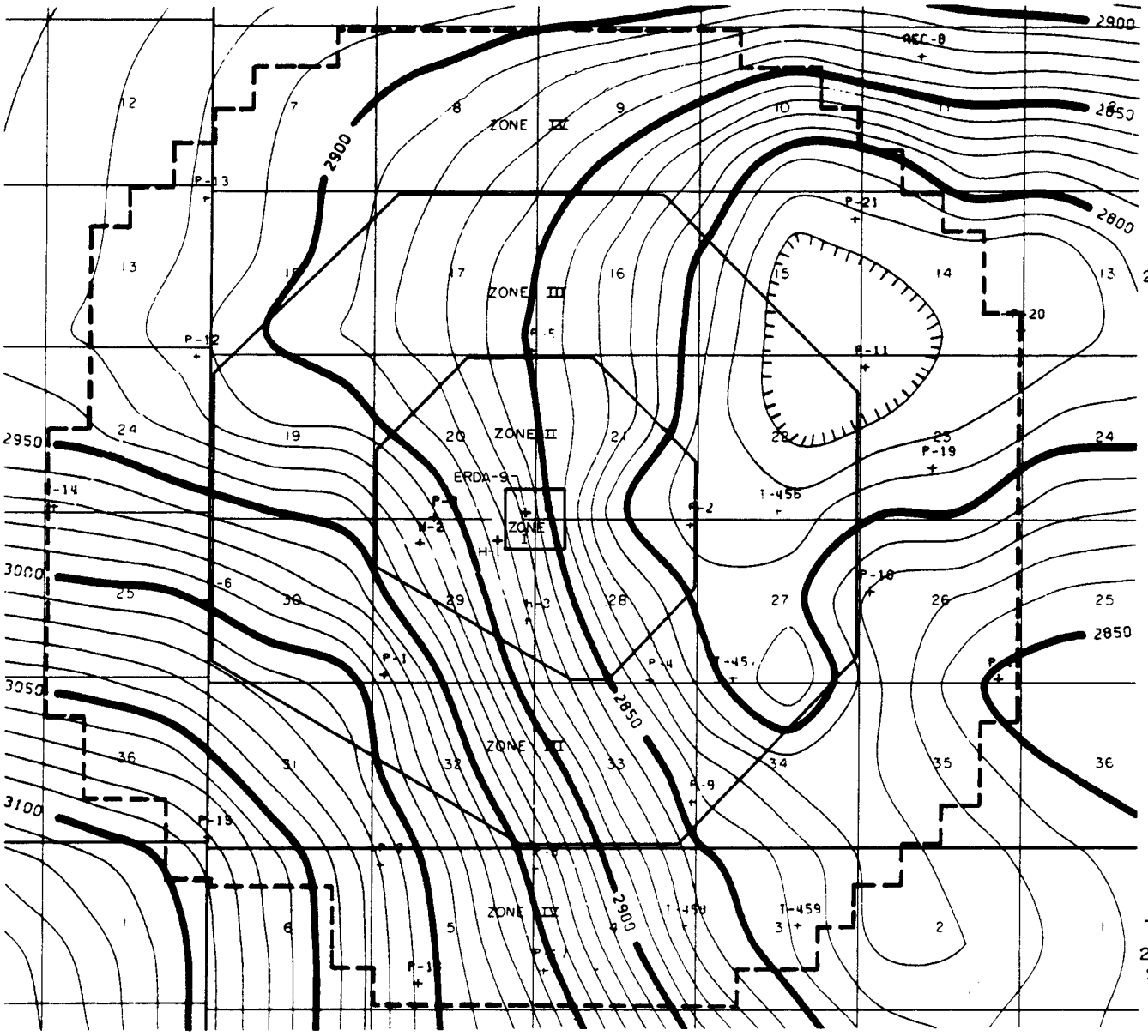
Note:
Borehole sources of data are shown.

REFERENCE:

Griswold, 1977, figure 9

STRUCTURE CONTOURS ON TOP OF CULEBRA DOLOMITE MEMBER

FIGURE 4.4-11



Contour interval, 10 feet

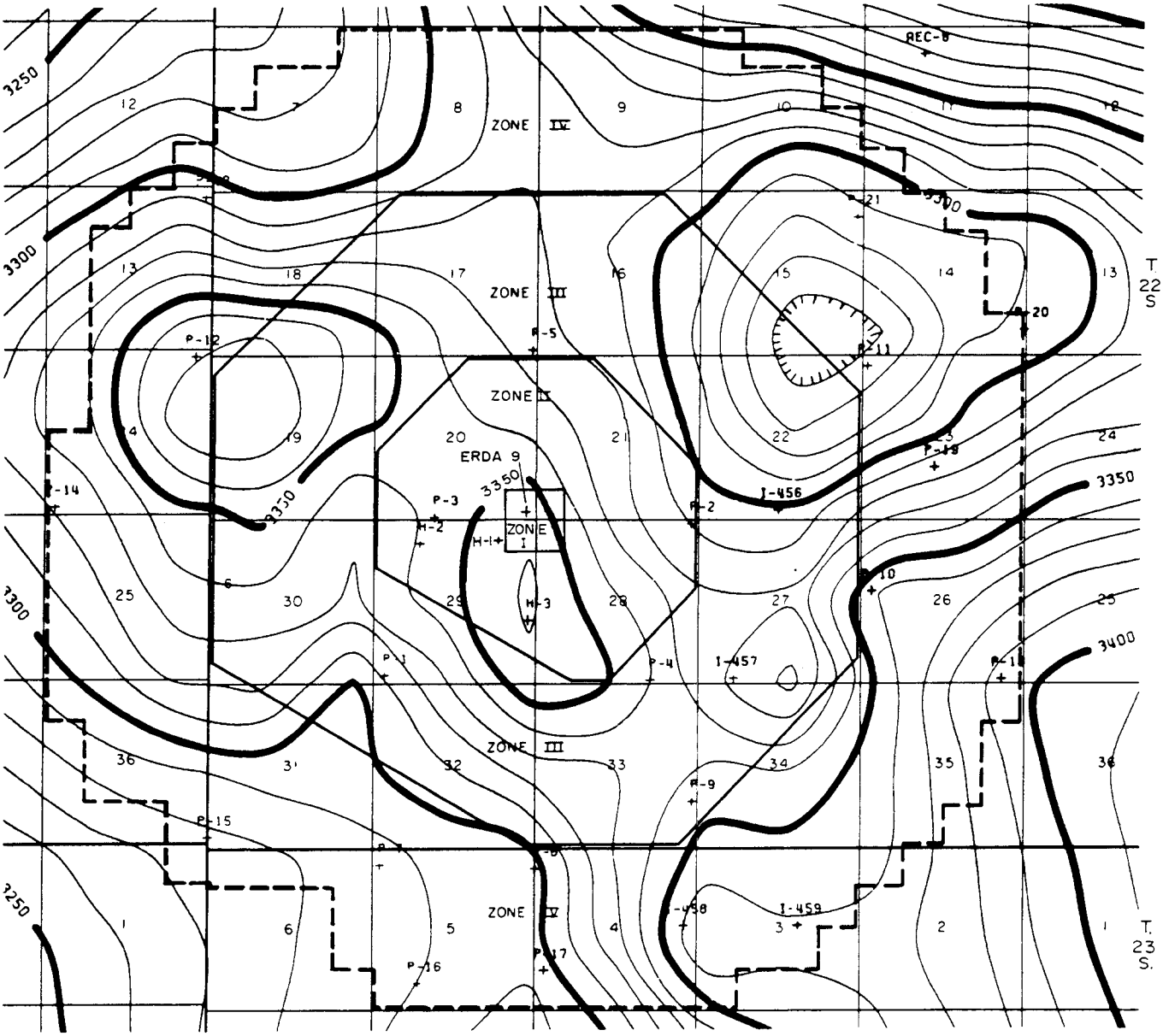
Note:
Borehole sources of data are shown.

REFERENCE

Griswold, 1977, figure 8

STRUCTURE CONTOURS ON TOP OF RUSTLER FORMATION

FIGURE 4.4-12



R. 30 E.

R. 31 E.

Contour interval, 10 feet

Note:
Borehole sources of data are shown.

0 1 2 3

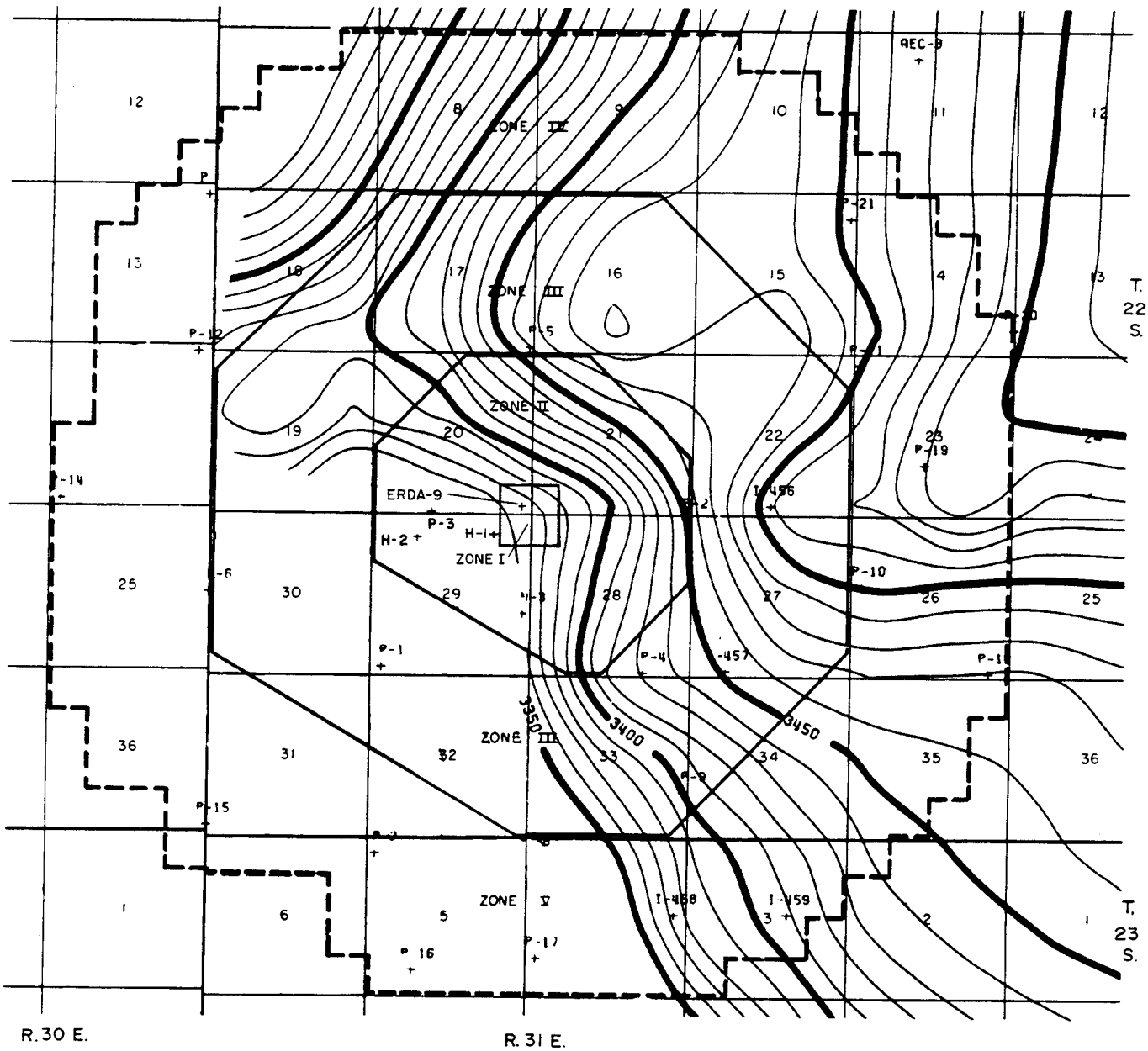
SCALE IN MILES

STRUCTURE CONTOURS ON TOP OF DEWEY LAKE REDBEDS

REFERENCE:

Griswold, 1977, figure 8

FIGURE 4.4-13



Contour interval, 10 feet

Note:
Borehole sources of data are shown.

0 1 2 3

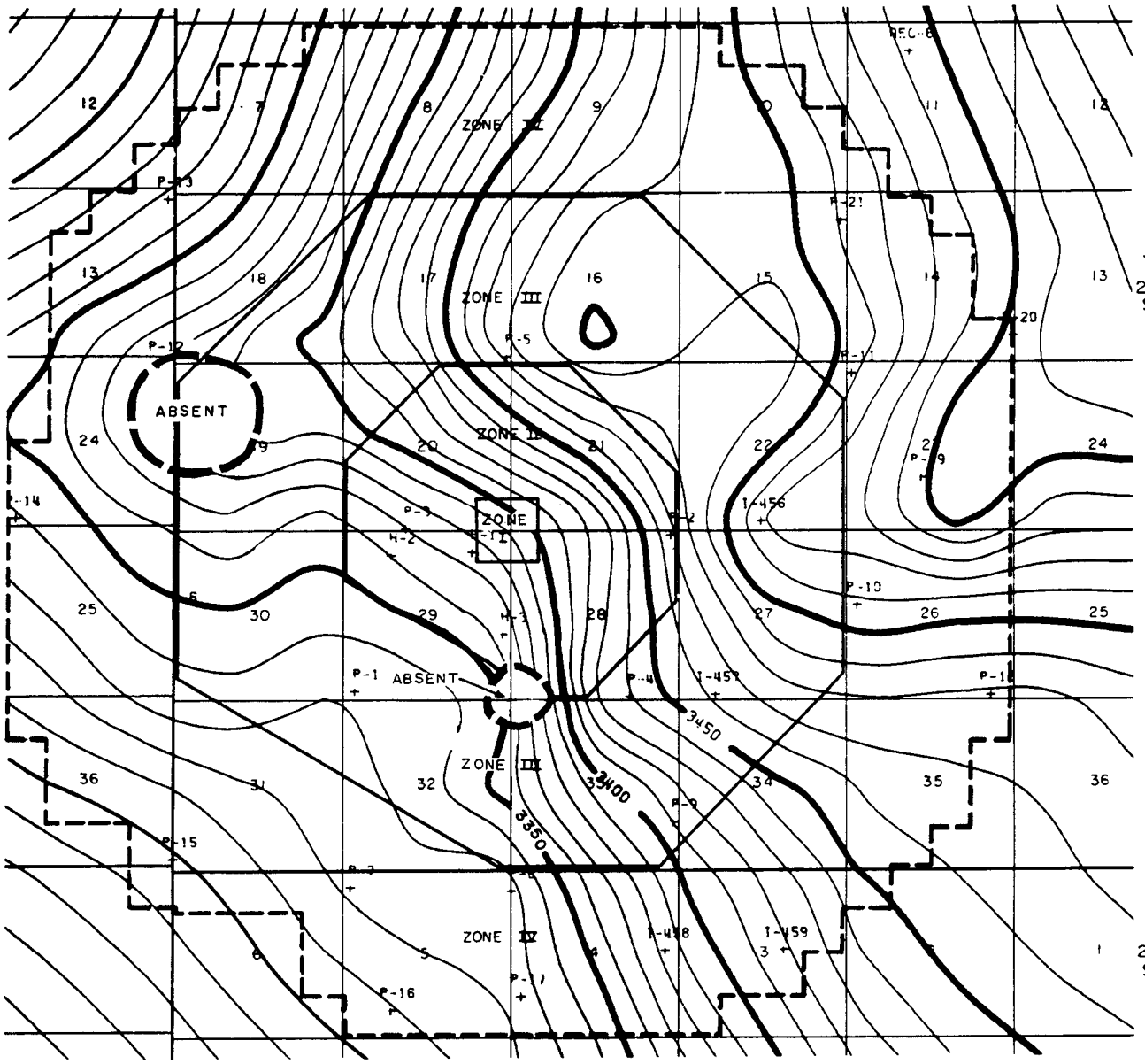
SCALE IN MILES

REFERENCE:

Griswold, 1977, figure 8

STRUCTURE CONTOURS ON TOP OF SANTA ROSA SANDSTONE

FIGURE 4.4-14



0 1 2 3

SCALE IN MILES

Contour interval, 10 feet

Note:
Borehole sources of data are shown.

N

STRUCTURE CONTOURS ON TOP OF GATUNA FORMATION

REFERENCE:

Griswold, 1977, figure 8

FIGURE 4.4-15

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BOREHOLE INFORMATION FOR T

TABLE

HOLE NO.	T/R/S	COLLAR ELEVATION	SALADO ELEVATION	BASE 124 ELEVATION	TOTAL DEPTH
I-123	21/30/34	3170	2182	1382	1880
W-7	21/31/31	3333	2743	2046	N/A
FC-63	21/31/32	3409	2719	1997	1483
FC-68	21/31/32	3430	2610	1881	1644
F-52	21/31/34	3485	2625	1970	1823
FC-65	21/31/34	3465	2645	1856	1669
FC-69	21/31/34	3461	2632	1962	1562
ERDA-6	21/31/35	3536	2721	1999	2775
AEC-7	21/32/31	3662	2664	1874	3918
C-1	22/30/1	3357	2727	1954	13950
D-96	22/30/3	3189	2609	2133	1210
V-168	22/30/3	3170	2660	2108	1173
D-82	22/30/10	3149	2669	2102	1135
D-121	22/30/11	3202	2642	2045	1266
J-A	22/30/11	3191	2673	2014	14923
J-E	22/30/11	3220	2626	1991	13950
D-120	22/30/13	3338	2654	1930	1500
D-48	22/30/14	3337	2627	1937	1524
D-202	22/30/23	3323	2703	1981	1443
D-104	22/30/24	3388	2629	1883	1596
P-12	22/30/24	3376	2627	1867	1598
P-14	22/30/24	3358	2671	1939	1545
D-203	22/30/26	3317	2647	1965	1443
D-181	22/30/27	3288	2748	2039	1345
D-198	22/30/27	3258	2748	2069	1302
D-229	22/30/27	3218	2825	2068	1266
D-232	22/30/27	3258	N/A	2063	1221
D-36	22/30/34	N/A	N/A	N/A	N/A
D-180	22/30/34	3210	2790	2083	1230
D-188	22/30/34	N/A	N/A	N/A	N/A
D-230	22/30/34	3231	2821	2067	1195
JR-1	22/30/36	3308	2802	2037	17555
D-160	22/30/36	N/A	N/A	N/A	N/A
F-81	22/31/3	3471	2551	1797	1735
F-2	22/31/5	3404	2529	1818	1690
CM-1	22/31/6	3376	2668	1961	14050
V-134	22/31/6	3363	2622	1898	1563
F-70	22/31/7	3388	2490	1867	1603
F-82	22/31/8	3382	2472	1781	1684
F-92	22/31/8	3420	2470	1688	1818
F-1	22/31/9	3422	2482	1781	1747
F-91	22/31/10	3460	2390	1755	1788
AEC-8	22/31/11	3542	2548	1801	4910
P-20	22/31/14	3553	2450	1662	1995
P-21	22/31/15	3510	2467	1705	1915
P-5	22/31/17	3472	2525	1767	1830
P-13	22/31/18	3345	2624	1874	1576
D-207	22/31/19	3406	2595	1886	1613
ERDA-9	22/31/20	3415	2555	1765	2890
I-376	22/31/20	3410	2570	1819	1702
P-3	22/31/20	3382	2596	1803	1676
I-377	22/31/22	3490	2476	1720	1876
I-456	22/31/22	3520	2451	1667	1975
P-11	22/31/23	3506	2448	1673	1940
P-19	22/31/23	3546	2429	1629	2000
WRT-1	22/31/23	3595	2406	1596	4766
P-10	22/31/26	3508	2422	1620	2009
P-18	22/31/26	3479	2391	1590	1993
I-457	22/31/27	3460	2480	1683	1885
P-2	22/31/28	3478	2470	1683	1895

P—ERDA POTASH HOLE
V—U.S. POTASH CO. (MISSISSIPPI POTASH)
D DTS DUVAL CORP.
I—INTERNATIONAL MINERALS
PP—PERMIAN POTASH
F—FC KERR McGEE
N/A—NOT AVAILABLE

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HOLE NO.	T/R/S	COLLAR ELEVATION	SALADO ELEVATION	BASE 124 ELEVATION	TOTAL DEPTH
P-4	22/31/28	3441	2511	1688	1857
P-1	22/31/29	3445	2668	1859	1591
P-6	22/31/30	3554	2695	1892	1573
I-374	22/31/30	3340	2735	1931	1538
P-15	22/31/31	3310	2768	1957	1465
P-9	22/31/33	3408	2528	1714	1796
I-375	22/31/33	3390	2600	1788	1746
D-123	22/31/34	3432	2444	1644	1880
G-1	22/31/34	3450	2495	1708	4475
JEN-1	22/32/18	3696	2471	1664	4896
BAS-1	22/32/19	3620	2378	1578	4802
FED-1	22/32/31	3627	2294	1447	4777
B-1	23/30/1	3280	2825	2115	14312
I-383	23/30/1	3272	2832	2061	1307
JR-3	23/30/1	3288	2806	2041	15692
D-1	23/30/2	3241	2809	2032	1310
D-31	23/30/2	3244	2812	2038	1314
D-179	23/30/2	3244	2794	1997	1350
D-176	23/30/3	3197	2782	2078	1223
D-177	23/30/3	3151	2741	2088	1188
D-197	23/30/3	3141	2731	2110	1136
D-227	23/30/3	3246	2818	N/A	1073
D-18	23/30/10	3190	2806	2040	1265
I-278	23/30/10	3120	2780	2035	1217
I-373A	23/30/10	3140	2765	2036	1242
I-411	23/30/10	3128	2753	2041	1208
I-443	23/30/11	3185	2770	2028	1270
I-445	23/30/12	3235	2765	1968	1385
D-TS5	23/30/13	3210	2685	1848	1495
PP-19	23/30/13	N/A	N/A	N/A	N/A
I-370	23/30/13	3220	2740	1986	1341
I-446	23/30/13	3210	2730	1976	1345
I-447	23/30/13	3250	2741	1891	1480
I-453	23/30/13	3240	2730	1963	1405
I-385	23/30/14	3165	2770	2045	1235
I-442	23/30/14	3170	2755	2007	1275
I-444	23/30/14	3130	2745	2003	1240
I-454	23/30/14	3170	2735	2000	1300
D-19	23/30/15	3149	2727	1957	1369
I-440	23/30/15	N/A	N/A	N/A	N/A
AA-2	23/31/2	3453	2383	1583	5190
I-459	23/31/3	3418	2482	1679	1855
I-458	23/31/4	3385	2549	1762	1750
P-8	23/31/4	3336	2621	1791	1660
P-17	23/31/4	3340	2625	1805	1660
P-7	23/31/5	3332	2702	1873	1575
P-16	23/31/5	3323	2677	1853	1585
CB-1	23/31/5	3320	2662	1845	4150
JR-7	23/31/6	3319	2713	1920	14590
I-384	23/31/7	3290	2790	1964	1438
I-449	23/31/7	3310	2680	1906	1515
PP-7	23/31/11	3485	2375	1593	2033
PP-8	23/31/14	3485	2405	1594	2079
PP-17	23/31/15	3418	2468	1689	1920
PP-20	23/31/15	3429	2469	1660	1910
I-389	23/31/18	3280	2715	1871	1538
I-448	23/31/18	3290	2625	1900	1510
I-450	23/31/18	3300	2690	1854	1570
FED-5	23/32/7	3539	N/A	N/A	4712

REFERENCE:

Adapted from Griswold, 1977

GCR CHAPTER 5

SEISMOLOGY

5.1 INTRODUCTION

The study of the Los Medanos site region's seismicity is of interest for two reasons. First, it forms the primary basis for the analysis and selection of reasonably expected vibratory ground motion for use in aseismic design; second, when considered along with the geology and tectonic history of the region, it provides some indication of current and long-term tectonic stability. In this chapter both aspects of the regional seismicity are discussed.

In Section 5.2 the temporal and geographic distribution of observed earthquakes in the site region are discussed. The regional seismicity is considered in two separate time intervals suggested by the type and quality of information available during each interval. These intervals are: before 1962, and from 1962 to the present. In the post-1962 period, several specialized instrumental studies are considered in addition to a more general regional instrumental survey.

Using the information developed on regional seismicity, and some additional simple assumptions about regional tectonism, a preliminary analysis of probabilistic vibratory ground motion at the ground surface is derived in Section 5.3 in a way that is useful for seismic design characterization at the site during its active phase of development and use. This analysis shows that short-term accelerations during the operational phase are likely to be very modest. Probabilities at which higher acceleration levels occur depend almost exclusively on the assumptions made about the seismic capabilities of the immediate site area.

Finally, in Section 5.4, regional seismicity is considered as an indicator of long-term tectonic processes. Regional stress patterns, as implied by focal mechanism solutions for regional earthquakes and in-situ stress measurements, and regional tectonism, as implied by earthquake

recurrence statistics, are both considered. Several tentative conclusions are reached as a result of this study and are outlined at the conclusion of this chapter.

5.2 SEISMICITY

In this section the temporal and geographic distribution characteristics of observed earthquakes in the site region are discussed. Detailed discussion is restricted to earthquakes within 300 kilometers (about 186 miles) of the Los Medanos site in view of historical analysis by Sanford and Toppozada (1974).

As always, in studying any single earthquake or group of earthquakes, it is important to note the date of occurrence in relation to the state of the art of seismology at the time. The certainty with which fundamental properties of earthquakes, such as size and location, can be determined largely depends on the availability and quality of instrumental data. Prior to 1960, nearly all information on the strengths and distribution of earthquakes in New Mexico was determined without the aid of instruments (Sanford, 1965). Therefore, inferences which may be drawn from pre-1960 seismicity studies are fundamentally different and more speculative than instrumentally derived parameters.

Instrumental studies of earthquakes in New Mexico began in June 1960 when high magnification seismographs were placed in operation by the New Mexico Institute of Mines and Technology at Socorro, and by the Atomic Energy Commission at Sandia Base near Albuquerque (Sanford et al., 1972). These two stations provided some information on locations and strengths of earthquakes in central New Mexico, but accurate information about locations throughout the state was not available until the beginning of 1962, when additional high-gain stations went into operation in New Mexico and bordering states (Las Cruces, N.M.; Payson, Arizona; Ft. Sill, Oklahoma). Also at this time the United States Coast and Geodetic Survey (U.S.C.G.S.) established a regular reporting station at Albuquerque. Instrumental seismology for the state of New Mexico as a whole dates from this time.

In this discussion the format of a previous study by Sanford and Toppozada (1974) is followed. Regional seismicity of the Los Medanos site area is considered in two distinct time frames in accordance with the types of data available. Preinstrumental data, roughly that before 1962 in the site area, is treated first; a separate study of the later period for which seismograph records exist follows in several separate subsections.

Two very recent investigations of seismicity on a much more local scale affect the Los Medanos site. One involves recordings made on a continuously operating, vertical component, high frequency system installed and operated at the site itself by personnel from the New Mexico Institute of Mining and Technology at Socorro. The principal objective of this station, which has gathered data for most of the interval April 5, 1974, to October 29, 1977, and which continues to function, has been to determine if seismic activity is occurring at or near the proposed nuclear waste repository at such a low level that it might not be adequately detected by more standard instrumental data surveys (Sanford et al., 1976a). The other recent study is one designed to investigate in detail local small magnitude seismicity in and near the Central Basin Platform of west Texas. To this end, a seismic array centered near Kermit, Texas, has been installed. Initial operation of this array began in early November 1975, and some preliminary conclusions have been reached at this time (Hays, 1977; Rogers and Malkiel, 1978). Both of these recent study efforts will be discussed in separate subsections of this report.

In a final subsection, two small earthquakes important to the question of background seismicity level in the immediate site area are discussed.

5.2.1 Preinstrumental Data - Regional

Most historic earthquakes in New Mexico cataloged before seismic instrumentation occur in the Rio Grande Valley area between Albuquerque and Socorro. About half the earthquakes of Modified Mercalli Intensity V

or greater in New Mexico between 1868 and 1973 are in this region. In conformity with previous studies (Sanford and Toppozada, 1974; Sanford et al., 1978) these events are not considered to be of immediate concern for this study and will not be discussed further. As will be seen, the area within roughly 200 kilometers of the site has experienced only low intensity earthquakes prior to the first availability of seismographic data in 1961; there have been a few modestly damaging earthquakes during the same interval between 200 and 300 kilometers from the site. The area up to 300 kilometers from the site is defined as the site region in the following discussions.

Figure 5.2-1 shows locations of earthquakes occurring before 1961 that have been assigned epicenters within 300 kilometers of the site. Table 5.2-1 lists the events shown on Figure 5.2-1. Intensities appearing in this table, and anywhere in this section, are Modified Mercalli intensities (Wood and Neumann, 1931).

The primary source used was Sanford and Toppozada (1974), although some supplemental descriptive material was obtained from Neumann and Bodle (1932), Neumann (1932, 1938, and 1940), Murphy and Ulrich (1951), Murphy and Cloud (1954 and 1957), Northrop and Sanford (1972), and Coffman and Von Hake (1973). An abridged version of the Modified Mercalli Intensity Scale of 1931 may be found in Table 5.2-2. In the descriptions below, intensities in parentheses were assigned by Sanford and Toppozada (1974) based only on their personal evaluation of the data.

1923, Mar. 7 El Paso, Texas V Felt in Sierra Blanca (166 kilometers to SE), Columbus (130 kilometers to W), Alamogordo (135 kilometers to N). Newspaper accounts suggest epicenter in northern Chihuahua. (Sanford and Toppozada, 1974).

1926, July 17 Hope and Lake Arthur, N.M. III Earth sounds heard in NE direction at Hope; windows rattled at Lake Arthur. (Sanford and Toppozada, 1974).

1930, Oct. 4 Duran, N.M. IV A moderate shock felt by many. Rolling motion, rumbling sound, rattled windows. No damage. (Neumann and Bodle, 1932).

1931, Aug. 16 Valentine, Texas VIII At Valentine, the point of maximum destruction, all types of buildings, especially adobe, were heavily damaged; many chimneys fell. There were some cracks in the ground, and tombstones rotated both clockwise and counterclockwise. While people were panic-stricken, there were no fatalities and only a few minor casualties. There were cracked walls and damaged chimneys in several towns in Brewster, Jeff Davis, Culberson, and Presidio Counties. Some rockslides occurred in the mountains. There were rumbling and roaring sounds. This earthquake would have been severe in a densely populated region. (Coffman and Von Hake, 1973).

1931, Aug. 16 Valentine, Texas (V) Strong aftershock of intensity VIII event.

1931 Aug. 18 West Texas V at Alpine, Pecos, Lobo, and Valentine; IV at Carlsbad, N. Mex. This was preceded by a lighter shock on the same day. Recorded at Tucson. (Neumann, 1932).

1931, Aug. 19 Valentine, Texas (V) Strong aftershock of intensity VIII event.

1931, Oct. 2 El Paso, Texas III "To-day", El Paso, Texas. Feeble. (Neumann, 1932).

1931, Nov. 3 Valentine, Texas (V) West Texas. Felt at Valentine. Aftershock of August 16 earthquake. Recorded at Tucson.

1935, Dec. 20 Clovis, New Mexico III-V Two Shocks. A tile wall in a creamery was cracked. Another report of wall paper being split (AP news item). (Northrop and Sanford, 1972).

1936, Jan. 8 Carlsbad, N.M.? (IV) Felt by few; press reports some property damage (Neumann, 1938). Newspaper account indicates this earthquake was probably centered near Ruidoso, N.M. (Sanford and Toppozada, 1974).

1936, Aug. 8 El Paso, Texas (III) Weak shock not felt elsewhere (Neumann, 1938).

1936, Oct. 15 El Paso, Texas (III) "Earth tremor" shortly before noon. No details. (Neumann, 1938).

1937, Mar. 31 El Paso, Texas (V) Slight. Felt by many. (Neumann, 1940).

1937, Sept. 30 Ft. Stanton, N.M. V Slight. Awakened many. (Neumann, 1940).

1943, Dec. 27 Tularosa, N.M. IV Rattled windows. (Sanford and Toppozada, 1974).

1949, Feb. 2 Carlsbad, N.M. IV Press reported two distinct shocks which were felt by several. A few people were frightened. Windows, doors, and dishes rattled; houses seemed to shudder momentarily. (Murphy and Ulrich, 1951).

1949, May 23 East Vaughn, N.M. VI Felt over an area of only about 1300 square miles. "Results of a questionnaire coverage indicated the felt area to be a 20-mile strip connecting Pastura with Vaughn and East Vaughn. Maximum intensity VI at the last named place where a few things fell from shelves, loose objects rattled and buildings creaked. Deep rumbling and grinding sounds were heard before and during shock" (Murphy and Ulrich, 1951). Many people were awakened and many were frightened. One person felt the shock while driving a car 20 miles southeast of Vaughn on the highway to Roswell. (Northrup and Sanford, 1972).

1952, May 22 Dog Canyon, New Mexico (about 70 miles northwest of Carlsbad). IV Felt by two in ranch house. Windows, doors, and dishes rattled; house creaked. (Murphy and Cloud, 1954).

1955, Jan 27 Valentine, Texas IV Felt by many. Houses shook (Murphy and Cloud, 1957).

As can be seen from the above data, there have been no earthquakes of epicentral intensity V or greater recorded as occurring within about 200 kilometers of the Los Medanos site when noninstrumental data alone is considered. The strongest earthquake reported to occur within 300 kilometers of the site was the Valentine, Texas event of August 16, 1931. The reported maximum intensity for this shock was VIII on the Modified Mercalli scale (Table 5.2-2). Reports of earthquake intensity for a wide area have been compiled into several isoseismal maps (Neumann, 1932; Sellards, 1933). Intensities in these maps are based on the Rossi-Forel scale which was subsequently abandoned for the Modified Mercalli Scale of 1931. Sanford and Toppozada (1974) have assigned Modified Mercalli intensities on the basis of descriptions of the earthquake effects for this event and plotted the isoseismal map shown in Figure 5.2-2. According to this map the intensity at the site was probably no greater than V. This is the largest known historical site intensity.

Close to the source, the isoseismals are elongated northwest-southeast conforming to the structural grain of the region. Further from the epicenter, the earthquake had higher intensities to the east than west due to lower topographic relief to the east (Sanford and Toppozada, 1974), differences in attenuation, or some other reason. The data to the southwest, in Mexico, are particularly sparse.

Two instrumental locations have been published for this earthquake. The U.S.C.G.S. (Neumann, 1932) places the epicenter at 29.9°N and 104.2°W with an origin time of 11:40:15 GMT. Byerly (1934), who made a detailed instrumental investigation of this earthquake, found the epicenter to be

at 30.9°N and 104.2°W with an origin time of 11:40:21 GMT. Byerly's epicenter, 110 kilometers north of the U.S.C.G.S. epicenter is closer to the region of highest reported intensities and may for this reason be considered the more accurate of the two. Although neither is particularly close to Valentine, Texas, the USCGS and Byerly epicenters bracket this area of max reported intensity fairly well. For the purposes of Figure 5.2-1 and Table 5.2-1, Valentine, Texas, has been adopted for the location of the main earthquake and its aftershocks in agreement with the work of Sanford and Toppozada (1974).

The area over which an earthquake is perceptible can be used to estimate its magnitude (Slemmons et al., 1965; Wiegel, 1970), although this relationship is an empirical one different for different regions of the United States. If a felt area of 4.5×10^5 mi^2 is accepted (1.15×10^6 km^2) as reported by the U.S.C.G.S. (Neumann, 1932) and a magnitude-felt area formula for the central United States and Rocky Mountain region is used (Wiegel, 1970), a magnitude of about 6.4 is calculated for the Valentine, Texas, earthquake. This result appears reasonable and is compatible with the maximum intensity reported for the shock (Sanford and Toppozada, 1974). It is also in good agreement with the estimate of magnitude for this event calculated at Pasadena (Gutenberg and Richter, 1954).

Other earthquakes within 300 kilometers of the site were probably not perceptible or resulted in low intensities in the site area.

5.2.2 Instrumental Data--Regional

As mentioned above instrumental studies of earthquakes in New Mexico began in June 1960 when high-magnification seismographs were placed in operation on the campus of the New Mexico Institute of Mining and Technology at Socorro and by the Atomic Energy Commission at Sandia Base near Albuquerque (Sanford et al., 1972). Most of the early seismic research at Socorro was concentrated on near shocks (Sanford and Holmes, 1961, 1962; Sanford, 1963) because of this initial station distribution

and because information from other stations located in New Mexico and adjacent states was not available in sufficient quantity for a study of the seismicity of the entire state. This situation changed about the beginning of 1962 when stations at Albuquerque and Las Cruces, New Mexico; Payson, Arizona; and Ft. Sill, Oklahoma; began continuous operation.

Detailed reports on the instrumental seismicity of New Mexico as a whole have appeared in a number of publications, principally Sanford (1965), Sanford and Cash (1969), and Toppozada and Sanford (1972). Collectively, these papers cover the interval January 1, 1962, through June 30, 1971. The study of instrumental seismicity in this area, as in any other, evolved over this 11 year period. Not only did more data become available as more seismograph stations began operation, but these data were processed in increasingly sophisticated ways. The ways regional earthquakes have been located and analyzed during this period are summarized below. For a more complete discussion, the reader is referred to the original reports; both those mentioned above and Sanford et al. (1972), Sanford and Toppozada (1974), Sanford (1976a), Sanford (1976b), and Sanford et al. (1976b).

The method used to initially locate the earthquakes during the period January 1, 1962, through June 30, 1964 (Sanford, 1965) was based on the procedure described by Richter (1958). This is an arc intersection procedure where: 1) a trial origin time is estimated from measured S-P intervals, 2) a depth is selected, either 5 kilometers or 10 kilometers, 3) station-epicenter distance is calculated from the P-O (origin time) intervals and a T-D curve (in this instance a graph relating travel time to distance for each of the two depths of focus) and 4) the epicenter is determined from the intersection of the arcs whose radii have just been calculated in step 3) above. If no satisfactory intersection occurs, the process is repeated after adjustment of the origin time estimate. The time-distance curves used by Sanford (1965) in this process were based on a simple crustal model close to the average of those found for the region in previous studies (Tatel and Tuve, 1955; Stewart and Pakiser, 1962;

Romney et al., 1962). The crustal model adopted consisted of a single 39 kilometers thick layer with a P-wave velocity of 6.0 km/sec overlying a half-space with a P-wave velocity of 8.0 km/sec. The two T-D curves, one for a depth of focus of 5 kilometers and one for a 10 kilometers focal depth, were calculated using this model.

For earthquakes occurring between July 1, 1964, and December 31, 1967, a slightly different format was used to present the data (Sanford and Cash, 1969). Whenever available, origin times and epicentral coordinates were taken directly from U.S.C.G.S. reports. Two types of data distributed by the U.S.C.G.S. were consulted; the Monthly Summary series, or where these were not yet published, as for the period October 1966 through December 1967, the Preliminary Determination of Epicenters reports. A majority of the New Mexico earthquakes listed in this period were not located by the U.S.C.G.S., however. When this was the case, events were located precisely as outlined above for the earthquakes of January 1962 through June 1964.

Finally, for initial location of those shocks occurring from January 1968 to June 1971, inclusive, the procedure adopted was identical to that of the previous reporting period except that for those earthquakes located by the New Mexico Institute of Mining and Technology a focal depth of 8 kilometers was used to construct the T-D curves (Toppozada and Sanford, 1972).

The method of assigning magnitudes to the earthquakes of New Mexico has also undergone some evolution. From the start the idea has been to calculate a close analog to the Richter local magnitude (M_L). Magnitude can be expressed by the equation $M_L = \log A - \log A_o$, where A is the maximum trace amplitude (almost always the crustal shear wave, Sg, for local and regional New Mexico earthquakes, Sanford, personal communication, 1978) in millimeters on the seismogram and A_o is the corresponding trace amplitude for a calibration earthquake selected as the standard. The numbers obtained for M_L are dependent on the magnification and frequency response of the seismograph used, and on the

selection of the standard shock. The original Richter scale is based on the Wood-Anderson seismograph, an instrument which records horizontal motion, whose natural period is 0.8 second, and whose static magnification and damping are 2800 and 0.8 critical, respectively. Furthermore, the standard or zero magnitude event is defined such that it would produce a trace deflection of one thousandth of a millimeter when recorded by a Wood-Anderson seismograph at a distance of 100 kilometers.

The direct application of the Richter scale to New Mexico earthquakes was impossible, because none of the available data came from Wood-Anderson seismographs. As an initial best estimate, Sanford (1965) decided to rate the shocks on the basis of the amplitude a Wood-Anderson instrument would produce had it recorded these shocks; that is, maximum trace deflections were first converted to ground displacements, which in turn, were converted to equivalent Wood-Anderson trace amplitudes using the known response characteristics of this instrument. An attempt was made to consider response differences between the actual recording seismograph and the Wood-Anderson seismograph as a function of frequency. The Richter values for A_o were adopted with no attempt to consider possible source or wave transmission differences between those earthquakes occurring in California, where the Richter Scale was developed, and those occurring in New Mexico. Most of the magnitudes were calculated from the maximum SH (or horizontally polarized shear wave) ground motions reported by the station at Las Cruces. When no SH amplitude information was available from the Las Cruces station, magnitude was assigned on the basis of the maximum SV ground motion at Albuquerque. The relation between SV (or vertically polarized shear wave) motion at Albuquerque and magnitude was established from data on shocks detected by both the Las Cruces and Albuquerque stations (Sanford, 1965). This initial attempt to assign magnitudes to New Mexico earthquakes was never intended to be completely accurate but rather to serve as rough indications of the relative strengths of shocks.

Slightly different procedures were followed for magnitudes calculated for the two later reporting periods of July 1964 to December 1967 and January 1968 to June 1971. In these periods three magnitudes are listed: 1) U.S.C.G.S., 2) Albuquerque, and 3) Socorro. Magnitudes assigned by the U.S.C.G.S. (or its later administrative equivalents, such as the National Oceanic and Atmospheric Administration) are body wave magnitudes (m_b) based on the maximum amplitude of the initial P phase. Magnitudes calculated from Albuquerque and Socorro seismograms are based on the amplitudes of the S phases as noted above. For Albuquerque, the maximum SH ground motion was converted to an equivalent Wood-Anderson trace amplitude and the previous procedure was used to obtain an estimate of the equivalent Richter magnitude. A similar procedure was used for Socorro magnitudes, except that for these computations it was necessary to substitute maximum SV motion for maximum SH motion. Checks at the Socorro station indicate SH averages about 1.5 times as large as SV. This correction factor was included in the Socorro magnitudes computations.

Since the initial publication of the 1962-1972 instrumental data (Sanford, 1965; Sanford and Cash, 1969; Toppozada and Sanford, 1972) several additional studies have been undertaken to partially rework this data. Two of these, Sanford and Toppozada (1974) and Sanford et al. (1978), are of particular interest since they deal almost exclusively with earthquakes within 300 kilometers of the Los Medanos site. Sanford and Toppozada (1974) list a total of 34 earthquakes in this area. Of these, 12 appeared in the previously discussed studies, 13 represented new locations by the New Mexico Institute of Mining and Technology not previously published, and the remaining events were taken directly from U.S. Department of Commerce reports, either the Seismological Bulletin or Earthquake Data Reports. An updated version of this listing is presented in Sanford et al (1978). In this update four shocks have been added to the Sanford and Toppozada (1974) tabulation: February 11, 1964; March 3, 1964; October 20, 1964; July 26, 1972. The last of these is most noteworthy because of its proximity to the site. This event will be considered in greater detail in a later subsection. The October 20, 1964

earthquake is included here in conformity with Sanford et al (1978) even though this event apparently falls slightly beyond the 300 kilometers circle specified as the region of interest.

The most significant difference between the 1978 and all previous tabulations is in the magnitudes assigned to the individual earthquakes. The shocks listed in Sanford et al. (1978) have local magnitudes (M_L) substantially lower than those published earlier by the New Mexico Institute of Mining and Technology or the U.S.C.G.S. These revised magnitudes came about because in calculating local magnitudes for single earthquakes, it was noticed that a systematic increase in calculated magnitude occurred with increasing distance from the earthquake. This strongly suggested that more efficient transmission of the phase producing maximum trace amplitude was occurring in New Mexico than would be indicated by an uncritical use of the A_o standard earthquake amplitude attenuation factor of Richter (1958). Therefore, a correction factor for attenuation differences, as well as another correction factor for individual station effects, has been incorporated in the latest magnitude calculations.

Listed in Table 5.2-3 and shown in Figure 5.2-1 are the 38 earthquakes as they appear in Sanford et al. (1978). These data represent the latest and best estimate of all significant parameters associated with those earthquakes occurring within 300 kilometers of the Los Medanos site for the interval January 1, 1961, through December 31, 1972.

5.2.3 Specialized Instrumental Studies--Station CLN

With the publication of Sanford and Toppozada (1974), the first phase of the investigation of southeastern New Mexico seismicity ended. This early phase was concerned with the estimation of seismicity in the Los Medanos area based on careful evaluation of available geologic and seismic data. In early 1974 the emphasis changed. Since at that time no data were available from a station very near the site area itself, it was decided that acquisition of new instrumental data from such a station

would be of immediate value. With the installation of a high-gain seismograph in the site area, the question of the occurrence of low level seismic activity at or near the proposed waste repository could be more meaningfully addressed. Therefore, at the beginning of April, 1974, a single component (vertical) high-gain, continuously recording seismograph station (given the letter designation CLN by the U.S. Geological Survey) was installed in a shack located in a caliche pit very near the proposed nuclear waste disposal site. Analysis and interpretation of the data collected by this station may be found in Sanford et al (1976a), Caravella and Sanford (1977) and Sanford et al (1978). In this section the findings presented in these publications will be briefly discussed.

The essential elements of station CLN are a short-period, vertical seismometer (Earth Sciences Ranger SD 211), an amplifier (Astrodata 120), a film recorder (Earth Sciences RF 220), and a WWVB radio receiver (Specific Products--T60). The recording rate is 1 mm/sec, a speed that can produce high-resolution seismograms of small local and regional earthquakes. At this recording rate, the seismograph requires a film change every three weeks. Otherwise, the station is self-sufficient. Five minutes of the WWVB coded time signal is placed on the record every two hours to assure excellent time control. The ground displacement response of the seismograph has varied slightly over its operating lifetime as the free period and percent critical damping of the seismometer changed. These changes are summarized in Sanford et al. (1978). However, the magnification response of the system has remained essentially constant within the frequency range 4 to 30 Hz. The peak magnification is near 455 thousand times when a factor of 12 for record enlargement during photographic processing is included. This peak occurs near 22 Hz.

For most of the time since the station went into operation on April 5, 1974, the seismograph has performed as expected, except for the changes in response characteristics already mentioned. However, there were times when no records were obtained and when the station was without time signals. Table 5.2-4 lists these periods and the reasons for the breaks

in service. From April 5, 1974, to October 29, 1977, the total reporting period considered in this subsection, the station was in operation 83 percent of the time.

During the April 1974 to October 1977 period, 291 events identifiable as local and regional earthquakes (Sg - Pg $\leq$ 81 seconds, where Sg and Pg are the crustal shear-wave and compressional-wave arrival times) were recorded at station CLN. For a complete list of these events see Sanford et al. (1978, Table 3). For each earthquake the date, arrival time (GMT), and character, whether impulsive or of several phases, are given. The Sg phase amplitudes (from which magnitudes are determined) are also listed. With the aid of additional arrival times from other regional seismograph stations, epicenters for 75 of these 291 events were obtained. This group of 75 events may be further subdivided into those which are fairly well located (49) and those for which only tentative epicentral locations may be given (26). Table 5.2-5 lists the origin times, locations, and magnitudes (and seismograph stations used) for the seismic events whose epicenters are reasonably well known. A map of these epicenters is shown in Figure 5.2-3. Table 5.2-6 lists the remaining events for which there are insufficient data to allow exact locations. For many earthquakes in Table 5.2-6 two epicenters are possible because readings are presently available from only two stations. In this case, the epicenter is listed that is most compatible with the locations of the well-determined events.

Figure 5.2-4 shows histograms of the number of recorded earthquakes versus the Sg-Pg interval in seconds. The upper histogram represents the complete data set at station CLN for all those events whose Sg-Pg interval is less than or equal to 40 seconds. Major peaks in the histogram occur at Sg-Pg intervals of 8 to 13 seconds, 22 to 24 seconds, and 31 to 36 seconds. The middle histogram shows those events in the CLN data set which occurred during local day-time hours (12:00-02:00 GMT), and the bottom histogram those during the local nighttime hours (02:00-12:00 GMT). The similarity in shape of the middle and bottom histograms suggest that explosions from any small number of specific

sources have been largely eliminated from the data set. However, the disproportionate number of events during the day-time hours (7.62 X 10^{-3}/hour) compared to the nighttime hours (5.14 X 10^{-3}/hour) does not rule out the possibility that some cultural sources still exist in the data set.

Because a substantial fraction of the shocks within each of the prominent peaks of the histogram in Figure 5.2-4 are located, speculation on the epicenters for the other shocks is possible. All of the located shocks within the Sg-Pg distance range of 8 to 13 seconds have epicenters within the area from 31.7° to 32.3°N and from 102.8° to 103.2°W. These coordinates bracket a section of the Central Basin Platform centered roughly on the southeastern corner of New Mexico. All of the evidence suggests that all shocks with Sg-Pg times from 8 to 13 seconds are generated within this section of the Center Basin Platform.

Nearly all of the located shocks with Sg-Pg intervals between 22 and 24 seconds have epicenters within the area from 31.5° to 31.85°N and from 102.2° to 102.8°W. The region defined by these coordinates is centered on a section of the Central Basin Platform located about 50 kilometers southeast of the southeastern corner of New Mexico. Most unlocated shocks with Sg-Pg intervals from 22 to 24 seconds are believed to originate from this section of the Central Basin Platform.

The known epicenters for shocks with Sg-Pg intervals from 31 to 36 seconds indicate a number of tectonically active regions are contributing to this peak in the histogram. Notable among these is a region centered on Valentine, Texas, the site of a strong earthquake in 1931 (Sanford and Toppozada, 1974), and much of the Tularosa Basin.

5.2.4 Specialized Instrumental Studies--Central Basin Platform

The first earthquake to be located in the Central Basin Platform from instrumental data occurred on February 3, 1965. This event attracted little attention at first although it was recorded at a number of

regional stations (Socorro, New Mexico; Lubbock, Texas; Ft. Sill, Oklahoma; Vernal, Utah; Las Cruces, New Mexico; El Paso, Texas; and Albuquerque, New Mexico) and was located by the New Mexico Institute of Mining and Technology (Sanford and Cash, 1969). It was not, for example, listed in the Preliminary Determination of Epicenters reports of the U.S.C.G.S.

To learn more about the seismicity of the Central Basin Platform in conjunction with their study of southeastern New Mexico earthquake risk, Sanford and Toppozada (1974) examined the total available record from station FOTX, a Long Range Seismic Measurements (LRSM) station near Ft. Stockton, Texas, in operation from June 21, 1964 to April 12, 1965. Apparently, this is the only high-magnification station (350-400 thousand times at 1 Hz) to have operated for any substantial period within 120 kilometers of the Central Basin Platform before installation of station CLN in 1974. FOTX was in operation at the time of the February 3, 1965 earthquake on the Central Basin Platform. Based on this examination a number of earthquakes believed to have originated in the Central Basin Platform were found including two occurring before the February 3, 1965 event. Prior to examination of the FOTX records these two events on November 8 and 21, 1964 were unknown. All events located by Sanford and Toppozada in the Central Basin Platform during the operation of FOTX - and based primarily on readings from this station - are listed in Table 5.2-7.

The studies by Sanford and Toppozada (1974) suggested earthquake activity on the Central Basin Platform at a level higher than expected, but were not conclusive because of the very small amount of instrumental data available close to this area. About all that could be said at that time was that eight significant earthquakes (see Table 5.2-8) had occurred near the Central Basin Platform between November 1964 and September 1971 ranging in magnitude (new revised estimates as discussed in Section 5.2.2) from 2.5 M_L to 3.2 M_L; that one of these events, August 14, 1966, had an associated maximum intensity of VI on the Modified Mercalli scale; and that a number of smaller earthquakes had apparently occurred

at about the same location during the operating lifetime of station FOTX. The basis for this latter supposition was that all of the measured Sg-Pg intervals on the FOTX seismograms yielded an epicentral distance corresponding to the distance between the FOTX station and the area of activity on the Central Basin Platform. In addition, for some of the stronger shocks, arrival times were available from the Las Cruces station (LCN). The difference between P arrival times at LCN and FOTX was the same (34.7 plus or minus 0.5 sec) for the unlocated shocks as for the located events in November 1964 and February 1965. Thus, it is reasonably certain that the Central Basin Platform has been seismically active since mid-1964. Since the activity rate was roughly the same at the end as at the beginning of the 10-month period for which FOTX records were available, it can be supposed that earthquakes also occurred before mid-1964. If such activity had occurred, it probably would not have been detected on the regional seismograph stations then in existence.

The instrumental coverage of this part of the country has improved markedly in the past several years. The first important improvement took place in the spring of 1974 when station CLN was installed by personnel of the New Mexico Institute of Mining and Technology. Data recorded by this station between April 1974 and the end of October 1977 has already been discussed in detail in subsection 5.2.3. However, it should be mentioned that of the 49 earthquakes recorded during this period by CLN and enough other regional stations to allow accurate location (Sanford et al., 1978), 24 of them occurred within the active parts of the Central Basin Platform. Of the 26 less well located earthquakes of Table 5.2-6 and Figure 5.2-3, 13 of them are thought to belong to the Central Basin Platform area. Thus, for the period of operation of station CLN through October 1977 (which represents the last records so far analyzed from this station) nearly half of the events located within 300 kilometers of the Los Medanos site have occurred within the Central Basin Platform

The most recent advancement in the instrumental coverage of the Central Basin Platform area took place with the initiation of operation of the

Kermit, Texas, seismic array in November 1975. The remainder of this subsection is concerned with discussions of the operation and preliminary findings of this array.

Based on the seismicity information developed by Sanford and Toppozada (1974) the Central Basin Platform was instrumented with an array of seismograph stations encompassing the largest historical events discussed above. The purpose of this array is to study, in some detail, the seismicity of this region which is of interest both because it is important to the evaluation of seismic risk at the Los Medanos site and because secondary petroleum recovery projects have been active in this area for a period roughly coincident with its known seismic activity. It is hoped that ultimately such a study will answer questions fundamental to an evaluation of the implications of Central Basin Platform earthquakes to the tectonism, not only of the platform, but of surrounding regions. Evaluation of the Kermit, Texas, array data has not yet progressed to this point, but some preliminary discussion is possible at this time. The treatment below is largely abstracted from Hays (1977) and Rogers and Malkiel (1978).

The Kermit seismic network currently consists of 10 self-contained radio telemetry systems placed in a grid pattern covering 2200 square kilometers. Each field station is equipped with a single component vertical seismometer and accompanying amplifier-transmitter equipment. The seismometers are Mark Products L-4C's with a natural period of one second and 67 percent critical damping. Typical magnifications range from 25 to 50K near 1 Hz increasing 6dB/octave to 10 Hz. A receiver station is centrally located at the Winkler County Airport at distances from individual stations ranging from 12 to 40 kilometers. The current locations of the 10 array stations are shown in Figure 5.2-5 taken from Rogers and Malkiel (1978). Those stations designated by a three symbol code followed by an "A" represent second locations for these instruments. The moves were usually made to diminish background noise levels or improve foundation conditions. The initial location of these stations may be found in Hays (1977). In general, the effect of unfavorable surface

geology and high cultural noise in this area has posed problems that have resulted in less than optimum station gain for a micro-earthquake study (Rogers and Malkiel, 1978).

Once the signals are placed on the phone lines, recording and timing take place at the National Earthquake Information Center (NEIC) in Golden, Colorado. Signals from the individual stations are put on film (in a 20 channel Develocorder microfilm recorder) and the highest quality station (KT7, see Figure 5.2-5) is simultaneously recorded on a Helicorder visible recorder to provide rapid identification of events of interest. Film recording speed is 3 cm/min and optical enlargement of 20 times permits resolution of plus or minus 0.01 seconds for impulsive arrivals. Direct recording of station WWV also insures correct absolute timing.

The average level of detection within the array is given as magnitude M_{LD}=2.0, where M_{LD} is a magnitude determined from the coda length as discussed in Lee and Lahr (1972). This represents a relatively low array sensitivity due to the surface geology and unfavorable operating environment as previously mentioned. Detection threshold for individual stations varies from a high of M_{LD} = 2.5 in oil fields with sandy surface conditions to a low of M_{LD} = 0.5 along the west edge of the array where low levels of pumping, and caliche "bedrock", allow higher gains to be used. In the discussion below, M_L will be used for M_{LD} wherever the Rogers and Malkiel (1978) data are referenced.

During the current reporting period (November 1975 through July 1977) 407 events have been detected of which 135 have been well enough recorded to be located. These earthquake locations were determined using the hypocenter location program HYPO71 (Lee and Lahr, 1972) and a four layer over a half-space crustal model developed by Stewart and Pakiser (1962) for eastern New Mexico.

Of the 135 located events, 56 occurred within the area of the array. these earthquakes are shown in Figure 5.2-6 and listed in Table 5.2-9. Of these 56 earthquakes, 22 have been located using the readings from only

three stations. This is inadequate to allow hypocentral depth to behave as an unknown in the formal location algorithm so that for all these events an assigned depth of 5 kilometers is used (denoted 5.00* in Table 5.2-9). For an additional 14 events, locations have been accomplished using only four stations. In this case the hypocenter may be fixed deterministically but no redundancy in possible locations exists to allow some estimate of the uncertainty in the formal location. Thus, of the 56 internal, and presumably best located, earthquakes of Table 5.2-9 only 20 are available with an estimate of both depth and hypocentral uncertainty, at least in a formal sense.

An interesting independent estimate of the accuracy with which events have been recently characterized in the Central Basin Platform is provided by a comparison of earthquakes common to both Tables 5.2-9 and 5.2-5. There are only four such events. The majority of those earthquakes appearing in both the Sanford et al. (1978) and Rogers and Malkiel (1978) "well located" data sets are somewhat peripheral to the Kermit array as will be seen below. The location and origin time agreement is very good; differences averaging 0.04 degree and 0.6 seconds respectively. Such modest differences can probably be easily explained by minor model differences and, in the case of the Sanford et al. (1978) data set, focal depth assumptions. However, estimates of local magnitude, M_L, differ significantly. The four events under consideration average over 0.9 magnitude units higher in the Rogers and Malkiel data set than that of Sanford et al. This point is worth keeping in mind.

Table 5.2-10 lists those earthquakes occurring on the periphery of the Kermit array with locations that use readings from at least five array stations. This does not necessarily imply that these events are well located. In fact, many are given a low location quality factor by Rogers and Malkiel (1978). Indeed, these authors do not plot the formal hypocentral positions for earthquakes occurring outside the boundaries of the array but instead outline zones in which these events apparently lie. These zones are meant only to be indicative of the general area where earthquakes appear to be occurring. Both the zone boundaries and formal locations are shown in Figure 5.2-6.

The events listed in Table 5.2-10 may be compared with those in Table 5.2-5 in a manner similar to that discussed above in connection with Table 5.2-9. Of the 51 earthquakes around the periphery of the Kermit, Texas, array as determined by array station readings, 15 also appear in Table 5.2-5. The average origin time difference is greater in this case, being 1.9 sec., and a larger epicenter location difference of 0.1 degree is also present. Again, the most interesting differences are in local magnitude, M_L. As before, the Kermit array data set shows magnitudes consistently higher (in this case 0.84 units higher) than the New Mexico Institute of Mining and Technology values as they appear in Sanford et al. (1978).

Solely to present consistent-looking plots, events listed in Tables 5.2-9 and 5.2-10 and shown in Figure 5.2-6 have been scaled to circumvent this magnitude disparity. That is, the symbol used for a particular earthquake epicenter of magnitude M_L in Figure 5.2-6 is the same as would have been used for a magnitude M_L-0.85 in previous epicenter plots.

All available data through mid-1977 for the Central Basin Platform have now been considered. It is clear that continuing effort in this area will improve the understanding of this seismicity. Before outlining the speculations that have been made based on information to date, it seems appropriate here to briefly summarize this seismicity in very general terms.

There is little doubt that the Central Basin Platform has been seismically active since at least mid-1964. Its activity before this time will likely remain speculative. There is no evidence of historical felt reports for events felt in this area similar to the epicentral intensity = VI earthquake of August 14, 1966, even though local histories and newspapers have now been searched specifically for any such reference (Sanford and Toppozada, 1974). Conclusions as to the lack of previous seismic activity on this basis, however, must be tempered somewhat by the knowledge that this part of western Texas has never had a large population.

Since the first instrumental detection of events in the Central Basin Platform region, the number of recorded earthquakes has been largely a function of the number and sophistication of the seismograph stations available to record them. With the startups of station CLN in 1974, and, more important, with the Kermit array, large numbers of small earthquakes are now being noted that previously would have completely escaped notice. It is now clear that, at least for the last several years and probably for the last decade, the Central Basin Platform has been the most seismically active area within 300 kilometers of the Los Medanos site in terms of number of events.

It is worthwhile here to put the Central Basin Platform activity into perspective. Even though some events near magnitude 0 are recorded (Rogers and Malkiel, 1978), fewer than ten detected events are reported for many months during the operation of the Kermit array. This rate is relatively low compared with the activity rates of some of the more active areas in the eastern U.S. such as Blue Mt. Lake, New York (Sbar et al., 1972), or southeastern Missouri (Stauder et al., 1976). The largest known earthquake to occur in the Central Basin Platform had, by the most recent estimate, a magnitude of less than 3-1/4. It is very difficult to believe that any event very much larger than this (say $M_L \geq 5$) could have escaped instrumental notice during the past 50 years or so. The Valentine, Texas, earthquake of 1931, to the south, for example, had an epicentral intensity of VIII on the Modified Mercalli Scale and was recorded worldwide (Byerly, 1934). The magnitude of this event has been estimated to be 6.4 based on the felt area (Sanford and Toppozada, 1974). The I_o=VI event of August 1966, where I_o is epicentral intensity, has recently been assigned a magnitude somewhat less than 3. In short, the Central Basin Platform has exhibited some activity since mid-1964, but this activity has been of small magnitude. There is no evidence to suggest that moderate or large magnitude events occurred before mid-1964. Within limits imposed by general regional and worldwide seismographic capabilities, there is no evidence to allow a determination of the small magnitude earthquake activity in this area before 1964.

In the remaining discussion, the causes and implications of the Central Basin Platform seismicity, as best these have been determined, are considered. This discussion is speculative since the definitive evidence critical to a unique view of either the causes or implications of these earthquakes does not yet exist. Figure 5.2-6 shows the 107 earthquakes of Tables 5.2-9 and 5.2-10, as well as the approximate boundaries of the Central Basin Platform and a series of pre-Permian faults inferred from drilling. These faults, which are all deeply buried, are taken from 1:9600 scale maps provided by Geomap Corporation to Rogers and Malkiel (1978). From a comparison of fault and epicenter locations it is clearly not possible to associate the earthquakes with known faulting although an alignment of epicenters in the southwest corner of the array appears to occur on a short fault segment. Other events or groups of events appear equally likely to occur in the vicinity of faults as not. In a very general sense, however, it appears that both the eastern and western boundaries are active (Rogers and Malkiel, 1978). The basic conclusion from all instrumental data is that seismic activity is equally likely to occur anywhere along the Central Basin Platform structure as asserted by Sanford et al. (1978) without particular regard to small scale structural details such as individual pre-Permian faults.

Attempts have also been made to relate Central Basin Platform seismicity to secondary oil recovery operations in the area. Both the spatial and temporal association of Central Basin Platform seismicity with secondary recovery projects at oilfields in the area are very suggestive of some cause and effect relationship.

Shurbet (1969) was the first to suggest that seismic activity on the Central Basin Platform is related to water injection for secondary recovery of oil. His suggestion was based on the clearly established association between earthquakes and waste injection into crystalline bedrock at the Rocky Mountain Arsenal near Denver (Healy et al., 1968). Subsequently, a direct association between earthquakes and fluid injection for secondary recovery of oil was established at the Rangely field in northwestern Colorado (Healy et al., 1972). As the fluid pressure builds

up during injection, the effective stress across pre-existing fractures diminishes with an associated decrease in frictional resistance to sliding.

There appears to be a correlation between the number of active waterflood projects and the first known occurrence of earthquakes in 1964. Although waterflood projects began in this area as early as 1944, the number of projects began to increase considerably in the mid-1960's and, on the average, injection pressures have also increased with time (Rogers and Malkiel, 1978). A study of the number of active secondary recovery projects versus time in this area shows a rapid increase in the early 1960's, a peak in 1968, and relative constancy since that time. The increase in secondary recovery activity occurs prior to, but in rough conjunction with, the first occurrence of earthquakes in the area. During the period of operation of the Kermit array, the largest earthquakes recorded have occurred in the vicinity of the Keystone unitized oil field. The Dollarhide unitized field, although outside the boundaries of the array, appears to be one of the most seismically active areas. Other areas of seismic activity occur, however, that are not within the major oil field boundaries, and major secondary recovery fields exist that apparently are not seismically active. Although the evidence is not conclusive, based on this seismicity pattern and the absence of recent geologic faulting within the Central Basin Platform it is believed that the best working hypothesis at this time is that earthquakes are associated with the release of low level residual stress by secondary recovery operations. It is neither proved nor precluded by a consideration of current best estimates of regional stress regime (Hays, 1977) as discussed in a later subsection.

5.2.5 The Events of July 26, 1972 and November 28, 1974

Questions on the tectonism and seismic activity very near or at the site are of great interest. For this reason the single most important seismic event to occur since installation of station CLN at the Los Medanos site has been the earthquake at 03:35:20 GMT on November 28, 1974 (see Table 5.2-5 and Figure 5.2-3). This earthquake, whose most recently estimated

magnitude is 3.6 (Sanford et al., 1978), had an epicenter about 40 kilometers northwest of station CLN. If it is an indication of normal background seismicity in the immediate site area, this event might cause a reevaluation of previous estimates of seismic risk at the Los Medanos site by Sanford and Toppozada (1974) who considered the likely principal sources of site vibratory ground motion to be a major earthquake to the west, no closer than approximately 115 kilometers, and a moderate earthquake in the Central Basin Platform. Because of its potential importance, this event has attracted considerable notice. It was prominently mentioned in two studies (Sanford et al., 1976a; Sanford et al., 1978) and was the main topic of another (Caravella and Sanford, 1977).

As may be seen from Table 5.2-5 the event of November 28, 1974 has been located by the New Mexico Institute of Mining and Technology at about 32.6°N, 104.1°W by using phase readings from six stations. An independent location by the U.S. Geological Survey places this earthquake at 32.3°N, 104.1°W. Both solutions give a virtually identical origin time. At the time of this earthquake, a rockfall and considerable ground cracking were reported at the National Potash Co. Eddy County Mine. The location of this rockfall was 32.55°N, 104.04°W and it occurred within about one minute of the calculated earthquake origin time. In view of this rather remarkable coincidence the question naturally arose as to the cause and effect relationship of the rockfall to the recorded seismic event. The issue was whether the source of this event could be related to a non-tectonic cause such as mine collapse at the Eddy County Mine or if it should be considered a more normal release of accumulated strain energy. Clearly the epicentral uncertainty grossly implied by the two different formal solutions found by the New Mexico Insitute of Mining and Technology and the U.S. Geological Survey allowed actual spatial coincidence of rockfall and seismic disturbance. Therefore it was decided that a more careful location effort would be worthwhile.

As information was being collected for this redetermination effort, it was discovered that a previous rockfall had occurred at the National Potash Co. Eddy County Mine on July 26, 1972. A check of past seismograph

records revealed that a seismic event had been recorded at a number of regional seismograph stations, too. A subsequent location using these readings put this event at 32.6°N, 104.1°W and assigned a magnitude of M_L=2.8 (see Table 5.2-3). Thus this event, although weaker, was found to be located very near the November 28, 1974 event, and study of the individual station records indicated that its coda was of nearly identical character to the later event. Since more records were available for the earlier event, it was decided that a detailed relocation effort would be attempted for it first. The question of the nature of its source was still of primary concern.

The relocation method is described thoroughly in Caravella and Sanford (1977) and will only be outlined here. The origin time was picked by extrapolation to the S-P interval equal zero intercept of a straight line fit of S-P versus P data. Such a procedure, using data from all six stations recording the July 26, 1972 event (LUB, SNM, ALQ, JCT, TUC, and GOL) yielded an origin time of 04:35:40.4; $\pm$ about 3.3 seconds at the 95 percent confidence level. A similar linear regression using only the first five S-P intervals yielded an origin time of 04:35:43.9 $\pm$ about 2.8 seconds at the same confidence level. Ultimately, the five interval origin time was selected because a better location was obtained with it.

To develop a velocity model to use in the relocation effort the following procedure was adopted: seismic wave arrival times from the underground nuclear explosion GNOME were noted. This explosion, which was detonated at 19:00:00 GMT on December 10, 1961, at 32.264°N, 103.866°W (located about 35 km south of the National Potash Co. Eddy County Mine) was recorded by many of the stations noted above (see Romney et al., 1962). From these arrival times, crustal and subcrustal velocities were developed over the ray paths from GNOME to each individual station. In essence, each station was modeled as being underlain by two layers over a half space. The velocity and thickness of the upper layer were assumed known from independent sources (Reddy, 1966; Romney et al., 1962; Wilson et al., 1969; Major, 1975; Shurbet, 1975; Toppozada and Sanford, 1976) and the velocity (and implied critical incidence angles) of the lower (and main)

crustal layer was then found by an iterative technique for each station independently. Subcrustal velocities could then be similarly found. Corrected crustal velocities (layer two) determined in this way ranged from 6.31 km/sec to 6.02 km/sec. Thus lateral inhomogeneity is built into the model.

Using the station-dependent model and the preferred origin time, 95 percent confidence interval arcs were drawn from each station. The results are shown in Figure 5.2-7. As can be seen, the intersecting arcs so constructed define a rather large area of approximately 1900 km^2. Although the Eddy County Mine lies very near this area, other locations within the same area have the same formal likelihood of being the epicentral location.

The November 28, 1974, seismic event was not relocated in the same way. Instead, another fundamental question was asked. That is, could the two events, July 1972 and November 1974, have occurred at the same focus based on existing seismographic evidence. The test applied is that if the events had the same hypocenter, the differences in arrival times of specific phases at common stations should be the same for all stations. As may be seen from Table 5.2-11 this is not the case for the limited data set available.

The difference between the smallest and largest time difference is 1.4 sec. Caravella and Sanford (1977) believe this is too large to be explained by reading errors. The time differences indicate, under this conclusion, that the two events did not have the same hypocenter, even though location uncertainties are such that either of them might, by itself, have occurred at the rockfall site. The time differences can be explained by locating the hypocenter of the November 28, 1974 event about 10 kilometers northwest or southwest of the July 26, 1972 shock (Caravella and Sanford, 1977). At this time, then, best available analysis indicates that both of these small events did not occur at the Eddy County Mine and cannot both be caused by some nontectonic source at that location. In the seismic risk analysis of the next section, therefore, some background earthquake activity in the immediate site area is considered.

5.3 SEISMIC RISK ANALYSIS

In this section, a broad characterization of the site region's seismicity is developed in a way useful for making conservative earthquake-resistant design decisions. This risk analysis is intended to be applicable only to vibratory ground motion resistant design of surface facilities on good foundations. Generalization of the results of this analysis to less idealized conditions, such as design of subsurface facilities for shaking during an earthquake or allowance for poor surface foundation conditions (should they be encountered), may be accomplished at a later time without altering the import of the original analysis. However, it must be emphasized that in this section the risk formally presented is intended to be a meaningful and conservative estimate of proper design values for short-term features of the facility. "Short-term" as used here means time periods on the order of decades. Specifically, it is not believed that any results presented here can be simply extrapolated to periods of tens or hundreds of thousands of years even though formal extrapolations of this kind are possible. This is not a severe handicap in this case. Although the lifetime of the repository will be longer than the limits of applicablility of this risk analysis, the length of time for which vibratory ground motion will be of concern is much shorter (during surface facilities use) and, in fact, falls well within the intent of this analysis.

There are a number of ways to characterize site seismicity in a way useful for rational design against the effects of earthquake associated ground shaking. One measure of the proper design value is the maximum historical site intensity which can be estimated from the historical earthquake record and some intensity attenuation law, whether this law is explicitly or only implicitly considered. As noted in the previous section, the maximum historical intensity at the Los Medanos site is estimated to be less than or equal to V on the Modified Mercalli Intensity Scale (Wood and Neumann, 1931). This characterization of earthquake design motion has the great advantage of being simple and straightforward. It is not, however, generally used for important structures or facilities because it does not

provide a basis for estimating whether future events will result in site intensities exceeding the maximum historical site intensity. This is a serious drawback for areas with a relatively short historic record such as the United States, and especially its western half.

To construct seismic design values for a particular site that go beyond a simple interpretation of a maximum historical measure of ground motion, something more than historical seismicity must be considered. Therefore, the geology of a region is often used in several ways to supplement historic earthquake data. There are several studies that attempt to present a seismic zonation of the United States using both seismic and geologic arguments. The stated intent of one of these (Richter, 1959) is to present a seismic regionalization showing the maximum reasonably expectable intensity during future earthquakes on ground of prevailing character. The Los Medanos site is in a region of intensity VIII according to this study. Algermissen 1969) has developed a Seismic Risk Map that has been closely associated with editions of the Uniform Building Code since 1970 (Uniform Building Code, 1970, 1973, and 1976) and by this association is most directly applicable to an estimate of proper design of structures with lifetimes measured in decades. The Los Medanos site intensity is shown to be V and/or VI in this zonation. Both these seismic risk maps, which were considered for the site region by Sanford and Toppozada (1974), are based on essentially the same data. The differences are due to varying interpretations and intent. That the interpretations are not really very far apart is indicated by a statement by Richter (1959) that an individual structure intended for a lifetime of the order of 30 years might within that life be exposed to shaking of no more than one scale degree below that mapped. Thus, over several decades, the Los Medanos site might reasonably be subjected to shaking at around the V to VII intensity level according to both Richter and Algermissen.

Although based on both historical seismicity and large scale geologic features, the seismic regionalization maps of Richter and Algermissen do not explicitly consider frequency of occurrence of damaging earthquakes. More fundamentally, the subjective decisions implicit in any

characterization of future earthquake ground motion are largely concealed and not subject to scrutiny. Any shifts of emphasis or new geologic or seismic information are, therefore, very difficult to incorporate into such zonations. In recent years, several procedures have been developed that allow formal determination of earthquake design parameters to be made (Cornell, 1968; Cornell and Vanmarke, 1969), and a number of studies incorporating these procedures have been performed (e.g., Cornell and Merz, 1975: Shah et al., 1975; Algermissen and Perkins, 1976). In typical seismic hazard analyses of this kind, the definition of seismicity is made by using geologic and tectonic data as well as observed earthquake locations. The region of study is divided into seismic sources within which future events are considered equally likely to occur at any location. For each seismic source area the rate of occurrence of events above a chosen threshold level is estimated, using the observed frequency of historical events. The sizes of successive events in each source are assumed to be independent and exponentially distributed; the slope of the log-number versus frequency relationship is estimated from the relative frequency of different sizes of events observed in the historical data. This slope, often termed the b value (Richter, 1958), is determined either for each seismic source individually or for all sources in the region jointly. Finally, the maximum possible size of events for each source is determined, using judgment and the historical record (McGuire, 1977).

It is clear from this description that all assumptions, no matter what the level of subjectivity employed in making them, must be made explicit. In addition, this method of determining site-specific earthquake risk may be used for a wide range of geologic and seismic assumptions. In this section, the method of Cornell (1968) will be applied to the question of risk as a function of ground shaking at some prescribed level at the Los Medanos site. Input parameters at each stage of the development will be taken from current best information available in the literature. These input parameters are discussed below in some detail following a general discussion of the mechanics of the Cornell method itself. Finally, several curves showing probablility of maximum ground surface acceleration versus acceleration level, will be presented and discussed for several

different assumptions about the individual source area capabilities. The conclusions that may be drawn from these curves will be considered. It is believed that the data, treated in this way, may be used to arrive at a general preliminary statement of risk from vibratory ground motion that is applicable at the site during its active phase of development and use.

5.3.1 The Method of Cornell

Cornell (1968) developed a method to produce relationships between ground motion parameters, such as peak ground displacement or maximum ground acceleration, and their average return period. The data used include best estimates of average activity levels for various potential sources of earthquakes. Arbitrary geographical relationships are allowed between these potential sources and the site. Cornell provides a technique for integrating the individual influences of these sources into the probability distribution of the ground motion parameter and the average return period then follows directly. The potential sources are modeled geometrically in such a way as to permit a solution of closed analytical form.

In this Section, a calculation is made of the probability that a random peak ground acceleration "A" will exceed a given value "a" once an event of magnitude greater than some threshold level has occurred. Before the method can be used, a geometric model or characterization of the potential earthquake sources must be made. Cornell develops the necessary formulation for point, line, and annular area sources. The geological structure and seismic history of the Los Medanos site do not imply that linear or point source models are appropriate, so use of the technique begins with an approximation of the source regions (Algermissen and Perkins, 1976) by annular segments (see Fig. 5.3-5). As discussed in the next subsection, the annular segments are in all cases believed conservative approximations of the source regions.

Let acceleration be related to Richter magnitude M and hypocentral distance R (in kilometers) by the equation:

$$a = b_1 \exp(b_2 M) R^{-b_3}$$

where a is in units of cm/sec^2 and the values of the constants (b_1, b_2, b_3) are discussed in a later subsection. Then if M and R are assumed to be probabilistically independent within the source areas, the probability of an acceleration A exceeding a given value a can be expressed as:

$$P\left[A \geq a\right] = 1 - F_M(m) = P\left[M \leq (\ln a + b_3 \ln R - \ln b_1)/b_2\right]$$

where F(m) is a distribution function of earthquake magnitudes, which can be calculated using a recurrence relation of the form (Gutenberg and Richter, 1942):

$$\log N = \underline{a} - \underline{b}M$$

where $\underline{a}$ and $\underline{b}$ are constants.

To find the proportion of events having magnitudes in the range $m_o < M < m$ the number of such events ($N_{m_o} - N_m$) is divided by the total total number of events with magnitude greater than m_o

$$F_M(m) = (N_{m_o} - N_m)/N_{m_o} = 1 - \exp\left[-B(m - m_o)\right]$$

where $m_o < m \infty$ and B is used to denote the constant b ln10. However, it is desirable to impose an upper limit on the magnitude of an event that may occur in a given source area, i.e., to specify that $m_o \leq m \leq m_1$. Our cumulative distribution function must now satisfy the boundary condition $F_M(m \geq m_1) = 1$ so:

$$F_M(m) = C\left[1 - \exp\left[-B(m - m_o)\right]\right]$$

where C is a constant such that

$$C = 1/\left[1 - \exp\left[-B(m_1 - m_o)\right]\right] \equiv 1/(1 - k_{m_1})$$

In this case, the probability expression may be rewritten as

$$P\left[A \geq a\right] = 1 - F_M(m) = \left[-k_{m_1} = \exp\left[-B(m - m_o)\right]\right]/(1 - k_{m_1})$$

where $k_{m_1} = \exp\left[-B(m_1 - m_o)\right]$. For values of m less than m_o, $\left[P\ A \geq a\right] = 1$ while for values of $m > m_1$, $P\left[A \geq a\right] = 0$.

Aside from the limits on the range of r due to the inner and outer radii of the annular segment, it is important to note that the condition m_o m m_1 also places limits on the range over which the above probability is valid. Specifically, the condition on m implies, for a given acceleration value a, that:

$$\left[\exp(b_2 m_o/b_3)\right](b_1/a)^{1/b_3} \leq r \leq \left[\exp(b_2 m_1/b_3)\right](b_1/a)^{1/b_3}$$

The lower boundary value of r may be thought of as the distance from the site within which any event of magnitude m or greater will result in an acceleration of a or greater. In other words, the probability is unity that for values of r less than the cutoff value a random acceleration A will exceed the chosen a. The upper boundary is the maximum radius from the site at which an event of magnitude m could have a nonzero probability of causing an acceleration a, given an attenuation law of the proper form. A schematic representation of these limits on r, for a given a, over which the above probability is valid is shown in Figure 5.3-1 (top).

In order to find the cumulative distribution $F_M(m)$ for all possible values of the focal distance and their relative likelihoods, integration over the annular area under consideration is performed:

$$P[A \geq a]_{\text{annular area}} = \frac{1}{2\pi} \int_0^{2\pi} \int_d^{r_o} P[A \geq a] \cdot f_{R,\Theta}(r,\theta)\, dr d\theta$$

where $f_{R,\Theta}(r,\Theta)$ is the probability density function of R, Θ the coordinates of a random focal position within the annulus (see Fig. 5.3-1bottom). Assuming that $f_{R,\Theta}(r,\Theta)$ is independent of Θ, the probability of the source falling within the annular area bounded by X (Fig. 5.1-1bottom) is just the ratio of this area to the total area or

$$F_{R,\Theta}(r,\theta) = \pi(X^2 - \Delta^2)/\pi(\ell^2 - \Delta^2) = (r^2 - h^2 - \Delta^2)/(\ell^2 - \Delta^2)$$

so then

$$f_{R,\Theta}(r,\theta) = \frac{d}{dr} F_{R,\Theta} = 2r/(\ell^2 - \Delta^2)$$

Substituting the expression for $f_{R,\Theta}(r,\Theta)$ into the probability equation and integrating, an expression is found of the form:

$$P[A \geq a]_{ann.} = \frac{2}{\ell^2 - \Delta^2}(1 - k_{m_1})^{-1}[Da^{-B/b_2}\left(\frac{1}{(\gamma-1)d^{\gamma-1}}\left[1 - \left(\frac{r_0}{d}\right)^{-(\gamma-1)}\right]\right) - \frac{k_{m_1}}{2}(r_0^2 - d^2)]$$

where

$$D = b_1^{B/b_2}\exp(Bm_o) \quad : \gamma = Bb_3/b_2) - 1$$

The question of the random number of occurrences in any time period is next considered. It is assumed that for the magnitudes of interest the occurrence of any event is Poissonian, that earthquakes have equal likelihood of occurring anywhere within the source area considered, and that the average occurrence rate, ν per year, is constant in time. The above three assumptions, particularly that of Poissonian distribution of events, are fundamental.

It may then be shown that the probability that $A_{max}(t)$, the maximum value attained by A over a time of t years, will be less than or equal to a is:

$$P\left[A_{max}(t) \leq a\right] = \exp(-p\nu t)$$

where p is the annular area probability, $\left[P\ A \geq a\right]_{ann.}$, calculated above and is the average occurrence rate..

The risk or annual probability that A_{max} will exceed a is

$$1 - P\left[A_{max}(t=1) \leq a\right] = 1 - \exp(-p\nu)$$

Sources near the Los Medanos site will be modelled by angular segments of an annulus. In this case, a simple modification of p in the above exponential is required but the method is otherwise the same.

The average return period, T, of an acceleration equal to or greater than a is defined as the reciprocal of $P\left[A_{max} \geq a\right]$, that is:

$$T(\text{years}) = 1/P\left[A_{max} \geq a\right]$$

Tables of values of annual risk (and average return period) versus values of a can be constructed for each source area near and surrounding the site. The risk at the site arising from all such sources may then be found by combining the results above in the following way: Consider source areas A, B, and C to be independent in a statistical sense. Then, where $P^{ABC}\left[A_{max} \leq a\right]$ is the familiar probability that the maximum value of A, the peak ground acceleration arising from composite source area ABC, is less than a at the site, is

$$P^{ABC}\left[A_{max} \leq a\right] = P^{A}\left[A_{max} \leq a\right] \bullet P^{B}\left[A_{max} \leq a\right] \bullet P^{C}\left[A_{max} \leq a\right]$$

If it is assumed that all the sources are modeled by annular segments (i.e., not a combination of annular and line sources), then the composite probability of exceeding a in terms of the probability results for the individual areas can be written as

$$P^{ABC}\left[A_{max} \geq a\right] = 1 - P^{ABC}\left[A_{max} \leq a\right]$$

or:

$$P^{ABC}[A_{max} \geq a] = 1 - [(1 - P^{A}[A_{max} \geq a]) \cdot (1 - P^{B}[A_{max} \geq a]) \cdot (1 - P[A_{max} \geq a])]$$

This equation is the desired formula for combining the previous probability results into a composite curve for "risk" which takes into account influences of all the various source areas near the site.

Thus, given certain input parameters, and estimates of average activity rates for potential sources of earthquakes, Cornell's method offers the means by which to make a quantitative estimate of the seismic risk at a site. Subject to certain fundamental assumptions stated above, the results can be expressed in a form that is easily applied and interpreted.

In the next subsection, the values used for input parameters such as constants of attenuation, and average seismic activity rates for individual source areas, will be discussed. The choice of annular segments approximating the source areas surrounding the site will also be discussed in some detail.

5.3.2 Input Parameters

The first input parameters that must be considered are those having to do with acceleration attenuation as a function of earthquake magnitude and epicentral distance. An unmodified use of Cornell's (1968) hazard analysis method requires, as seen above, a law of the form

$$a = b_1 \exp(b_2 M) R^{-b_3}$$

where a is acceleration in cm/sec^2, M is earthquake magnitude, and R is distance in kilometers. A number of relationships of the above form exist in the literature (Esteva and Rosenblueth, 1964; Seed, et al., 1968; Orphal and Lahoud, 1974). In all these studies, however, the constants b_1, b_2, and b_3 are found for data collected exclusively, or almost exclusively in the western part of the United States and are

therefore applicable there. Recently, several reasons have emerged, both theoretical and empirical, that indicate fundamental differences in acceleration attenuation in the central part of the U.S. For example, it has been demonstrated that the attenuation of body waves (Evernden, 1967) and surface waves (Mitchell, 1973; Nuttli, 1973a) is appreciably lower east of the Rocky Mountains than west. This serves to explain the much larger areas of perceptibility and of damage for central United States earthquakes than for west coast earthquakes of the same magnitude. It is also the source of the reluctance here to use previously published attenuation constants uncritically for this study. With particular reference to attenuation of acceleration, Nuttli (1973b) found that in the central United States the acceleration values of greatest engineering significance may be related to the vector resultants of the vertical and horizontal components of the sustained maximum surface-wave motion rather than to isolated peaks. This is true for ground motion at some distance from the source and for a wide range of magnitudes. The amplitude and shape of the attenuation curve for surface waves (Lg) in the frequency range of interest is known (Nuttli, 1973b) so that the accelerations associated with the Sg/Lg part of the earthquake ground motion coda may be plotted as a function of frequency and epicentral distance (see Nuttli, 1973c, Figure 8) for an event of a given magnitude.

The site area is very close to the western margin of the region of interest in Nuttli's studies so that it is not immediately clear that central United States attenuation laws are more pertinent than their western counterparts. It is believed, however, that there are several reasons for adopting a central United States formula. First, the site geology seems appropriate. The site is near the western boundary of the High Plains physiographic province (Sanford et al., 1976b) which extends eastward well into that part of the continental United States considered the "central U.S." by Nuttli (1973c). Second, there are features of the time histories recorded in the site region that are suggestive of kinship with central United States records. For example, the maximum record motions are almost always in the Sg part of the coda (Sanford, personal communication, 1978) in analogy to central United States Sg/Lg motion.

This feature has the interesting implication that magnitude scales are most naturally developed for this wave in the site region. Third, as mentioned in subsection 5.2.2, recent revision in the method of magnitude determination of events in the source region by stations in this region has been made necessary by the realization that peak record amplitudes have not attenuated with distance as quickly as implied by the uncritical use of Richter's (1958) standard earthquake ground amplitude values. Finally, the observation made by Sanford and Toppozada (1974) that the Valentine, Texas isoseismals apparently encompass more area to the east than to the west of the source is an indication on a very graphic level that attenuation is less in that direction. All these observations, although not rigorously indicative, are at least suggestive of acceleration attenuation in the site region similar to that found appropriate for the central region of the country. For these reasons, it was decided to use such a law for this seismic hazard analysis.

Algermissen and Perkins (1976) found that east of 105°W longitude the Schnabel and Seed (1973) curve developed from western United States data was consistent at about the magnitude 7.6 level with the similarly defined acceleration attenuation curve suggested by Nuttli (1973c) for the central United States out to distances of about 50 kilometers. Beyond this distance, the Nuttli curve attenuates at a slower rate (see Algermissen and Perkins, 1976, Figure 3). Curves applicable to other magnitudes are drawn by Algermissen and Perkins (1976) tangent to the Schnabel and Seed curves, but taking the same general shape as the Nuttli curve. These curves are shown in Figure 5.3-2 for magnitudes of 4.2, 5.2, 5.6, 6.6, 7.6, and 8.5. It is clear that these curves will not fit a single attenuation law of the form desired for simple application of Cornell's (1968) method as discussed in the previous subsection. Such a form requires not only a constant slope for all distances but a constant line spacing for equal magnitude intervals. Neither of these requirements is met by the acceleration attenuation curves taken from Algermissen and Perkins. The task then is to find proper coefficients for a Cornell type attenuation law such that the predicted acceleration so derived for a given magnitude and distance will be conservative

relative to the plotted values taken from Algermissen and Perkins. After some experimentation, the coefficients b_1=17, b_2=0.92, b_3=1.0 were selected (Bickers, 1978). Curves using these values are also shown in Figure 5.3-2 for the same suite of magnitudes. As can be seen from this figure, the model equation with the above constants yields higher accelerations for all values of magnitude and distance than the corresponding Algermissen and Perkins curves and is most closely matched to these curves in the region 10 kilometers $< R <$ 300 kilometers and $5 < M < 6$. This adopted attenuation law, therefore, represents a conservative compromise between the estimated curves of previous authors and the required form of Cornell.

The next feature needed for hazard curve development for the site is some idealization of the regional seismic source areas. Whatever configuration is ultimately chosen for the geometry and location of the source regions affecting the site, the fundamental data are basically regional seismicity and geology. These features of the southeastern New Mexico region have already been evaluated in the literature (Algermissen and Perkins, 1976) with precisely the intent of developing an estimate of maximum acceleration in rock in a probabilistic format. Therefore, it was decided to investigate the feasibility of using these same source zones in the slightly different context of the current hazard evaluation.

As originally defined, the probabilistic estimate of maximum acceleration determined by Algermissen and Perkins (1976) was based primarily on the seismic record; geologic data, primarily distribution of faults, was employed only to a minor extent. In particular, the general principle used by these authors in the construction of seismic source zones was that future earthquake occurrences are assumed to have the same general time rate characteristics as the earthquakes in the past in the same overall region, but that future earthquakes in a particular area might occur over somewhat more extended areas than indicated by historical data. In practice, the seismic source zones were drawn using the following guidelines:

1) Areas of seismicity where shocks of maximum Modified Mercalli intensity V or greater have occurred were considered source zones. (Note that intensity and magnitude are deterministically related by the formula (Gutenberg and Richter, 1942) $M_c = 1.3 + 0.6I_o$ where "M_c is the magnitude corresponding to I_o" (Algermissen and Perkins, 1976). Thus I_o = V is equivalent to M_c = 4.3). For any given zone the average distance from the epicenters to the boundary was chosen to be approximately the average separation distance for earthquakes of the maximum intensity found there, when these were sufficiently numerous to establish such a distance. If the maximum intensity earthquake in a source area only occurred once or twice (as in the case of source areas in and near southeastern New Mexico), the distance between earthquakes of the second largest intensity was used.

2) Some zones such as described above were extended to include adjacent areas where evidence of Holocene faulting is present. This type of extension was used in the Great Plains and Southern Rocky Mountains where epicentral clusters could be associated with faults appearing on the tectonic maps of the United States.

3) From 2) above, areas of known Quaternary faulting are generally within source zones, if the faulting is associated with at least low-level historical seismicity. Except as noted above, Quaternary or older faulting not associated with historical earthquakes of Modified Mercalli intensities greater than V or magnitudes greater than 4.0 was not included within source areas.

Using these principles, the seismic source zones of interest to the calculation of hazard at the site as drawn by Algermissen and Perkins are shown in Figure 5.3-3. As seen below, independent studies of regional Quaternary faulting and the more detailed seismicity studies of the last several years do not seriously imply the modification of these source area boundaries with one conceptual exception involving small earthquakes within the immediate site area. This observation is most directly supported by considering the historical seismicity through 1972 as shown

in Figure 5.2-1 in conjunction with the three earthquake source zones of Algermissen and Perkins as shown in Figure 5.3-3. To aid this comparison, the epicenters of the former figure have been drafted on to Figure 5.3-3. It is clear from this superposition that the large majority of significant historical seismicity conforms well with the zonation presented. The location of the Valentine, Texas, earthquake and its aftershocks (if these are formally constrained to share the location of the main event in this sequence), apparently lie slightly to the east of the boundary of the southernmost seismic source zone if the Byerly (1934) location is used. It should be noted, however, that the instrumental location is not well constrained by the data available at the time of Byerly's study and, in particular, the epicentral uncertainty is such that a more southerly or westerly location is equally likely. For example, as may be seen from Figure 5.3-2 both the U.S.C.G.S. instrumental location for this event and the town of Valentine, Texas itself are within the source zone as drawn by Algermissen and Perkins. For the purposes of this risk analysis, the Valentine earthquake and its aftershocks are assumed to have occurred within the southernmost seismic source zone of Algermissen and Perkins.

Of more immediate concern is the scattered residual small magnitude seismicity occurring throughout the site area which cannot be associated with any of the source zones as drawn in Figure 5.3-3. This problem was recognized by Algermissen and Perkins (1976). These authors treated these isolated earthquakes which could not be associated with known faults or tectonic features as seismic background and the same shall be done here. On a nationwide basis these events could have an intensity of VII or less on the Modified Mercalli Scale and were assumed capable of happening over broad areas of the midwest; however they produced acceleration levels below the lowest acceleration contour on their map, because this contour represented the 0.04g level with a 90-percent probability of not being exceeded in a 50-year period (Algermissen and Perkins, 1976). Since acceleration levels for much longer time intervals are of interest in this study, some more explicit treatment of these random events will be necessary, and some explicit source zone including

the site must be considered. This is the conceptual modification of the Algermissen and Perkins study mentioned above.

A simple calculation is adequate to show that it is not necessary to consider any source zone other than the four already mentioned--the three of Figure 5.3-3 and an additional one including the site. The next closest source zone of Algermissen and Perkins is approximately 300 kilometers away from the site and all others are even farther away. Using this distance, the attenuation law considered above and (for the moment) an arbitrary maximum magnitude 7.5 earthquake, the maximum acceleration at the site is slightly less than 0.06g. Thus, such a source zone cannot contribute anything to site accelerations higher than this at any probability level. Furthermore, as will be more forcibly indicated in the next subsection where some actual hazard curves will be discussed, the contributions to probabilities of occurrence from distance source zones even at lower acceleration levels are insignificant when compared to the contributions from the closer zones.

An independent estimate of the appropriateness of the source zones as drawn in Figure 5.3-3 can be obtained from a consideration of faults offsetting Quaternary geomorphic surfaces. This is an independent estimate in the sense that no episode of surface faulting associated with historic seismicity is known in the site region. Nevertheless, Quaternary faulting has often been used as an indicator of the seismic activity of an area over a longer time span than is furnished by the historical seismicity record (e.g. Allen et al., 1965). Sanford and Toppozada (1974) have made an investigation of fault scarps within 300 kilometers of the disposal site, exclusive of the Permian Basin in which the site lies. This investigation consisted primarily of a literature search supplemented by limited reconnaissance of aerial photographs. The study was restricted to fault scarps offsetting Quaternary alluvial surfaces because these are the only fault displacements whose age can be estimated with any certainty. The authors note that tectonic movements in the area may have occurred during the Quaternary along faults cutting older rocks, but detection of recent offsets along such faults are nearly

impossible. Bachman and Johnson (1973) have completed a detailed investigation of the surface features in the Permian Basin which indicates recent fault scarps of a tectonic nature do not exist in this area. Since completion of the Sanford and Toppozada (1974) study, further studies on the existence or nature of fault scarps in the general site region have been actively pursued by Dr. Muehlberger and his students of the University of Texas, Austin (Sanford et al., 1978). To date, the most recent data are consistent with the picture derived from the earlier studies. That is, the Rio Grande Rift and southern Basin and Range provinces have abundant geologic evidence - primarily recent fault scarps - of recent crustal movements (Sanford et al., 1972; Muehlberger et al, 1978) whereas the High Plains, which is the physiographic province of the Permian Salt Basin in the site area, does not. The closest known Quaternary offset is about 125Km from the site.

Shown in Figure 5.3-4 are the faults noted by Sanford and Toppozada (1974) and Muehlberger et al. (1978) superimposed on the Algermissen and Perkins source zones. The references used in construction of these fault traces are Talmage (1934), Reiche (1938), Kelley (1971), Dake and Nelson (1933), King (1948, 1965), Kottlowski (1960), Kottlowski and Foster (1960), and Pray (1961). Also shown is the eastern boundary of the area of investigation of Sanford and Toppozada, that is, the western boundary of the Permian Basin.

It is clear that the Quaternary faults are completely contained within the two western seismic source zones of Algermissen and Perkins. These two zones may be combined under the name "southern Basin and Range--Rio Grande Rift" source zone since they include the parts of those provinces significant to the evaluation of probabilistic acceleration at the site. The reason for combining the two original zones is implied by a comparison of Figures 5.3-3 and 5.3-4. Although the historical seismicity has been of a higher level in the more southerly of the two zones (Algermissen and Perkins assign a maximum intensity of VIII to this southerly zone to correspond to the Valentine, Texas, earthquake and one of only V to the northern zone), the Quaternary fault offset strongly

suggests that to insure conservatism this pattern should be considered a happenstance of the short historical earthquake record. Thus for the purposes of this analysis, the seismic capabilities of the southern zone will be shared by the region to its north. Although only epicenters of earthquakes occurring prior to 1973 are shown in Figure 5.3-3, the implications of more recent activity as they affect the southern Basin and Range--Rio Grande Rift source zone (which will be referred to only as the Rio Grande Rift source zone in the following discussion for brevity) are similar. For example, Figures 5.2-3 and 5.2-4 show that the known epicenters for shocks between April 1974 and November 1977 with Sg-Pg intervals at station CLN from 31 to 36 seconds occur in apparently historically active regions, notably centered around Valentine, Texas and much of the Tularosa Basin. That is, they occur precisely in the Rio Grande Rift source zone as defined above.

One important implication of these studies is that the easternmost of the three Algermissen and Perkins source zones, that corresponding to the post-1964 seismic activity around Wink, Texas, on the Central Basin Platform, is based on seismic evidence alone. This activity was discussed in detail in subsection 5.2.4. For the purposes of specifying a conservative source zone geometry, the only geometrical issue with regard to the Central Basin Platform source zone, then, is the closest approach of the Central Basin Platform relative to the source zone used to model it. Shown in Figure 5.3-4 is an outline of the buried Central Basin Platform as it appears in Rogers and Malkiel (1978). It may be easily seen that the closest approach to the site of the Algermissen and Perkins Central Basin Platform seismic source zone implies its use is adequate. Therefore, this zone, as drawn, will be used for the model to be developed. The general model will consist of three source zones:

1) The Rio Grande Rift zone drawn by combining the western source zones as discussed above.

2) The Central Basin Platform zone as shown in Figure 5.3-4.

3) A site source zone centered at the site and with a radius to be specified below.

There are two purely geometrical issues to be resolved. The first involves specifying a focal depth for the events in each of the source zones. The second is really an exercise in adapting the irregular zones, as shown, to Cornell's method much as it was necessary to adapt the form of the attenuation law.

There is little doubt that the focal depths of earthquakes in the site region should be considered shallow. As we saw in subsection 5.2.2, early instrumental locations were achieved using an arc intersection method employing travel-time-distance curves calculated from a given crustal model and the assumption that focal depths were either 5 kilometers, 10 kilometers, or for later calculations, 8 kilometers. Good epicentral locations could generally be obtained under these assumptions. Confidence in calculated or assumed focal depths is greatly increased, of course, if at least one recording station is situated not much farther away from the epicenter than the focal depth. This situation is not generally realized for New Mexico region earthquakes but several specialized studies for which this criterion has been satisfied are suggestive. For an approximately two-year period beginning in June 1960, several hundred natural microearthquakes having S-P intervals of less than 2.3 seconds were recorded by high-magnification seismographs west of Socorro, New Mexico (Sanford and Holmes, 1962). Rather detailed studies of the depths of these events indicated hypocenters ranging from 2.7 to 6.3 kilometers. More recently, and nearer to the site, preliminary data from the Kermit, Texas, array indicate focal depths ranging from very near the surface down to about 10 kilometers although only about 20 percent of the events are located at depths greater than about 3.7 kilometers (Rogers and Malkiel, 1978). For the formal instrumental location procedure with array data, an initial trial hypocenter at 5 kilometers depth is used by these authors.

Within the range discussed - that is, focal depths of from 0 to 10 kilometers - the issue of selecting a proper depth for the probabilistic acceleration analysis at this site is clearly important only in the site source zone itself. For example, the difference in hypocentral distance - the distance to be used in the acceleration attenuation formula - for a closest approach event in the Central Basin Platform is only 1.93 kilometers in this depth range assuming that the closest approach of this source zone is 25 kilometers as is indicated by Figures 5.3-3 or 5.3-4. This is clearly the greatest difference of this kind outside the site source zone. Within the site source zone the selection of focal depth can be, formally, very important simply because the form of the attenuation law used asymptotically approaches infinite acceleration at very small distances. This is certainly not mechanically realistic and is not the intent of the empirical fitting process to an attenuation law of this form. There is some empirical evidence that the rate of increase of peak acceleration with decreasing hypocentral distance becomes less as the zone of energy release is approached. This is the case for example, for the Parkfield and San Fernando, California earthquakes of 1966 and 1971, respectively (see Page et al., 1972, Figures 4 and 6). Some empirical acceleration attenuation curves make use of this property in extrapolating to the vicinity of energy release. Most importantly for our purposes here, the attentuation curves of Schnabel and Seed (1973) are constructed in this manner and it is these curves that form the basis for near-source acceleration as a function of magnitude used by Algermissen and Perkins (1976). Since it is the intent here to follow these authors insofar as conservatism allows, it was decided to use a focal depth of 5 kilometers in all source zones of this study including that of the site. For smaller hypocentral distances, the form of the attenuation law adopted here deviates significantly from that suggested by Algermissen and Perkins in such a way as to severely exaggerate the importance of very small but very close shocks in the estimation of probabilistic acceleration at the site pertinent to design. This may be seen from Figure 5.3-2.

The manner in which the irregular source zone geometry of Figures 5.3-3 and 5.3-4 may be adapted to the method of Cornell (1968) is shown in Figure 5.3-5. As has been implied above, the seismicity of the site region is, at best, poorly related to observed faults - whether observed Quaternary faults do not occur, as in the case of the Central Basin Platform source zone (Rogers and Malkiel, 1978) or whether they do, as in the case of the Rio Grande Rift source zone (Sanford et al, 1972). Since the boundaries of the latter zone are so drawn as to be as close or closer than known recent faults, conservatism is served by allowing the largest earthquake postulated for specific faults within the region to occur randomly throughout the region. For these two reasons, lack of apparent fault control and additional conservatism, areal source zones were used (see subsection 5.3.1). Thus the object is to approximate the given source zones by a series of annular segments. This is done in such a way that total source zone area is conserved, and such that excluded area of the Algermissen and Perkins zones is replaced by annular areas closer to the source. Finally, closest approach distances are conserved. These criteria are followed in construction of the pattern in Figure 5.3-5. The site source region is drawn to be centered at the site and to include all area not already in another source zone. The radius of this site source zone will be determined by magnitude restrictions.

With the attenuation law and geometry defined for this hazard analysis, the question of the right recurrence formulas for each source zone is next addressed. A number of empirically fitted curves of the form $\log N = a - bM$ have been published for the site region in a broad sense (Sanford and Holmes, 1962; Algermissen, 1969). As before, N is the number of earthquakes of magnitude greater than or equal to M in some area and over some time period. The constants a and b are determined by fitting the data, usually in a least squares procedure. Although data for any time period may be used, all the formulas considered explicitly here will be normalized to one year. In addition, all formulas will be normalized to source areas of 10^5 square kilometers for ease of comparison. For these broad regional studies, b values around 1.0 have been found.

Several studies published recently regarding the immediate site region are not in good agreement with the previous results. For example, graphs of magnitude versus number of earthquakes for events within 300 kilometers of the site exclusive of shocks from the Central Basin Platform and aftershocks of the 1931 Valentine, Texas earthquake yield recurrence formulas of the form

$$\log N = 1.65 - 0.6M_L \quad \text{per yr per } 10^5 \text{ km}^2$$

using instrumental data only, and

$$\log N = 1.27 - 0.6M_L \quad \text{per yr per } 10^5 \text{ km}^2$$

using both historical and instrumental data (Sanford and Toppozada, 1974). Because the numbers of shocks used to establish the linear portions of these curves is very small (16 and 25, respectively), and the total time intervals over which data were collected is very short (11 and 50 years, respectively), an error in the slope (or b value) is quite possible. In fact, a certain dissatisfaction with these results on the part of Sanford and Toppozada is indicated by their development of alternate curves somewhat arbitrarily defined to have a slope of 1.0 instead of 0.6. Algermissen and Perkins (1976) calculate recurrence curves for a number of their source zones. For example, for source zone 45 (as defined in either Figure 5.3-3 or 5.3-4) they find the equivalent of

$$\log N = 0.53 - 0.52\, M_C \quad \text{per yr per } 10^5 \text{ km}^2$$

while for source zone 43, no formula is found, presumably for lack of data. Clearly, the difficulties of finding meaningful recurrence relations for such a short and areally restrictive interval in a region of low seismicity are formidable. Another problem is also implied by the last two equations. Magnitude M_C in the Algermissen and Perkins

formulation is somewhat vaguely defined, as mentioned above, as the magnitude corresponding to I_o in the equation:

$$M_c = 1.3 + 0.6\ I_o$$

where I_o is maximum intensity on the Modified Mercalli Scale. There seems to be no rigorous and straightforward way to relate this magnitude to the M_L of Sanford and Toppozada. Even the definition of M_L, upon which development of recurrence curves is fundamentally dependent, has been revised in the past few years as was seen in subsection 5.2.2

Fortunately, recent work (Sanford et al., 1976b) allows a preliminary treatment of the data that circumvents the worst of these problems. This recent study is based on eleven years of instrumental seismicity data which have been reinterpreted with respect to magnitude. In addition, recurrence formulas are computed for broad physiographic regions of New Mexico vastly increasing the data base. The criterion used in this current hazard analysis will be to use the Sanford et al. (1976b) recurrence formula for the physiographic province in which an individual source zone occurs with the value scaled down to reflect area differences. For example, Sanford et al. (1976b) find

$$\log N = 2.4 - 1.0\ M_L \quad \text{per yr per } 10^5 \text{ km}^2$$

for the High Plains province where the site is located, and

$$\log N = 2.5 - 1.0\ M_L \quad \text{per yr per } 10^5 \text{ km}^2$$

for the Basin and Range - Rio Grande Rift region. The area of the High Plains province of interest for this analysis is approximately 3.4×10^4 km^2 surrounding the site but exclusive of part of the Central Basin Platform. Thus the proper recurrence formula becomes

$$\log N = 1.93 - M_L \quad \text{Site source zone}$$

Similarly, the part of the Southern Basin and Range - Rio Grande Rift region of interest has been referred to in the above discussion as the Rio Grange Rift source zone and had an area of about 1.15×10^5 km^2. The proper recurrence formula becomes

$$\log N = 2.56 - 1.0\ M_L \quad \text{Rio Grande Rift source zone}$$

This leaves only the Central Basin Platform which is essentially a special case. Although the above two formulas were developed for areas near 2×10^5 km^2 in extent with the increase in confidence therefrom derived, this cannot be done for the Central Basin Platform source zone because it is unique and very limited in area. It, therefore, cannot be treated as simply a scaled-down version of some broader region. Although recent work using data from the Kermit array (Rogers and Malkiel, 1978) is available for this source zone, it was decided to use the recurrence formulation of Sanford et al., (1978) for this hazard analysis both for consistency in approach and because this treatment is the only one to calculate a recurrence formula for this source zone using revised magnitude estimates. Based on the seismicity detected in the Central Basin Platform since the installation of station CLN in April 1975, the cumulative number of shocks versus magnitude may be expressed as

$$\log N = 3.84 - 0.9\ M_L \quad \text{per yr per } 10^5 \text{ km}^2$$

Assuming that the active portion of the Central Basin Platform had an area of 8×10^3 km^2 during this period (Sanford et al, 1978) the proper recurrence relation becomes:

$$\log N = 2.74 - 0.9\ M_L \quad \text{Central Basin Platform source zone}$$

These are the recurrence relationships used in the current hazard analysis for the site.

One feature of several of these recurrence formulas is apparent: that is, they are very similar when normalized to equal source areas. This is

somewhat surprising in that the geologic indications of recent tectonism vary from source zone to source zone. One way in which the seismic and geologic data may be reconciled is to impose some upper limit on the magnitude of the earthquake that can occur in the geologically quiet areas that is less than the maximum magnitude event that can occur in source zones with evidence of Quaternary tectonism in the form of fault offset. This will be discussed in a later section but is mentioned here as a preface to the final aspect of source region characterization necessary to perform a hazard analysis: that is, maximum magnitude event within each source zone.

It is clear that a simple consideration of maximum historical magnitude within each of the three source zones as specified above will not be adequate to assure conservatism. This is particularly true of the northern part of the Rio Grande Rift source zone (Zone 43 of Algermissen and Perkins, 1976) where a maximum historical intensity of only V is known. As discussed above, the fault scarps in this area, particularly along the margins of the San Andres and Sacramento Mountains, indicate the strong possiblity that major earthquakes have occurred in this region within the past 5×10^5 years. The length of the faulting in these two areas (about 60 to 100 kilometers) suggests earthquakes comparable in strength to the Sonoran earthquake of 1887 (Sanford and Toppozada, 1974). This major earthquake (M=7.8) produced 80 kilometers of fault scarp with a maximum displacement of about 8.5 m extending southward from the U.S. - Mexico border at about 109°W longitude. Sanford and Toppozada (1974) assume that a similar event is possible in the future west of a line in good agreement with the eastern boundary of the Rio Grande Rift zone as shown in Figure 5.3-5. This eclipses the more southerly Valentine, Texas, earthquake whose magnitude has been variously estimated to be 6.1 (Algermissen and Perkins, 1976) and 6.4 (Sanford and Toppozada, 1974). For the purposes of this analysis, a maximum magnitude event of 7.5 will be assumed able to occur anywhere within the Rio Grande Rift source zone in general agreement with Sanford and Toppozada.

Selection of maximum magnitude events for the site source zone and the Central Basin Platform source zone is more difficult. Algermissen and Perkins (1976) assign a maximum historical intensity of VI to the Central Basin Platform. This is presumably the earthquake of August 14, 1966 which has been assigned this intensity in United States Earthquakes, 1966 (Von Hake and Cloud, 1968). On the basis of this intensity and the empirical relationship of Gutenberg and Richter (1942):

$$M = 1.3 + 0.6\ I_o$$

a maximum magnitude event of 4.9 has been selected for the Central Basin Platform by Algermissen and Perkins (1976) as appropriate for their probabilistic acceleration analysis. The magnitude scale was designed to give some indication of the elastic energy released at the earthquake source, and in this context, the 4.9 value above is almost certainly an exaggeration of the energy really released during this particular earthquake. This conclusion is based on both macroseismic and instrumental evidence. For example, one of the descriptions of this shock was, "Like a stick of dynamite being detonated several hundred feet away" (Von Hake and Cloud, 1968). This and a general consideration of felt effects are consistent with the contention that this earthquake has been assigned a relatively high epicentral intensity primarily because it occurred very near a population center. In addition, several magnitudes have been published for this earthquake (U.S.C.G.S. - 3.4; Sanford et al. 1978 - 2.8) which are substantially lower than the 4.9 value used by Algermissen and Perkins.

The maximum instrumental magnitude for an event in the Central Basin Platform source zone is open to some debate because of the apparently different application of magnitude scale by various agencies for this region. The largest earthquake in this region before installation of station CLN had a magnitude less than 3.25 according to the most recent calculations at New Mexico Institute of Mining and Technology (Sanford et al., 1978). Between 1974 and October 1977, during the operation period of CLN for which data is currently available, a number of earthquakes

have been located by Sanford and his colleagues, none of which have been assigned magnitudes greater than 3.2. In the Rogers and Malkiel (1978) study of data from the recently established Kermit array, events with magnitudes approaching 4 are listed. However, as was stated in subsection 5.2.4, a direct comparison of magnitudes for earthquakes listed in both the New Mexico Institute of Mining and Technology and Kermit array data sets shows that events are routinely assigned magnitudes almost one unit higher in the latter listing. Therefore, the maximum historical magnitude earthquake in the Central Basin Platform Source Zone is still a matter for conjecture although some value between 3.0 and 4.0 is most likely.

The features of this source zone that might bear on its possible maximum magnitude are the lack of recent geologic evidence of tectonism, and the high activity rate which may or may not be directly associated with secondary oil recovery efforts. Sanford and Toppozada (1974) conjecture that the maximum magnitude might be 6.0 for this source zone, and in this study of hazard their example will be followed for one set of calculations. Because this value may be exceptionally conservative, an alternate maximum magnitude of 5.0 is also considered.

With regard to the site source zone, there is even less indication that significant magnitude events are reasonably likely. There is no Quaternary fault offset (Bachman and Johnson, 1973) and seismic activity is low. However, recent studies (Caravella and Sanford, 1977) have shown that some level of background seismicity must currently be considered for the site area if conservatism is to be served. Apparently, an earthquake which may be tectonic in origin and with a magnitude of 3.5 has occurred within the site source zone itself (see subsection 5.2.5). Two maximum magnitudes were considered in the hazard analysis of this section: 4.5, that is the maximum historical event plus one magnitude unit; and 5.0, a rather ad hoc attempt to consider additional conservatism in general agreement with the size of a random event possible in the central United States and not associated with a particular source zone (Algermissen and Perkins, 1976).

All the parameters necessary to perform a probabilistic acceleration hazard calculation for the Los Medanos site after the method of Cornell (1968) have now been presented and discussed. In the next subsection the results of these calculations are considered.

5.3.3 Results

The basic results are shown in Figures 5.3-6 and 5.3-7. These are plots of the probabilities that the maximum annual acceleration will exceed some specified acceleration versus the specified acceleration. For example, in Figure 5.3-6, Curve 1, which shows the contribution to risk at the site due to earthquakes in the Rio Grande Rift source zone as shown in Figure 5.3-5, indicates that the probability that the maximum acceleration at the site from this source zone in any one year will exceed 0.05g is approximately 1.8×10^{-5} or 1.8 in one hundred thousand. Probabilities are similarly found for other values of acceleration.

In both Figures 5.3-6 and 5.3-7, six curves are shown. Curve 1 is the same in both figures and represents the probabilistic maximum acceleration distribution for the Rio Grande Rift source zone as described above. Curves 2 and 2' are also the same in both figures, representing the risk from the site source zone when its maximum magnitude is 5.0 and 4.5, respectively. Curve 3 in each figure is the risk distribution from earthquakes in the Central Basin Platform source zone. In Figure 5.3-6, the maximum magnitude event in this zone is assumed to be 6.0 while in Figure 5.3-7 it is given a value of 5.0. Finally, curves 4 and 4' are the total probabilistic maximum accelerations at the site from all source areas combined. For example, Curve 4 in Figure 5.3-6 is the risk at the site assuming the geometric and recurrence properties, and the acceleration attenuation, of the last subsection and a maximum magnitude of 6.0 in the Central Basin Platform source zone and 5.0 in the site source zone.

Probabilities for accelerations below 0.03g have not been calculated. This is because of a feature of the method used. For a given source geometry and minimum magnitude, the lower limit of validity of probabilistic acceleration is fixed (see Figure 5.3-1top) such that $a \geq a'$.

$$a' = 17 \exp 0.92 m_o d^{-1}$$

where m_o is the minimum magnitude and d is minimum distance to any source zone. For the worst case, d = 5 km. The value for m_o, 2.4, is the same for all source zones and is derived from an estimate of the smallest earthquakes recorded uniformly throughout the state of New Mexico (Sanford et al., 1978). Substituting these values into the above expression results in $a' = 30.9$ cm/sec^2 or $a' = 0.03g$.

There are several interesting features that may be derived from a comparison of the four curves, 4 and 4' in both Figures 5.3-6 and 5.3-7. First, it may be noted that in spite of the greater conservatism exercised in the selection of model parameters for this study than in the Algermissen and Perkins (1976) study--on which so much of the current risk evaluation depends--the basic conclusion of Algermissen and Perkins that the site is in an area with less than one chance in ten that an acceleration of 0.04g will be exceeded in any 50 year period is in very good agreement with the results shown in Figures 5.3-6 and 5.3-7. To see this it may be noted that the return period for the Algermissen and Perkins study is about 475 years. For the slightly more conservative curves of Figure 5.3-6, the maximum accelerations at this return period are around 0.045g while in Figure 5.3-7 they are 0.035g.

Secondly, it is interesting to note that under the assumptions of the previous section the significance of the Rio Grande Rift source zone to the total risk at the site is relatively small at all acceleration levels. Because of the earthquake recurrence relationships for the various source zones, this will be true at lower acceleration levels no matter what assumptions are made about the maximum magnitudes in the site

and Central Basin Platform source zones. At higher acceleration levels, this will be true unless the lowest maximum magnitude proper for the site source zone is lower than the 4.5 value considered here. Although probabilities are low at all site acceleration levels from the Rio Grande Rift source zone, the maximum acceleration at the site from a 7.5 shock at a distance of 115 kilometers using the attenuation law of subsection 5.3.2 is 0.15g. This is slightly greater than the 0.1g acceleration assumed to be the maximum at the site in previous studies (Sanford and Toppozada, 1974).

In the case of the Central Basin Platform source zone, a comparison of the two figures shows an interesting phenomenon. For the case where 6.0 is the maximum magnitude event, probabilities are largely controlled by earthquakes in this source zone up to accelerations of around 0.1g. For higher accelerations, the site source zone is more important. If 5.0 is a better maximum magnitude shock in the Central Basin Platform, its significance as a source of risk is completely eclipsed by the site source zone itself at all acceleration levels.

Perhaps the most universal feature of all four total risk curves is their dominance by the site source zone at higher accelerations. If the probabilities at which these higher acceleration levels occur are thought to be of interest, it is the assumptions that are made about the immediate site area that are most critical.

It is believed that the presentation in this section gives the broadest possible assessment of seismic risk at the site in a way that shows explicitly the assumptions used and, to a small extent at least, the effect of varying some of these assumptions. Acceleration is not the only parameter of design significance, of course, so that a plot of its probability is not the whole story even if such a plot is completely accurate.

5.4 SEISMOLOGICAL DATA AND SITE REGION TECTONISM

In previous sections the historical record of seismicity in the site region has been explored as well as the way this record, when combined with very general geologic arguments, can be used to estimate risk levels attached to various possible seismic design acceleration values. In this section the extent to which this seismological data may be used to draw inferences of a longer term nature is considered. The interval over which seismological data can be collected is still very brief; the total available earthquake record, and especially that fraction of it representing the period of instrumental observation, covers a period of time that is very short compared to the total geologic time scale. Thus, a comparison of the regional tectonism derived from a study of geologic processes and structures, with that derived from a study of earthquakes, involves a question of consistency: that is, are the characteristics of regional earthquakes consistent with known geologic structures and the large-scale stresses thought to have been active in their evolution?

Implicit in this concept of tectonics is the definition of tectonic earthquake that is used in this section. The subject of tectonics as it is used here is structural geology. Tectonic earthquakes are those believed to be associated with faulting. This is taken to exclude minor shocks due to less important causes (Richter, 1958). As mentioned in subsections 5.2.4 and 5.2.5 it is not clear that the detected earthquakes in either the site source zone or the Central Basin Platform are tectonic under this definition. There seem to be few geologic structures in either area that would lead one to expect significant tectonism either now or for vast times in the past. Nevertheless, conservatism suggests that these events should be considered tectonic at this stage of our knowledge, and this assumption was made for the seismic risk analysis of the previous section.

Seismology, in the context of tectonism, will be considered below under two general headings: implications about the regional stress regime from focal mechanism solutions, and implications about regional activity from

historic recurrence statistics. Although earthquakes are sometimes used to delineate specific active structures in a way important to discussions of regional tectonism this will not be attempted here, primarily because even in areas with recent faulting, such as occur in the southern Basin and Range province, or in areas with sophisticated seismic array location capabilities as in the Central Basin Platform, the known earthquakes are simply not well correlated with specific geologic structures on a detailed scale.

The ultimate association of seismic and geologic processes is derived from the observation that the structural behavior of an element of the earth's crust is often associated with the release of elastic strain energy in the form of earthquakes. The nature of this association itself, however, may be far from simple. This is especially true of small earthquakes whose characteristics are derived from processes taking place in a very small volume of a crust that, in this context, must be considered very inhomogeneous. As was seen in Section 5.2, the latest calculations show that only one instrumentally located earthquake within 300 kilometers of the site (the Valentine, Texas, event) has exceeded magnitude 4.6. Similarly, within 300 kilometers of the site but outside the Rio Grande Rift source zone as defined in Section 5.3 no earthquake has exceeded magnitude 3.5. This should be kept in mind throughout this section. It may also be noted that most empirical experience in relating tectonic features to seismicity, or vice versa, has been gathered in regions that are much more active than the site region. This too was mentioned in Section 5.2 and is made very clear by comparing earthquake recurrence statistics for the site region with similar statistics for an area such as California. The picture presented by a comparison of seismologic with structural geologic data appears confused for the site region. At least these two data sources are not consistent in the same way or to the same degree that is found in other regions characterized by larger historical earthquakes. It is premature to attempt a reconciliation here, if indeed one is necessary, so that in this section existing evidence (although often only preliminary) is outlined and briefly discussed.

5.4.1 Regional Stress Orientation

The catalog of published crustal stress measurements in the Los Medanos region is a short one. It consists of three focal mechanism solutions and one in situ hydrofracture determination. Another in-situ stress measurement was quoted recently in connection with west Texas studies (Rogers and Malkiel, 1978), but this measurement is some distance to the east, on the Llano uplift. In this very limited data collection, there is little agreement, and none should necessarily be expected since the measurements come from different structural blocks.

The earliest indication of the stress regime for a point within the general Los Medanos site region (when defined as it has been in this chapter as within 300 kilometers of the site) comes from an analysis of first motion polarities from the Valentine, Texas, earthquake of August 16, 1931. In his study of this event Byerly (1934), carefully noted the polarity, azimuth, and epicentral distances of waves at all stations recording this earthquake. He concluded that the observed polarity pattern could be explained by normal movement on a shallow fault striking N35^{o}W, and dipping very steeply to the west. He also noted that certain stations did not fit this pattern and attributed most of these discrepancies to difficulties in observing the true first arrival, which was apparently lost in the noise at these stations. Fortunately, all polarity readings were listed in Byerly's paper for this earthquake, which was recorded at distances ranging from 5.8^{o} to 104.8^{o}. Applying the recent techniques of stereographic projection to Byerly's data, Sanford and Toppozada (1974) obtained an independent but very similar solution shown in Figure 5.4-1a. This solution indicates predominantly dip-slip motion along a normal fault striking N40^{o}W and dipping 74° southwest, or motion of a similar nature on a fault striking N19^{o}W and dipping 18° northeast. The first possibility is preferred because of the structural fabric of the epicentral region with which it is consistent. The inconsistent polarity readings are those noted previously by Byerly. It is worth mentioning that the regional stresses implied by this solution (P-axis or axis of maximum compressive

stress striking N51°E and plunging 62° to the northeast and T-axis or axis of least compressive stress striking S61°W and plunging 28° to the southwest) are the only ones for this region that are incontrovertibly of some tectonic significance.

The remaining two focal mechanism solutions available at this time for the site region have been very recently determined from data recorded at the Kermit array. One solution is a composite of data from three small earthquakes that occurred within a 7-day period in January 1976 and is reproduced from Rogers and Malkiel (1978) in Figure 5.4-1b. The other solution is from a single earthquake on April 26, 1977, in the same area as the other three near array station KT5 (see Figure 5.2-5) and is reproduced, also from Rogers and Malkiel, in Figure 5.4-1c. These are the only events occurring during array operation that have produced a sufficient number of clear first motion polarities to allow focal mechanism solutions.

The earthquakes from which the composite solution of Fig. 5.4-1bottom was derived occurred on January 19, 22, and 25, 1976 and had U.S.G.S. assigned magnitudes of 3.47, 2.83, and 3.92, respectively. It has already been noted in Section 5.2 that these magnitudes appear to be almost a unit larger than those most recently calculated for shocks in this area by Sanford and his colleagues at the New Mexico Institute of Mining and Technology. The preferred fault plane, based on the geologic structure of the Central Basin Platform, strikes N19°W and dips to the west at 53°. The sense of fault motion is that of normal faulting. Similarity to the solution for the Valentine earthquake is clear. The data for the April 1977 event do not fit this type of solution and do not permit a unique mechanism to be obtained. Normal, thrust, and strike-slip mechanism are possible. The normal solution shown in Figure 5.4-1c is the only one considered by Rogers and Malkiel to be relatively consistent with the composite mechanism and the regional tectonics.

The tectonic significance of these last two focal mechanisms is confused by their occurrence in an area where both active fluid withdrawal and

injection are taking place. This confusion is apparently not lessened by considering the in situ stress data. Hydrofracture data from a well in Howard County, Texas to the east (Fraser and Pettit, 1962) indicate a tension axis that trends south-southeast. Overcoring data from Hooker and Johnson (1969) even further to the east in Burnet County, Texas, on the Llano uplift show reversion to a southwest trend for the tension axis. According to Rogers and Malkiel (1978), both the Howard and Burnet County data show a horizontal axis of maximum compression. This is in disagreement with the focal mechanisms, for which the greatest compressive stress is steeply plunging. Also, von Schonfeldt et al. (1973) have indicated that the greatest principal stress in this area is a vertically oriented, overburden induced compressive stress because hydrofracture experiments generally produce vertical fractures in Texas, except in some shallow wells (Hays, 1977). In the face of such a variety of interpretations, it is premature to speculate on the significance, or lack of it, of these data. Any such speculation will have to wait on the collection of new data or additional analysis of existing information.

5.4.2 Tectonism and Earthquake Recurrence Relations

In Section 5.2 the seismicity of the Los Medanos site region was studied. It was noted that most of the activity of recent years had occurred in the Central Basin Platform in two particular areas located such that Sg-Pg intervals at station CLN very near the site were 8 to 13 seconds and 22 to 24 seconds (Sanford, et al. 1978). Another group of epicenters for shocks with Sg-Pg intervals from 31 to 36 seconds were found by these authors to occur in several tectonically active regions to the southwest and west of the site--notably near Valentine, Texas, and in much of the Tularosa Basin. These three Sg-Pg intervals account for the most important peaks on the histogram appearing in Figure 5.2-5. Earthquakes at other distances contribute a general background occurrence level also apparent in this histogram. At least some of these events are known to have occurred in the general site region and not in association with either the Central Basin Platform or the Rio Grande Rift source

zones of the previous section. This characterization of the regional seismicity is interesting because there is abundant geologic evidence for recent tectonic activity for the source zones to the west and none for the Central Basin Platform.

This situation can be described more quantitatively by considering earthquake recurrence statistics. Relations of the form logN=a-bM for the three source zones of Section 5.3 have already been shown. These formulas, taken from Sanford et al. (1976b) and Sanford et al. (1978) may be normalized to equal time intervals and areas for comparison (assuming such a comparison is meaningful) to give:

$$\log N = 2.5 - M_L \quad \text{Rio Grande Rift zone}$$

$$\log N = 2.4 - M_L \quad \text{High Plains Province}$$

$$\log N = 3.84 - 0.9\, M_L \quad \text{Central Basin Platform}$$

where in each case the formulas give the number of occurrences, N, of events with magnitude M_L or greater per year in a 10^5 km^2 area. It is clear that if these relations truly indicated some measure of tectonic activity in effect for a long time period the relative tectonic importance of these areas would be in conflict with that implied by the geologic data. This is particularly true for the Central Basin Platform activity.

Several explanations have been offered to resolve this conflict (Sanford et al., 1978). One is that a recent change in regional stress may be responsible. In this view, the tectonic implications of very recent seismicity are preferred to those of the geologic record. The other extreme possibility is that the observed recent seismicity, especially in the Central Basin Platform, has little bearing on tectonism in the sense normally used in connection with magnitude recurrence relations. Thus, the geologic implications to past and recent (and, by extrapolation, future) tectonism are preferred to those of recent seismicity. Finally,

there is an intermediate position which attempts reconciliation of both the geologic and seismic data by prescribing some particular mode of crustal behavior in the High Plains physiographic province and the Central Basin Platform. The only explicit property of this mode of behavior is that large magnitude earthquakes do not occur; hence, extrapolation of the recurrence formulas above to large magnitudes is fundamentally inaccurate.

The first possibility, that the regional geology of the High Plains province and Central Basin Platform is in essence misleading, is the least satisfactory. There does not seem to be any implication of recent regional stress changes in the more active areas of New Mexico. Sanford et al. (1972) performed calculations comparing the implications to tectonic activity of recent fault offset in the Rio Grande Rift (where recent is defined as less than 4×10^5 years old) with similar implications from recurrence statistics both from historical earthquakes and from microearthquake studies (Sanford and Singh, 1968). These calculations show that if the fault scarps are less than 4×10^4 years old, the seismicity obtained is compatible with the historical earthquake activity in the Socorro region. If the age span of the fault scarps is increased to about 2×10^5 years, the seismicity becomes close to that indicated by the microearthquake studies. It may also be noted here that the focal mechanism solution obtained for the Valentine, Texas, earthquake is consistent with the sense of fault motion implied by the geologic structure of that area.

Using similar types of arguments some limits can be placed on how recently the change in stress postulated for the High Plains province and the Central Basin Platform must have taken place. Consider that part of the High Plains province designated as the site source zone in Section 5.3. Then the recurrence relation is, after Sanford et al. (1976b):

$$\log N = 1.93 - M_L$$

The use of this formula in an uncritical way leads to the conclusion that an earthquake of magnitude greater than or equal to 7.0 should occur in this zone on the average of once in about 10^5 years. Such an earthquake would certainly leave physical evidence of fault offset. If the High Plains province of New Mexico is taken as a whole, a similar earthquake would be expected on the average of once in slightly over 2×10^4 years. Assuming that earthquake occurrence is distributed as a Poisson process, it can be concluded that an earthquake of magnitude 7.0 or greater has a 63 percent likelihood of occurring in a given 2×10^4 year period and that it has a 90 percent likelihood of occurring in a given 2×10^5 year period. Nevertheless, no evidence is known of fault offset suggesting earthquakes of this size anywhere in the High Plains during comparable or longer time periods. Thus, if there have been changes in regional stress that are responsible for the observed conflict between geologic and seismic data, these changes probably have taken place more recently than within the last 2×10^4 to 2×10^5 years.

A similar calculation may be applied to the Central Basin Platform. In this case on the basis of seismic evidence the recurrence interval for a magnitude 7.0 earthquake is about 3500 years. As in the High Plains, there is no geologic evidence for such an earthquake. Thus, the geologic and seismic evidence appear to contradict one another unless the current seismicity is the result of a tectonic stress change that took place within the last several thousands or tens of thousands of years. The implications of recurrence intervals for large earthquakes developed from short term seismic data should not form the basis for rationally discarding contradicting geologic evidence.

The second possibility as it is presented here applies only to the Central Basin Platform. That is, the recurrence statistics for earthquakes in this small area are not related to tectonism in the usual sense of this concept and should not be used for tectonic implications of long time intervals. The principal support for this view is outlined in Sanford and Toppozada (1974). Basically, it has been postulated that the earthquakes on the Central Basin Platform are related to massive fluid

injection for secondary recovery of oil. Both the spatial and temporal association of this seismicity with these secondary recovery projects are very suggestive. This has already been discussed in greater detail in subsection 5.2.4 and will not be repeated here. The wide variety of hypotheses regarding the stress field in the area of the Central Basin Platform neither preclude nor prove any causal relationship between the earthquakes and secondary recovery operations (Hays, 1977), but, the widely observed phenomenon of increased seismic activity during fluid injection (Healy et al., 1968; Healy et al., 1972) argues strongly against the uncritical extrapolation of short term magnitude recurrence formulas under the present conditions.

The third possibility, that the geologic and seismic data are not really in conflict, is the most satisfying from a philosophical viewpoint. It is certainly simpler to derive meaningful conclusions about the physical properties of a system that is not changing than about one that is. It has already been mentioned that such consistency exists for the Rio Grande Rift, at least in gross terms. A similar reconciliation might be possible for the High Plains province or the Central Basin Platform by restricting the maximum magnitude of an earthquake that can occur in either the High Plains physiographic province or the Central Basin Platform.

The simplest restriction that can be applied to the magnitude of shallow seismic events that have occurred in the past is imposed by the size or absence of observed faulting. An argument of this type has been used above in considering the questions of recent stress regime changes. In very general terms, it is believed that where recent geologic faulting exists, even in the absence of observed large magnitude earthquakes, conservatism requires that such seismic activity should be anticipated (Allen et al., 1965; Sanford et al., 1972); that is, to a high level of confidence, large recent faults in an area imply large magnitude earthquakes must be considered there. The converse argument, that large magnitude shallow earthquakes always produce episodes of large scale shallow faulting is even more widely believed. This assertion appears so

absolute because the definitions of "large" earthquake and "large-scale" faulting have been left purposely vague. A more empirically useful statement might be that the largest recent fault offsets (in terms of both fault length and fault displacement) that are found in an area under a given set of geologic conditions and after an adequate search impose an upper limit on the magnitudes of past earthquakes.

The general relation between magnitude of shallow-focus earthquakes and size or volume of the deformed region and the length and amount of displacement of activated surface faults has long been recognized (Tsuboi, 1956; Richter, 1958). Tocher (1958) developed an early empirical relation between magnitude and fault length, and between magnitude and the product of fault length and maximum displacement. Many subsequent refinements have been formulated by adding additional data points (Iida, 1959 and 1965), applying the method to specific areas, as for southern California (Albee and Smith, 1966), and by refining the source data either for the western United States (Bonilla, 1967 and 1970; Bonilla and Buchanan, 1970) or for the world (Ambraseys and Tchalenko, 1968; Bonilla and Buchanan, 1970). Various dislocation models have been proposed by seismologists (Aki, 1967; Brune, 1968; Chinnery, 1969; King and Knopoff, 1968 and 1969; Press, 1967; and Wyss and Brune, 1968) one of which (King and Knopoff, 1968) was used by Sanford et al. (1972) in connection with fault offset-magnitude comparisons in the Rio Grande Rift as discussed above. A recent recompilation and reconsideration of fault offset data has been performed by Slemmons (1977). He finds, for North America data and faulting of all types that

$$\log D = -4.47 + 0.67M$$

$$\log L = 1.61 + 0.44M$$

where both D (fault displacement) and L (fault length) are in meters. Using these formulas, fault lengths of 6.46, 10.72, 17.78, 29.51, 48.98, and 81.28 kilometers are found for magnitudes from 5.0 to 7.5 in half magnitude increments. The respective displacements are 0.08, 0.16, 0.35,

0.77, 1.66, and 3.59 meters. Thus, if an area has been mapped so well that no fault of length about 18 kilometers and maximum displacement of about 1/3 meter could escape notice in strata of a given age, then it could be maintained that no event of magnitude greater than or equal to 6.0 had occurred in that area in the time since formation of the strata. Explicit statements of the kind necessary about the minimum observable fault are not generally available in the literature. If it is assumed that the conclusion of Bachman and Johnson (1973), that no recent fault scarps of a tectonic nature exist in the Permian Basin, is applicable at the scale of the minimum observable fault associated with a magnitude 6.0 earthquake, then the conflict between the geologic and seismic recurrence data is resolved. That is, the recurrence data may not be extrapolated beyond magnitude 6.0. Arguments of this type, although they are clearly over-simplified and depend on relationships between magnitude and fault offset derived from widely scattered data, are of interest at least for purposes of comparison with similiar studies made in other areas.

A more complete treatment of this type would have to address the issue of regional deformation. This involves not only the offset associated with a single earthquake but the deformation implied by summing the effects of all earthquakes. If total strain energy released as seismic waves is calculated from the magnitude recurrence relations, estimates of total available strain energy and total implied steady state deformation may be derived. These are both dependent on the maximum magnitude event allowed, since significant strain and most of the energy are associated with the larger events (Richter 1958). Thus, general deformation rates may be derived as a function of maximum magnitudes, and observed deformation rates may be used to infer an acceptable maximum magnitude for the region over which deformation is observed. Unfortunately, application of this type of analysis is subject to more complication and uncertainty than a simple fault argument. It seems clear, however, that deformation of a type that would be associated with accumulation and release of elastic strain energy has not been very important in the Permian Basin for very long periods of time.

Although other explanations cannot be precluded, it seems that the most reasonable interpretations of seismic implications to tectonism at this time are:

1) Observed geologic and seismic data are in general agreement in the Rio Grande Rift and Southern Basin and Range zones and that future significant earthquakes can be expected there.

2) The current level of activity on the Central Basin Platform is probably related to fluid injection for secondary recovery of oil. This fluid injection makes it unwise to question the geologic data of the area solely on the basis of this high seismic activity level (see Chapter 10).

3) The geologic data, principally the lack of recent geologic faulting, and the seismic data for the High Plains province, in which the site lies, can probably be reconciled by imposing a maximum magnitude limit on the earthquakes that may occur here.

5.5 SUMMARY

Non-instrumental and regional instrumental studies of earthquakes prior to 1972 in southeastern New Mexico indicate that the most significant sources of earthquakes were the Central Basin Platform region near Kermit, Texas, and the area about 200 km or more west and southwest of the site (Rio Grande Rift Zone). The strongest earthquake reported to occur within 300 km is the intensity VIII Valentine, Texas, event of August 16, 1931, at a distance of approximately 210 km. The closest shock (as of 1972) reported from these studies was a magnitude 2.8 event on July 26, 1972, about 40 km northwest of the site. The record from regional studies of events west and southwest of the WIPP site 200 km or more is consistent with the record of Quaternary faulting in that area.

Instrumental studies near the WIPP site since 1974 and near Kermit, Texas, since late 1975 have recorded additional evidence of the seismic activity for the site and region. The pattern obtained from near the site is similar to that from regional studies; about one-half of the located events in the data set occur on the Central Basin Platform while most of the rest occur to the west and southwest of the site in the Rio Grande Rift Zone. The data set also includes three events within about 40 km of the WIPP site since 1972. Two events have been assigned magnitudes of 2.8 and 3.6; the third event (from 1978) has only preliminary data available.

Data reported for the Central Basin Platform from the Kermit, Texas, array continue to show that location as the most active seismic area within 300 km of the site in terms of number of events. The largest earthquake known to occur in the Central Basin Platform had, by the most recent estimate, a magnitude of less than 3-1/4. The activity appears equally likely to occur anywhere along the Central Basin Platform structure without particular regard to small scale structural details such as pre-Permian buried faults. The spatial and temporal coincidence of this seismicity with secondary petroleum recovery projects suggest a close relationship, but this has not yet been satisfactorily established. The lack of known Quaternary faults from the seismically active region of the Central Basin Platform is suggestive that large magnitude earthquakes are not occuring or have not occurred within the recent geologic past in the area.

Analysis of the regional and local seismic data indicate that the 1000 year acceleration is less than or equal to 0.06 g and the 10,000 year acceleration is less than or equal to 0.1 g for all models tried. Probabilities at which higher acceleration levels occur depend almost exclusively on the assumptions made about the seismic potential of the immediate site area.

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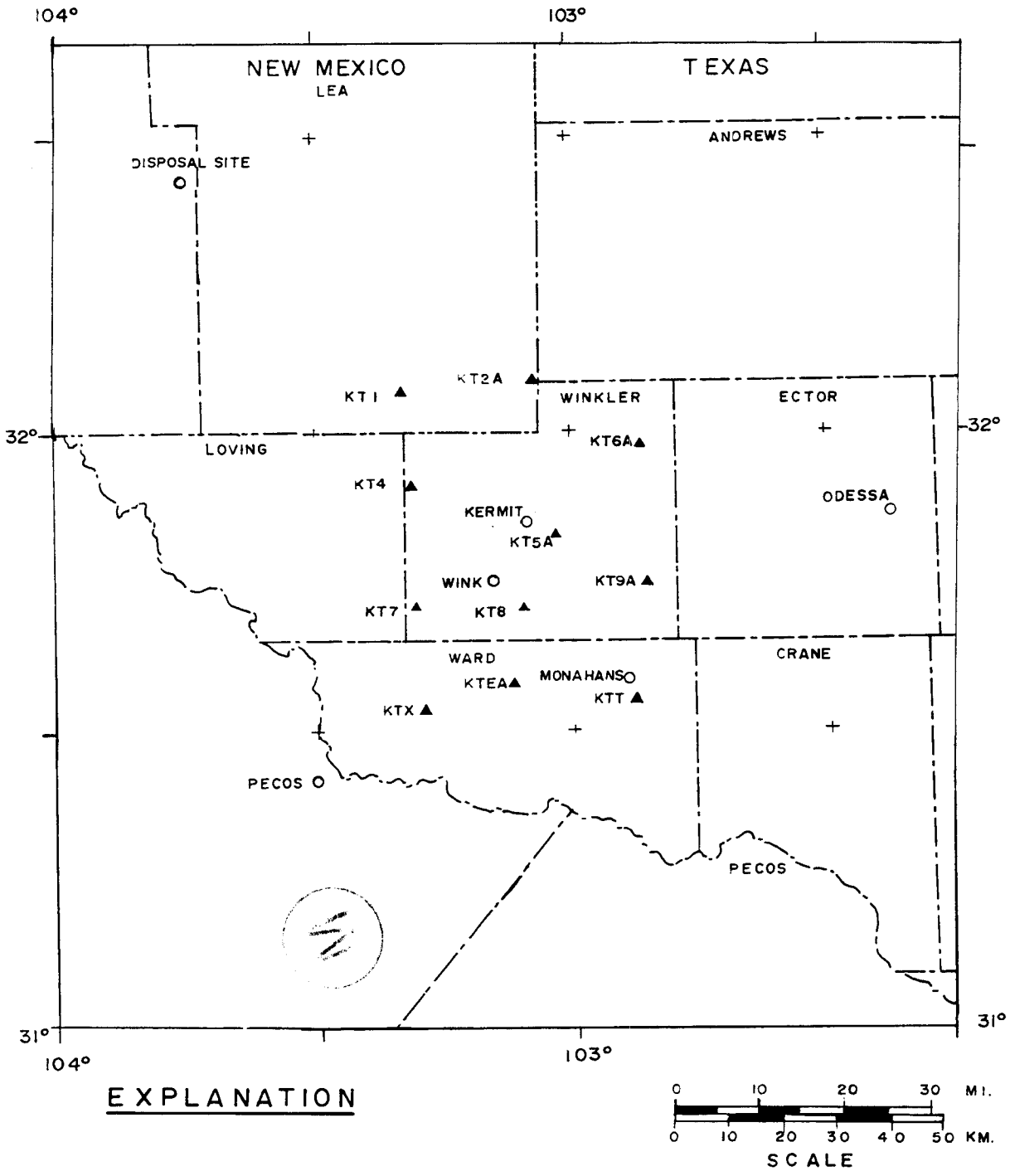
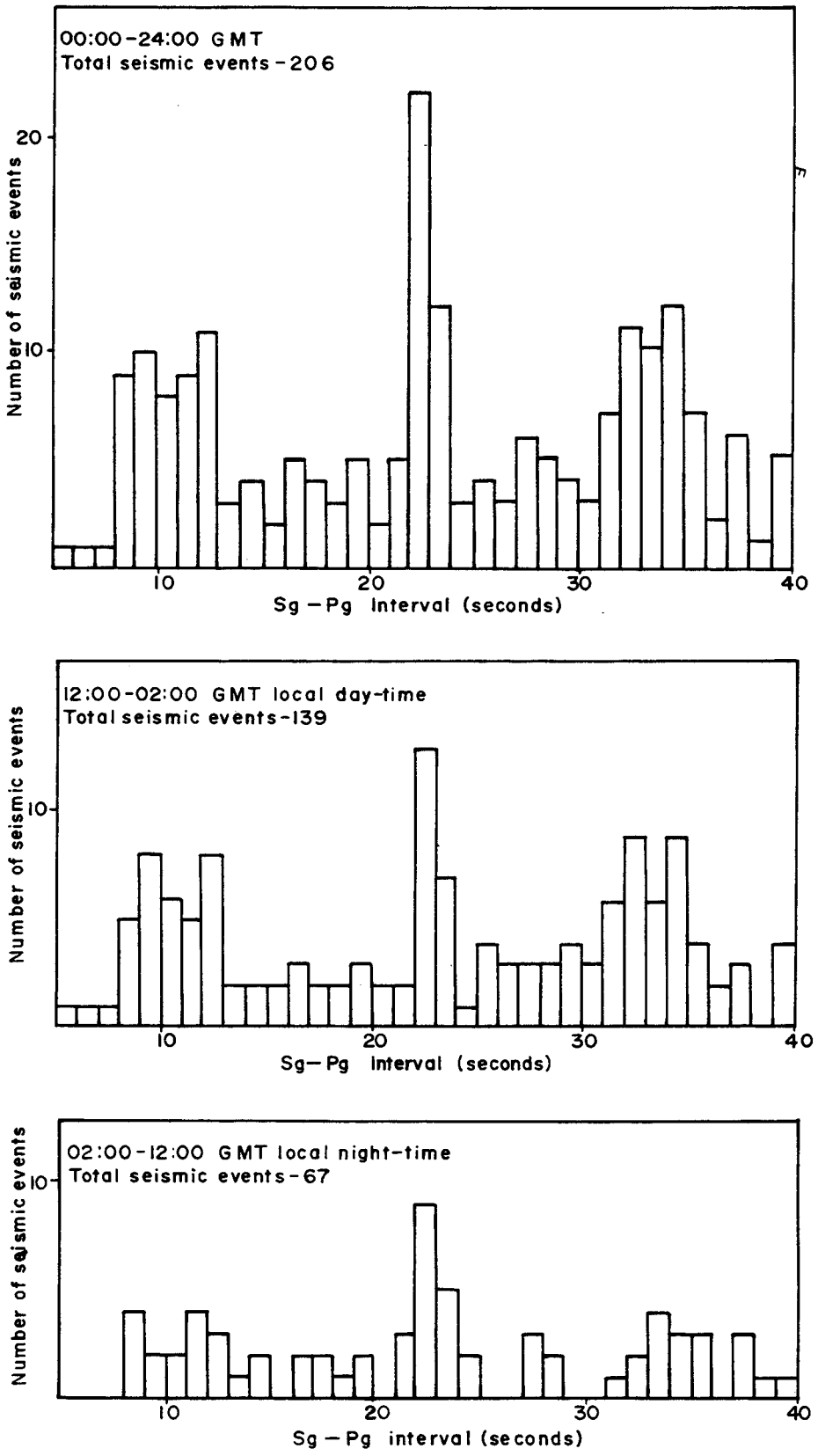


Current seismograph station locations in the Kermit array shown in relation to surrounding cultural features (from Rogers and Malkiel, 1978). Stations with an addended A have been moved from their original sites.

KERMIT ARRAY CONFIGURATION

FIGURE 5.2-5



EXPLANATION

Histograms of the number of earthquakes versus Sg-Pg interval for data collected at station CLN from April 5, 1974 to October 29, 1977. Total number of events in top frame is separated into two subsets in the lower frames.

REFERENCE:

Sanford et al., 1978

EVENT-DISTANCE HISTOGRAMS

FIGURE 5.2-4

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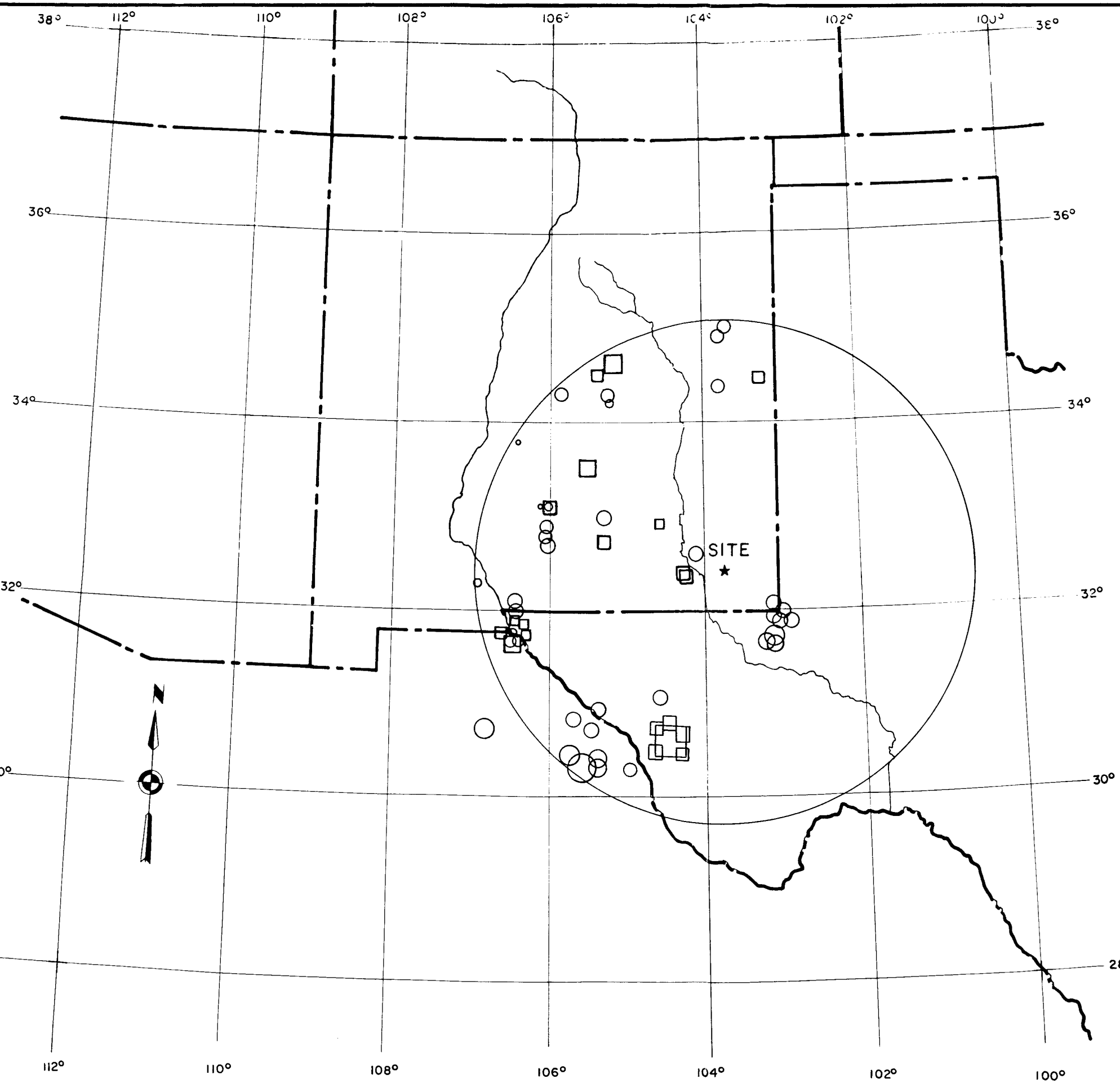

EXPLANATION

Locations of earthquakes within 300 km of the repository site. Locations shown with square symbols are based on reports of felt earthquakes prior to 1961. Epicenters shown with circles were determined instrumentally and cover the period 1961 through 1972. In the Central Basin Platform and Chihuahua areas where crowding occurs some epicenters are slightly offset for drafting convenience. The true epicenters are listed in Tables 5.2-1 and 5.2-3.

Local Magnitude	Maximum Intensity
∘ <1.5	□ III
○ 1.51-2.0	□ IV
○ 2.01-2.5	□ V
○ 2.51-3.0	□ VI
○ 3.01-3.5	□ VII
○ 3.51-4.0	□ VIII
○ 4.01-4.5	
○ 4.51-5.0	

0 100 200 300 KM
0 50 100 150 200 MI
SCALE

REFERENCE:

SANFORD AND TOPPOZADA (1974)

REGIONAL SEISMICITY 1923–1972

FIGURE 5.2-1

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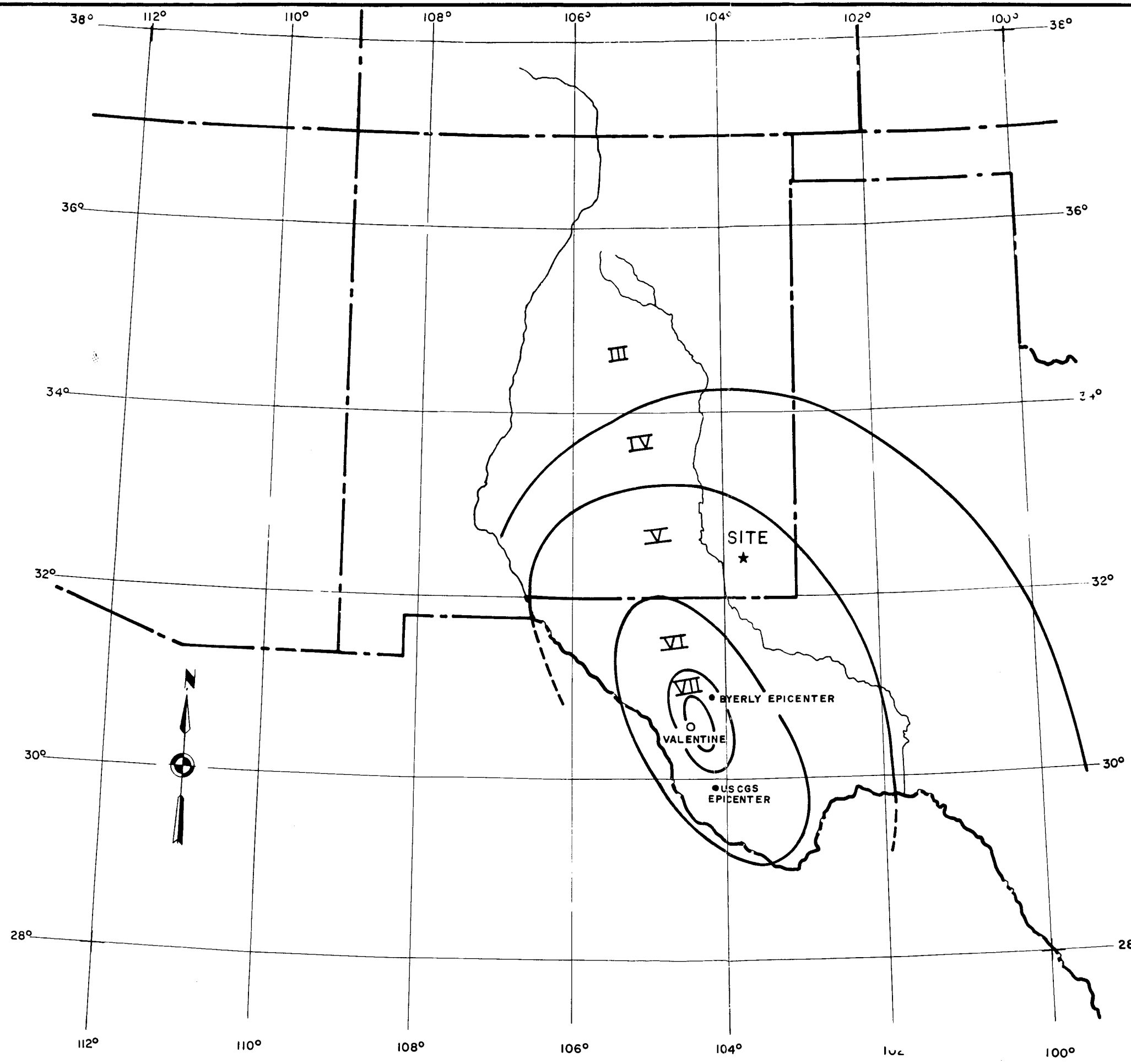
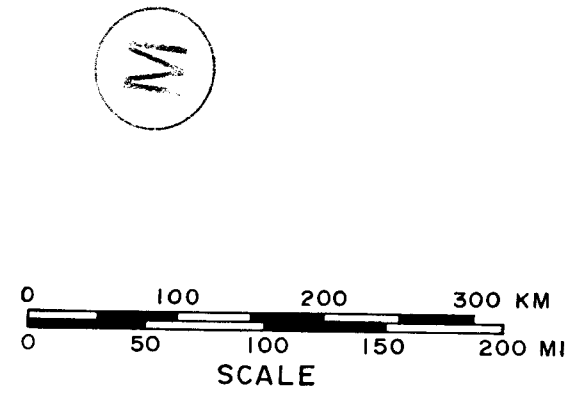
EXPLANATION

Isoseismal map for the Valentine, Texas earthquake of August 16, 1931 (after Sanford and Toppozada, 1974). Intensities are in the Modified Mercalli scale of 1931 (see Table 5.2-2). Also shown are the instrumental epicenters for this earthquake as determined by the U.S.C.G.S. (Neumann, 1932) and Byerly (1934).





VALENTINE, TEXAS EARTHQUAKE ISOSEISMALS

FIGURE 5.2-2

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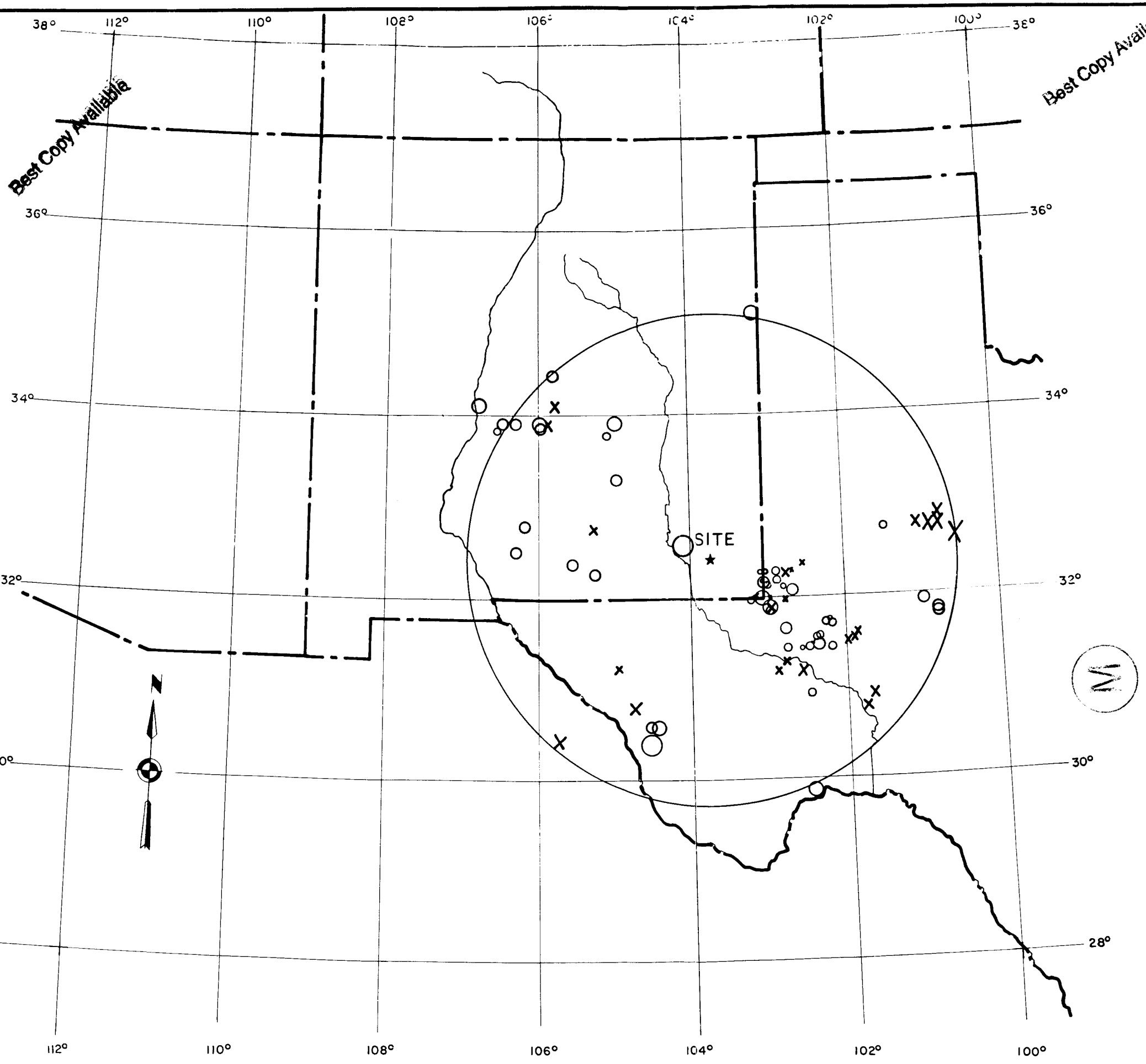

EXPLANATION

Epicenters of earthquakes within 300 km of the repository site located after the installation, and with the help, of Station CLN. Epicenters shown as circles are well located using phase arrival times from at least three and usually many more seismographic stations. Epicenters shown as X's are only tentative locations as explained in the text. In areas where crowding occurs some epicenters are slightly offset for drafting convenience. The true epicenters are listed in Tables 5.2-5 and 5.2-6.

Local Magnitude	Well-Determined Locations	Tentative Locations
<1.5	°	×
1.51-2.0	o	×
2.01-2.5	O	x
2.51-3.0	O	X
3.01-3.5	O	X
3.51-4.0	O	X
4.01-4.5	O	X

0 100 200 300 KM
0 50 100 150 200 MI
SCALE

REFERENCE:
SANFORD et al (1978)

EARTHQUAKES LOCATED AFTER INSTALLATION OF STATION CLN

FIGURE 5.2-3

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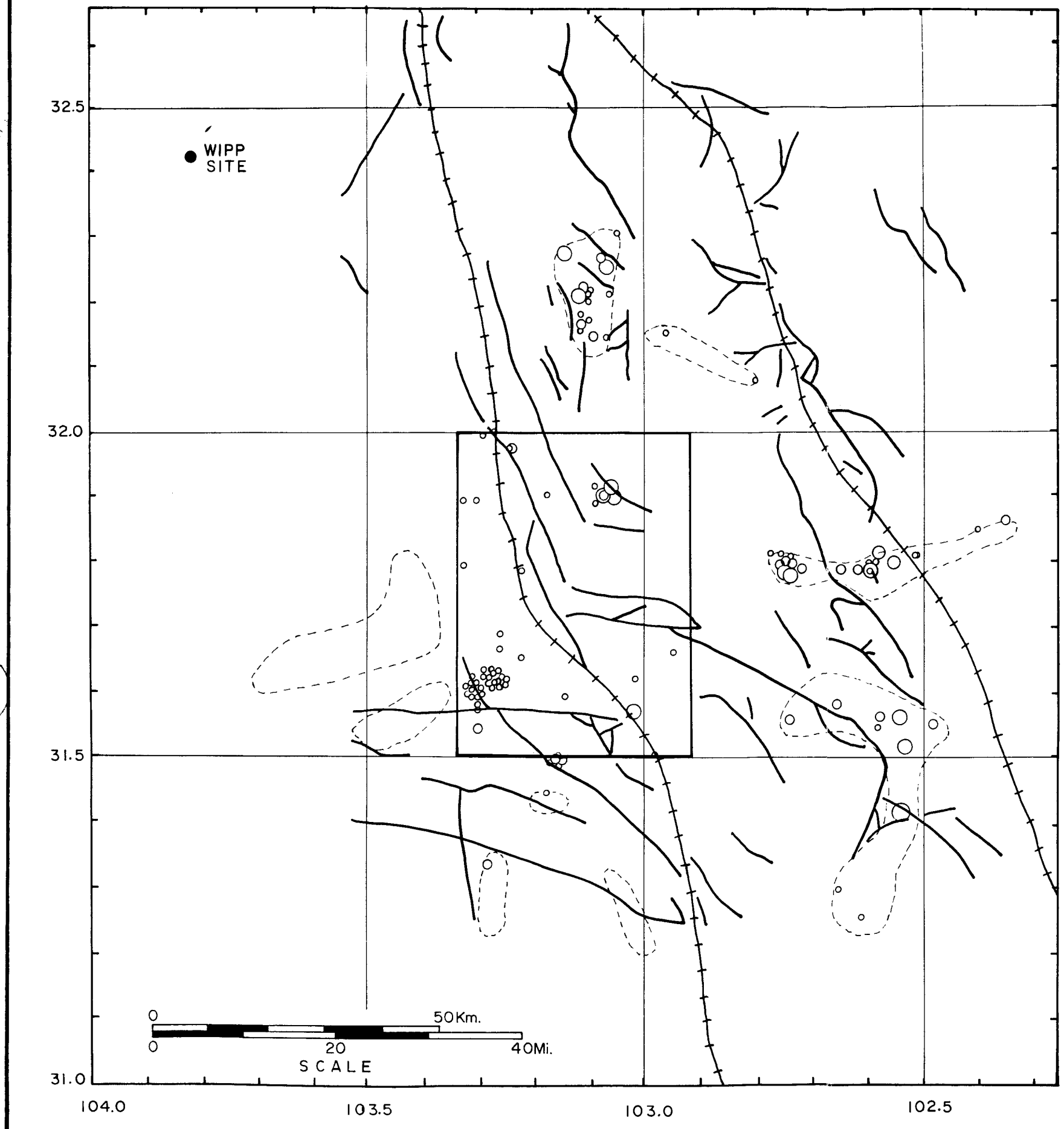

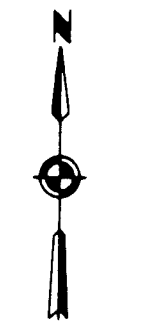

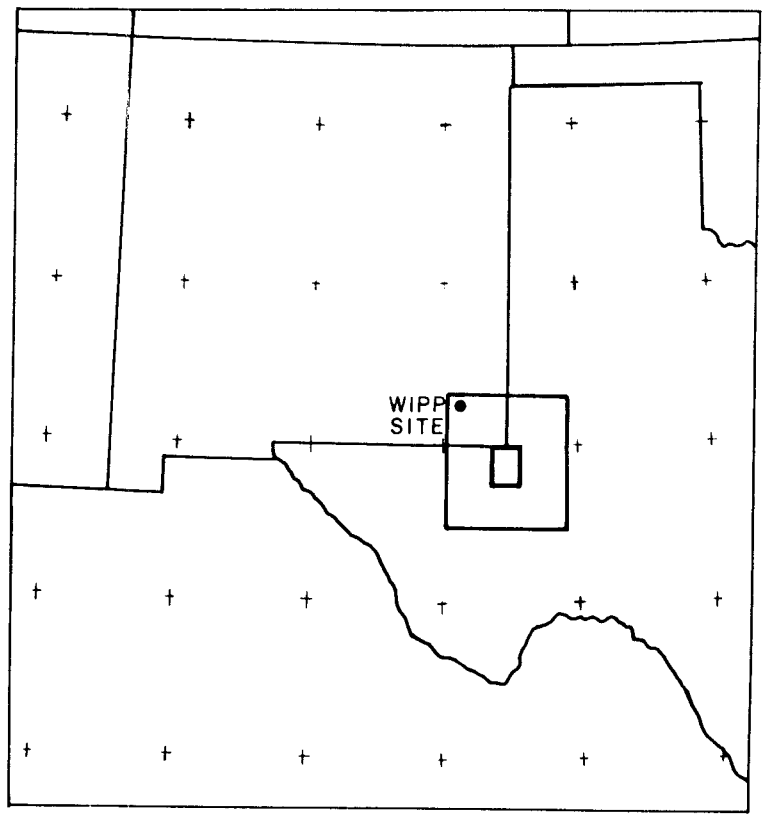

EXPLANATION

Earthquakes located using the Kermit array network. All located events within the array, denoted by the small rectangular area in the map to the left, are shown as well as those shocks on the array's periphery located by five or more array stations. The light dashed lines enclose peripheral epicenters whether or not they satisfy the five station criterion. Solid lines are pre-Permian faults, and the cross hatched lines the boundary of the Central Basin Platform both after Rogers and Malkiel, 1978. The regional location map above shows both the total map area to the left and the Kermit array limits in a large scale context.

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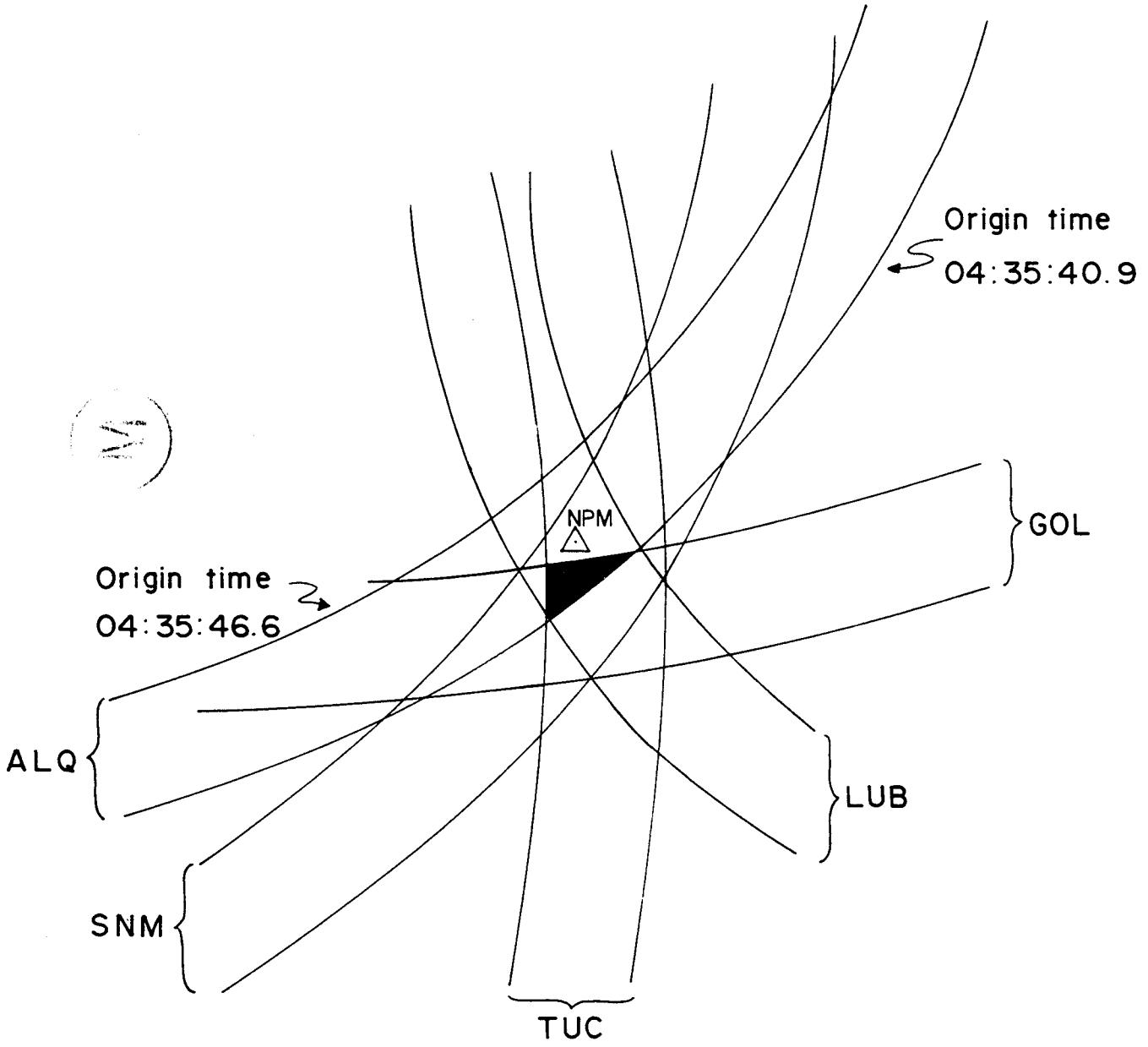
Magnitude

- ○ ≤ 2.35
- ○ 2.36 – 2.85
- ○ 2.86 – 3.35
- ○ ≥ 3.36

REFERENCE :
ROGERS AND MALKIEL (1978)

EVENTS LOCATED USING KERMIT ARRAY DATA

FIGURE 5.2-6



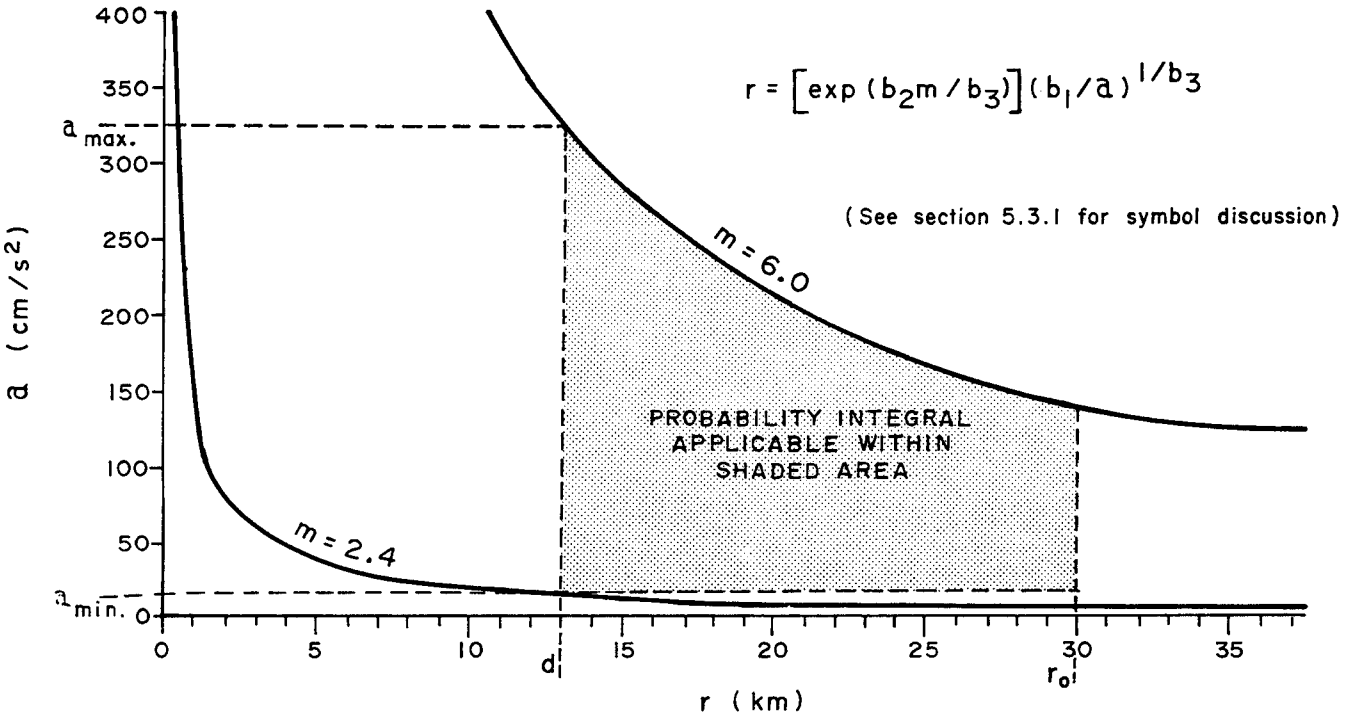
EXPLANATION

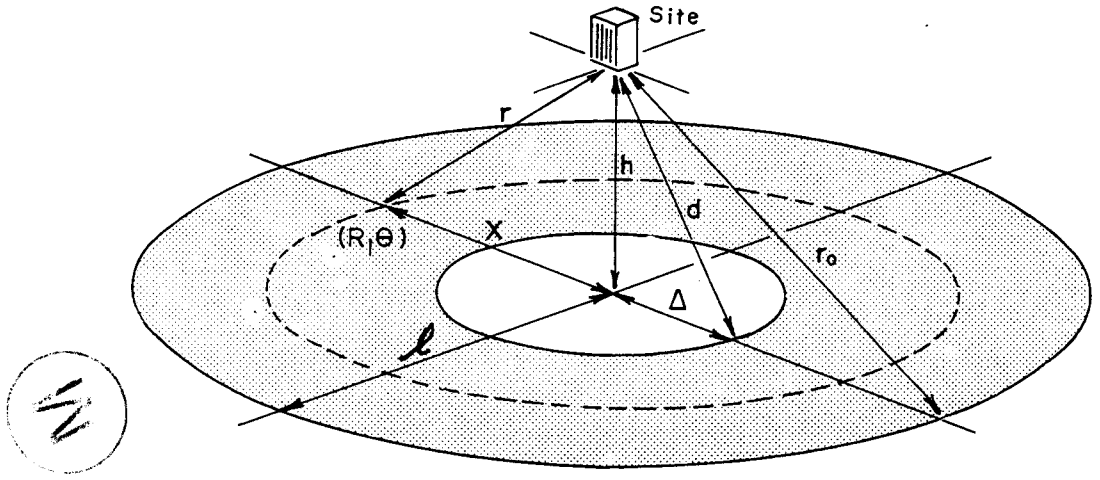
The area defined by arc intersections using the 95% confidence intervals for the origin time. NPM is the National Potash Company Eddy County Mine location. All arcs shown are for Pg waves. Actual area of mutual intersection is shaded.

REFERENCE: Caravella and Sanford, 1977.

LOCATION UNCERTAINTY
FOR THE JULY 26, 1972 EVENT

FIGURE 5.2-7





EXPLANATION

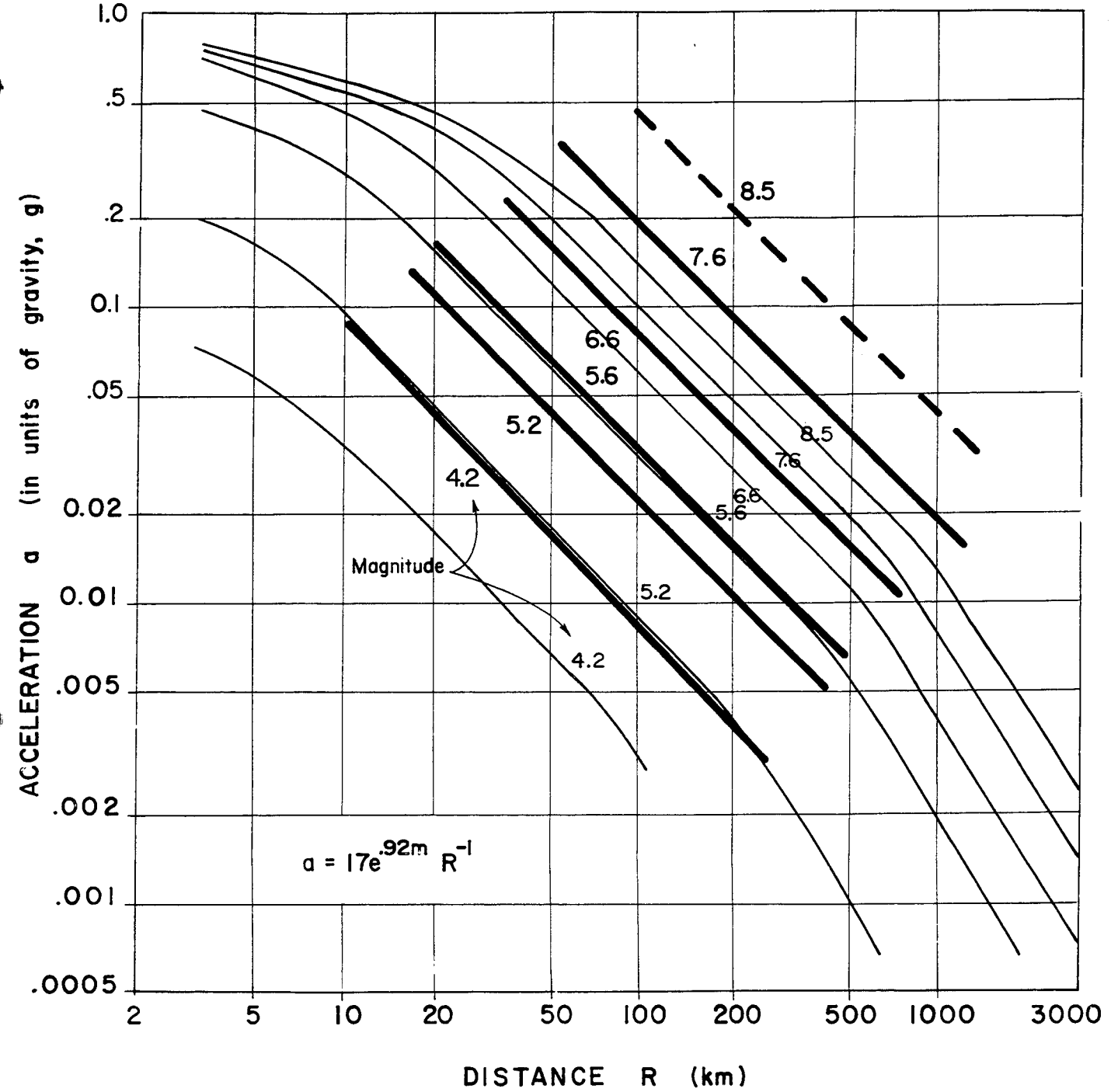
TOP - geometric and attenuation law constraints on limits of integration for the annular area probability integral. The shaded region represents values over which the probability is valid.

BOTTOM - schematic of annular source area showing variables of integration.

(After Cornell, 1968).

PARAMETERS FOR THE DETERMINATION OF PROBABILISTIC ACCELERATION

FIGURE 5.3-1



EXPLANATION

Comparison of acceleration attenuation curves for areas of the United States east of 105°W longitude after Algermissen and Perkins (1976) (light lines) with those used in the site hazard analysis of this report (heavy lines). The equation for the recommended attenuation curves is shown in the inset.

RECOMMENDED

ATTENUATION CURVES

FIGURE 5.3-2

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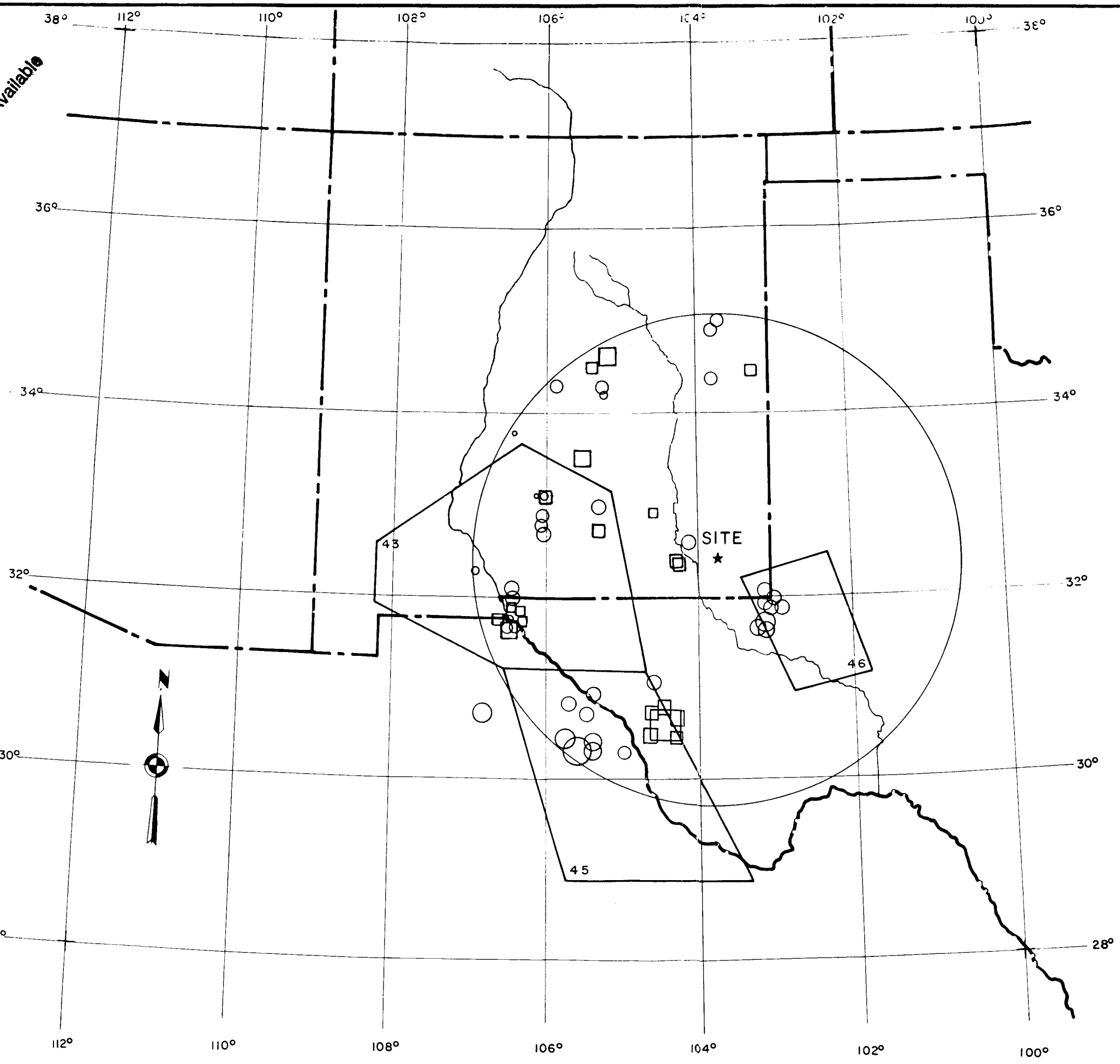

EXPLANATION

Seismic source zones are taken from Algermissen and Perkins (1976). The numbering of the three zones shown is in conformity with that study. For purposes of discussion Zones 43 and 45 are the Southern Basin and Range-Rio Grande rift source zones (northern and southern region respectively). Zone 46 is the Central Basin Platform source zone. Earthquake epicenters are exactly as shown in Figure 5.2-1 of this report. All information concerning them may be found in the explanation for that figure.

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0 100 200 300 KM
0 50 100 150 200 MI
SCALE

SEISMIC SOURCE ZONES

FIGURE 5.3-3

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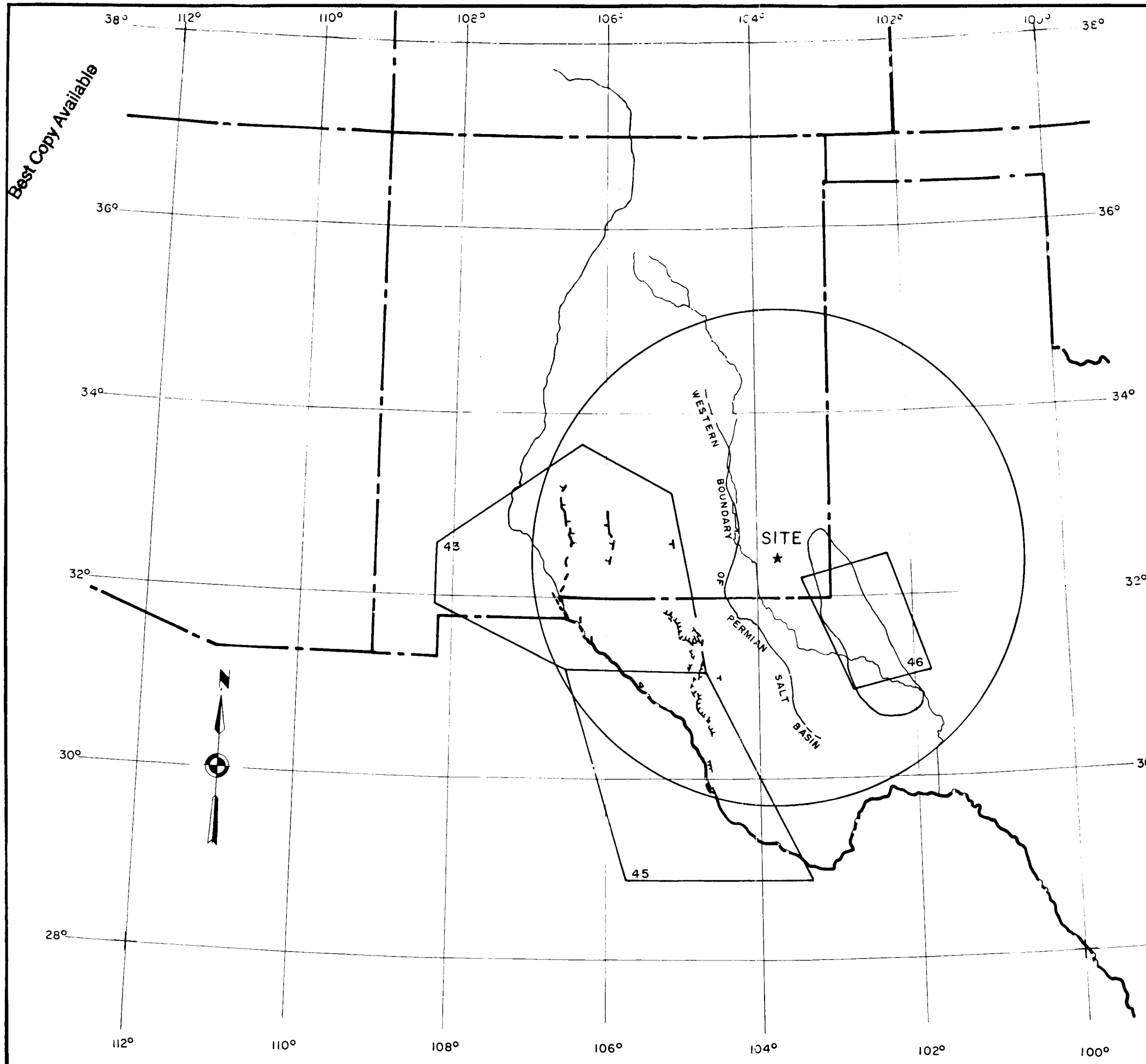

EXPLANATION

Seismic source zones are as shown in Figure 5.3-3 of this report. Plotted Quaternary faulting features are taken from Sanford and Toppozada (1974; Fig. 6) and Muehlberger et al (1978; Fig. 2). The western boundary of the Permian Salt Basin is taken from Figure 6 of Sanford and Toppozada (1974). The outline of the Central Basin Platform shown is taken from Rogers and Malkiel (1978).

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STRUCTURAL FEATURES IN THE SITE REGION

FIGURE 5.3-4

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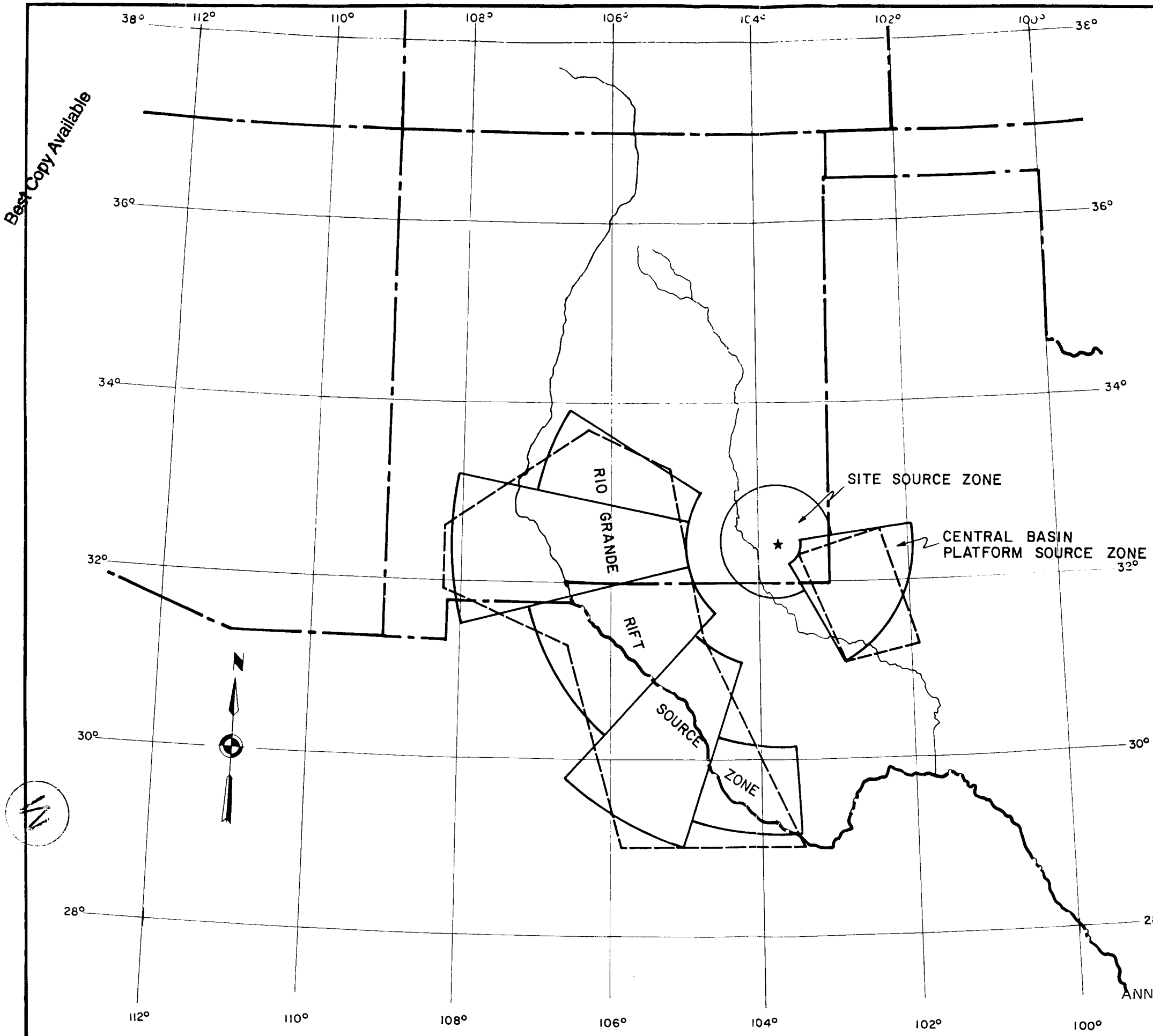
EXPLANATION

Annular segment source zones used in the seismic risk study. These source zones approximate the irregular polygon zones of Figure 5.3-3 which are also shown in dashed lines.



ANNULAR SEGMENT APPROXIMATION OF SOURCE ZONES

FIGURE 5.3-5

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ACCELERATION PROBABILITY CURVES – SET 1

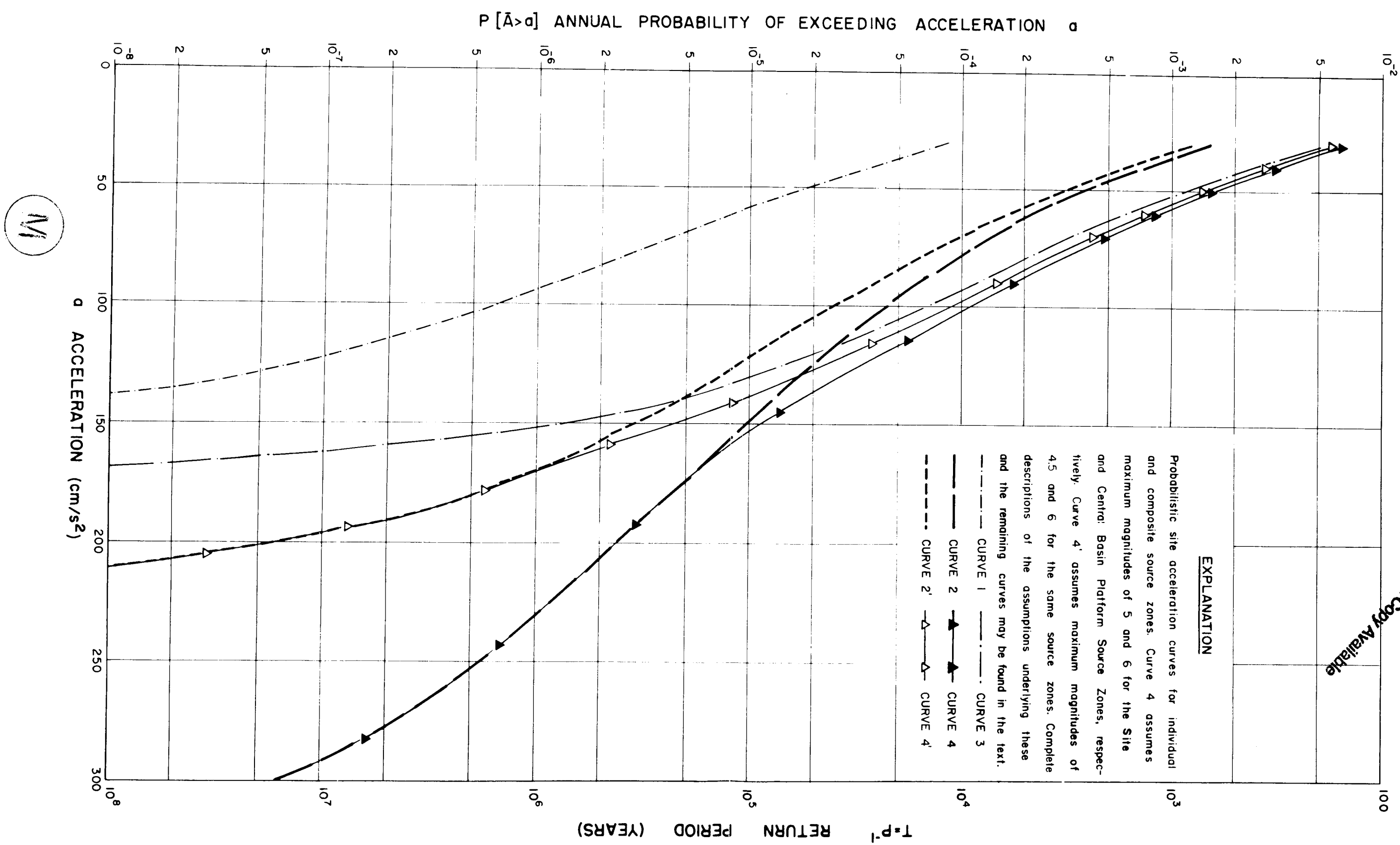

FIGURE 5.3-6

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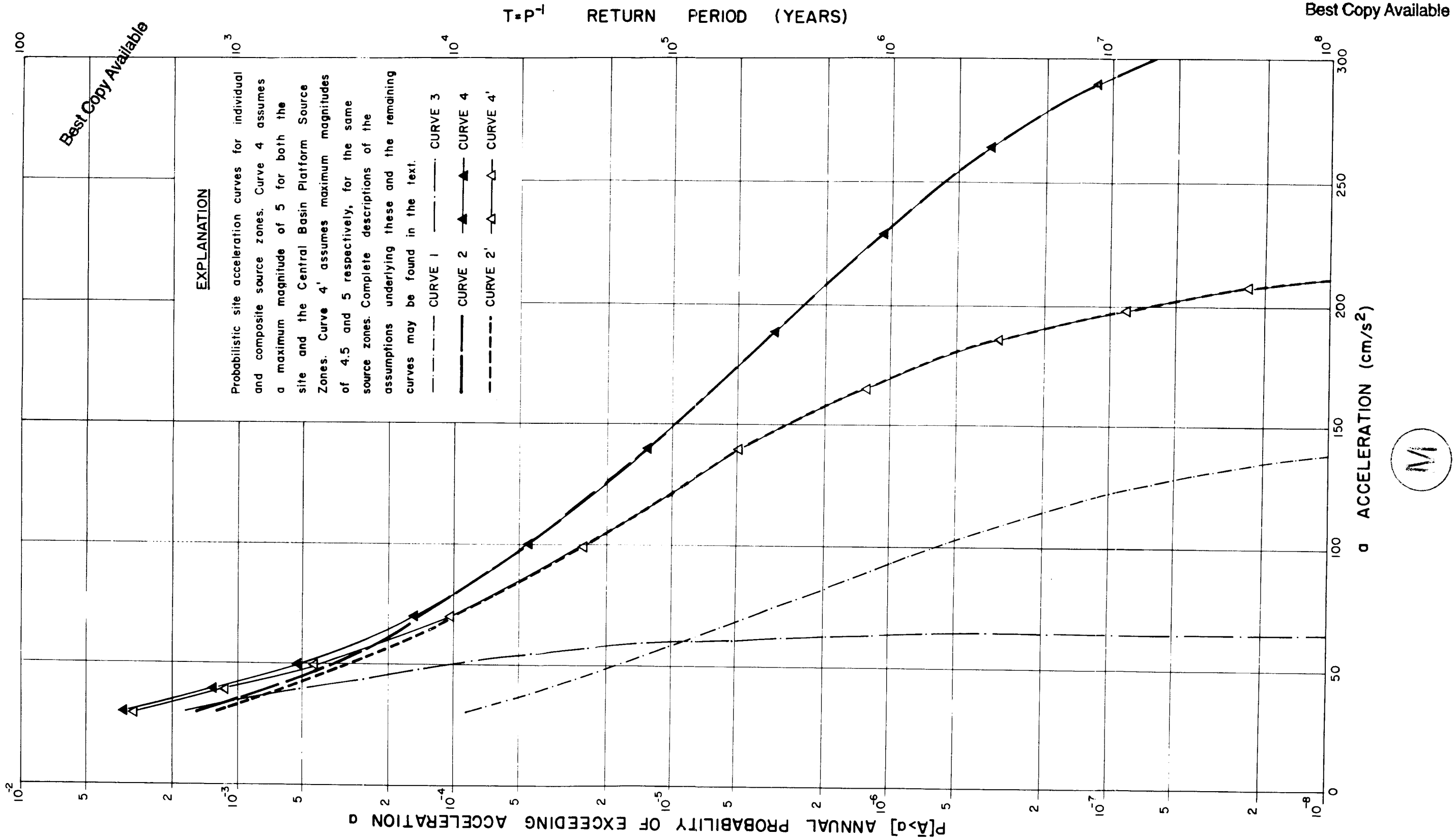

ACCELERATION PROBABILITY CURVES – SET 2

FIGURE 5.3-7

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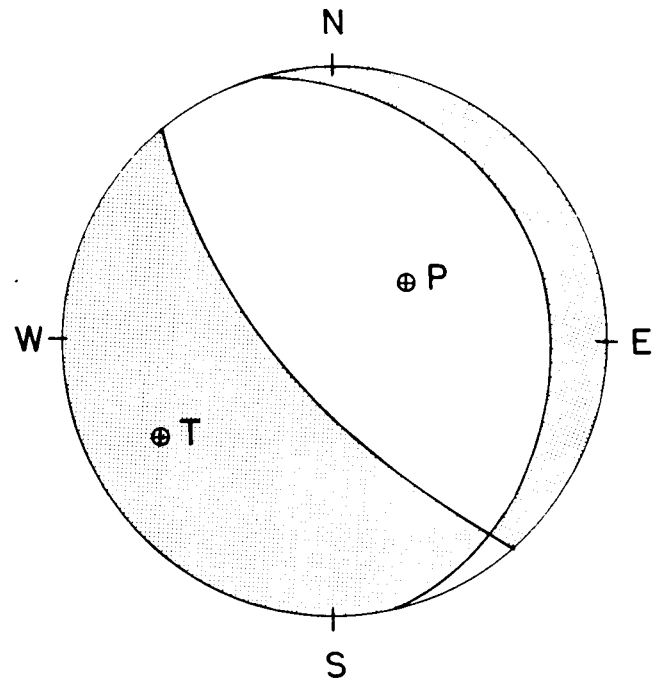
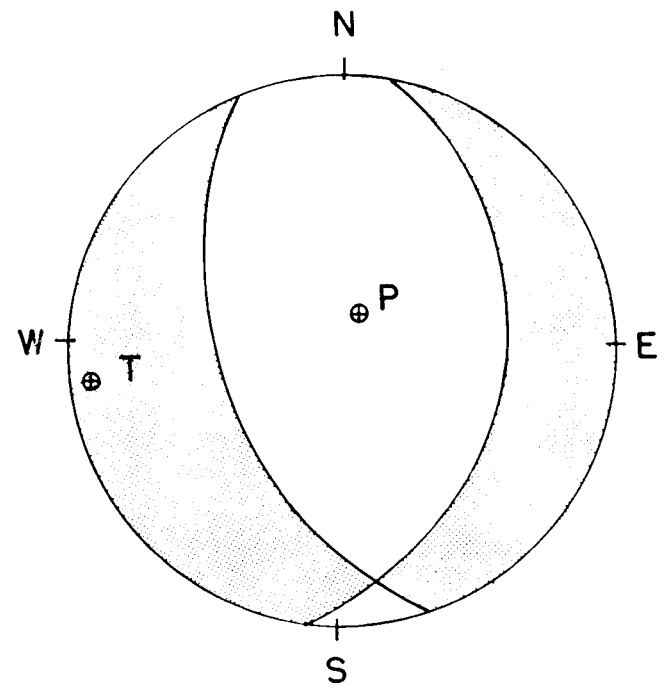
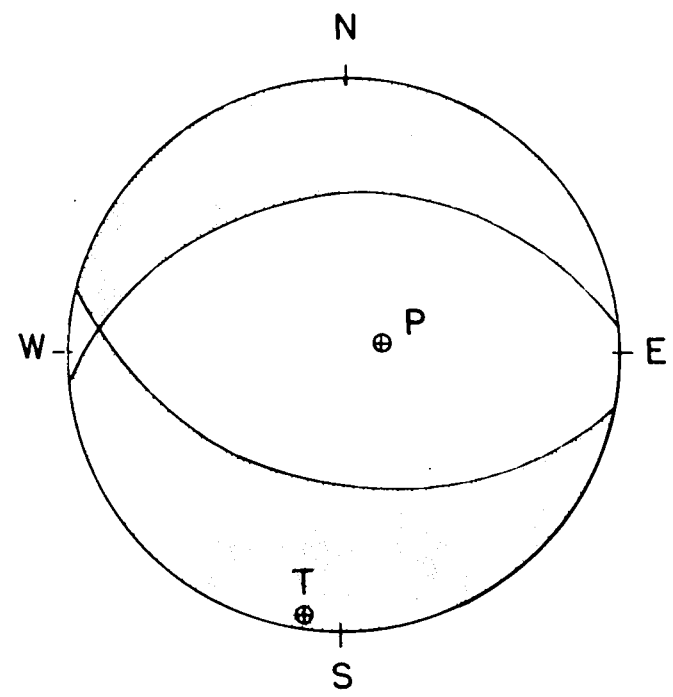


a



b



c

EXPLANATION

Plots of lower focal hemisphere projections of P-wave polarities for a) the August 16, 1931 Valentine, Texas earthquake, b) a composite solution for three small earthquakes on the Central Basin Platform which occurred in January, 1976, and c) one possible solution for an earthquake in the same area of the CBP ocurring on April 26, 1977. P is the maximum and T the minimum compressive stress axes for each solution.

REGIONAL FOCAL MECHANISM SOLUTIONS

FIGURE 5.4-1

Table 5.2-1

EARTHQUAKES OCCURRING BEFORE 1961 AND
CENTERED WITHIN 300 KILOMETERS OF THE SITE

DATE Yr/Mo/Day	ORIGIN TIME (GMT)	LOCATION	INTENSITY	DISTANCE (km)
23/03/07	04:03	El Paso, Tex.	V	260
26/07/17	22:00	Hope and Lake Arthur, N.M.	III	90
30/10/04	03:25	34.5°N 105.4°W	(IV)	280
31/08/16	11:40	Valentine, Tex.	VIII	210
31/08/16	19:33	Valentine, Tex.	(V)	210
31/08/18	19:36	Valentine, Tex.	V	210
31/08/19	01:36	Valentine, Tex.	(V)	210
31/10/02	?	El Paso, Tex.	(III)	260
31/11/03	14:50	29.9°N 104.2°W	(V)	295
35/12/20	05:30	34.4°N 103.2°W	III-IV	230
36/01/08	06:46	Carlsbad, N.M.	(IV)	40
36/08/08	01:40	El Paso, Tex.	(III)	260
36/10/15	~18:00	El Paso, Tex	(III)	260
37/03/31	22:45	El Paso, Tex.	(IV)	260
37/09/30	06:15	Ft. Stanton, N.M.	(V)	200
43/12/27	04:00	Tularosa, N.M.	IV	220
49/02/02	23:00	Carlsbad, N.M.	(IV)	40
49/05/23	07:22	34.6°N 105.2°W	IV	280
52/05/22	04:20	Dog Canyon, N.M.	IV	158
55/01/27	00:37	Valentine, Tex.	IV	210

MODIFIED MERCALLI INTENSITY SCALE OF 1931

[Abridged]

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel scale.)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale.)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale.)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. (IV to V Rossi-Forel scale.)

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale.)

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale.)

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. (VIII Rossi-Forel scale.)

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars. (VIII+ to IX Rossi-Forel scale.)

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+Rossi-Forel scale.)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel scale.)

XI. Few, if any (masonry), structures remain standing. Bridges destroyed, Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

INSTRUMENTALLY LOCATED EARTHQUAKES WITHIN 300 KM OF THE LOS MEDANOS SITE: 1962-1972

DATE Yr/Mo/Day	ORIGIN TIME GMT	LOCATION Lat N/Long W		MAGNITUDE M L
69 May 12	08:26:18	32.0	106.4	3.0
69 May 12	08:49:16	32.0	106.4	2.6
69 Jun 1	17:18:24	34.2	105.2	2.0
69 Jun 8	11:36:02	34.2	105.2	2.4
69 Oct 19	11:51:34	30.8	105.7	2.8
71 Jul 30	01:45:50	31.7	103.1	3.1
71 Jul 31	14:53:48	31.6	103.1	3.2
71 Sep 24	01:01:54	31.6	103.2	3.0
72 Feb 27	15:50:04	32.9	106.0	2.3
72 Jul 26	04:35:44	32.6	104.1	2.8
72 Dec 9	05:58:39	31.7	106.4	2.2
72 Dec 10	14:37:50	31.7	106.5	2.2
72 Dec 10	14:58:02	31.7	106.5	1.8

INSTRUMENTALLY LOCATED EARTHQUAKES WITHIN 300 KM OF THE LOS MEDANOS SITE: 1962-1972

DATE Yr/Mo/Day	ORIGIN TIME GMT	LOCATION Lat N/Long W		MAGNITUDE M L
62 Mar 3	18:16:47	33.8	106.4	1.2
62 Mar 6	09:59:10	31.1	104.6	3.0
64 Feb 11	09:24:10	34.4	103.7	2.5
64 Mar 3	01:26:27	35.0	103.6	2.2
64 Jun 18	20:20:18	33.1	106.1	1.2
64 Jun 19	05:28:39	33.1	106.0	1.7
64 Oct 20	00:53:00	30.7	106.8	3.1
64 Nov 8	09:26:00	31.9	103.0	2.7
64 Nov 21	11:21:24	31.9	103.0	2.5
65 Feb 3	19:59:32	31.9	103.0	3.0
65 Apr 13	09:35:46	30.3	105.0	2.5
65 Aug 30	05:17:30	31.9	103.0	2.6
66 Aug 14	15:25:47	31.9	103.0	2.8
66 Aug 17	18:47:21	30.7	105.5	2.9
66 Aug 19	04:15:44	30.3	105.6	4.6
66 Aug 19	08:38:21	30.3	105.6	3.6
66 Sep 17	21:30:13	34.9	103.7	2.2
66 Nov 26	20:05:41	30.9	105.4	2.6
66 Nov 28	02:20:57	30.4	105.4	3.3
66 Dec 5	10:10:37	30.4	105.4	3.3
67 Sep 29	03:52:48	32.3	106.9	2.0
68 Mar 9	21:54:26	32.7	106.0	2.9
68 Mar 23	11:53:39	32.7	106.0	2.3
68 May 2	02:56:44	33.0	105.3	2.6
68 Aug 22	02:22:26	34.3	105.8	2.1

Table 5.2-4

INTERRUPTIONS IN OPERATION OF SEISMOGRAPH STATION CLN.

From		To		Cause
Time	Date	Time	Date	
Records were not obtained for the following periods:				
08:34	April 29, 1974	20:39	May 1, 1974	Recorder ran out of film.
13:13	May 18, 1974	07:03	May 19, 1974	Developing error.
07:18	May 31, 1974	13:32	June 12, 1974	Operating error changing film.
03:31	June 20, 1974	15:47	June 25, 1974	Developing error.
08:08	Sept 1, 1974	07:05	Sept. 2, 1974	Ran out of film.
17:09	Sept. 27, 1974	21:35	Sept. 28, 1974	Ran out of film.
03:23	Dec. 24, 1974	19:20	Jan. 5, 1975	Film broke.
07:37	May 28, 1975	18:08	June 7, 1975	Galvanometer light burned out.
20:23	June 21, 1975	18:20	July 4, 1975	Film broke.
17:50	Oct. 12, 1975	19:16	Oct. 26, 1975	Programmer-chronometer removed for repair.
19:31	Nov. 8, 1975	23:22	Jan. 12, 1976	Loss of power from thermal-electric generator.
12:40	Nov. 20, 1976	19:35	Jan. 17, 1977	Failure of voltage regulator on thermal-electric generator.
19:35	May 23, 1977	18:49	June 4, 1977	Film advance inoperative.
19:18	Sept. 13, 1977	18:20	Sept. 17, 1977	Film advance inoperative.
22:20	Oct. 6, 1977	18:47	Oct. 8, 1977	Film advance inoperative.
Station was operating without internal time for the following periods:				
22:01	May 1, 1974	07:18	May 31, 1974	Programmer-chronometer malfunction.
23:55	Aug. 18, 1974	23:55	Sept. 1, 1974	" " "
22:30	Nov. 28, 1974	03:23	Dec. 24, 1974	" " "

Table 5.2-5

WELL DETERMINED EPICENTRAL LOCATIONS
FOR
EARTHQUAKES AFTER INSTALLATION OF STATION CLN

DATE Yr/Mo/Day	ORIGIN TIME	LOCATION Lat°N/Long°W	DISTANCE to CLN (km)	CLN MAGNITUDE
74/08/26	07:33:22.0	34.4 105.8	305.9	2.4
74/09/26	23:44:08.5	32.8 106.2	235.8	2.4
74/10/15	10:07:57.9	33.9 106.5	316.9	2.3
74/11/01	10:45:49.6	33.8 106.6	314.9	2.0
74/11/12	02:31:57.3	31.9 100.8	288.9	2.5
74/11/12	07:14:28.5	31.9 100.8	273.7	2.2
74/11/21	16:22:58.6	32.5 106.3	240.3	2.4
74/11/21	18:59:05.8	32.1 102.7	105.7	2.1
74/11/22	08:54:05.1	32.8 101.5	213.6	2.0
74/11/22	14:11:13.2	33.8 105.1	211.7	1.9
74/11/28	03:35:20.5	32.6 104.1	43.1	3.6
75/02/02	20:39:22.6	35.1 103.1	317.3	2.7
75/07/25	08:11:40.0	29.9 102.5	309.8	2.8
75/08/01	07:27:47.3	30.4 104.6	239.3	3.9
75/10/10	11:16:55.9	33.3 105.0	160.4	2.1
76/01/10	01:49:57.0	31.7 102.8	123.4	2.1
76/01/14	07:01:31.5	34.1 106.8	353.7	2.6
76/01/19	04:03:30.4	31.9 103.0	93.8	2.4
76/01/22	07:21:57.8	31.9 103.0	89.1	2.0
76/01/25	04:48:27.5	32.0 103.1	80.2	2.9
76/01/28	07:37:48.5	32.0 101.0	262.9	2.4
76/03/18	23:07:04.8	32.2 102.9	77.9	1.6
76/03/20	16:15:58.0	32.2 103.1	63.8	1.4
76/03/27	22:25:22.0	32.2 103.1	64.1	1.8

Table 5.2-5 (Continued)

DATE Yr/Mo/Day	ORIGIN TIME	LOCATION Lat°N/Long°W	DISTANCE to CLN (km)	CLN MAGNITUDE
76/04/01	14:46:58.0	33.9 106.0	275.5	2.6
76/04/06	18:09:00.2	33.9 105.0	208.6	2.7
76/04/18	03:48:18.5	33.9 106.0	271.2	2.1
76/04/21	08:40:05.5	32.3 102.9	81.4	1.7
76/05/03	06:52:59.0	32.4 105.6	182.4	2.4
76/05/06	17:18:23.8	32.0 103.2	71.9	1.8
76/05/21	13:17:35.0	32.3 105.3	149.0	2.2
76/06/15	02:19:58.3	31.6 102.4	158.4	1.7
76/06/15	08:50:20.0	31.5 102.4	164.0	2.1
76/08/10	09:03:11.6	31.8 102.2	158.0	1.4
76/08/10	10:15:13.8	31.8 102.2	166.0	1.7
76/08/25	01:27:48.5	31.5 102.5	156.3	1.8
76/08/26	15:22:12.7	31.8 102.2	160.8	1.7
76/08/30	11:51:25.2	31.5 102.6	145.9	1.4
76/08/30	13:07:47.5	33.9 106.3	297.8	2.3
76/08/31	12:46:22.4	31.5 102.8	130.6	1.9
76/09/05	10:39:45.7	32.2 102.8	93.8	1.4
76/09/17	02:47:46.9	32.2 103.1	62.7	2.1
76/09/19	10:40:46.4	30.6 104.5	222.9	3.0
76/10/14	11:02:59.7	32.3 103.1	63.9	0.9
76/10/22	05:06:11.8	31.5 102.2	176.2	2.0
76/10/23	12:51:36.9	31.6 102.4	161.6	1.6
76/11/03	23:24:14.7	31.0 102.5	199.3	1.8
77/01/29	09:40:43.5	30.6 104.6	220.0	2.1
77/02/10	01:22:49.4	32.3 103.1	60.2	1.0

Table 5.2-6

TENTATIVE EPICENTRAL LOCATIONS FOR
EARTHQUAKES AFTER INSTALLATION OF STATION CLN

DATE Yr/Mo/Day	ORIGIN TIME	LOCATION Lat°N/Long°W		DISTANCE TO CLN (km)	CLN MAGNITUDE
74/08/17	07:35:18	30.4	105.8	300	3.5
76/03/20	12:42:20	31.2	105.0	180	2.3
76/04/01	14:40:26	34.1	105.8	280	2.8
76/04/01	14:51:17	33.9	105.9	270	2.8
76/05/04	15:05:40	32.0	103.2	70	1.9
76/05/08	11:46:38	32.0	102.8	100	1.8
76/05/11	23:04:38	32.3	102.8	90	1.9
76/05/26	11:52:26	32.4	102.6	110	1.7
76/06/14	23:29:50	31.6	101.9	200	2.3
76/06/16	14:05:12	31.6	101.9	200	2.3
76/08/05	22:23:29	30.8	101.8	260	3.0
76/08/25	01:21:01	32.8	101.1	260	2.8
76/09/10	23:17:48	30.9	101.7	260	2.8
76/10/13	19:11:06	32.0	103.0	90	1.5
77/03/14	10:10:22	32.9	100.8	290	3.5
77/03/19	21:27:49	31.3	102.8	160	2.2
77/03/20	07:54:05	32.3	102.8	90	2.3
77/04/12	23:18:27	31.2	102.6	170	2.9
77/04/16	06:44:22	31.2	102.9	160	2.1
77/04/17	21:47:07	31.5	102.0	190	2.1
77/04/26	09:03:05	31.9	103.0	100	2.6
77/06/07	23:01:17	32.7	100.6	300	4.5
77/06/08	00:51:29	32.8	100.8	280	4.0
77/06/17	03:37:05	32.8	100.9	270	3.9
77/08/03	02:11:48	32.8	105.3	150	2.5
77/08/21	03:01:16	30.8	104.8	210	3.4

Table 5.2-7

Central Basin Platform earthquakes recorded at Ft. Stockton Station (FOTX) from June 21, 1964 through April 12, 1965*

Date Yr/Mo/Day	FOTX-P Arrival Time GMT	FOTX-S-P Interval Secs.	LC-P Arrival Time GMT
64/06/22	07:07:47	14	07:08:22
64/07/13	12:20:03	14	
64/07/13	16:18:17	14	
64/07/19	02:34:16	13	
64/08/14	14:56:37	14	14:57:11
64/09/07	13:42:36	14	13:43:10
64/09/08	22:06:20	15	
64/09/11	12:33:08	14	
64/11/08	09:26:19	S**	09:26:53
64/11/16	02:06:05	15	
64/11/17	08:05:14	14	
64/11/18	10:20:30	14	
64/11/19	11:39:59	14	
64/11/19	11:40:30	14	
64/11/21	11:21:42	S**	11:22:17
64/11/23	03:30:18	14	
64/11/25	23:18:43	14	
64/11/26	00:03:13	14	
64/11/27	16:29:53	14	16:30:28
64/11/28	23:46:55	14	
64/12/01	20:59:50	13	
64/12/01	06:49:47	13	
64/12/05	23:09:43	14	
64/12/07	06:24:12	14	
64/12/07	06:31:40	14	
64/12/08	17:16:02	14	
64/12/13	19:19:19	13	
64/12/14	15:20:26	14	
64/12/26	00:08:29	14	
65/01/08	14:01:13	14	
65/01/12	20:35:19	14	
65/01/12	20:49:38	14	
64/01/21	11:51:51	14	
65/02/02	09:59:19	13	
65/02/03	19:59:52	S**	20:00:27
65/03/08	21:00:01	14	
65/03/09	03:46:18	14	
65/04/02	07:30:58	14	

* Listing of shocks restricted to events whose maximum peak to peak amplitudes exceeded 20 mm.

** Earthquake too strong on the seismogram to read S-P interval

Table 5.2-8

EARTHQUAKES IN THE CBP LOCATED WITH REGIONAL STATIONS BETWEEN 1962-1972

DATE Yr/Mo/Day	ORIGIN TIME (GMT)	LOCATION Lat°N/Long°W		MAGNITUDE
64/11/08	09:26:00	31.9	103.0	2.7
64/11/21	11:21:24	31.9	103.0	2.5
65/02/03	19:59:32	31.9	103.0	3.0
65/08/30	05:17:30	31.9	103.0	2.6
66/08/14	15:25:47	31.9	103.0	2.8
71/07/30	01:45:50	31.7	103.1	3.1
71/07/31	14:53:48	31.6	103.1	3.2
71/09/24	01:01:54	31.6	103.2	3.0

Table 5.2-9
EARTHQUAKES LOCATED WITHIN THE
KERMIT ARRAY NOV 75-JUL 77

Date	Origin time	Lat N	Long W	Depth	M_L	#Sta
1976						
Jan 19	04:03:30.4	31.91	103.07	0.12	3.47	6
22	07:21:57.0	31.90	103.08	0.01	2.83	9
25	04:48:27.7	31.90	103.08	0.89	3.92	9
Feb 25	22:22:59.4	31.78	103.23	0.03	-	4
May 03	08:00:40.1	31.99	103.29	5.56	1.96	5
03	11:27:41.8	32.00	103.27	6.54	2.00	5
04	15:05:39.1	31.97	103.24	0.16	2.32	5
06	17:18:23.6	31.97	103.23	6.88	2.59	6
08	11:46:41.8	31.90	103.18	1.17	1.90	6
27	21:16:06.9	31.89	103.30	5.00*	1.60	3
28	16:15:23.6	31.89	103.32	5.00*	1.49	3
Jun 18	16:51:18.4	31.79	103.32	5.00*	1.68	3
Aug 05	18:53:09.2	31.57	103.02	9.29	3.01	4
Sep 05	16:10:27.7	31.61	103.31	5.00*	2.24	3
10	19:18:43.4	31.91	103.09	5.00*	2.25	3
Nov 04	23:27:54.0	31.67	103.26	0.12	1.74	4
05	22:55:30.4	31.65	103.22	5.00*	1.63	3
06	22:30:23.6	31.68	103.26	0.16	1.64	4
Dec 18	18:27:45.7	31.62	103.02	0.17	2.26	6
24	07:34:53.3	31.61	103.30	5.00*	1.45	3
25	12:58:34.9	31.63	103.29	0.41	1.18	4
26	12:15:04.6	31.63	103.26	0.00	1.17	4

Table 5.2-9
EARTHQUAKES LOCATED WITHIN THE
KERMIT ARRAY NOV 75-JUL 77

Date	Origin time	Lat N	Long W	Depth	M_L	# Sta
1977						
Jan 08	20:20:27.2	31.50	102.98	5.00*	1.95	3
14	13:33:33.4	31.60	103.31	5.00*	1.12	3
18	04:39:59.5	31.61	103.27	0.52	0.25	4
20	23:01:01.2	31.61	103.27	5.00*	1.75	3
Mar 12	00:05:23.8	31.62	103.29	5.00*	1.90	3
24	10:31:36.3	31.61	103.27	3.93	0.81	4
24	21:13:10.4	31.67	102.95	2.65	1.77	4
29	00:35:34.9	31.62	103.27	3.43	1.67	5
Apr 03	13:48:09.2	31.49	103.17	0.12	2.36	5
03	14:24:07.1	31.49	103.17	0.04	2.43	6
04	00:44:05.3	31.48	103.17	0.29	2.37	5
04	04:35:56.8	31.50	103.17	0.41	2.11	6
04	04:47:29.9	31.49	103.17	0.17	1.77	5
04	21:40:16.3	31.59	103.31	5.00*	1.68	3
04	22:55:54.0	31.59	103.30	5.00*	1.77	3
05	19:23:03.2	31.58	103.30	5.00*	1.60	3
06	23:22:30.9	31.59	103.31	5.00*	1.66	3
07	18:56:55.6	31.59	103.30	5.00*	1.67	3
07	22:32:29.3	31.60	103.30	5.00*	1.78	3
09	09:44:39.5	31.62	103.28	4.12	0.64	4
09	11:04:14.2	31.62	103.27	1.80	0.56	4
16	01:21:11.4	31.61	103.30	5.00*	0.51	3
16	06:44:22.0	31.62	103.26	3.91	1.26	4
16	14:38:39.6	31.61	103.25	0.34	0.52	7
17	20:52:38.3	31.63	103.31	5.00*	0.63	3

Table 5.2-9
EARTHQUAKES LOCATED WITHIN THE
KERMIT ARRAY NOV 75-JUL 77

Date	Origin time	Lat N	Long W	Depth	M_L	# Sta
18	18:08:24.1	31.61	103.27	6.63	2.14	7
20	12:59:58.7	31.61	103.31	5.00*	0.74	3
23	18:58:46.7	31.59	103.14	0.01	0.69	4
26	09:03:07.3	31.90	103.07	4.02	3.10	8
26	09:05:50.4	31.89	103.09	2.67	1.06	5
May 19	04:25:30.6	31.62	103.26	0.20	1.00	4
Jun 09	11:37:35.4	31.61	103.26	5.00*	1.33	3
29	23:59:46.6	31.54	103.30	0.14	2.76	5
Jul 25	17:45:48.1	31.57	103.30	5.00*	1.27	3

* Focal depths constrained to 5 km

Table 5.2-10 Page 1 of 3

EARTHQUAKES LOCATED AROUND THE PERIPHERY OF THE KERMIT ARRAY BY 5 OR MORE ARRAY STATIONS

Date	Origin time	Lat N	Long W	Depth	M_L	# Sta
1976						
Mar 15	02:30:48.3	32.15	102.96	0.12	1.56	5
20	16:15:55.5	32.30	103.05	0.35	1.70	5
27	22:25:21.0	32.21	103.10	0.06	1.49	9
Apr 12	08:02:35.9	32.17	103.11	0.45	2.38	5
21	08:40:07.4	32.21	103.10	0.25	2.53	6
May 01	11:13:40.8	32.27	103.14	9.92	3.04	8
Jun 15	02:20:00.5	31.58	102.65	0.76	2.39	7
15	08:50:20.9	31.55	102.48	6.85	2.67	13
Aug 10	09:03:12.2	31.86	102.35	0.14	2.39	7
10	10:15:18.2	31.80	102.55	0.55	2.87	9
25	01:27:49.3	31.56	102.58	3.89	2.79	9
26	15:22:17.7	31.79	102.59	0.75	3.03	11
31	12:46:21.1	31.56	102.73	7.84	2.78	9
Sep 05	10:39:49.4	32.16	103.11	0.18	1.68	5
17	02:47:45.4	32.21	103.10	0.20	2.98	10
17	03:56:28.9	31.42	102.54	1.66	3.44	7
19	10:23:24.4	32.14	103.09	7.29	2.41	6
Oct 14	11:03:00.1	32.21	103.07	2.74	2.32	6
22	05:06:15.9	31.57	102.54	3.03	2.94	7
25	00:27:04.2	31.81	102.58	6.59	2.95	7
25	10:52:27.3	31.85	102.40	0.17	2.15	5
26	10:44:44.1	31.33	103.28	0.46	2.81	7
Dec 12	23:00:14.0	31.52	102.53	7.59	3.21	11
12	23:25:56.0	31.55	102.58	0.13	2.33	7
19	21:26:16.0	31.79	102.64	0.25	2.61	5

Table 5.2-10
EARTHQUAKES LOCATED AROUND THE PERIPHERY OF THE KERMIT ARRAY BY 5 OR MORE ARRAY STATIONS

Date	Origin time	Lat N	Long W	Depth	M_L	# Sta
19	23:54:22.7	32.18	103.11	1.48	2.26	6
19	23:56:46.5	32.26	103.08	1.04	2.85	6
1977						
Feb 10	01:22:50.5	32.17	103.10	2.04	2.03	6
18	14:10:36.8	32.20	103.10	3.89	1.17	5
Mar 05	22:56:10.0	31.30	102.65	2.14	2.35	9
17	15:14:13.3	32.14	103.07	2.21	0.95	6
20	07:54:08.0	32.21	103.10	0.99	2.22	8
23	11:02:51.8	31.81	102.51	4.69	1.93	6
Apr 04	01:47:50.4	31.44	103.18	3.96	2.11	5
07	05:45:39.4	32.24	103.17	1.53	2.91	7
12	23:18:26.4	31.26	102.61	0.21	2.24	9
25	10:12:51.1	32.08	102.80	5.94	1.35	6
28	12:54:36.9	31.81	102.51	0.46	2.16	7
28	12:55:40.5	31.79	102.59	4.21	2.17	7
28	12:57:20.3	31.80	102.59	4.77	1.73	7
28	15:22:37.7	31.79	102.61	3.14	2.46	8
29	03:09:40.4	31.80	102.58	1.25	1.73	6
Jul 11	12:31:55.7	31.79	102.73	2.93	2.74	10
11	13:29:49.8	31.79	102.73	2.49	2.19	9
12	17:06:06.3	31.79	102.71	4.86	2.44	9
18	12:37:30.6	31.80	102.74	0.97	2.90	8
22	04:01:10.1	31.80	102.73	3.42	3.35	8
22	04:18:10.5	31.80	102.73	2.30	2.50	7
22	04:36:51.0	31.81	102.75	0.38	1.67	6

Table 5.2-10

EARTHQUAKES LOCATED AROUND THE PERIPHERY OF THE KERMIT ARRAY BY 5 OR MORE ARRAY STATIONS

Date	Origin time	Lat N	Long W	Depth	M_L	# Sta
24	09:23:00.5	31.80	102.73	2.04	2.49	10
26	02:01:09.3	31.81	102.77	0.27	1.45	9

DIFFERENCES IN ARRIVAL TIMES BETWEEN THE EARTHQUAKES ON JULY 26, 1972 AND NOVEMBER 28, 1974

Station	Phase	Earthquake on July 26, 1972	Earthquake on Nov. 28, 1974	ΔT
LUB	Pn	04:36:20.3	03:35:58.25	22.05
ALQ	Pn	04:36:36.8	03:36:13.35	23.45
SNM	Pg	04:36:36.9	03:36:13.85	23.05

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DOE/CAO-96-2160

Final
No-Migration
Variance Petition

June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume VI of VIII

Appendices GCR(cont.), LTHBL, LTM, MASS

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DUPLICATE

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Volume II

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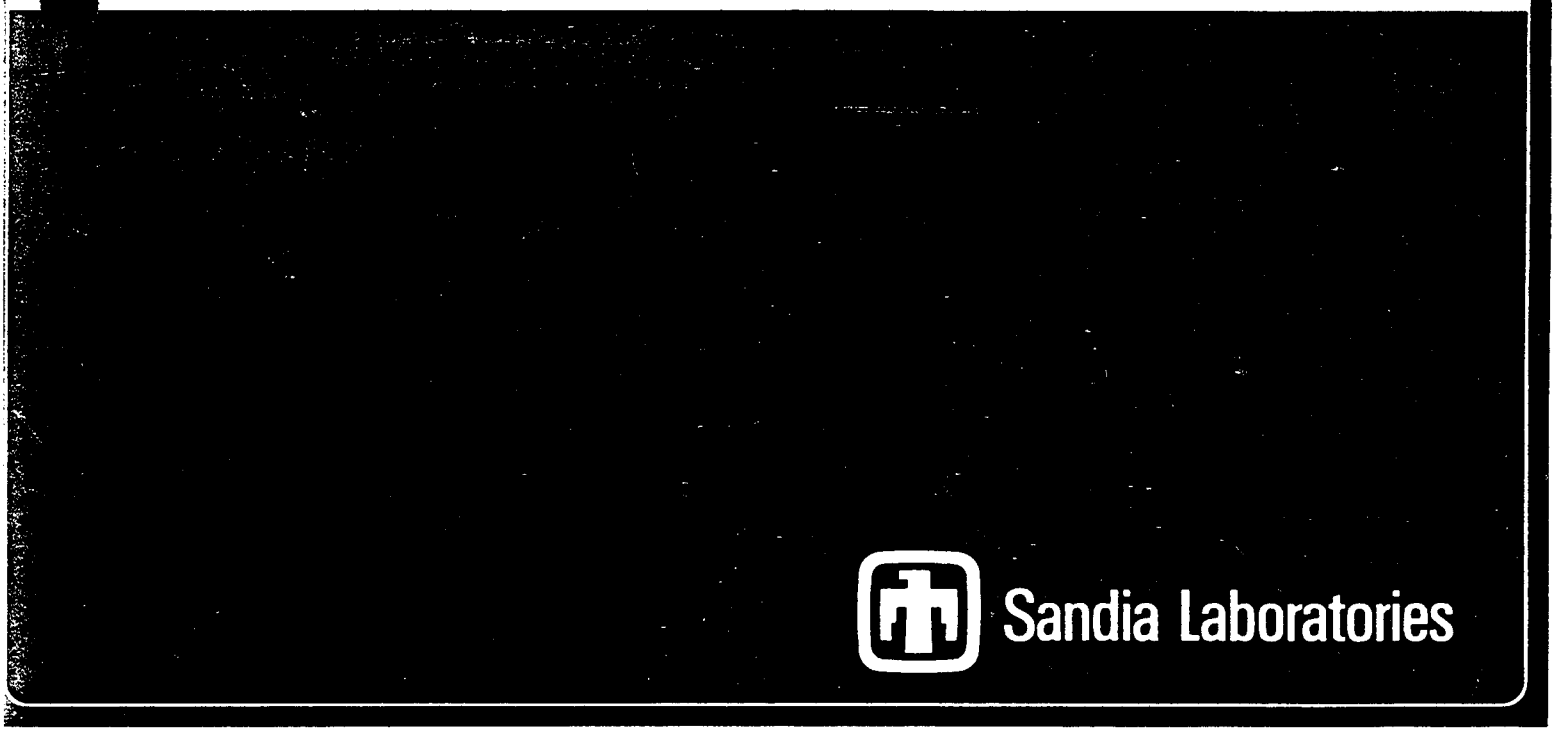
Dennis W. Powers, Steven J. Lambert, Sue-Ellen Shaffer, Leslie R. Hill, Wendell D. Weart, Editors



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GEOLOGICAL CHARACTERIZATION REPORT WASTE ISOLATION PILOT PLANT (WIPP) SITE, SOUTHEASTERN NEW MEXICO

SAND78-1596

VOLUME II

Dennis W. Powers, Steven J. Lambert, Sue-Ellen Shaffer,
Leslie R. Hill, Wendell D. Weart, Editors

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GEOLOGICAL CHARACTERIZATION REPORT

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APPENDICES

GCR CHAPTER 6
HYDROLOGY

6.1 INTRODUCTION

The location of the proposed WIPP site is within the surface water boundaries of the Rio Grande Water Resources Region and the groundwater boundaries of the Unglaciated Central region of the Permian Basin. In addition, the site lies within the boundaries of the Delaware Basin, a portion of the Unglaciated Central region that includes some of the least productive aquifers in the United States. The Delaware Basin is characterized by a semiarid climate with low rainfall and runoff, high evaporation, and frequent strong winds. The proposed site contains neither perennial streams nor surface water impoundment, and the water bearing strata beneath the site do not yield large quantities of water to wells. Shallow wells in the local area are generally used only for watering livestock and typically produce non-potable groundwater with total dissolved solids (TDS) concentrations in excess of 3,000 parts per million (ppm).

Hydrologic studies of the water resources surrounding the site have been supported by universities and state and federal agencies since the late 1930's (Robinson and Lang, 1938; Theis and Sayre, 1942; Hendrickson and Jones, 1952; Bjorklund and Motts, 1959; Nicholson and Clebsch, 1961; Brokaw et al., 1972; Hiss, 1975a). The early studies were primarily concerned with the control of water quality in the Pecos River for agricultural usage downstream from the brine discharge at Malaga Bend (Robinson and Lang, 1938; Hale et al., 1954). The first investigations of hydrogeologic parameters describing the occurrence and flow of groundwater in close proximity to the proposed WIPP location began in the late 1950's with Project Gnome (Cooper, 1962; Gard, 1968; Cooper, 1971).

Hydrologic studies at the site and adjacent site areas have concentrated on defining the hydrogeology and associated salt dissolution phenomena (Griswold, 1977; Lambert and Mercer, 1977; Mercer and Orr, 1977; Mercer and Orr, 1978; Anderson, 1978). These investigations are directed toward a more quantitative evaluation of the salt dissolution process, the

hydrogeologic parameters affecting groundwater movement, and the major elements of surface and groundwater quality affecting water resource use and local ecology. The collection of hydrologic data is projected to continue for several years to provide site-specific information for a detailed safety analysis of the WIPP.

Hydrologic test results to date have been used to make bounding calculations of hypothetical occurrences based upon simplifying assumptions of the physical system. Future measurements obtained from the experimental programs and analysis of the test data will be used to refine the initial bounding calculations and to provide a more detailed description of the physical system and system dynamics. The use of computer models as predictive tools is expected to be closely coordinated with current test results from an established monitoring network. Compatible chemical tracers will be injected directly into the groundwater system as a test of the predictive computer results. Also, the use of chemical tracers during construction phases of the WIPP may provide an early indication of leaky borehole plugs or faulty repository seals, if any, far in advance of radionuclide concentrations in the groundwater system.

6.2 SURFACE WATER HYDROLOGY

The area proposed for the Waste Isolation Pilot Plant (WIPP), located in southeastern Eddy County, New Mexico, lies at an average elevation of 3410 feet above mean sea level (MSL) in the Northern Chihuahuan Desert. Although the area belongs to the drainage basin of the Pecos River, surface drainage patterns at the site are not well defined. Preliminary studies indicated that areal requirements for the surface facilities, underground storage, and safety considerations during the operation of the repository would be as shown in Table 6.2-1 (see also Table 2.1).

6.2.1 Surface Water Features

The Rio Grande Water Resources Region, which includes the Pecos River basin, is an area of 88,968 square miles. The Pecos River basin has a

total drainage area of about 44,535 square miles (approximately 20,500 square miles of which do not contribute to river flow), a maximum basin width of about 130 miles, and an overall length of about 500 miles before combining with the Rio Grande River. The Pecos is generally perennial, except in the reach below Anton Chico and in the reach between Fort Sumner and Roswell, where the low flows percolate into the stream bed. About 60 percent of the annual flow occurs between April and September.

The Pecos River is located west of the site and flows southeast through Carlsbad. At the closest point (river mile 430), the Pecos River is approximately 14 miles west of the WIPP site center. The total drainage area of the river at this location is 19,000 sq. miles. A few small unnamed creeks and draws constitute all tributaries flowing westward of the Pecos River within 20 miles north or south of the site. From the west, the Black River (drainage area of 400 square miles) joins the Pecos at a point approximately 16 miles southwest of the site near river mile 436. The Delaware River (drainage area of 700 square miles) joins the Pecos near river mile 446, and a number of small unnamed creeks and draws join at various points along this reach. Pecos River flow in this reach is regulated by storage in Lake Sumner (river mile 401.9), Lake McMillan (river mile 404.2), Lake Avalon (river mile 407.2) and several other smaller upstream dams that divert water for irrigation. The salient features of the five existing dams on the Pecos River in a reach extending 25 miles upstream and 25 miles downstream of the WIPP site are listed in Table 6.2-2. The approximate slope of the Pecos riverbed in the vicinity of the WIPP site is 4.5 ft/mile (U.S.G.S. Topographic Maps NI 13-11 & NI 13-12).

There are no major lakes or ponds within 10 miles of the WIPP site center. Laguna Gatuna, Laguna Tonto, Laguna Plata and Laguna Toston are lakes located to the north more than 10 miles from the site. All these lakes are at or above elevation 3,450 feet. Therefore, surface runoff from the site would not flow toward any of the lakes to the north. To the west and northwest, Red Lake, Lindsey Lake, Salt Lake, and a few unnamed ponds are located more than 10 miles from the site, between elevations 3,000 and 3,300 feet (U.S.G.S. Topo. Maps, 1:250,000).

Surface water and groundwater withdrawals in the Pecos River basin are listed in Table 6.2-3.

6.2.2 Precipitation Patterns

The nearest station to the WIPP site for which climatological records are available is located at Carlsbad, about 26 miles west of the site, at an elevation of 3,120 feet MSL (U.S. Weather Bureau, 1961). Over a period of more than 71 years (NOAA, 1977), the annual precipitation at Carlsbad ranged from 2.95 inches to 33.94 inches. The average annual precipitation over a period of 30 years (1931-1960) was 12.43 inches (U.S. Weather Bureau, 1961). The average annual precipitation from 1951 to 1974 was 9.78 inches at Artesia (elevation 3320 feet), which is about 48 miles northwest of the WIPP site. At Hobbs (elevation 3615 feet), which is about 44 miles northeast of the site, the average annual precipitation for the period 1951-1974 was 14.29 inches. Interpolation of precipitation data for Carlsbad, Artesia and Hobbs indicates that the average annual precipitation at the site should be approximately 12 inches, which is nearly equal to the average annual precipitation at Carlsbad. Therefore, the precipitation patterns at Carlsbad are assumed to be representative of the conditions at the WIPP site.

Maximum, average, and minimum monthly precipitation at Carlsbad over a period of 30 years (1931-1960) are given in Table 6.2-4. The maximum monthly precipitation, 12.28 inches, occurred in May. With the exception of May and August, when the record minimum monthly precipitation were 0.18 and 0.01 inch, respectively, the record minimum precipitation for all other months has been 0.00 inch. The maximum daily precipitation since 1905 occurred in August, 1916, and was 5.12 inches.

The maximum daily and monthly snowfalls at Carlsbad since 1905 have been 10 inches (December, 1923) and 17.8 inches (February, 1905), respectively (U.S. Weather Bureau, 1961).

In general, summer rain is more abundant than that of other seasons and is caused by thunderstorms generated by the southeasterly circulation of moist air from the Gulf of Mexico. Approximately 75 percent of the total annual precipitation occurs from April through September. Winter rainfall is least abundant and is caused mainly by frontal activity associated with the movement of the Pacific storms across the country from west to east (NOAA, 1977).

6.2.3 Drainage

The site is located between elevations 3,250 and 3,570 feet MSL (Griswold, 1977). General ground slope in the vicinity is approximately 39 feet/mile from the northeast to southwest. Average ground slope from north to south is approximately 13 feet/mile. A topographic and surface water divide (Antelope Ridge) exists approximately 8 miles east of the site center and 4 miles from the exterior boundary of Zone IV (Refer to Table 6.2-1).

In general, the surface in the site vicinity is hummocky and covered by sand dunes. The local slope is poorly defined, and rain collects in pools between sand dunes and evaporates, is transpired, or sinks into the sand. Surface runoff from an area of about 10 sq. miles to the northeast, along with that from the site area, drains through a number of small draws which terminate in unnamed ponds to the southwest. Runoff is typically 0.1 to 0.2 inches annually.

6.2.4 Floods

Historically, floods for the Pecos River are reported to have occurred in 1904, 1905, 1915, 1916, 1919, 1937, 1941, 1942, and 1966 (NOAA, 1977). The earliest flood for which discharge information is available occurred on October 2, 1904, following the failure of Avalon Dam. During this flood, the flow at Avalon gaging station (river mile 406.3) exceeded 90,000 cfs. The corresponding river stage is not available. The river stage at Red Bluff (river mile 459.8) is reported to have reached 28 feet

(gage datum of 2850.05 feet) during this flood. Another major flood occurred on August 7, 1916, when the discharge at Carlsbad Station (river mile 419.1) reached 70,000 cfs.

A third major flood occurred in September, 1919, when the river stage at Malaga gaging station (river mile 432.2) was recorded as 29.4 feet (gage datum of 2895.64 feet). The corresponding discharge was 40,400 cfs. The highest flood of record (through 1976) for the Pecos River occurred on August 23, 1966, when the discharge and stage at Malaga were 120,000 cfs and 42.1 feet, respectively (U.S. Geological Survey, 1976). The minimum surface elevation of the site is more than 310 feet above this maximum historic flood level.

6.2.5 Evaporation and Transpiration

In New Mexico, potential evaporation is much greater than the average annual precipitation. In the southeastern valleys, evaporation from a class A pan is on the order of 110 inches per year. During the warm months, May through October, evaporation in the southeast portion of the state is approximately 73 inches.

The record high temperature at Carlsbad is 112°F (June, 1902). The record low temperature at this station is 7°F (January, 1911). The maximum, average and minimum monthly temperatures at this station over a period of 30 years (1931-1960) are given in Table 6.2-5 (U.S. Weather Bureau, 1961). June, July and August are the warmest (average temperature of 80.7°F) while December and January are the coldest months of the year (average temperature of 44.3°F).

In this type of desert climate, more than 90 percent of all infiltrated water evaporates or transpires. The high rate of evapotranspiration is aided by the frequent winds, the low relative humidity (typically 36 percent during daylight hours), and the high mean annual temperature (61°F).

6.2.6 Infiltration

Soils at the site are generally comprised of sands extending to a depth of as much as 25 feet. Actual sand dunes cover a good portion of the site area. With pervious sand on the surface, infiltration rates are high and probably similar to the 1.6 inch-per-hour intake rate of Harkey Sand Loam (75 percent sand) near Carlsbad (Blaney and Hanson, 1965). Groundwater in the area of the site is more than 50 feet below surface elevations. Because the surface sands are underlain by a caliche layer about 2 to 8 feet thick, percolation of rainfall through the sands to the nearest groundwater would be only a portion of the total infiltration. Most infiltration will return to the atmosphere by evapotranspiration.

6.2.7 Surface Water Quality

Water quality in the Pecos River basin is affected by mineral pollution from natural sources and from irrigation return flows. Springs near the headwaters of the basin below Colonias, New Mexico, are estimated to discharge approximately 707 tons per day of dissolved solids into the Pecos River. Below Lake McMillan, springs flowing into the river are usually submerged and difficult to sample; however, dissolved solids concentrations between 3350 and 4000 ppm have been measured in springs that could be sampled. The chemical quality of these mineral discharges indicates the nonpotable character of the ground water in contributing source beds. Inflow of concentrated brine solutions at Malaga Bend increases the chloride content of the Pecos River by an estimated 370 tons per day (see account by Swenson in Bachman and Johnson, 1973). Time-weighted averages of water quality parameters for three sampling stations on the Pecos River between Carlsbad and Malaga Bend are shown in Table 6.2-6. In general, natural spring flows and irrigation return flows progressively concentrate salts downstream. Further downstream at Red Bluff Reservoir, the water is useable occasionally during high flow periods.

6.3 GROUND WATER HYDROLOGY

Detailed investigations of ground water conditions at the proposed site are being conducted to identify the presence of ground water, to measure ground water quality, and to determine hydraulic conductivity and other characteristics of the stratified rocks. The data will provide a basis for assessment of the continued isolation of the proposed repository from ground water circulation. The thick halite beds of the Salado Formation at the WIPP site are isolated from circulating ground water by beds of low hydraulic conductivity, both above and below the formation. In the vicinity of the proposed site, fresh or potable ground water is not present except in small, isolated, near-surface perched bodies.

Investigations to evaluate the transport of radionuclides by ground water flow in the southeastern New Mexico portion of the Delaware Basin were made by the Water Resources Division of the U.S. Geological Survey for Project Gnome in the late 1950's. Since that time, several studies have been carried out by individual consultants, the U.S. Geological Survey, Oak Ridge National Laboratories, and Sandia Laboratories. These studies have been directed to the specific task of providing a better understanding of the relationship between the proposed waste repository and ground water movement. The following is a description of ground water occurrence and flow as understood from the studies completed to date. Ground water is first described on a regional basis, then the results of site specific studies are reviewed, and, finally, dissolution of salt evaporites is discussed.

6.3.1 Regional Ground Water Conditions

Ground water within the Delaware Basin is predominantly of poor quality, with total dissolved solids concentrations in excess of 3,000 ppm. The only large quantities of potable ground water are found in aquifers west of and along the Pecos River. To the west in the Guadalupe Mountains, many rock units of the basin crop out, and the soluble salts have been leached from the Ochoan evaporites.

Important aquifers of the region are the San Andres Limestone and the Capitan Limestone and related reef limestones. The San Andres is a major source for irrigation waters in the Roswell basin, and other areas to the north and northwest of the site. The Capitan aquifer southwest of the community of Carlsbad is the primary source of municipal water. An important aquifer in the region east of the proposed site is the Ogallala Formation. Unconsolidated alluvium along the Pecos River yields large amounts of relatively fresh ground water in some areas, although it is commonly of marginal quality for drinking purposes.

From the outcrop areas west of the Pecos River, ground water moves eastward. The shallow aquifers, those cut by the Pecos River, discharge to the river, either directly or to alluvium of the river channel. The Capitan aquifer is the oldest permeable formation that may have contact with the river. Ground water in permeable formations older than the Capitan is not directly affected by the river, is present under confined conditions, and migrates eastward into the Delaware Basin.

East of the Pecos River, thick beds of evaporites are present at depth, and brines are common in the underlying permeable formations. Ground water in any of the rock units east of the river in Eddy County is of brackish quality, at best. Fresh meteorically-derived ground water does not flush out the poor quality waters in these aquifers. Consequently, the major utilization of ground water in the central and eastern Delaware Basin is for oil-field flooding. The predominant source of the ground water is the Capitan aquifer.

The shallow aquifers east of the Pecos River are limited in extent, are low yielding, and usually contain water of poor quality. Recharge to these shallow aquifers is presumed to be from precipitation on outcrop areas or from overlying formations, and migration of the water generally follows surface drainage patterns, eventually reaching the Pecos River.

In discussing ground water occurrences in relation to the proposed repository, it is convenient to relate them to the Salado Formation because the Salado and its associated evaporite formations have very low hydraulic conductivities and form a barrier to vertical flow (see Table 9.2.3-1). Aquifers stratigraphically below the Salado are widespread and contain large quantities of brine under confined conditions. Aquifers present above the Salado in the proposed site area are either limited in extent or very low-yielding. This upper ground water is of poor quality (TDS concentrations greater than 3,000 ppm) and occurs under unconfined, as well as confined, conditions.

6.3.2 Hydrology of Rocks Underlying the Salado Formation

The halite beds of the Salado Formation that are proposed for the repository are underlain by thick anhydrite and salt beds of the Castile Formation. They act as an aquiclude, separating the Salado from the underlying sandstones of the Delaware Mountain Group. The sandstones are present at a depth of about 4,200 feet in the site area. The hydraulic conductivity of the sandstones of the Delaware Mountain Group, associated with the relatively high hydraulic conductivity of the shelf-margin facies (the Capitan Limestone) and the shelf facies (which includes the San Andres Limestone) make this group the most important hydrologic system underlying the Salado. The hydrology of these Guadalupian-age rocks has been investigated in detail by Hiss (1975a).

Considerable information derived from hydrocarbon exploration in the basin is available on the hydrologic properties of the formations underlying the Permian evaporites. As reported by Lambert and Mercer (1977), the Delaware Mountain Group is the uppermost of the oil- and gas-producing horizons, which extend to the Ellenburger Group at a depth of about 18,000 feet. Several zones are encountered that contain water, oil, and/or gas that are under sufficient pressure to maintain a potentiometric surface at an elevation above that of the Salado Formation. Some of the zones have sufficient hydraulic conductivity to allow flow rates of several hundred barrels per day. In addition to the

Delaware Mountain Group, the Atoka zone at a depth of about 13,150 feet, and the Strawn (Desmoinesian) zone at about 12,900 feet are other oil and gas production zones that are considered deep aquifers by Lambert and Mercer (1977).

Deep Hydrologic Units. The hydrologic parameters of pre-Guadalupian zones are not as well defined, nor are they as hydrologically significant to the proposed repository as the Guadalupian-age rocks. Nevertheless, a review of them is presented, based primarily on McNeal's (1965) analysis of hydrodynamics of the Permian Basin. He described the potentiometric surfaces of seven zones, using elevations of outcrops where cut by a stream or body of water, static water levels in cable tool holes or water wells, and formation pressures converted to potentiometric surface elevations. McNeal prepared maps showing the regional potentiometric surfaces in terms of fresh water, using density differences of the various brine concentrations and depths of the nearby wells. The three deep hydrologic units reviewed are the Ellenburger Group, the Devonian zone, and the Mississippian- Pennsylvanian zone.

1) Ellenburger Group. The Ellenburger Group consists mainly of chert-bearing limestones and dolomites. It is a widespread unit, covering some 100,000 square miles in southeastern New Mexico and northwestern Texas (McNeal, 1965, Figure 1). The unit is estimated to be 350 feet thick at the proposed site (Lambert and Mercer, 1977) and as much as 1000 feet thick elsewhere in the region. The potentiometric surface compiled by McNeal for the Ellenburger indicates an altitude range from 4,200 feet MSL southwest of the site to less than 1,400 feet MSL in central Texas. In the vicinity of the WIPP site, the ground surface elevation is about 3200 feet MSL. The average gradient of the potentiometric surface is about 8 feet per mile in an easterly direction. Water in the Ellenburger is a brine solution, with a dissolved solids range of 50,000 ppm to more than 200,000 ppm. No water production data are available for this group.

2) Devonian Zone. McNeal's potentiometric surface for the Devonian hydrodynamic zone ranges in altitude from 4,000 feet MSL in the vicinity of the Glass Mountains to 3,200 MSL feet along the Lea County - Texas line. In the Midland Basin, there are nearly hydrostatic conditions at an elevation range of 2,800 to 3,200 feet MSL. A high potentiometric nose extending across southeast Eddy County indicates a potentiometric surface at the proposed site of about 3,700 feet MSL. Salinity of the formation water is less than 50,000 ppm in most of southeast New Mexico. In west Texas, salinity reaches 200,000 ppm in one area.

The Devonian, as inferred from McNeal's potentiometric map, extends throughout southeast New Mexico and northwest Texas. He has included Silurian data in the eastern (Texas) subcrop area. The potentiometric surface generally slopes to the east, and the average gradient appears to be about 7 feet per mile.

3) Mississippian-Pennsylvanian Zone. Mississippian rocks are thin and few data are available on the occurrence of fluids under the Delaware Basin. McNeal (1965) delineated a potentiometric surface for the Mississippian zone of West Texas, but has not extended it into New Mexico.

There are three water-bearing zones in Pennsylvanian age rocks. In ascending order they are the Morrow, the Atoka, and the Strawn (Desmoinesian). Lambert and Mercer (1977, p. III-2) report that the Morrow may be a high pressure, low capacity reservoir with water-production rates ranging from 10 to 20 barrels per day. The Atoka also may be an overpressured reservoir with enough head to yield fluid columns of 3375 to 6552 feet MSL at gradients of 0.47 psi per foot. The water is produced from gas wells at rates ranging from 21.6 barrels per day to as much as 214.4 barrels per day (Texas American's Todd Federal Well No. 1).

Lambert and Mercer (1977) report that several wells have been drill stem tested in the Desmoinesian age Strawn zone and several others have been completed as oil wells. On five drill stem tests, the calculated heads

ranged from 3350 to 6203 feet MSL. Water production was reported to be as much as 416 barrels per day in one drill-stem test, and one well (Phillip's James "E" No. 1) produced an average of 106 barrels per day. A potentiometric surface of the Strawn zone is presented by McNeal (1964, Figure 4), but the only area in the Delaware Basin for which data were available was in the southwestern part of Eddy County. Elevation of levels in that area range from 3,200 feet to 3,800 feet MSL. The gradient is easterly at about 20 feet per mile.

Bone Spring Formation. According to Lambert and Mercer (1977), the Bone Spring Formation (Leonardian Series) can be considered an aquiclude. They report that bottom-hole pressure data from the majority of seven wells tested had insufficient heads to prevent downward movement of shallower water. They suggest the pressure data indicate the formation has a low capacity and contains reservoirs of limited volume.

Guadalupian Age Rocks. The most important aquifers of the Delaware Basin are part of a hydrologic system that incorporates rocks of Guadalupian age. The system comprises three interconnected aquifer groups; the shelf aquifers (including the San Andres Limestone and the Artesia Group), the Capitan aquifer (including primarily the reef deposits - Capitan and Goat Seep Limestones), and the basin aquifers (sands of the Delaware Mountain Group). These aquifers are depositionally juxtaposed, but are distinguished in most areas by contrasting hydraulic conductivities, water salinities, and potentiometric levels. Along the north and northwest interface, hydraulic conductivity of the shelf aquifer, although lower, is near the hydraulic conductivity of the Capitan aquifer. The basin aquifers have the lowest values of hydraulic conductivity, and the Capitan is a discharge point for ground water flows in them. Recharge to these basin aquifers probably occurs in outcrop areas along the west flank of the Delaware Basin. Ground water then moves generally eastward, downdip in the tilted beds. Data on aquifer characteristics, compiled by Hiss (1975a), are summarized in Table 6.3-1. Hydrologic, lithologic, and physical properties of the formations in which these aquifers occur are discussed below.

1) Delaware Mountain Group Aquifer. The Delaware Mountain Group includes, in ascending order, the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations and comprises the basin facies of the system. The combined thickness of these formations ranges from less than 2,000 feet in the southern part of the Delaware Basin to more than 4,000 feet in southwestern Lea and eastern Eddy Counties, New Mexico (Hiss, 1975a).

The Brushy Canyon Formation is as much as 1,000 feet thick and consists chiefly of sandstone with limestone lenses and occasional conglomerate at the base. No wells are known to be extracting water from this formation in Eddy County (Hendrickson and Jones, 1952).

The Cherry Canyon Formation is also as much as 1,000 feet thick and consists of thin-bedded, fine-grained sandstone and some persistent limestone beds. The lower one-fourth of the formation persists as a sandstone tongue striking northwestward into the Guadalupe Mountains which may yield water to some wells and springs in that area (Hendrickson and Jones, 1952).

The Bell Canyon Formation ranges in thickness from 670 to 1,040 feet and consists mainly of sandstone and thin beds of limestone (King, 1948). The formation interfingers to the northwest with the reef limestone of the Capitan Formation, providing the potential hydrologic interconnection of the Guadalupian Age rocks. Large springs near the base of the reef escarpment west of the Pecos River are probably supplied by ground water moving through the upper beds of the Bell Canyon Formation (Hendrickson and Jones, 1952).

An average hydraulic conductivity of 0.016 ft/d (feet per day) and a porosity of 15.65 percent were determined by Hiss (1975a) from analyses of approximately 4,500 samples of rock core cut from the Delaware Mountain Group in Eddy and Lea Counties, New Mexico, and Ward and Winkler Counties, Texas. Hiss also computed a similar hydraulic conductivity from productivity indexes (approximately equivalent to specific

capacities) obtained from an oil company for two wells in the El Mar field located on the boundary between Lea County, New Mexico, and Loving County, Texas.

Hiss (1975a) indicated that similar values of hydraulic conductivity were reported by earlier writers for much of the same part of the Delaware Basin.

Hiss compiled a potentiometric surface map of the Delaware Mountain Group, of which the northern Delaware Basin portion is shown in Figure 6.3-1. The data used by Hiss in compiling the map were taken at different times over a period of about 25 years between the late 1940's and early 1970's. However, he believes the contours are representative of conditions during the period 1960 and 1970. Although some local changes to the potentiometric surface are due to oil and water withdrawals during that period, no data suggest that the regional directional trend has changed. The potentiometric surface data for the brines have been corrected to "fresh-water" density, indicating a potentiometric elevation of 3350 feet MSL in the vicinity of the proposed WIPP site. The hydraulic gradient in the northern portion of the basin dips northeasterly at approximately 15 feet per mile.

Quality of the water in the Delaware Mountain Group is generally poor. An isochlor map compiled by Hiss (1975a, Figure 26) shows a chloride-ion concentration range from 50,000 to 150,000 ppm in the east half of the Delaware Basin. Concentration diminishes to approximately 1,000 ppm southward in the vicinity of the Glass Mountains and northwestward in the vicinity of the Guadalupe Mountains. These are outcrop areas where the Guadalupian Age rocks probably have been recharged by precipitation. However, analyses of water samples taken from the hydrologic system in the vicinity of the repository site indicate that the brine solutions do not contain oxygen and hydrogen isotopes in ratios characteristic of meteoric waters. The relative proportions of O^{18}/O^{16}, and deuterium/hydrogen ratios have probably been altered through interaction with the rock of the formation (Lambert, 1978; see also Chapter 7 of this report).

According to Hiss, recharge to the basin aquifers is through precipitation on the outcrops in the Guadalupe, Delaware, Apache, and Glass Mountains, and from downward leakage through the younger rocks in areas where the overlying soluble Ochoan evaporites have been removed. The potentiometric surface (Figure 6.3-1) indicates water moves north and northeastward, and discharge is to the overlying Capitan and shelf aquifers.

2) Capitan Aquifer. The Capitan Limestone and the underlying Goat Seep Limestone constitute the main body of the Capitan aquifer, which is the reef facies of the Guadalupian rocks. Hiss (1975a) describes the aquifer as a long continuous unit that extends in an arcuate strip along the north and east margins of the basin, with exposures in the Guadalupe and Glass Mountains, as well as the Delaware and Apache Mountains. The thickness of the aquifer ranges from a few hundred to more than 2,000 feet, and the average width is approximately 10 miles (Hiss, 1975a, Figure 11). It is one of the most important aquifers of the region and is a major control in the hydrologic system (Mercer and Orr, 1977).

Relatively few aquifer tests have been performed to measure the hydraulic conductivity of the Capitan aquifer. The data compiled by Hiss (1975a) are summarized in Table 6.3-1. Hiss calculated that the hydraulic conductivity of the Capitan aquifer along the western margin of the Central Basin Platform in Texas and New Mexico ranges from 1 to 25 ft/d and estimated that for most of southern Lea County and for about 15 miles east of the Pecos River valley from Carlsbad it is about 5.0 ft/d. Although Hiss was unable to conduct any aquifer tests in the area west of the Pecos River, he concluded that high production wells, the presence of caverns, and high porosity suggest that the hydraulic conductivity of the Capitan is higher west of the river than east of the river. The hydraulic conductivity is probably very high, as well, in the Glass Mountains, because of numerous small caverns (Hiss, 1975a). The coefficient of transmissivity of the Capitan aquifer along the northern and eastern margins of the Delaware Basin is estimated by Hiss to range from 10,000 ft^2/d (square feet per day) in thick sections to less than 500 ft^2/d in the vicinity of eroded, thin sections of the reef.

The Capitan aquifer receives some recharge by direct infiltration on outcrops in the Guadalupe and Glass Mountains, and probably more by percolation of discharge from the basin and shelf aquifers along the north and east margins of the basin. Water-table conditions exist in the aquifer west of the Pecos River and in the Glass Mountains, but to the north of the Glass Mountains and east of Carlsbad water in the aquifer is confined. Hiss believes that water entering the Capitan aquifer in the Guadalupe Mountains moves northeastward toward Carlsbad where most of the water discharges into the Pecos and Carlsbad Springs. The Pecos River controls the movement of ground water in the Capitan aquifer in the vicinity of Carlsbad, and east to the ground-water divide near the Eddy-Lea County line (figure 6.3-1).

Hiss (1975a) believes that a deep submarine canyon cut into the Capitan Limestone is present near the Eddy-Lea county line, and a hydraulic restriction is formed to constrain the eastward movement of water in the aquifer from the vicinity of the Pecos River. Apparently there is little movement of water between the Pecos River and the Eddy - Lea County line. East of the hydraulic restriction, the potentiometric surface declines with an eastward gradient. Hydrographs of observation wells, established by the U. S. Geological survey in the Capitan aquifer from Carlsbad east and south to the Texas - New Mexico state line have recorded these water level differences. Water levels during the years 1967 through 1972 indicate that from Carlsbad eastward to near the Eddy - Lea County line, the potentiometric surface has remained nearly constant, responding to minor fluctuations of the Pecos River. East of the county line, water levels declined more than 100 feet, at a constant rate, during those 6 years (Hiss, 1975a, Figure 24). The eastward gradient and decline in potentiometric surface are caused primarily by the large withdrawals of water for oil-field water flooding in eastern New Mexico and western Texas (Mercer and Orr, 1977). These withdrawals are apparently the primary discharge from the aquifer at the present time. The similar potentiometric heads and directions of movement of the Capitan and shelf aquifers along the northeast and east sides of the basin (Figure 6.3-1) suggest some discharge from the shelf aquifer also

occurs. In analyzing potentiometric data prior to 1950, when large extractions of water from the Capitan had not developed, Hiss (1975a), concluded that discharge at the time was east, into the shelf aquifers.

Water of good quality, although hard, is available in the Capitan aquifer in the area west of Carlsbad (Hendrickson and Jones, 1952), and apparently in the Glass Mountains. However, in the major portion of the aquifer, east of the Pecos River, quality is poor. Chloride-ion concentration increases from 200 ppm just west of Carlsbad to as much as 23,000 ppm east of the community. Along the east flank of the basin, salinity of Capitan water is significantly lower than that in the adjacent shelf and basin aquifers, ranging from about 1,100 to 5,000 ppm in most wells (Hiss, 1975a, Figure 26).

3) Shelf Aquifers.

The shelf aquifers do not have a direct impact on hydrologic conditions underlying the proposed site because the Capitan aquifer is a hydrologic boundary. Nevertheless, they are in close hydraulic connection with that aquifer, and would apparently accept some discharge from the Capitan, should the extensive pumping from the Capitan be discontinued.

The lowermost unit of the Guadalupian age shelf or "back-reef" facies, known as the San Andres Limestone, extends over much of southeast New Mexico and into northwest Texas. The average thickness of the unit is about 1500 feet. Overlying the San Andres are formations of the Artesia Group. Strata in these formations that yield significant quantities of water are the shelf aquifers. The contact between the Capitan and shelf aquifers is gradational and difficult to differentiate in some areas. In the Pecos River Valley between Carlsbad and Roswell, and to the west of that area, the shelf aquifers are quite porous and yield large quantities of potable water to wells (Hendrickson and Jones 1952). The hydraulic conductivity of the aquifers east of the river and in the Central Basin Platform are significantly less than those to the west, and water quality is poor (Hiss, 1975a).

Measurements of hydraulic conductivity and porosity of core samples of the shelf aquifers were collected by Hiss (1975a) and the data are summarized in Table 6.3-1. It can be seen that the hydraulic conductivities in this area are at least one order of magnitude less than hydraulic conductivities of the Capitan aquifer. Potentiometric levels of the shelf aquifer, shown on Figure 6.3-1, are similar to those of the Capitan aquifer along the east side of the Delaware Basin. In the vicinity of Carlsbad, however, the levels are as much as 200 feet higher than those of the Capitan, suggesting poor interconnection between aquifers in that area.

The major areas of recharge to the shelf aquifers are probably north and west of Carlsbad in the Guadalupe mountains and areas west of the Roswell basin. Water in the shelf aquifers to the north moves either southwestward to the Pecos River, or southeastward onto the Central Basin Platform. Water quality in the shelf aquifers varies considerably from one area to another, but is generally poor east of the Pecos River. Chloride-ion concentrations in excess of 150,000 ppm are indicated by Hiss (1975a, Figure 26) north of the Capitan aquifer and along the east flank of the Delaware Basin. However, a narrow band of better quality water (salinity less than 10,000 ppm) in the San Andres Limestone is indicated to the northeast, between the shelf and the Central Basin Platform.

Castile Formation. The Castile Formation overlies the Delaware Mountain Group and consists predominantly of anhydrite with halite interbeds, and subordinate limestone. Its thickness ranges from 1,300 to 2,000 feet over most of the Delaware Basin. In most of the basin hydraulic conductivity of the Castile is very low so that this formation acts as a confining layer for the underlying Delaware Mountain Group (Mercer and Orr, 1977). However, west of the Pecos River, the salt beds have been removed, hydraulic conductivity of the residuum is higher and water is available to wells (Bjorklund and Motts, 1959).

In the central Delaware Basin, isolated pockets of brine and associated hydrogen-sulfide gas have been encountered by various oil companies in

the Castile, and also in the Sandia Laboratories exploratory hole, ERDA-6 (Mercer and Orr, 1977). High-pressured brines encountered in three oil wells east of the proposed site reportedly have had flow rates as high as 20,000 barrels per day. These brines are present near the top of the formation, suggesting a brine zone, but since no other wells have encountered brines, the zone is apparently not continuous (Rose, 1977). Brine from ERDA-6 further suggests a long isolation time on the order of one million years for that pocket (Barr, Lambert and Carter, 1978).

Salado Formation. Massive beds of halite of the Salado Formation are the intended host rock for the WIPP repository. The formation extends more than 100 miles both north and east of the Delaware Basin and underlies an area of approximately 25,000 square miles (Pierce and Rich, 1962). Formation thickness in the Los Medanos area is 1,976 feet, as measured at ERDA-9, and the depth to the top is 848 feet.

Porosity of the halite is very low and interconnected pores are virtually non-existent. Lack of open fractures is assured because of the high plasticity of the material. As a result, hydraulic conductivity of the beds is effectively zero. As reported by C. L. Jones (1973), microscopic to very small angular cavities in grains of halite contain very minor amounts of brine and gas. Less common are much larger cavities or pockets in the halite beds that contain halite-saturated brine and nitrogenous gas confined under pressure sufficient to produce a "blow-out" when encountered during drilling. Nevertheless, the brine pockets do not appear to be interconnected, but seem to be isolated fluid bodies within the rock.

Because halite is quite soluble, it would readily dissolve if the beds came in contact with circulating, unsaturated solutions. West of the proposed site, where the Salado rises to the surface, progressively less halite is present as a result of leaching by percolating ground water. Where exposures existed, all of the salt has been removed (see Section 4.3.2.).

As discussed in Section 4.3.2., removal of salt from the Salado Formation in the western portion of the basin where it is exposed, or near the surface, has formed a residuum of clay, gypsum and sand. In the Carlsbad area along the Pecos River and to the west, Bjorklund and Motts (1959) report that these clays are dense, and are referred to as "red beds". They suggested that the residue has slowed ground-water infiltration and subsequent salt removal.

Underlying Nash Draw, a salt dissolution zone is present in the residuum at the contact between the Salado and the overlying Rustler Formation. As reported by Mercer and Orr (1977), the dissolution zone extends from the recharge area north of Nash Draw to its termination in the vicinity of Malaga Bend. Water penetrates the overlying units through fractures and solution zones in the recharge area and moves southward along the top salt, and discharges into the Pecos River at Malaga Bend (Figure 6.3-2). The dissolved solids content of the brine at the river has been reported to be in excess of 300,000 ppm. Theis and Sayre (1942) calculated the discharge from the brine aquifer into the Pecos River at Malaga Bend to be about 200 gpm. Hale (in Hale, Hughes, and Cox, 1954) calculated a value of transmissivity of 8,000 ft^2/d from aquifer tests in the area between Malaga Bend and Laguna Grande de la Sal. Apparently, as salt has been progressively leached from the overlying beds, the residuum has developed a base of low hydraulic conductivity, preventing further downward leaching, and the dissolution zone has developed along the same structural control as Nash Draw (Robinson and Lang, 1938).

6.3.3 Hydrology of Rocks Overlying the Salado Formation

Nearly all of the water bearing formations overlying the Salado in the Delaware Basin are of materials with low hydraulic conductivity and which contain limited amounts of poor-quality water. The major hydrologic unit in the area that yields moderate quantities of marginal-quality water to wells is the alluvium of the Pecos River valley. Information on the hydraulic characteristics of these water bearing formations is limited, and only regional descriptions of potentiometric levels and hydraulic conductivity can be established.

Rustler Formation The Rustler Formation extends laterally beyond the limits of the Salado Formation and consists of interbedded anhydrite, dolomite, siltstones, clays, and halite. Two dolomite beds in the formation are water-bearing units, other than the Rustler-Salado contact, discussed above. The thickness of the dolomite beds ranges from 20 to 30 feet; these beds are areally extensive. The Magenta Dolomite is a finely crystalline, dense dolomite, and the Culebra Dolomite is vuggy and commonly associated with some anhydrite. The Magenta transmits only minor amounts of water and is not considered an important aquifer (Lambert and Mercer, 1977).

Although the Culebra Dolomite is areally persistent, yields of water vary considerably from place to place. Cooper and Glanzman (1971) suggested that the variability of yields is related to the size and number of fractures and openings in the dolomite, which in turn, could be related to its depth. In the northern part of Nash Draw, the dolomite is near the surface and is reported to yield as much as 700 gpm. East of Nash Draw, where the dolomite is covered with Triassic and younger rocks, yields are typically at least two orders of magnitude less.

Measurements of the hydraulic properties of the Culebra in the region are scarce, primarily originating from studies related to Project Gnome investigations (Cooper and Glanzman, 1971). Aquifer-performance tests in holes drilled for Project Gnome studies indicate a transmissivity of 460 ft^2/d, an average hydraulic conductivity of 16 ft/d, a storage coefficient of about 10^{-4}, and an average effective porosity of 10 percent.

Mercer and Orr (1977) prepared a map of the potentiometric surface from water levels measured in wells open to the Rustler Formation in the north portion of the Delaware Basin (Figure 6.3-2). The data were taken from several sources and represent a composite of the Culebra and Magenta dolomites, or other zones. However, it is believed that most wells are open to the Culebra dolomite bed because it is the most consistently producing rock in the vicinity.

These data indicate that water in the Rustler Formation moves west and southwestward across the Lea - Eddy County line, and southeastward from the community of Carlsbad toward Nash Draw, and the Pecos River to the south. Only the Magenta is exposed locally on the flanks of Nash Draw, and both the Culebra and the Magenta form the floor of wide sections of Nash Draw in the vicinity of Laguna Grande de la Sal.

A single water well in Lea County is reportedly deep enough to have reached Permian beds (Nicholson and Clebsch, 1961); otherwise no additional information is available on occurrence of water in the Rustler Formation in the area.

The Dewey Lake Redbeds. The youngest formation in the Ochoan Series, the Dewey Lake Redbeds, consists of orange-red siltstone with some mudstone and sandstone. This formation has been removed from the western and southern parts of the Delaware Basin by post-Permian erosion but is present in the subsurface throughout most of the site area. The thickness of the formation varies from about 200 feet to as much as 600 feet (Hiss, 1975a).

The Dewey Lake Redbeds are not an aquifer, although some permeable sand lenses are present and yield small quantities of water to a few wells. Regionally, the beds act as an aquiclude, restricting water at the surface from percolating downward to more permeable units in the underlying Rustler Formation.

Dockum Group. The Dockum Group consists of three formations. In ascending order, they are, 1) the Tecovas Formation, which consists of up to 300 feet of red shale, siltstone, and fine-grained sandstone, 2) the Santa Rosa Sandstone, which is composed of 100 to 650 feet of red, brown, and gray sandstone, and 3) the Chinle Formation equivalent, which consists of up to 1,300 feet of red, maroon, and purple shales and siltstones with lenses of fine-grained red-to-gray sandstone (Hiss, 1975a). The group is present only as a thin wedge in Eddy County, thickening to the east in Lea County and in Texas.

Both the Chinle Formation equilvalent and the Tecovas Formation are present only as thin, isolated remnants in southeastern New Mexico, primarily in Lea County. The few wells drilled into these formations yield small quantities of poor-quality water (Hiss, 1975a). In contrast, the Tecovas and Chinle are not considered aquifers in the Delaware Basin. The Santa Rosa Sandstone is a principal aquifer in several areas, particularly in Winkler and Ward Counties, Texas (Hiss, 1975a). It produces both fresh and saline water, depending on location. The westernmost extent of the Santa Rosa Sandstone is just into Eddy County, as shown in Figure 6.3-3. Water levels in wells open to the Santa Rosa Sandstone, reported by several sources, are the basis of the potentiometric surface by Mercer and Orr (1977) shown in Figure 6.3-3. Wells completed in the Santa Rosa Sandstone have low yields with specific capacities of 0.14-0.2 gpm per foot of drawdown (Nicholson and Clebsch, 1961); the formation porosity is about 13 percent.

Ground water recharge to the Santa Rosa Formation is from precipitation on the outcrop and percolation through sand dunes and the overlying Ogallala Formation to the east (Nicholson and Clebsch, 1961). Movement is generally southwest, but additional recharge apparently occurs along the potentiometric high that trends southwest along the eastern side of Eddy County. Discharge is to underlying formations at the edge of outcrops and reportedly downward through collapse zones such as San Simon Swale.

Ogallala Formation. The High Plains (Llano Estacado) region south of the Canadian River is mantled by the Ogallala Formation, which consists of Pleistocene sediments from 0 to 500 feet thick. South of Mescalero Ridge in Lea County the formation becomes discontinuous, and there are no definite remnants of the Ogallala west of easternmost Eddy County. Recharge to the Ogallala is by direct precipitation on the outcrop and by percolation through overlying sand dunes and alluvium. Nicholson and Clebsch (1961) reported that the saturated thickness of the Ogallala ranges from 25 to 175 feet. This variability can be attributed to the very irregular Triassic surface that underlies it. Movement of water in

the Ogallala is controlled to a great extent by the generally southeastward slope of the underlying Triassic red beds (Mercer and Orr, 1977).

Quaternary Deposits The Gatuna Formation is the oldest known Quaternary formation in the area and fills channels and steep-walled valleys cut primarily into the Dewey Lake red beds and Rustler Formation. In the type section and in the vicinity of Nash Draw where the Gatuna is readily recognizable, it is overlain by an extensive caliche zone that marks the Mescalero surface (Bachman, 1974). East of Nash Draw, there are few outcrops of the formation.

The Gatuna Formation yields limited amounts of water to wells where the water is in isolated gravel and sand lenses. Yields of one to five gpm are small but are usually sufficient for stock and domestic use. Ground water from the Gatuna probably percolates downward into Triassic sandstone or the Rustler Formation (Mercer and Orr, 1977).

Younger quaternary deposits are represented by alluvium. The most extensive alluvial deposits are along the west side of the Pecos River north of Malaga. Isolated patches of alluvium, however, occur along the Pecos to the south. In some areas the thickness is nearly 300 feet, and yields are reported to be as much as 3,000 gpm (Hendrickson and Jones, 1952). The source of water is primarily underflow from west of the Pecos River augmented by leakage from canals and from irrigation return flow.

Alluvium east of the Pecos River is restricted to relatively small closed depressions. Nash Draw and Clayton Basin contain Quaternary alluvium, and, in places such as Laguna Grande de la Sal, contain lake or playa deposits. The thickest alluvial deposits occur within San Simon Swale where they are in excess of 500 feet. Ground water present in the San Simon alluvium may be derived from discharge from the Santa Rosa Sandstone (Mercer and Orr, 1977). The lake and playa deposits often yield some water, although it is generally highly mineralized.

6.3.4 Regional Ground Water Use

Ground water is used in the region for irrigation, municipal supplies, rural domestic supplies, stock watering, a few industrial purposes, and for secondary oil recovery (usually referred to as "oil field flooding"). In southeastern New Mexico and western Texas almost all the ground water produced is used for this latter category. The Capitan aquifer is the largest source, but supplies are also taken from the Santa Rosa Sandstone and the Rustler Formation (Hiss, 1975a).

Demand for water throughout the region has increased steadily over the past three decades and is expected to continue into the 1980's. Production from the Capitan aquifer alone increased from approximately 80,000 acre-feet in 1950 to about 700,000 acre-feet in 1970 (Hiss, 1975a, Figure 38). The increase has been fairly linear over the 20 year period. Most of the increased demand has been for oil-field flooding which began in the early 1950's. The largest amount of pumping for this purpose is in Ward and Winkler Counties, Texas, and is primarily extracted from the Capitan aquifer. The other major source is the San Andres Limestone. According to Hiss (1975a), the cumulative total of water produced from these aquifers for the period 1920-1969, in thousands of acre-feet, is as follows:

	Eddy County	Lea County	West Texas	Total
Industrial	65.4	-	-	65.4
Irrigation	151.0	-	223.7	374.7
Municipal	162.0	-	-	162.0
Secondary Recovery	0.6	2.8	293.0	296.4
TOTAL	379.0	2.8	516.7	898.5

Listed below (in acre-feet) is a summary of usage in Eddy County for the year 1949 (Hendrikson and Jones, 1952) and in Lea County for the year 1954 (Nicholson and Clebsch, 1961). It is reasonable to assume that the quantities reported for industrial, irrigation, municipal, and rural use

have increased a moderate amount. The quantity listed for secondary recovery has increased moderately in southeastern New Mexico and dramatically in west Texas, as noted above.

	Eddy County (1949)	Lea County (1954)
Industrial	4,000	2,710
Irrigation	130,000	2,600
Secondary Recovery	0	40
Rural Domestic/Stock	2,000	450
TOTAL	141,000	6,350

Occurrence of large quantities of potable ground water is restricted to west of the Pecos River, and most of this water is extracted from the Capitan aquifer. Hiss (1975a) reported that the municipal water supplies for the communities of Carlsbad and White's City are obtained from wells completed in the Capitan aquifer. Hiss also reported that water pumped from the Capitan aquifer is used to irrigate about 2,300 acres of farmland in the Pecos River valley, the immediate vicinity of Carlsbad.

In addition, water pumped from the Capitan aquifer at Carlsbad is transported by pipeline to a potash refining plant located about 18 miles east of Carlsbad. Approximately 3,740 acre-feet of water per year was used to refine potash ore during the period 1965-1969.

Oil Field Secondary Recovery. In the early 1950's, the petroleum companies operating in the region initiated a process to recover crude oil that could no longer move to wells under existing reservoir pressure. This secondary recovery technique is one in which water is injected under pressure into the oil-bearing formation to drive the residual oil to the pumping wells. Injection may be into existing depleted wells or into wells constructed specifically for this purpose.

According to Hiss (1975a, Table 15), a cumulative total of nearly 300,000 acre-feet of water has been produced from the Capitan aquifer for

secondary recovery versus a total of about 725,000 acre-feet actually used in the flooding process. The difference of 425,000 acre-feet has been supplied from other sources including the San Andres Limestone and the Ogallala and Rustler Formations. The major areas of extraction for this use are in Ward and Winkler Counties, Texas.

Ground Water Utilization East of the Pecos River, Southeast New Mexico. In this area, small amounts of ground water are used for rural domestic supplies, stock watering, gasoline plants, and gas stripping. The Rustler Formation, the Santa Rosa Sandstone, and the Artesia Group are the principal hydrologic units pumped for those purposes. In the Nash Draw area, relatively large quantities of ground water have been taken from the Rustler Formation for use in potash refining. In the past, considerable amounts were pumped for irrigation in Lea County, but this has apparently been discontinued (Nicholson and Clebsch, 1961).

Gasoline plants use a considerable amount of water for their cooling and boiler systems. Nicholson and Clebsch (1961) report that in Lea County a total of 2400 acre-feet of ground water was used for this purpose in 1959. Gas stripping plants in the area also use water for extracting hydrogen sulfide and carbon dioxide from residual gas. Nicholson and Clebsch (1961) estimated that 150 acre-feet per year is used for this purpose.

In 1972, Cooley (1973, Table 4) inventoried the existing and abandoned wells in a nine-township block in east-central Eddy and west-central Lea Counties, New Mexico. Most of these wells are of low yields and are used mainly for domestic supplies and stock watering. Table 6.3-2 is extracted from the Cooley survey; well locations are shown on Figure 6.3-4.

6.3.5 Ground-Water Occurrence at the Proposed Site

The wells in the vicinity of the site (Figure 6.3-4) indicate that ground water above the Salado Formation is found only in limited quantities, and

is commonly of such poor quality, that it is not usable. Where the quality is marginal, it is utilized for watering stock, and is considered a valuable resource (Nicholson and Clebsch, 1961). Below the Castile Formation, at considerable depth, the Bell Canyon Formation might yield large quantities of water, but it would be brine. Although these units are technically regarded as aquifers, in the following discussion, only the hydrologic characteristics of fluid-bearing zones underlying the proposed site will be described. These zones are not identified as aquifers because an aquifer readily yields good quality water to wells.

Fluid-bearing Zones. The hydrologic exploration at the proposed site performed by the U. S. Geological Survey to date has been directed primarily to the fluid-bearing rocks of the Rustler Formation, and to the Rustler-Salado contact zone. They directly overlie the Salado salt and furnish a potential, although remote avenue for salt dissolution and radionuclide transport (Mercer and Orr, 1978). Additionally, brines in the sands of the underlying Bell Canyon Formation have been tested. These fluids are under sufficient head to allow them to reach the Salado salt. Because the brines are undersaturated, they could dissolve the salt. However, to reach the Salado, these fluids would have to first penetrate the Castile Formation. Permeabilities (or lack of permeability) of the Castile and Salado Formations at the site have been determined by drill-stem tests in two exploratory holes: ERDA No. 9 and AEC No. 8. The tests, summarized by Lambert and Mercer, 1977, Tables 1 and 2, indicate that the two formations are extremely tight. The tests gave no indication of fluid content in either formation.

Other zones that were briefly tested include zones in the Dewey Lake red beds where circulation was lost during drilling, or where hydraulic conductivity was believed to be measurable. However, no appreciable amounts of fluid were encountered (Mercer and Orr, 1978).

When the exploration and testing were completed, Mercer and Orr (1978) made several conclusions concerning the occurrence of fluids in the rocks. These include the following:

Monitoring of fluid-bearing zones in the Rustler Formation indicate that stabilized heads decrease with depth; consequently, potential fluid movement would be downward in rocks above the salt. However, the large head differences between fluid-bearing units within the Rustler indicate little or no vertical connection.

Head distribution determined for the Culebra dolomite indicates fluid movement to the southeast across the site. Gradients range from 7 to 120 ft/mi and vary as a function of hydraulic conductivity.

Head distribution within the Magenta dolomite has been determined only in three holes and indicates fluid movement to the southwest. The hydraulic gradient is 50 ft/mi.

Fluids in the Culebra and Magenta are expected to move primarily along fracture systems, and measurements of the effective porosities and hydraulic conductivities in low-yielding fractured rocks are very difficult to obtain.

Brines were found at some locations along the Rustler-Salado contact, but extremely low yields were measured.

Although evaluation of the testing of Bell Canyon sands is not complete, preliminary results at AEC-8 indicate the potentiometric surface, corrected to fresh-water density, is higher than similarily corrected levels of fluid zones in the Rustler Formation.

Hydrologic Testing. The geologic and geophysical exploration performed at the site provides a detailed understanding of the stratigraphy and structure of the underlying formations. This work was described in previous sections. In coordination with the exploratory drilling, a program of hydrologic testing and monitoring was established. As a result, considerable data on the occurrence of ground water have been collected. The ground-water studies are continuing and the data collected will further our understanding of the site conditions.

In addition to continued monitoring of the existing observation wells, long-term pumping tests to measure vertical connection between zones, and other tests have been planned. Also, some hydrologic information is available from the recently completed ERDA 10 test hole, located approximately 8.5 miles southwest of the proposed site.

One of the major problems faced in this program is the difficulty of measuring hydrologic parameters in materials of extremely low hydraulic conductivity in the field. Thorough testing of even the more permeable zones, such as the Culebra Dolomite, requires long periods of time, as well as close control of the interval being tested. To collect a sufficient quantity of water from these materials for proper water quality sampling requires long periods of time. Recovery of water levels in observation wells to static conditions is very slow; levels in some of the wells on site had not stabilized after more than 12 months of monitoring. Nevertheless, the data collected are sufficient to provide a good measure of the hydraulic characteristics and an understanding of ground-water occurrence at the proposed site. Hydrologic test data as of August, 1978, are available from 9 exploratory holes within the proposed land withdrawal boundary, and from the hole designated AEC 8, which is just outside the boundary, as shown on Figure 6.3-5. The U. S. Geological Survey Water Resources Division has been directing the testing program. A summary of drilling and testing operations is given for each hole in Section 6.4. A full description of the testing program and the data collected is presented in Mercer and Orr, 1978. The following discussion is extracted from that report.

The objectives of the program have been to determine the static head or reservoir pressure, the water-yielding potential (i.e., hydraulic conductivity and transmissivity) of the rock strata, and the chemistry of formation waters. These hydrologic tests are made in the exploratory test holes both during drilling and after the hole has been drilled to total depth.

Five of the test holes were specifically designed for hydrologic testing (H-1, H-2 complex, and H-3); the others were drilled for other purposes as well (potash mineral evaluation and/or geologic exploration) but were adapted for hydrologic testing. After drilling and testing wells H-1 and H-3, triangular arrays H-4, H-5, and H-6 complexes were designed similar to the H-2 complex but with a 100-foot well spacing. The additional sets of triangular arrays (H-4, H-5, and H-6) have been completed recently and testing has started.

The H-series test holes were drilled with air and detergent to avoid the undesirable mudcake that occurs when drilling with gel. This method also allows detection of fluid-producing zones that are encountered during drilling. When detected, some of these zones were tested before completion of drilling for a preliminary estimate of yield. On completion of drilling, geophysical logging was performed in all holes. These logs provided detailed information on lithologic changes, formational characterstics, potential zones of water yield, and borehole diameter changes. These data are used to select intervals to be tested, as well as provide information on hole conditions in the selection of packer seats.

Following logging, each potential zone of water yield was isolated with packers, and a drill-stem test (DST) was conducted. The DST is a temporary well completion designed to furnish hydrologic data, such as representative samples of formation fluid, undisturbed formation pressures, and indications of the formation permeablity, and/or transmissivity. The standard DST, as used in oil-field exploration, was run in test holes AEC 8 and ERDA 9, but in the other tests the procedures were modified. The modification most commonly made was in the method of recording formation pressures. In the standard DST, pressures are recorded throughout the test by a Bourdon-tube pressure recording gage (pressure bomb) located near the bottom of the drill string. Data from this pressure bomb cannot be retrieved until after completion of the test. In the modification DST used in these investigations, the fluid was initially removed from the tubing, and the stabilizing fluid levels

were measured in the drill string. This modification allowed for continuous monitoring throughout the test. Additionally, pressure-monitoring devices were placed above and below packers to determine the degree of isolation of the zone from the rest of the borehole.

The test zones were bailed or swabbed until temperature, conductivity, and density of fluid in the casing stabilized to assure that the fluid was representative of formation fluid. Samples were then collected, treated according to standard U. S. Geological Survey techniques, and chemically analyzed for the major and trace elements and for radiochemistry. Results of these analyses are listed in Table 6.3-3. The geochemistry of these fluids is discussed in Chapter 7.

During the bailing, the volume and rate of fluid withdrawal were monitored. The rate of recovery following withdrawal was measured, and yields from test zones were then calculated. The results of these tests are summarized in Table 6.3-4.

After all potential water zones were tested in the open hole, casing was installed and grouted in all holes except ERDA 9. Selected intervals were perforated for monitoring potentiometric levels, and provision was made for long-term hydrologic testing. Radioactive tracer tests were conducted in some of the holes after they had been cased and perforated to examine the cement-bond for leaks between casing and the borehole wall. These tests also yielded some information on vertical distribution of permeability across the test interval. The perforated zones were then tested for yield by bailing or swabbing, as was done in the open hole, and results are summarized in Table 6.3-4.

When the testing of the cased holes was completed, the holes were prepared as multiple observation wells. The holes are used to monitor potentiometric levels of two separate zones with the use of packers and inner tubing. In some wells, a third zone was perforated, but a bridge plug was set above it, and the zone is not available for periodic

monitoring. Figure 6.3-6 illustrates the method of completing the wells, and Table 6.3-5 indicates the zones monitored at each observation well.

Periodic monitoring of the fluid levels in the wells began after completion of testing. Because of the low yield of the zones tested, considerable time is required after bailing for the recovery of fluid to reach a stabilized level. Most levels had stabilized by October 1977, as indicated in Table 6.3-6. These levels provide a measure of the potentiometric surfaces of the monitored zones, and an indication of hydraulic gradients.

Bell Canyon Formation. During the WIPP hydrologic testing program, cores were taken in the Bell Canyon Formation in exploratory hole AEC 8. Analyses of these cores indicated the presence of two sandstone units whose permeabilities were higher than those of the surrounding rocks. These units are referred to as the lower sand and upper sand; their depths are, respectively, 4,844 to 4,860 feet, and 4,821 to 4,827 feet.

Hydrologic testing of the two sand units was made only in cased, perforated zones. There was no open-hole testing. These tests included formation pressure testing, fluid level monitoring, aquifer yields, recovery rates, water sampling, and geophysical logs. Radioactive tracer logs were also run on this hole. Analysis of the data had not been completed at the time of the report by Mercer and Orr (1978).

After the fluid in the casing had been removed by swabbing to a depth of approximately 4,200 feet, the lower sand yielded 31 gallons of fluid in 166 minutes (average 0.2 gpm), recovering to a depth of 4,095 feet. The zone was then shut-in, and a static formation pressure of 2,037 lbs/in^2 was reached in 44-1/2 hrs. The upper sand was not tested for yield. Static formation pressure was 2,044 lbs/in^2 after 57 hours.

Samples collected from the two sand units indicate that these units contain dense brines. For example, the upper sand contains 189,000 ppm of total dissolved solids, 175,000 ppm of which is sodium chloride

(Mercer and Orr, 1978, p. 80). The major constituents from the analyses are listed in Table 6.3-3. Density of the brines of each zone was determined to be 1.11 gm/cm^3 for the upper sand, and 1.12 gm/cm^3 for the lower sand. These values were used to correct static heads to fresh-water equivalents (Table 6.3-6).

Rustler-Salado Contact. The contact zone between the Rustler and Salado Formations was tested in holes H-1, H-2c, H-3, P-14, P-15, P-17, and P-18.

Both open-hole and cased-hole tests were run on the Rustler-Salado contact in H-1 and H-3, and cased hole tests were run in H-2c, P-14, P-15, P-17, and P-18. Without exception, all tests showed very low yields, typically producing a few gallons per day in the cased holes and only slightly more in the open holes (Table 6.3-4). A yield of 9.1 gallons in a 20-hour period (in H-1) was the highest yield recorded. Based on the collected data, Mercer and Orr (1978, p. 83) calculated transmissivities from the yield data, ranging from 10^{-1} ft^2/day (in P-14) to 10^{-4} ft^2/day (in P-18). Recovery rates in the monitoring wells are so slow that the level had not stabilized in P-18, after 4 months (Table 6.3-6).

Samples were taken from all of the test wells except P-18. Analyses of these samples show that the fluid in the Rustler-Salado contact zone is a saturated brine containing more than 300,000 ppm total dissolved solids (Table 6.3-3).

Culebra Dolomite. The Culebra dolomite was tested in holes H-1, H-2b, H-2c, H-3, P-14, P-15, P-17, and P-18. Logs of these holes indicate that the thickness of this unit is about 28 feet and that its depth ranges from 410 to 940 feet below ground level.

Both open-hole and cased-hole tests were run in the Culebra in H-1 and H-3, and cased hole tests were run in H-2c, P-14, P-15, P-17, and P-18. Yields varied considerably. At P-14, 720 gallons of fluid were bailed with no noticable drawdown, while P-18 produced only 16 gallons of fluid

in 33 days of monitoring. Preliminary transmissivity values calculated by Mercer and Orr (1978) also reflect the variability with values of 140 ft^2/day at P-14, 10^{-1} ft^2/day at H-1, and 10^{-4} ft^2/day at P-18.

Mercer and Orr (1978) reported that fluids in the Culebra have a total dissolved solid range of 23,700 to 118,300 ppm, and a sodium chloride range of 17,900 to 89,200 ppm. The major constituents of samples taken from the Culebra are listed in Table 6.3-3.

Magenta Dolomite. The Magenta Dolomite was tested only in H-1, H-2a, and H-3. In these holes the Magenta is 25 feet thick and the top of the unit is 502 feet below ground level.

Both open-hole and cased-hole modified drill stem tests were run on the Magenta in H-1 and H-3; well number H-2a was constructed as an observation well for the Magenta. The open-hole drill-stem test on the Magenta in H-1 produced only 13 gallons of fluid in 13 hours. A subsequent swabbing of the permeable zone produced 107 gallons of fluid, which indicated higher productivity than the DST displayed. In the cased-hole test, the Magenta zone was bailed constantly until a pumping level of 424 feet (depth) was attained. After bailing was stopped, the fluid level recovered to a depth of 340 feet in 33 days. In H-3, an open hole drill-stem test produced 23 gallons of fluid in 38 hours, but 442 gallons were swabbed from the hole after the DST was discontinued. In the cased hole test, 1 hour of bailing produced 6 feet of drawdown, and recovery was from 405 to 401 feet in 33 days of monitoring. Preliminary transmissivity values computed by Mercer and Orr (1978) range from 40 ft^2/d to less than 1 ft^2/d.

The quality of the Magenta fluids is poor (Table 6.3-3), with a total dissolved solids range of 10,300 to 29,700 ppm. The sodium chloride range is from 6800 to 24,300 ppm.

Salt-Residue Zone. Rocks of the Rustler Formation in which halite beds have been removed by leaching--salt-residue zones--were considered to be

areas for possible fluid retention. A potential zone was identified from geophysical logging and drill stem tests performed in H-1 and H-3. Results show that very little fluid now exists in those zones. In H-1, the suspected zone yielded 11.2 gallons of fluid in 12 hours of monitoring.

6.3.6 Dissolution of Salt in the Permian Evaporites

Features apparently caused by solution and/or subsidence are common in southeastern New Mexico. The extensive karst plain of the Llano Estacado (the High Plains or Caprock region) indicate the prominence or rock solution as a geologic process. Depressions near the WIPP site range from small features no more than a few meters in diameter to large features such as Laguna Grande de la Sal (Salt Lake), 11 miles to the west-southwest of the WIPP site, and Laguna Plata and Laguna Gatuna, 14 miles to the north. Not all depressions in the region, however, have been formed by solution and collapse. Some have been formed by wind action, and others are the result of solution or etching of the caliche. Salt Lake does appear to occupy an area of coalesced collapse dissolution sinks, but Laguna Plata and Laguna Gatuna appear to have formed as solution blowouts in windborne sand deposits.

A report to Sandia Laboratories by R. Y. Anderson was prepared in early 1978. This report served to assemble and summarize available data regarding the dissolution of evaporites in the Delaware Basin. The Anderson (1978) report also proposed a set of working hypotheses for the origin of various dissolution features, in order to guide future Sandia investigations of evaporite dissolution relevant to the potential integrity of the WIPP horizons and adjacent evaporites. In the text that follows, an attempt is made to distinguish available data from working hypothesis, whenever Anderson (1978) is cited.

It has been estimated that as much as 50 percent of the original salt of the Delaware Basin evaporites has been removed (Anderson, 1978) either by surface erosion or by subsurface dissolution and transport by ground

water. These processes have been in progress intermittently through more than 100 million years (Bachman, 1974). At least four erosional periods, in which the removal of salt could have been accomplished, can be recognized. These include: 1) Early Triassic time, 2) Jurassic through Early Cretaceous time, 3) a Late Cretaceous through mid-Tertiary period, and 4) post-Ogallala uplift and erosion.

Of the processes which accomplished the removal, two types of salt dissolution have been recognized in the Delaware Basin. The more familiar dissolution is the removal of salt by waters percolating downward from above (primarily from precipitation falling directly on the ground surface above the salt). The percolating water removes soluble salts, leaving behind a residuum of insoluble material that is referred to as a leached zone (Vine, 1963). The shallow dissolution beneath Nash Draw is such a zone and is apparently the route of lateral migration of the leached salts that discharge into the Pecos River.

A second type of salt dissolution has been recognized as having dissolved salt from somewhere within the body of evaporites, generally resulting in the collapse and lowering of the overlying stratigraphic units. Anderson (1978) recognized the resulting insoluble residue as a blanket dissolution breccia which occurs to the west of the present salt edge in the basin. In addition, deep dissolution phenomena within the evaporites may have developed more localized collapse features that have been recognized around the margin of the basin and within the basin (Maley and Huffington, 1953). The origin of these deep dissolution features and breccias is more problematical than the origin of surface dissolution and the rates of dissolution more difficult to assess. Source of the water to dissolve the salt is hypothetically assumed to be aquifers underlying the salt beds, communicating through fracture systems in the intervening anhydrite beds.

Shallow Dissolution. The depth of shallow dissolution in the evaporites (base of leached zone) is highly irregular, but is usually less than 300 feet in the vicinity of the proposed site (see Section 4.3.2). It is

developed in the western part of the Delaware Basin where the evaporites are exposed, or near the surface. For example, in Nash Draw, where the Rustler Formation is exposed, leaching extends into the Salado, and the permeable residuum contains brine (Vine, 1963). It appears that percolating ground waters move laterally toward Nash Draw, eventually discharging to the Pecos River after becoming saturated with salt.

East of Nash Draw, down dip into the basin, the evaporite formations become progressively deeper, and the present-day top of salt becomes progressively higher in the stratigraphic section. The top of salt is at the top of the Salado Formation about 2 miles west of the center of the proposed site, and becomes progressively higher in the Rustler Formation across the site (Figure 6.3-7, also see Figure 2-6).

Jones (1972) reported the solution front in the Salado Formation to be between 2 and 3 miles west of the center of the site. Bachman (1974) described a thinning of the upper member of the Salado Formation to the west and north that he attributed to a combination of thinning inherent in the original deposition processes and thinning due to subrosion "during the middle and late Cenozoic. West of the line marked "edge of Salado salt" in Figure 6.3-8, there is almost a fourfold reduction in thickness of the upper member of the Salado Formation to as little as 150-170 feet in some places. This is the residue of a 500-foot thick section from which the soluble portions have been leached by circulating ground water. Wherever the upper member of the Salado has been thinned by dissolution, the section of rock between the upper surface of the remaining salt and the top of the formation consists of clay with crudely interlayered seams of broken gypsum (from rehydration of anhydrite) and fine-grained sandstone.

As dissolution progresses and the salts are carried away, voids develop and the residual layer is weakened until it is no longer able to support the overlying material. Slumping of the residue and the associated collapse of the roof can extend to surface elevations, resulting in a

topographic sink. The distinctive pitted topography that results is termed karst. Such topography, in which surface drainage is poorly defined, is extensive in southeastern New Mexico.

Bachman (1974) reported that dolines (that are believed to develop into shallow sinks on the rock surface beneath the soil mantle) are very common, and suggested that the course of the Pecos River southward from Carlsbad to the proximity of the New Mexico-Texas state line lies in a major belt of collapsed sinks. For example, along the east side of the Pecos River, southeast of Carlsbad at Malaga Bend, a linear scarp is believed to have formed along a collapse structure that is now occupied by the river. Other major collapse features mentioned by Bachman include Clayton Basin and Nash Draw. Bachman believes that these features formed as coalescing sinks, probably during Pleistocene time.

Another large depression cited by Bachman is San Simon Sink, located 22 miles east of the proposed site. Shallow dissolution is a factor in the development of this sink, which is apparently still in process. The last recorded collapse in San Simon Sink occurred approximately 40 years ago (Nicholson and Clebsch, 1961). Many sinks along the Pecos River Valley have collapsed in historic time (Bachman, 1974). As recently as 1973 a small collapse sink formed at Lake Arthur, N.M., about 50 miles (80 km) north of Carlsbad.

Deep Dissolution. Large, deep dissolution features filled with Cenozoic sediments overlying the inner margin of the Capitan reef (Figure 6.3-8) were recognized by some of the first geologists working in the Delaware Basin (Maley and Huffington, 1953). The source of water to dissolve the salt was assumed to be the Capitan aquifer.

The extent of large-scale dissolution structures is shown on Figure 6.3-8. The dissolution wedges were identified through varve correlation across the basin in the Castile Formation and recognition of dissolution breccia beds in the western part of the basin (Anderson et al., 1972). These studies suggest that deep dissolution wedges in the Castile

Formation occurred in the lower Salado and upper Castile salt beds (Anderson, 1978). The position of the eastern margin of the western wedge coincides with the location of dissolution features containing deep Cenozoic fill (Figure 6.3-8). The development of these features and the wedge was apparently a complex process. It probably included initial wedge development adjacent to the reef, similar to that seen in the eastern wedge (Anderson 1978), and later combined with shallow dissolution.

The most prominent small-scale, (less than 1 mile across) dissolution features in the vicinity of the Delaware Basin have been described by Vine (1960) as "domal karst features". The subsurface projection of one of these (dome "C") was encountered at the level of the McNutt potash zone by Mississippi Chemical Corporation. It was found to be a chimney in the Salado Formation filled with clay-cemented brecciated rock belonging to strata above the 7th ore zone. There are other erosion-breached domes similar to Vine's dome "C" in the vicinity of Nash Draw. The subsurface expression of the domes, if any, is virtually unknown. A chimney containing cemented rubble (incorrectly termed a "breccia pipe") was encountered in commercial exploratory drilling within the proximity of a low circular hill near the Wills-Weaver Mine, but this chimney was not associated with a breached-dome at the surface. Recent geophysical surveys of the region have revealed that some of these hills, including the "Weaver Pipe" and dome "C", are associated with resistivity lows. Both Vine (1960) and Anderson (1978) have proposed mechanisms for origin of these features, all of which remain to be tested by field investigations of their subsurface structure and composition (see Chapter 10). These mechanisms involve various combinations of differential solution, hydration of anhydrite to gypsum, and salt intrusion. An attempt to reconcile these mechanisms and apply them to the origin of domes near Queen Lake southwest of Nash Draw was made by Reddy (1961).

Anderson believes that the dissolution giving rise to these features is an ongoing process. The proposed site is in an area of the Delaware Basin that is free of regional deep dissolution, but localized features

are present in the vicinity. Nevertheless, the extensive investigation carried out at and near the proposed site, including exploratory holes, ERDA-10, ERDA-11, ERDA-9, and AEC-8, indicate that deep dissolution is not taking place there. ERDA 10 was located and drilled specifically to evaluate the suggestion of Anderson that the absence of Halite III in the Castile south of the WIPP site was due to deep dissolution. Examination of the core revealed no apparent solution residue or collapse breccia; the recently collected data indicate nondeposition rather than dissolution since this was the nearest probable location of regional deep dissolution, its absence implies a lack of threat to the WIPP site from this phenomenon.

Rates of Dissolution. It is evident that dissolution is an active process, and can be expected to continue in the future. The potential hazard to the proposed site by continued dissolution in nearby places such as Nash Draw, 7 to 8 miles west of the site, can be evaluated if the rates of dissolution are known. In relation to human activity, the rate of dissolution is almost immeasureably slow. However, in terms of geologic processes, an attempt to estimate the rate is not altogether impractical. As stated by Bachman (1974): "Active geologic processes have not changed since the close of Tertiary Ogallala time, about 3-4 m.y. (million years) ago. However, the rates of these processes have varied considerably. It is assumed that the rates of these processes will continue to vary and that prediction of future events can be made by assuming that the extremes of past conditions will not be exceeded in the future."

With this in mind, Bachman analyzed the rate of dissolution in Nash Draw since the development of the Mescalero caliche, estimated to be 600,000 years ago. The following summarizes his analysis (Bachman, 1974):

Collapse of the Mescalero caliche along the margins of Nash Draw indicates that this depression has formed, at least in part, since the deposition of the caliche.

Along Livingstone Ridge on the east side of Nash Draw, the Mescalero caliche is undeformed at elevations above 3,300 feet. It dips steeply into the depression along the ridge and occurs at elevations of 3,200 feet, and less, within the depression. Along Quahada Ridge on the west side of Nash Draw the Mescalero is likewise undeformed at elevations about 3,300 feet, but it dips steeply into Nash Draw and occurs as collapsed fractured masses within the depression (NE 1/4 sec. 1, T. 22 S., R. 29 E.).

A cross section through potash exploratory holes in Nash Draw indicates the approximate extent of salt dissolution in the Salado Formation since Mescalero time (Figure 6.3-9).

Nash Draw appears to have subsided between Livingstone and Quahada Ridges as much as 180 feet since Mescalero time. At one locality the surface of Nash Draw is 180 feet below the projected altitude of the Mescalero caliche (See figure 6.3-9). However, the interval between the top of the Salado Formation and the top of marker bed 124 at the same location is 420 feet, or 330 feet less than at Livingston Ridge where relatively little Salado salt has been removed. It is therefore interpreted that about 150 feet of Salado salt was removed before Mescalero time and about 180 feet has been removed since Mescalero time. At another locality, Nash Draw subsided approximatley 160 feet below the projected elevation of the Mescalero caliche while about 120 feet of Salado salt was being removed. There is a discrepancy here of about 40 feet that could be explained by surficial erosion.

Thus, in the area of Nash Draw that subsided 180 feet, the average rate of vertical dissolution over the 600,000 years was about 0.33 feet per 1000 years (Bachman, 1974).

These conclusions are based on the available geologic evidence, but the assumption should not be made that this rate of dissolution is a constant for the region. At least two other factors must be considered in this interpretation, but geologic information is not currently available to permit evaluation of them. The factors are:

Dissolution and subsidence rates probably have not been constant in Nash Draw during the past 600,000 years. A major part of this subsidence may have occurred during periods of high humidity in late Pleistocene (Wisconsin time).

The subsidence in Nash Draw, whenever it occurred in the Pleistocene, is not an average rate for the region. In the area of "the Divide," between Antelope and Livingstone Ridges, the Mescalero caliche is relatively undisturbed and probably no dissolution has occurred there since Mescalero time.

Calculations have also been made of the removal of salt from the Rustler and Salado Formations in Nash Draw based on the rates of discharge of dissolved sodium chloride and calcium sulfate into the Pecos River by brine seeps at Malaga Bend. Active dissolution of halite from the upper part of the Salado Formation occurs in the solution breccia zone at the base of the Rustler Formation in Nash Draw (Brokaw et al. 1972). The brine solution is believed to be recharged by aquifers in the Rustler and above, and its discharge is thought to be primarily at the Malaga Bend brine seeps and the salt lakes in Nash Draw. Piper (1973) calculated that the salts discharged into the Pecos River between Malaga Bend and a point 6 miles (10 km) downstream amount to 310,000 tons (2.8×10^8 kg) of NaCl and 170 tons (1.5×10^8 kg) of $CaSO_4$ each year. This is equivalent to a loss of 0.16 vertical feet of salt section per thousand years, a rate of the same order of magnitude as that calculated from the subsidence of Nash Draw.

An alternative approach of estimating vertical dissolution was used by F.A. Swenson (Bachman and Johnson 1973). He investigated the tonnage of salt dissolved and discharged by springs and streams along the east flank of the basin and found the maximum tonnage for the many subbasins to be 955 tons per square mile of drainage area each year. If the discharge continued at that rate it would mean a vertical dissolution of about 0.5 foot of salt in 1,000 years, provided the dissolution was distributed evenly over the area drained.

A rate of lateral shallow dissolution of salt in the western part of the Delaware Basin has been estimated to be about 6 to 8 miles per million years horizontally (Bachman and Johnson 1973). These estimates were based on the assumption that the salt-bearing Salado Formation extended to the Capitan reef escarpment on the western edge of the basin at the end of Ogallala time. It is now recognized that dissolution of this salt could have occurred at previous times in the past, and the average rate of salt removal by shallow dissolution is believed to be much slower than those estimates which establish an upper bound.

As stated previously, it is estimated that about 50 percent of the original volume of salt has been removed from the Basin. In considering the rate at which the salt was removed, it is generally recognized that much of the erosion and dissolution probably occurred since the beginning of Cenozoic time. This is a period of major uplift and erosion. Anderson pointed out (1978) that the dissolution features are closely associated with Cenozoic and postuplift hydrologic and structural controls. Nevertheless, as early as Jurassic time the basin was tilted and the western portion shown on Figure 6.3-8 was exposed and subject to erosion (Bachman, 1976). The hydrologic and structural conditions were apparently similar at that time to those of the Cenozoic, and the Jurassic climate is recognized to have been wet. Thus, it seems quite likely that the deep dissolution and erosional processes of salt removal could have been significantly accelerated during the Jurassic period.

The rate of deep dissolution is difficult to assess, and Anderson (1978) does not believe that estimates can be made with any degree of confidence, considering the available data. He suggests that if it is assumed that 1) deep dissolution progresses at a constant rate, and 2) that significant dissolution did not begin until after stripping of the Ogallala Formation from the basin (3-4 million years ago), projection of that rate would imply all of the lower Salado salt would be removed in about another million years. However, he does not believe the assumptions are valid.

Deep dissolution, as hypothesized by Anderson, would seem to have been a significant geologic process in Jurassic time, as well as in the Cenozoic. It is apparent that further study of these factors is needed to fully assess the impact on the proposed site. Sandia Laboratories and the U.S. Geological Survey are currently performing studies to provide data which should aid in this evaluation (see Chapter 10).

6.4 HYDROLOGY DRILLING AND TESTING SUMMARY

6.4.1 HOLE NO. H-1

LOCATION: T.22 S., R.31 E., Sec. 29

ELEVATION: 3,403.2 feet (ground level)

DEPTH DRILLED: 848 feet

DATE COMPLETED: June 9, 1976

DRILLING CONTRACTOR: Sonora Drilling Co., Carlsbad, N. Mexico

DRILLING METHOD: Auger 18 inch hole (0-40 feet)
Rotary 7.88 inch hole with air-air/mist (40-731 feet)
Core 4.75 inch hole with air mist (731-842 feet)
Ream 9.88 inch hole (40-848 feet)

CASING RECORD: 10.75 inch O.D. steel surface pipe, (0-40 feet) cemented to surface
7 inch O.D. steel casing (0-848 feet), cemented to surface (cement plug to 797 feet, drilled to 831 feet)

GEOPHYSICAL LOGS: Differential Temperatures
BHC Acoustic
Compensated Densilog
Dual-Laterolog

Micro-Laterolog
Compensated Neutron-Gamma
Sperry-Sun Magnetic Survey

HYDROLOGIC TESTING (OPEN HOLE):

A. 699-842 feet: DST, of Rustler-Salado Contact, 9.1 gallons of water in 20 hours

B. 667-699 feet: DST of Culebra Dolomite, 10.6 gallons of water in 11.5 hours

C. 626-667 feet: DST, of suspected salt residue, 11.2 gallons of water in 12 hours.

D. 562-592: DST of Magenta Dolomite, 13 gallons of water in 13.5 hours; after hole was drilled to 592 feet inflow of 490 gpd was observed.

HYDROLOGIC TESTING (CASED HOLE):

E. 803-837 feet: Perforated zone, Rustler-Salado contact, water level rose from 826.5 to 811 (25 gallons) in 33 days.

F. 675-703 feet: Perforated zone, Culebra Dolomite, fluid level rose from 665 to 406 (416 gallons) in nine days.

G. Tracer, ^{131}I, no annulus leaks, no flow in 694-703 interval, major loss in 675-694 interval, tracer injection rate of 8 gpm, total 1634 gal. injected.

H. 562-590 feet: Perforated zone, Magenta Dolomite, after bailing, water rose from 424.5 to 340.7 feet in 33 days (53 gallons), could not bail below 424 feet.

I. Culebra water level stable at 390 feet depth. (October 1977)

J. Magenta water level stable at 249 feet depth. (October 1977)

DRILLING & TESTING SUMMARY

6.4.2 HOLE NO. H-2a

LOCATION: T.22 S., R.31, E., Sec. 29

ELEVATION: 3,377.1 feet (ground level)

DEPTH DRILLED: 563 feet

DATE COMPLETED: February 19, 1977

DRILLING CONTRACTOR: Pennsylvania drilling Co., Carlsbad, N. Mexico

DRILLING METHOD: Auger 18 inch hole (0-33 feet)
Rotary 8.75 inch hole with air-air/mist (33-513 feet)
Core 4.75 inch hole with air/mist (513-563 feet)
(cut 2.25 inch diameter core)

CASING RECORD: 10.75 inch O.D. steel casing (C-33 feet) cemented to surface
6.63 inch O.D. steel casing, (0-511 feet), cemented to surface

Geophysical Logs: None. Available from H2C, 90 feet away.

HYDROLOGIC TESTING:

A. 0-188 feet: Stopped drilling after encountering wet zone at 185 feet; interval produced no appreciable fluid in 5 hours

B. 513-563 feet: Open hole, Magenta Dolomite, water rose from 556.8 to 538.7 in one day (22 gallons).

C. Magenta static level at 249 feet, October, 1977

DRILLING & TESTING SUMMARY

6.4.3 HOLE NO. H-2b

LOCATION: T.22 S., R. 31 E., Sec 29

ELEVATION: 3,377.1 feet (ground level)

DEPTH DRILLED: 661 feet

DATE COMPLETED: February 12, 1977

DRILLING CONTRACTOR: Pennsylvania Drilling Co., Carlsbad, N. Mexico

DRILLING METHOD: Auger 18 inch hole (0-33 feet)
Rotary 8.75 feet hole with air-air/mist (33-611 feet)
Core 4.75 inch hole with air/mist (611-661 feet) (cut 2.25 inch diameter core)

CASING RECORD: 10.75 inch O.D. steel casing (0-33 feet) cemented to surface
6.63 inch O.D. steel casing, (0-609 feet)., cemented to surface

Geophysical Logs: None. Available from H2C, 75 feet away.

HYDROLOGIC TESTING:

A. 611-661 feet: Open hole, Culebra cored interval, water rose from 636.9 to 458.0 feet in one day (260 gallons). Level stable at 352 feet (February 1977)

B. Hole # H-2c was bailed from the Culebra while monitoring H-2b in the Culebra. First response in H2b was detected 50 minutes after bailing of H2C started.

C. 510-538 feet: Perforated zone, Magenta Dolomite, water rose from 560 to 420 feet in one day (210 gallons).

D. Well constructed for monitoring at Culebra Dolomite via tubing and Magenta via annulus. Culebra static level at 351 feet, Magenta static level at 292 feet (perforations may be blocked).

DRILLING & TESTING SUMMARY

6.4.4 HOLE NO. H-2c

LOCATION: T.22 S., R.31 E., Sec 29

ELEVATION: 3,377.1 feet (ground level)

DEPTH DRILLED: 795 feet

DATE COMPLETED: February 5, 1977

DRILLING METHOD: Auger 18 inch hole (0-33 feet)
Rotary 8.75 inch hole with air/mist (33-743 feet)
Core 4.75 inch hole with air/mist (743-795 feet)
(cut 2.25 inch diameter core)

CASING RECORD: 10.75 inch steel casing (0-33 feet) cemented to surface
6.63 inch O.D. steel casing, (0-742 feet), cemented to surface.

Geophysical Logs: Compensated Densilog
Dual-Laterolog
BHC Acoustilog
Micro-Laterolog

Compensated Neutron-Gamma
4-Arm Caliper
USGS Lithologic-log

HYDROLOGIC TESTING:

A. 743-795 feet: Open hole, Rustler-Salado cored interval produced 14 gallons in 18 days.

B. 624-652 feet: Culebra perforated zone, water rose from 656.4 to 446.6 in one day (310 gallons). Static level at 352 feet. (March 1977)

C. Tracer ^{131}I, no flow below 642 in casing, fluid loss zone was between 631 and 644, especially 640-644 where core indicates pitted and fractured dolomite, tracer injection rate was 8 gpm, total 697 gal. injected.

D. Dual completion monitoring (Rustler-Salado via tubing and Culebra via annulus) shows Culebra stable at 355 feet (October 1977) and Rustler-Salado still recovering at 34 feet per month. (June 1978)

DRILLING AND TESTING SUMMARY

6.4.5 HOLE NO. H-3

LOCATION: T.22 S., R.31 E., Sec. 29

ELEVATION: 3,388.7 feet (ground level)

DEPTH DRILLED: 894 feet

DATE COMPLETED: August 12, 1976

DRILLING CONTRACTOR: Pennsylvania Drilling Co., Carlsbad, New Mexico

DRILLING METHOD: Auger 18 inch hole (0-38 feet)

Rotary 7.88 inch hole with air-air/mist (38-894 feet)

Ream 8.75 inch hole (38-894 feet)

CASING RECORD: 10.75 inch O.D. steel surface pipe (0-38 feet) cemented to surface.
6.63 inch O.D. steel casing, (0-891 feet), cemented to surface (cement plug to 804 feet drilled to 864 feet)

Geophysical Logs: Compensated Densilog
Micro-Laterolog
Dual-Laterolog
BHC Acoustilog
Compensated Neutron-Gamma
Differential Temperature

HYDROLOGIC TESTING (OPEN HOLE)

A. 800-868 feet: DST, Rustler-Salado contact, produced 1.8 gallons of water in 16.5 hours;

B. 672-703 feet: DST, Culebra, produced 2.1 gallons of water in 21.5 hours.

C. 703-780 feet: DST, salt residue, 2 gallons of water in 26 hours.

D. 558-608 feet: DST, Magenta, 23 gallons after 37.5 hours. after developing operation via swabbing.

HYDROLOGIC TESTING (CASED HOLE)

E. 813-837 feet: Perforated Rustler-Salado contact; produced 37 gallons in 32 days.

F. 675-703 feet: Perforated Culebra, bailed hole and monitored, recovery was up to 410 from an initial level of 550 feet (200 gallons in 8 days).

G. Tracer ^{131}I, showed no flow below 696 feet; major fluid losses in intervals 684-692 and 692-695; tracer injection rate was 8 gpm, total injected 450 gal.

H. 562-590 feet: Perforated Magenta, bailed 360 gallons in one hour with 6 feet of drawdown.

I. Dual-completion monitoring (Culebra via tubing and Magenta via annulus) indicate Culebra static level at 404.5 and Magenta static level at 245.1 as of October 1977.

DRILLING & TESTING SUMMARY

6.4.6 HOLE NO. P-14

LOCATION: T.22 S., R.30 E., Sec. 24

ELEVATION: 3,358.1 feet (ground level)

DEPTH DRILLED: 1,545 feet.

DATE COMPLETED: October 3, 1976

DRILLING CONTRACTOR: Boyles Brothers Drilling Co., Las Cruces, New Mexico

DRILLING METHOD: Rotary 8.75 inch hole with air (0-20 feet)
Rotary 7.88 inch hole with air-air/mist (20-784 feet)
Rotary with air/mist (784-1,168 feet)
Core with brine mud (1,168-1,545 feet)

CASING RECORD: 8.63 inch O.D. steel casing (0-20 feet)
4.50 inch O.D. steel casing, (0-775 feet) cemented to surface, hole plugged back from 1,345 feet to 759 feet with cement.

Geophysical Logs: Gamma
Gamma-Gamma
Neutron
Caliper

HYDROLOGIC TESTING (CASED HOLE)

A. 676-700 feet: Perforated Rustler-Salado, fluid level rose from 730 to 620 feet in one day (75 gallons).

B. 573-601 feet: Perforated Culebra, bailed 720 gallons of water in three hours with no drawdown.

C. Tracer ^{131}I, showed 63 percent fluid loss in interval 583-590, remaining loss in interval 573-583; no loss below 590 feet. Injection rate 7 gpm. Total injected 1634 gal.

D. Dual-completion monitoring (Rustler-Salado via tubing and Culebra via annulus); Rustler-Salado stabilized at 386 feet, Culebra stabilized at 324 feet (October 1977)

DRILLING & TESTING SUMMARY

6.4.7 HOLE NO. P-15

LOCATION: T.22 S., R.31 E., Sec. 31

ELEVATION: 3,309.7 feet (ground level)

DEPTH DRILLED: 1,465 feet

DATE COMPLETED: October 14, 1976

DRILLING CONTRACTOR: Boyles Brothers Drilling Co., Las Cruces, New Mexico.

DRILLING METHOD: Rotary 8.75 inch hole with air (0-20 feet)
Rotary 7.88 inch hole with air-air/mist (20-515 feet)
Core 4.75 inch hole with air/mist (515-600 feet) (cut 2.25 inch diameter core)
Ream 7.88 inch hole with air/mist (515-637 feet)
Rotary 5 inch hole with air/mist (637-1,038 feet)
Core with brine mud (1,038-1,465 feet)

CASING RECORD: 8.63 inch O.D. steel casing (0-20 feet)
4.50 inch O.D. steel casing, (0-635 feet), cemented to surface, hole plugged back from 1,465 to 600 feet with cement, cement drilled out to 620 feet.

Geophysical Logs: Gamma
Gamma-Gamma
Neutron
Caliper
Spectralog

HYDROLOGIC TESTING:

A. 532-556 feet: Perforated Rustler-Salado contact, fluid rise from 618 to 497 in 42 days (81 gallons).

B. 410-438 feet: perforated Culebra, fluid rose from 496 to 420 feet in one day (50 gallons); 125 gallons in 33 days

C. Dual Completion monitoring (Rustler-Salado via tubing and Culebra via annulus) shows Rustler-Salado static level at 324 feet and Culebra at 308 feet as of October, 1977.

DRILLING AND TESTING SUMMARY

6.4.8 HOLE NO. P-17

LOCATION: T.23 S., R.31 E., Sec. 4

ELEVATION: 3,339.5 feet (ground level)

DEPTH DRILLED: 1,660 feet

DATE COMPLETED: October 26, 1976

DRILLING CONTRACTOR: Boyles Brothers Drilling Co., Las Cruces, New Mexico.

DRILLING METHOD: Rotary 8.75 inch hole with air (0-20 feet)
Rotary 7.88 inch hole with air-air/mist (20-755 feet)
Rotary with air/mist (755-1,220 feet)
Core with brine mud (1,220-1,660 feet)

CASING: 8.63 inch O.D. steel casing (0-20 feet)
4.50 inch O.D. steel casing, (0-751 feet), cemented to surface, hole plugged back from 1,660 feet to 720 feet with cement, cement drilled out to 731 feet.

Geophysical Logs: Gamma
Gamma-Gamma
Neutron
Caliper

HYDROLOGIC TESTING (CASED HOLE)

A. 702-726 feet: Perforated Rustler-Salado contact; fluid rose from 726 to 622 feet (71 gallons in 73 days).

B. 558-586 feet: Perforated Culebra, single packer set at 683 feet, bailed and monitored for 29 days with fluid rise from 622 to 372 feet.

C. Dual Completion monitoring (Rustler-Salado via tubing and Culebra via annulus) indicates fluctuating levels; problem could be leaking bridge packer or communication in cemented annulus.

DRILLING & TESTING SUMMARY

6.4.9 HOLE NO. P-18

LOCATION: T.22 S., R.31 E., Sec. 26

ELEVATON: 3,478.7 feet (ground level)

DEPTH DRILLED: 1,998 feet

DATE COMPLETED: November 5, 1976

DRILLING CONTRACTOR: Pennylsvania Drilling Co., Carlsbad, New Mexico.

DRILLING METHOD: Rotary 8.75 inch hole with brine mud (0-18 feet)
Rotary 7.88 inch hole with brine mud (18-1139 feet) to casing depth.
Rotary with brine mud (1,139-1,630 feet)
Core with brine mud (1,630-1,998 feet)

CASING RECORD: 8.63 inch O.D. steel casing (0-18 feet)
4.50 inch O.D. steel casing, (0-1, 138 feet), cemented to surface, hole plugged back from 1,998 feet to 1,125 feet with cement.

Geophysical Logs: Gamma
Gamma-Gamma
Neutron
Caliper

HYDROLOGIC TESTING (CASED HOLE)

A. 1076-1100 feet: Perforated Rustler-Salado contact, fluid rise from 1123 to 1073 feet in 73 days (34 gallons)

B. 912-940 feet: Perforated Culebra, bailed and monitored recovery for 33 days with fluid rise from 1045 to 1022 feet (16 gallons).

C. Dual completion (Rustler-Salado via tubing, Culebra via annulus) indicated Rustler-Salado at 755 feet and still recovering as of October, 1977.

DRILLING & TESTING SUMMARY

6.4.10 HOLE NO. AEC-8

LOCATION: T.22 S., R.31 E., Sec. 11

ELEVATION: 3,531.9 feet (ground level)

DEPTH DRILLED: 3,019 feet (1974), deepened to 4,910 feet (1976)

DATE COMPLETED: August 5, 1976

DRILLING CONTRACTOR: Sonora Drilling Co., Carlsbad, New Mexico

DRILLING METHOD: Core, ream, rotary 7.88 inch hole with brine mud (31-3,019 feet)
Core, ream, rotary 7.88 inch hole with brine mud (3,018.5-4,910.5 feet)

CASING RECORD: 8.63 feet O.D. steel casing (0-874 feet), cemented to surface.
5.50 inch O.D. steel casing, (0-4,907 feet), cemented to 880 feet.

Geophysical Logs; Compensated Neutron
Micro-Laterlog
Dual-Laterolog
Gamma

HYDROLOGIC TESTING (CASED HOLE)

A. 4,844-4,860 feet: Perforated lower sand lense of Bell Canyon Formation; fluid level rose from 4126 feet to 4095 feet in 166 minutes (31 gallons).

B. 4,832 - 4,910 feet: Production packer with sentry monitoring device showed formational pressure of 2037 lbs/ in^2 reached in 44.5 hours; fluid density was 1.11 g/cm^3.

C. Tracer ^{131}I, along with temperature logs, indicated major fluid loss in interval 4839 to 4860 feet; minor communication down casing to 4870 feet; tracer injection rate was 14 gpm. Total injected 2289 gal.

D. 4,821-4,827 feet: Perforated upper sand lense of Bell Canyon Formation; single packer set at 4835 feet; swabbed fluid to 2600 feet; pressure monitor installed at 4805 feet; shut-in pressure recovered to 2037 lbs/in^2 in 57 hours, fluid density was 1.12 gm/cm^3,

E. Tracer ^{131}I, showed no upward or downward communication; injection rate at tracer was 11 gpm. Total injected 300 gal. Injection was occurring uniformly in the lower 4 feet of perforations.

F. Dual completion monitoring (lowering sand via tubing and upper sand via annulus) indicate lower sand stablized at 615 feet and upper sand at 560 feet as of November, 1977.

6.5 SUMMARY

The proposed site contains neither perennial streams nor surface water impoundment, and the water bearing strata above and below the evaporite section do not yield large quantities of water to wells. At its closest point, the Pecos River is approximately 14 miles southwest of the WIPP site. Water bearing strata in the local site area at stratigraphic horizons above the proposed repository include the Santa Rosa Sandstone and the Culebra and Magenta members of the Rustler Formation. Hydrologic units below the repository horizons include the Bell Canyon Formation of the Delaware Mountain Group. Ground water velocities vary with porosity, hydraulic conductivity, and head gradient but are typically 0.3 ft/d in the Santa Rosa Sandstone, 0.5 ft/d in the Rustler Formation, and 0.0006 ft/d in the Bell Canyon Formation. Shallow wells in the local area are generally used only for watering livestock and typically produce nonpotable ground water with total solute concentrations in excess of 3,000 ppm.

Natural potentiometric levels of fluids from rocks above and below the evaporites at the WIPP site (from the Rustler and Bell Canyon Formations, respectively) are comparable (about 2950 to 3050 above mean sea level). The head differential between upper and lower units varies within about 200 feet on the periphery of the site, the sign and magnitude of the differential depending upon precise geographic location.

Gentle eastward tilting of the Delaware Basin resulting in the exposure of the Salado Formation to near-surface waters has given rise to the removal of a wedge-shaped mass of soluble salts between the Guadalupe escarpment (30 miles due west of the site), where there remains no rock salt, and a point about 3 miles due west of the site center, where the Salado Formation is intact.

The proposed site is in an area of the Delaware Basin that is free of regional deep dissolution, but localized shallow features are present in the vicinity. A shallow salt dissolution zone (called the "brine aquifer") occurs in Nash Draw at the contact between the Salado and

Rustler Formations. This local shallow dissolution area ranges in width from 2 to 10 miles and has a length of approximately 30 miles. The brine solution flows southwesterly at a rate of about 0.2 ft/d and discharges into the Pecos River at Malaga Bend. The average rate of vertical dissolution has been estimated to be between 0.33 and 0.5 feet per 1,000 years, and the average rate for lateral dissolution has been estimated to be between 6 and 8 miles per million years.

Climatological records show that mean annual precipitation of the site is approximately 12 inches per year. Aided by the low relative humidity (typically 36% during daylight hours) and high mean annual temperature (61°F), most of the annual precipitation returns to the atmosphere through evaporation and transpiration. Runoff is typically 0.1 to 0.2 inches annually.

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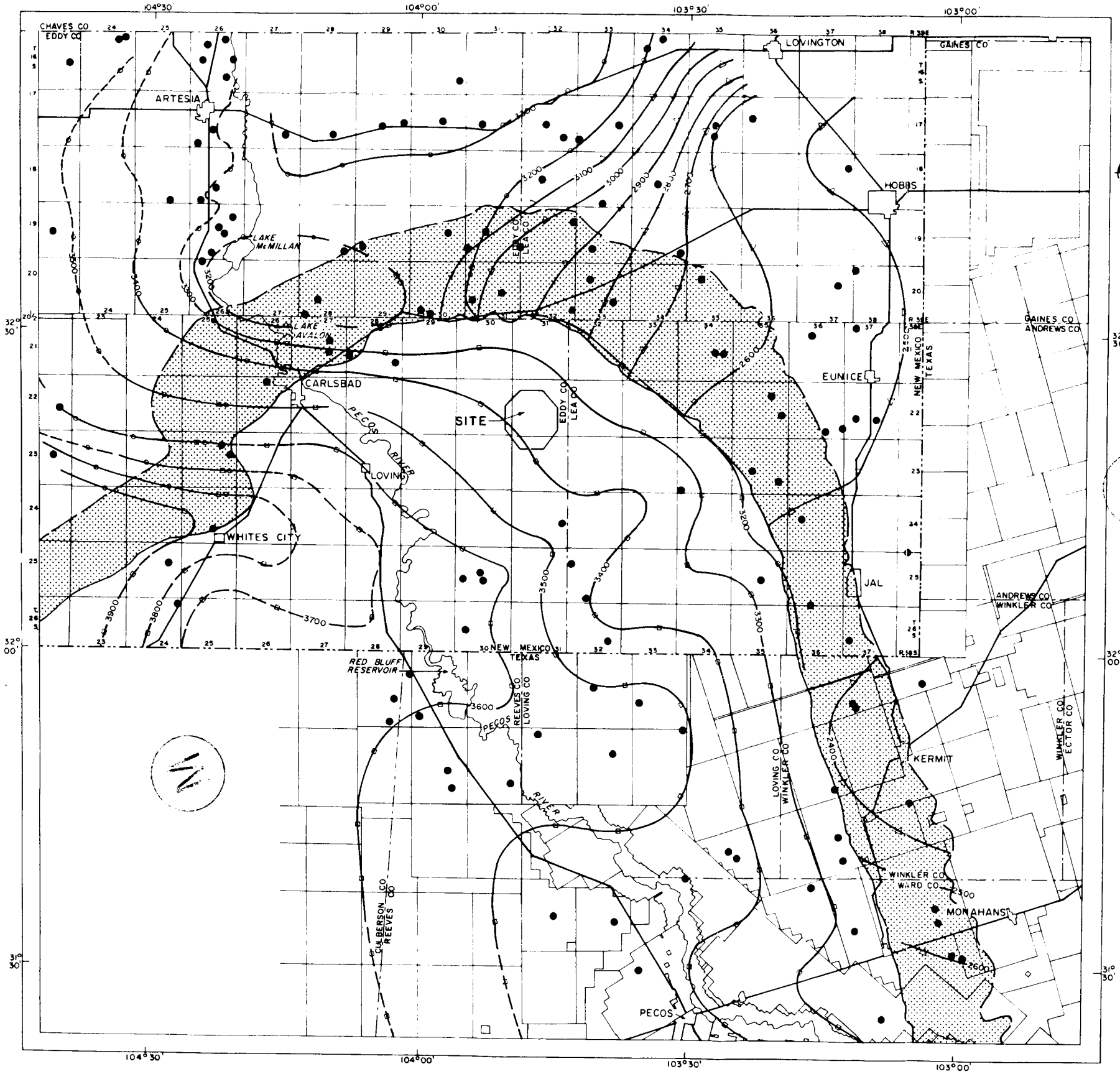


EXPLANATION

Position of Capitan aquifer

Approximate position of extreme shelfward edge

Basinal edge

CONTOURS OF HEAD (in feet above sea level) Values of head are expressed as water with specific gravity of 1.00. Contours are dashed wherever data are sparse or of doubtful reliability.

Head measured in shelf aquifer system where the hydraulic communication with the Capitan aquifer is relatively poor

Head measured in the Capitan aquifer system where the hydraulic communication between the two aquifers is relatively good

Head measured in basin aquifer system where the hydraulic communication with the Capitan aquifer is relatively poor

The contours express a generalized regional head considered to be reresentative for basin and shelf aquifers during the period 1960 to 1970. Similarly, contours in the Capitan aquifer are an interpretation of the head representative for the latter part of 1972.

Considerable subjective judgment was used in contouring the data points. In general two factors were weighed in considering each data point.

(1) The year in which the head was measured. This is important because prior fluid withdrawl from the oil and water fields causes a decline in head in nearby areas.

(2) The reliability of the data: In general the data were ranked according to reliability in the following order: fluid level in water wells, initial oil field bottom-hole pressures, and analysis of pressures from drill-stem tests.

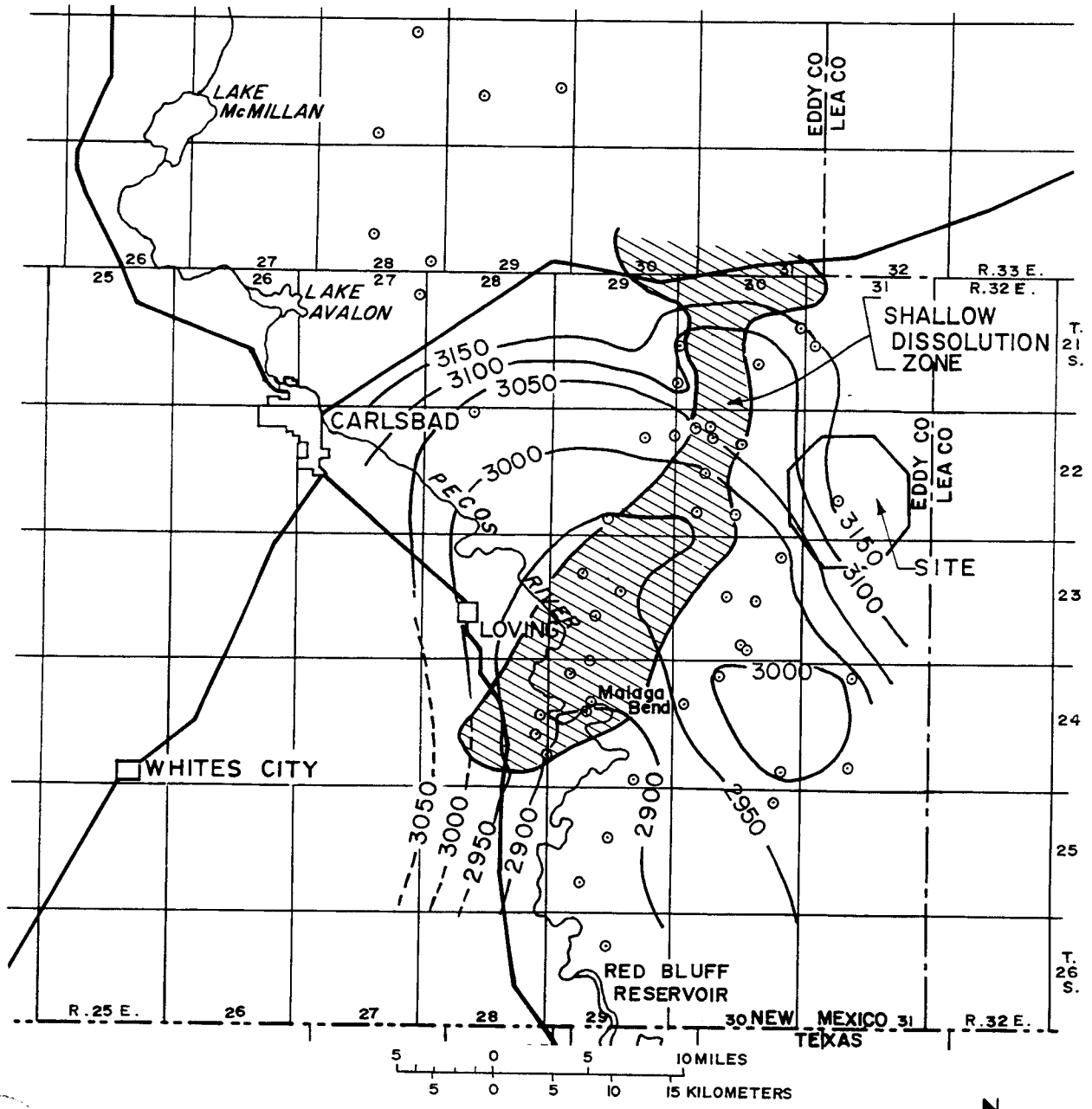
Well penetrating sediments of Permian, Ochoan, Guadalupian, or Leonardian age in which pressure or water level was measured

Reference: Fig 22 Hiss, W. L., 1975

5 0 5 10 MILES
5 0 5 10 15 KILOMETERS

POTENTIOMETRIC SURFACE OF THE GUADALUPIAN AQUIFER SYSTEM

FIGURE 6.3-1



EXPLANATION

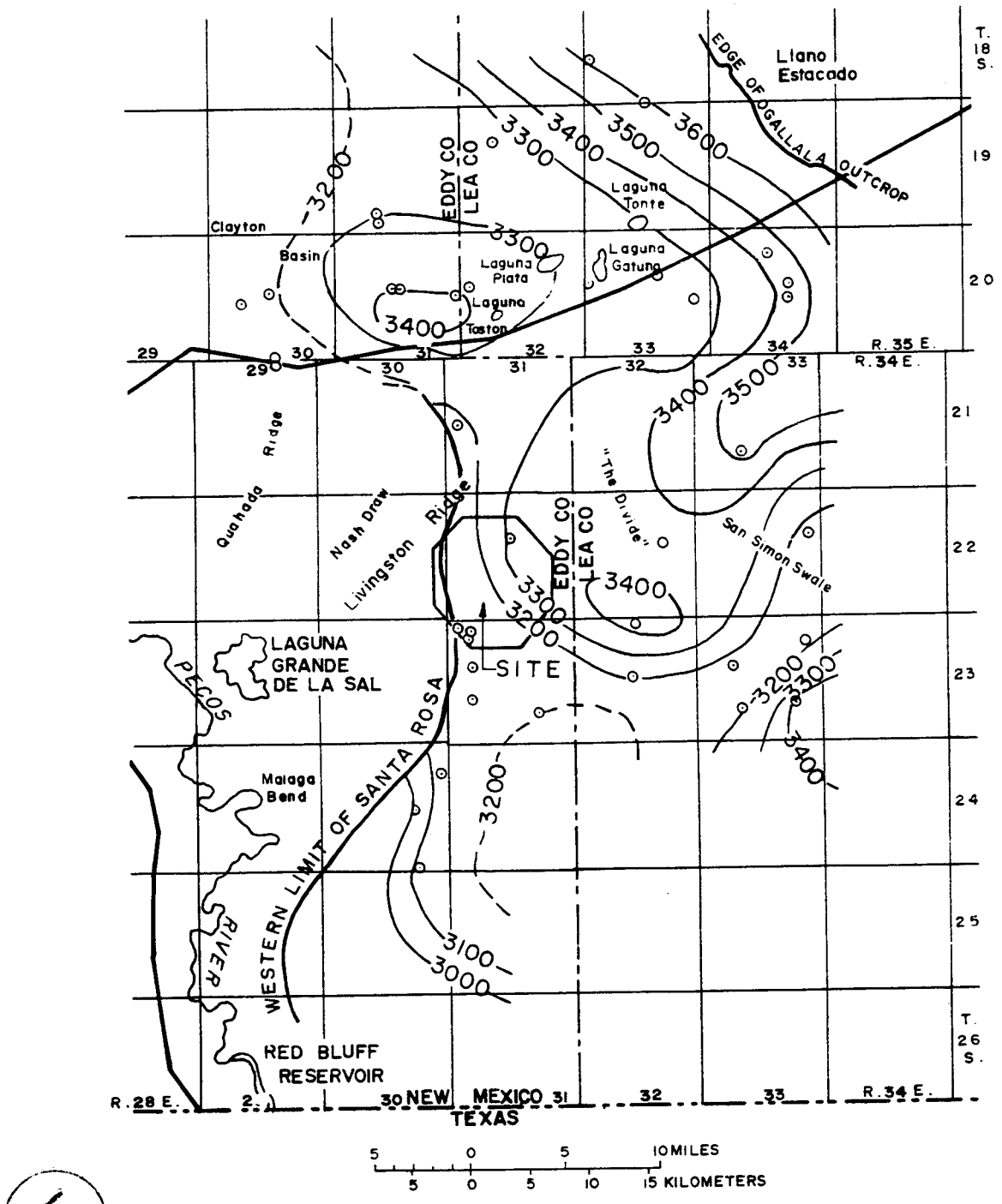
⊙ Well or exploratory hole open to the Rustler Formation.

3000 -- Potentiometric elevation contour based on water levels measured in wells, 1952 – 1973. Dashed where approximately located. Datum is mean sea level.

Reference: Figures 5 & 6, U.S.G.S. Open File Rpt. 77-123, 1977

POTENTIOMETRIC SURFACE
RUSTLER FORMATION AND AREAL
EXTENT OF SHALLOW DISSOLUTION ZONE

FIGURE 6.3-2



EXPLANATION

⊙ Well open to Triassic rocks

Potentiometric elevation contour, based on water levels measuerd in wells, 1952 - 1973. Dashed where approximately located. Datum is mean sea level.

POTENTIOMETRIC SURFACE
SANTA ROSA SANDSTONE

Reference:

Mercer and Orr, 1977, figure 7.

FIGURE 6.3-3

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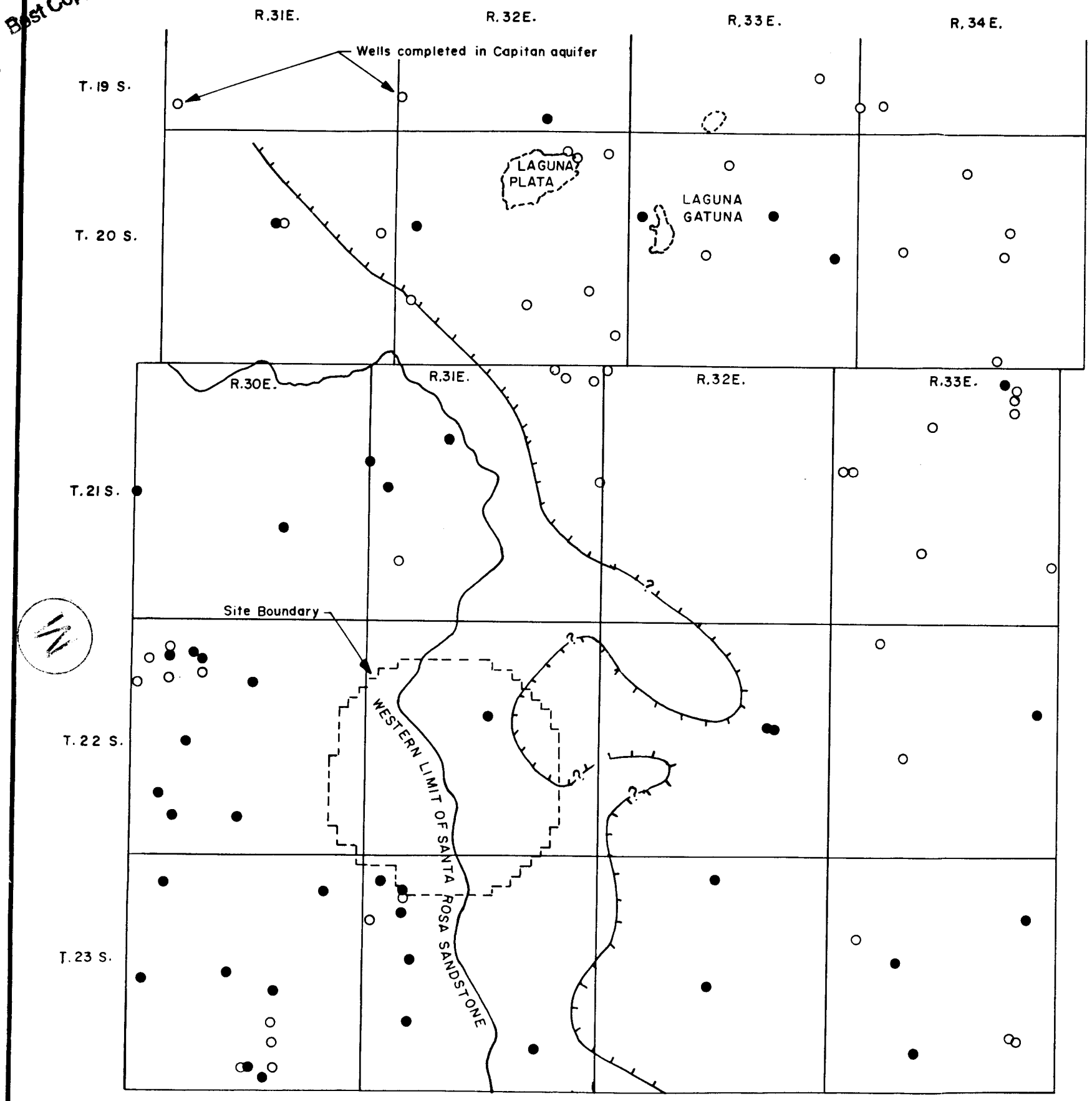
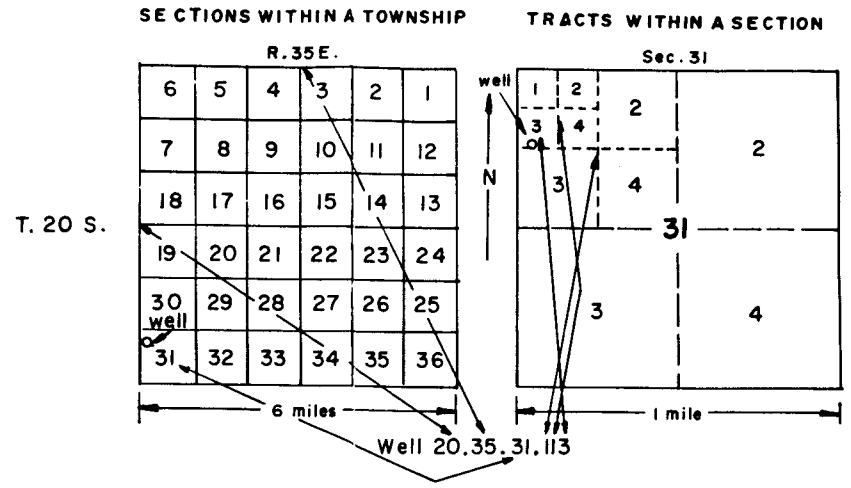




WELL-NUMBERING SYSTEM

The well number consists of four parts separated by periods. The first part is the township number, the second part is the range number, and the third part is the section number. The fourth part of the number consists of three digits which denote the particular 10-acre tract within the section in which the well is located.

EXPLANATION

- Approximate western limit of occurrence of ground water in the Santa Rosa Sandstone.
- ○ Water well completed in surfical deposits or upper sandstone beds of the Chinle Formation.
- ● Water well completed in lower sandstone beds of the Chinle Formation, Santa Rosa Sandstone, Dewey Lake Redbeds, or Rustler Formation.

NOTE:
See Table 6.3—2 for descriptions of wells.

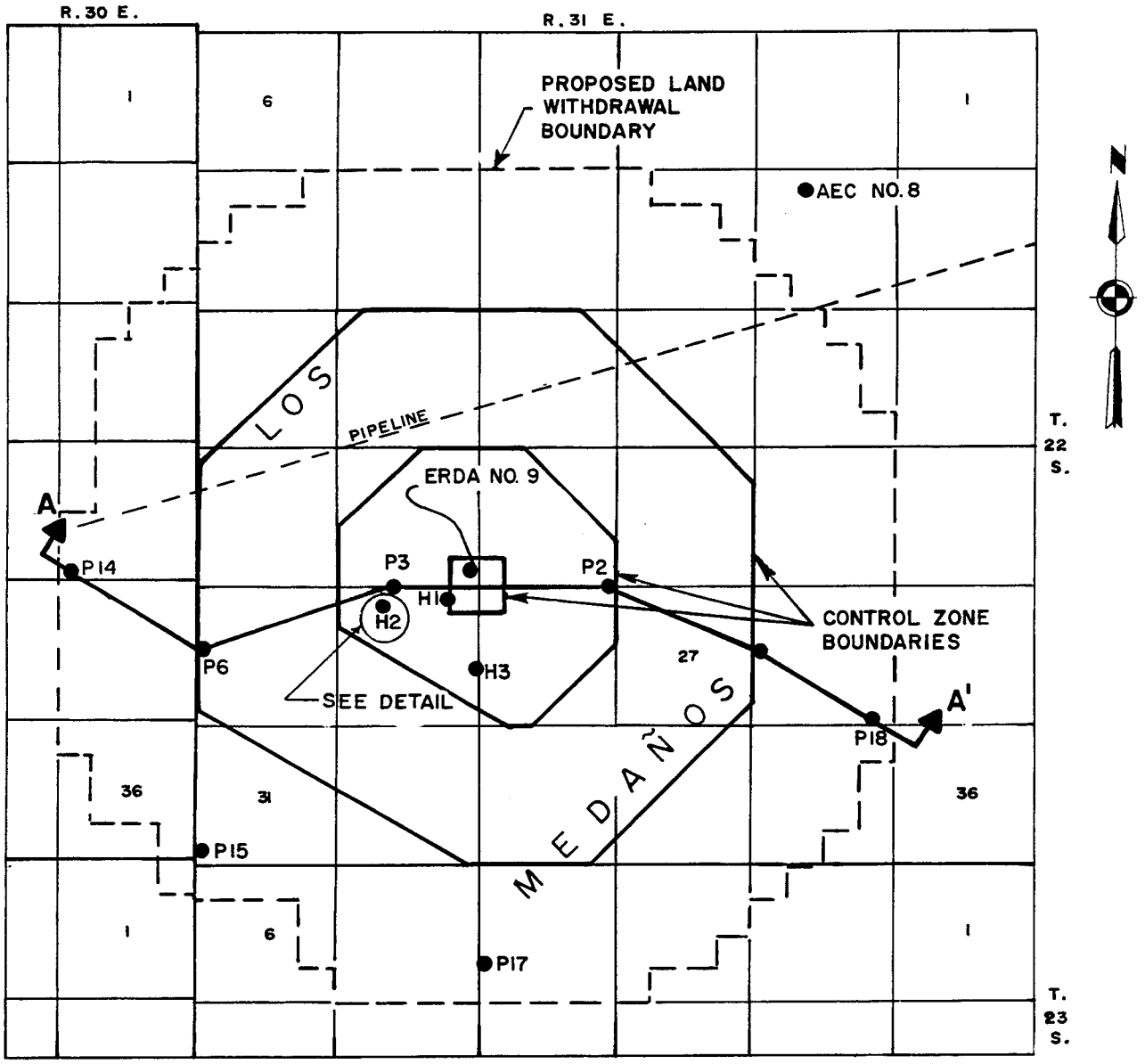
Reference: USGS Open File Report 4339-7, Jones, C.L., et al, 1973

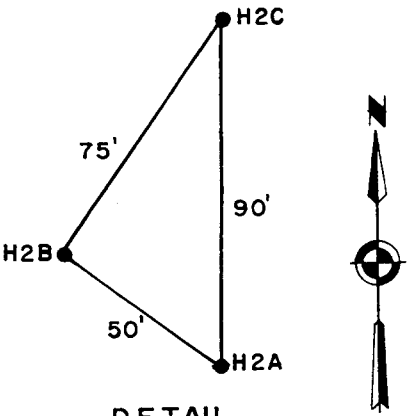
0 1 2 3 4 5
SCALE IN MILES

N

WATER WELL SURVEY

FIGURE 6.3-4





DETAIL

(H2 Configuration)

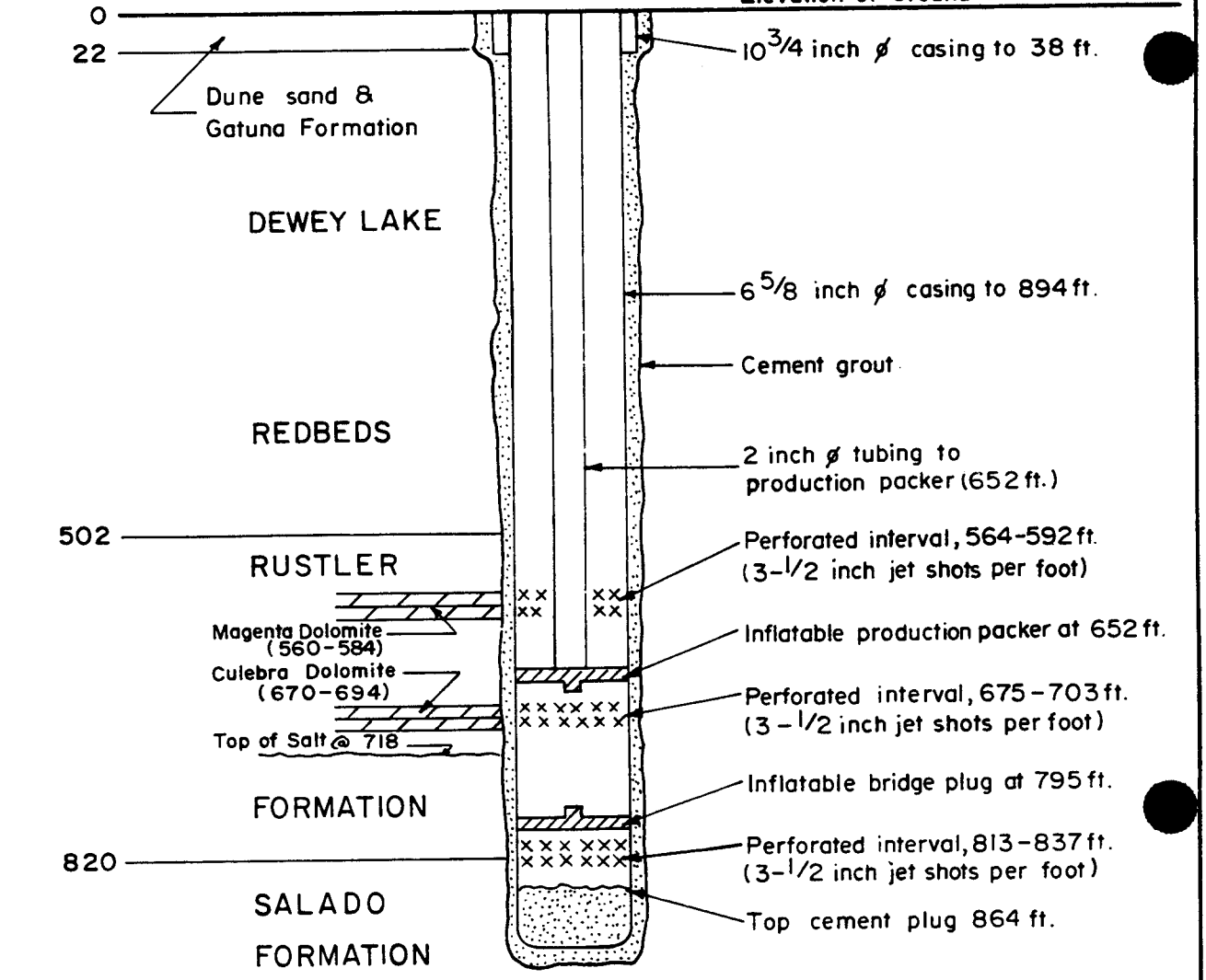
0 1 2

SCALE IN MILES

See figure 6.3-7 for Section A-A'

HYDROLOGIC TEST HOLES

FIGURE 6.3-5



Status October 1977:

Total depth drilled: 894 ft.
Diameter of drilled hole: 9 7/8 inch
Monitoring Culebra through tubing
Monitoring Magenta in annulus
Contact zone not accessible (bridge plug)

CONSTRUCTION OF OBSERVATION WELL

FIGURE 6.3-6

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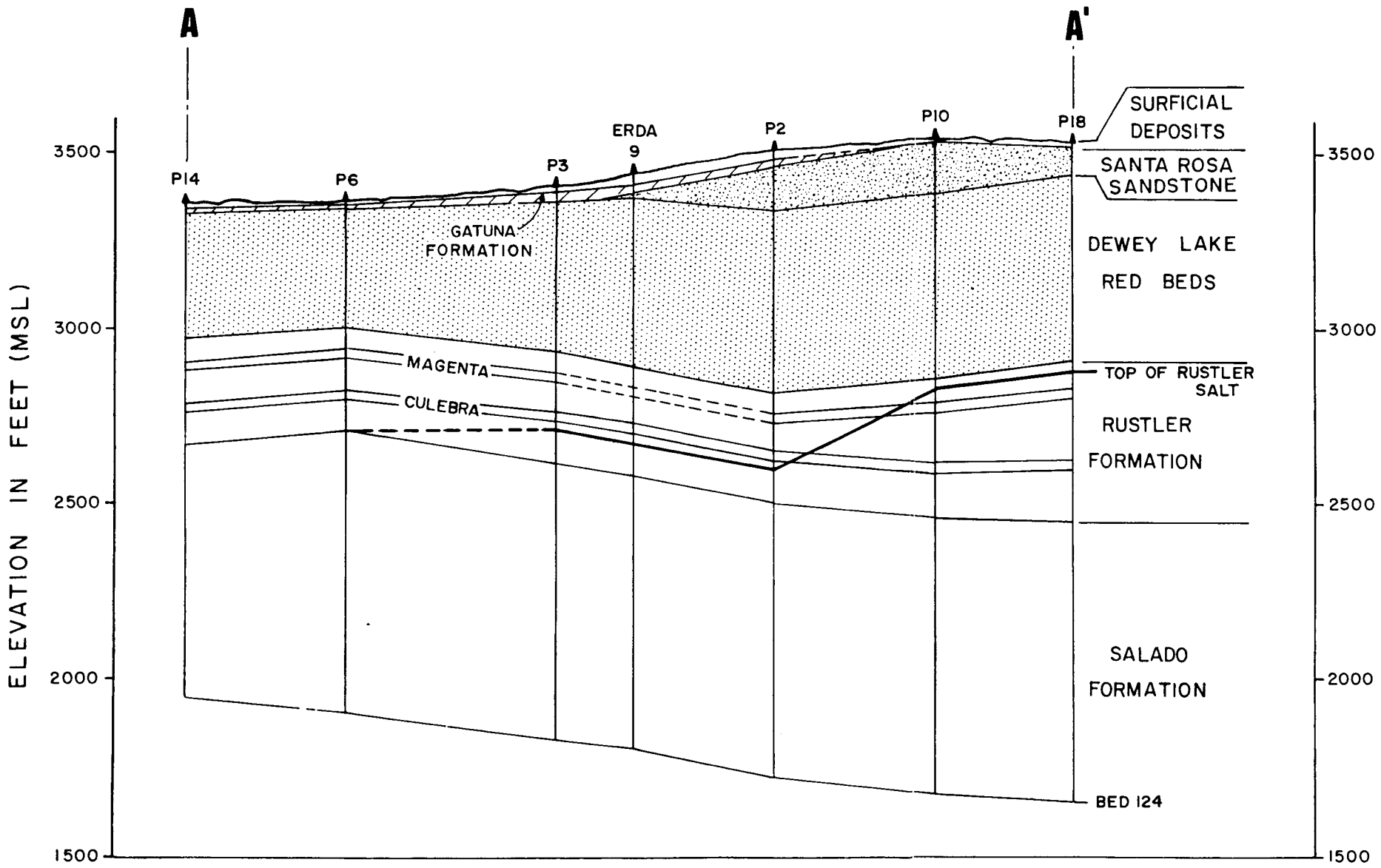
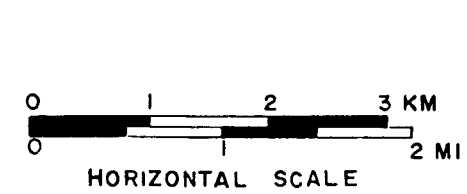


REFERENCES:

Lambert and Mercer, 1978, fig.4, p.I-15

NOTE:

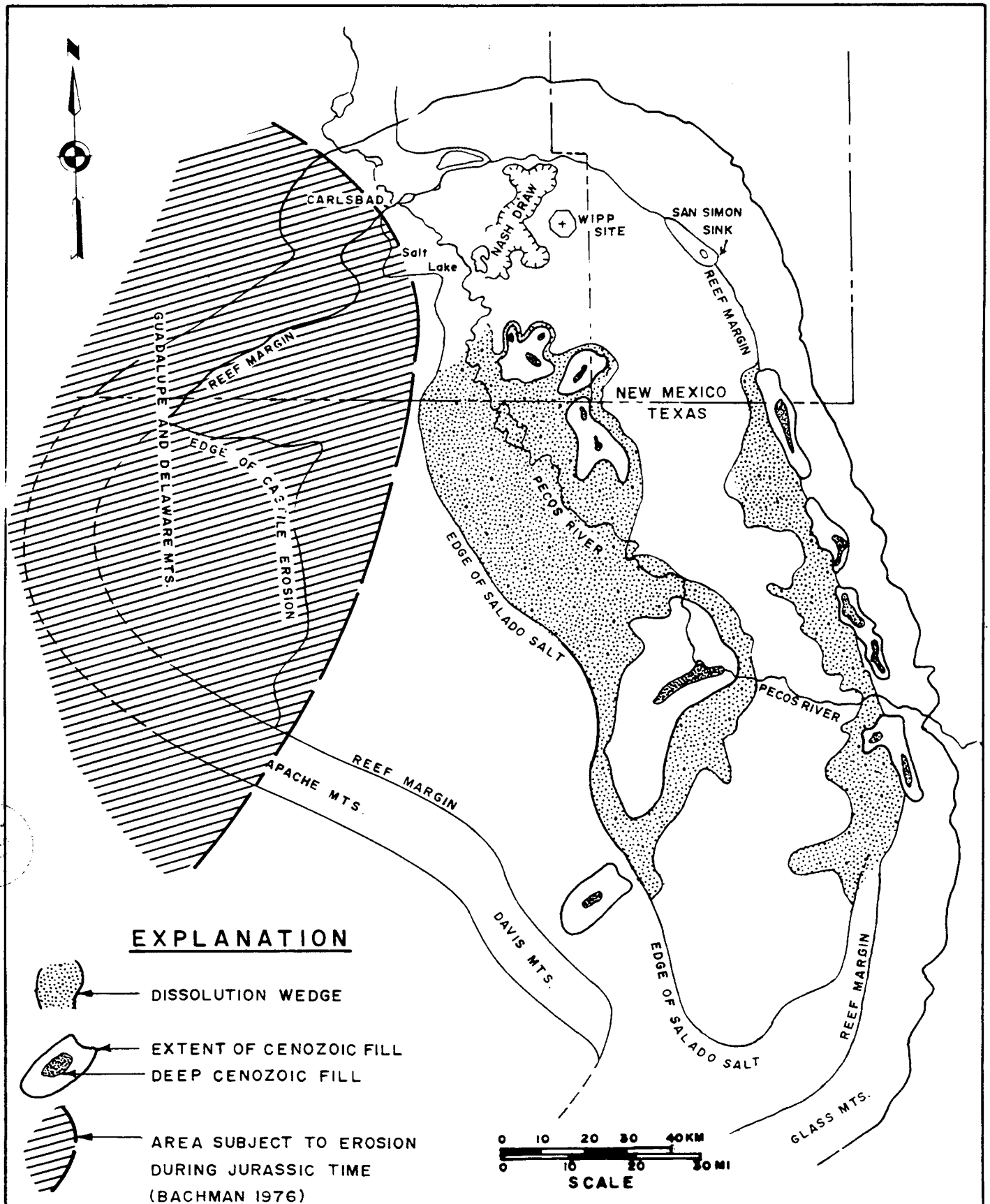
For location of Section see Figure 6.3-5.



GEOLOGIC SECTION
THROUGH THE LOS MEDANOS AREA

FIGURE 6.3-7

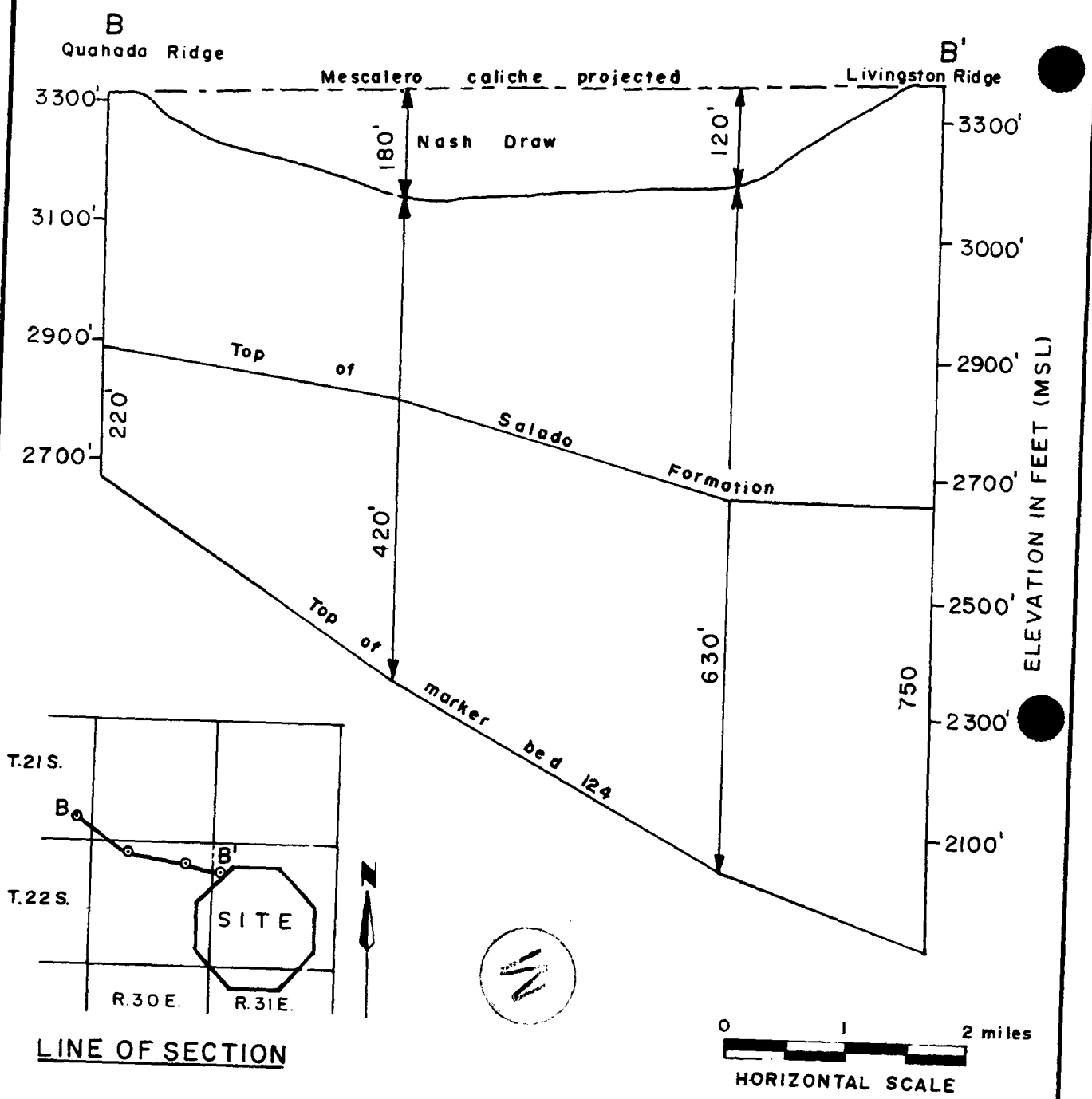
11 x 17 "B" SIZE



Reference: Based on Figure 1 from Anderson, 1978

DISSOLUTION FEATURES AND EXTENT OF EROSION IN DELAWARE BASIN

FIGURE 6.3-8



Reference: Fig. 11, USGS Open File Report 74-194, 1974

RELATIONSHIP OF NASH DRAW TO DISSOLUTION IN SALADO FORMATION

FIGURE 6.3-9

Table 6.2-1. AREAL REQUIREMENTS OF THE WIPP SITE

Zone	Zone Use	Approximate Acreage
I	Surface Facilities	60-(100)
II	Underground Storage	1,860
III	1-mile wide zone surrounding Zone II No mining or drilling.	6,230
IV	1-mile wide zone surrounding Zone III. Mining and drilling in conformance with ERDA specifications are allowed.	10,810
	TOTAL	18,960

29.6 square miles

TABLE 6.2-2

SALIENT FEATURES OF MAJOR DAMS UPSTREAM AND

DOWNSTREAM FROM WIPP SITE

Name of Reservoir	River	Drainage Area (sq. mi.)	Type of Dam	Year Completed	Height (ft.)	Max. Storage Capacity (AF)	Purpose
Sumner	Pecos	4,390	earth	1937	143	258,500	Irrigation
McMillan	Pecos	16,990	earth	1908	40	66,600	Irrigation
Avalon	Pecos	18,070	earth	1907	40	36,600	Irrigation
Red Bluff	Pecos	20,720	earth	1937	98	405,000	Irrigation & Hydro-power
Two Rivers	Rio Hondo	963	earth	1963	93	262,221	Flood Control
	Rocky Arroyo	64	earth	1963	116		

TABLE 6.2-3

WATER USE DATA FOR THE PECOS BASIN

Use category	Surface-water and groundwater withdrawals (mgd) 1975[a]
Agriculture	1546
Steam-electricity	12
Manufacturing	0
Domestic	47
Commercial	8
Mining	151
Public lands	4
Fish hatcheries	3
Total	1771

SOURCE: U.S. Water Resources Council, Second National Assessment of Water and Related Land Resources, in press.

[a]The total groundwater withdrawal for 1975 was 1079 mgd.

TABLE NO. 6.2-4

PRECIPITATION AT CARLSBAD, N.M. (in inches)

Period of Record 1931-1960

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Max. Precip	2.31	1.93	4.27	3.99	12.28	6.24	5.48	4.41	7.36	6.13	1.55	2.12	33.94
Av. Precip.	0.44	0.37	0.46	0.54	1.76	1.33	1.56	1.60	1.94	1.61	0.35	0.47	12.43
Min. Precip.	0	0	0	0	0.18	0	0	0.01	0	0	0	0	4.40

SOURCE: U. S. Weather Bureau, 1961.

TABLE NO. 6.2-5

TEMPERATURES AT CARLSBAD, N.M. (in ^{o}F)

Period of Record 1931-1960

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Max. Temp	50.4	54.8	61.2	69.1	74.6	83.6	84.2	84.6	80.6	70.8	57.4	52.6	66.3
Av. Temp.	43.8	48.4	54.8	63.3	71.4	79.8	81.4	80.8	74.2	64.1	51.5	44.7	63.2
Min. Temp.	35.2	43.6	47.8	60.1	68.4	73.4	77.4	76.7	70.2	58.2	45.8	37.5	60.3

SOURCE: U. S. Weather Bureau, 1961.

TABLE NO. 6.2-6

WATER QUALITY PARAMETERS (TIME-WEIGHTED AVERAGE)
FOR SAMPLING STATIONS ON THE PECOS RIVER,
OCTOBER, 1975, TO SEPTEMBER, 1976

Station No.	Discharge (cfs)	pH	Dissolved-solids concentration (mg/1) Total	Chloride	Sulfate	Sodium	Calcium
08405000 (Carlsbad)	12	7.7	2,500	531	1100	322	334
08406500 (Near Malaga)	26	7.7	5,390	1690	1820	1030	524
08407000 (Pierce Canyon Crossing)	28	7.5	13,900	6500	2280	4020	551

SOURCE: U. W. Geological Survey, Water-Data Report NM-76-1.

TABLE NO. 6.3-1 AQUIFER CHARACTERISTICS OF THE GUADALUPIAN AGE ROCKS (ADAPTED FROM HISS, 1976, TABLES 6 AND 7)

Geologic Unit	Avg. Hydraulic Conductivity (ft/day)	Average Porosity (%)	No. of samples or tests	
			Conductivity	Porosity
Rock Core Analysis				
Tansill Fm.	0.006	4.23	399	381
Yates Fm.	0.026	9.74	11,287	11,387
Seven River Fm.	0.140	6.56	4,367	4,485
Queen Fm.	0.029	7.79	7,324	7,648
Grayburg Fm.	0.032	7.15	1,971	1,973
Grayburg-San Andres (Und.)	0.033	5.76	7,062	7,313
Glorieta Sandstone	0.027	9.16	3,128	3,115
Delaware Mt. Gp.	0.016	15.65	4,549	4,493
Pumping Tests (San Andres)				
T.20S, R.38E, Sec. 7	0.20		(Drawdown Test)	
Same well as above	0.20		(Recovery Test)	
T.22S, R.37E, Sec. 29	0.30		(Drawdown Test)	
Pumping Tests (Capitan)				
T.21S, R27E, Sec. 5	2.4		(Recovery Test)	
T.21S, R.28E, Sec. 30	16.0		(Recovery Test)	
T.21S, R.34E, Sec. 24	3.0		(Specific Capacity)	
T.21S, R34E, Sec. 14	1.7		(Specific Capacity)	
Same Well	1.9		(Drawdown Test)	
Same Well	1.4		(Recovery Test)	
T.24S, R36E, Sec 4	24.0		(Drawdown Test)	
T.24S, R36E, Sec. 16	7.4		(Specific Capacity)	

TABLE 6.3-2 -- Records of Wells in the Los Medanos Area, New Mexico
(Adapted from Cooley, 1972, Table 4)

Location Number	Altitude Above Mean Sea Level (feet)	Depth of Well (feet)	Diameter of Well Casing (inches)	Depth Below Land Surface (feet)	Date of Measure-ment	Geologic Source	Use and Remarks
19.32.34.434	3560	260	--	Dry	9-22-72	QTs, Trc, Trsr(?)	Unused; 3 wells at this locality; no access for entering casing in the other 2 wells.
19.33.26.244	3609	--	6	90.58	9-25-72	QTs, Trc(?)	Electric Submersible; stock.
26.244a	3609	101	--	90.93	9-25-72	QTs, Trc(?)	--
19.34.31.131	3620	53	6	Dry	9-25-72	QTs	Unused; 2 ft. of water in bottom of hole--probably does not represent true water level.
31.232	3632	120R	6	--	9-25-72	QTs, Trc(?)	Windmill; stock; "Hardin Well," no access to enter casing.
20.31.13.412	3440	30	6	1.12	9-18-72	QTs	Unused.
15.130	3460	105	6	62.10	9-18-72	QTs(?), Trsr	Unused.
15.130a	3460	79	6	63.39	9-18-72	QTs(?), Trsr	Unused; 5 wells at this location of which only 1 is an operating well.
15.130b	--	--	--	--	--	QTs(?), Trsr	Windmill; stock.
20.32. 1.312	3510	20	6	Dry	9-22-72	QTs	Unused; deepest of 4 wells at this location, all wells are dry.
24.333	3555	67	5	37.67	9-11-72	QTs	Unused
24.333a	3555	--	--	--	--	QTs(?)	Windmill; stock.
27.144	3545	30	--	23.67	9-18-72	QTs	Unused; no casing present.
36.214	3585	--	--	P43.88	9-18-72	QTs	Windmill; stock; 3 wells at this location at Bingham ranch, well pumping estimated at 2 gallons per minute.

TABLE 6.3-2 (continued)-- Records of Wells in the Los Medanos Area, New Mexico

Location Number	Altitude Above Mean Sea Level (feet)	Depth of Well (feet)	Diameter of Well Casing (inches)	Depth Below Land Surface (feet)	Date of Measure-ment	Geologic Source	Use and Remarks
20.33. 4.432	3555	4		Dry	9-22-72	QTs	Unused.
18.123	3521	249	6.5	245.58	9-25-72	Trc	Unused.
21.111	3536	49	6	36.90	9-25-72	QTs	Unused.
24.124	3630	680	12	405.15	9-22-72	Trc, Trsr(?)	Windmill; stock; "West Windmill," watersand at about 300 feet as reported by driller.
20.34. 4.444	3633	200	8	P174.08	10-2-72	Trc	Windmill; stock; "Robert's Well," old oil test drilled before 1930.
14.133	3648	230		190.25	10-2-72	Trc	Windmill; stock.
17.334	3640	220(?)	8	P129.68	10-2-72	Trc	Windmill; stock; "City Service Well," possibly oil test.
22.224	3655	220	12	196.49	10-2-72	Trc	Windmill; stock; "North Well," old oil test
34.432	3770	96	6	89.50	10-2-72	QTs	Windmill; stock.
21.30.18.333	3220	156	6	129.54	9-25-72	Pru	Unused.
22.423	3180	130	6	111.50	9-25-72	Pru	Unused.
21.31. 1.131	3580	30R	6	20.80	9-18-72	QTs	Windmill; domestic & in stock; at Campbell Ranch.
1.241	3600	--	--	--	--	--	"Grave Well."
2.221	3570	35	--	29.80	9-18-72	QTs	Windmill; stock.
7.331	3350	367	14	192.10	9-14-72	Pru, Prc (?)	Unused.
13.244	3600	68	6	Dry	9-13-72	QTs, Trc	Unused.
18.411	3310	--	6	158.32	9-14-72	Pru	Windmill; stock; "New Well."
30.421	3300	176	6	Dry	9-25-72	Pru	Unused.

TABLE 6.3-2 (continued)-- Records of Wells in the Los Medanos Area, New Mexico

Location Number	Altitude Above Mean Sea Level (feet)	Depth of Well (feet)	Diameter of Well Casing (inches)	Depth Below Land Surface (feet)	Date of Measure-ment	Geologic Source	Use and Remarks
21.32. 6.111	3598	54R	--	44.00R	9-18-72	QTs	Windmill; domestic & stock; at Allred Ranch; 2 wells at this location.
21.33. 2.231	3810	1150R	--	--	9-22-72	Trsr	Unused; could not pass tape below 550 feet in 1972.
2.420	3770	94	6	79.58	9-22-72	QTs	Windmill; stock.
4.434	3805	147	--	129.66	10-2-72	QTs(?), Trc	Unused.
4.434a	3805	127	--	Dry	10-2-72	QTs(?), Trc	Unused.
18.114	3890	150	--	140.75	9-12-72	QTs	Windmill; stock.
18.114a	3890	175	--	142.88	9-12-72	QTs	Unused.
18.123	3855	--	--	--	9-12-72	QTs(?)	Windmill; stock.
18.123a	3855	145	8	117.30	9-12-72	QTs	Unused.
18.131	3895	11	--	Dry	9-12-72	QTs	Unused.
25.421	3670	67	--	56.58	9-22-72	QTs	Windmill; stock; "West Well."
28.124	3688	210	8	179.00	9-22-72	Trc	Windmill; stock; "Standard Wells," 3 wells at this location.
22.30. 5.431	3120	225	14	53.25	9-19-72	Pru, Prc(?)	Unused.
6.444	3140	176	22	92.40	9-19-72	Pru	Unused.
7.244	3110	58	12	Dry	9-19-72	Pru	Unused.
10.311	3135	68	6	63.70	9-12-72	Pru	Unused; at Crawford Ranch.
20.120	3076	10	5	Dry	9-19-72	QTs, Pru	Unused.
32.111	3010	35	6	32.70	9-19-72	Pru	Unused.
22.31.15.130	3460	--	--	144.07	9-12-72	Trsr(?) Pdl	Windmill; stock.
15.130a	3460	--	--	145.50	9-12-72	Trsr(?) Pdl	Unused.

TABLE 6.3-2 (continued)-- Records of Wells in the Los Medanos Area, New Mexico

Location Number	Altitude Above Mean Sea Level (feet)	Depth of Well (feet)	Diameter of Well Casing (inches)	Depth Below Land Surface (feet)	Date of Measure-ment	Geologic Source	Use and Remarks
22.32.14.323	3717	380	--	367.80	9-13-72	Trsr	Jenson Jack; stock; "Comanche Wells."
14.324	3720	380(?)	--	370.40	9-13-72	Trsr	Windmill; stock; "Comanche Wells."
22.33. 5.321	3650	10	6	0.0	9-22-72		Windmill; stock; well on edge of Dagger Lake.
13.231	3515	490	6	388.05	9-21-72	Trc	Windmill; stock; "Roger's Well."
13.231a	3515	400	6	388.05	9-21-72	Trc	Windmill; stock.
20.244	3602	--	--	--	--		Unable to locate well in 1972.
23.30. 2.444a	3250	315	7	257.73	9-20-72	Prc	Windmill; stock; "Little Windmill," well 444 destroyed.
6.424	2980	--	6	0.0	9-20-72	--	Unused; "Nash Well," area flooded by lake.
19.123	3045	--	7	68.55	9-20-72	Prc	Windmill; stock.
21.122	3165	--	5	--	9-20-72	Pru, Prc(?)	Windmill; stock; "Indian Well," no access for
		204	5	179.25	4-6-59	Pru, Prc(?)	water level measurement.
22.234	3210	244	--	227.32	9-20-72	Pru, Prc(?)	Unused.
33.244	3438	696	--	--	--	Pru, Prc	Abandoned; at Gnome Site, plugged 6-25-69, USGS No. 5.
34.133	3413	518	--	433.91	9-25-72	Pru, Prc	Observation; at Gnome Site, USGS No. 4.
				433.67	12-12-61	Pru, Prc	
34.133a	3413	--	--	427.03	9-25-72	Pru, Prc	Unused; at Gnome Site, USGS No. 8.
34.234	3401	568	6	415.70	4-14-62	Pru, Prc	Observation; at Gnome Site, USGS No. 6, drld to 1499' & plugged back to 568'.
34.234a	3402	563	6	418.10	4-16-62	Pru, Prc	Observation; at Gnome Site, USGS No. 7, drld to 1507' & plugged back to 563'.
34.324	3426	567	--	441.67	9-25-72	Pru, Prc	Observation; at Gnome Site, USGS No. 1.
				442.40	9-22-60	Pru, Prc	

TABLE 6.3-2 (continued)-- Records of Wells in the Los Medanos Area, New Mexico

Location Number	Altitude Above Mean Sea Level (feet)	Depth of Well (feet)	Diameter of Well Casing (inches)	Depth Below Land Surface (feet)	Date of Measure-ment	Geologic Source	Use and Remarks
23.31. 6.320	3300	213	8	144.72	2-4-59	Pdl	Windmill; domestic.
6.320a	3300	400R	--	--	--	Pdl, Pru	Windmill; domestic; tape will not pass 222' in 1972.
6.444	3310	--	6	106.35	9-20-72	Pdl	Windmill; domestic.
7.240a	3315	--	6	62.27	9-20-72	Pdl	Windmill; stock.
17.310	3305	--	--	--	9-20-72	Pdl, Pru	Windmill; stock.
26.340	3451	--	6	250.47	9-20-72	Pdl	Windmill; stock.
29.113	3335	--	4	139.90	9-20-72	Pdl	Windmill; stock.
23.32. 3.311	3660	550R	8	--	9-13-72	Trsr	Windmill; stock.
3.311a	3660	--	10	204.18	9-13-72	Trsr	Unused.
21.241a	3680	515	--	480.75	9-21-72	Trsr	Windmill; stock.
		550	6	510.00R	4-13-59	Trsr	
23.33.12.312	3530	388	12	351.45	9-21-72	Trsr	Windmill; stock; "Allred Well."
17.423	3702	650(?)	8	504.40	9-21-72	Trc(?), Trsr	Submersible; stock "Graham Wells."
26.421	3645	173	6	165.15	9-21-72	Trc	Windmill; stock; "Tip Top Wells."
26.421a	3645	189	6	P184.00	9-21-72	Trc	Windmill; stock; "Tip Top Wells."
28.334	3675	544(?)	--	500.00R	11-27-53	Trc(?), Trsr	Windmill; stock & domestic; at Brinninstool Ranch, 2 wells at this location, tape will not pass 220' in either well.

Explanations

(1) Geologic source: QTs, surficial deposits; Trc, sandstone beds in the Chinle Formation; Trsr, Santa Rosa Sandstone; Pdl, Dewey Lake Redbeds; Pru, Rustler Formation above Culebra Dolomite Member, including Magenta Dolomite Members; Prc, Culebra Dolomite Member of Rustler Formation.

(2) Altitute: From topograhical maps.

(3) Depth of well: All depths of wells were obtained in 1972; all depths to water in the wells measured in 1972 or before are listed; R, reported depth; P, pumping level; < , less than.

TABLE 6.3-3: Water Quality Data (from Table 2, Mercer and Orr, 1978)
reported in parts per million

Monitor Well	Date of Sample	pH Units	Temperature (Celsius)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)
Magenta Dolomite										
H-1	5/10/77	7.2	22.0	1,000	460	6,200	840	93	0	3,600
H-2a	2/22/77	8.6	22.0	820	170	2,700	81	74	0	2,400
H-3	5/10/77	8.0	22.5	1,200	480	9,300	250	51	0	3,400
Culebra Dolomite										
H-1	3/17/77	7.3	22.5	820	1,800	29,000	5,600	100	0	11,000
H-2b	2/22/77	8.4	21.5	690	160	2,100	91	59	5	3,000
H-2c	3/16/77	8.1	20.5	680	120	3,600	120	62	0	3,200
H-3	3/17/77	7.4	21.5	1,500	670	19,000	630	115	0	5,700
P-14	3/14/77	6.0	21.5	3,100	760	7,600	600	357	0	1,400
P-15	5/10/77	10.2	21.5	770	63	6,900	1,700	63	24	3,200
P-17	5/10/77	7.4	22.5	1,700	1,600	30,000	120	77	0	5,000
P-18	5/10/77	7.2	24.5	5,600	16,000	9,200	6,200	310	0	980
Rustler-Salado Contact										
H-1	2/22/77	7.9	21.0	13,000	30,000	56,000	17,000	675	0	520
H-2c	2/23/77	5.9	20.5	9,200	25,000	66,000	9,100	199	0	1,300
H-3	2/24/77	7.6	21.5	18,000	25,000	59,000	14,000	467	0	370
P-14	2/24/77	7.2	24.5	570	1,200	120,000	1,300	222	0	10,000
Delaware Sand										
AEC-8	9/22/77	6.0	30.0	10,000	2,500	55,000	860	420	0	240

Table 6.3-3 Continued

Monitor Well	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved Solids (Sum of constitents)	Nitrate* +Nitrate (N)	Ortho* Phosphorus (P)	Boron* (B)	Iron* (Fe)	Manganese* (Mn)
Magenta Dolomite									
H-1	10,000	2.0	1.7	22,200	0.04	0.03	3.3	0.22	0.95
H-2a	4,100	-	6.0	10,300	0.04	0.01	0.22	0.06	< 0.05
H-3	15,000	1.8	6.4	29,700	0.08	0.04	13.0	0.04	0.22
Culebra Dolomite									
H-1	49,000	0.8	0.6	97,300	0.03	0.00	18.0	0.79	2.8
H-2b	2,800	2.0	1.7	8,890	0.01	0.03	9.5	0.02	0.2
H-2c	4,700	1.6	3.5	12,500	0.16	0.00	10.0	0.11	0.14
H-3	29,600	0.5	1.2	57,200	0.07	0.00	20.0	0.05	0.12
P-14	20,000	0.9	33	33,700	0.01	0.02	0.7	17	0.5
P-15	11,000	1.2	1.6	23,700	0.04	0.03	4.7	0.1	0.02
P-17	54,000	1.5	1.0	92,500	0.06	0.11	1.7	1.2	3.0
P-18	80,000	1.2	1.0	118,000	0.81	0.40	100.0	0.54	4.5
Rustler-Salado Contact									
H-1	210,000	-	0.0	327,000	0.29	0.00	110	1.5	52
H-2c	200,000	-	2.0	311,000	1.1	0.00	150	2.5	78
H-3	210,000	-	1.0	327,000	0.77	0.00	1.9	1.5	3.8
P-14	180,000	-	2.0	313,000	0.34	0.08	1.7	2.1	3.4
Delaware Sand									
AEC-8	120,000	1.2	3.6	189,000	0.11	0.05	53	23	14.0

* Due to sampling conditions, analyses of NO_3^{-1}, PO_4^{-3}, BO_3^{-3}, Fe^{+2}, and Mn^{+2} are probably no more precise than $\pm$15%. The others have a precision of about $\pm$5%.

TABLE 6.3-4 Fluid Yield From Test Zones
(gallons per day)

Hole No.	Test Interval (depth in ft)	Magenta Dolomite	Culebra Dolomite	Salt Residue Zone in Rustler Fm.	Rustler-Salado Contact	Bell Canyon Sand
	Open hole, drill stem tests (1)					
H-1	562 - 592	23.1				
	626 - 667			22.4		
	667 - 669		22.1			
	669 - 842				10.9	
H-3	558 - 608	14.1				
	672 - 703		2.3			
	703 - 780			1.8		
	800 - 868				2.6	
	Open hole, bailing tests (2)					
H-2a	513 - 563	27				
H-2b	611 - 661		260			
H-2c	743 - 795				0.8(3)	
	Cased hole with perforated interval, bailing tests (2)					
H-1	562 - 590	66				
	675 - 703		46(4)			
	803 - 827				1.0(5)	
H-2b	510 - 538	210				
H-2c	624 - 652		310			

TABLE 6.3-4 (continued) Fluid Yield From Test Zones
(gallons per day)

Hole No.	Test Interval (depth in ft)	Magenta Dolomite	Culebra Dolomite	Salt Residue Zone in Rustler Fm.	Rustler-Salado Contact	Bell Canyon Sand
	Cased hole with perforated interval, bailing tests (2)					
H-3	562 - 590	(8640)(6)				
	675 - 703		200			
	813 - 837				11/32d(8)	
P-14	573 - 601		(5760)(7)			
	676 - 700				75	
P-15	410 - 438		50		2.0/42d(8)	
P-17	558 - 586		170			
	702 - 726				1.0/72d(8)	
P-18	912 - 940		0.5/33d(8)			
	1076 - 1100				0.5/73d(8)	
AEC-8	4844 - 4860					269(9)

NOTES:

(1) Inflows measured over periods ranging from 11.5 to 37.5 hours.
(2) Inflows monotired for periods ranging from 8 days to 217 days. Rate based on inflow during first 24 hours.
(3) Inflow of 14 gallons in 18 days (no other data).
(4) Inflow of 416 gallons in 9 days (no other data).
(5) Average trend after 33 days recovery.
(6) Bailed 360 gallons in 1 hour with 6 feet of drawdown.
(7) Bailed 720 gallons in 3 hours with no drawdown.
(8) Early measurements inconclusive; inflow for period of days (d) indicated.
(9) Recovery measured for only 2.8 hours.

TABLE NO. 6.3-5

OBSERVATION WELLS - MONITORING ZONES

WELL NO. (GROUND ELEV.)	ZONE TESTED	ACCESSIBLE DEPTH	INTERVALS ELEV.
H-1	Magenta	562-590	2841-2813
(3403)	Culebra	675-703	2728-2700
	Rustler-Salado	803-827	2600-2576
H-2a	Magenta	No tests except levels	
H-2b	Culebra	510-538	2867-2839
H-2c	Culebra	624-652	2753-2725
(3377)	Rustler-Salado	743-795	2634-2582
H-3	Magenta	562-590	2837-2799
(3389)	Culebra	675-703	2714-2686
	Rustler-Salado	813-837	2576-2552
P-14	Culebra	573-601	2785-2757
(3358)	Rustler-Salado	676-700	2682-2658
P-15	Culebra	410-438	2900-2872
(3310)	Rustler-Salado	532-556	2778-2754
P-17	Culebra	558-586	2782-2754
(3340)	Rustler-Salado	702-726	2638-2614
P-18	Culebra	912-940	2567-2539
(3479)	Rustler-Salado	1076-1100	2403-2379
AEC-8	Bell Canyon (Upper)	4821-4827	[1289-1295]*
(3532)	Bell Canyon (Lower)	4844-4860	[1312-1328]*

*Elevations in brackets are below mean sea level; all other elevations are above msl. All depths and elevations are given in feet.

TABLE NO. 6.3-6

POTENTIOMETRIC LEVELS
OCTOBER 1977
(Elevation in Feet)

Observation Well	Ground Surface Elevation	Magenta Dolomite	Culebra Dolomite	Rustler-Salado Contact	Delaware Sands "Upper"	Delaware Sands "Lower"
H-1	3,403	3,154	3,013	Not Monitored[1]		
H-2a	3,377	3,128	Not Penetrated	Not Penetrated		
H-2b	3,377	3,081	3,026	Not Penetrated		
H-2c	3,377	Not Screened	3,021	34'/Month[2]		
H-3	3,389	3,141	2,984	Not Monitored[1]		
P-14	3,358	Not Screened	3,034	2,970		
P-15	3,310	Not Screened	3,002	2,975		
P-17	3,340	Not Screened	2,968	2,970		
P-18	3,479	Not Screened	8'/month[2]	40'/month[2]		
AEC-8	3,532	Not Screened	Not Screened	Not Screened	2,927	2,933

NOTES:

[1]The Rustler-Salado contact is accessible, but is temporarily off.

[2]Recovery Rate: Level in tubing had not reached static level in October, 1977

GCR CHAPTER 7

GEOCHEMISTRY

7.1 INTRODUCTION

In the context of this Geological Characterization Report, "geochemistry" is taken here to include a description of chemical properties of geologic media presently found in the surface and subsurface environments of southeastern New Mexico in general, and of the proposed WIPP withdrawal area in particular. "Chemical properties of geologic media" might be extended to include a description of present understanding of chemical processes which have taken or are taking place in southeastern New Mexico rocks. This geochemistry chapter of the WIPP Geological Characterization Report does not consider any aspect of artificially-introduced material, temperature, pressure, or any other physico-chemical condition not native to the rocks of southeastern New Mexico. These as-yet hypothetical considerations belong in the realm of interactions between radioactive waste and rock, a subject of the experimental programs initiated as part of the WIPP studies that are not yet completed. Early experimental results of radionuclide interactions with southeast New Mexico rocks and fluids are reported in Chapter 9.

A substantial fraction of this chapter consists of original source material, never before published in any format aside from reports of investigations resulting from research contracts. Much of this material is, however, in the process of being recast so as to be suitable for presentation in various professional forums. Some material has already been so presented.

Information contained herein was offered if the work involved was at a suitable stage of completion so as to allow conclusions to be drawn. Some subjects of investigation related to geochemistry require several years more investigation, even for final site characterization, and are discussed in Chapter 10, "Continuing Studies." Subjects of the present chapter are those which provide background data of relevance to (1)

experimental programs involving radioactive waste and its interaction with geomedia, (2) borehole plugging, (3) the intrinsic physico-chemical stability of southeastern New Mexico rocks in the geologic past, and (4) safety assessment, which is described in other major documents relating to the proposed WIPP. These data include mineralogy, volatile constituents of rocks, the constitution, origin and history of liquids and gases found in rocks, and the lengths of time which have passed since the latest episodes of thermodynamic instability resulting in rock/fluid interactions.

In the absence of a satisfactory theoretically-formulated mathematical model which can accurately predict phase equilibria among complex evaporite minerals, an empirical approach, based on observed assemblages, is adopted here. Such modelling is beyond the scope of this document.

It will be noted that volatile contents of evaporites were determined by three different methods: static heating (Section 7.5.3), thermogravimetric analysis (Section 7.5.2) and counting of fluid inclusions (Section 7.6). Each set of data was collected for a different geochemical purpose, but results from all techniques show comparable amounts of volatile constituents in the evaporites. The most accurate results, however, are probably those derived from static heating.

7.2 THE MINERALOGY OF DELAWARE BASIN EVAPORITES AND RELATED ROCKS OF THE LOS MEDANOS AREA

7.2.1 Introduction

The foregoing sections on geology and stratigraphy have briefly mentioned generalized mineralogies of Delaware Basin rocks of the Los Medanos area. Here it becomes of interest to present a more thorough exposition of mineralogies. This is done for a variety of reasons: (1) mineralogies affect properties of rocks important to physical aspects of mining, (2) soluble minerals in rocks potentially give rise to solutions which can interact with waste and its containers, and (3) minerals in

rocks have various degrees of sorptive affinities for radionuclides and can serve to decrease their mobility. While this section is devoted mainly to an account of the minerals found in the main Ochoan evaporite section (Castile and Salado Formations), mineralogies of some Guadalupian rocks and some rocks above the main evaporite section are included. This information is particularly useful to the consideration of radionuclide mobility in rocks containing substantially more fluid than the evaporites, and is of fundamental importance to in situ experiments involving waste-rock interactions. Also, investigations of fluid inclusions, sources of volatiles, groundwater geochemistry and age-dating of rocks and waters are closely related to mineralogy.

7.2.2 Previous Work

Southeastern New Mexico evaporites have been economically important for many years because they contain the well-known McNutt Potash Zone in the middle part of the Salado Formation. Descriptions of mineralogies of the McNutt and adjacent portions of the Salado have been given in several previous reports covering much of the Permian Basin, and environs of southeastern New Mexico (Brokaw et al., 1972; Jones, 1973; Jones, 1974a; Jones, 1974b; Jones, 1975). A detailed review of the economic mineralogy of the McNutt Potash Zone underlying Los Medanos appears in Chapter 8 of this report. This section on mineralogy has been developed as background critical to mine design, waste-rock-fluid interactions, and other aspects of geochemistry, such as age-dating and radionuclide migration.

7.2.3 Overview of Evaporite Mineralogy

X-ray powder diffraction examination of 50 core samples from ERDA #9 in the center of the study area (Figure 4.1-2) has been completed. Only qualitative information was obtained from these preliminary cores in order to assess mineralogical variations among selected horizons.

As-received cores were crushed and ground to bulk powder to provide a representative sample of that zone, x-ray specimen mounts weres scanned

at 1°/min on a diffractometer equipped with copper x-ray source, graphite monochrometer and scintillation detector.

Eight minerals were identified in the 50 samples:

1.	anhydrite	$CaSO_4$
2.	clay	$Al_2Si_4O_{10}(OH)_2 \quad xH_2O$
3.	halite	$NaCl$
4.	loeweite	$Na_{12}Mg_7(SO_4)_{13} \quad 15H_2O$
5.	magnesite	$MgCO_3$
6.	polyhalite	$K_2Ca_2Mg(SO_4)_4 \quad 2H_2O$
7.	quartz	SiO_2
8.	sylvite	KCl

Their occurrence is given qualitatively in Table 7.1 with a corresponding graphical distribution shown in Figure 7.1. Trace amounts of the potassium minerals sylvite and polyhalite were found in the proposed TRU horizon (2034-2110'), and the high-level horizon (2594-2692') was void of potash.

7.2.4 Mineralogy of Fluid-Bearing Zones in the Rustler Formation and Delaware Mountain Group

Mineralogies of certain fluid-bearing rocks above and below the main evaporite sequence have been determined as background information for radionuclide sorption studies.

Magenta Member, Rustler Formation (AEC No. 8). The Magenta member of the Rustler Formation is largely ferroan dolomite, probably containing minor ankerite which gives rise to the reddish color in weathered outcrops. This rock also contains detrital quartz, and gypsum forms as crystals, filling the vugs in the dolomite, which can be up to several cm across.

Culebra Member, Rustler Formation (AEC No. 8). Like the Magenta, the Culebra member is largely dolomite, with traces of detrital quartz. In addition, small amounts of calcite are found.

Bell Canyon Sandstone (AEC No. 8). The Bell Canyon Formation is the uppermost unit in the Delaware Mountain Group immediately underneath the main evaporite sequence. It is mostly detrital quartz and major feldspar with a matrix of kaolinite and chlorite cemented with calcite and minor amounts of dolomite.

Cherry Canyon Sandstone (Pine Springs Outcrop). Although the Cherry Canyon Formation was not sampled in any WIPP exploratory borehole, its stratigraphic position directly underneath the Bell Canyon made it of interest in preliminary radionuclide sorption measurements. The detrital component is largely quartz, and the cement is mostly dolomite. Minor amounts of albite and microcline contribute to the detrital component, and minor amounts of gypsum and calcite are found in the cement.

7.3 DETAILED CHEMISTRY AND MINERALOGY OF SOLUBLE AND INSOLUBLE COMPONENTS OF THE SALADO FORMATION

7.3.1 Introduction

While this section deals primarily with results obtained from cores from AEC No. 7 and AEC No. 8, exploratory holes three miles northeast of the present study area (Figure 4.1-2), these holes provided material of sufficient lithologic similarity to ERDA No. 9 so as to be of value. The analytical strategy employs a normative-type calculation, in which mineralogical compositions are derived mathematically from bulk chemical compositions. The results of those calculations then can be compared to mineralogies determined petrographically or by x-ray diffraction. This section serves as fundamental background information for the chapters on silicate mineralogy and sources of volatile components within the evaporites.

7.3.2 Materials and Methods

Sample Preparation and Handling. The core samples as received were halved and one-half was retained while the remaining half was crushed and ground. The ground sample was size-distributed as shown in Table 7.2.

The samples were all double-wrapped for storage in plastic bags due to their hygroscopic nature. A portion of the crushed sample weighing approximately 20 grams was accurately weighed and dried in an oven at 70°C for two hours to determine weight loss. The dried sample was then added to 200 ml of distilled water, stirred for 1 hour, and filtered. The filtered material was dried and weighed to determine the insoluble portion of the sample while the filtrate contained the soluble portion of the sample.

Analysis of Soluble Portion. The elements potassium, calcium, magnesium, silicon, iron, aluminum, and strontium were analyzed by standard atomic absorption methods using a Perkin-Elmer 403 Atomic Absorption Spectrophotometer. Sodium, typically difficult to analyze precisely, was analyzed using an Orion Specific Ion Sodium electrode and an Orion Research Model 801 pH meter. Sulfate was determined gravimetrically as barium sulfate; chloride was determined volumetrically by titrating with mercuric nitrate (Vogel, 1961)

Analysis of Insoluble Portion. The insoluble portion was separately analyzed only if the insoluble percentage was greater than 0.5% of the total sample weight. Samples containing less than 0.5% insolubles did not provide sufficient material for analysis, and it was deemed that even a major constituent in such a small percentage of the total would not contribute significantly to the sample behavior. A portion of the water-insoluble material weighing about 100 mg was dissolved in HF, using the following procedure in a teflon-lined high pressure bomb (Bernas, 1968; 1973) obtained from Parr Instruments. Nitric acid (1 ml) was added

to wet the sample and 3 ml of 50% HF were added. The bomb was assembled and placed in a 70°C oven for 2 hours. The contents of the bomb were quantitatively transferred to a polypropylene beaker containing 2.8 g of boric acid and about 30-40 ml deionized water. The boric acid was allowed to dissolve with stirring and the solution diluted to 100 ml in a volumetric flask and stored in a polyethylene bottle. A solution containing all of the matrix material was prepared for use in making standards for the atomic absorption spectrophotometer. All analyses were performed as described in the preceding section. Samples were tested for the presence of carbonates using concentrated HCl but only occasionally was a trace amount detected.

Thermal Analysis. Samples analyzed for weight loss upon heating were ground so that greater than 90% of the sample was smaller than 100 mesh. Each sample was dried for at least 3 days at 65°C in a thermostatically regulated oven. This temperature was chosen to avoid the long-term dehydration of gypsum described elsewhere in this report. Low temperature weight loss (70°C for 2 hours) was used to measure absorbed water. This weight loss is probably higher than for rock distant from the sample collection point owing to absorption of drilling water. Samples of 100 mg weight were heated for differential thermal analysis (DTA) using a Fisher 200A DTA apparatus at a rate of 10°C/min from 25°C to 500°C.

Thermogravimetric analysis was carried out with a Fisher 100A TGA apparatus and a Cahn Model R6 electrobalance at a rate of 5°C/min from 60°C to 500°C using 100 mg of sample material. A few samples were heated to 800°C and are described elsewhere in this subsection.

Results of Analyses. Whole-rock chemical analyses, soluble-insoluble fractions, and weight losses upon heating are presented in Appendix 7.A. These analyses are converted to relative numbers of moles of components by multiplying weight percents by appropriate values of 1000/molecular weight. The results are listed in Appendix 7.B. If the insoluble fraction of a sample exceeds 0.5 weight percent, separate calculations are provided for both the soluble and insoluble fractions of the sample.

7.3.3 Results and Discussion

Distribution of Mineral Phases. Chemical analyses may be used to estimate, semiquantitatively, the amounts of constituent minerals present in a rock. This is accomplished by distributing the quantitatively determined chemical components among mineral phases known qualitatively to be present in the rock. The method was as follows:

> The distribution of the total number of moles (Nt) of a given chemical component (c) among the various mineral phases (p) present in a rock is described by the equation

$$Nt,c = \Sigma\ (Np)\ (Nc,p)$$

where:

Nt, c = the total number of moles of the component c in the rock

Np = the total number of moles of each of the mineral phases p in the rock,

Nc,p = the number of moles of the component c in one mole of phase p.

This equation is simply a statement of conservation of mass, indicating that the total amount of a given chemical component must be distributed among the minerals containing that component; this distribution is controlled by the specific chemical compositions of the minerals. An expression of the form of the above equation may be written for each of the components present in a rock sample. For a given rock, one of three conditions are possible for the set of simultaneous equations describing the distribution of all components in that rock:

1) if the number of equations (1 for each component) is equal to the number of unknowns (the moles of each of the phases), an exact solution to the equations may be determined.
2) if the number of components exceeds the number of phases (more equations than unknowns) the system is overdetermined and a solution to the equations may be evaluated by a method such as least squares regression.
3) if the number of components is less than the number of phases (more unknowns than equations), the system is indeterminate.

If either of the first two criteria are met, the chemical composition of the rock can be employed to calculate the quantitative amounts of minerals known, qualitatively, to be present.

An important assumption for the treatment described above is that the chemical composition of all mineral phases is known. This is necessary in order to define Nc,p for all phases in the mass balance equations. If a mineral of variable composition is present in a rock sample (i.e., a solid solution), an additional variable is introduced to the set of equations; that is, the composition of the solid solution. This additional variable may change a set of N equations and N unknowns (condition 1 above) to an indeterminate set containing N + 1 unknowns. If such is the case, it is necessary to employ some additional analytical technique to determine the actual composition of the unknown. On the other hand, if the solid solution is present in a rock meeting condition 2 above, it will suffice to simply introduce two values of Np for the phase; in other words, an unknown for the number of moles of each of the pure end-members of the solid solution present. The composition of the mineral is then defined by the relative number of moles of each of the end-members present.

Qualitative mineralogy may be carried out by a variety of methods such as x-ray diffraction and thin-section analysis in addition to straight-forward examination. The chemical data obtained during this study have been used to attempt to estimate relative amounts of minerals present in the various samples. With only a few exceptions, the rocks are made up essentially of halite, and other mineral phases are present in comparatively minor or trace amounts.

Samples from the Carlsbad boreholes consist of two chemically distinct fractions: (1) water-soluble chlorides and sulfates of sodium, potassium, calcium, and magnesium, and (2) water-insoluble silicates of potassium, magnesium, and aluminum with quartz and iron oxide. Minerals of the first group generally contain stoichiometric compositions, whereas those of the second group exhibit extensive compositional variation. In

the case of the soluble portion, sodium occurs mainly with chloride as halite, while the other cations combine in various proportions with sulfate (and only occasionally chloride) forming minerals such as polyhalite, anhydrite, and kainite. These sulfates are of importance because they contain hydrate water which may be released upon heating. Silicates also undergo dehydration at elevated temperatures, but generally much higher temperatures are required than for the soluble salts because the water must be derived through destruction of hydroxyl groups. Compositions of minerals from these two classes are listed in Table 7.3.

Recognizing that soluble potassium, calcium, and magnesium are combined with sulfate, a semiquantitative estimate of various sulfate phases may be made by plotting the relative numbers of moles of the cations on triangular composition diagrams. The compositions of various stoichiometric mineral phases in the sulfate group are shown on such a diagram in Figure 7.2. No sulfate of potassium alone is common in nature, so sylvite is placed at the potassium apex of the triangle. Also shown on this diagram are the chloride and chloride-sulfate of potassium and magnesium. Not shown on Figure 7.2 are the soluble sulfates containing sodium. After plotting a given sample composition in terms of relative numbers of moles of soluble K_2O, CaO, and MgO, the total number of moles of these cations is compared to the number of moles of sulfate determined analytically; if the two are equal, then the minerals in the rock are estimated using the location of the sample on the diagram. If the cation sum is greater than available sulfate, an appropriate amount of chloride is added to make up the charge balance. Relative amounts of chloride and sulfate are then used in conjunction with the cations to determine appropriate amounts of carnallite, kainite and/or sylvite. If on the other hand, cations are deficient relative to sulfate, then sodium is added to the sulfate group to form bloedite, glaserite and/or glauberite.

The addition of sodium or chloride must be compatible with the relative amounts of these two components in the analysis. Generally, these are

present in such large amounts that a small error in their contents provides sufficient amounts for addition to the potassium-calcium-magnesium-sulfate fraction. In many instances, it is found that when it is necessary to do such addition, the appropriate component (sodium or chloride) is present in excess of the other necessary to form halite. Where such addition is not compatible with the chemical analysis, examination must be made of the insoluble portion of the sample. Where anhydrite-gypsum is present in significant amounts in a sample, the relatively low solubility of $CaSO_4$ (and possibly polyhalite) causes this phase to appear in both the soluble and insoluble fractions.

Minerals of the insoluble fraction consist of quartz, iron oxide, and a variety of clay minerals which are difficult to identify due to fine-grain-size and compositional variability. Iron probably occurs chiefly as either hematite (much of the halite is tinted orange) or an equivalent hydrated form although it may substitute for aluminum to a minor extent in clay minerals.

According to our chemical analyses, the remainder of the insoluble fraction is made up of the components K_2O, Al_2O_3, MgO, and SiO_2. Because the first three of these generally occur combined with the fourth, potential mineralogy of the samples may be evaluated by comparing insoluble analyses to mineral compositions plotted on the compositonal triangle K_2O-Al_2O_3-MgO shown in Figure 7.3. On this diagram, mixed-layer solid solution among potassium and magnesium montmorillonites and seawater-illite is indicated by the shaded area between these three endmember components. It should be noted that the chlorite composition plotted on Figure 7.3 is that which has been observed in present day seawater sediments and evaporites. Relative proportions and amounts of minerals occurring in a given sample are evaluated by distributing potassium, aluminum, and magnesium along appropriate limiting phase compositions. Silica is then distributed among these phases according to stoichiometry, and any excess occurring in the sample analysis is considered to be free quartz.

Halite is by far the most abundant mineral in the soluble fractions of the samples. In only a few cases is halite a minor or trace constituent. Polyhalite and anhydrite/gypsum are accessory minerals in most samples, and in two of these, $CaSO_4$, is a major component. In normative calculations for sulfate deficient samples, kainite and carnallite are included, whereas thenardite, glaserite, bloedite, and kieserite appear in sulfate-excess and balanced samples. These phases are rarely present in more than trace amounts and are calculated to occur in such small quantities as to be insignificant in terms of contributions to hydrate water. Sample 8-1652 (i.e., 1652 feet depth in AEC No. 8) is significantly different from other soluble material in that it is calculated to contain relatively large amounts of the soluble salts sylvite, polyhalite, leonite, and glaserite. The drilling log reports loss of mud at this point, so it is uncertain as to whether a rock is of exotic mineralogy, or one from which certain cations have been leached by moving drilling mud, or one which has exhibited the incongruent solubility of polyhalite, leaving a sample of abnormal chemistry.

Most of the insoluble analyses plot within the triangle bounded by the phases Mg chlorite-K feldspar-talc on Figure 7.3. These minerals are recognized to occur in evaporite sequences which have undergone mild diagenesis ($P < 100$ atm, $T < 100^{\circ}C$), forming as a result of interaction of brine with amorphous aluminosilicate detrital material (Braitsch, 1971). The only other phases calculated to occur in the insoluble fraction are mixed-layer illite-montmorillonite, quartz, and iron oxide. It should be noted that the presence of the mixed layer silicate as well as chlorite and talc may be difficult to establish if they occur in very fine grain size. None of the observed silicate phases undergo dehydration below $500^{\circ}C$, according to the DTA.

Effects of Heating Samples. A number of different responses to heating were exhibited by the samples. Heating to $70^{\circ}C$ was designed to measure absorbed water recognizing that gypsum dehydrates, according to thermochemical data, at about $70^{\circ}C$. In normal differential thermal analysis, gypsum undergoes stepwise dehydration to hemihydrite and

anhydrite at about 150° and 185°C, respectively. Kopp, (University of Tennessee, pers. comm.) has observed that gypsum dehydrates upon fine grinding and prolonged heating at 70°C, hence the observed DTA breakdown is probably a result of kinetic factors. Consequently, samples analyzed using thermogravimetric analysis were powdered and placed in an oven at 70°C for several days prior to analysis of weight loss at elevated temperatures. Samples 7-1171 and 8-2563 both contain major $CaSO_4$, but only the latter showed gypsum-type dehydration. This appears to indicate that sample 7-1171 actually contained anhydrite whereas sample 8-2563 contained gypsum since only 8-2563 showed significant weight loss at 70°C but both analyses summed to near 100%.

Essentially isothermal dehydration was observed over a continuum of temperatures from 100° to 500°C for a large number of samples. In addition, weight loss over a 50° to 100°C span in temperature was observed for most samples, but generally at temperatures above 300°C. These two types of weight loss probably indicate single-mineral dehydration for isothermal loss, and dehydration as a result of mineral-mineral chemical interaction for the weight loss occurring over a large temperature span. Such solid interaction is demonstrated by sample 8-1953 which contains both anhydrite and polyhalite but minimal bloedite. Figure 7.4 shows the DTA curves for pure polyhalite and gypsum. Comparison of these two curves to that of sample 8-1953 shows the 325°C exotherm of polyhalite to be lacking while the lower temperature endotherms of gypsum are present. We suggest the missing polyhalite endotherm is a result of chemical interaction between polyhalite and anhydrite somewhere between 200° and 325°C. Such interaction among evaporite minerals should probably be investigated in some detail in terms of retention of hydrate H_2O.

A few samples were heated to 800°C to get an indication of how much weight might be lost from samples at high temperatures (>500°C). Of the nine samples examined under these "extreme" conditions, four began <u>gaining</u> weight at about 700°C. One sample increased in weight by about 15% between 725° and 800°C. This gain in weight is not a result of

oxidation of iron (eg. Fe^{+2} in chlorite) since sample 8-2050 did not contain any iron. That the gain in weight may be caused by formation of an extremely hygroscopic phase at high temperatures as a result of solid-solid chemical interaction upon heating. Whether or not such a phase forms would undoubtedly depend upon the initial mineralogy of the rock to provide the correct reactant phases since not all sample exhibited this weight gain. The water necessary for this rehydration is probably a result of the fact that the testing laboratory is cooled during the summer months (the analyses were run in early June) by evaporation which results in high relative humidity.

A composite histogram of weight loss of all samples at elevated temperatures is shown in Figure 7.5. The distribution appears to be log-normal with the maximum density near 0.25% weight loss upon heating 500°C. Over half of the samples (56%) show weight loss of 0.5% or less, and only 15 samples exceed 1%. Figures 7.6A and 7.6B are plots of sample weight loss vs depth for the two drill holes. Samples showing more than 1% weight loss upon heating are scattered throughout the depth range but are generally separated by more than one hundred feet of low-water-loss material. There is a broad correlation between higher weight loss and increasing insoluble content of sample, but no clearcut relationship is seen between weight loss and silica content. It is concluded that high temperature weight loss is contributed by both silicate and sulfate minerals. It can be stated in general, however, that samples showing less than 1% weight loss contain less than 10 wt % insoluble material.

7.3.4 Conclusion

Most of the samples showed very little water loss between 200° and 300°C and there were only small water losses at temperatures 200°C and 300°C. As can be seen by examining the data, there are several zones where there is essentially no change in sample behavior with heating to moderate temperatures. These areas show good potential as burial sites for nuclear waste.

7.4 DETAILED PETROLOGY AND SILICATE MINERALOGY OF SOME PERMIAN BASIN ROCKS

7.4.1 Introduction

The purpose of this section is to describe and evaluate the petrologic, mineralogic and geochemical properties of designated core samples, primarily from the ERDA - 9 drill hole and various grab samples exposed in mines and at the surface, in connection with the WIPP (Waste Isolation Pilot Plant) site evaluation.

ERDA - 9 penetrates the Mescalero Caliche, Gatuna Formation Santa Rosa Sandstone, Dewey Lake Red Beds, Rustler Formation, Salado Formation and the uppermost 50 feet of the Castile Formation (Figure 4.3-3). Primary interest is focused on selected intervals within the Salado and uppermost Castile Formations.

The general problems under study are: 1) the genesis of the dominantly evaporite succession with associated silicates and 2) the extent of post-depositional alteration of these sediments. The basic approach (and analytical method) is broadly threefold. First, detailed study of the occurrence and mineralogy of silicates, particularly clay minerals, in the evaporite succession (disaggregation, size fractionation, x-ray diffractometry). Second, bulk chemical analysis of whole rock, water soluble, acid insoluble, and clay size fraction (x-ray fluorescence, atomic absorbtion spectroscopy, other rapid procedures). Third, macroscopic and microscopic petrography (handspecimen and microscope mineral identification, description of form, texture and lithology of mineral associations, and x-ray diffractometry of bulk samples).

7.4.2 Procedure

After core intervals were selected for study, cores were cut lengthwise, mostly in the form of 1/2, less commonly 1/4, of the core. Criteria for selection and additional procedures for analysis of these samples are

described in the following sections on the silicate mineralogy, geochemistry and petrography.

7.4.3 Silicate Mineralogy and Geochemistry

Systematic logging of ERDA - 9 core and accompanying gross mineralogy have been described in Chapter 4. This section is focused on selected segments of the core and examination of the paragenesis of minor constituents, namely the silicate minerals, their composition, and their interpretation in terms of depositional and postdepositional phenomena.

Silicate mineralogy and geochemistry have not been comprehensively studied within the Ochoan rocks and the Permian Basin. Adams (1969) has reported briefly on the occurrences of talc in argillaceous rocks as a part of this extensive study of bromine distribution throughout the section; specialized clay mineral determinations by Grim et al. (1961) and Fournier (1961) have been undertaken on a limited number of samples and with minimal regard to their detailed stratigraphic setting and geneses.

In an effort to provide substantially more complete understanding of the silicates associated with the Permian evaporites, some 70 samples of the ERDA - 9 core ranging from 300 feet below the Salado-Rustler contact (1163.3 foot depth) down to a few tens of feet below the Salado-Castile contact (2867.6 foot depth) were selected. The following criteria were used in the selection: (1) representation of major lithologies; (2) detailed representation of an apparent "cycle" of evaporite deposition which occurs repeatedly through the Salado Formation section; (3) representation of intervals under consideration for waste storage sites; (4) detailed representation of selected polyhalite-anhydrite occurrences toward interpreting the genesis of the unusually abundant polyhalite; and (5) representation of the sequences which may provide data for interpreting postdepositional solution and recrystallization phenomena. In Table 7.4, we list the samples by depth, gross lithology, and stratigraphic position, as well as by character of data obtained; Table 7.5 provides a cross-listing for relating sample number to depth.

Sample Preparation and Analysis. The core was split and one split rebagged for future reference. One to 10 cm segments of the remaining half were selected for analysis (petrographic, mineralogic, and/or chemical) and sectioned off. A 1 cm slab of this was retained for petrographic examination; the remainder was coarsely crushed and a split retained for whole rock analysis. The larger fraction of the sample was leached with excess demineralized water to dissolve the halite host. This was repeatedly centrifuged, decanted, and rewashed to remove all traces of dissolved halite from the residue. The residue was dried, reweighed, and a split suspended in boiling EDTA solution in order to separate the "acid-soluble" salts (sulfate and carbonate minerals) following the procedure of Bodine and Fernalld (1973). Again, after repeated centrifuging, decanting and washing to remove EDTA and to dissolve solid components from the insoluble residue, the suspension was dried and reweighed. Table 7.6 depicts the quantities of sample residues insoluble in water and EDTA. A split of this fraction was resuspended in water, thoroughly disaggregated with an ultrasonic probe, and separated into the $> 2\ \mu m$ and $< 2\ \mu m$ (effective spherical diameter) fractions by timed gravity settling. Oriented diffractometer mounts of the fine fraction were prepared by pipetting several drops of each suspension onto glass slides and air-drying. Smear (paste) mounts and mounts using the conventional commercial powder mounts were used for the $< 2\ \mu m$ insoluble fraction as well as for the other fractions. In addition, pellet or uniformly compressed mounts or "briquettes" of these fractions prepared for x-ray fluoresence were also used for diffraction.

Where sufficient sample was available, normal procedure for the silicate fraction included: (1) diffraction data for the whole EDTA-insoluble fraction using the briquettes or paste mounts; (2) oriented (sedimented) clay-size mounts on glass which were air-dried, glycol saturated, heated to $300^{\circ}C$, and heated to $500^{\circ}C$. Conventional x-ray diffractometer traces were obtained at a scanning speed of $2^{\circ}2\theta$/min with Cu-radiation and a curved crystal monochromator.

X-ray fluorescence work involved briquette mounts using the vacuum-path Norelco fluorescence goniometer with quartz and gypsum analyzing crystals. In this study, standard regression procedures are used along with matrix evaluation for calculating abundances from the raw data. However, at this time the data can only be reported in terms of a unit-slope regression from one standard. Because of the severe errors such a procedure may induce, only "semi-quantitative" chemical results are claimed for this report.

Silicate Mineralogy. The following silicate minerals have been identified in the course of this study; their distribution is given in Table 7.7.

Quartz - Quartz occurs throughout the entire interval of the stratigraphic section analyzed; however, it does not occur in every sample. Quartz is generally fine-grained ($<10\mu m$), subhedral to anhedral, and readily identified in diffraction traces by its very strong peak at 3.34Å and moderate peak at 4.26 Å; interference by the micas and mica-clays with the former and by potash feldspar for the latter only rarely preclude its ready identification.

Illite (mica-clay) - Illite also occurs throughout much of the stratigraphic interval. It is readily observable in diffraction traces with its strong 10Å and 3.34Å peaks and its moderate 5.0Å peak (001, 003, and 003 respectively). All illites observed in the core are dioctahedral as based upon (060) < 1.52 Å and (001, 002, and 003) <1.0, 5.1, and 3.44 Å respectively. Many of the illites contain recognizable but small quantities of interlayered smectite, presumably saponite or other trioctahedral varieties, based on the slight asymmetry of the (001) reflection.

Feldspar - Feldspar occurs frequently, but generally in small quantities, throughout the section and its identification is based principally on one or more diffraction maxima in the 3.17 - 3.30Å range. Unfortunately, its abundance is usually low and when coupled with the presence of other

minerals its diffraction maxima for resolving its composition and its thermal character are not interpretable; both plagioclase and K-feldspar have, on occasion, been recognized.

Chlorite - Chlorite is commonly a minor constituent and its presence is often difficult to establish. With a 14 Å periodicity its maxima can be masked by smectities, various interlayered species, and by the 7 Å minerals, kaolinite and serpentine. In glycol saturated specimens, the 14 Å peak from expandable clays can be removed and at 500°C the 7 Å peak from kaolinite is lost. Even so with only a small amount present in such an assemblage it can remain undetected.

Talc - Talc is rare throughout the core. It is common in the ore zones (Adams, 1969) but appears to be nearly absent from the other lithologies. Talc is identified by very sharp, strong reflections at 9.5 and 3.15 Å (001 and 003); the former is quite distinct from the broad reflection at 9.0 - 9.7 from a regular interlayered chlorite-saponite (corrensite).

Serpentine - Serpentine, like talc, is relatively rare in the section and is confined to the lowermost interval (below 2820.3 and at or below the Salado-Castile contact) in rock salt and anhydrite. Serpentine is identified by strong peaks at ~7.3Å and ~3.6 Å (001 and 002 respectively for a single-layered variety). These maxima are noticeably greater than the 7.0 - 7.2 Å and 3.5 - 3.65 Å reflections attributable to chlorite. In our samples, these larger spacings are characteristically sharp and are not accompanied by the odd (00) reflections of the 14Å minerals.

Expandable Clays - Expandable clays, the smectities, vermiculites, and mixed-layer clays containing either of these constituents, are the dominant clays of the section and are ubiquitous (Table 7.8). We have recognized at least four such clays; however, their definitive identity has not yet been resolved.

a. Saponite (e.g. JS-CS-9 at 1466.9') expands to >16Å with glycol saturation and collapses to < 14Å upon heating, (further heating would yield an ~9.5 Å peak).

b. (?) Illite-saponite (e.g. JL-CS-2 at 1440.5' JL-CS-10 at 1325.3') with an air-dried maximum at 10.2 - 10.3 Å, glycol saturation at 10.0 Å and with or without a less intense shoulder or separate peak at 11.3 - 12.1Å, and collapsing to 9.8Å at 300°C. We have not ruled out a mixed-layer talc saponite identification for this phase.

c. Chlorite-saponite (e.g. MB-CS-21 at 1404.6' and MB-CS-32 at 2541.5') exhibits a 14 Å peak expanding to 15.5Å with glycol saturation and collapse to <14 Å upon heating. The chlorite-vermiculite phase described by Fournier (1961) and Grim et al. (1961) is probably this chlorite-saponite; the expansion with glycol is too great for this to be a chlorite-vermiculite. In some cases the interlaying is random; in others it is regular and produces a distinct superlattice peak (~29Å); in most there is some regularity with a slight shoulder present in the 25-30° 2θ present (these shoulder "maxima" are exceedingly difficult to plot precisely and all contain ±0.3-0.5° 2 θ definition).

Nearly all of the diffraction data in Table 7.8 can be assigned to one of these three clay phases, yet data from several samples are not yet resolved, e.g. MG-CS-13 at 2518.3. It should be noted that smectities are smectite-bearing mixed-layer clays which commonly appear to be "stripped" by the EDTA-dissolution of nonsilicates; they commonly show 12-13.8Å air-dried spacings. However, suspending these clays in $MgCl_2$ or NaCl solutions and then rewashing and redrying restores the appropriate 14-15Å spacing.

In Appendix 7.C, we present a number of the diffraction diagrams illustrating these silicate assemblages.

Distribution of Clay Materials. Some general but tentative observations regarding these minerals throughout the section are:

(1) Serpentine appears to be restricted to the lower 40 feet of the analyzed section; it most commonly occurs in anhydrite and associated rock salt.

(2) Talc is not restricted to assemblages from bitterns as suggested by Adams (1969).

(3) Interlayered illite-saponite (or talc-saponite) appears to be resricted to polyhalite lithologies or adjacent anhydrite. It appears to be absent from clay beds and associated rock salts and from the polyhalite-free remainder of the section.

(4) Expandable clays appear to show somewhat less relative abundance in clay beds (1244.8, 1247.2, 1328.6, 1441.7, and 1468.1 ft.) than in the silicate assemblages from the evaporite rocks.

(5) Furthermore, the mixed-layered clay species in each of these clay seams consists solely of the well developed regularly interstratified chlorite-saponite (corrensite).

7.4.4 Mineralogy of Duval Mine Samples

Several samples of wall-rock were taken from the 4th ore zone (langbeinite level) of the Duval Nash Draw potash mine, about 5 miles west-by-southwest from the study area. These samples include a dark brown clay parting (the DV-4 series) taken from the upper boundary of the 4th ore zone.

Untreated oriented powders were scanned from 2 to 60 degrees two theta. The untreated slide was glycolated by vapor-soaking on a rack in a container filled partially with ethylene glycol. An additional oriented powder was heated at 450°C. Both the glycolated and the heated specimens were scanned from 2 to 3 degrees two theta.

Whole rock samples were analyzed by loading a small amount of randomly oriented rock powder in a Norelco powder holder. This powder was scanned from 5 to 80 degrees two theta and the resulting diffractogram compared to values compiled in the Joint Committee on Powder Diffraction Standards file to determine bulk mineralogic composition. Mineralogic abundances noted were estimates based on comparative peak intensities.

All samples x-rayed (both clays and whole rocks) were scanned with Ni-filtered CuKα radiation. A time constant of two seconds was used with a scintillation counter detector and pulse height analyzer. The goniometer slit system consisted of a divergent and anti-scatter slit of 1 degree and a 0.003 inch receiving slit.

The results for Duval Mine samples appear in Table 7.9. For comparison, "dirty salt" from about 2100 feet depth in ERDA No. 9 has about 8% by weight insolubles.

7.4.5 Chemical Composition

Since appropriate regressions for each component based on several standards have not yet been calculated and matrix effect corrections have not yet been made, the analyses in Table 7.10 must be considered as only semiquantitative. In most cases, most totals are between 85 and 98%; perfectly reasonable totals with the remainder being chiefly water. A few totals exceed 100% and a few others are less than 85%; these are unquestionably in error. These data, however, do illustrate a number of important relations and are compatible with the mineralogic data.

Thus for example, those analyses with high alkali content (JS-CS-2 at 1440.5', JC-CS-6 at 1441.5, MB-CS-27 at 2067.0, MB-CS-31 at 2512.5, MB-CS-13 at 2518.3, MB-CS-10 at 2705.8, and MB-CS-36 at 2758.4) show substantial feldspar with or without abundant mica-clay.

In general, the chemical data support the mineralogic determinations. The silicate fractions are extraordinarily high in MgO (~20-30 wt % MgO)

and correspondingly low in CaO (~1 wt % CaO); Al_2O_3 is low (~8-12 wt % Al_2O_3) for clay mineral assemblages. Thus, except for illite, our clays are trioctahedral with only chlorite containing appreciable Al_2O_3.

7.4.6 Petrography

Petrographic analysis, both macroscopic and microscopic, is used in three ways: first, determination of the mineralogy of samples; second, given the mineralogy of a sample, description of lithology; third, the primary utility of petrographic analysis in this study, description of the texture of the sample. Texture refers to grain or crystal size, shape (habit or form), orientation, relationships (such as nature of contacts between crystals or grains) among different minerals and lithologies.

Macroscopic Petrography.

Sample Preparation and Procedures - Slabs, approximately 1 cm thick, were cut lengthwise using a band saw, from the 1/2 or 1/4 core samples. One face of a remaining core sample was then polished using a sander with various grit sandpapers. The sample was not to be used for silicate mineralogy-geochemistry analysis in order to avoid contamination. The polishing enhanced textural detail. Faces were also polished on some slabs.

Samples were selected from the core in which mineralogy based on macroscopic identification was obscure or uncertain for x-ray diffractometry of the bulk sample. Conventional diffractometry methods, as described previously, were used.

Macroscopic Petrographic Description - The mineralogy, lithology and texture in the polished sections of all the core intervals selected were described. Appendix 7.D is a brief extract from 54 pages of sketches accompanied by textural descriptions of these core intervals. Table 7.11 is a summary of the gross lithology reported largely as macroscopic

mineral identification and core footage. Table 7.11 indicates that macroscopic mineral identifications are generally reliable, especially for coarse-grained minerals, but visual estimation of the relative minerals abundances are less reliable. Estimates of relative abundances based on x-ray diffraction analysis are regarded as "semi-quantitative" and maybe in error, but it is still more reliable because of its greater precision, if not accuracy, compared to visual estimation.

Plates 7.1 through 7.6 are photographs of polished faces of cores or slabs illustrating typical textures. Plate 7.1 shows a variety of shapes of halite in anhydrite. The occurrence as beds or laminae or irregular lenses is inferred to be primary because halite and anhydrite can precipitate jointly or alternately from evaporating seawater. The apparent swallow-tail form of halite in laminated anhydrite is a problem because no primary occurrence of this form of halite is known. The swallow-tail form can occur as a twinned crystal of gypsum, but coprecipitation of gypsum and anhydrite is thermodynamically impossible. One interpretation is primary precipitation of calcium sulfate only as gypsum in the form of rapidly growing swallow-tail twins and finely crystalline aggregates. Then post-depositional alteration of the finely crystalline aggregates to anhydrite takes place, and the twinned crystals alter either directly to halite or first to anhydrite which then alters to halite, with preservation of the primary swallow-tail forms. This interpretation is favored by the almost exclusive dominance of gypsum rather than anhydrite as the primary precipitate in modern environments and lab experiments. Controversial thermodynamic analyses also favor gypsum as the primary precipitate, even metastably.

Plate 7.2 also illustrates occurrence of halite in well laminated anhydrite. This is interpreted as primary coprecipitation of halite and gypsum with these textures followed by post-depositional alteration of gypsum to anhydrite with preservation of primary texture.

Plate 7.3 illustrates an occurrence of halite and polyhalite. The triclinic crystal system of polyhalite is unlikely to produce a rectangular outline in cross section whereas the cubic habit of halite or

the orthogonal morphology of anhydrite would. Thus, the rectangular outline of the polyhalite body suggests post-depositional alteration of anhydrite, (to a lesser extent of halite) to polyhalite as does the occurrence of most polyhalite in irregular masses among halite masses. Thermodynamic and experimental considerations as well as observation of modern evaporites indicate that polyhalite does not precipitate from evaporating seawater.

Plate 7.4 illustrates coarse, relatively pure halite with anhedral, granular texture. The halite contains small crystals of anhydrite, probably a post-depositional alteration product of a primary coprecipitate of halite and gypsum.

Plate 7.5 illustrates another texture of halite in anhydrite with traces of magnesite. As previously indicated, it is believed to result from primary co-precipitation of halite and gypsum with post-depositional alteration of gypsum to anhydrite with preservation of primary texture. Magnesite is not known to precipitate from evaporating seawater but calcite does, suggesting post-depositional alteration of a primary (probably calcium) carbonate to magnesium carbonate.

Plate 7.6 illustrates textures in a dominantly anhydrite rock. The occurrence of the swallow-tail form near the stratigraphic top of the specimen as well as previously related discussions suggest primary precipitation of gypsum followed by post-depositional alteration of anhydrite, which could occur shortly after deposition, with preservation of primary textures.

Microscopic Petrography.

Sample Preparation and Procedure - The 1 cm thick slabs were converted to standard and oversize thin sections following conventional procedures (with the following exceptions) to minimize chemical alteration of the sample. Fluid in contact with the sample was a pure vegetable cooking

oil. Temperatures during the thin sectioning process did not exceed 30°C. Samples were put in dessication jars during impregnation to minimize contact of fluid acetone with the sample.

Microscopic Petrographic Description - Plates 7.7 through 7.12B are photomicrographs of thin sections of rock samples from the Permian Basin of southeast New Mexico. The samples are not from ERDA-9 core but are representative of mineralogies, lithologies and textures commonly encountered in the core.

Plate 7.7 is a photomicrograph of relatively finely crystalline euhedral to subhedral halite. The crystal form, relative clarity (although containing very fine crystals of anhydrite) and occurrence of fluid inclusions as both negative crystals and subspherical forms all suggest little post-depositional alteration with the exception of alteration of primary gypsum to anhydrite.

In Plate 7.8 also dominantly of halite (typical of the rock in Plate 7.4), there is a startling contrast to the texture in Plate 7.7. Crystals in Plate 7.8 are anhedral to subhedral, cloudy, coarser and devoid of fluid inclusions (the apparent void in the lower left was produced by plucking of a cleavage fragment from the specimen during sectioning). Because the texture shown in Plate 7.7 is regarded as indicative of little post-depositional alteration, the texture in Plate 7.8 is considered as indicative of extensive alteration, greater than that required for the postulated gypsum to anhydrite alteration which is also postulated for very fine crystals of anhydrite within the halite in Plate 7.8. These contrasting textures are also apparent in thin sections of carbonate rocks. Bathurst, (1975, especially Chapter 12), deals with recognition of chemically precipitated calcite (analogous to Plate 7.7) versus calcite post-depositionally altered from argonite or some other form of pre-existing calcite (analogous to Plate 7.8). Bathurst uses and builds upon terminology and concepts of the causes and processes of these alterations developed by Folk (1965).

Plate 7.9 shows an occurrence of halite with sylvite. The irregular bodies and irregular contacts of the sylvite (as well as the anhedral nature of the halite and bodies of intimately mixed halite and sylvite) are interpreted to be the product of post-depositional alteration. This interpretation is also favored by the fact that sylvite does not occur as a primary precipitate in the marine evaporite succession.

Plates 7.10A and 7.10B show the irregular and gradational nature of the contact between polyhalite and halite and the concentration of opaques, probably hematite, along the contact. These observations and those discussed under Plate 7.3 are interpreted to be products of post-depositional alteration of either anhydrite or halite to polyhalite.

Plate 7.11 shows the microscopic texture typical of many laminated or banded anhydrites of the Castile and Salado Formations. Neither x-ray diffractometry nor staining techniques have been used to determine the mineralogy of the carbonate. This texture is interpreted as annual varves by Anderson et al. (1972).

Plate 7.12A and 7.12B show dominately massive anhydrite, typical of much of the unlaminated anhydrite in the Salado Formation but atypically cut by a veinlet of gypsum. The rock sample was taken from outcrop and the gypsum veinlet is interpreted to have been produced by alteration of anhydrite to gypsum during uplift and exposure.

The petrographic descriptions and interpretations generally agree with those in the classic and relevant report of Schaller and Henderson (1932).

7.4.7 Interpretations and Tentative Conclusions

1. All of the samples discussed under macroscopic and microscopic petrography exhibit mineralogy, lithology and textures which are indicative of post-depositional alteration of the sediments (dated at 204 million years in Section 7.8). It is believed that fluids

migrating through the sediments are responsible for most of these alterations. Interestingly, the alteration of primary gypsum to anhydrite would liberate abundant volumes of fluid.

2. The abundance of polyhalite and the atypical mineral assemblages (sylvite-langbeinite vs kainite/carnallite-kieserite) of the ore zones suggest either drastic recrystallization or a former primary evaporite depositional environment. The areal extent of the Ochoan rocks and their great thickness coupled with paleogeographic evidence and the marine character of the underlying Permian strata appear to preclude the second alternative. Further evidence of the post-depositional origin of the present assemblage includes the low and highly variable bromine values in the Salado Formation rock salts (Holser, 1966; Adams, 1969). Age dates on K-bearing salts, discussed later in this chapter, further suggest recrystallization shortly after deposition.

3. The general mineralogy and chemistry of the EDTA-insoluble (silicate) fractions of the evaporite beds throughout the Salado and uppermost Castile Formations preclude their detrital origin.

4. The silicate assemblages and their chemistry further supports the hypothesis of post-depositional alteration of these rocks -- at least throughout much of the Salado Formation.
   a. The predominance of smectities (saponite) and trioctahedral smectite-bearing clays suggest relatively immature assemblages. The silicate assemblages of the Zechstein (Permian) of Germany are almost entirely nonsmectitic except for the well-crystallized, well-ordered regular interstratified chlorite-(smectite/vermiculite) mineral corrensite (Fuchtbauer and Goldschmidt, 1969). The Haselgebrige (Permo-triassic) of the Austrian alps similarly contains no smectites nor even smectite-bearing mixed-layered clays (Bodine, 1971), and the same is true for the Silurian salts of New York (Bodine and Standaert, 1977). The development of the unusual illite-saponite/talc/saponite phase with polyhalite suggests immaturity of the silicate

phase with respect to the evaporite phase. Any further phase changes that would take place in the silicate appear to be kinetically inhibited.

b. The variability of the clay assemblages and their lack of correlation with major evaporite lithologies bespeaks strongly of recrystallization accompanying migrating post-depositional pore fluids. Except for the unusual 10.3 Å phase with polyhalite, the only other lithic correlations are: (1) reasonably well crystallized corrensite as the only expandable clay in the discreet clay seams and (2) the occurrence of serpentine in the uppermost Castile Formation. The former is tentatively attributed to the "closed system" nature of the impermeable salzton beds; they were not subject to the attacks by a variety of migrating pore fluids of different composition. The latter relates to the vertical distance between K-Mg-bearing salt beds and the Castile Formation, which essentially comes in contact only with less mobile fluids in equilibrium with halite-anhydrite.

c. It is very tentatively suggested that many of the salzton seams formed through accumulation of silicate debris included in salts which have been dissolved; their association with the soluble K-Mg salt ore zones and with the extensive polyhalite replacement of anhydrite beds appears remarkable and may provide the geometry for the "plumbing system" in which migrating pore fluids circulated. It is also recognized that some of the salzton beds may well represent recrystallized detrital accumulations during periods of no evaporite deposition as suggested by Adams (1969). If migrating groundwaters do flow in some such controlled pattern, ore mineral distribution in each ore zone should reflect this, i.e. remnants of the primary carnallite-kieserite farthest from the source of the brines, enveloped by langbeinite and langbeinite-sylvite assemblages, in turn enveloped by langbeinite and langbeinite-sylvite assemblages, in turn enveloped by sylvite, and finally by barren halite. Similarly polyhalite

crystallization should be at a maximum under the langbeinite-sylvite assemblage within a given "cell" and would likely decrease both away from and toward the lateral pore fluid source.

In summary, substantial evidence has been accumulated that there has been extensive salt recrystallization, most noticeably within the McNutt ore zone. This is considerably less noticeable in the lower Salado and Castile Formations, but may simply reflect the far simpler evaporite mineralogy and persistence of substantially more homogeneous compositions within the pore fluids.

Preliminary computer modeling does, for example, substantiate that a typical primary marine evaporite salt assemblage of carnallite-kieserite-halite can, when under continued attack by migrating halite-gypsum saturated pore fluids flowing down dip in a hypothetical cell, generate a progression of salt facies with remnants of the primary assemblages farthest from the source. Toward the source, the following succes on of assemblages would be found: langbeinite-carnallite-halite (or langbeinite-kieserite-halite) then langbeinite-halite, then langbeinite-sylvite-halite facies, then sylvite-halite, culminating toward the source in a barren halite facies. At the same time, the K-Mg rich pore fluids which were generated through ore mineral dissolution and alteration would no longer be in equilibrium with anhydrite; anhydrite would alter to polyhalite until the solution chemistry reached the polyhalite-anhydrite equilibrium composition. The precise thermodynamic conditions and mineralogic reactions which governed these alterations are not known; however, the age of this recrystallization of evaporites has been determined to be in excess of 204 million years. For more details regarding this recrystallization which closely followed deposition, the reader is referred to Section 7.8.

7.5 VOLATILES AND FLUID INCLUSIONS IN MINERALS OF THE SALADO FORMATION

7.5.1 Introduction

Sources of liquids and gases native to the evaporites must be considered. One source is the intergranular fluid to be found in the pore spaces between mineral crystals and lithic fragments. These fluids are discussed in detail in a subsequent section (7.7). Another fluid source is the water of crystallization chemically bound in hydrous minerals. Yet a third source is fluid inclusions inside the mineral crystals themselves, which can behave as separate micro-geochemical systems.

Data presented in the overview Section 7.5.2, and Section 7.5.3 result from heating bulk rock samples to recover all types of fluid. In the major portion of the Salado, the total recovered amounted to less than 0.5 weight percent of the rock. As discussed in the overview section, it was possible to separately identify: (1) loosely-bound volatiles, (2) chemically-bound volatiles, and (3) fluid inclusions.

The sections on mineral sources of water and on fluid inclusions endeavor to place the data in the context of the mineralogy of the rocks serving as hosts for the volatiles. It will be noted that geochemistry in the context of the mineralogy is a pervasive theme in all parts of the geochemistry section of this report. This is true for the sections which follow on groundwater geochemistry and radiometric age-dating also. It will also be noted that the characterization of geochemical properties of solutions in the Salado confirm the qualitative measurements of fluid inclusion solute contents.

This chapter contains considerable data which will assist in the anticipation of short and long term physico-chemical conditions likely to arise during the experiments involving heat-producing radioactive wastes.

7.5.2 Overview of Volatile Contents of Evaporites

Themogravimetric analyses of 35 selected core samples from ERDA No. 9 were made. These were many of the same samples which were qualitatively examined for mineralogy by x-ray diffraction (refer to Section 7.2.3).

These analyses were made by suspending powdered samples from a microbalance while dry nitrogen flowed above the sample. The samples were heated by 5°C/minute until the temperature reached 500°C and were held there until gas evolution had ceased. A hygrometer was inserted downstream to register qualitatively whenever moisture was evolved.

The as-received salt core specimens were massive pieces approximately 4 inches in diameter and 1-2 inches thick. No attempt was made to obtain homogenized samples by powdering the entire piece. Instead nuggets were chiseled from the center of the specimen. The nuggets were crushed and ground to a powder just prior to the weighing and transferring to the microbalance system. A maximum of ten minutes elapsed between the start of crushing and the start of analysis. Thus, the possible loss or gain of moisture prior to testing was minimized. Powdered samples were necessary to minimize decrepitation.

The complete test results are presented in Table 7.12. Figure 7.7 illustrates the typical kinds of weight-loss curves observed. About half the specimens showed 0.5% weight-loss (curve A). Curve B is common with the rapid weight-loss occurring sometimes at 300° and sometimes above 400°C. Some samples show two stages. Only two samples followed curve C, where weight-loss was observed from the beginning of the run. The weight-loss curves for all samples are filed and are available for inspections.

Replicate runs were made in several cases, predominantly those which showed the larger weight-losses, and good agreement, i.e. within 5%, was observed.

All mass-loss is not due solely to water. Only the weight-loss below 300°C can be attributed largely to water; the weight-loss at higher temperatures is in part due to decomposition of carbonates or other volatile-bearing minerals.

Results were correlated with the x-ray diffraction results previously reported in an effort to identify which minerals may be decomposing. No definite conclusions could be reached so selected samples were analyzed for the evolved gases by gas chromatography/mass spectrometry. In particular, this was done for the samples 2302.6, 2516.3, 2658.5, 2786.5 and 2821.0.

The highest weight-loss was experienced by sample 2302.6. Its total ion chromatogram (Appendix 7.E) shows data channel numbers calibrated approximately in terms of temperature. Conspicious peaks occur at 100°C, 250°C and 300°C. Detailed mass spectra are given for 50°C, 100°C, 150°C, 200°C and 250°C; the most prominent mass peak is 18, corresponding to water. At higher temperatures, mass 14 (monoatomic nitrogen) becomes abundant. Even at lower temperatures, mass 28 (diatomic nitrogen) is present.

Sets of peaks separated by 12 mass units, corresponding to carbon, (95, 83, 71; 81, 69, 57, 45) probably represent fragments of hydrocarbons present in the diesel oil which was the lubricant used to core the hole. The contribution of mass 44 (CO_2) to the spectrum is a minimum at 200°C and rises again at higher temperatures. The low-temperature contribution is again probably due to the contaminant diesel oil.

At the highest temperatures, the mass peaks 15, 16, and 17 (CH_3, CH_4, O, OH) are accentuated along with 14, 18, and 28 (N, H_2O and N_2). All the individual ion chromatrograms for mass numbers 14, 18, 19, 20 and 44 have coincidental peaks at about 25°C and 300°C. Water and carbon dioxide are almost continuously evolved over the entire temperature range, but the coincidence of all the peaks for N, H_2O, F(?) and CO_2 (mass peaks 14, 18, 19, and 44, respectively) implies that evolution of

these components at 250°C and 300°C is related to a common source. Since halite decrepitates, releasing its fluid inclusions at about 250°C, those inclusions appear to be the most probable source of volatiles evolved at 250°C. Similarly since polyhalite dehydrates at a temperature slightly above 300°C, fluid inclusions in that mineral might be also released at that temperature (see Section 7.3). A detailed treatment of fluid inclusions appears in a subsequent discussion.

Mass numbers 32, 48, 64 and 80 have sharp coincidental chromatogram peaks at channel 517. These mass numbers most probably represent O_2, SO^{+2}, (possibly O_3 made inside the mass spectrometer) SO_2 and SO_3 released from the sudden decomposition of a sulfate. Similarly mass 36 (HCl) is released in major quantity at this point. All these phenomena occur at a slightly lower temperature than the main 200°C event, and their relationship with that event possibly indicates the presence of a very volatile sulfate phase rapidly decomposing when the halite fluid inclusions begin to rupture. Daughter crystals of gypsum in halite fluid inclusions would indicate a high concentration of sulfate in the inclusions (see subsequent discussion) and such a solution might give rise to the observed sulfur species in the mass spectrum.

The sample with the next greatest total mass loss (2786.5, 3.64%) is considered next. Many of the same features of the chromatograms in Appendix 7.E are observed here as in the previous sample. The main difference is the appearance of a large hump of many volatiles (H_2O, F, N_2, O_2) released at less than 100°C. This is consistent with the occurrence of clay minerals which can absorb various volatiles at surface and interlayer sites. Volatiles would be expected to be weakly bound at these sites. The same hump as before appears at 250°C, incorporating N, H_2O, HF(?), N_2, O_2, HCl, CO_2 and SO^{+2}, but only the postulated SO_2 species appears to be catastrophically released and is probably a product of ionization in the mass spectrometer.

A hump incorporating N, H_2O, HF, N_2, O_2, HCl, CO_2 and SO^{+2} occurs substantially below 300°C. This peak probably corresponds to release of water and other volatiles born of OH and fluid inclusions in the clay minerals, when the clays decompose upon dehydration.

Sample 2516.3 (2.15% mass loss) was unusual in that it contained magnesite. As is seen in the chromatograms in Appendix 7.E, the loss of H_2O and N_2 from various sources provides most of the pattern, which was not sampled at a temperature greater than about 240°C. There is almost a continuum of absorbed O_2 released. The most significant feature of this sample is the high-temperature loss of CO_2, presumably from the decomposition of magnesite.

Finally, the most abundant-type sample is considered: those which have mass losses less than 0.5%. These are characteristic of most of the main evaporite section and contain very little other than halite and anhydrite. Typical examples of these rocks are samples 2658.5 and 2821.0 (Appendix 7.E). The main difference between these two is the apparent larger number of types of volatile sites in the shallower sample. Absorbed N, H_2O, N_2, and O_2 form a large, broad hump at low temperature, with catastrophic release (of fluid inclusions?) of H_2O, N_2, HCl, and CO_2 at higher temperature in 2821.0. In 2658.5, the catastrophic release of H_2O, N_2, HCl, and CO_2 (with possibly some SO^{+2}) appears to occur in smaller episodes as various sets of fluid inclusions are ruptured at higher temperature.

7.5.3 Mineral Sources of Water in the Salado Evaporite Sequence

Introduction. The purpose of this section is to describe the mineralogy and petrologic characteristics of samples taken from two coreholes of the Salado salt from the boreholes AEC Nos. 7 and 8 in Lea and Eddy Counties, near Carlsbad, New Mexico, and the degree to which the evaporite rocks present would dehydrate if subjected to the heat generated by containers of radioactive wastes (radwaste). In a previous study, (Fallis, 1973) the general characteristics of evaporite deposits and their minerals were

described and a detailed mineralogic and petrologic study of two cores from the Hutchinson Salt near Lyons, Kansas, was made. The results at that time indicated that water losses ranging from 0.4 to 19.0 weight % might be anticipated if the surrounding rocks were heated to 100°C.

Sample splits corresponding to ones in this section were also discussed in Section 7.3. A comparison of those results and these is presented in the following section.

Sampling and Sample Preparation. Segments of the original 4 inch (10.2 cm) cores were split in half, lengthwise, for chemical analysis and weight loss determination by thermogravimetric analysis (previous section). Eighty-three samples (coded by core number and depth) arrived wrapped in plastic to reduce the possibility of absorption of moisture during shipping and handling. Core AEC-7 was drilled in Lea County, New Mexico, and core AEC-8 in Eddy County, New Mexico.

Throughout the sample preparation, care was taken to not expose any of the samples to water; however, since it was necessary to cut, grind and sieve various portions of the samples, it was not possible to completely protect them from exposure to moisture in the air. During those periods when samples were not actively being worked upon, they were kept in plastic bags, tightly-stoppered bottles, etc.

Since several different analyses were to be made, it was necessary to obtain representative sample splits which would correspond to each other as closely as possible. A more complete discussion of sample preparation is given in the thesis by Combs. However, for convenience, a brief summary of the methods used in sample preparation is given below:

1. A representative segment of each core sample was chosen and removed by sawing the original core (normal to the axis of the core) with a dry blade, masonry-type saw. This new segment was typically about three inches (8 cm) long.

2. Next, a slice was cut from each core segment (parallel to the axis of the core) with the approximate dimensions 3 x 2 x 1/2 inches (8 x 5 x 1 cm) for use in preparing the thin sections. The sections were prepared by Fred Roberts Petrographic Section Service, Monterey Park, California. They were cut using oil rather than water and mounted with an epoxy cement which was not heated.

3. About one-half of the remainder of each core segment was crushed and sieved, and representative portions selected to be analyzed by x-ray diffraction, x-ray spectroscopy and by static heating methods for water loss determination. (Later, some additional separations were made and portions of the samples selected for bromine analysis using x-ray spectrocopy. These procedures will be described briefly in the following sections.)

Analytical Methods Used in This Study. Several different kinds of analyses were performed on the samples received. The methods used include static weight loss determinations (water loss), mineralogical and petrological analysis, and some chemical analyses using x-ray spectrocopy.

The weight loss determinations were made in essentially the same manner as for samples studied from Lyons, Kansas, and which was reported previously (Fallis, 1973). Splits of the several samples (sample size generally ranged from 1.5 to 2.0 gms and in the 60 to 120 mesh size fraction) were heated to $102 \pm 5^{\circ}C$ for periods ranging from 2 to 42 days. The results of repeated analyses indicated that the precision of weight loss determinations was generally $\pm$ 0.1 to 0.2%. When new sample splits were used, the "precision" dropped to approximately $\pm$ 0.2 to 0.3%. Some data concerning precision are presented in Appendix 7.F.

In addition to the weight loss determinations performed near $100^{\circ}C$, weight loss determinations were also made for several samples which had been heated to $170 \pm 5^{\circ}$ (for 2 days) and $300 \pm 10^{\circ}C$ for (2 to 3 days). The results of the weight loss analyses are reported in Appendix 7.G and discussed in the following section.

Mineralogical and petrological analyses were made using x-ray diffraction and standard petrological techniques. A summary of important mineralogical and petrological data is given in Appendix 7.H and discussed following the next section. The chemical analyses were made using two variants of the x-ray spectrographic method, x-ray fluorescence analysis (wave length dispersive) and x-ray emission spectroscopy (non-dispersive). The chemical analyses were made primarily for bromine, which can be used to aid in the interpretation of the origin of evaporite deposits, and semi-quantitative analyses were made for chlorine, sulfur and iron.

Weight Losses for Cores, AEC NO. 7 and 8. Weight loss data for the samples studied are tabulated in Appendix 7.G and illustrated in Figure 7.8. In general, the weight losses are much less than those found for samples from the site at Lyons, Kansas. The range of weight loss values at 102±5°C for the Carlsbad samples (Salado salt), Cores Nos.7 and 8 was from 0.0 to 3.5% with the majority of samples showing losses less than 0.5%, while the Hutchinson salt, Cores Nos. 1 and 2 was from 0.5 to 19.0%, and most of the samples showed weight losses from 1 to 5%. A plot of approximate range of water loss at 102±5°C to be expected at various depths is shown in Figure 7.9. This is based on data from both Lyons, Kansas and Carlsbad, New Mexico sites.

Based on the results of the various heat treatments, the following conclusions can be drawn concerning the behaviour of the samples from Carlsbad:

1. Samples consisting almost entirely of halite and/or anhydrite show weight losses (up to 300°C) which are typically less than 0.5% and probably less than 0.3%. The final total loss will depend on the amounts of clay minerals and minor hydrated evaporite minerals, such as polyhalite, which are present.

2. Larger water losses (>1% at 102±5°C) are generally associated with the presence of clay minerals (and/or gypsum) in more than trace amounts. The exact losses will depend on

the kinds and amounts of clays present, the temperatures to which they are heated and the length of time for which they are heated.

3. At some temperatures between 170° and 300°C, polyhalite, which is a common accessory mineral constituent in some parts of the Salado salt, will start to break down. It can contribute water to the extent of about 6% of its weight in the rock being heated.

4. Although present in only minor amounts (or absent) in the samples that were analyzed, there are other evaporite minerals such as carnallite, kainite, leonite, etc., near the potash ore zones (the McNutt potash zone at approximately 1600' to 1800').

The weight losses determined in Section 7.3 are compared with these in Appendix 7.G. It should be noted that the earlier data were determined by thermogravimetric analysis; hence, weight losses were not determined at any fixed temperatures but at the actual temperatures at which the decompositions were detected. In order to make the data more comparable, the previous data were rearranged and weight losses taking place within certain temperature ranges were combined. The reader is referred to Section 7.3 for the specific temperatures at which weight losses occurred. It should also be noted that the two sets of data are not directly comparable, since the weight losses of this section were accomplished by heating under static heating conditions for periods of 2 or more days, while the previous data were obtained under dynamic conditions (much more rapid heating). As a general rule, the decomposition temperature of any given mineral will be higher under conditions of dynamic heating rather than static heating.

Even so, there is generally good agreement between the two sets of data which were obtained by different investigators using different techniques. Most minor discrepancies can be explained on the basis of

differences in the methods of analysis. Only a few real discrepancies seem to exist (such as for sample at 1697 in Core #7). This is to be expected since each group rceived different halves of the core and since Section 7.3 involved sample splits of the entire core segment while this work involved only a sample split corresponding to the portion of the core used in preparing the thin section. Since there are both vertical and lateral variations in mineral content within the cores, samples might occasionally have been analyzed which were mineralogically different.

The rocks being considered at the proposed WIPP site, New Mexico, appear to be much more favorable than those from Lyons, Kansas. Even so, some mineral water is still present and is apt to be released during the period when the rocks are heated by the waste containers. It will be important to determine the maximum temperatures to be reached, the volume of rock which will be heated, and the probable maximum volume of water which will be released.

Mineralogy and Petrology of Cores No. 7 and 8. In some respects the mineralogy and petrology of the core samples from Carlsbad are similar to those of the core samples from Lyons. Both cores were taken through evaporite sequences and hence encountered sedimentary sequences containing typical saline minerals such as halite, anhydrite and polyhalite. In addition, clay minerals, magnesite, gypsum, quartz, feldspar, carnallite, celestite (?), glauconite and kainite (?), were detected in smaller amounts. The presence of any of the other less common evaporite minerals in the samples studied is uncertain. In general, they only occur in such small amounts and/or such fine grain sizes that positive identification was not possible using the diffractometer and petrographic miscroscope. In Section 7.3 it was noted that several of these less common minerals are apparently present in many of the samples analyzed. Readers of this section should be aware that the analyses are based on the actual minerals observed (modal analysis) in thin section as supplemented by X-ray diffraction while the analyses presented in Section 7.3 were done by computer manipulation of the chemical analyses determined for each sample (normative analysis). Such

normative analyses can be quite useful, especialy when working with very fine grained or glassy materials. However, it should be noted that normative analyses may generate mineral assemblages which do not agree with the actual minerals present, as was pointed out in section 7.3.

Summaries of the mineralogic and petrologic features of the individual samples studies are presented in Appendix 7.H. For the reader's convenience, some general comments about the mineralogy and petrology of these samples are presented below. An excellent study of the mineralogy and petrology of the rocks in this region is given by Schaller and Henderson, 1932. Brief description of the major minerals noted in the Carlsbad samples follow.

Halite. Most of the halite is colorless and shows excellent cubic cleavage. These features, coupled with less low relief and isotropic optical character, make its identification easy. Sometimes the halite is colored red or orange by minute inclusions of hematite (or other iron oxides) or other minerals such as polyhalite. The grain size showed a wide range, from less than 1 mm (fine grained), to greater than 1 cm (coarse grained). Grains between 1 mm and 1 cm are considered to be medium grained.

Because halite fractures and cleaves so readily, it is difficult to determine whether the numerous breaks observed in thin sections were already present at depth or whether they developed during the coring operation, shipping, handling, thin section preparation, etc. More fractures are noted at the outer margins of each of the thin sections. However, some of them must have occurred prior to the taking of the core because they are filled (at least in part) with other minerals, petroliferous material, etc. In several cases fracture zones could be traced across the entire width of a thin section.

Inclusions (liquid, solid and gas) are common in the halite. During the preparation of some samples hydrogen sulfide (gas) was released. In many cases the inclusions are oriented with respect to the cubic crystal

planes. These oriented inclusions appear to represent hopper crystals which grew at the water surface in times of quiet water and are inferred to represent deposition from shallow water.

Intergrowths of relatively well-formed, cubic crystals of halite with clay and silt-size minerals are likewise inferred to represent very shallow conditions, perhaps even subaerial exposure for brief period.

"Patches" (regular to irregular, more or less equidimensional areas) and "stringers" (regular to irregular areas which are generally elongated in one direction) of anhydrite, polyhalite, clay and silt-sized minerals are common in halite. Sometimes these patches and stringers follow grain boundaries, but often they cut across grains. Where they follow grain boundaries, they may represent (nearly) simultaneous growth of the halite crystals and smaller amounts of the other mineral phase(s). Where they cut across grains, they presumably represent deposition of the minerals along zones of weakness or along which solutions passed. Enough of this latter material is present to demonstrate that there were opportunities for solutions to migrate through these relatively impermeable rocks, even though it is not possible to determine just how far the solutions actually traveled.

Anhydrite. Anhydrite was recognized on the basis of its relatively high birefringence, differences in relief upon rotation and cleavages at right angles. Normally, anhydrite shows parallel extinction, too, but because of twinning, replacement phenomena, etc., this characteristic was not always useful.

Anhydrite occurs in three major types. "Primary" anhydrite, which is commonly bedded, is very fine grained (much less than 1 mm) and somewhat fibrous in character. It also occurs in coarser-grained crystals and twinned crystals (sometimes over 1 cm long). At least some of these larger crystals appear to be pseudomorphs (replacement) after previously-existing gypsum crystals. Sometimes, very small amounts of questionable gypsum are noted nearby, perhaps as a result of partial

rehydration of the anhydrite. Finally, there are more or less isolated crystals and crystal clusters of anhydrite which occur in patches and stringers within the halite or are intergranular with halite. These may be associated with polyhalite and/or clay and silt-sized minerals. This type of anhydrite is thought to be authigenic (formed in place from fluids contained in the pores of the rock or passing through the rock).

Anhydrite can be replaced by polyhalite if fluids containing potassium, magnesium and additional sulfate ions are present. Many examples of this replacement were observed.

A few examples of bedded, nodular anhydrite were observed. The nodules may have originally been composed of gypsum which was later replaced by anhydrite. The origin of such bedded nodules is thought by some workers to represent depositions in very shallow water which was periodically exposed (Sabkha facies).

Polyhalite. Polyhalite was recognized on the basis of its relatively low birefringence, inclined extinction and complex twinning. (Unfortunately in some fine-grained material and/or mixtures, polyhalite and anhydrite can be confused because their optical properties of relief and birefringence are almost the same in certain orientations).

Much of the polyhalite observed is rather fine grained (much less than 1 mm in size for the individual cyrstallites) and often fibrous. However, some larger crystals are numerous, isolated crystals and crystal clusters were observed. Polyhalite is often reddish due to iron oxide inclusions, but this is not universally true.

Some of the polyhalite appeared to be a bedded form associated primarily with halite and lesser anhydrite. Polyhalite also is found replacing anhydrite and associated with nearby patches and stringers of clay and silt-sized minerals. Whether the clay, etc., provided some of the ions necessary for formation of polyhalite or just acted as a pathway for solutions passing through the rock cannot be determined.

Minor Minerals. Minor minerals were identified on the basis of their optical properties and X-ray diffraction analyses, which were occasionally aided by information contained in the well logs for the cores. Just a few brief comments for each mineral are given here.

Clay minerals. Overall, much less clay is present in the samples from Carlsbad than was present in the Lyons samples. X-ray diffraction peaks attributed to clay minerals were noted in nine samples from Core #7 and in fourteen samples from Core #8. Based on the X-ray patterns and peaks noted at approximately 7, 10, 11.5, 14 and 15 angstroms, major clay minerals present include illite, chlorite, mixed-layer clays and possibly some kaolinite.

Magnesite. Although well-crystallized magnesite was not detected in thin sections, some very fine-grained, relatively high birefringent phase was noted in some thin sections and magnesite peaks were detected in some thin sections and magnesite peaks were detected in a number of X-ray patterns. Schaller and Henderson (1932) stated that many of the clays in the samples they studied were magnesitic. The common association of polyhalite with clay and silt-sized minerals may be due in part to the magnesium ions in the magnesitic shales and clays.

Gypsum. Gypsum is monoclinic and in thin section has low birefringence and low, negative relief. Twins ("swallowtail") are fairly common. Well-crystallized gypsum was detected in only one thin section among the samples studied. In addition, several of the sections contained small amounts of questionable gypsum in association with anhydrite and/or polyhalite. However, the amounts present were much less than 1% and could not be confirmed by X-ray diffraction.

Quartz and feldspar. These minerals are present in two forms, as detrital (silt and very fine sand-sized) material deposited along with the clays, and also as authigenic minerals which formed in or near patches and stringers of clay and silt-sized minerals.

Sylvite. A few thin sections contain small amounts of sylvite which was recognized on the basis of its distinctive reddish purple color (due to iron oxide inclusions) and lower relief than halite. Most of the sylvite observed was associated with polyhalite as well as with halite. There were no samples from the sylvinite (mixed halite and sylvite) zones. Adams (1967) reported that not all sylvite is colored; however, in the thin sections studied, the distinctive color was useful in locating the small amounts present.

Carnallite. Only one section contains detectable carnallite. This mineral was suspected on the basis of nearby carnallite as noted in the well log. Its high negative relief and "metallic" luster due to inclusions were used to confirm its presence.

Celestite (?). In two or three thin sections some isolated spear-shaped crystals and clusters of crystals with relatively high relief were noted. Although no positive identification could be made, it is suspected that these are celestite, which is the most common strontium mineral present in evaporite deposits.

Glauconite. A few greenish, rounded grains of glauconite were noted, generally associated with the clay and silt-sized minerals. Not enough of this material was present to attempt to determine its origin or source.

Kainite(?). Kainite (?) was observed in only one thin section. It is a monoclinic mineral with moderate birefringence and negative relief.

Summary and conclusions. The results of this study indicate that the Salado Salt in the samples received is composed primarily of fine to coarse-grained halite with polyhalite, anhydrite, and clay minerals. Other minerals detected in small amounts include gypsum, magnesite, quartz, feldspar, sylvite, carnallite, celestite (?), glauconite, and kainite(?). It should be noted that the samples received for analysis were selected from halite-rich zones in most cases; hence, some of the rarer evaporite minerals such as kieserite, langbeinite, leonite,

bischofite, etc., noted by Schaller and Henderson (1932) were not detected either because they were absent from the specimens analyzed or present in amounts too small (or too fine grained) to identify.

There is much petrographic evidence that the Salado salt was deposited in rather shallow water and may have been exposed subaerially at times. This evidence includes the presence of numerous hopper crystals (which can develop at the air-water interface of quiet, shallow seas) and the intergrowth of euhedral grains of halite with clay and silt-sized minerals, anhydrite, and polyhalite. The latter texture can develop in an exposed, mud-flat type environment. Previous workers, such as Anderson, et al. (1972), have concluded that the underlying, Castile Formation was deposited in deep water, perhaps as much as 2100' (650 m) deep. Hence, there must have been a major change in environmental conditions between the deposition of Castile and that of the Salado.

Petrographic evidence also suggests that local fluids native to the Salado have been able to move through the Salado salt (during recrystallization) along beds and seams of clay and silt, and to a lesser degree along fractures (see Section 7.8). These paths are now marked by entrapped fluid inclusions, zones of altered minerals and zones along which new minerals have been deposited.

Water loss determinations for over eighty samples from cores #7 and #8, indicate a range of water loss (upon heating to $102\pm5^{o}C$) from 0.0 to 3.5%, which is considerably below the water losses for samples from Lyons, Kansas. It whould be noted that the samples from the Lyons site came from much shallower depths than those from the Carlsbad area. In the section on weight losses, the ranges of dehydration to be anticipated with respect to depth are shown graphically. It appears that the ranges determined for the relatively shallow Lyons site merge with the ranges determined for the deeper Carlsbad site.

Most of the dehydration water at relatively low temperatures (near $100^{o}C$) appears to come from clay minerals, although gypsum may make a

contribution for samples taken at shallow depths. At higher temperatures, polyhalite will start to contribute to the dehydration of water. This dehydration takes place somewhere between 170° and 300°C. Pure polyhalite rock can lose up to 6% water. In general, the purer halite beds have weight losses below 0.3 to 0.5%.

As far as can be determined from the samples available for study, the rock units present in the Salado salt seem to release much less water when dehydrated than do the rocks of the Hutchinson salt from Lyons. Hence, the site near Carlsbad would seem to be more favorable (in so far as dehydration water goes) than Lyons. However, these rocks are not totally without water, and most units will lose from 0.0 to 0.3% water when heated and some units may lose up to 3.5% water.

Finally, it was noted during the preparaton of some of the samples that H_2S (and possibly some natural gas) was released when the samples were crushed. No H_2S was detected mass spectrometrically (previous section), which probably attests to a sensitivity of the human nose for H_2S that is unapproachable even with the most sophisticated available instrumentation.

7.6 FLUID INCLUSIONS IN CORE SAMPLES FROM ERDA NO. 9

7.6.1 Introduction

Fluid inclusions in the host rock are of interest to several aspects of nuclear waste disposal. First, determination of their origin and nature may provide insight into the complex sequence of processes and events from original deposition of the salt through to the present; such insight may well be of value in site evaluation. Second, fluid inclusions provide one source of water (and other volatiles) that would certainly aid in the corrosion and eventual breach of the waste containers, and subsequent leaching of the waste itself. Third, fluid inclusions, and their reaction under the thermal pulse from hot wastes, could have an effect on important physical properties of the hot host rock, such as deformation rates and particularly melting.

7.6.2 Samples Studied

Most samples studied were taken from ERDA core No. 9, and came from the following footage intervals:

From	To
1799.0	1799.5
1902.0	1902.3
2065.0	2065.4
2095.1	2095.5
2272.4	2272.7
2391.0	2391.3
2611.5	2611.8
2658.7	2659.0
2760.0	2760.2
2820.8	2821.2
2058.8	2059.0
2070.4	2070.6
2606.5	2606.9
2617.2	2617.7
2626.7	2627.0
2659.0	2659.2
2665.0	2665.1
2692.4	2692.6
2699.8	2700.0

In addition to the above "representative" samples, four nonrepresentative samples from ERDA No.9 were selected because they contained plainly visible large inclusions, suitable for special tests:

2061.2 - 2061.6

2064.5 - 2065.0

2614.7 - 2615.0

2518.5 - 2619.0

In order to test certain sample preparation and inclusion extraction procedures with no loss of important core, two pieces of core from AEC 8 were also picked:

2059.5 - 2059.8

2462.0 - 2462.9

In the Kerr-McGee potash mine, Lea County, New Mexico, northwest of the WIPP site a 4-m igneous dike has cut potash ore beds. As this represents a natural simulation of some of the heat effects of canister storage, it is instructive to examine the fluid inclusions in samples taken at measured distances from this dike:

MB-77-8	White halite 1-2 cm from dike
MB-76-3	Barren salt 0.2 m from dike
MB-76-4	"Ore" horizon 2.5 m from dike
MB-76-5	"Ore" -21 m from dike

Of these samples, the field evidence indicates that only MB-77-8 has been molten. The others show some mineralogical effects of the heating, but as sedimentary structures are preserved, they have presumably not melted (M. Bodine, personal communication).

7.6.3 Sample Preparation

Sections. A thick slice was cut from each sample using a diamond saw and ethyl alcohol lubricant. One side was fine ground with an alcohol slurry of abrasive (1200 grit), ultrasonically cleaned in alcohol, mounted on glass with cold-setting epoxy resin, and cured in 16 hrs. at room temperature. The section was then ground down on a lap, using an alcohol slurry, to 3-8 mm thickness (depending on opacity) and then polished by finer abrasives, ending with either 1200 grit or 0.3 μm Al_2O_3. Plates with fine-ground surfaces were examined using a matching silicone oil or saturated brine and coverglass. Coarse cleavages could be examined directly, without polishing.

A small section (~ 2 X 4 cm) was cut first, perpendicular to the core axis (when nature of sample permitted orienting), then one or more larger plates (5 X 8 cm) were cut parallel with the core axis.

Coarse water-soluble residues. 100- to 150- gram samples were dissolved in tap water at room temperature with frequent stirring. The solution was decanted frequently to remove dissolved salts and finely divided solids such as clays.

7.6.4 Methods of study

Petrographic Examination. All slides and preparations were examained with the petrographic microscope, but phases present other than halite were not determined due to the short time available and the redundancy with extensive mineralogical work by others. Most examination time was spent on finding and characterizing the nature, size, frequency and distribution of the fluid inclusions.

Considerable time was spent determining the volume of fluid inclusions in the plates, through counts of representative portions. This determination was based on measurements with a graduated ocular (calibrated with a stage micrometer) and several assumptions. First, the inclusions were considered to be cubes (based on observation); one edge was measured and then the volume calculated. Larger inclusions (~ 1mm edge length) that were obviously not cubes were estimated from the summation of a series of smaller cubes. Second, since bubbles were very rare (only about 0.1% of the inclusions), and small (~ 1% of inclusion volume), they were ignored. Third, most inclusions in these samples were of one or the other of two types (essentially the same as the types "A" and "B" discussed in a later section on Results), and any given small portion of salt contained only one type. As the bulk of the sample in any plate could be characterized easily into these two types the approximate volume percent of the samples for each type could be estimated. A ~500 mm^3 volume of the plate was then selected from each type, visually estimated to be representative of that type in that plate, and the volume percent of inclusions determined in it by measurement and counting, using a transparent grid template at 500X. The total volume percent of inclusions was then calculated from the weighted average. The weight percent of inclusion fluid was calculated, assuming the salt to have a density of 2.2 and the brine to be 1.3 g/cm^3. Large numbers of very tiny inclusions were estimated from counts and estimates of small

but visually representative volumes. Although the relative errors involved in this step are large, the total contribution by these small inclusions, even though they are extremely abundant, was very small. Most of the fluid found was present as a small number of large inclusions that could be measured more accurately. All inclusions over 200 μm (edge length) in the count volume were measured. The overall measurement error in volume percent of inclusions present is believed to be on the order of ±5% of the value stated for a given plate. Other variables, particularly rare, still larger, centimeter-sized inclusions that were opened during coring or sample preparation (and hence not counted), and the large difference between different plates from the same sample, introduced much larger errors.

Heating Stage. The liquid in inclusions trapped as homogenous fluid at above surface temperature shrinks on cooling, forming a bubble that provides a measure of the amount of differential shrinkage of liquid and host crystal. As the bubbles in the inclusions were small, relatively little heating was needed to cause homogenization. Hence a new heating stage was set up, consisting of a bath of silicone oil with an electric immersion heater and thermometer. Temperature equilibration was achieved through convection and frequent stirring. The individual runs were approximately 2-3 hrs. in length. Many inclusions that had no bubble as received developed one on cooling the silicone to $\sim -6^{\circ}C$ with solid CO_2. On subsequent heating this bubble would decrease in volume but persist as a very small bubble at room temperature. Heating was done on the stage of a low power binocular microscope, since the inclusions were large and scattered.

Freezing stage. The depression of the freezing point of the fluid in an inclusion (i.e., the "freezing temperature") is a function of the composition of the fluid. Using this techique under the microscope can permit a quick measure of the salinity of 10^{-10} g of fluid, a far smaller sample than can be measured by any other method. Metastable supercooling is common, so most inclusions had to be cooled to very low temperatures (three hours in CO_2-acetone at -78° or even LN_2 at $-196^{\circ}C$) to cause freezing. Subsequent slow warming of the sample while

surrounded by rapidly circulating refrigerated acetone of known temperature under the microscope permits recording the temperature of disappearance of the various solid phases formed on freezing (salts, hydrates, and ice), under equilibrium conditions.

If an inclusion is frozen completely to a mixture of solids, with no liquid, it becomes rather opaque. On warming, the first melting wets the crystal interfaces, suddenly making the mass more translucent, and permitting recrystallization to coarser crystals with time. This is called the "first melting temperature." It ranges from -21°C for pure NaCl solutions to -51°C for $CaCl_2$ solutions.

Crushing stage. If a host crystal containing an inclusion with a bubble is surrounded by a fluid and gradually crushed while under the microscope so that the behavior of the bubble can be observed, the presence of noncondensable gas in the bubble, and its pressure, can be determined. The test is only crudely quantitative in terms of pressure (based on the volume precent expansion), but it is extremely sensitive as a detector of small amounts of gas. Less than one billion molecules of gas can be detected readily. Numerous cleavage fragments of salt containing various types of inclusions were crushed on several models of crushing stages to determine the amount and pressure of any noncondensable gases present.

Coarse water-soluble residues. These were studied in oil immersion mounts in hopes that some of these phases were sufficiently coarse to contain fluid inclusions that would provide data on their conditions of formation.

Decrepitation. A portion of the core weighing approximately 100 g was split out with a rock splitter; where possible the outside core surface was avoided, due to the probability of physical deformation and resultant leakage of incluions. This piece was wrapped loosely in aluminum foil, weighed, and heated to the run temperature (150-250°C) over a period of 8 hours to avoid thermal shock, held at run temperature for 3-4 days, cooled and reweighed to determine weight loss. Following this the homogenization temperature range was redetermined for a series of

inclusions that appeared, on petrographic examination, to be representative. Crushing tests were also repeated on the heated samples to detect the presence of noncondensable gases under pressure.

7.6.5 Results of Petrographic Examination

Inclusions type A. This is the most abundant type by far. It consists of slightly rounded cubic cavities (Plates 7.13 and 7.14) filled with liquid and generally no other phase, except for rare tiny vacuum (shrinkage) bubbles that comprise ~ 1% by volume of those inclusions having bubbles. Only about 0.1% of the inclusions have bubbles, usually the larger inclusions only, but there are exceptions (see below). Type A inclusions occur as dense irregularly shaped clouds of randomly distributed but crystallographically oriented inclusions (e.g., Plate 7.16). In such dense arrays, individual inclusions are rarely over 20 μ m on an edge (Plate 7.18), few are > 5 μ m, and most are in the range 0.5-2.0 μ m, with the highest concentrations in the smallest sizes (Plate 7.19). Estimates of the maximum number of such inclusions, based on counts of representative volumes, show about one inclusion per 100 μm^3, or 10^{10} per cm^3. If these are assumed to average one μm^3 in volume, such cloudy halite would contain about one volume percent of fluid.

In addition to these irregular clouds, abundant type A inclusions occur in crystallographically arranged (cubic) planes and zones in the host halite, frequently with parallel inclusion-free zones (Plates 7.13 and 7.14).

In some zones type A inclusions grade into more sparsely distributed but larger inclusions ($\leq$ 100 μ m), as seen in Plates 7.14 and 23-24. These coarser inclusions may represent incipient recrystallization of the host. The distinction between these larger type A inclusions and type B (next section) may seem inexact, but actually there is little overlap.

Inclusion type B. Type B inclusions, although far less abundant than type A, carry most of the inclusion fluid in these samples, since they are much larger ($\geq$ 100 μ m to several millimeters). Although large, many have no bubble as found (Plate 7.20), but may develop one if cooled slightly ($\sim -7^{o}C$) and warmed back to room temperature. They are generally irregular if large ($\geq$ 500 μ m) and are more nearly euhedral negative cubes if smaller (Plates 7.15 and 7.17). They occur as single isolated inclusions in otherwise almost optically clear halite, and as dense groups of many inclusions, in part interconnected with tubular extensions (Plate 7.15).

The host halite for type B inclusions may occasionally have cloudy wisps of type A inclusions, but they are never immediately adjacent to a large inclusion (Plates 7.15 and 7.17). These features suggest that salt originally containing only clouds of "primary" type A inclusions has been partly or completely recrystallized to form coarser crystals of clear salt with type B inclusions. This interpretation is supported by the grain size of the host salt, which is almost always coarser in those parts of a sample containing type B inclusions (see Table 7.13 in next section on weight percent of fluid). The boundary between cloudy primary and clear recrystallized salt is sometimes curved (Plate 7.16). If it were straight, it might not be possible to distinguish it from a primary growth zone boundary between fast cloudy and slow clear growth. Most areas of type A occur as irregular masses within single crystals of mainly recrystallized halite (Plates 7.15 and 7.17).

Relatively few samples, particularly sample 1902.2, show birefringent crystals of an unidentified phase inside what appear otherwise to be type B inclusions. These are equant to bladed crystals of moderately high birefringence ($\sim$ 0.06) and moderate index of refraction (but well above that of the surrounding brine). Many are twinned (Plates 7.25 and 7.26), and when prismatic or bladed, the extinction positions are strongly inclined to the crystal elongation. As the distribution of these crystals is irregular, and as a similar birefringent phase occurs in some of the same samples (Plate 7.27) the occurrence in the inclusions might be interpreted as accidental trapping of solids present at the time of

trapping of the inclusions. All 10 inclusions in one group in sample 1902.2 (Plate 7.27) contain these crystals, in roughly the same amount (estimated at ~ 5% by volume), thus suggesting that they are true daughter crystals, formed by precipitation from the trapped fluid. Another plane of inclusions in this same sample, only 400 μ m away, contains only liquid (Plate 7.28) so it is concluded that the fluids present during recrystallization changed in composition with time.

Inclusions Type C. This type is similar to type B in size, shape, and occurrence, but rarer, and differs only in containing a relatively larger gas bubble, of variable volume, but > 1% by vol. (Plate 7.29). A larger gas bubble can originiate by several processes -- leakage, necking down, higher temperature of trapping, or primary gas. The gas bubbles in these inclusions are found to be under pressure (see "Results of crushing stage studies"), so it is believed that such inclusions have trapped a mixture of gas and liquid (i.e., primary gas). In some (e.g., Plate 7.30), such inclusions have apparently formed by a refilling of an earlier type B inclusion with a gas-liquid mixture along a crack.

Inclusion Type D. This type occurs in curving planes outlining some of the individual crystal boundaries (Plates 7.31 and 7.32). It was probably full of fluid under natural conditions, but as the grain boundary permitted leakage and desiccation, these are now full of gas (presumably air).

7.6.6 Weight Percent of Fluid

A summary of the results of measurements of the volume percent of fluid in the inclusions is given in Table 7.13. In calculating these volumes some simplifying assumptions had to be made, in addition to those mentioned in Section 7.6.5. For simplicity the host salt volume counted was categorized as type A or B on the basis of the maxiumum size of inclusions it contained. If these were $\leq$ 1 mm, it was called type A. This division is not the same as given in the descriptions of type A and B inclusions, where ~ 100 μ m inclusions are considered as probably indicative of recrystallization, but this has little effect on the results, since on the average, over 90% of the fluid is present as type B

inclusions > 1mm in about 30% of the volume of the salt. Table 7.13 shows that these samples now contain a total of from 0.17 to 2.86% fluid by volume, and average 0.61. These values correspond to 0.1 to 1.7 weight percent fluid as extremes, and average 0.36 weight percent. These results are compatible with those reported in Sections 7.5.2 and 7.5.3.

These values have a measurement error of about ± 5% of the amount found. Much larger, however, is the variability introduced by the samples themselves. Thus three parallel plates were cut at ~ 3-cm intervals through samples 2272, and yielded 1.23, 0.36, and 0.20 volume percent fluid.

Even more important to consider is the bias inherent in these measurements due to substantial and unpreventable loss of inclusions. Examination of the cores showed some centimeter-sized cavities, the sites of former fluid inclusions. No inclusion this size could possibly be included in our count since the plates counted had to be <1 cm in thickness to be translucent. In addition, in situ all natural intergranular porosity in these salt beds was possibly full of fluids. The type D inclusions found represent probably only a trivial part of the total in situ water content present as such "imperfectly sealed fluid inclusion." Large scale in situ porosity tests would be needed to evaluate this variable.

7.6.7 Results of Heating Stage Studies

Only 35 inclusions were run, as listed in Table 7.14. These are mostly from type B inclusions. Some of these inclusions had to be cooled to below room temperature to nucleate a bubble before the run (Plates 7.20, 33 and 34). Why some very tiny inclusions have vapor bubbles (Plate 7.36), yet many large ones have persisted metastably as stretched liquid (i.e., one phase) is puzzling. The data are too sparsely distributed to determine whether the range of values (20.4 to 45.5°C) represents a real difference between samples. One group of inclusions in sample 2821 with birefringent daughter crystals showed no change in the crystals on heating to 24.5°C.

7.6.8 Results of Freezing Stage Studies

Inclusions in NaCl have a special type of behavior on freezing, as a result of reaction of the water of the inclusions with the walls to form the new incongruently-melting phase hydrohalite ($NaCl.2H_2O$), at temperatures below $+0.15^{\circ}C$. As a result, the inclusion enlarges and becomes full of birefingent crystals upon being held at low temperatures. Evidence of this expansion remains on warming to room temperature. Furthermore, the volume resulting from expansion to form ice is frequently larger than the original volume of the inclusion, and the inclusion's walls crack to relieve the pressure (Plate 7.35).

The freezing data are summarized in Table 7.15. If the solution present is simply NaCl and H_2O, the last crystal of hydrohalite will melt at $+0.15^{\circ}C$, assuming equilibrium has been obtained (which is an extremely slow process for this phase). Although only relatively few large type B inclusions were run, many smaller type A inclusions were also watched at the same time. None were found to have either first melting at -21° or freezing at $+0.15^{\circ}C$, so none consist of essentially pure NaCl solutions. Much hydrohalite formed in these inclusions, but as there were birefringent crystals (generally with birefringence less than that of hydrohalite) that persisted well above $+0.15^{\circ}C$, the last solid is a phase other than hydrohalite, and the solutions must contain significant quantities of materials other than NaCl (Plate 7.37). This is also very evident from the first melting temperatures.

7.6.9 Results of Crushing Stage Studies

Bubbles in types B and D inclusions from several samples were examined on the crushing stage. All disappeared immediately on opening, indicating that they consist of water vapor (at $\sim$ 20 mm pressure), and hence collapse at one atmosphere. The bubbles in several type C inclusions showed considerable expansion, however, indicating gas under pressure. Thus the bubble in the inclusions shown in Plate 7.38 expanded 270% by volume on opening (Plate 7.39), indicating that nearly three atmospheres of noncondensable gas is present. The composition of this gas is unknown at present.

A previously unrecorded inclusion deformation phenomenon was also observed in some inclusions that were in a sample that was under uniaxial stress on the crushing stage at room temperature but had not been broken to release the inclusions. These inclusions developed a scalloped pattern along the corners (Plate 7.40), presumably due to solution at points of stress concentration and redeposition elsewhere. This pattern developed over a relatively few minutes at effectively constant stress. At least some volume change occurred in this process, since the bubble in the inclusion disappeared at constant temperature.

7.6.10 Results of Study of Coarse Water-Insoluble Residues

The weight percent of such residues ranged from 0.005% (sample 2391 to 0.3% (sample 2821). Unfortunately, however, although there were a variety of phases present in the residues, none of the crystals contained visible fluid inclusions. Some samples emitted a petroliferous odor and showed oily films on the water surface during leaching; it is not known whether these represent contamination from the oil-based drilling mud used in part of the coring, or natural oil in the samples (as is present in other salt deposits, as integranular films and inclusions). No oil inclusions were seen in this work.

7.6.11 Decrepitation Tests

These tests were run only on the last nine samples of the first 19. A summary of the test data and results is given in Table 7.16. On examination of the material after the decrepitation tests, several general features were evident. The nature of the test is such that systematic inclusion counts before and after the test on the same sample are impossible. It was obvious that although most of the larger inclusions had decrepitated, and were empty, many small inclusions ($\leq \sim 100$ μm) had not. These small inclusions appear perfectly normal in distribution, but almost all had developed appreciable vapor bubbles (Plate 7.41), with a vapor/liquid ratio that is obviously higher after heating than that present in two-phase inclusions before heating. Only the 150°C sample still had inclusions without bubbles; a few 10-20 μm one-phase liquid inclusions were found there. All three samples showed some "steam" inclusions - cubic negative crystals with fillets of liquid

in the corners. No gas under pressure was found in any of the heated inclusions. In most cases, the weight losses increase with increasing run temperature; the several exceptions are probably a result of nonhomogeneous distribution of inclusion in the sample aliquots taken.

Homogenization temperatures were determined on two-phase inclusions remaining in the samples after the decrepitation tests. The results are given in Table 7.17, along with the volume percent of vapor phase, estimated from measurements of bubble diameters.

7.6.12 Study of Suite of Samples from Kerr-McGee

The three samples closest to the lamprophyre dike (See Chapter 3) yielded usable inclusions. (Sample MB-76-5 was too fine grained and opaque to be usable by the sample preparation techniques used here, and will not be considered futher in this report.) In all three samples about 15% of the small inclusions ($< \sim 20$ μm) were without bubbles as received. Most inclusions in all three samples were normal, two-phase inclusions with a small bubble. Homogenization temperatures were determined on a representative group of these two-phase inclusions in each, with results as shown in Table 7.18.

Freezing runs were made on inclusions in two of these samples. In both cases the first melting temperatures were well below that of a pure $NaCl-H_2O$ system ($< -28^{\circ}C$ for MB-77-8 and $< -31.0^{\circ}C$ for MB-76-4). On warming, the last solid phase to dissolve in both samples was an unidentified phase, presumably a hydrate other than $NaCl \cdot 2H_2O$. This dissolved at +11 to $+18^{\circ}C$ (MB-77-8) and at +4 to $+7.2^{\circ}C$ (MB-76-4).

One 75- μm inclusion was found in MB-77-8 that yielded an entirely different freezing behavior. This inclusion contains a single homogenous fluid at room temperature, presumed to be gas (Plate 7.43a). On cooling to the range -70 to $-75^{\circ}C$ this inclusion develops a number of grains of an unidentified solid (Plate 7.43f). On warming to about $-68^{\circ}C$, a liquid/vapor meniscus becomes visible (Plate 7.43e), with solid grains

still present. The last of these grains disappears at $\sim -56^{\circ}C$ (Plate 7.43d); on further warming the liquid/gas meniscus becomes faint (Plate 7.43c) and the two homogenize, by expansion of the liquid, at $-20.9^{\circ}C$ (Plate 7.43b). This behavior is difficult to interpret in terms of composition. CO_2 has its triple point at $-56^{\circ}C$, in exact agreement with the disappearance of the solid phase at $-56^{\circ}C$ observed here, but obviously the inclusions cannot contain just CO_2, as there is liquid present at a lower temperature. The nature of the mixture of gases can only be guessed at this time.

The crushing tests in the Kerr-McGee mine samples were most revealing. The normal, small-bubble inclusions contain a vacuum bubble (i.e., water vapor at $\sim$20 mm presure). Many inclusions that either had a very large bubble or appeared to contain gas only, from all three samples, were found to contain either vacuum (Plates 7.44 and 7.45), or a partial vacuum (Plates 7.46 and 7.47). These are probably from the trapping of bubbles of steam, with or without some noncondensable gas and brine. All three samples also contained a few inclusions with gas under greater than atmospheric pressure. These inclusions were one-phase as first observed, and except under special circumstances, it is not possible to distinguish between a vacuum, dense gas, or even liquid, in such single inclusions. It is only on crushing, when these inclusions formed bubbles of noncondensable gas in the surrounding fluid, that the internal pressure became evident. By measuring the size of the inclusions before crushing, and the diameter of the bubbles evolved, we obtain a crude measure of the internal pressure, assuming each unit volume expansion corresponds to one bar pressure. In a few inclusions, the contents changed to a two-phase, liquid + vapor system during the expansion (Plate 7.48), but usually the pressure release was too sudden to reveal if there was a transient two-phase condition. The volume expansion varies for different inclusions, from 30- to 40-fold (Plates 7.49 and 7.50) to a maxiumum of perhaps 100-fold (Plate 7.51). As the immersion medium used is an oil in which methane is probably readily soluble, this gas is more likely CO_2, since the bubbles dissolve in the oil very slowly.

Interpretation of the data from the Kerr-McGee mine samples is difficult at this time. The presence of an inclusion filled with a dense CO_2-rich (?) gas in sample MB-77-8, (in halite that was probably molten at the time of intrusion of the dike) is not unexpected, since there is a small amount (0.2-2%) of magnesite in the adjoining rock (M. Bodine, personal communication). The dike shows no evidence of carbonate alteration, however, and there is a problem in explaining the presence of inclusions of low-temperature, gas-free brine, apparently pure steam, and dense CO_2 in the same sample. Formation of these types at different times is obviously required, but there is no other indication of differences in conditions or time of origin.

The temperature at which the dense gas inclusion was trapped is of interest. Although the melting point of pure NaCl is 800°C, other materials present here in the potash ore zone (such as KCl) will lower this temperature. If we assume that the gas inclusion contains pure CO_2, the -21°C homogenization indicates a filling density of about 1.03 g/cm^3 (Roedder, 1965). Combining this with the estimate of confining pressure of ~ 38 MPa (380 bars) yields an obviously erroneous "trapping temperature" of 0°C. The several inconsistencies and difficulties in interpretation of the data from the Kerr-McGee samples cannot be resolved until additional studies are made.

7.6.13 Discussion

Geological Significance. Several aspects are evident from these various results. First, the fluids in all the inclusions, both type A in primary salt crystals and type B in recrystallized salt, are strongly saline brines, with significant amounts of other salts present in addition to NaCl. These brines differ from one inclusion to another, indicating that a range of fluids has been present at various times in these beds, but no inclusions with simple NaCl solutions were found, as are found in other salt beds and as might be expected if pure salt beds have been fractured in the presence of meteroically-derived (fresh) ground water. The original deposition of salt occurred from highly-concentrated brines, and

presumably all waters that have passed through these samples since have had dissolved in them amounts of other minerals in addition to NaCl. Such fluids have caused extensive recrystallization of the salt, and presumably other mineralogical changes, so that little of the original salt texture remains. Second, at some stage in this recrystallization, gas-liquid mixtures were present in the pores of these beds. Third, this recrystallization occurred at near-surface temperatures (20-45°C). Fourth, the movement of these fluids must have been slow, as the evidence of extensive inclusion metastability indicates very clean solutions, free from the solid nuclei present in most fast-moving near-surface waters.

The fluids from which the salt crystals making up these beds originally crystallized were exceedingly saline brines with much material other than NaCl in solution, as shown by the freezing data on primary inclusions in hopper salt. These hopper crystals appear to have grown on the surface and then to have sunk, as described by Dellwig (1955). All but about 1% of this original hopper salt texture has been eliminated by recrystallization at some unknown later time, yielding coarser, clearer crystals of salt, and presumably gross changes in the mineral assemblage other than halite. Some of the clear salt surrounding the chevron structures may represent crystallization of these hopper nuclei on the bottom of the basin, but most is believed to be from recrystallization. This recrystallization occurred in the presence of exceedingly saline brines and with much material other than NaCl in solution. The brine may have been composed essentially of fluids from the primary fluid inclusions, released during the recrystallization. It was trapped as large inclusions in the recrystallized salt and comprised the bulk of the liquid now present in the samples as studied in the laboratory. Although the salt beds now appear dry to the eye, the samples contain 0.1 to 1.7 weight % fluid as examined, and may contain more in situ. At some stage or stages early in the history of these beds, the fluids present in these rocks varied in composition. (See section 7.7) A very few were saturated with organic gases such as methane and actually contained bubbles of a separate gas phase. Others contained additional salts in solution, resulting in the precipitation of various crystalline solids

from the liquid within inclusions in halite. The relative time sequence of these various fluids is not known, and most inclusions have neither methane nor crystalline solids. The latest episode of any recrystallization has been dated at 204 million years, slightly younger than Permian.

Homogenization temperatures of inclusions in recrystallized salt range from 20.4 to 45.5°C. During burial, creep from recrystallization in a salt bed with intergranular films of solution should result in the hydrostatic pressure on fluids (during trapping in a crystal) being essentially equal to the lithostatic pressure. If an overburden of 5000 ft. (1524 m) is assumed to have been present during the recrystallization, the maxiumum pressure (lithostatic) would have been ~ 38 MPa (380 bars). There are no PVT data on the specific fluids present in the inclusions, but if the data on a 25-percent NaCl solution are used, this pressure would suggest a maximum pressure correction of 36°C (Potter, 1977), and hence trapping (i.e., recrystallization) temperatures of 56-82°C. However, the true pressure correction may be lower, particularly since the fluids are more saline than 25-percent NaCl. Thus there is a drop of 12°C in the pressure correction on changing from 20-percent NaCl to 25-percent NaCl.

The presence of smooth planes of primary hopper salt inclusions of various sizes, separated by planes of inclusion-free salt, with the plane orientation horizontal, proves that these minute inclusions have not moved measurably since deposition, although they have been in a geothermal gradient presumably similar to that of the present for about 225 m.y.

The widespread occurrence of metastable phenomena in these inclusions, even in some large ones, suggests that fluid flow in the past through these beds has been very slow. Also, the fact that <u>all</u> inclusions that have been frozen prove to contain bitterns, and none was found with just $NaCl-H_2O$ solution, proves that at no time during the history of these samples did ground water, saturated <u>only</u> with respect to NaCl, ever penetrate into these particular samples.

Nuclear Waste Disposal Significance. The most signficant aspects at this stage in the study are as follows: First, the amount of fluid water solution now present in the samples as fluid inclusions averages 0.36 weight percent. Second, although noncondensable gases are present under pressure in some inclusions, the total amount is very small. Third, the inclusions change dimensions signficantly within minutes at room temperatures when the host crystal is subjected to uniaxial stress; this might suggest more rapid movement of inclusions in a thermal gradient if simultaneously under stress, as in mine pillars. Fourth, and possibly most significantly, the distribution of primary inclusions indicates that they have not moved visibly (i.e., less than a few micrometers at most), in the 225 million years since they formed, yet they have been in the small but finite geothermal gradient all this time. All fluid inclusions can be expected to move when placed in a thermal gradient. Since there is usually a thermal coefficient of solubility, material will dissolve on one wall and precipitate on the other. The rate of movement is a complex function of numerous variables (including inclusion size), but the temperature coefficient of solubility is probably the most limiting parameter in the case of NaCl. In the pure system $NaCl-H_2O$, the solubility change per 100g H_2O is low, only 0.03gm/^{o}C in the range of 0-100°C. This increases by approximately a factor of two at the elevated temperatures expected near the wastes. This coefficient is comparable in the $NaCl-MgCl_2-H_2O$ system.

All these aspects will now be treated in expanded detail.

Amount of Water in the Beds. Although this is the most important single datum that might be obtained from inclusion studies, fluid inclusion counting can provide only approximate values. The nature of the samples and the necessary sample preparation are such that there is a bias toward low values built into these data. Superimposed on this uncertainty in accuracy is poor precision in the measurement, due to variability of the sample material. For example, adjacent slabs of the same sample showed a five-fold range. It is probable that precisely calibrated neutron logs, reflecting the amount of hydrogen in the beds, give a more accurate

evaluation of the total water present, since they would effectively integrate over a much larger sample and would include the effects of the liquid-filled intergranular cavities which these tests miss.

One important aspect of the inclusions on the properties of the salt is the effect of the constitutents present on the lowering of the temperature of melting, and on the amount of liquid present at any given temperature. In this connection it is important to note that the inclusions' fluid is not water, but a strong bittern with probably significant quantities of magnesium ions. This will certainly affect the temperature coefficient of solubility of NaCl in these liquids, and will have important effects on the vapor pressure of these liquids (see below).

Corrosive Gases in the Inclusions. Although gas analyses by mass spectrometry are still to be made on the inclusion fluids, it is evident from the crushing studies that the inclusions in these samples, at least, contain very little noncondensable gases. Although hydrogen sulfide was found as an important constituent of gases in a gas pocket in another drill hole, (ERDA-No. 6, Section 7.7), there can be very little, if any, in these inclusions. The human nose is a rather sensitive detector of H_2S, ordinarily responding to a minimum of $\sim 10^{-10}$g. No odor of H_2S was detected during preparation of these samples, when relatively large volumes of inclusion liquid were exposed to the air. Gases such as HCl formed within the inclusions or by reactions of inclusion fluids with other minerals during heating, and under intense gamma radiation, may be a much more important cause for corrosion than those now present in the inclusions.

Effects of Water on Physical Properties of the Salt. The intergranular porosity in these salt beds, <u>in situ</u>, possibly contains some aqueous solution. Such fluids will tend to be squeezed out of the salt beds over geological time as recrystallization along grain boundaries and other processes permit compaction, just as the residual water in a sandstone is eliminated during the formation of a quartzite. Such flow will occur, however, only if there is an escape route for the fluid to take. As

pointed out very aptly by Baar (1977), there is much evidence from high pressure fluid pockets that salt rocks in situ are generally impermeable at depths exceeding about 300 m. It may well be that under such conditions, which preclude further "dewatering", the fluid in these intergranular films is still able to migrate short distances, enough to permit it to coalesce into "pockets", perhaps at points of slightly reduced pressure, just as a plastic shale will flow to the crest of folds in firmer rocks. These "pockets" might be represented in part as the short-lived seeps observed in potash mines.

Even if the intergranular liquid were to be removed completely, yielding a polycrystalline texture with salt crystals in true contact with each other, there is no driving force to remove the fluid inclusions from within the individual halite crystals. If such a salt bed is deformed to the point of rupture of salt crystals, any inclusions along the rupture will provide water to "lubricate" the fracture and hence lower the apparent strength of the rock. Although one might expect that a new fracture would preferentially follow planes of inclusions, as from the healing of former fractures, Gerlach and Heller (1966) have shown that the salt recrystallized in the vicinity of such a healed fracture is actually stronger than the adjacent unrecrystallized salt, and new fractures could not be made through the inclusions. Actually, most of the fluid in inclusions in the Carlsbad salt is in large, apparently randomly arrayed inclusions in recrystallized salt, and examination of fractures through such samples suggests that cracks induced in the laboratory experiments reported here have preferentially taken routes through such inclusions.

One example of the surprising effects of inclusion fluids on the properties of salt crystals is found in the behavior of fluid inclusions in single crystals of salt under uniaxial stress (Plate 7.40). Under these conditions, fluid inclusions visibly change shape, and volume, within a few minutes, at room temperature. This is a new inclusion phenomenon, never reported before.

Evidence of Previous Solution Movement in These Beds. The fluid inclusion evidence obtained so far on solution movements is encouraging in that it indicates at most only very slow movement, and suggests that part of the fluids now present in these beds may even be nearly Permian in age. The lack of any pure $NaCl-H_2O$ inclusions also argues against any previous sudden inrush of groundwater that could be trapped as inclusions in halite before it had time to acquire a full complement of other salts.

Movement of Inclusions in a Thermal Gradient. All fluid inclusions should move when the host crystal is placed in a thermal gradient. The nature and rate of such movement has been the subject of numerous studies, since it is of consequence in the chemical industry. Wilcox (1968) summarizes this extensive work (citing 111 references). Similar migration of inclusions is also an important cause for degradation of laser crystals grown at high temperatures by the Czochralski technique (Hopkins et al., 1976). Most liquid inclusions move up the thermal gradient, but if the vapor bubble is large relative to the liquid, and particularly if boiling occurs, the movement may be in the reverse direction (Wilcox, 1969; Anthony and Cline, 1972; Chen and Wilcox, 1972). The rate of movement is independent of inclusion size in many systems, but strongly (and directly) dependent on inclusion size in others (Wilcox, 1969); there may be a threshold size below which no movement occurs (~ 10 μ m in KCl; Anthony and Cline, 1971a). Large inclusions may break up during movement (Wilcox, 1968; Anthony and Cline, 1973). Many factors may affect the rate of migration, even in a given host, including gravity, composition, surface tension, inclusion shape, crystal anisotropy and imperfections, presence of a foreign gas, etc. In salt, since the thermal coefficient of solubility is small at surface temperatures, but increases greatly with increase in temperature, the rate of movement in a given gradient can be expected to increase with increase in ambient temperature. Higher ambient temperature also increases the travel rate by increasing the solubility, the diffusion coefficient, and the interface kinetics, and the increase in rate was found to be particularly striking in NaCl (Wilcox, 1968, p. 20). The

fact that the inclusions in Carlsbad salt have not moved measurably during geological time in the geothermal gradient is perhaps an indication of exceedingly slow rate, or perhaps a result of a very weak driving force.

Accurate prediction of behavior of in situ inclusions in the thermal gradient around a canister in salt cannot be obtained at this time, as there are too many uncontrolled variables. Since most inclusions at Carlsbad contain no bubble or only a very small bubble, they will move toward the canister, as was shown to occur at Project Salt Vault (Holdoway, 1974). The rate of this movement will depend most particularly on the inclusion size, the ambient temperature of the grain, the temperature gradient, and the temperature coefficient of solubility of NaCl in the particular inclusion fluid involved. The average distance that an inclusion must travel before it intersects a grain boundary will vary with the grain size of the salt, but seldom would be over 1 cm.

What can be expected when the inclusion reaches a grain boundary? Anthony and Cline (1971b) showed that grain boundaries in crystal aggregates tend to trap migrating droplets, but Anthony and Sigsbee (1971) showed that gas bubbles (10-50 μm) migrating in polycrystalline camphor could cross grain boundaries. However, migrating bubbles were observed to drag grain boundaries when the bubble concentration on the grain boundary was large. In Project Salt Vault, Holdoway (1974) says only that "little migration across grain boundaries appears to have occurred." Obviously, if a grain boundary is very tight, a large inclusion could cross it without effect. But if the grain boundary is composed of different material, the fluid could spread out along it as a film. Any such film should act as an inclusion, with material diffusing across it away from the heat source.

The behavior of an inclusion migrating to the wall of an open cavity (e.g., that holding the canister) will be different. On contacting the cavity, Anthony and Cline (1974) and Wilcox (1968, 1969) have shown that

some evaporation occurs, a vapor bubble forms, the inclusion seals itself, and now that it has a large bubble, it reverses direction and moves back the way it came, this time going down the gradient.

Decrepitation Release of Liquid Inclusions. In view of the expected slow migration rates of liquid inclusions in the thermal gradients established by the canisters, it seems probable that release of inclusion fluid by decrepitation will be an important process. An individual inclusion, if it is assumed to have rigid walls, to contain 25-percent NaCl solution, and to homogenize at 40°C, will develop 70.0 MPa (700 bars) internal pressure when heated to 100°C, and 200 MPa (2000 bars) at 200°C (Potter, 1977). However, salt cannot stand such internal pressures without yielding. Even a strong, hard mineral such as quartz starts to decrepitate when the internal pressure in its fluid inclusion reaches 80 $\pm$ 3 MPs (800 $\pm$ 3 bars) (Khetchikov and Samoilovich, 1970), and halite can be expected to decrepitate when the internal (inclusion) pressure reaches four times the yield stress for monolithic halite, under no confining stress (Cline and Anthony, 1971).

When Carlsbad halites were heated, some of the inclusions decrepitated in part causing the samples to fragment, and yielding an average weight loss of 0.13% (150°C), 0.22% (200°C), and 0.73% (250°C). This means that this much volatiles left the system. More inclusion fluid may well have been exposed, and merely lost water until its concentration of salts was such that the vapor pressure of H_2O at that temperature was less than one atmosphere. Salts in solutions in these brines (including materials other than NaCl as well) have effects on the vapor presure and hence on any vapor transport.

In addition to those inclusions that decrepitated, however, many inclusions remain sealed as liquid inclusions in the sample after heating, albeit in a changed form. These have permanently deformed their walls to form a larger chamber, and now have a much larger shrinkage bubble, proportional to the amount of expansion. (Why some decrepitate and others expand is at present unanswered; residual stresses in the host

crystal may be involved.) This expansion phenomenon is not new - it has been reported at various times in the past. It is the net result of several volume changes during heating of the inclusion. On heating, the host salt expands, enlarging the cavity as well. This effect is small, yielding a cavity volume increase of only 1.2% from 40 to 140°C. The fluid in the inclusion dissolves more salt from the walls on heating; the net volume effect of this (generally a decrease; i.e., an increase in cavity volume) will vary widely with the composition of the solution. Thermal expansion of the brine would develop high pressures if the walls were rigid, but instead, in the presence of liquid, the inclusion walls frequently just expand. The amount of expansion is roughly proportional to the temperature of heating, i.e., the inclusion fluid streches the walls until its internal pressure drops just below that needed to cause further stretching at that temperature. Nucleation of a vapor phase may even occur (Geguzin and Dzyba, 1973), in which case loss of water to the expanding vapor phase also helps to limit the expansion. Some of the thermodynamic variables of the process have been modeled by Cline and Anthony (1971) for the pure halite system.

7.7 THE GEOCHEMISTRY OF DELAWARE BASIN GROUNDWATERS IN RELATION TO THEIR HOST ROCKS

7.7.1 Introduction

Geochemical studies of waters found in Permian and younger rocks of the Delaware Basin (Southeast New Mexico, West Texas) have assumed a new importance in recent years. This began in 1975 when Sandia Laboratories, in cooperation with the United States Energy Research and Development Administration undertook studies of the suitability of Delaware Basin evaporite deposits for the long-term storage of radioactive wastes generated by the national nuclear defense program.

In particular, three aspects of fluid geochemistry have bearing on an understanding of the geology of the area:

1. Rock history - the relationships between dissolution features and nearby fluids which may have dissolved evaporites.

2. Fluid history - evidence of rock/fluid interactions preserved in fluid chemistry, indicating the complexities of fluid movement.

3. Fluid origins - the ultimate sources of fluids which have participated or have potential for participating in dissolution of evaporites.

Many of the waters considered here were bailed from preexisting wells with the assistance of the United States Geological Survey, between December, 1975, and June, 1976. In addition, boreholes for subsurface exploration of Los Medanos (the ERDA study area) tapped some fluid producing zones. These holes include ERDA No. 6,. which at a depth of 2711 feet produced saturated brine associated with H_2S-rich gas from the Castile Formation. In this hole, stratigraphic marker beds were found several hundred feet above their expected positions (Anderson and Powers, 1978). Nine holes penetrating the Rustler Formation have facilited hydrological testing and sampling of Rustler waters. Finally, samples of waters were collected from pools in Carlsbad Caverns. Table 7.19 is an inventory of water samples, together with their collection locations. New Mexico locations are given in Figure 7.10, showing their distribution with respect to the Capitan Limestone.

Three geochemical approaches will be followed in this subchapter. Each approach will consider a few examples of various "types" of water:

1. Solute chemistry - dissolved solids content.

2. Thermodynamics - equilibia and non-equilibria of a fluid-gas system.

3. Stable isotope ratios - variations in deuterium and oxygen - 18 content.

7.7.2 Data

Analytical results for the 29 waters are given in Table 7.20. Solute analyses are expressed in mg/l, performed according to APHA (1971) methods, with modifications by Collins (1975). Analyses by Martin Water Laboratories have a precision of about ± 5 to 10%; others ± 3% (Table 7.19).

Stable isotope analyses were made according to Epstein and Mayeda (1953) and Bigeleisen et al (1952), and are reported in " δ " notation as deviation of the D/H or $^{18}O/^{16}O$ ratio from the corresponding ratio of Standard Mean Ocean Water (SMOW) (Craig, 1961b, Epstein and Mayeda, 1953), in parts per thousand (‰, "per mille") for example:

$$\delta D = \frac{(D/H)\ \text{sample} - (D/H)\ \text{SMOW}}{(D/H)\ \text{SMOW}} \times 1000$$

The precision of $\delta\ ^{18}O$ values is better than ± 0.1‰ and that of δ D is better than ± 1‰ .

Solutes. In this discussion "fresh water" is taken to contain less than 3000 mg/l total dissolved solids (TDS), and is potable at least to local cattle. "Brackish water" refers to TDS contents between 3000 and 30000 mg/l. Brines are waters containing more than 30000 mg/l TDS. According to these definitions, number 1, probably 18 and 26 through 29 (Table 7.19) are fresh waters, found in the Capitan and Santa Rosa Formations. Numbers 2, 6, 11, 17, 22, 24 and probably 19 through 21 are brackish, and include most Rustler waters, one Capitan and one Castile. The fresh and brackish waters contain the solutes expected to be found in carbonate and anhydritic or gypsiferous aquifers. All the other waters are brines, and include the Salado, Morrow, Delaware (Bell Canyon) waters, two Castile, one Capitan, and even two Rustler waters; these Rustler samples came from the Culebra dolomite member, adjacent to halite-bearing parts of the Rustler Formation.

Brines are treated in the most detail here, since their presence has implications regarding either their representation of original evaporite mother-liquors, or their solutes having been derived through rock-water interaction. Their geochemical complexity cannot be understood from solute chemistry alone, and a brine occurrence in a particular rock unit does not necessarily imply that the brine has interacted with its host rock.

The chloride/bromide ratios, where obtainable, of all the brines were between 430 and 900, compared to 292 for modern sea water (Collins, 1975). If the Permian Basin water had a Cl/Br ratio similar to that of sea water, as suggested by Holser (1963) for fluid inclusions in Kansas salt, then these Delaware Basin brines do not contain "original" Permian water as a major component. Since halite crystallizing from sea water selectively excludes bromide from the NaCl lattice, halite has a Cl/Br greater than 300 (Adams, 1969), as would brine resulting from the dissolution of halite. Hence, the sodium chloride in these brines has been dissolved from rocks, but not necessarily the rocks in which the brines were found.

Rather than discuss abundances of individual ions in brine solutions, it is more instructive to consider solute ions combined as solids which might be expected to precipitate from solution upon complete evaporation. Following the crystallization sequences compiled by Braitsch (1971), not only some similarities will be noted between the resulting normative mineral assemblages, but also some significant differences. Waters 16, 9, and 14 (Salado, Bell Canyon, Castile) will be presented as examples.

Water from the Duval Mine Vent Hole is similar to the other potash mine seeps (Numbers 3, 4 and 5) all of which are saturated solutions. Table 7.21 shows the relative proportions of minerals expected to precipitate from this solution. This assemblage is similar to that expected to precipitate from sea water, even though the relative proportions are different (note the overwhelming preponderance of carnallite). In view

of the incongruent dissolution of polyhalite resulting in a calcium-poor solution, this brine is what one would expect for water which has dissolved a potash deposit. Note the presence of normative borax, an evaporite mineral not commonly reported in the Carlsbad potash district (cf. Jones, 1975).

Waters from the more saline portions of the Capitan aquifer (numbers 11, 12 and 13) contain the normative assemblage dolomite-anhydrite-kainite(or carnallite)-halite±sylvite, in various proportions, and are also indicative of solutes obtained by dissolution of adjacent evaporites.

Water number 9, from the Bell Canyon Formation, is examined in Table 7.22. The solution is calcium-rich, as indicated by the less common minerals tachyhydrite and antarcticite. These two minerals are not known to precipitate from sea water, and together with a magnesium deficit distinguish this water from a simple solution of primary evaporites. Graf et al. (1966), have given attention to the origin of calcium chloride waters, and emphasized shale ultrafiltration as an explanation. Other possibilities include diagenetic reactions in which magnesium in solution displaces calcium in carbonates to form dolomite, or in which Mg-rich sheet silicates are formed, having given up more easily replaceable cations such as Na and Ca (Grim, 1968), which were present in the original minerals (kandites and smectities). Mg-rich sheet silicates are present in the Ochoan evaporites overlying the Bell Canyon (see subsection 7.4). Since brine number 9 is a saturated solution, and since calcite, not dolomite is the prevalent carbonate mineral of the Bell Canyon, neither dolomitization nor shale ultrafiltration (which tends also to produce a low-Ca water, which has not yet been found) appears to be a satisfactory model for the in situ evolution of Bell Canyon brine. The sulfate deficiency could have arisen from biogenic degradation of sulfate. The most likely explanation for the in situ Ca-enrichment is ion exchange. This brine probably did not originate in the Bell Canyon, but its solutes probably came from nearby evaporites.

Waters 8 and 10 have a much lower TDS content than does 9, but otherwise yield most of the same minerals. The high strontium content of all three could be taken to indicate that these waters have indeed participated in the recrystallization of carbonates, but probably not within the Delaware Mountain Group of sandstones, which includes the Bell Canyon Formation. According to the Sr/Ca studies of Oxburgh et al. (1959), this solution would have been in equilibrium with a calcite containing about 4000 ppm Sr, a value too high for most natural calcites and dolomites. The Sr in solution could easily have come from the diagenetic alteration of aragonite outside the Bell Canyon.

On July 30, 1975, borehole ERDA No. 6 produced saturated brine (number 14, Table 7.19) and H_2S-rich gas (0.16 cubic feet STP per gallon) from a fractured, gray, laminated Castile anhydrite unit 2711 feet below the surface. Similar phenomena in the Castile have been reported by oil companies, but with an order of magnitude more gas. The analysis of one other such brine (Shell Bootleg, number 15 in Table 7.19) is given in Table 7.20, and is quite similar to the ERDA No. 6 brine. The solutes are resolved in Table 7.23, and aside from thenardite and LiCl (resulting from an almost economic concentration of lithium) are similar to the case of the dissolved potash deposit. Na_2SO_4 has been previously reported in subsurface brines (Reeves, 1963), and thenardite is known to precipitate from local surface lakes. Lithium is a common component of evaporites formed near igneous rocks, but the nearest igneous rock is several kilometers away (Calzia and Hiss, 1978). The brine is sodium-rich and magnesium poor. Once again in terms of ion exchange, a loss of evaporite-derived magnesium into silicates, which give up sodium, appears to be the mechanism here, although this need not have taken place in the Castile. Such like processes may account both for magnesium depletion in the solution and the formation of magnesium silicates in the evaporite sequence.

Thermodynamics. The ERDA No. 6 gas and brine are the only fluids which lend themselves to multiphase thermodynamic considerations. The gas amounted to 1.22 liters (STP) per liter of liquid, and consisted of

55% CO_2, 28% H_2S, 15% CH_4, 1.5 N_2 and 0.5% C_2H_6, determined mass spectrometrically. The H_2S is not saturated in the solution, even in the light of the salting-out effect of high TDS content (Randall and Failey, 1927), and amounts only to 0.02 molal. In order to examine the role of sulfur in this system (the only multivalent element common to both liquid and gas phases) a predominance area diagram (cf. Garrels and Christ, 1965), was constructed for the system S-O-H with the variables pH and oxygen partial pressure, and with total sulfur equal to 0.36 molal (approximating the sulfate and H_2S in solution). The resulting diagram is Figure 7.11, for the field-temperature of 25°C. The field-measured pH is 6.3, and samples of the brine containing dissolved H_2S were observed to precipitate elemental sulfur upon standing at atmospheric conditions. The diagram shows that at pH 6.3, the sulfur field occurs between the sulfate and H_2S fields. Thus, the diagram correctly predicts the oxidation of H_2S to sulfur, and the sulfate and H_2S cannot be in thermodynamic equilibrium with one another at pH < 7. Unfortunately, the oxidation potential was not measured, and the precise position of the ERDA No. 6 system on the diagram is not known. The most probable origin of the H_2S is biogenic reduction of sulfate, an ion abundant in the surrounding rocks as anhydrite as well as in solution. Kuznetsov et al (1963), have indicated that bacteria such as Desulfovibrio aestuarii can exist in saturated NaCl solutions, although their activity is inhibited by bivalent cations, which are not prevalent in the ERDA No. 6 brine.

Stable Isotopes. Analysis of water samples for their $^{18}O/^{16}O$ and D/H ratios has been found to be a useful method of identifying the source of water molecules, and to some degree identifying the types of interactions the water has undergone in the presence of other phases.

Figure 7.12 is a δ D versus $\delta\ ^{18}O$ plot for Delaware Basin groundwaters. Most of the earth's meteoric waters have isotopic compositions which fall between the lines described by the equations:

$$\delta D = 8 \ \delta\ ^{18}O + 5 \text{ (Epstein } \underline{et}\ \underline{al}\text{., 1965; 1970)}$$

and

$$\delta D = 8 \ \delta\ ^{18}O + 10 \text{ (Craig, 1961a).}$$

These lines are included in Figure 7.12, and the area between them is labelled "Meteoric Field."

Most of the points in Figure 7.12 lie in or near the meteoric field. Except for Carlsbad Caverns, a $\delta\ ^{18}O$ value of -7‰ and a δD value of -50 ‰ appears to be a good approximation to local meteoric water in the Delaware Basin. The Caverns are part of the hydrologic system independent of the rest of the Capitan. Their enrichment in D and ^{18}O reflects the water's origin from air mass conditions different from those which produce other Basin rains.

Bracketing the cluster of meteoric points are two dashed lines whose intervening field is labelled "evaporation." This field is the trajectory of isotopic compositions that the meteoric waters would follow during evaporation. The trajectory slope is 5, according to Craig et al. (1963). The few points that lie in or near the evaporation field (4 Rustler and 1 Castile) may indeed have suffered partial evaporation prior to infiltration, but definitely originated as metoric water.

The dashed line through the origin, also of slope 5, is the trajectory of isotopic compositions of evaporating sea water. This line is also valid for the evaporation of warm-climate coastal meteoric waters ($\delta\ ^{18}O \approx -2$‰, $\delta D \approx -10$‰, as indicated by the intersection of this line with the meteoric field. Such waters were postulated by Holser (1963; 1966) to have been potential contributors to the Delaware Basin. The figure shows that the waters of positive $\delta\ ^{18}O$ values are not the products of partial evaporation either of Delaware Basin water or of modern meteoric water. This conclusion is the same as that drawn from the Cl/Br ratios.

The environments in which the Salado, Morrow and Delaware (Bell Canyon) waters were found involved a rock/water ratio that was very large, as deduced from the low productivity of these reservoirs. Consequently, any interaction involving isotopic exchange between these waters and host rocks would tend to alter the isotopic composition of the water toward δ D and $\delta^{18}O$ values consistent with equilibrium isotopic fractionation between water and minerals in the rock. Calcite in the Bell Canyon Sandstone had a $\delta^{18}O$ value of +25.1‰, a value only slightly less than typical marine carbonate. This implies only minor isotopic alteration of easily exchanged carbonate oxygen in the rock through the action of water, and indicates lack of calcite-water isotopic equilibrium in the Bell Canyon. The oxygen and hydrogen in clay minerals are known to be readily exchangeable with water (O'Neil and Kharaka, 1976). The Delaware, Morrow and Salado waters have isotopic compositions that are suggestive of at least partial isotopic exchange between local meteoric waters and clay minerals in the sediments, in which the mineral/water ratio was very large (cf. Savin and Epstein, 1970) for at least several thousand years. Other mineral sources of exchangeable oxygen and hydrogen are fluid inclusions, whose stable isotopes have yet to be studied, and the water of crystallization of many evaporite minerals. The potash seep waters may have interacted with hydrous minerals. However, gypsum-water is the only such mineral-water system for which the $^{18}O/^{16}O$ and D/H fractionation factors are known.

None of the waters have resulted directly from the dehydration of gypsum to form anhydrite. If ERDA No. 6 were such a water, the point marked "G" in Figure 7.12 would be the isotopic composition of the water from which that gypsum precipitated (using the gypsum-water fractionation factors of Fontes and Gonfiantini, 1967). "G" is not consistent with evaporating Delaware Basin water, whose anticipated δ D - $\delta^{18}O$ trajectory was discussed above. The isotopic composition of ERDA No. 6 brine is consistent with an approach to isotopic equilibrium between water and clay minerals, not necessarily in the Castile. Its isotopic exchange, together with its history of cation exchange, has resulted in a brine whose history appears to be similar to that of oil field brines of Alberta and the Gulf Coast (cf. Clayton et al., 1966).

7.7.3 Summary

Many types of rock/fluid interactions are evident in the geochemistry of groundwaters found in the Delaware Basin. It is not possible to completely characterize these interactions from solutes or stable isotopes alone, nor through a study of water alone without a similar study of rock. In addition to fresh and brackish waters, which have acquired solutes from their host rocks, the brines have here illustrated three examples of various types of rock/fluid interactions:

1. dissolution of evaporites (saline Capitan waters).

2. dissolution of evaporites with isotopic exchange between fluid and rock (Salado potash seeps).

3. dissolution of evaporites, isotopic exchange, and cationic exchange (Delaware, Morrow and ERDA No. 6 waters).

The latter two types indicate more profound interaction than the first, since these involve changes in the water molecules themselves.

No original Permian waters could be identified. If much of the evaporite section has been recrystallized, as Holser (1963) suggests, not even the fluid inclusions are expected to preserve such waters.

7.8 RUBIDIUM-STRONTIUM SYSTEMATICS OF THE SALADO FORMATION, SOUTHEASTERN NEW MEXICO

7.8.1 Introduction

One of the important reasons for studying bedded salt deposits for a radioactive waste repository is to determine their intrinsic geological stability and to understand the behavior of alkali and alkaline earths in such a system assuming leakage of isotopes such as ^{90}Sr and ^{137}Cs.

If it can be demonstrated that such isotopes are likely to be retained at or very near the possible leakage area, then the potential danger of such leakage is minimized. Alternately, if it is found that there has been widespread migration of alkali and alkaline earth elements in the prospective storage sites, then these sites may be unfavorable for retention of ^{90}Sr, ^{137}Cs, etc. assuming leakage occurs. Furthermore, if the latest episode of diagenetic evaporite recrystallization can be dated, arguments can be made for the geochemical requilibration of the evaporite assemblage into a thermodynamically stable configuration, reducing the liklihood of such events in the future.

To address this problem the WIPP study area and nearby sites were chosen for investigation, utilizing the well-established Rb-Sr geochronologic method of age determinations. This method is especially well suited for addressing alkali and alkaline earth retention and/or migration because of the species involved and its simplicity. Because of geochemical similarities (ionic radii, ionization potential, charge) Rb can be used as an analogue for Cs, and ^{90}Sr will behave as any other Sr isotope. Hence the Rb-Sr ages will allow, in theory, meaningful interpretation of the stability of the Salado Formation in terms of Rb and Sr retention and/or migration.

The basic age equation is:

$$T = \frac{(^{87}Sr/^{86}Sr)_m - (^{87}Sr/^{86}Sr)_o}{(^{87}Rb/^{86}Sr)_m \quad (\lambda)}$$

where:

T = age in years

$(^{87}Sr/^{86}Sr)_m$ = measured isotopic ratio normalized to $(^{86}Sr/^{88}Sr) = 0.1194$ (the average abundance ratio in the earth)

$(^{87}Sr/^{86}Sr)_o$ = initial isotopic ratio before $^{87}Rb\ (\beta^-)^{87}Sr$ radiogenic decay (R_o) occurs.

$(^{87}Rb/^{86}Sr)_m$ = measured isotopic ratio (calculated from Rb/Sr ratio).

(λ) = decay constant for ^{87}Rb = 1.42×10^{-11}/y.

The $(^{87}Sr/^{86}Sr)_m$ term is the sum of $(^{*87} + ^{87}N)_{Sr}/^{86}Sr$ where *87 and ^{87}N refer to radiogenic and normal mass 87 respectively.

The initial ratio $(^{87}Sr/^{86}Sr)_o$ can either be assumed, determined by measurements on Rb-free phases formed at T =0, or determined by extrapolation from an isochron (i.e. line of slope $e^{T\lambda} - 1$ along which all samples of the same age and initial ratio but with different Rb/Sr ratios will fall; see Faure and Powell, 1972). The last of these choices is considered the most reliable due to natural variations of the initial ratios in nature, even from supposedly uniform, Rb-free, reservoirs.

7.8.2 Previous Work

K-Ar dating of evaporites has been shown by numerous investigators to be extremely risky (see discussion in Faure, 1977) due to loss of radiogenic ^{40}Ar by diffusion and other processes. Some K-Ar ages have beeen attempted for salts from the WIPP study area at Los Medanos (Shell Dev. Co.; 1973). For sylvites, minimum dates from 18 $\pm$ 8 to 74 $\pm$ 8 m.y. were obtained while two langbeinite-sylvite mixtures yielded nearly identical dates of 137 $\pm$ 8 and 147 $\pm$ 8 m.y. Only one very pure langbeinite (18%K) yielded a date of 245 $\pm$ 10 m.y.; this date is in excellent agreement with the 225-240 m.y. age range assigned to the Late Permian evaporites of the Castile and Salado formations.

The only other officially reported work is that by E. L. Tremba (1973; unpub. Ph.D. dissertation) in which he reports widely scattered data for evaporites from the Los Medanos area. Tremba's (1973) work was not directed toward problems of local alkali or alkaline earth migration, however, and composite samples were commonly taken which would, in

effect, mask any such local effects. He reports two model Rb-Sr dates of 241 ± 23 m.y. and 208 ± 8 m.y. respectively for (1) a K-ore zone from the Saunders Mine and (2) two separate aliquots of a water-soluble K-ore. An initial ratio of 0.7077 was used in both cases. For water soluble samples from mine faces within the Saunders Mine, Tremba reports a 129 ± 5 m.y. isochron but, without adequate justification, one point (#3SS) is omitted from the isochron calculation. As a model age for this one point yields an apparent model date of 330 m.y. (R_o = 0.708), then the significance of the 129 ± 8 m.y. date, based on only 4 of 5 samples, is difficult to interpret.

Similarly, five samples from Tremba's core 184, first ore zone, yield an apparent isochron date of 120 ± 28 m.y. but with an extremely high initial ratio of 0.7226 ± 0.0092. The argument is made that the two 120 to 129 m.y. isochrons can be explained by some type of Cretaceous "rehomogenization event". This interpretation can be criticized because 27 low-K samples from core 184 yield a mean $(^{87}Sr/^{86}Sr)_m$ = 0.7077 ± 0.0001; and any hypothesized rehomogenization event must explain how selective parts of the core can be affected whereas others are not. For example, Tremba argues that recrystallization involving polyhalite may have taken place at approximately 120 m.y. ago at which time the initial ratio was increased by rehomogenization to above 0.72; yet the data in Table 7.24 yield at least one sample (ERDA-9, 1759.1-1759.8) with $^{87}Sr/^{86}Sr_m$ = 0.7064. Furthermore, if one uses the individual points for Tremba's 129 m.y. isochron and assumes an initial ratio of 0.7077 (based on his data), a range in model dates results from about 185 m.y. to 100 m.y. (not counting sample EV-13 with a very low $^{87}Rb/^{86}Sr$ ratio). The reason for this apparent scatter is unanswered by Tremba's work.

7.8.3 Analytical Procedure

Sample Preparation. Samples studied thus far have been core segments from WIPP exploratory holes. The core segments were about four inches in diameter and ranged in length from 4 to 12 inches. These samples first

were trimmed by air saw to remove all outer surfaces that may have contacted drilling brines or been otherwise contaminated. Only the remaining prism of rock was retained for analysis; the outer portions were stored for possible use in the future.

Enough of the remaining inner portions were ground to -100 mesh to produce approximately 200 g of rock powder. About 30 g of this powder was quartered out and saved for whole rock analysis.

Separation of Water-Insoluble From Water-Soluble Material. The concentration of water-insoluble residue in a sample was determined during the separation of the soluble from the insoluble material. Approximately 60 g of powdered sample, weighed to the nearest 0.01 g, was placed in a 250 ml glass centrifuge tube together with about 175 ml of distilled and deionized H_2O. The bottle was then capped and the mixture shaken vigorously for about 3 minutes, centrifuged for 15 minutes and decanted into S and S 576 filter paper. This procedure was repeated with 175 ml of H_2O followed by a third leaching of 150 ml of H_2O.

The resulting solution was transferred into a Pyrex 600 ml beaker, which was placed on a 150°C hotplate until no more liquid remained. The salt residue was then quantitatively removed from the beaker, weighed, and stored for analysis.

Separation of the < 2 Micron Fraction. The < 2 micron fraction was separated from the insoluble residue remaining from the above procedure. The insoluble residue was repeatedly washed and centrifuged until a disperson of the clay-sized material was obtained. The washed slurry was then put into 1000 ml cylinders for gravity settling. The length of time necessary for settling was calculated from the equation noted by Folk (1968). Fractions finer than 2 microns were siphoned off after the proper length of time had passed. A portion of the < 2 micron fraction was used for oriented slides (for x-ray diffraction analysis); the remainder was dried, ground to -100 mesh and used for Rb-Sr isotopic and other geochemical analyses.

X-ray Diffraction Analysis of Clay and Evaporite Minerals. Thus far, identification of clay minerals has been based solely on x-ray diffractograms, obtained from a Norelco wide range diffractometer. Untreated oriented powders were scanned from 2 to 60 degrees two theta. The untreated slide was glycolated by vapor-soaking on a rack in a container filled partially with ethylene glycol. An additional oriented powder was heated to 450°C. Both the glycolated and the heated specimens were scanned from 2 to 30 degrees two theta.

Whole rock samples were analyzed by loading a small amount of randomly oriented rock powder in a Norelco powder holder. This powder was scanned from 5 to 80 degrees two theta and the resulting diffractogram compared to values compiled in the Joint Committee on Powder Diffraction Standards file to determine bulk mineralogic composition. Mineralogic abundances noted were estimates based on comparative peak intensities.
All samples x-rayed (both clays and whole rocks) were scanned with Ni-filtered CuK radiation. A time constant of two seconds was used with a scintillation counter detector and pulse height analyzer. The goniometer slit system consisted of a divergent and anti-scatter slit of 1 degree and a 0.003 inch receiving slit.

Rb-Sr Isotopic Analysis. Procedures for the dissolution of samples for Rb-Sr isotopic analyses varied dependent on the samples mineralogic composition. All samples were first weighed accurately and placed into a 100 ml teflon evaporating dish; the amount of sample to be dissolved was determined to ensure at least 10 mg Sr and Rb would be in solution. The sample was then spiked with ^{84}Sr and ^{87}Rb solutions. Samples which contained silicate minerals were dissolved with 30 ml reagent grade HF and 3 ml vycor distilled $HClO_4$ on a hot plate. Samples containing only water soluble material were dissolved with 50 ml of distilled and deionized H_2O and 10 ml of vycor distilled 6N HCl. Samples containing large amounts of sulfate minerals were first dissolved in aqua regia and then treated with HF and $HClO_4$.

After complete dissolution of the powder and evaporation of all HF and $HClO_4$, the samples were digested with 25 ml of H_2O and 25 ml of HCl.

The mixture was then reduced to about 5 ml by slow evaporation and allowed to cool overnight. After cooling the solution was filtered through S and S #576 filter paper and loaded onto the top of a chromatography column charged with sulfonated polystyrene, a chromatographic grade cation exchange resin.

The column was washed with 2N HCl repeatedly while the effluent was flame tested for cationic composition. Rb and Sr fractions were collected at the appropriate intervals indicated by the flame test. The collected fractions were subsequently dried, redissolved and transferred to precleaned quartz microvials. The microvials, containing the samples, were fused, cooled and stored for mass spectrometric analysis.

All Rb and Sr concentrations were determined by standard isotope dilution techniques. All Rb and Sr isotopic ratios were measured using a 23 inch, 90 degree sector, solid source, single filament Nuclide mass spectrometer equipped with an electrometer and strip-chart recorder.

7.8.4 Results

Samples for the present study were provided from Sandia Laboratories drill cores AEC-8, ERDA--6, and ERDA 9 drill cores. Samples were studied for their Rb-Sr systematics by mass spectrometer and (Table 7.24, 7.25), mineralogy by x-ray diffraction (Table 7.26). Additional geochemical studies are planned (i.e., rare earth elements, by instrumental neutron activation analysis).

Samples have been divided into whole rocks, water soluble portions, and the minus-two micron fractions. This approach varies significantly from Tremba's (1973) approach in that he worked with water soluble and total water insoluble fractions; the latter were not treated for separation of authigenic from allogenic fraction. This will be discussed later.

Whole rocks may yield uncertain results due to the unknown nature of water insoluble fractions within them. Similarly, the water soluble fractions are meaningful only if the nature of the water insoluble

fraction is studied. This last point can best be addressed by detailed study of the clay-size (minus-two micron), authigenic minerals common to evaporites.

(1) Whole rocks: the water insoluble content of whole rocks varies from less than 1 percent to 32 percent, with a mean of 6.5 percent if sample Dv-4D (clay rich) is omitted. The basic mineralogy of these samples is a halite rich assemblage with some samples rich in sylvite and/or polyhalite as well. Langbeinite-rich samples are rare. The Rb-Sr isochron for eleven samples is shown in Figure 7.13. The date of 132 m.y. must be considered very approximate as nine of the eleven samples plot essentially on the ordinate. Of these last eleven, nine are used to yield a reasonable estimate of initial ratio = 0.7081 $\pm$ 0.0005 (in agreement with Tremba's 1973 value of 0.7077).

(2) Water soluble samples: in working with water soluble samples the assumption is made that ions released into solution will not be absorbed onto the surface of the insoluble material. This is probably true only if the insoluble material consists of allogenic quartz, feldspars, etc. but <u>not</u> clay minerals. An isochron for five water soluble samples yields an apparent date of 206 m.y. with R_o = 0.7084 (Figure 7.14). While this date is not unreasonable for the Permian-Triassic boundary, it is slightly low.

(3) Minus-two micron fraction: the authigenic clay minerals which one might predict for an evaporite sequence are present in this fraction (Table 7.26). Of interest is that this material is (a) authigenic as demonstrated by the x-ray diffraction work and (b) is also the dominant part of the water insoluble fraction. Thus the apparent

isochron date (Figure 7.15) of 325 m.y. needs explanation. If one remembers that many of the clay partings in the potash mines are interpreted as being of aeolian origin, then it is very likely that such aeolian clay minerals will, in part, reflect their provenance. This has been noted before by Hurley et al. (1962) for minus-two micron clay minerals from the Bermuda Rise. Of interest here is that our 325 m.y. date (Figure 7.15) is virtually identical with Tremba's (1973) 331 m.y. date for total water-soluble material.

7.8.5 Discussion

There are several ways to treat the data gathered so far. First a composite of whole rocks, water soluble and minus-two micron size clay minerals yields an isochron date (Figure 7.16) of 165 $\pm$ 20 m.y. with R_o = 0.7115. This date must be interpreted as a minimum due to the fact that the best estimate of R_o is 0.7081 $\pm$ 0.0004 according to the data presented in Table 7.24.

It is also apparent that the whole rocks by themselves are, in general, too halite-rich and possess Rb/Sr ratios which are too low for isochron work. When to this is added the uncertainty introduced by the insoluble material mixed with possible pre-T_s (i.e. time of sedimentation) material smaller than two microns, plus some detrital feldspar, quartz, etc., then the whole rocks can be assumed to be unsuitable for the isochron work.

If the clay minerals in the minus-two micron fraction are aeolian, pre-T_s material may account for the pre-Permian date of 325 m.y. (Figure 7.15). Similarly, since the clay mineralogy (Table 7.26) is very typical of evaporite clay minerals, then an alternate explanation is that these clay minerals have acted as local sinks for some $^{*87}Sr$ presumably remobilized during and after lithification and diagenesis. A lower age limit for this event is set by the 206 m.y. date from the water soluble fraction.

When only the water soluble and minus-two micron clay mineral fractions are considered together, a 204 m.y isochron (Figure 7.17) results with R_o = 0.7137. This date is only somewhat lower than the Permian-Triassic boundary and can safely be interpreted as a minimum due to the high initial ratio (0.7137). This interpretation assumes, however, that the clay minerals equilibrated with the evaporite medium (i.e. salts plus brine plus remnant sea water) at the time of sedimentation and this point remains to be unequivocally demonstrated.

Many of the above mentioned uncertainties will almost certainly be resolved by additional samples now in various stages of analysis for Rb-Sr systematics plus additional samples not yet treated. Furthermore, scanning electron microscope studies are planned to help resolve the problems of aeolian versus non-aeolian authigenesis hypotheses regarding clay mineral occurrences. Finally, rare earth element (REE) data, when complete, will greatly enhance understanding of the evaporite-insoluble material systematics of the Los Medanos area.

7.8.6 Concluding Statements

These data are of importance to he WIPP in the Los Medanos area because: (1) Widespread recent rehomogenization of radiogenic ^{87}Sr would be obvious if consistently high $^{87}Sr/^{86}Sr$ ratios were determined either from Rb-poor phases or by extrapolation from all samples with high Rb/Sr to the ordinate (Figures 7.13-7.17). This is not the case, and in fact values for whole rocks yield a mean of 0.7081, and several isochrons yield extrapolated values from approximately 0.709 to 0.713. The entire set of data argues against large amounts of radiogenic ^{87}Sr-enriched brine, having been formed post-200 m.y. ago, subsequently leaving its imprint in the recrystallized minerals. (2) the Rb-Sr isochron based on water soluble fractions and clay minerals, Figure 7.17 yields a date of 204 m.y. This date, in view of R_o = 0.7137 (i.e. higher than 0.7084), must be interpreted as a minimum date pending further analyses. (3) The clay minerals (Table 7.26) are of special interest in that they are typical of evaporite clay minerals formed during evaporite diagenesis,

yet they have been interpreted as aeolian. If they are aeolian, then some mixture of kaolinite-montmorillonite-illite would be expected rather than the saponite-chlorite-montmorillonite-serpentine-talc-illite assemblage noted. Since the clay minerals yield (Figure 7.15) a pre-sedimentation apparent date of 325 m.y. with high R_o (0.7123), then it is possible that these clays acted as local sinks for radiogenic ^{87}Sr (and Rb?) released during early diagenesis from roughly 235 m.y to 204 m.y.; such an interpretation is consistent with the data obtained to date. Tremba (1973) has argued for some mid-Cretaceous "rehomogenization event" at about 120 m.y. ago but inspection of his data coupled with these data do not support such an hypothesis. (4) REE are especially sensitive as geochemical tracers and forthcoming data, coupled with continued Rb-Sr and other work, should permit resolution of some of the problems concerning alkali and alkaline earth retention/migration in the geologic past at the Los Medanos site.

7.9 URANIUM ISOTOPE DISEQUILIBRIUM IN GROUNDWATERS OF SOUTHEASTERN NEW MEXICO AND IMPLICATIONS REGARDING AGE-DATING OF WATERS

7.9.1 Introduction

History. Regional exploration of bedded salt deposits for a radioactive waste repository in the Delaware Basin (Permian, New Mexico) included boreholes into the evaporites and associated rocks. These rocks contained various amounts of fluids, already described (Lambert, 1978). Although the halite deposits of the Ochoan Epoch are the prime target of consideration for waste storage, the older rocks of the Guadalupian Epoch are included in the present study, because of the Capitan reef, a body of cavernous limestone which encircles the Basin. The Capitan not only is the dominant rock in the Carlsbad Caverns, but also supplies potable water to the city of Carlsbad. Therefore, it is appropriate to consider possible connections between the Capitan and accumulations of water found in pockets in the evaporites. Brine and gas pockets are known to occur in the Carlsbad district potash mines and in the Castile Formation (anhydrite and halite) underlying the Salado Formation.

One exploration hole, ERDA No. 6, drew national attention (Boffey, 1975), when it encountered an accumulation of saturated NaCl brine laced with Na_2SO_4, accompanied by H_2S-rich gas at 826 m below the surface. Discovery of this artesian fluid, together with bedding-plane dips in the host Castile Formation exceeding 70°, led to abandonment of that particular site. Geophysical investigations showed that this and other occurrences of brine and gas were associated with closed structure contours drawn for the Castile formation. These structures, restricted to a narrow strip of evaporites near the reef have been termed "salt anticlines" (Anderson and Powers, 1978). Core from the fluid-producing zone of ERDA No. 6 consisted of gray laminated anhydrite whose fractures were filled with massive crystalline white anhydrite (Plate 7.52). While isolated fluid accumulations are not rare in evaporites, the possible use of the region for radioactive waste disposal requires attention to the origin of this particular type of accumulation. In the extreme cases, the fluid originates directly from water from the Capitan Reef, or the water was entrapped in the Castile Formation at the time for evaporite deposition in the Permian. In the first case, the water would have an age little older than Capitan waters. In the second case, the water would be in excess of 230 million years old.

Implications. Indeed, the very presence of the ERDA No. 6 accumulation of fluid poses several questions:

1. How long has the water been confined in the pocket?
2. Does the time of the water's intrusion correspond to any significant known geologic events?
3. What is the source of the water?
4. How long has this pocket been disconnected from nearby aquifers such as the Capitan Reef, if it ever was connected?
5. What are the limits to rates of influx (if any) or recharge and discharge (if any) of this fluid pocket?
6. To what degree does the ERDA No. 6 occurrence (or any other in the area) represent a flowing system?
6. Which radiometric clock should be used to age-date the water and what should be taken as initial conditions for age-dating?

7.9.2 Analytical Approach

General Geochemistry of Groundwaters. A number of groundwaters from the Delaware Basin have been characterized in terms of their general geochemistry with respect to their host rocks (Lambert, 1978). In terms of solutes, all waters from below the fresh-saline interface in the Capitan were similar to each other. In addition all shallow ($\leq$300 m depth) waters were similar to one another and all deep ($\geq$ 1000 m depth) waters were similar to one another. The ERDA No. 6 water was unique in its solute content, indicative of profound disequilibrium between solution and host rock and also between solution and associated gas phase.

In terms of D/H and $^{18}O/^{16}O$ ratios, Capitan and shallow waters all are similar and are of meteoric origin. (Carlsbad Caverns waters are also of meteoric origin, but are not related to other waters in the Capitan.) Deep water stable isotope ratios are similar to one another, and are not characteristically meteoric. ERDA No. 6 has uniquely non-meteoric isotopic ratios among those of Delaware Basin waters. No waters were found which represent original evaporite mother-liquor.

Experimental Procedures. In spite of the evidence that this fluid has experienced profound interactions with rock (Lambert, 1978), radioisotopes were examined to establish that the ERDA No.6 fluid was not of relatively recent origin. Plutonium concentration was determined by isotope dilution employing a spike of ^{244}Pu. The actual measurement was made on a three-stage thermal emission solid source mass spectrometer equipped with pulse counting for ion detection. The instrument has a very high abundance sensitivity (10^7) and low background, allowing for the determination of precise isotopic ratios on small samples amounting to 0.1 to 1 nanograms of plutonium. The plutonium concentration of the ERDA No. 6 brine was found to be less than 10^{-15} grams per gram, corresponding to the lower limit of analytical detectability. The absence of plutonium suggests the brine has been isolated at least since 1945, a date corresponding to the first atmospheric detonation of nuclear weapons.

Carbon 14 was measured in the CO_2, which amounted to 55% of the total gas collected from ERDA No. 6. Carbon 14 content was counted in a gas proportional detector whose efficiency was calibrated with the NBS oxalate standard. The result was the same as the background, which was about 2 counts per minute in a 1.5 liter detector at 2 atmospheres pressure. From this it was concluded either that the brine is older than about 30,000 years or possibly that carbonates in the host rock have diluted the carbon in the system with non-radioactive carbon.

The disequilibrium of the activity of ^{234}U relative to ^{238}U in natural waters has been attractive as an indicator of the age of groundwaters (Osmond and Cowart, 1976). ^{234}U and ^{238}U are related by the decay scheme:

$$^{238}_{92}U \xrightarrow[4.5 \times 10^9 a]{\alpha} {}^{234}_{90}Th \xrightarrow[24d]{\beta-} {}^{234}_{91}Pa \xrightarrow[1\ min]{\beta} {}^{234}_{92}U \qquad (1)$$

It has been proposed that excess ^{234}U builds up in confined waters as an aging effect as a result of the alpha-recoil of ^{234}Th, which ejects ^{234}Th out of the host rock crystal lattice into the water (Kigoshi, 1971; Kronfeld et al., 1975). From a knowledge of decay constants and initial activity ratio α_0 ($\alpha = \lambda_{234} N_{234} / \lambda_{238} N_{238}$), the time of confinement is calculated. It cannot be assumed, however, that the earth's natural abundance ratio, $\alpha = 1.00$, is a priori valid for a confined rock-water system. The water carried in with it an initial uranium concentration and original activity ratio, α_0 . The water ultimately comes to thermodynamic equilibrium with its host rock and may leach or even deposit ^{234}U and ^{234}Th. Uranium concentrations and α -ratios of rocks and waters in this study were determined by isotope dilution mass spectrometry, described above. Figure 7.18 shows the locations of principal water samples of this study. Table 7.27 shows uranium conentrations and values of α for various waters.

7.9.3 Results and Discussion

The overleaf of Plate 7.52 shows the variations of U content and α in anhydrite of rock core taken from the zone which produced fluid in ERDA No. 6 (826 m, 2709 ft depth). Table 7.27 shows that in ERDA No. 6, both U concentration and α vary with time, until U concentration falls asymptotically to about 2 parts in 10^9, and α rises asymptotically to about 1.35. In the early part of a several-hour flow test, water samples were found to be contaminated with drill mud and spallations from metal pipe. By 1400 hours not only had the uranium reached steady state values, but the iron concentration had fallen from 260 parts in 10^6 (1130 hours) to a steady value of 5 parts in 10^6 (1400 hours), indicating the flushing out of drilling-introduced contaminants. Thus, the later samples are probably representative of the fluid accumulation.

The total variation in α among all water samples is relatively small (1.2 to 5.2). In contrast, absolute uranium content in the waters of Table 7.27 varies by more than two orders of magnitude. Similarly, rock material illustrated in Plate 7.52 shows a wide variation in U content: 1 to 2 parts in 10^6 for "original" laminated gray anhydrite down to 20 to 30 parts in 10^9 in the secondary white anhydrite fracture filling only a few centimeters away.

7.9.4 Applicaton of the Uranium Isotope Disequilibrium Model

If N_2 is the amount of ^{234}U present in a phase, and N_1 is the amount of ^{238}U, the change in ^{234}U content with time in the brine is

$$\left(\frac{dN_2}{dt}\right)_{brine} = \lambda_1 N_1 - \lambda_2 N_2 + Q_1 + Q_2, \qquad (2)$$

in which Q_1 is the rate of release of ^{234}Th (the parent of ^{234}U) from the rock, Q_2 is the rate of release of ^{234}U from the rock and λ_1 and λ_2 are decay constants for ^{238}U and ^{234}U, respectively.

Release rates Q_1 and Q_2 can be modeled in the fashion of Kigoshi (1971), who studied the release of ^{234}Th from zircon powder. He gave the accumulated activity of ^{234}Th in solution after time t as

$$(\lambda_{Th}\ N_{Th})_{brine} = 1/4\ L\ S\rho\ (N_{238}\ \lambda_1)_{rock}\ (1 - e^{-\lambda_{Th}t}), \quad (3)$$

in which λ_{Th} is for ^{234}Th, L is the recoil distance of ^{234}Th in decay scheme (1) above, S is the surface area of parent rock, ρ is its density, and N_{238} is expressed as the number of ^{238}U atoms per gram of rock. Thus, the activity of ^{234}Th in the brine is related to the activity of ^{238}U in the rock by a proportionality constant, and, of course, the time-dependent term. When t >> 24 days, (3) can be approximated as

$$(\lambda_{Th}\ N_{Th})_{brine} \approx f_1 \cdot (\lambda_1\ N_1)_{rock}, \quad (4)$$

in which f_1 is now the leach fraction of ^{234}Th, incorporating 1/4 L S ρ in (3). In general, ^{238}U activities in rock and coexisting brine will not be equal, but will be related by a distribution coefficient r, which is theoretically an equilibrium constant, neglecting the kinetics of dissolution and precipitation:

$$(\lambda_1\ N_1)_{rock} = r\ (\lambda_1\ N_1)_{brine} \quad (5)$$

In actual fact, the time required to achieve chemical equilibrium between rock and brine might be very long relative to the half-life of ^{234}Th. Q_1 now becomes

$$Q_1 = r \cdot f_1 \cdot (\lambda_1\ N_1)_{brine} \quad (6)$$

Similarly, the amount of ^{234}U released is dependent on the decay of its precursor ^{238}U, and on the equilibrium ratio r, and on the leach fraction for ^{234}U, f_2:

$$Q_2 = r \cdot f_2 \cdot (\lambda_1\ N_1)_{brine} \quad (7)$$

In addition, some fraction, f_3, of the ^{238}U will be leached from the rock,

$$\lambda_1 N_1 = r \cdot f_3 \cdot (\lambda_1 N_1)_{brine} + (\lambda_1 N_1)_{brine} \quad (8)$$

Now, equation (2) becomes:

$$\left(\frac{dN_2}{dt}\right)_{brine} = (\lambda_1 N_1)_{brine} \left[1 + r (f_1 + f_2 + f_3)\right] - \lambda_2 N_2 \quad (9)$$

If f is defined as a composite leach fraction $(f_1 + f_2 + f_3)$, the solution to (9) is:

$$N_2(t) = \frac{\lambda_1}{\lambda_2-\lambda_1} (1+fr) N_1(t) + N_1(t=0) \quad \frac{\lambda_2 N_2(t=0)}{\lambda_1 N_1(t=0)} \quad \frac{\lambda_1}{\lambda_2} (1+fr) \quad e^{-\lambda_2 t} \quad (10)$$

which allows us to express the solution in terms of $\alpha = \frac{\lambda_2 N_2}{\lambda_1 N_1}$:

$$\alpha_{brine} = \frac{\lambda_2}{\lambda_2-\lambda_1} (1 + fr) + \left[\alpha_o - \frac{\lambda_2}{\lambda_2-\lambda_1} (1 + fr)\right] e^{-(\lambda_2-\lambda_1)t} \quad (11)$$

and since $\lambda_2 >> \lambda_1$

$$\alpha_{brine} \approx 1 + fr + \left[\alpha_o - 1 + fr\right] e^{-\lambda_2 t} \approx \alpha_b \quad (12)$$

The corresponding equation for the rock is:

$$\left(\frac{dN_2}{dt}\right)_{rock} = \lambda_1 (1 - f) (N_1)_{rock} - \lambda_2 (N_2)_{rock} \quad (13)$$

Since for a closed system, the $^{234}U/^{238}U$ equilibrium activity ratio is 1.000, the solution to (13) is:

$$N_2(t)_{rock} = \frac{\lambda_1}{\lambda_2-\lambda_1} (1 - f) N_1(t)_{rock} + \frac{\lambda_1}{\lambda_2} N_1 (0)_{rock} e^{-\lambda_2 t} \quad (14)$$

$$- \frac{\lambda_1}{\lambda_2-\lambda_1} N_1 (0)_{rock} (1 - f) e^{-\lambda_2 t}$$

which in terms of α is

$$\alpha_{rock} = \frac{\lambda_2}{\lambda_2-\lambda_1}(1 - f) + e^{-(\lambda_2-\lambda_1)t} - \frac{\lambda_2}{\lambda_2-\lambda_1}(1 - f)\, e^{-(\lambda_2-\lambda_1)t} \quad (15)$$

The approximation $\lambda_2 >> \lambda_1$ reduces the equation (15) to

$$\alpha_{rock} \approx 1 - f + f\, e^{-\lambda_2 t} \approx \alpha_r \quad (16)$$

Let us now assume that the geochemical conditions (i.e. U content and α) observed in the ERDA No. 6 rock-fluid assemblage represent equilibrium conditions. This requires the mutual consistency of equations (12) and (16), and that

$$f = \frac{(\alpha_o - 1)(\alpha_r - 1)}{\alpha_b - \alpha_o + r(\alpha_r - 1)} . \quad (17)$$

Anhydrite found in the veins is the most recently formed phase in the core, and using the U values from 1709.4 white anhydrite (U = 33 parts in 10^9, α = 1.04); Plate 7.52 overleaf), and the averages of the last two ERDA No. 6 brines in Table 7.27, (U = 2.01 parts in 10^9, α = 1.35) equation (17) gives rise to the plot in Figure 7.19. Note the prominent singularity at $\alpha_0 = 2.01$, and that $\alpha_0 \leq 1.971$ at f = 1 (corresponding to 100% leaching, and $\alpha_0 \geq 2.052$ at f = -1 (corresponding to all the uranium in the rock having precipitated from the brine).

Solving equation (12) for t, we obtain an expression for the age of the brine:

$$t = \frac{\ln\left(\frac{\alpha_b - 1 - fr}{\alpha_o - 1 - fr}\right)}{-\lambda_2} . \quad (18)$$

For values of $\alpha_0 \leq 1.971$, negative ages result. Only for values of $\alpha_0 \geq 2.052$ are realistic ages obtained. This result implies that there has been minimal leaching from the rock. Furthermore, it suggests rather that precipitation of uranium has occured from brine to rock which is consistent with reducing conditions implied by the presence of H_2S.

Clearly, the amount of precipitation which has occurred (negative leaching) is related to the original α_0 at the time of closure of the rock fluid system.

Values of α for nearby waters in the Capitan limestone (Table 7.27) which by proximity afford a possible source of water for the ERDA No. 6 brine pocket, are mostly in excess of 1.35. In addition, the ERDA No. 6 brine is not saturated in $CaSO_4$ (Lambert, 1978), and is not likely to have been responsible for the precipitation of substantial amounts of vein anhydrite. Furthermore, the limited volume of the brine pocket (Griswold, 1977) could not realistically be expected to dissolve and reprecipitate anhydrite in veins to the extent observed in the core. Therefore, the α_0 of the ERDA No. 6 brine must have been larger than 2.052, with very little interaction with the reservoir rock.

7.9.5 Model Ages Based on No Leaching

Values of α and α_0 will in this model allow an age determination of a water to be made. The highest α value thus far determined is 14.2, the result of isotope dilution mass spectrometry performed on a sample from Israel supplied by J. Kronfeld, which gave an α value of 10.1 $\pm$ 1.6 by alpha-spectroscopy (Kronfeld et al., 1975). In addition, the occurrence of waters elsewhere in the Delaware Basin (Table 7.27 suggests that a reasonable α_0 value might be 5.14 (in the Capitan limestone), the highest thus far found in the Basin. If the ERDA No. 6 brine represents water escaped from the Capitan, and its α_0 was on the order of 5, Figure 7.19 shows that its interaction with the ERDA No.6 reservoir rock (fractured Castile anhydrite) precipitated less than 6% of the rock's uranium from the brine.

Neither total concentration nor isotopic composition of uranium in the ERDA No. 6 brine was inherited through interaction with the Capitan limestone, for the ERDA No. 6 brine contains substantially more uranium that the Capitan waters (Table 7.27) presently do. Likewise, uniformity in the stable isotope composition of Capitan waters (Lambert, 1978) shows

that the peculiar stable isotope composition of ERDA No. 6 water cannot have arisen by interaction with the Capitan limestone. Composition of stable and unstable isotopes in ERDA No. 6 brine might have arisen from interaction between water and rocks encountered by the water if it moved from the Capitan to its ERDA No. 6 environment.

In its simplest form, equation (18), under conditions of no interaction between ERDA No. 6 brine and its reservoir rock, reduces to:

$$t = \frac{\ln\left(\frac{\alpha_b - 1}{\alpha_o - 1}\right)}{-\lambda_2} \qquad (19)$$

which very nearly corresponds to the combination of the solutions to the equations $\frac{dN_1}{dt} = -\lambda_1 N_1$

$$\frac{dN_2}{dt} = -\lambda_2 N_2 + \lambda_1 N_1$$

for which

$$t \approx \frac{\ln\left(\frac{\alpha_b - 1}{\alpha_o - 1}\right)}{-\lambda_2 + \lambda_1} \qquad (20)$$

The above conclusions allow limits to be assigned to the age of confinement of the ERDA No. 6 brine, and also to ages of waters in the Capitan. Equation (20) differs from equation (19) only by the approximation that

$$\frac{\lambda_2}{\lambda_2 - \lambda_1} \approx 1,$$

since $\lambda_2 = 2.806 \times 10^{-6}$ a $^{-1}$ for ^{234}U
and $\lambda_1 = 1.537 \times 10^{-10}$ a $^{-1}$ for ^{238}U.

Figure 7.20 shows the family of curves obtained from equation (20), using observed values of α from Table 7.29, and various values for α_0. The model ages indicated on Figure 7.19 for the ERDA No. 6 brine are less

than those in Figure 7.20 because 4 to 5 percent interaction between brine and rock (uranium precipitation) involves loss of uranium from solution by means other than radioactive decay. There is no evidence for any degree of chemical equilibrium between ERDA No. 6 rock and fluid. If we realistically limit f (Figure 7.19) to have a value between -0.02 and -0.50, the minimum age of the ERDA No. 6 occurrence is 570,000 years (α_0 = 6). In actual fact, as the data of Kronfeld et al. (1975) suggest, maximum α_0 values are universally in the range 10 to 15, and the age is between 800,000 and 1,000,000 years. According to the no-interaction model, (Figure 7.20), if water escaped from the Capitan (α_0 = 5.14) into the brine pocket, this must have occurred at least 880,000 years ago. The highest α_0 value (14.2) confirmed by isotope dilution mass spectrometry gives an age of 1,300,000 years.

If the Carlsbad area (near the Pecos River) is a major recharge area for much of the Capitan reef, and if Carlsbad water (α_0 = 5.14) is the basis for age-dating other waters in the Capitan, ages between 300,000 and 1,100,000 years are obtained. The maximum α_0 (14.2) would imply that Capitan waters are at least 400,000 years old.

7.9.6 Implications and Conclusions

A mathematical model based upon analytical data has showed that the ERDA No. 6 occurrence of brine can be age-dated by the uranium-disequilibrium method. Combinations of leach fractions and ages were derived, and the interaction between rock and fluid was indicated to be minimal. If the brine pocket was once connected to the Capitan Reef, the most productive aquifer in the region, such connection was severed at least 500,000 years ago, and probably more than 900,000 years ago. The brine pocket has been stagnant ever since, and there is little evidence to indicate that chemical equilibrium has been established among the solid, liquid and gaseous phases involved in the brine pocket.

Even though the α value of the ERDA No. 6 brine was close to those of nearby metoric waters taken from the northern apex of the Capitan Reef, these α values are far removed from those of more remote meteorically-derived saline Capitan waters from the east and west arms of the reef (Carlsbad No. 7 and Shell No. 28). In fact, the remote waters appear to be younger than apex waters (Hackberry and Middleton), implying the groundwater flow in the reef is indeed toward the apex and recharge is in the east and west part of the reef.

Fresh and saline Capitan Reef waters have retained their meteoric D/H and $^{18}O/^{16}O$ ratios, even though the ages of some of them are comparable to that of ERDA No. 6. Although reef apex waters and ERDA No. 6 brine are radiometrically similar, the solutes and stable isotopes of ERDA No. 6 reflect a more profound rock/fluid interaction than Capitan waters have experienced. This interaction, however, is more likely to have taken place in rocks between the Capitan and the brine pocket than in the brine pocket itself.

The ERDA No. 6 reservoir rock has not replenished ^{234}U to the brine in spite of long contact. Furthermore, uranium mobility into the white recrystallized anhydrite from the gray laminated anhydrite from the gray laminated anhydrite was shown to be very low in this anoxic environment.

Dating by the uranium-disequilibrium method is not necessarily dependent on a closed system, and bounds on ages can be assigned. Requirements for $^{234}U/^{238}U$ dating include: α values of fluid and rock, leach rate, and knowledge of a value for original activity ratio, α_0. The α value for the rock is necessary to evaluate the degree of rock-fluid disequilibrium. The leach rate might be negligible even in a closed system. A unique solution to an age-dating problem, however, requires knowledge of initial conditions, just as in case of the well-established uranium-lead and carbon 14 age-dating techniques.

7.10 SUMMARY

Geochemical investigations of the WIPP site have been undertaken to characterize and quantify the mineralogy and petrology of the Delaware Basin evaporites and associated non-evaporites, volatile constituents and fluid inclusions native to the evaporites, the geochemistry of groundwaters native to the rocks, and the lengths of time that the evaporites and groundwaters have existed in their present environments. While these investigations have utilized a number of techniques of analytical chemistry, the choice and analysis of samples, together with interpretations of results, are carried out in the context of the WIPP geology.

The most common mineral in the Permian (Ochoan) Salado Formation, which is proposed for radioactive waste emplacement, is halite. Some of the halite contains minor amounts of anhydrite, and traces of trioctahedral clays and detrital minerals. Locally throughout the Salado Formation marker beds of anhydrite and polyhalite occur at intervals of a few tens of meters. Local accumulations of potassium and magnesium sulfates occur in the McNutt potash zone in the upper part of the Salado.

The petrographic textures, geochronology, and the presence of minerals which are not primary precipitates of sea water, such as sylvite and polyhalite, indicate that much of the evaporite section last underwent recrystallization more than 200 million years ago, shortly after Permian deposition. The trace clay mineral fraction of the rock salt has efficiently entrapped and held radiogenic strontium for at least the last 200 million years. The aqueous solutions involved in this recrystallization were not in communication with fluids outside the evaporite section.

Volatiles presently occur in the evaporite section as the chemically-combined water of crystallization, hydroxyl-groups bound in sheet silicates, short-lived seeps exposed in mines, and as physically-entrapped inter- and intracrystalline fluid inclusions. The

total volatiles recovered from rock salt heated to 600°C typically amount to less than 0.5 weight percent (about 1.5% by volume). In addition to water, traces of nitrogen, CO_2 and contaminants from the coring operation are recovered from subsurface evaporite cores taken from boreholes. The fluid inclusions appear to have been entrapped at 20 to 45°C, and contain NaCl, $MgCl_2$ and minor amounts of other solutes. Fluid inclusions not affected by recrystallization have not moved in the ambient geothermal gradient since the Permian deposition.

Isolated pockets of aqueous solutions now found in the evaporites have no geochemical relationship to surface-derived meteoric waters or to groundwaters above and below the evaporites; neither do they represent original evaporite mother liquors. Such pockets probably are relics of the post-depositional recrystallization which took place more than 200 million years ago, at which time they might have inherited their geochemically distinct solute assemblages and stable isotope compositons.

Stable isotope and solute content studies of meteorically-derived groundwaters west of the WIPP site and peripheral to the Delaware Basin indicate that simple uptake of solutes from rocks with which they have come in contact did not alter their meteoric isotope ratios. Thus, waters participating in active dissolution of salt, which has not occurred in the Salado Formation at the WIPP site, could be readily identified by their geochemistry.

The origin and age of an artesian brine pocket in the Castile Formation, northeast of the WIPP site was evaluated by a uranium isotope disequilibrium model. It was concluded that this accumulation (encountered in borehole ERDA No. 6) has no connection with any other known groundwaters, and has been in its present environment for at least 880,000 years.

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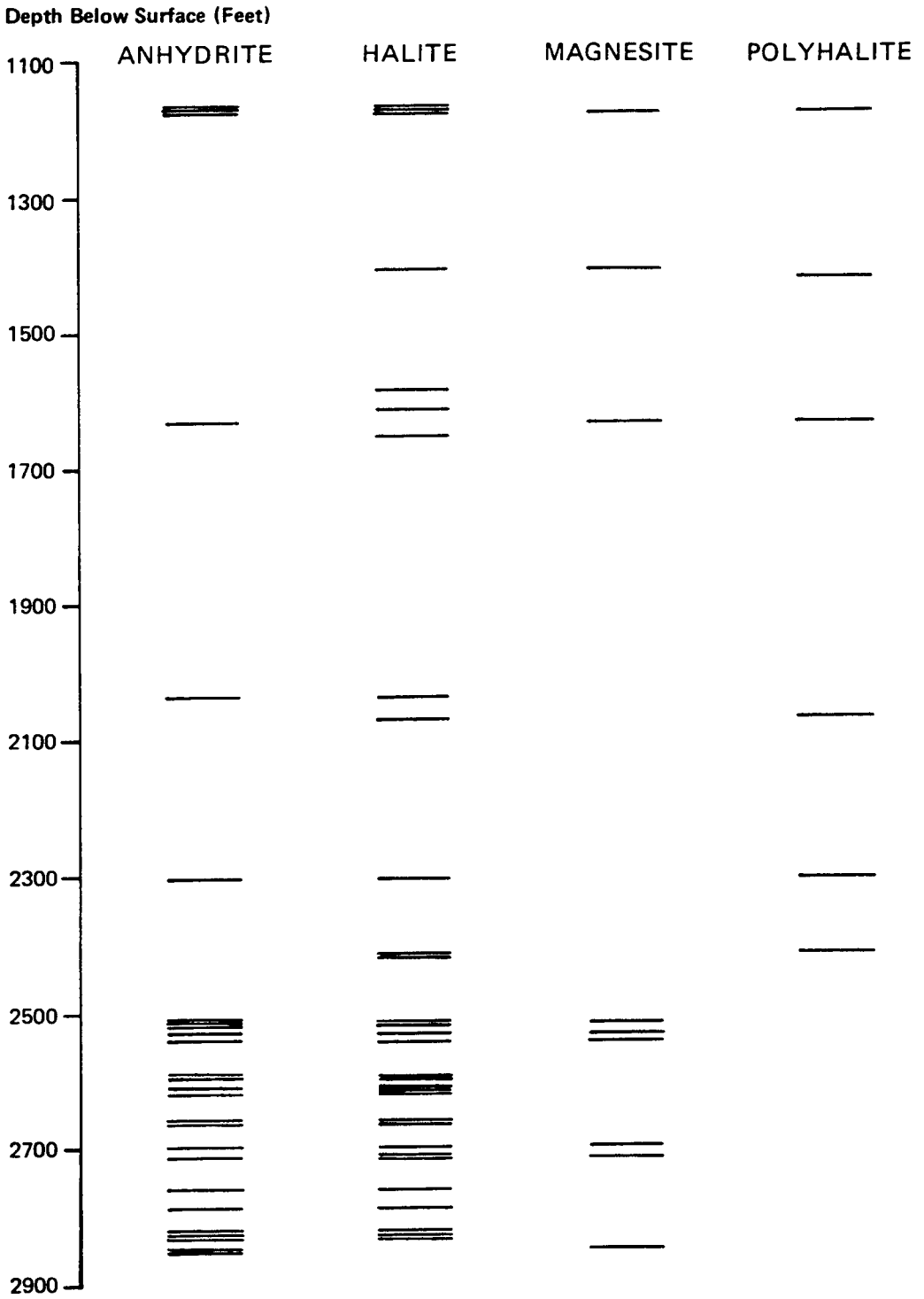


FIGURE 7.1

DISTRIBUTION OF MINERALS IN ERDA #9 CORE SAMPLES

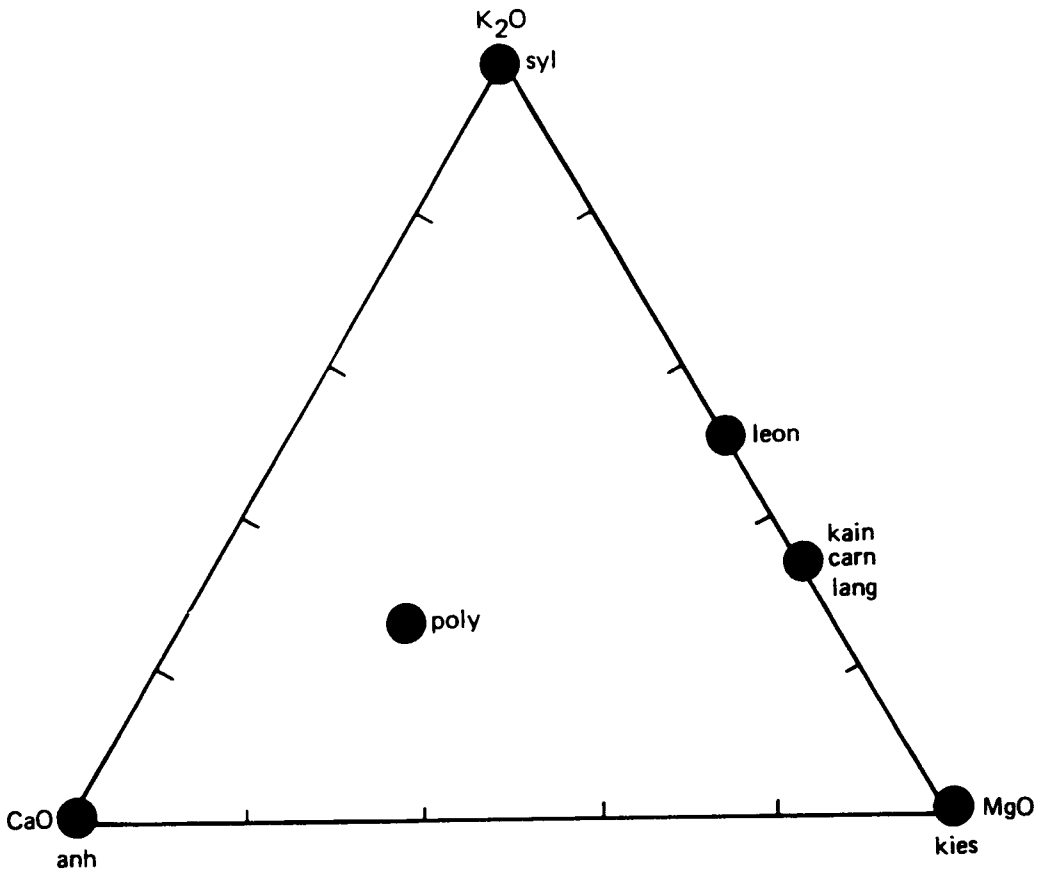


FIGURE 7.2

TRIANGULAR COMPOSITION DIAGRAM OF

SOLUBLE SULFATE-GROUP MINERALS

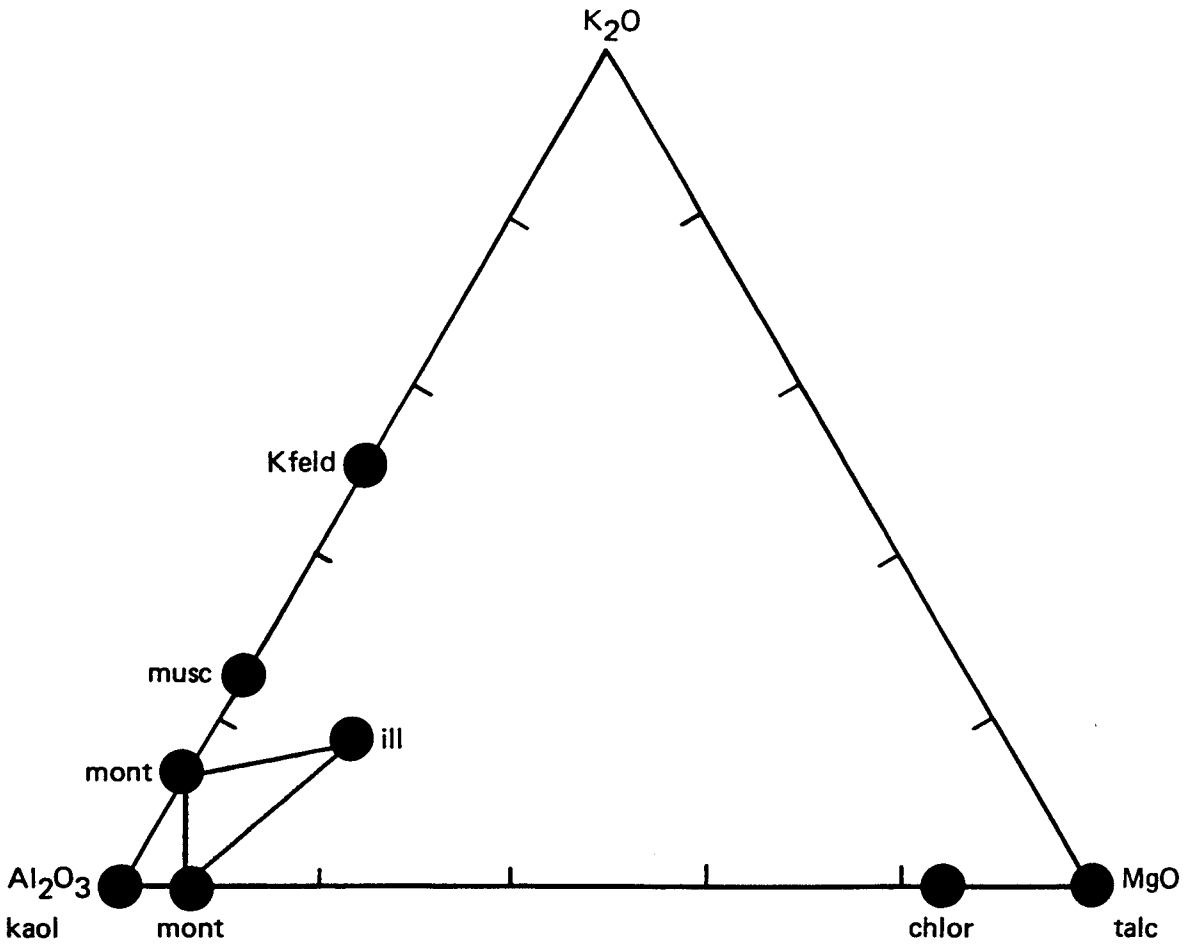


FIGURE 7.3

TRIANGULAR DIAGRAM OF

INSOLUBLE SILICATE-GROUP MINERALS

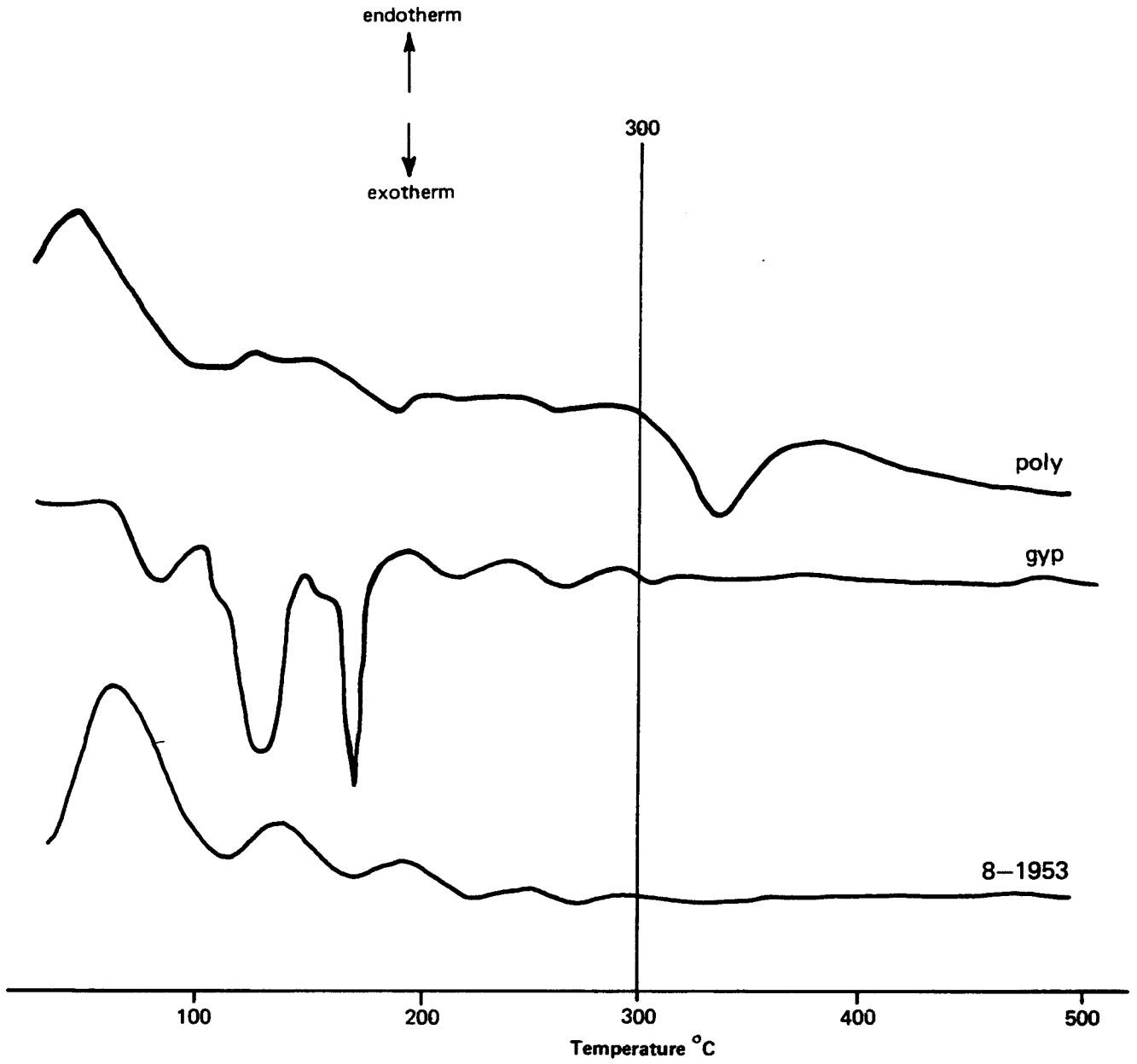
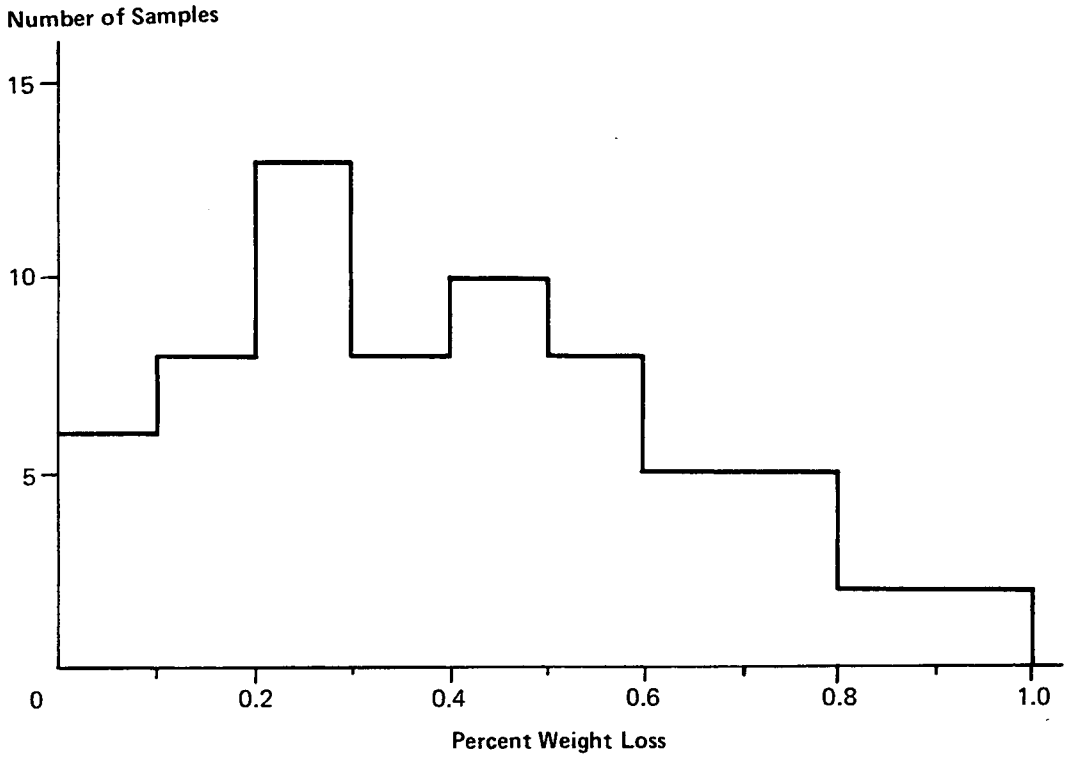


FIGURE 7.4

DIFFERENTIAL THERMAL ANALYSIS CURVES

FOR GYPSUM AND POLYHALITE



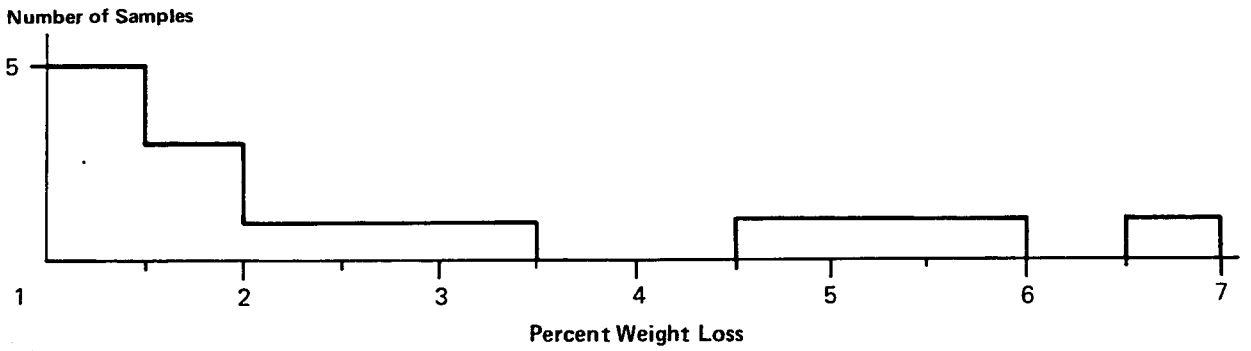


FIGURE 7.5

TOTAL WEIGHT LOSSES AT ELEVATED TEMPERATURES

(500°C) FOR CORES FROM AEC NOS. 7 AND 8

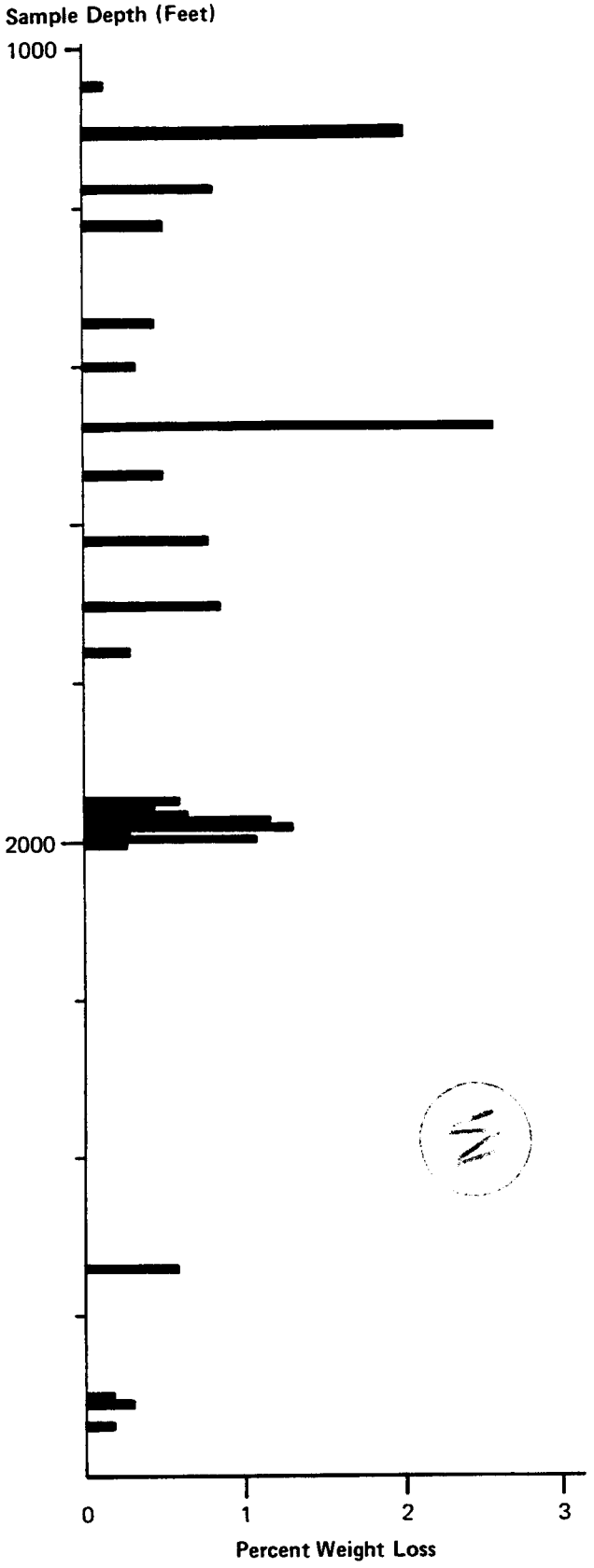


FIGURE 7.6A

AEC NO. 7 SAMPLE WEIGHT LOSSES VS. DEPTH

AT ELEVATED TEMPERATURES (500°C)

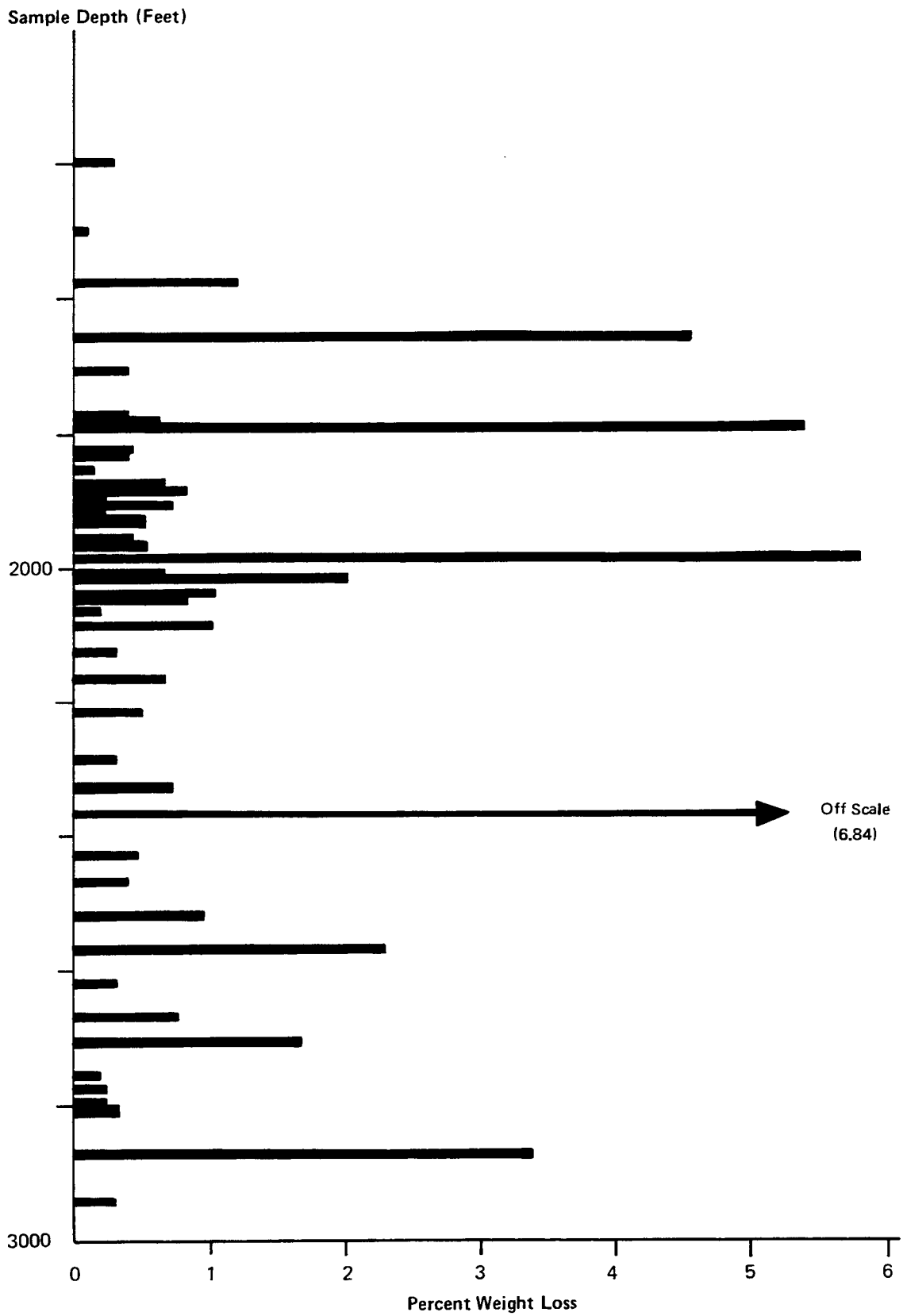


FIGURE 7.6B

AEC NO. 8 SAMPLE WEIGHT LOSSES VS. DEPTH

AT ELEVATED TEMPERATURES (500°C)

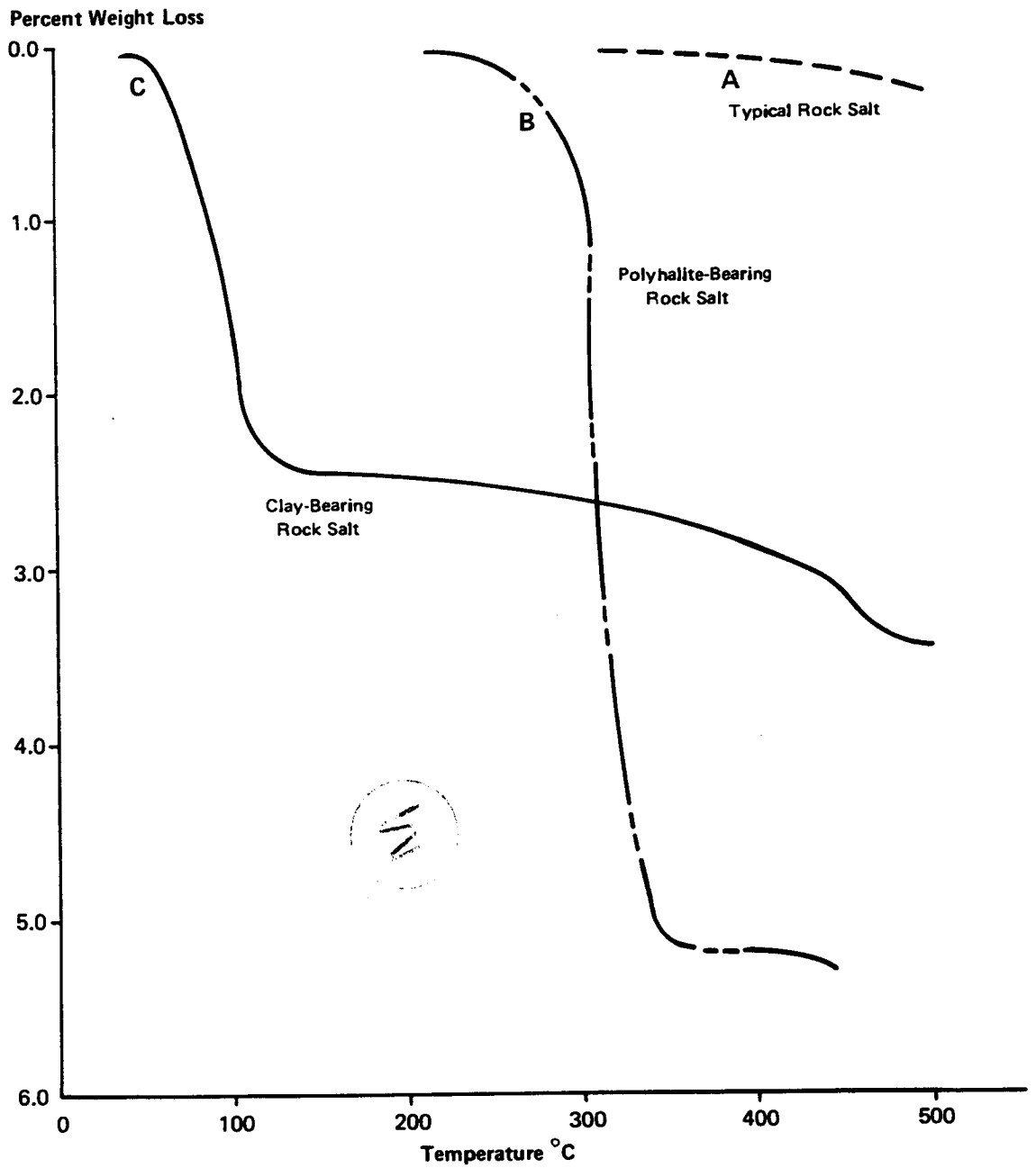


FIGURE 7.7

TYPICAL WEIGHT-LOSS CURVES FOR ERDA #9 EVAPORITE CORE

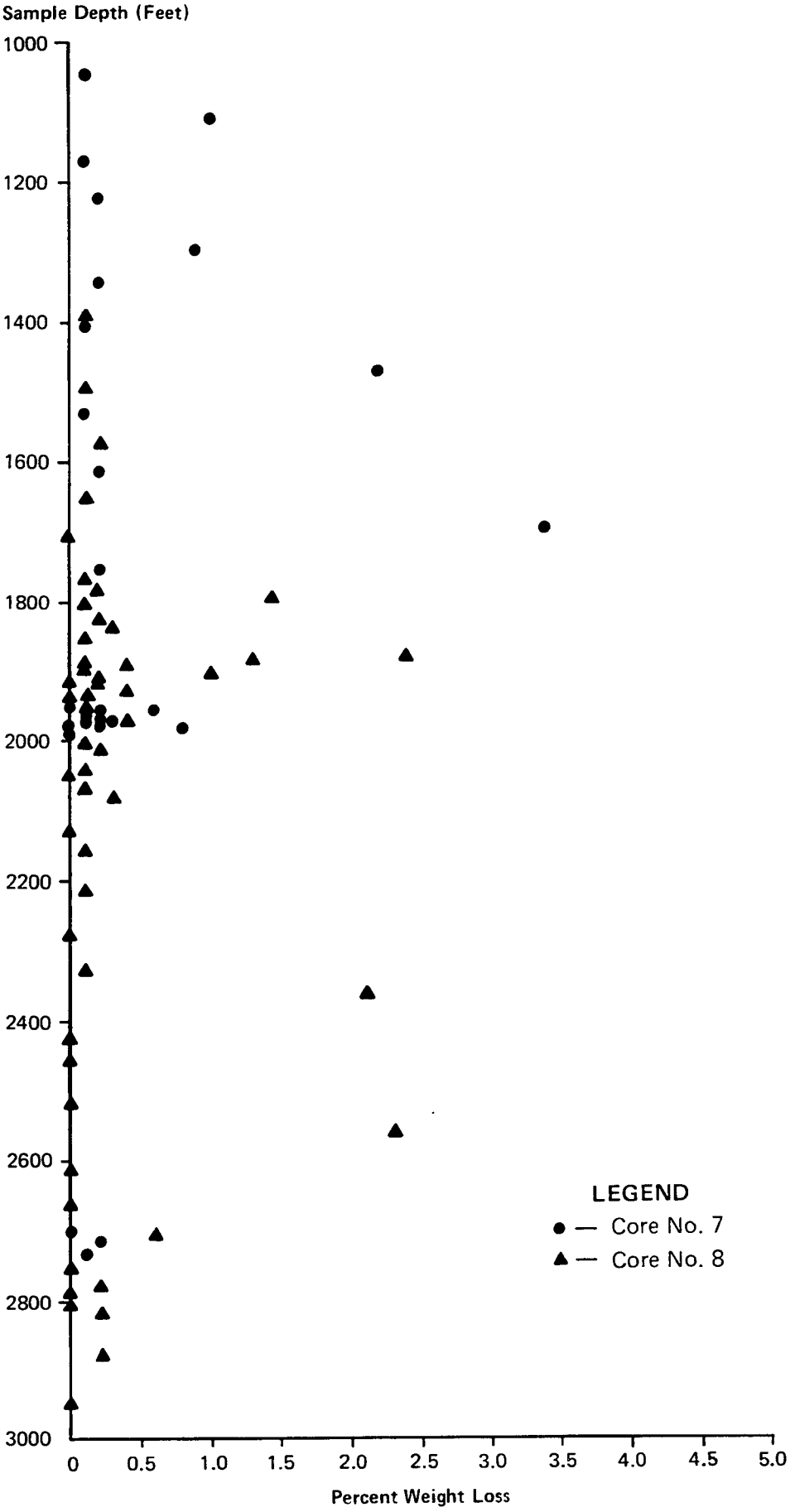


FIGURE 7.8 WEIGHT LOSS DATA FOR SAMPLES (102±5°C)

FROM CORES NO. 7 AND NO. 8 NEAR CARLSBAD, NEW MEXICO

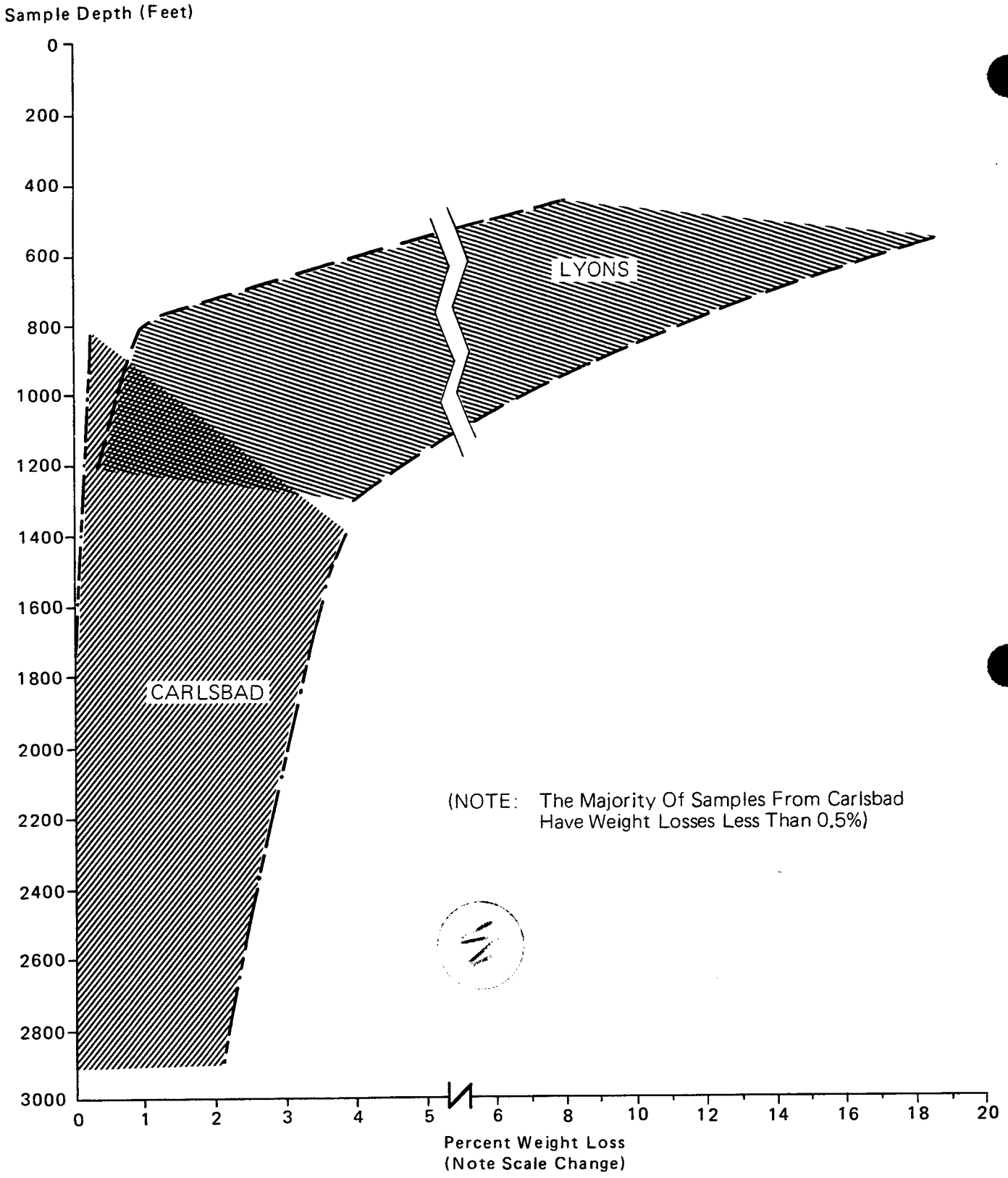


FIGURE 7.9 APPROXIMATE RANGE OF WEIGHT LOSS TO BE EXPECTED At 102 + 5°C VS. DEPTH FOR SAMPLES FROM LYONS, KANSAS AND CARLSBAD, NEW MEXICO

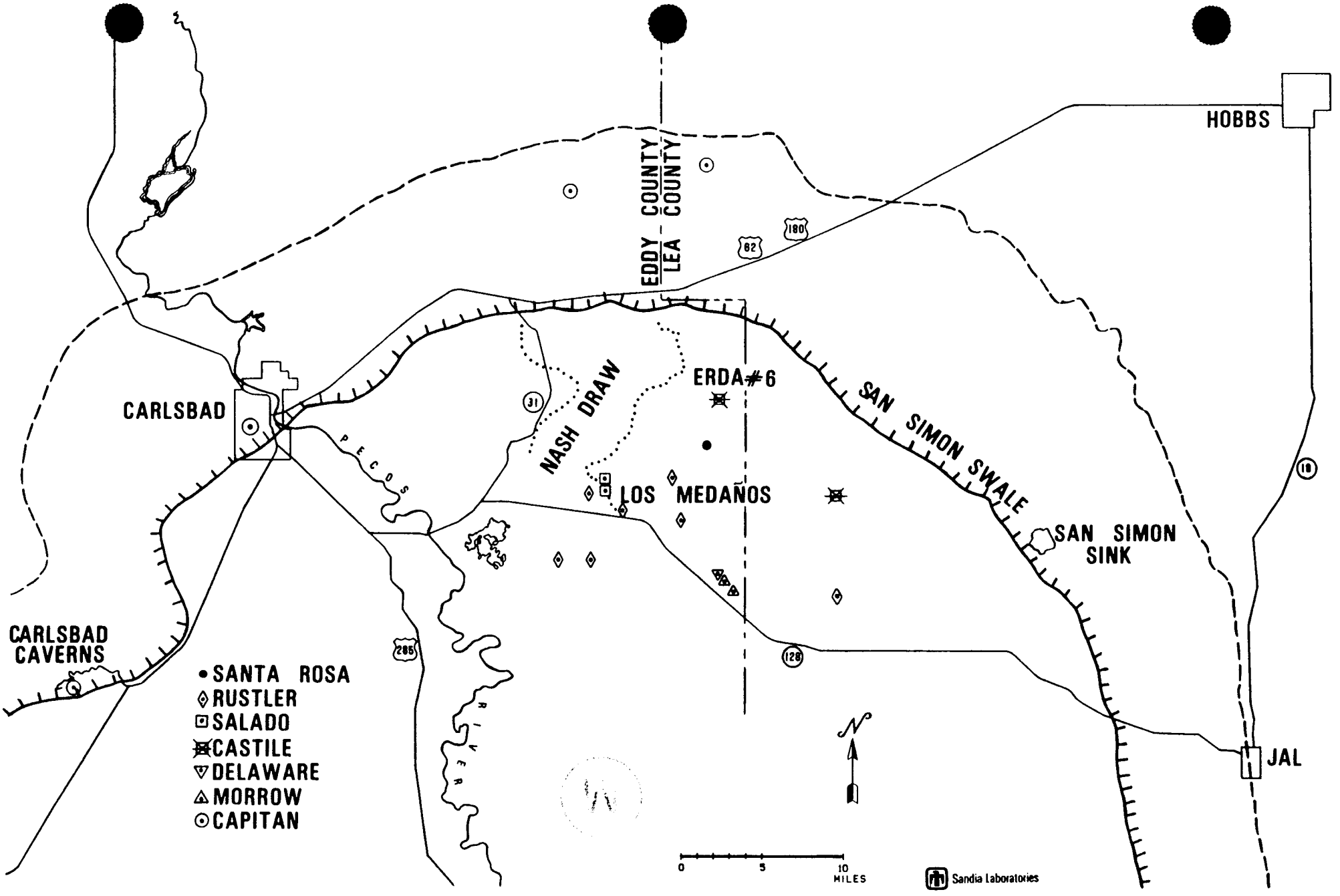


FIGURE 7.10 Map of the New Mexico portion of the Delaware Basin, showing locations of water sampling points in this study. The solid hachured line is the basinward margin of the Capitan Reef; the dashed line is the shelfward edge.

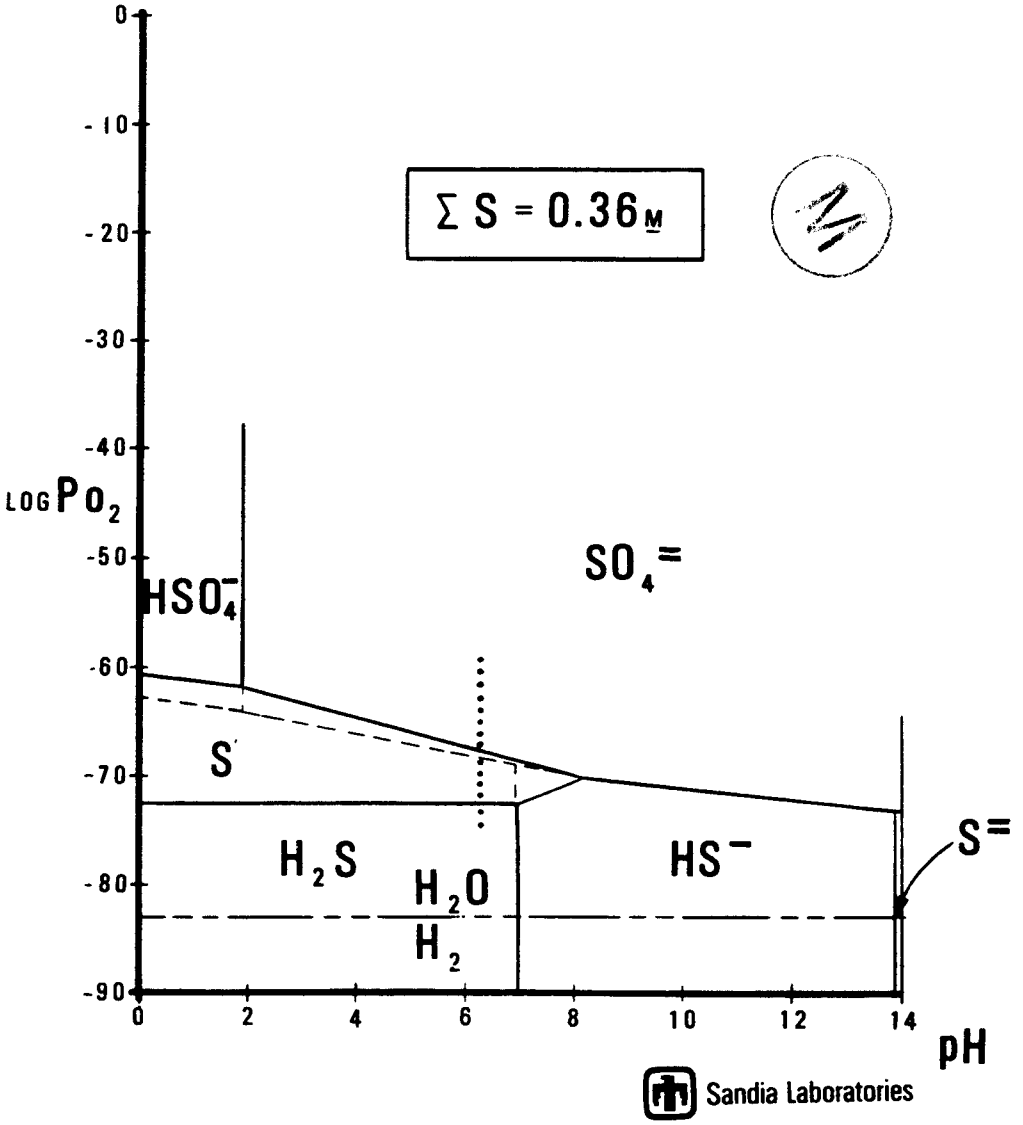


FIGURE 7.11 Predominance area diagram, oxygen partial pressure versus pH, for the System S-O-H at 25°C, 1 atmosphere and total sulfur concentration of 0.36m. Dashed lines are metastable extensions of boundaries. Dotted line represents the field-measured pH of ERDA No. 6, 6.3.

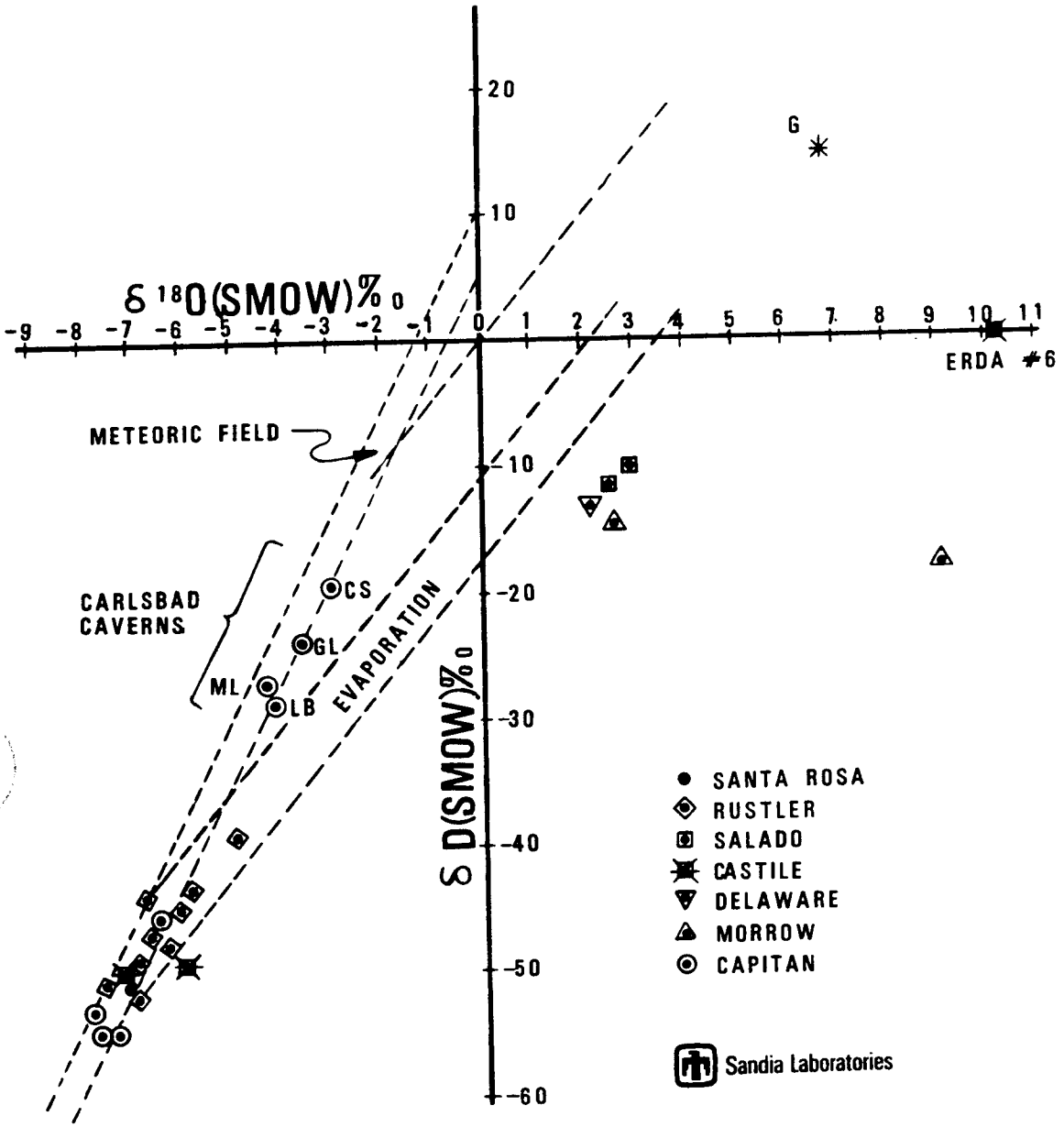


FIGURE 7.12 Stable isotope compositions, δD versus $\delta^{18}O$, for Delaware Basin groundwaters. Relationships are shown for meteoric waters, evaporating meteoric and sea waters. Hypothetical evaporite mother-liquor for gypsum (G) is shown for the case in which ERDA No. 6 is taken to be the water of crystallization for that gypsum.

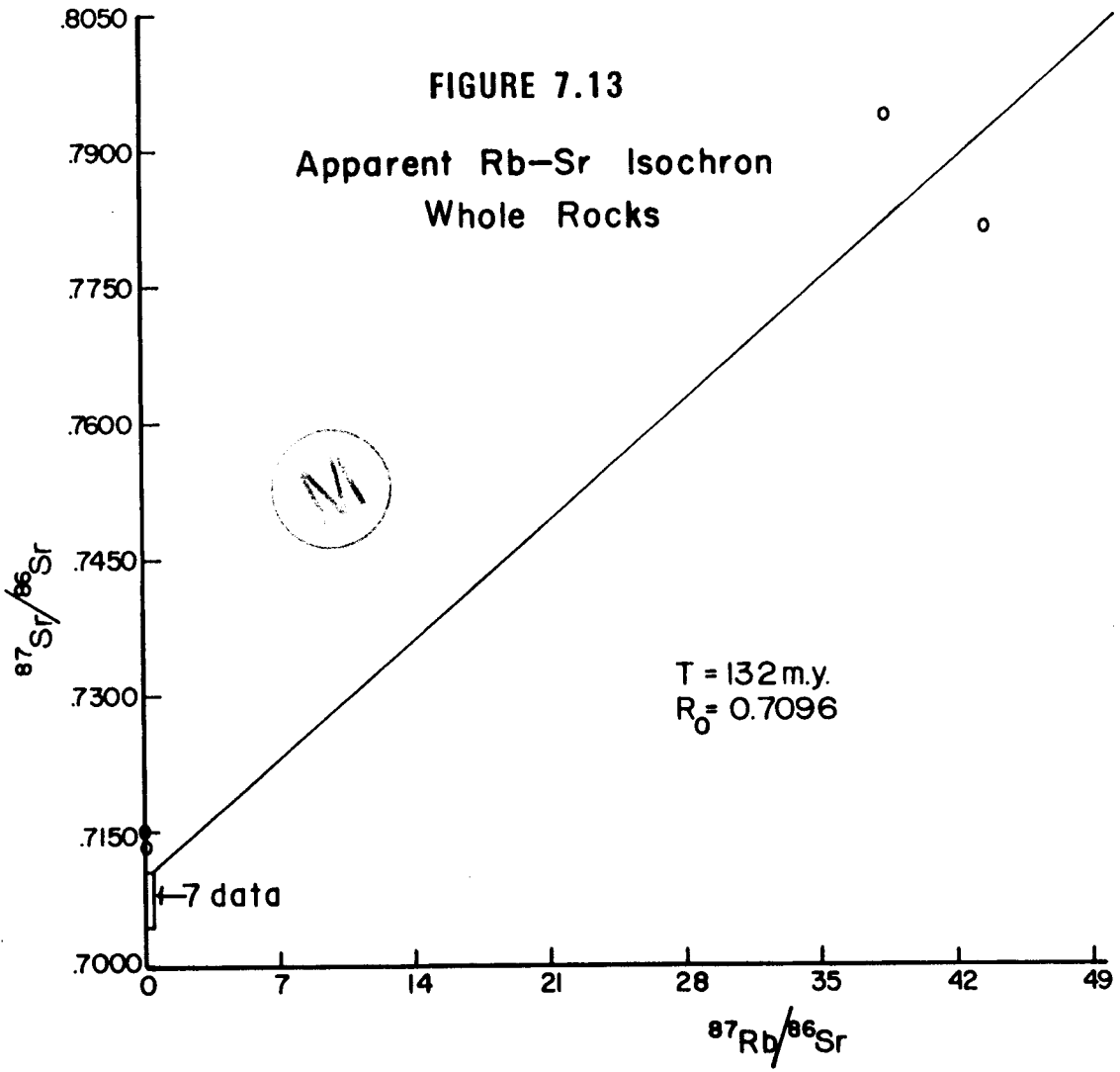


FIGURE 7.13

Apparent Rb–Sr Isochron
Whole Rocks

FIGURE 7.14

Apparent Rb–Sr Isochron
Water Soluble Fraction

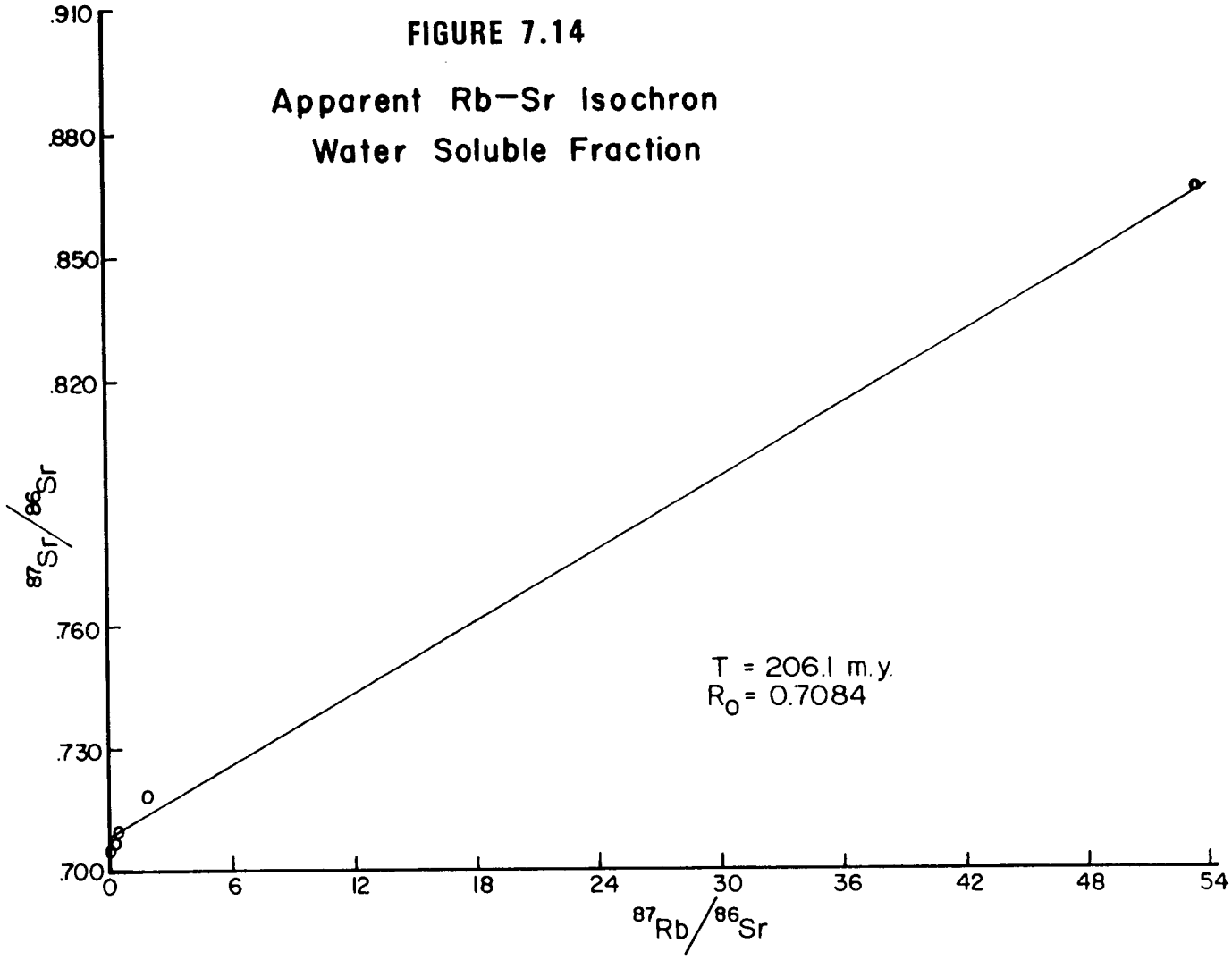


FIGURE 7.15

Apparent Rb—Sr Isochron
Clay Mineral (<2M) Fraction

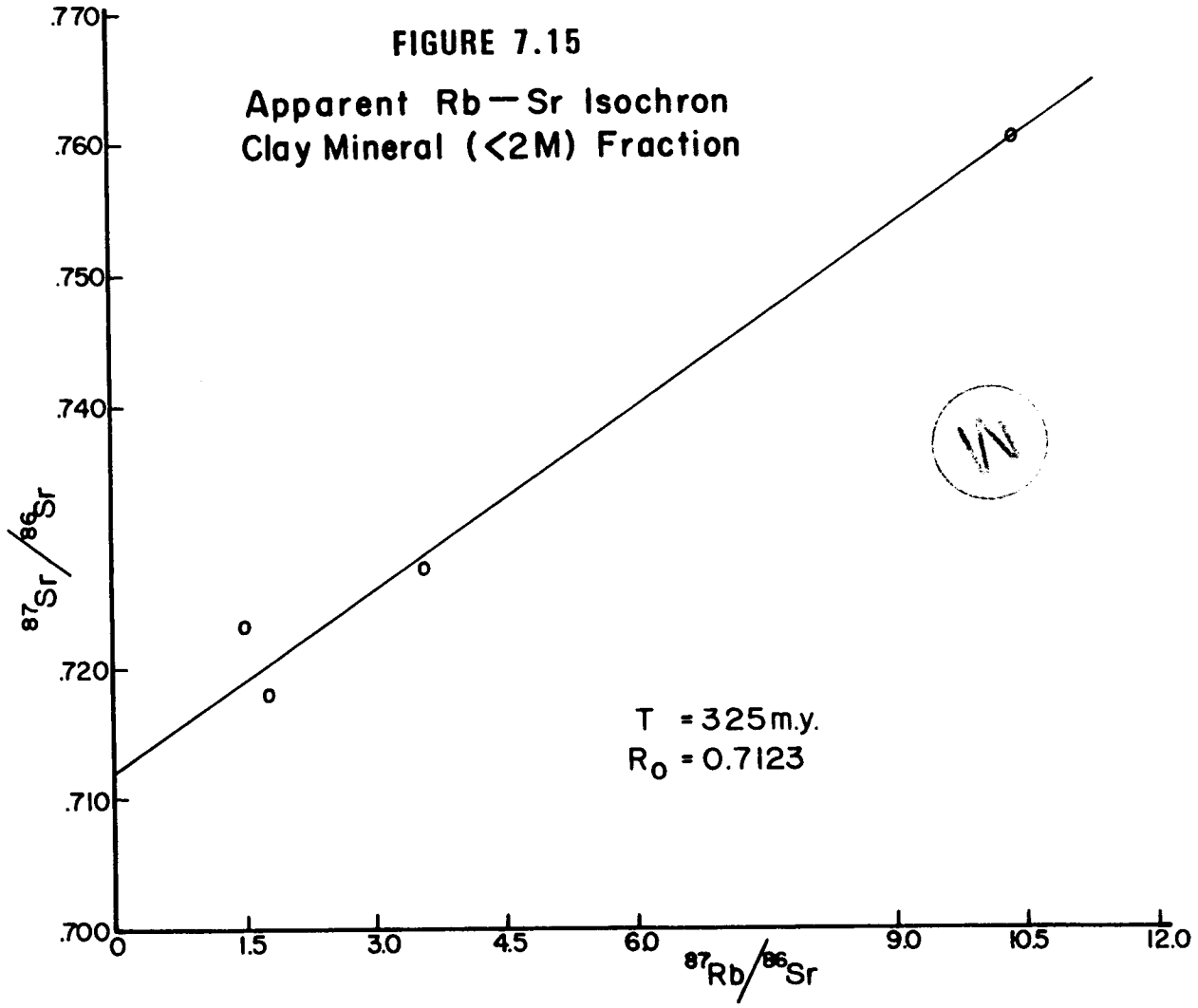


FIGURE 7.16

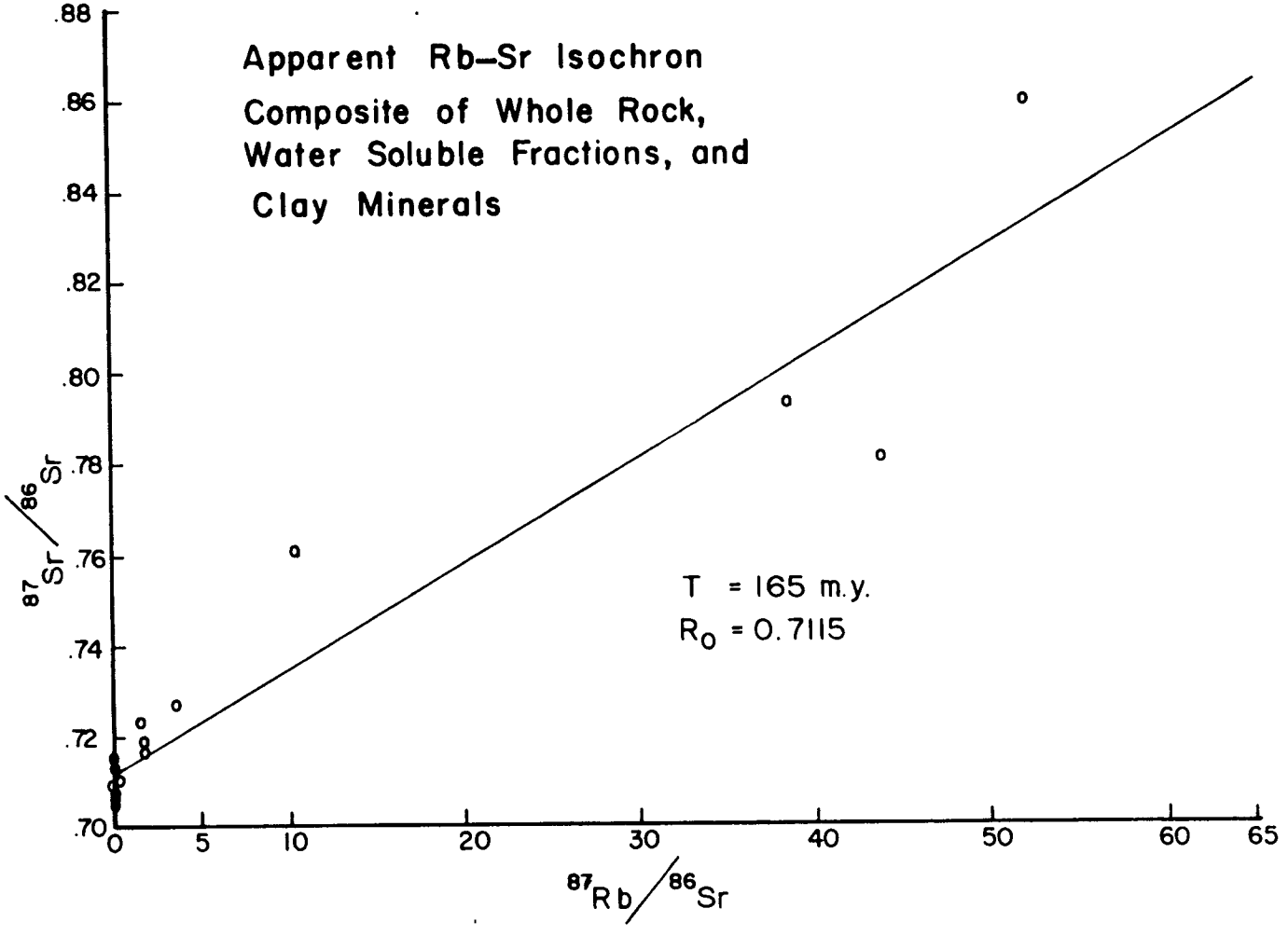
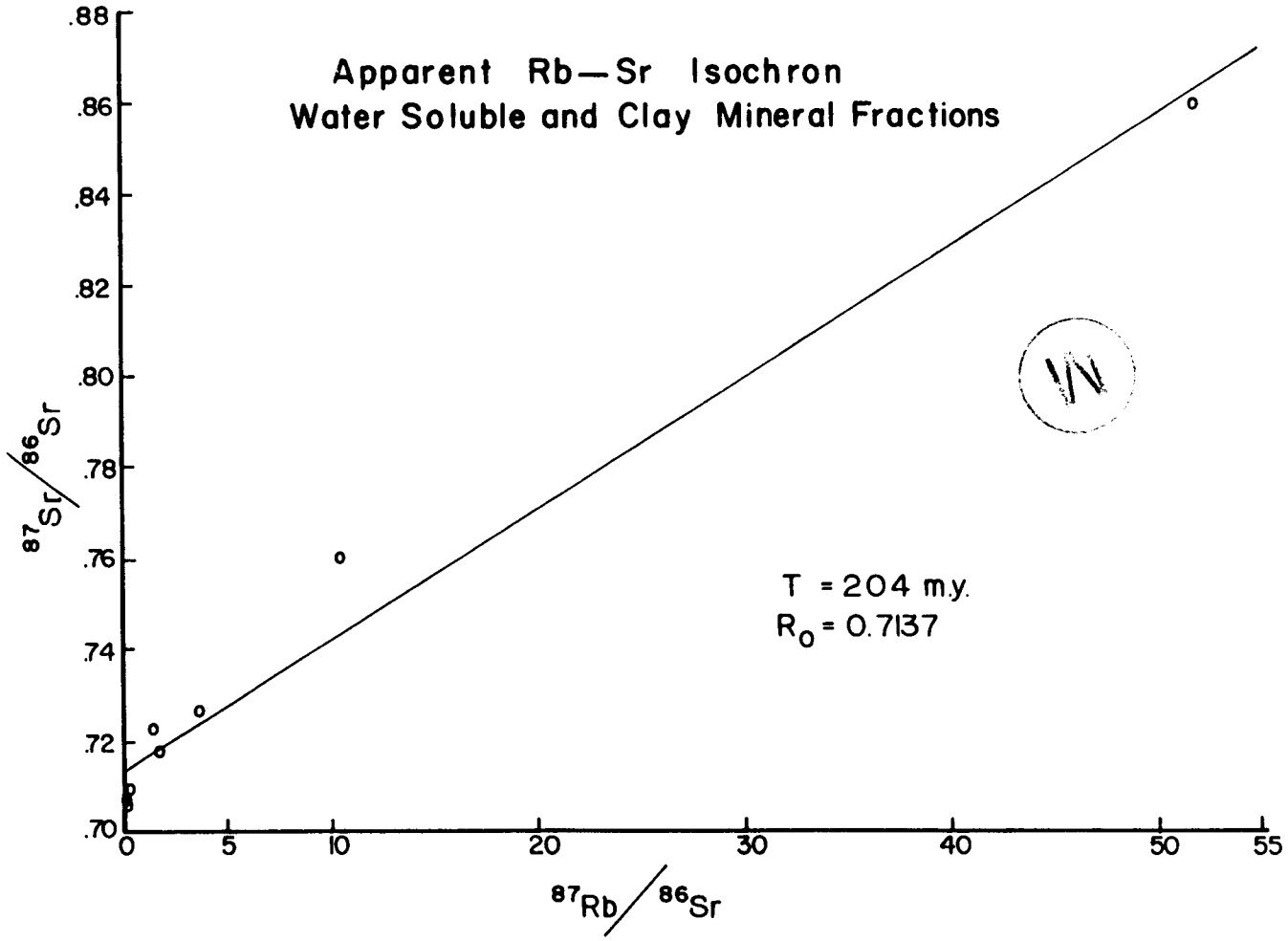

Apparent Rb–Sr Isochron
Composite of Whole Rock,
Water Soluble Fractions, and
Clay Minerals
T = 165 m.y.
R_0 = 0.7115
$^{87}Sr/^{86}Sr$
$^{87}Rb/^{86}Sr$
.88
.86
.84
.82
.80
.78
.76
.74
.72
.70
0
5
10
20
30
40
50
60
65

FIGURE 7.17


Apparent Rb—Sr Isochron
Water Soluble and Clay Mineral Fractions
T = 204 m.y.
R_o = 0.7137
$^{87}Sr/^{86}Sr$
$^{87}Rb/^{86}Sr$
.88
.86
.84
.82
.80
.78
.76
.74
.72
.70
0
5
10
20
30
40
50
55

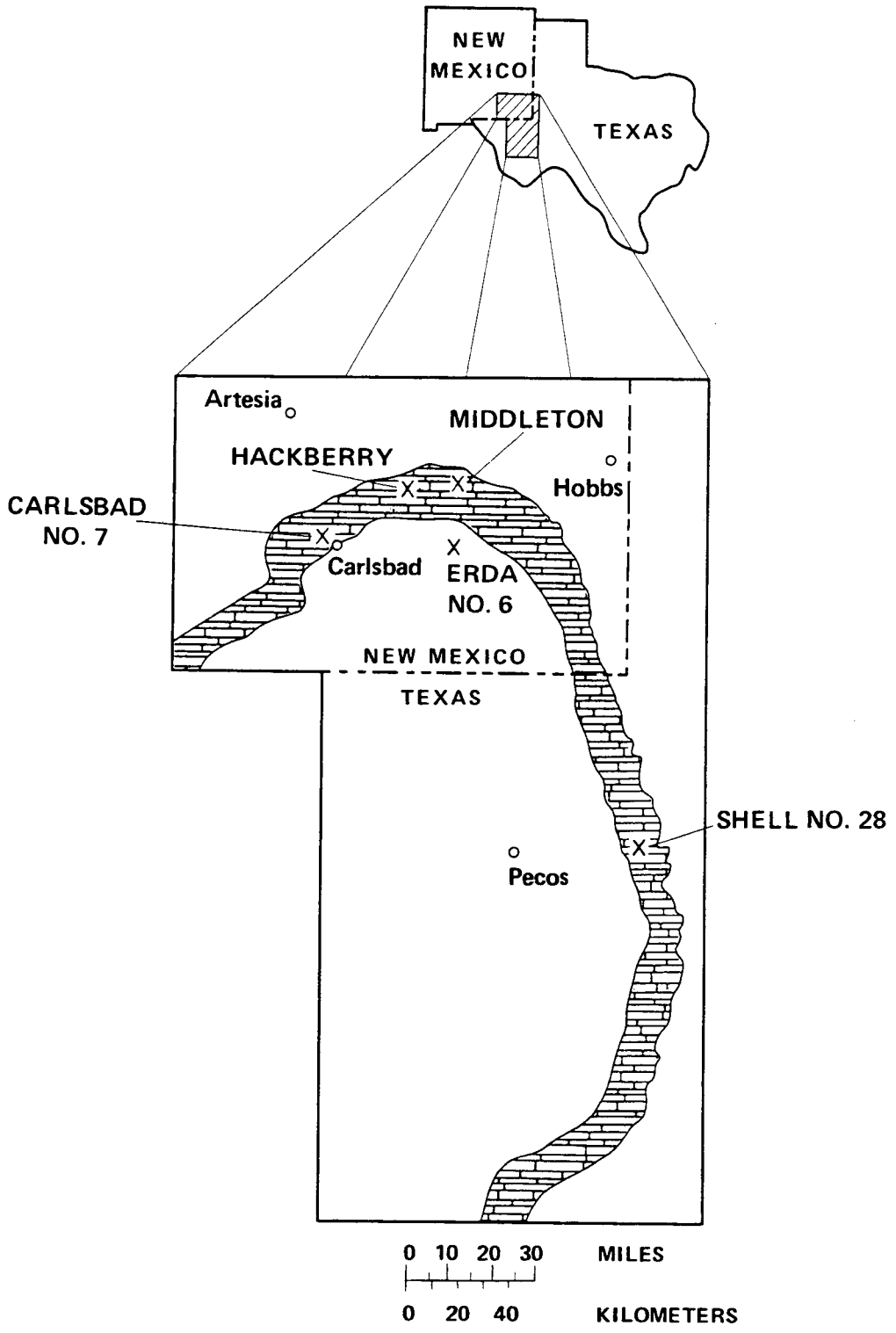


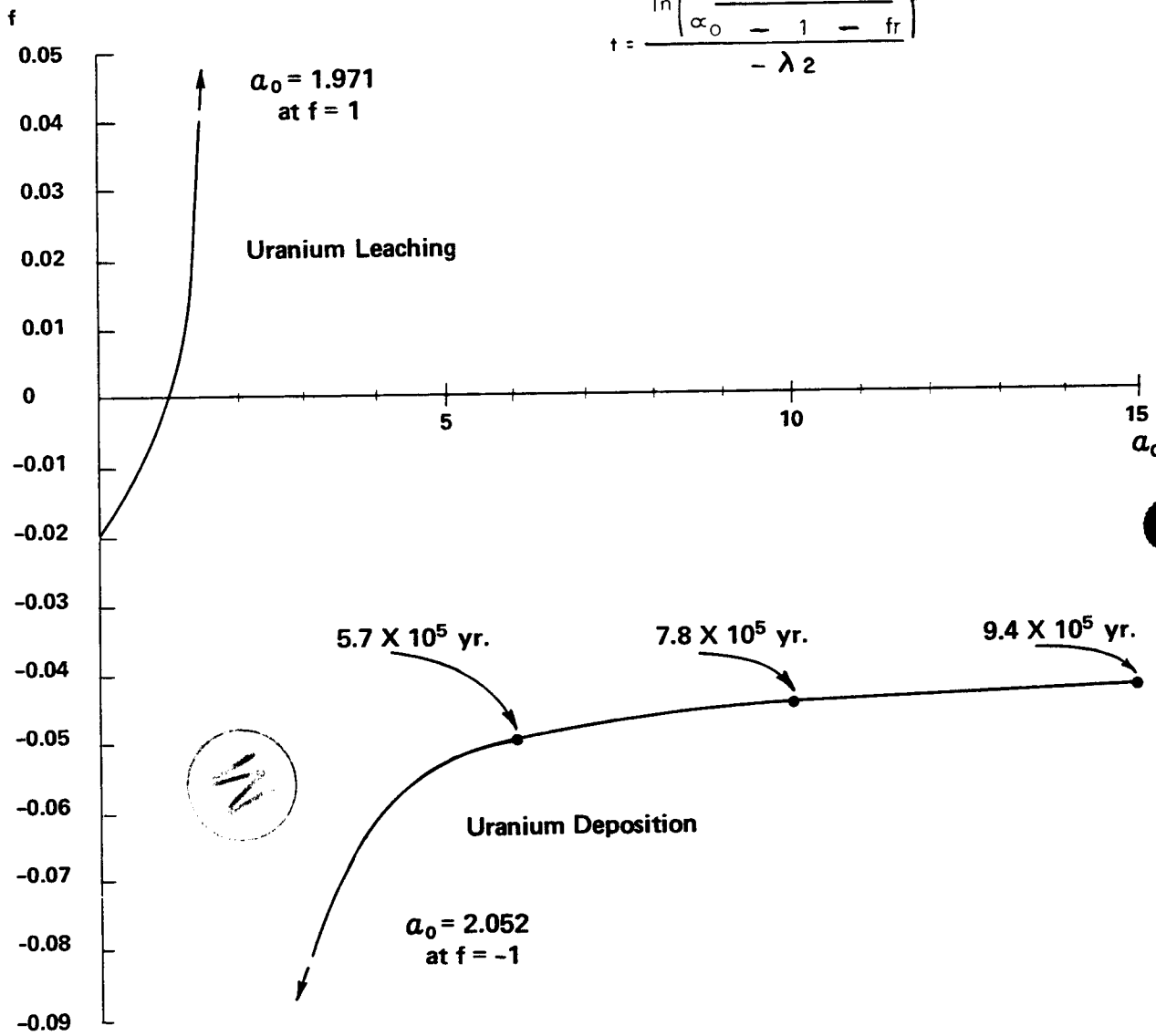
FIGURE 7.18 Map of a portion of the Delaware Basin (southeast New Mexico, west Texas) showing locations of holes whose fluids are sampled for $^{234}U/^{238}U$-disequilibrium age-dating. The brick-pattern shows the surface projection and outcrop of the capitan reef limestone. (from Hiss, 1975)

FIGURE 7.19 Graph of the equation $f = \frac{(\alpha_0 - 1)(\alpha_r - 1)}{\alpha_b - \alpha_0 + r(\alpha_r - 1)}$

for the ERDA No. 6 assemblage of rock and brine, in which r = 16.42, $\alpha_r = 1.04$, $\alpha_b = 1.35$.

Uranium disequilibrium ages for the brine are shown according to the equation

$$t = \frac{\ln\left(\frac{\alpha_b - 1 - fr}{\alpha_0 - 1 - fr}\right)}{-\lambda_2}$$



Note that the ERDA No. 6 assemblage is indicative of uranium deposition ($f < 0$) rather than uranium leaching.

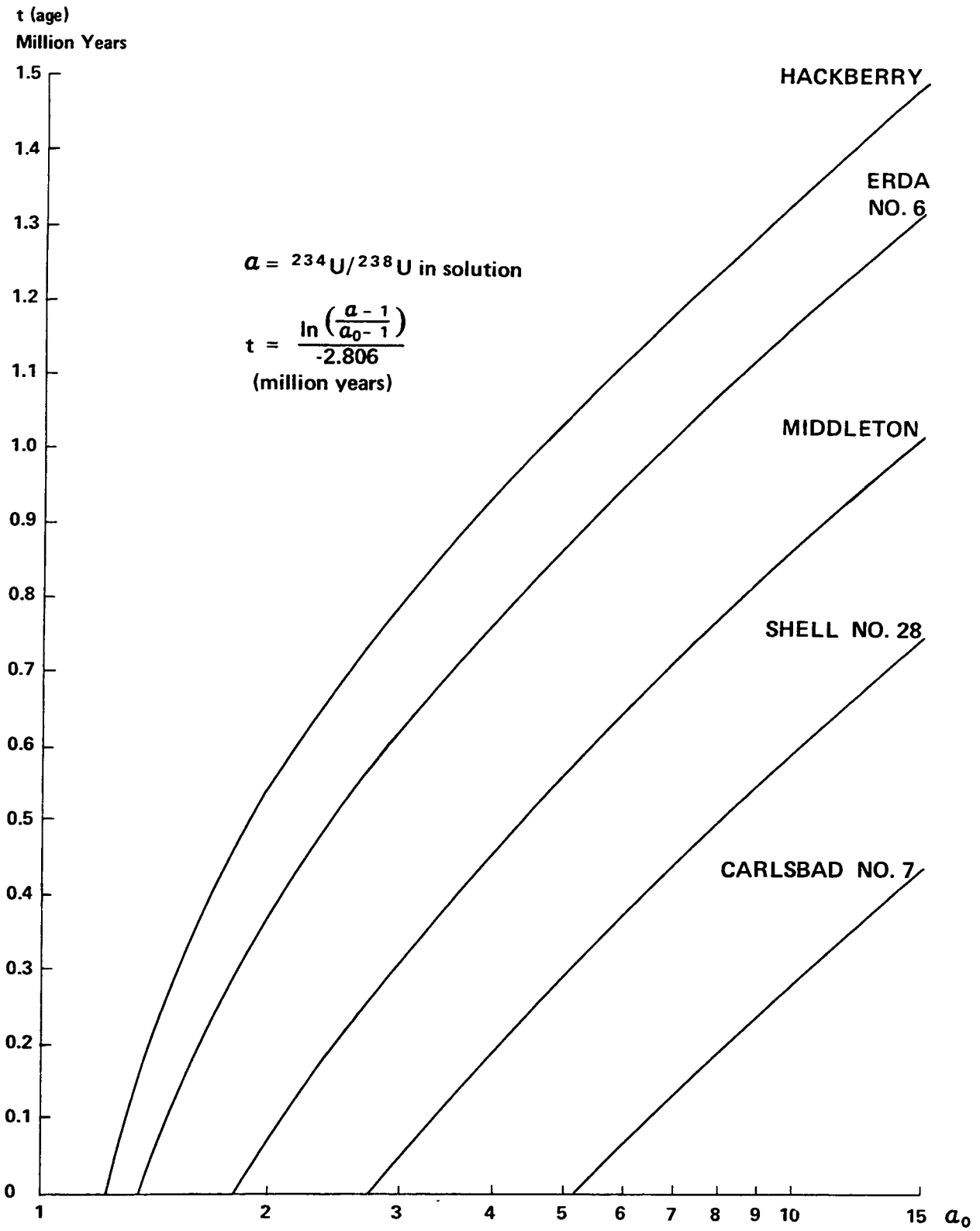


FIGURE 7.20 Uranium disequilibrium ages as a function of original $^{234}U/^{238}U$ ratio, for Delaware Basin groundwaters. These curves are derived from a model involving no exchange or uranium between rock and water.

TABLE 7.1. MINERAL CONTENT OF ERDA #9 CORE SAMPLES (M=MAJOR, T=TRACE).

ERDA 9
CORE #

(DEPTH IN FEET)	ANHYDRITE	CLAY	HALITE	LOEWEITE	MAGNESITE	POLYHALITE	QUARTZ	SYLVITE
1162.7	T	.	M	.	.	.	.	.
1165.7	M	.	M	.	.	.	.	.
1168.0	M	.	T	.	.	.	.	.
1168.8	.	.	M	.	.	.	.	.
1172.8	.	.	M	.	.	M	.	.
1173.4	M	.	.	.	M	.	T	.
1174.1	.	.	M	.	.	M	.	.
1405.7	.	.	M	.	T	.	.	.
1418.8	.	.	.	.	.	M	.	.
1584.0	.	.	M	.	.	.	.	.
1610.0	.	.	M	.	.	.	.	.
1632.4	M	.	.	.	M	.	.	.
1632.8	.	.	.	.	.	M	.	.
1648.5	.	.	M	T	.	.	.	.
2034.7	M	.	M	.	.	.	T	.
2035.7	T	.	M	.	.	.	.	T
2036.3	.	.	M	.	.	.	.	.
2065.0	.	.	M	.	.	.	.	.
2067.5	.	.	M	.	.	T	.	.
2302.6	M	.	T	.	.	M	.	.
2413.7	.	.	M	.	.	M	.	.
2414.2	.	.	M	.	.	M	.	.
2415.6	M	.	M	.	.	.	.	.
2512.0	M	.	M	.	.	.	.	.
2516.3	M	.	M	.	T	.	.	.
2518.8	M	.	.	.	.	.	.	.
2528.7	M	.	.	.	T	.	.	.
2529.0	M	.	T	.	.	.	.	.
2538.5	M	.	.	.	T	.	.	.

TABLE 7.1. MINERAL CONTENT OF ERDA #9 CORE SAMPLES (M=MAJOR, T=TRACE), continued

ERDA 9
CORE #

(DEPTH IN FEET)	ANHYDRITE	CLAY	HALITE	LOEWEITE	MAGNESITE	POLYHALITE	QUARTZ	SYLVITE
2541.0	.	.	M	.	.	.	.	.
2542.0	.	.	M	.	.	.	.	.
2593.2	M	.	.	.	.	.	.	.
2594.5	.	.	M	.	.	.	.	.
2597.0	T	.	M	.	.	.	.	.
2608.9	T	.	M	.	.	.	.	.
2614.7	.	.	M	.	.	.	.	.
2619.6	T	.	M	.	.	.	.	.
2658.5	M	.	M	.	.	.	.	.
2663.3	T	.	M	.	.	.	.	.
2696.4	M	.	M	.	T	.	.	.
2706.5	.	.	M	.	.	.	.	.
2711.9	T	.	M	.	T	.	.	.
2759.0	T	.	M	.	.	.	.	.
2768.5	M	T	M	.	.	.	.	.
2820.7	M	.	M	.	.	.	.	.
2820.6	T	.	M	.	.	.	.	.
2821.0	T	.	M	.	.	.	.	.
2826.5	T	.	M	.	.	.	.	.
2845.3	M	.	.	.	T	.	.	.
2848.8	M	.	.	.	.	.	.	.

TABLE 7.2

Size Distribution of Ground Samples

Mesh	% of Sample *
> 20	5.2
20-28	8.8
28035	19.9
35-65	57.0
65-100	6.1
100-200	2.9
< 200	0.2

*Total $\neq$ 100 due to rounding

TABLE 7.3

Listing of Minerals Named in Subsection 7.3

Mineral Name	Chemical Composition
Anhydrite	$CaSO_4$
Bloedite	$Na_2\ Mg(SO_4)_2 \cdot 4H_2O$
Carnallite	$K\ Mg\ Cl_3 \cdot 6\ H_2O$
Chlorite	$Mg_5Al_2Si_3O_{10}(OH)_8$
Glaserite	$K_3Na(SO_4)_2$
Glauberite	$Na_2Ca(SO_4)_2$
Gypsum	$CaSO_4 \cdot 2H_2O$
Halite	NaCl
Illite	$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$
Iron Oxides (FEOX)	$Fe_2O_3 \cdot XH_2O$
Kainite	$KMgCl\ SO_4 \cdot 11/4\ H_2O$
K-Feldspar	$K\ Al\ Si_3O_8$
Kieserite	$MgSO_4 \cdot H_2O$
Langbeinite	$K_2Mg_2\ (SO_4)_3$
Leonite	$K_2Mg(SO_4)_2 \cdot 4\ H_2O$
Montmorillonite	$Mg_{0.16}\ Al_{2.33}\ Si_{3.67}\ O_{10}(OH)_2$
Polyhalite	$K_2Mg\ Ca(SO_4)_4 \cdot 2\ H_2O$
Quartz	SiO_2
Sylvite	KCl
Talc	$Mg_3\ Si_4\ O_{10}\ (OH)_2$
Thenardite	$Na_2\ SO_4$

TABLE 7.4

ERDA No. 9 Samples Chosen for Silicate Mineralogy

Depth (ft)	Sample	Gross Lithology	Stratigraphic Position
1163.3-1163.6	MB-CS-18	Rock salt	SALADO Fm.
1165.1	MB-CS-16	Anhydrite	
1166.17	MB-CS-17	o Anhydrite	
1167.5	MB-CS-1	Anhydrite	
1168.31	MB-CS-6	Anhydrite w/ halite	
1169.4-1169.5	MB-CS-19	Rock salt	
1172.9	MB-CS-5	Polyhalite	
1173.7-1173.8	MB-CS-20	Rock salt	
1242.5	JL-CS-24	Rock salt	
1242.9-1243.1	JL-CS-18	Polyhalite w/ halite	
1243.6-1243.7	JL-CS-27	Polyhalite w/ halite	
1244.2-1244.5	JL-CS-15	Rock salt w/ polyhalite	
1244.5-1244.8	JL-CS-16	Polyhalite w/ halite and clay	
1244.8	JL-CS-12	o Clay	
1245.0-1245.3	JL-CS-20	Rock Salt	
1246.7-1247.1	JL-CS-21	Rock Salt	
1247.1-1247.2	JL-CS-5	o Clay	
1325.2-1325.4	JL-CS-10	o Polyhalite w/ anhydrite veins	
1327.0-1327.2	JL-CS-23	Polyhalite	
1327.7-1327.8	JL-CS-26	Polyhalite w/ halite	
1328.2-1328.4	JL-CS-25	Polyhalite w/ halite and clay	
1328.6	JL-CS-3	o Clay	
1328.7-1329.8	JL-CS-17	Rock Salt	

TABLE 7.4, continued

Depth (ft)	Sample		Gross Lithology	Stratigraphic Position
1404.6-1404.7	MB-CS-21		Rock Salt	11th ore zone
1418.2	MB-CS-7		Anhydrite with clay seam	
1418.6	MB-CS-8		Polyhalite	marker bed 117
1440.4-1440.6	JL-CS-2	o	Polyhalite w/ halite	
1441.0-1441.3	JL-CS-6	o	Polyhalite	
1441.7	JL-CS-4	o	Clay	
1466.4-1466.6	JL-CS-11	o	Polyhalite w/ clay	
1466.8-1467.1	JL-CS-9	o	Polyhalite w/ clay	
1467.7-1468.1	JL-CS-22		Rock salt w/ clay	
1468.1	JL-CS-14	o	Clay	
1535.6-1535.8	JL-CS-8		Polyhalite w/ anhydrite	
1536.5	JL-CS-7		Anhydrite	
1536.5-1536.6	JL-CS-19		Polyhalite w/ clay	
1537.8-1537.9	JL-CS-18	o	Polyhalite w/ anhydrite	
1584.4-1584.5	MB-CS-22		Rock salt	near 5th ore zone
1609.5-1609.8	MB-CS-23		Rock salt	
1649.4-1649.6	MB-CS-24		Rock salt	near 4th ore zone
2034.5	MB-CS-14		Anhydrite	
2035.6-2035.9	MB-CS-25		Rock salt	
2036.5-2036.7	MB-CS-26		Rock salt	
2037.3	MB-CS-4	o	Anhydrite	

TABLE 7.4, continued

Depth (ft)	Sample	Gross Lithology	Stratigraphic Position
2065.3-2065.4	MB-CS-29	Rock salt	
2066.1	MB-CS-28	Rock salt	
2067.0	MB-CS-27	o Rock salt	
2414.8	MB-CS-30	Rock salt	~16 ft above marker bed 143
2512.5	MB-CS-31	o Rock salt	
2517.9	MB-CS-12	Anhydrite)	
2518.3	MB-CS-13	o Anhydrite)	
		)	Cowden Anhydrite
2528.0	MB-CS-11	Anhydrite)	
2541.2-2541.9	MB-CS-32	o Rock salt	
2608.9-2609.5	MB-CS-33	Rock salt	
2615.9-2616.4	MB-CS-41	Rock salt	
2616.4-2616.8	MB-CS-34	Rock salt	
2617.2-2617.7	MB-CS-35	Rock salt	
2705.2-1705.6	MB-CS-37	Rock salt	
2705.8	MB-CS-10	o Rock salt	

TABLE 7.4, continued

Depth (ft)	Sample	Gross Lithology	Stratigraphic Position
2758.2-2758.6	MB-CS-36	o Rock salt	
2819.1-2819.6	MB-CS-39	o Rock salt	
2820.2	MB-CS-15	o Anhydrite	
2820.3	MB-CS-2	Anhydrite	
2821.1-2821.7	MB-CS-38	Rock salt	
2827.3-2827.5	MB-CS-40	o Rock salt	
			2829
2846.0	MB-CS-9	o Anhydrite	
2848.4	MB-CS-3	o Anhydrite	CASTILE Fm.
2867.4-2867.6	MB-CS-42	Anhydrite	

o Samples subjected to semi quantitative analysis (see Table 7.10).

TABLE 7.5

Core depths of samples selected for mineralogic-geochemical analysis.

Sample	Depth (ft)
MB-CS-1	1167.5
-2	2820.3
-3	2848.4
-4	2037.3
-5	1172.9
MB-CS-6	1168.3
-7	1418.2
-8	1418.6
-9	2846.0
-10	2705.8
MB-CS-11	2528.0
-12	2517.9
-13	2518.3
-14	2034.5
-15	2820.2
MB-CS-16	1165.1
-17	1166.2
-18	1163.3-1163.6
-19	1169.4-1169.5
-20	1173.7-1173.8
MB-CS-21	1404.6-1404.7
-22	1484.4-1584.5
-23	1609.5-1609.8
-24	1649.4-1649.6
-25	2035.6-2035.9
MB-CS-26	2036.5-2036.7
-27	2067.0
-28	2066.1
-29	2065.3
-30	2414.8

Sample	Depth (ft)
MC-CS-36	2758.2-2758.6
-37	2705.2-2705.6
-38	2821.1-2821.7
-39	2819.1-2818.6
-40	2827.3-2827.5
MC-CS-41	2615.9-2616.4
-42	2867.4-2867.6
JL-CS-1	1441.5
-2	1440.4-1440.6
-3	1328.6
-4	1441.7
-5	1247.1-1247.3
JL-CS-6	1441.0-1441.3
-7	1536.5
-8	1535.6-1535.8
-9	1466.8-1467.1
-10	1325.2-1325.4
JL-CS-11	1466.4-1466.6
-12	1244.8
-13	1467.5
-14	1468.1
-15	1244.2-1244.5
JL-CS-16	1244.5-1244.8
-17	1328.7-1329.8
-18	1537.8-1537.9
-19	1536.5-1536.6
-20	1245.0-1245.3

TABLE 7.5, continued

Core depths of samples selected for mineralogic-geochemical analysis.

Sample	Depth (ft)	Sample	Depth (ft)
MB-CS-31	2512.5	JL-CS-21	1246.7-1247.1
-32	2541.2-2541.9	-22	1467.7-1468.1
-33	2608.9-2609.5	-23	1327.0-1327.2
-34	2616.4-2616.8	-24	1242.5-1242.8
-35	2617.2-2617.7	-25	1328.2-1328.4
		JL-CS-26	1327.7-1327.8
		-27	1343.6-1343.7
		-28	1242.9-1243.1

TABLE 7.6

Quantities of water-leach and EDTA-leach residues in samples from the ERDA-9 core. Sulfate lithologies (anhydrites and polyhalites) and salztons were not subjected to water leach.

Hole Depth (ft)	Sample Number	Bulk wt. (g)	LEACH RESIDUES (Percent of bulk) WATER	EDTA	EDTA Residue wt. (g)	Lithology
1163.5	MB-CS-18	1820	0.005	neg	neg+	rock salt
1165.1	MB-CS-16	40	>90	0.11	.043	anhydrite
1166.2	MB-CS-17	1229	>90	0.20	2.33	anhydrite
1167.5	MB-CS-1	38	>90	0.074	0.027	anhydrite
1168.3	MB-CS-6	358	>75	0.23	0.81	anhydrite
1169.4	MB-CS-19	209	0.36	0.005	0.011+√	rock salt
1172.9	MB-CS-5	40	>90	0.13	0.050	polyhalite
1173.7	MB-CS-20	259	0.012	neg	neg+	rock salt
1242.5	JL-CS-24	655	1.89	*	*	rock salt
1242.9	JL-CS-28	200	>75	0.76	1.52	polyhalite
1243.6	JL-CS-27	200	>75	0.60	1.21	polyhalite
1244.4	JL-CS-15	537	0.013	0.003	0.018	rock salt
1244.6	JL-CS-16	400	>75	1.13	4.51	polyhalite
1244.8	JL-CS-12	#	>90	>90	8.40	salzton
1245.1	JL-CS-20	400	6.18	1.15	4.60	rock salt
1246.8	JL-CS-21	747	0.21	*	*	rock salt
1247.2	JL-CS-5	#	>90	>90	2.70	salzton
1325.3	JL-CS-10	641	29.8	0.26	1.68	rock salt
1327.0	JL-CS-23	350	>75	0.25	0.89	polyhalite
1327.8	JL-CS-26	200	>75	0.30	0.61	polyhalite
1328.3	JL-CS-25	200	>75	1.13	2.26	polyhalite
1328.6	JL-CS-3	#	>90	>90	1.46	salzton
1328.7	JL-CS-17	1765	0.18	0.12	2.09	rock salt

TABLE 7.6, continued

Hole Depth (ft)	Sample Number	Bulk wt. (g)	LEACH RESIDUES (Percent of bulk) WATER	EDTA	EDTA Residue wt. (g)	Lithology
1404.6	MB-CS-21	244	2.5	1.0	2.43	rock salt
1418.2	MB-CS-7	40	>90	20.80	8.32	anhydrite
1418.6	MB-CS-8	1120	>90	0.62	6.94	polyhalite
1440.5	JL-CS-2	200	>75	0.83	1.66	polyhalite
1441.2	JL-CS-6	600	>75	0.13	0.80	polyhalite
1441.7	JL-CS-4	#	>90	>90	2.92	salzton
1466.5	JL-CS-11	400	>75	0.42	1.67	polyhalite
1466.9	JL-CS-9	200	>75	3.99	7.97	polyhalite
1467.9	JL-CS-22	860	4.17	1.22	10.5	rock salt.
1468.1	JL-CS014	#	>90	>90	3.30	saltzon
1535.7	JL-CS-8	400	>75	0.44	1.76	polyhalite
1536.5	JL-CS-7	320	>75	2.63	8.41	anhydrite
1536.6	JL-CS-19	360	>75	0.37	1.33	polyhalite
1537.8	JL-CS-18	400	>75	0.55	2.19	polyhalite
1584.4	MB-CS-22	248	0.53	0.42	1.20+√	rock salt
1609.6	MB-CS-23	473	0.037	0.017	0.081	rock salt
1649.5	MB-CS-24	176	1.6	1.1	1.90+√	rock salt
2034.5	MB-CS-14	104	>90	3.9	4.07	anhydrite
2035.7	MB-CS-25	891	0.23	0.009	0.078+√	rock salt
2036.6	MB-CS-26	810	0.23	0.025	0.20+√	rock salt
2073.3	MB-CS-4	145	>90	5.0	7.28	anhydrite
2065.3	MB-CS-29	1085	0.18	0.11	1.17+√	rock salt
2066.1	MB-CS-28	220	3.3	1.5	3.38	rock salt
2067.0	MB-CS-27	229	2.8	0.83	1.90	rock salt
2414.8	MB-CS-30	421	36.3	0.049	0.21	rock salt

TABLE 7.6, continued

Hole Depth (ft)	Sample Number	Bulk wt. (g)	LEACH RESIDUES (Percent of bulk) WATER	EDTA	EDTA Residue wt. (g)	Lithology
2512.5	MB-CS-31	1073	1.79	0.074	0.074	rock salt
2517.9	MB-CS-12	40	>90	0.024	0.010+	anhydrite
2518.3	MB-CS-13	586	>90	0.55	3.20	anhydrite
2528.0	MB-CS-11	40	>90	0.23	0.094	anhydrite
2541.5	MB-CS-32	891	0.70	0.21	1.83	rock salt
2609.2	MB-CS-33	901	0.043	0.015	0.14+✓	rock salt
2616.2	MB-CS-41	811	0.165	0.076	0.62+✓	rock salt
2616.6	MB-CS-34	660	0.071	0.004	0.027+✓	rock salt
2617.5	MB-CS-35	1015	1.17	0.18	1.83	rock salt
2705.4	MB-CS-37	638	13.3	0.65	4.14	rock salt
2705.8	MB-CS-10	450	>90	2.2	9.87	anhydrite
2758.4	MB-CS-36	421	6.6	0.77	3.25	rock salt
2819.3	MB-CS-39	982	2.2	0.27	2.65	rock salt
2820.2	MB-CS-15	520	>90	0.82	4.25	anhydrite
2820.3	MB-CS-2	640	>90	0.59	3.79	anhydrite
2821.4	MB-CS-38	916	1.25	0.039	0.36	rock salt
2828.7	MB-CS-40	920	1.22	0.13	1.17	rock salt
2846.0	MB-CS-9	200	>90	1.2	2.45	anhydrite
2848.4	MB-CS-3	656	>90	0.90	5.93	anhydrite
2867.5	MB-CS-42	240	>90	0.85	2.04	anhydrite

* Water-leach and EDTA-leach dissolutions of this sample not complete.
[illegible]ample is hand-picked fragment of saltzto[illegible]
[illegible]eported as containing "negligible insol[illegible]e residue" Table 7.7.
[illegible] A subsequent second dissolution of a substantially greater quantitiy of

TABLE 7.7

Relative Abundances of minerals in EDTA-insoluble residues.

Sample	Depth (ft)	EDTA-insoluble residue qtz	feld	hem	clay	<2 μm fraction of residue il	ch	serp	talc	exp
MB-CS-18	1163.5	Negligible insoluble residue								
MB-CS-16	1165.1	XX	--	--	X	X	a	--	--	XX
MB-CS-17	1166.2	XX	x	--	XX	x	a	--	--	XX
MB-CS-1	1167.5	--	--	--	XX	X	--	--	--	XX
MB-CS-6	1168.3	XX	x	--	XX	x	a	--	--	XX
MB-CS-19	1169.4	Negligible insoluble residue								
MB-CS-5	1172.9	XX	--	--	x	x	--	--	--	XX
MB-CS-20	1173.7	Negligible insoluble residue								
JL-CS-12	1244.8	XX	x	--	XX	X	X	--	--	X
JL-CS-5	1247.2	XX	x	--	XX	XX	X	--	--	X
JL-CS-10	1325.3	a	--	--	XX	--	--	--	--	XX
JL-CS-3	1328.6	XX	X	--	XX	X	X	--	--	X

TABLE 7.7, continued

Relative Abundances of minerals in EDTA-insoluble residues (cont'd).

	Depth	EDTA-insoluble residue				< 2 μm fraction of residue				
Sample	(ft)	qtz	feld	hem	clay	il	ch	serp	talc	exp
MB-CS-21	1404.6	XX	a	--	XX	x	x	--	X	XX
MB-CS-7	1418.2	--	x	--	XX	XX	X	--	--	X
MB-CS-8	1418.6	--	a	x	XX	x	x	--	--	XX
JL-CS-2	1440.5	X	XX	a	XX	a	a	--	--	XX
JL-CS-6	1441.2	X	XX	X	XX	XX	X	--	--	X
JL-CS-4	1441.7	--	X	--	XX	XX	X	--	--	X
JL-CS-11	1466.5	--	x	X	XX	XX	X	--	--	X
JL-CS-9	1466.9	XX	x	x	X	XX	X	--	--	XX
JL-CS-14	1468.1	X	X	--	XX	XX	X	--	--	XX

TABLE 7.7, continued

Relative Abundances of minerals in EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	EDTA-insoluble residue				< 2 μm fraction of residue				
		qtz	feld	hem	clay	il	ch	serp	talc	exp
JL-CS-8	1535.7	--	X	x	XX	XX	x	--	--	XX
JL-CS-7	1536.5	a	--	--	XX	--	--	--	--	XX
JL-CS-18	1537.8	X	--	x	XX	XX	x	--	--	X
MB-CS-22	1584.4	Negligible insoluble residue								
MB-CS-23	1609.6	XX	X	x	XX	XX	X	--	--	XX
MB-CS-24	1649.5	Negligible insoluble residue								
MB-CS-14	2034.5	XX	--	--	x	x	x	--	--	XX
MB-CS-25	2035.7	Negligible insoluble residue								
MB-CS-26	2036.6	Negligible insoluble residue								
MB-CS-4	2037.3	XX	--	--	X	x	x	--	--	XX

TABLE 7.7, continued

Relative Abundances of minerals in EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	EDTA-insoluble residue qtz	feld	hem	clay	< 2 μm fraction of residue il	ch	serp	talc	exp
MB-CS-29	2065.3	Negligible insoluble residue								
MB-CS-28	2066.1	XX	a	--	XX	a	a	--	--	XX
MB-CS-27	2067.0	XX	X	x	XX	x	x	--	--	XX
MB-CS-30	2414.8	XX	X	--	X	a	x	--	--	XX
MB-CS-31	2512.5	X	--	a	XX	x	x	--	--	XX
MB-CS-13	2518.3	X	x	--	XX	a	a	--	--	XX
MB-CS-11	2528.0	--	--	--	XX	--	--	--	--	XX
MB-CS-32	2541.5	X	a	--	XX	X	X	--	--	XX

TABLE 7.7, continued

Relative Abundances of minerals in EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	EDTA-insoluble residue qtz	feld	hem	clay	< 2 μm fraction of residue il	ch	serp	talc	exp
MB-CS-33	2609.2	Negligible insoluble residue								
MB-CS-41	2616.2	Negligible insoluble residue								
MB-CS-34	2616.6	Negligible insoluble residue								
MB-CS-35	2617.5	XX	X	a	XX	XX	X	--	--	XX
MB-CS-37	2705.4	XX	X	a	X	XX	X	--	--	XX
MB-CS-10	2705.8	XX	X	a	X	X	x	--	--	XX
MB-CS-36	2758.4	XX	X	a	X	XX	X	--	--	XX

TABLE 7.7, continued

Relative Abundances of minerals in EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	EDTA-insoluble residue				< 2 μm fraction of residue				
		qtz	feld	hem	clay	il	ch	serp	talc	exp
MB-CS-39	2819.3	XX	X	--	X	XX	x	--	--	XX
MB-CS-15	2820.2	XX	--	--	XX	--	a	--	XX	X
MB-CS-2	2820.3	a	X	--	XX	XX	--	--	--	XX
MB-CS-38	2821.4	--	--	--	XX	--	--	XX	--	XX
MB-CS-40	2827.4	--	--	--	XX	--	--	XX	--	XX
MB-CS-9	2846.0	a	--	a	XX	--	--	XX	--	XX
MB-CS-3	2848.4	--	--	--	XX	--	--	X	--	XX

TABLE 7.7, continued

Relative Abundances of minerals in EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	EDTA-insoluble residue qtz	feld	hem	clay	< 2 μm fraction of residue il	ch	serp	talc	exp
MB-CS-42	2867.5	--	--	--	XX	--	x	X	--	X

Minerals: qtz = quartz; feld = feldspar; hem = hematite; il = illite; ch = chlorite; serp = serpentine; exp = expandable (smectite-bearing).

Relative abundances: XX = dominant constituent; X = major constituent; x = minor constituent; a = accessory constituent. All abundances based on relative intensities of major diffraction maxima.

TABLE 7.8

Low-angle diffraction maxima (Å) of expandable clays in the < 2 μ m fraction of the EDTA-insoluble residues.

Sample	Depth (ft)	Air-dried	Glycol-saturated	375°C (> 1hr)	500°C (> 1hr)
MB-CS-16	1165.1	14.5	n.d.	n.d.	n.d.
MB-CS-17	1166.2	13.8, 30.5	15.5, 32.7	13.8, (29.4)	13.6, (25.2)
MB-CS-1	1167.5	14.5	n.d.	n.d.	n.d.
MB-CS-6	1168.3	14.5, (25.2)	15.5, (35.3)	13.6, 31.6	13.2, 11.8, (27.6)
MB-CS-5	1172.9	14.3	n.d.	n.d.	n.d.
JL-CS-16	1244.6	13.8, 29.4	15.5, 11.2, 31.6	n.d.	n.d.
JL-CS-12	1244.8	13.6, 29.4	15.5, 31.5	13.6	13.2
JL-CS-20	1245.1	13.8, (30.5)	15.5, 34.0	n.d.	n.d.
JL-CS-5	1247.2	14.5, 30.5	15.5, 11.2, 31.6	14.3	13.6
JL-CS-10	1325.3	10.2	10.4, (12.1)	9.8	9.8, 11.0-11.9
JL-CS-3	1328.6	14.0, 30.5	15.5, 11.2, 31.6	14.5, (31.6)	12.6-14.7, (22.21)
MB-CS-21	1404.6	13.8, 31.6	15.8, 34.0	13.8, (32.7)	13.4, (29.4)
MB-CS-7	1418.2	13.8, (30.5)	n.d.	n.d.	n.d.
MB-CS-8	1418.6	13.4	15.5, (34.0)	13.6, (27.6)	11.6, (27.6)

TABLE 7.8, continued

Low-angle diffraction maxima (Å) of expandable clays in the < 2 μm fraction of the EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	Air-dried	Glycol-saturated	375°C (> 1hr)	500°C (> 1hr)
JL-CS-2	1440.5	10.3	10.2, 11.8	9.8	n.d.
JL-CS-6	1441.2	10.7, 13.6, (29.4)	11.3, 15.5, (31.6)	10.2, 13.0-14.3	10.0
JL-CS-4	1441.7	13.8, 31.6	15.5, 31.6	13.8, (29.4)	13.2
JL-CS-11	1466.5	13.8, 11.2, (30.5)	15.2, (32.7)	13.6, (26.0)	n.d.
JL-CS-9	1466.9	14.7	16.1	13.8	13.8
JL-CS-22	1467.9	14.1, 31.6	15.5, 34.0	n.d.	n.d.
JL-CS-14	1468.1	13.6, 30.5	15.5, 32.7	13.6	13.2
JL-CS-8	1535.7	10.3, 13.6	9.4, 11.5, 16.1	9.8, 13.6	9.7
JL-CS-7	1536.5	10.3	9.3, 11.3	9.9	9.8
JL-CS-18	1537.8	14.3, 32.7	15.8, 34.0	n.d.	n.d.
MB-CS-23	1609.6	12.3	n.d.	n.d.	n.d.
MB-CS-14	2034.5	13.8, 30.5	15.2, 31.6	14.0, 11.9, (31.6)	11.9, 13.2, 29.4
MB-CS-4	2037.3	13.5	15.5, 31.6	13.2, (28.5)	13.0

TABLE 7.8, continued

Low-angle diffraction maxima (Å) of expandable clays in the < 2 μ m fraction of the EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	Air-dried	Glycol-saturated	375°C (> 1hr)	500°C (> 1hr)
MB-CS-28	2066.1	14.5, 30.5	15.5, 31.6	14.0, (29.4)	13.6, (30.5, 22.1)
MB-CS-27	2067.0	14.7, 29.4	16.7, 32.7	14.0, (29.4)	12.6, (26.0)
MB-CS-30	2414.8	13.8, 11.8, (29.4)	15.8, 12.8, (31.6)	13.8, 11.6, (24.5)	11.6, (26.0)
MB-CS-31	2512.5	12.6	n.d.	n.d.	n.d.
MB-CS-12	2517.9	12.8, 31.6	15.5, 31.6	n.d.	n.d.
MB-CS-13	2518.3	12.6, 26.0	17.0, 25.2	13.2, (26.8)	12.3, 10.3, 26.0
MB-CS-11	2528.0	13.2	n.d.	n.d.	n.d.
MB-CS-32	2541.5	13.8, 29.4	15.5, 31.5	13.4, (26.8)	14.2, (31.6)
MB-CS-35	2617.5	13.8, (29.4)	16.7, 32.7	13.8, (26.8)	12.6, 27.6
MB-CS-37	2705.4	14.5, 30.5	16.4, 34.0	13.8, (29.4)	12.5
MB-CS-10	2705.8	13.4	16.7, (35.3)	14.3, (30.5)	14.3, 11.8, (27.6)
MB-CS-36	2758.4	14.0, 29.4	16.4, 32.7	13.8, (29.4)	12.5, (29.4)

TABLE 7.8, continued

Low-angle diffraction maxima (Å) of expandable clays in the < 2 μm fraction of the EDTA-insoluble residues (cont'd).

Sample	Depth (ft)	Air-dried	Glycol-saturated	375°C (> 1hr)	500°C (> 1hr)
MB-CS-39	2819.3	14.5, 29.4	16.1, 31.6	14.5	13.6, (22.0)
MB-CS-15	2820.2	11.6, (26.8)	14.7, (27.6)	11.6, (24.5)	11.6, (26.8)
MB-CS-2	2820.3	14.5	----	10.4	9.8-17.7
MB-CS-38	2821.4	14.7	----	13.8	13.8
MB-CS-40	2827.4	14.7, 11.3	17.0	14.7	n.d.
MB-CS-9	2846.0	12.3, (24.5)	17.0, (28.5)	10.0 - 13.6, (29.4)	13.4
MB-CS-3	2848.4	12.3, (24.5)	17.3, (27.6)	12.63, (27.6)	11.6, (24.5)
MB-CS-42	2867.5	11.8	17.7	14.7	----

n.d. - data not yet determined

Values in parentheses, e.g. (30.5) represent diffraction maximum present only as shoulder.

TABLE 7.9

Mineralogy of Duval Mine Samples
4th Ore Zone

A. Evaporites

Mine Wall Samples	Halite	Sylvite	Polyhalite	Langbeinite
DV-1A	t	-	VA	-
DV-1B	VA	VA	-	-
DV-1C	VA	-	VA	t
DV-1D	VA	VA	t	-
DV-2A	A	VA	-	t
DV-2B	VA	-	A	-
DV-4A	A	-	VA	t
DV-4B	VA	-	-	-
DV-4C	VA	-	-	t
DV-4D	VA	-	-	t
DV-4E	t	t	-	VA
DV-5A	VA	-	-	-
DV-5B	VA	A	t	-

B. 2 Micron Fractions (Silicates)

Mine Wall Samples	Chlorite	Saponite	Chlorite-Saponite	Illite	Talc	Serpentine	Insoluble Residue (Wt. %)
DV-4B	t	-	VA	VA	t	A	15.7
DV-4C	-	-	VA	VA	t	A	12.3
DV-4D	t	t	VA	A	-	t	32.3
DV-5A	t	t	VA	A	t	A	10.3

VA : very abundant
A : abundant
t : tract
- : not detected

TABLE 7.10

Semiquantitive* chemical analysis of EDTA-insoluble fractions from ERDA-9 core.

	MB-CS-17	JL-CS-12	JL-CS-5	JL-CS-10	JL-CS-3	JL-CS-2	JL-CS-6	JL-CS-4
Depth (ft)	1166.2	1244.8	1247.1	1325.3	1328.6	1440.5	1441.2	1441.7
Lithology+	Anhydr.	Clay	Clay	Polyhal.	Clay	Polyhal.	Polyhal.	Clay
Weight Percent								
SiO_2	59.	50.	50.	59.	52.	56.	45.	38.
TiO_2	.8	.9	1.2	.2	1.4	.4	.7	1.4
Al_2O_3	12.	13.	15.	12.	15.	6.2	2.5	18.
FeO@	1.2	2.4	3.8	1.3	3.2	5.3	14.	4.5
MgO	20.	25.	20.	32.	18.	20.	15.	19.
CaO	.01	.01	.04	.002	.008	.02	.03	.06
Na_2O	1.2	1.2	1.0	1.0	.5	2.4	1.4	1.6
K_2O	1.8	2.3	3.0	.3	3.3	2.9	2.0	4.6

TABLE 7.10, continued

Semiquantitive* chemical analysis of EDTA-insoluble fractions from ERDA-9 core.

	MB-CS-17	JL-CS-12	JL-CS-5	JL-CS-10	JL-CS-3	JL-CS-2	JL-CS-6	JL-CS-4
Depth (ft)	1166.2	1244.8	1247.1	1325.3	1328.6	1440.5	1441.2	1441.7
Lithology+	Anhydr.	Clay	Clay	Polyhal.	Clay	Polyhal.	Polyhal.	Clay
Atom Proportions (al = 1.0)								
Si	4.2	3.2	2.9	4.3	3.0	7.6	15.	1.8
Ti	.04	.04	.05	.01	.06	.04	.2	.05
Al	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fe	.07	.13	.18	.08	.15	.61	4.0	.17
Mg	2.1	2.3	1.7	3.5	1.6	4.0	7.4	1.3
Na	.16	.15	.11	.14	.06	.64	92	.14
K	.16	.19	.22	.03	.24	.51	.87	.27

TABLE 7.10, continued

Semiquantitive* chemical analysis of EDTA-insoluble fractions from ERDA-9 core.

	JL-CS-11	JL-CS-9	JL-CS-14	JL-CS-18	MB-CS-4	MB-CS-27	MB-CS-31	MB-CS-13
Depth (ft)	1466.5	1467.0	1468.1	1537.8	2037.3	2067.0	2512.5	2518.3
Lithology+	Polyhal.	Polyhal.	Clay	Polyhal.	Anhydr.	Halite	Halite	Anhydr.
Weight Percent								
SiO_2	34.	42.	41.	43.	54.	65.	41.	54.
TiO_2	.6	.6	1.2	.6	.8	1.0	.9	.4
Al_2O_3	10.	9.0	14.	8.8	12.	14.	14.	7.0
FeO@	23.	3.7	3.3	8.2	3.7	4.7	N.D.	2.1
MgO	19.	29.	22.	21.	21.	9.3	18.	22.
CaO	.005	.005	.001	.03	.002	.02	.02	.04
Na_2O	1.3	.4	1.6	1.2	1.0	3.9	2.2	2.7
K_2O	2.9	2.6	4.1	2.0	1.5	4.1	2.6	2.5

TABLE 7.10, continued

Semiquantitive* chemical analysis of EDTA-insoluble fractions from ERDA-9 core.

	JL-CS-11	JL-CS-9	JL-CS-14	JL-CS-18	MB-CS-4	MB-CS-27	MB-CS-31	MB-CS-13
Depth (ft)	1466.5	1467.0	1468.1	1537.8	2037.3	2067.0	2512.5	2518.3
Lithology+	Polyhal.	Polyhal.	Clay	Polyhal.	Anhydr.	Halite	Halite	Anhydr.
Atom proportions (Al = 1.0)								
Si	2.9	3.9	2.5	4.2	4.0	3.9	2.5	6.2
Ti	.04	.04	.05	.04	.04	.04	.04	.03
Al	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fe	1.7	.29	.17	.66	.23	.23	--	.20
Mg	2.4	4.0	2.0	3.1	2.3	.83	1.7	3.8
Na	.21	.07	.19	.22	.14	.45	.26	.60
K	.31	.31	.32	.25	.14	.31	.21	.37

TABLE 7.10, continued

Semiquantitive* chemical analysis of EDTA-insoluble fractions from ERDA-9 core.

	MB-CS-32	MB-CS-10	MB-CS-36	MB-CS-39	MB-CS-15	MB-CS-40	MB-CS-9	MB-CS-3
Depth (ft)	2541.5	2705.8	2758.4	2819.3	2820.2	2827.4	2846.0	2848.4
Lithology+	Halite	Halite	Halite	Halite	Anhydr.	Halite	Anhydr.	Anhydr.
Weight Percent								
SiO_2	37.	61.	70.	67.	52.	33.	42.	44.
TiO_2	.8	.8	.8	.8	.1	.3	.2	.2
Al_2O_3	13.	12.	12.	12.	3.4	5.0	3.1	3.6
FeO@	3.4	4.4	3.4	3.3	.7	1.4	2.6	1.5
MgO	30.	17.	11.	13.	33.	29.	35.	37.
CaO	.002	.01	.1	.06	.007	1.0	.003	.003
Na_2O	1.0	2.9	2.3	2.1	1.6	.9	2.6	1.9
K_2O	1.7	1.8	1.4	1.8	.6	.9	3.3	.7

TABLE 7.10, continued

Semiquantitive* chemical analysis of EDTA-insoluble fractions from ERDA-9 core.

	MB-CS-32	MB-CS-10	MB-CS-36	MB-CS-39	MB-CS-15	MB-CS-40	MB-CS-9	MB-CS-3
Depth (ft)	2541.5	2705.8	2758.4	2819.3	2820.2	2827.4	2846.0	2848.4
Lithology+	Halite	Halite	Halite	Halite	Anhydr.	Halite	Anhydr.	Anhydr.
Atom proportions (Al = 1.0)								
Si	2.5	4.5	5.1	4.7	13.	5.6	11.	10.
Ti	.04	.04	.04	.04	.02	.04	.04	.04
Al	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fe	.19	.27	.21	.19	.15	.20	.59	.30
Mg	2.8	1.8	1.2	1.3	12.	7.3	14.	13.
Na	.13	.41	.33	.29	.77	.30	1.4	.87
K	.15	.17	.13	.16	.19	.19	1.1	.21

* Calculated from 1:1 linear regression; matrix effects and other than unit regression slope not yet included.

\+ Anhydr. = anhydrite; polyhal. = polyhalite.

@ Total iron as FeO.

TABLE 7.11

Mineralogy of Cores from ERDA No. 9

Core Footage	Gross Lithology (listed in decreasing order of abundance, lower case indicates (trace amount)	Bulk Mineralogy by X-ray Diffraction
1168.1	Anhydrite Halite Magnesite	Anhydrite Magnesite
1168.55	Anhydrite Halite Polyhalite	Anhydrite Halite Polyhalite
1173.5	Halite "Brown Material"	Halite Polyhalite trace 12A° (expandable) clay
1173.5	silty claystone or anhydrite	Anhydrite Polyhalite
1584.4	Halite "brown material" anhydrite	Halite polyhalite
1649.7	Halite polyhalite anhydrite	Halite polyhalite
2066.8	Halite '"brown material"	Halite Anhydrite quartz magnesite trace 10A° clay (illite) trace 14A° clay (chlorite)

TABLE 7.11, continued

Mineralogy of Cores from ERDA No. 9

Core Footage	Gross Lithology (listed in decreasing order of (trace	Bulk Mineralogy by X-ray Ditfraction abundance, lower case indicates amount)
2067.4	see 2066.8	Halite polyhalite quartz? trace 12A° (expandable) clay
2302	Polyhalite "White Material"	Anhydrite Polyhalite
2414.7	Polyhalite Halite Anhydrite	Halite Polyhalite
2415.0	see 2414.7	Polyhalite Anhydrite
2415.4	see 2414.7	Anhydrite
2529.5	Anhydrite magnesite?	Anhydrite Halite Magnesite
2538.5	Anhydrite Halite	Anhydrite Halite
2619.5	Halite anhydrite or magnesite	Halite Anhydrite
2820 B	Anhydrite Halite magnesite	Anhydrite Halite

BLE 7.12

Weight Losses Observed Upon Heating of ERDA No. 9 Cores

Specimen No. (depth)	Total Weight-Loss (%)	Mass-Loss (%) At Mean Temperature Ranges		
		100°C	300°C	450°
2034.7	1.60	0.70	0.36	.057
2035.7	0.20	----	----	----
2065.0	0.35	----	----	----
2067.5	0.52	----	----	----
2302.6	5.40	----	5.10	0.17
2413.7	1.38	----	1.00	----
2414.2	3.13	----	2.90	----
2415.6	0.10	----	----	----
2512.0	0.14	----	----	----
2516.3	2.15	----	----	1.55
2518.8	0.32	----	----	----
2528.7	2.12	----	----	1.52
2529.0	3.12	----	----	2.94
2538.5	1.55	----	----	1.20
2542.0	6.39	----	6.19	0.20
2593.2	1.47	----	----	1.20
2594.5	0.36	----	----	----
2597.0	0.37	----	----	----
2608.9	0.17	----	----	----
2614.4	0.13	----	----	----
2619.6	0.22	----	----	----
2658.5	0.48	----	0.10	0.17
2663.3	0.50	----	----	0.29
2696.4	1.12	----	----	0.80
2706.5	0.37	----	----	----
2711.9	0.47	----	----	0.21
2759.0	0.28	----	----	----
2786.5	3.64	2.27	----	0.90
2820.7A	0.36	----	----	0.17
2820.6B	0.35	----	----	0.12
2821.0	0.40	----	0.19	----
2826.5	0.36	----	0.27	----
2845.3	1.42	----	----	1.21
2848.8	0.86	----	----	0.53

TABLE 7.13

Data on the volume percent of fluid now present in the salt cores from ERDA No. 9.

Depth interval (feet)	Type Sampled	Volume sampled (mm^3)	Approx. grain size (mm)	Fraction of total slide	Fluid % by vol.	Total % by vol., whole slide
1799.0-1799.5	B	500	5 to 10	1/4	1.66	0.54
	A	500	1 to 5	3/4	0.17	
1902.0-1902.3	B	500	2 to 8	1/5	0.866	0.26
	A	500	0.5 to 3	4/5	0.11	
2065.0-2065.4	B	500	20 to 50	5/6	3.4	2.86
	A	500	20 to 50	1/6	0.20	
2095.1-2095.5	B	500	3 to 15	1/10	2.58	0.29
	A	500	3 to 15	9.10	0.039	
2274.4-2272.7	(B	470	10 to 15	1/2	2.29	1.23
	(A	470	5	1/2	0.17	
" "	(B	510	5 to 7	2/5	0.86	0.36
	(A	510	1 to 3	3/5	0.02	
" "	(B	520	5 to 7	1/3	0.55	0.20
	(A	520	1 to 3	2/3	0.02	
2391.0-2391.3	B	460	10 to 15	1/10	1.17	0.22
	A	460	3 to 10	9/10	0.12	
2611.5-2611.8	B	530	5 to 25	1/5	0.79	0.17
	A	530	2 to 5	4/5	0.015	
2658.7-2659.0	B	360	5 to 10	1/4	1.18	0.32
	A	360	2 to 8	3/4	0.039	

TABLE 7.13, continued

Data on the volume percent of fluid now present in the salt cores from ERDA No. 9.

Depth interval (feet)	Type Sampled	Volume sampled (mm^3)	Approx. grain size (mm)	Fraction of total slide	Fluid % by vol.	Total % by vol., whole slide
2760.0-2760.2	B	460	5 to 8	1/5	0.96	0.40
	A	460	3 to 5	4/5	0.27	
2820.8-2821.2	B	490	3 to 8	1/4	0.87	0.45
	A	490	2 to 5	3/4	0.31	

TABLE 7.14

Homogenization temperatures (°C) of two-phase liquid + gas inclusions from ERDA No. 9 core (numbers of inclusions run given in parentheses)

Depth interval	Homogenization temperatures
1799.0-1799.5	20.5(1), 21.0(1), 25(3)
1902.0-1902.3	25.1(1)
2065.0-2065.4	(none)
2095.1-2095.5	25.6(2), 34.5(1), 44.0(1), 45.5(2)
2272.4-2272.7	41.25(1), 42.5(1), 42.6(3)
2391.0-2391.3	23(4), 39(1)
2611.5-2611.8	(none)
2658.7-2659.0	43.0(1), 43.25(1), 43.5(1), 44(2), 45.0(1)
2760.0-2760.2	20.4(1), 21.6(1), 21.8(2)
2820.8-2821.2	22.5(1), 23.0(1), 25.5(1)

TABLE 7.15

Summary of freezing data (°C), mainly on type B inclusion in samples from ERDA No. 9 core

Depth	First melting temp.	Freezing temp.	Notes
1799	<-31.9	> +10	~20% liquid at -31.9
1902	<-32	> +10	
2095	<-28.4	+15	~20-25% xls at 0°C
"	-32.2	"	
2272	<-32.8	+11.8	~50% xls at 0°C
2391	<-26.1	> +12.8	
2760	<-32	> +12.7	

TABLE 7.16

Test data and weight loss (in %) from decrepitation tests. Roman numerals indicate amount of sample breakup after run:
I - unbroken; II - broken into 2 or 3 pieces;
III - broken into more than 3 pieces.

	Temperature, °C		
Core interval (ft)	150	200	250
2058.8 - 2059.0	0.16 II	0.23 II	0.76 III
2070.4 - 2070.6	0.16 II	0.12 I	0.35 III
2606.5 - 2606.9	0.02 I	0.24 II	0.95 III
2617.2 - 2617.7	0.06 I	0.30 I	0.62 II
2626.7 - 2627.0	0.19 I	0.28 I	1.04 III
2659.0 - 2659.2	0.14 I	0.13 I	0.59 III
2665.0 - 2665.1	0.19 I	0.18 I	0.75 III
2692.4 - 2692.6	0.06 I	0.26 I	0.83 III
2699.8 - 2700.0	0.19 I	0.24 II	0.65 III
Average	0.13	0.22	0.73
Heating schedule (hours)			
Room T to run T	7	9.5	8
Hold at run T	79	95	79
Run T to room T	~9	~9	~10

TABLE 7.17

Temperature of homogenization and volume % vapor of two-phase inclusions in salt of samples after decrepitation tests.

Decrepitation run temp. (°C)	Homogenization temp. (°C) Minimum	Maximum	Number of inclusions runs	Volume % vapor phase; avg. for ~25 inclusions
150	90	120	16	0.8
200	110	180	21	1.8
250	180	273	28	5.0

Note: Birefringent crystals, present in some of these inclusions, do not disappear during homogenization runs.

TABLE 7.18

Temperature of homogenization of two-phase inclusions in salt from near dike in Kerr-McGee mine, Lea County, New Mexico.

Sample no.	Distance from dike (m)	Temp. of homogenization (°C)		Number of inclusions run
		Minimum	Maximum	
MB-77-8	0.01 - 0.02	71	116	7
MB-76-3	0.2	60	110	6
MB-76-4	2.5	85	88*	9

* Two birefringent crystals remained unchanged, and a cubic crystal (KCl ?) dissolved at 82°C. (See Plate 7-42 for a similar inclusion.)

TABLE 7.19

INVENTORY OF FLUIDS SAMPLED FOR GEOCHEMICAL STUDIES
OF DELAWARE BASIN GROUNDWATERS

Sample No.	Sample Name	Formation Sampled	Location	Solutes	Stable Isotopes	Solute *Analyst
1	Carlsbad City #7	Capitan	T22S-R26E-S1	X	X	M
2	Duval Mine/Collector Ring	Rustler	T22S-R30E-S33	X	X	M
3	Duval Mine/Seep-BT26	Salado	T22S-R30E-S33	X	X	S
4	Duval Mine/Seep-BT48	Salado	T22S-R30E-S33	X	X	M
5	Duval Mine/Seep-BT58	Salado	T22S-R30E-S33	X		M
6	James Ranch	Rustler	T23S-R31E-S5	X	X	M
7	Fairview	Rustler	T23S-R32E-S36	X	X	M
8	Todd State 36-1	Morrow	T23S-R31E-S36	X	X	M
9	Todd Federal 26-4	Bell Canyon	T23S-R31E-S26	X	X	M
10	Todd Federal 26-1	Morrow	T23S-R31E-S26	X	X	M
11	Shell No. 28	Capitan	PSL Blk 74-S34(Texas)	X	X	M
12	Middleton	Capitan	T19S-R32E-S21	X	X	M
13	Hackberry	Capitan	T19S-R31E-S31	X	X	M
14	ERDA #6	Castile	T21S-R31E-S35	X	X	S
15	Shell Bootleg	Castile	T22S-R32E-S36	X		Sh
16	Duval Mine/Vent Hole	Salado	T22S-R30E-S33	X		M
17	UNM Pokorny	Castile	PSL Blk 61-S3(Texas)	X	X	M
18	Smith Livingston Ridge	Santa Rosa	T22S-R31E-S15		X	
19	Indian	Rustler	T23S-R30E-S21		X	
20	Mobley	Rustler	T23S-R30E-S19		X	
21	Mobley #3	Rustler	T23S-R30E-S2		X	
22	H1-Magenta	Rustler	R22S-R31E-S29	X	X	U
23	H1-Culebra	Rustler	T22S-R31E-S29	X	X	U
24	H3-Magenta	Rustler	T22S-R31E-S29	X	X	U
25	H3-Culebra	Rustler	T22S-R31E-S29	X	X	U
26	Green Lake	Capitan	Carlsbad Caverns		X	
27	Mirror Lake	Capitan	Carlsbad Caverns		X	
28	Longfellow's Bathtub	Capitan	Carbsbad Caverns		X	
29	Celery Stalk Pool	Capitan	Carlsbad Caverns		X	

* Analysts:
M - Martin Water Laboratories
S - Sandia
Sh - Shell
U - U.S. Geological Survey

TABLE 7.20

GEOCHEMICAL ANALYSES OF DELAWARE BASIN GROUNDWATERS
(Solutes in mg/l)

No.	pH	$\delta^{18}O$ °/oo	δD °/oo	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	Br^{-}	SO_4^{+}	HCO_3^{-}	TDS	Other Information
T 1	7.2	- 7.9	-54	74	29	8	1	10	0	72	285	474	NO_3:5
2	7.4	- 6.4	-48	1100	280	3600	405	6400	0	2500	122	14380	Sr:30
3	5.5	+ 3.0	-10	640	55400	27500	3000	236500	305	3650	1090	355085	BO_3:660
4	5.4	+ 2.6	-12	500	62600	44400	30250	251500	530	3300	1170	395000	BO_3:840
5	5.5			520	62000	46300	30250	250000	582	3100	1170	395000	BO_3:990
6	7.6	- 5.0	-40	590	175	68	5	400	0	1570	190	3240	NO_3:225
7	7.6	- 7.1	-53	590	200	120	3	142	0	2140	130	3350	
8	6.4	+ 2.7	-15	1600	240	11300	500	20600	23	300	380	35600	Sr:240
9	7.1	+ 2.2	-13	27600	6075	76700	1700	18500	410	210	215	295400	Sr:1750
10	6.6	+ 9.2	-18	4880	920	28700	200	55400	90	30	300	92400	Sr:1750
11	7.1	- 7.7	-56	940	280	2280	57	3900	0	2400	550	11300	
12	7.4	- 7.5	-55	1100	570	10600	330	17050		3720	300	33800	Sr:64
13	6.0	- 6.5	-46	2200	1680	68700	2950	110800		5150	132	192000	Sr:140,Fe:312
14	7.3	+10.3	0	130	350	112000	5100	186100	240	16000	1310	321000	BO_3:650,Li:160
15	7.7			550	1860	124500		185000		16800	1480	330700	
16	5.8			1260	38500	49000	52500	241500	385	3600	700	388650	BO_3:1160
17	1.6	- 6.0	-50	190	100	200	18	2700	0	570	0	3800	
18		- 7.2	-52										
19		- 6.3	-46										
20		- 6.9	-44										
21		- 5.9	-44										
22	7.4	- 6.8	-48	890	270	5700	70	8000		3900	92	18922	
23	7.6	- 7.0	-50	780	280	9400	190	12000		7400	105	30155	
24	7.4	- 7.3	-53	760	190	4200	100	5800		2600	1150	14800	
25	7.4	- 7.0	-53	1500	720	19000	450	33000		5200	88	60000	
26		- 3.6	-24										
27		- 4.3	-28										
28		- 4.2	-29										
29		- 3.0	-20										

TABLE 7.21

DUVAL MINE VENT HOLE WATER #16

One liter of solution might be expressed as the following amounts of common evaporite minerals:

0.006 moles	(1 gm)	$CaMg(CO_3)_2$	Dolomite
0.026 moles	(4 gm)	$CaSO_4$	Anhydrite
0.012 moles	(3 gm)	$KMgClSO_4 \cdot 11/4H_2O$	Kainite
1.343 moles	(370 gm)	$KMgCl_3 \cdot 6H_2O$	Carnallite
0.224 moles	(46 gm)	$MgCl_2 \cdot 6H_2O$	Bischofite
0.005 moles	(2 gm)	$Na_2B_4O_7 \cdot 10H_2O$	Borax
2.121 moles	(121 gm)	NaCl	Halite

TABLE 7.22

TODD FEDERAL 26-4 WATER #9

One liter of solution might be expressed as the following amounts of common evaporite minerals:

0.10 moles	(52 gm)	$CaMg_2Cl_6 \cdot 12H_2O$	Tachyhydrite
0.04 moles	(4 gm)	$KMgCl_3 \cdot 6H_2O$	Carnallite
0.59 moles	(129 gm)	$CaCl_2 \cdot 6H_2O$	Antarcticite
3.34 moles	(195 gm)	NaCl	Halite

TABLE 7.23

ERDA 6 WATER #14

One liter of solution might be expressed as the following amounts of common evaporite minerals:

0.003 moles	(1 gm)	$CaMg(CO_3)_2$	Dolomite
0.009 moles	(1 gm)	$MgCO_3$	Magnesite
0.011 moles	(3 gm)	$KMgClSO_4 \cdot 11/4H_2O$	Kainite
0.130 moles	(9 gm)	KCl	Sylvite
0.155 moles	(22 gm)	Na_2SO_4	Thenardite
0.048 moles	(14 gm)	LiCl	?
4.521 moles	(265 gm)	NaCl	Halite

TABLE 7.24

Rb-Sr Data for Evaporites from the Salado Formation

A. Whole Rocks

Core hole Interval	$(^{87}Sr/^{86}Sr)_N$	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$
AEC-8				
1622.4-1622.9	0.7056	5.0	112.4	0.13
1636.6-1637.1 (sylvite rich portion)	0.7816	120.1	8.0	43.77
1645.0-1645.3	0.7150	0.40	48.2	0.02
1671.2-1671.8	0.7097	5.6	39.8	0.41
1715.4-1715.7	0.7089	0.07	90.9	0.02
1762.0-1762.3	0.7099	1.3	37.9	0.10
1782.2-1782.4	0.7137	0.30	5.7	0.15
ERDA-9				
1404.8-1405.8	0.7934	67.1	5.1	38.41
1648.5-1649.0	0.7079	0.47	44.7	0.03
1759.1-1759.8 (polyhalite rich portion)	0.7064	4.9	793.5	0.02
ERDA-6				
1421.0-1421.7	0.7095	0.60	156.2	0.01

B. Water Soluble Portions

ERDA-8				
1607.0-1608.0	0.7173	26.7	44.7	1.73
ERDA-9				
1408.8-1405.8	0.8601	70.8	4.0	51.87
1709.0-1709.5	0.7094	0.99	8.5	0.34
1713.6-1714.0	0.7072	2.0	34.1	0.17
1772.0-1772.4	0.7067	1.5	57.7	0.07

C. < 2 Micron Fractions (Clays)

AEC-8				
1607.0-1608.0	0.7229	42.9	82.2	1.51
1671.2-1671.8	0.7273	43.9	35.2	3.62
ERDA-9				
1404.8-1405.8	0.7608	84.5	23.6	10.40
1772.0-1772.4	0.7181	29.4	48.1	1.76

TABLE 7.25

% Insoluble Residue in Whole Rock

Core hole Interval	Insoluble Residue (percent)
AEC-8	
1607.0-1608.0	9.0
1610.8-1611.3	9.0
1622.4-1622.9	2.0
1636.6-1637.1	3.7
1645.0-1645.3	0.8
1671.2-1671.8	11.3
1715.4-1715.7	1.1
1782.2-1782.4	12.5
ERDA-9	
1404.8-1405.8	7.2
1621.9-1622.2	0.8
1633.6-1634.1	0.4
1648.5-1649.0	2.1
1652.8-1653.1	0.3
1709.0-1709.5	1.1
1713.6-1714.0	18.2
1759.1-1759.8	0.7
1772.0-1772.4	12.6

TABLE 7.26

Mineralogical Data

Core hole Interval	Halite	Sylvite	Polyhalite	Langbeinite
A. Whole Rocks (Evaporite Mineralogy by XRD)				
AEC-8				
1607.0-1608.0	VA	VA	-	-
1610-8-1611-3	VA	A	-	-
1622.4-1622.9	VA	A	-	-
1636.6-1637.1	VA	VA	t	-
1645.0-1645.3	VA	t	-	-
1671.2-1671.8	VA	t	t	-
1715.4-1715.7	VA	t	-	-
1762.0-1762.3	VA	t	-	-
1782.2-1782.4	A	A	A	t
ERDA-9				
1404.8-1405.8	A	t	VA	VA
1621.9-1622.2	VA	t	-	-
1633.6-1634.1	VA	t	-	-
1648.5-1649.0	VA	A	-	-
1652.8-1653.1	VA	t	-	-
1709.0-1709.5	VA	A	-	-
1713.6-1714.0	VA	A	-	-
1759.1-1759.8	VA	A	t	-
1772.0-1772.4	VA	A	t	-
ERDA-6				
1421.0-1421.7	VA	t	-	-

TABLE 7.26, continued

Mineralogical Data

Core hole Interval	Halite	Sylvite	Polyhalite	Langbeinite

B. 2 Micron Fractions (Clays, Minerals)

Core Hole Interval	Chlorite	Saponite	Chlorite/ Saponite	Illite	Talc	Serpentine
AEC-8						
1607.0-1608.0	-	-	VA	A	t	A
1610.8-1611.3	t	-	A	A	-	A
1622.4-1622.9	-	-	t	A	A	t
1636.6-1637.1	-	-	A	VA	t	t
1645.0-1645.3	t	-	A	A	t	A
1671.2-1671.8	-	-	VA	A	-	t
1715.4-1715.7	A	-	t	VA	-	VA
1762.0-1762.3	t	t	-	A	A	t
1782.2-1782.4	A	-	t	VA	VA	A
ERDA-9						
1404.8-1405.8	-	-	A	VA	t	A
1648.5-1649.0	A	-	A	VA	VA	VA
1713.6-1714.0	-	-	VA	A	A	VA
1772.0-1772.4	-	-	VA	A	t	A
ERDA-6						
1421.0-1421.7	-	-	t	t	VA	t

VA: very abundant
A: abundant
t: trace
-: not detected

TABLE 7.27

URANIUM CONCENTRATIONS AND ISOTOPIC RATIOS IN DELAWARE BASIN WATERS

Sample	U Concentration	$\alpha(^{234}U/^{238}U)$	$\delta^{18}O$ (SMOW)‰	δD (SMOW)‰
Shell	0.60 parts in 10^9	2.75	-7.7	-56
Middleton	0.54 parts in 10^9	1.81	-7.5	-55
Hackberry	0.02 parts in 10^9	1.22±0.05	-6.5	-46
Carlsbad 7	0.05 parts in 10^9	5.14	-7.9	-54
ERDA 6 1140 hr.	89 parts in 10^9	1.11±0.04		
ERDA 6 1212 hr.	4.8 parts in 10^9	1.26±0.05		
ERDA 6 1445 hr.	2.14 parts in 10^9	1.37±0.07	+10.3	0
ERDA 6 1520 hr.	1.88 parts in 10^9	1.33±0.07		
ERDA 6 Drill Mud	67.2 parts in 10^9	1.19		
Brine Lake (Mud Ingredient)	56.3 parts in 10^9	2.04		

Arrows in these photographs point stratigraphically upward.

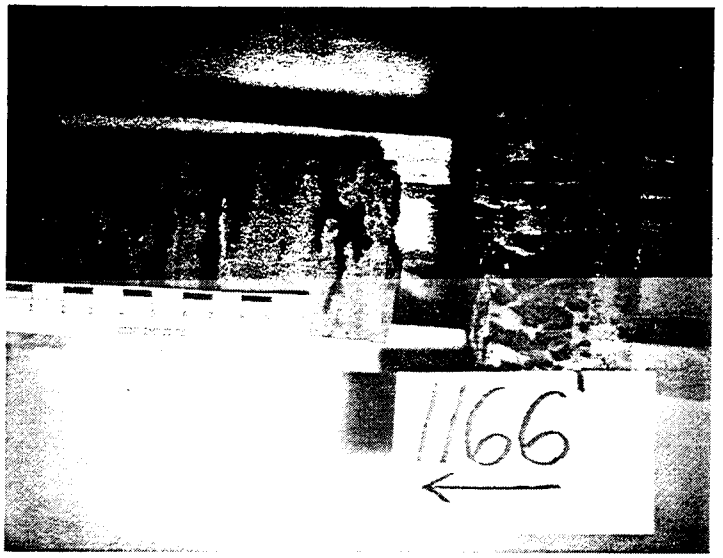


Plate 7.1. Core footage: 1165.4 to 1177.1 ft. (including 0.1 ft. gap) Brownish halite in gray anhydrite. Halite occurs as a thin bed at top of specimen, then as irregular lenses and thin laminae, finally as vertically elongate crystals, some with "swallow tail" form, near bottom of specimen. Locally horizontal laminae occur within the anhydrite due either to color change of the anhydrite or laminae of magnesite.

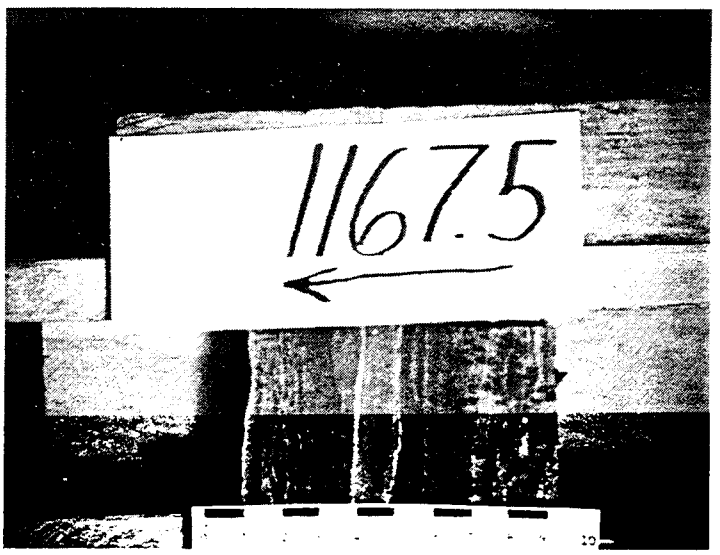


Plate 7.2. Core footage: 1167.5 ft. Dominantly light to dark gray, laminated anhydrite with thin, locally discontinuous, laminae of white magnesite and brownish, elongate halite oriented perpendicular to convex-upward, discontinuous laminae of light gray to white anhydrite.

Plate 7.3. Core footage: 2065.8 to 2066.6 ft. Dominantly clear to milky white halite crystals, approximately 10 mm in size, and reddish brown to pinkish brown polyhalite. Note rectangular outline of polyhalite body stratigraphically above the first 6 in 2066; but most polyhalite occurs around halite crystal boundaries below 2066 label.

Plate 7.4. Core footage: 2615.0 to 2615.6 ft. Dominantly coarse (ranging from 3 to 40, average 20 mm in size) halite crystals, some with cubic form but most anhedral, locally separated by microcrystalline white anhydrite.

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Plate 7.5. Core footage: 2705.8 ft. Coarse, ranging from 2 to 15 mm, light gray to black halite in white microcrystalline anhydrite and rare 1 to 2 mm bodies of pure white magnesite.

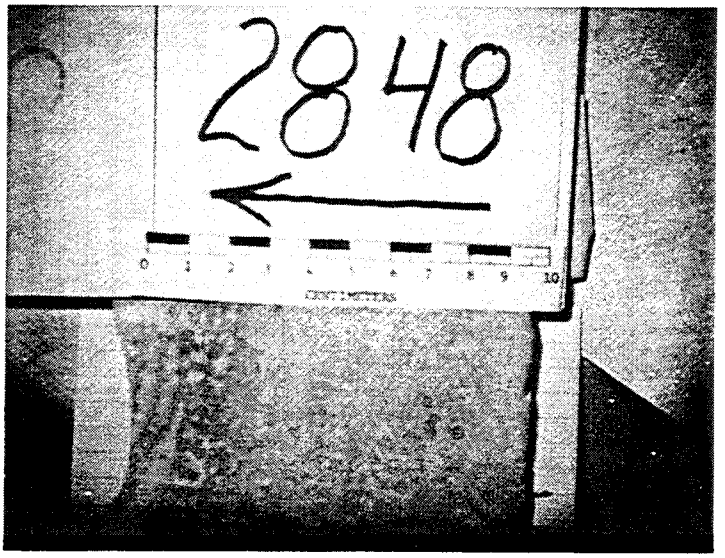

Plate 7.6. Core footage: 2848 ft. Varicolored (white and all shades of gray) anhydrite, some crystals near stratigraphic top of sample exhibit "swallow tail" form.

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Plate 7.7. Photomicrograph (25X, plane light) of halite: many euhedral (cubic) to subhedral, relatively clear crystals locally containing fluid inclusions. Crystal size ranges from 0.5 to 1.5 mm. Compare with Plate 7.8.

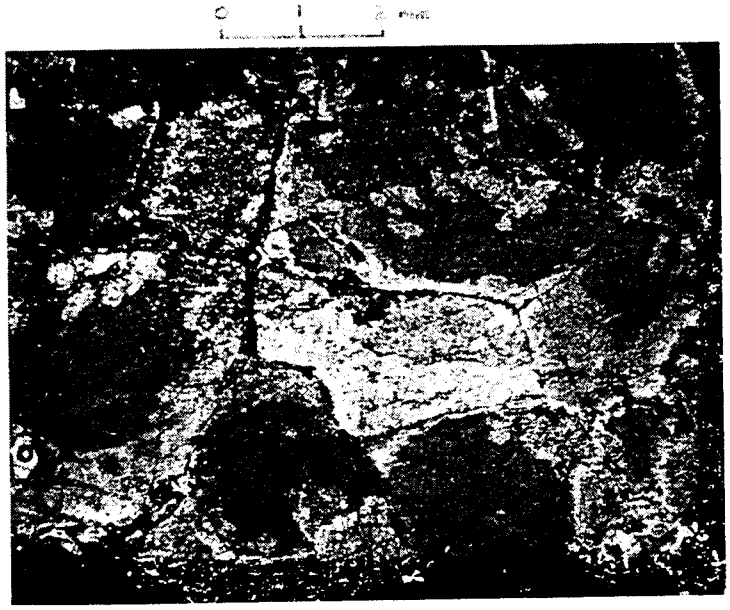

Plate 7.8. Photomicrograph (10X, plane light) of halite: subhedral to anhedral, cloudy crystals devoid of fluid inclusions. Crystal size ranges from 1.5 to 4.5 mm.

Plate 7.9. Photomicrograph (10X, plane light) of sylvite (reddish, translucent to black, opaque in photo) and halite: halite anhedra size ranges from 0.4 to 5 mm. Two subhedra dominantly of sylvite occur within halite anhedra, one subhedron/anhedron of mixed sylvite and halite occurs within a coarse halite subhedron, but most sylvite occurs as anastomosing bodies having gradational contacts with halite between halite anhedra.

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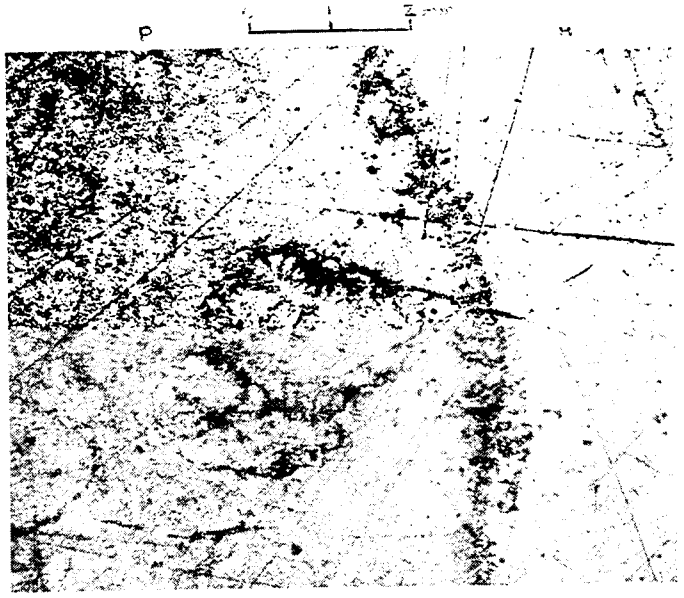

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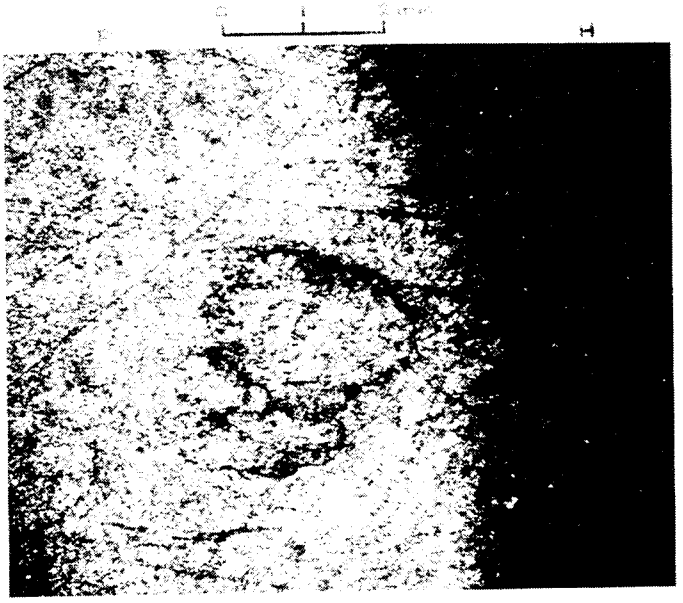

Plates 7.10A and 7.10B. Photomicrographs (10X, plane light in 7.10A, crossed nicols in 10B) of polyhalite (P) and halite (H): Polyhalite occurs as a cloudy anhedron (pinkish in hand specimen) locally containing smaller anhedra which are apparent due to concentrations of opaque (black in the photo, red under microscope reflected light) material, probably hematite. Concentrations of hematite also occur along the contact of polyhalite with halite which becomes extinct (black in 10B) under crossed nicols. The contact is irregular and gradational.

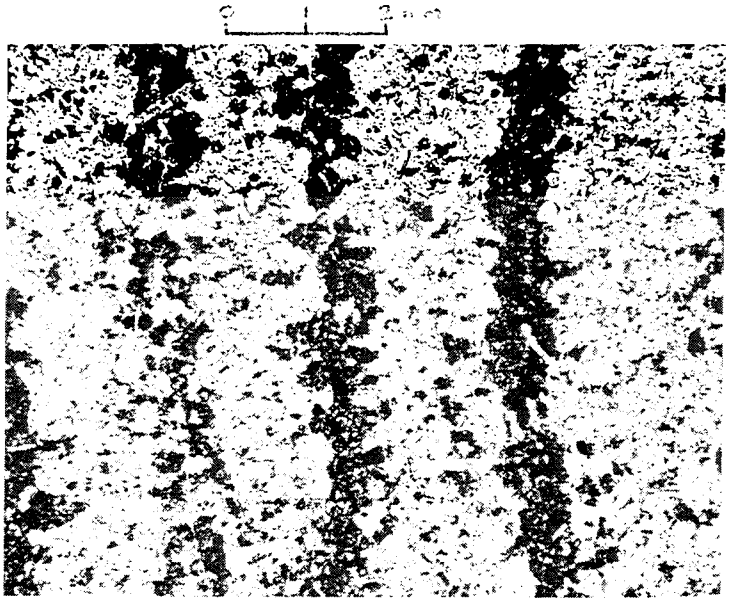

Plate 7.11. Photomicrograph (10X, plane light) of laminated anhydrite and calcium or magnesium carbonate: Dark thin laminae (approximately 1 mm thick) of dominantly carbonate anhedra separate thin laminae (approximately 2 mm thick) of dominantly anhydrite anhedra.

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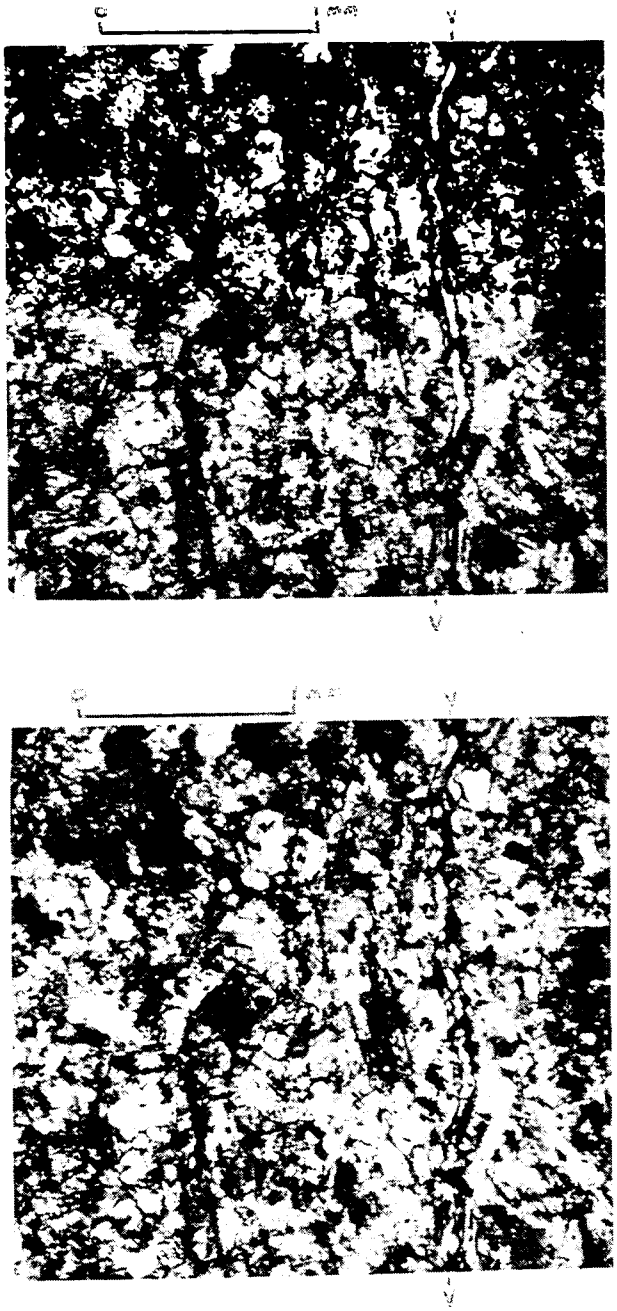

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Plates 7.12A and 7.12B. Photomicrographs (25X, plane light in Plate 7.12A, crossed nicols in Plate 7.12B) of anhydrite with veinlet (V) of gypsum. Anhydrite occurs as a mosaic of 0.04 to 0.4 mm anhedra and subhedra with high order interference colors in 12B. Veinlet somewhat discontinuous, is more apparent in 12A and consists of very elongate irregular anhedra of relatively clear gypsum with lower order interference colors than the anhydrite in 12B. The veinlet is approximatedly stratigraphically horizontal and is 0.06 mm thick, the width of a single elongate gypsum anhedron.

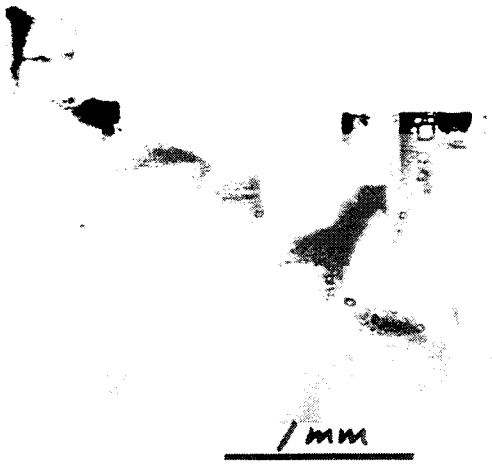

Plate 7.13 Group of dark unrecrystallized zones in essentially inclusion-free single crystal of halite of sample 2065. For detail on central area see Plate 7.14.

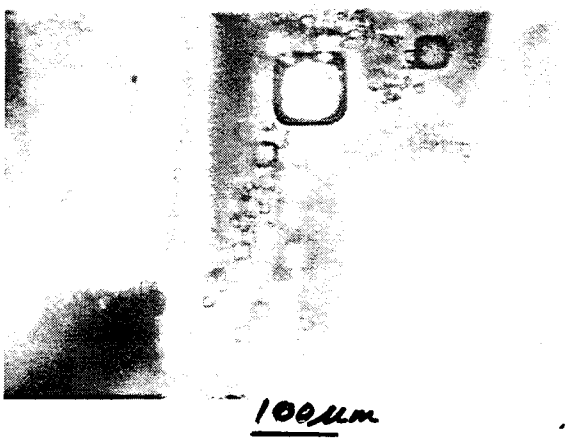

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Plate 7.14 Detail of area in Plate 7.13 showing sharp crystallographically controlled boundaries of inclusion-rich zones (type A). Such boundaries may represent primary crystallization features rather than recrystallization fronts.

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Plate 7.15 Recrystallized part of sample 2065 with large numbers of type B inclusions with small bubbles (e.g., see arrow) and some dark, cloudy unrecrystallized portions (details in Plate 7.16).

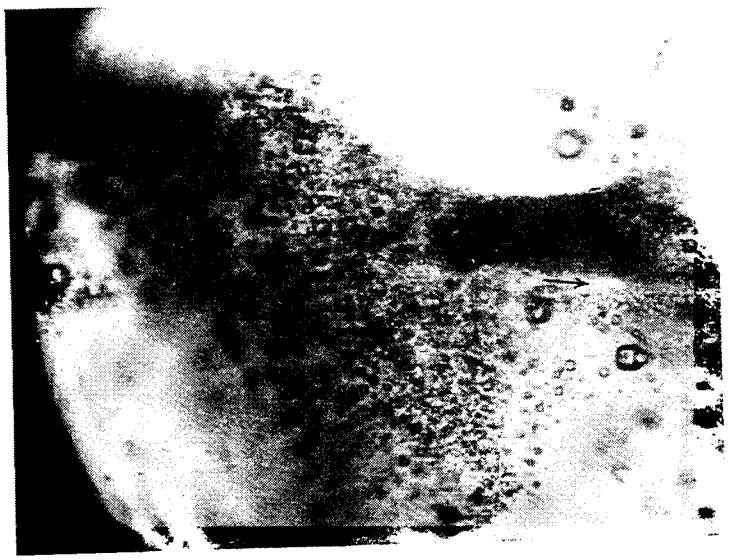

Plate 7.16 One of the dark areas in Plate 7.15 showing dense cloud of primary type A inclusions with some primary banding (arrow), and sharp but curving (solution?) contact with crystallographically parallel but almost inclusion-free recrystallized salt (at top).

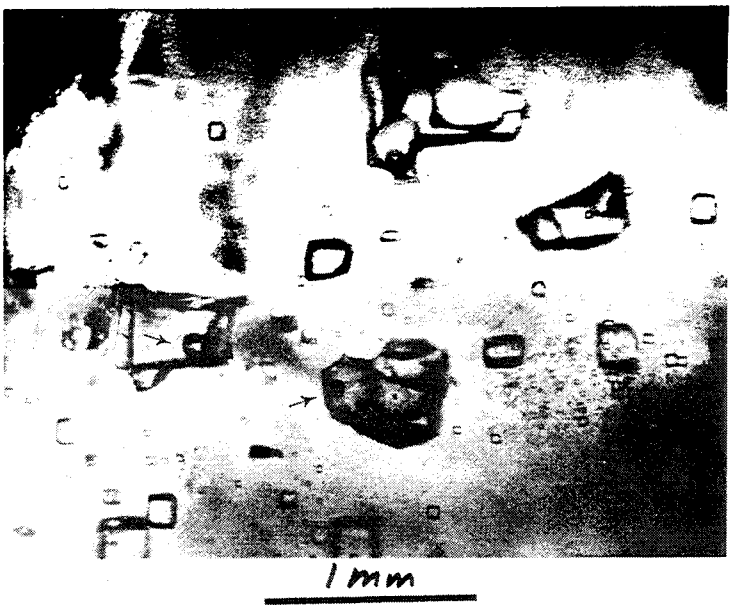

Plate 7.17 Coarsely recrystallized part of sample 2760, with many large type B inclusions, each with bubbles (arrows). Dark clouds are masses of unrecrystallized salt with large numbers of tiny type A primary inclusions (see Plates 7.18 and 7.19).

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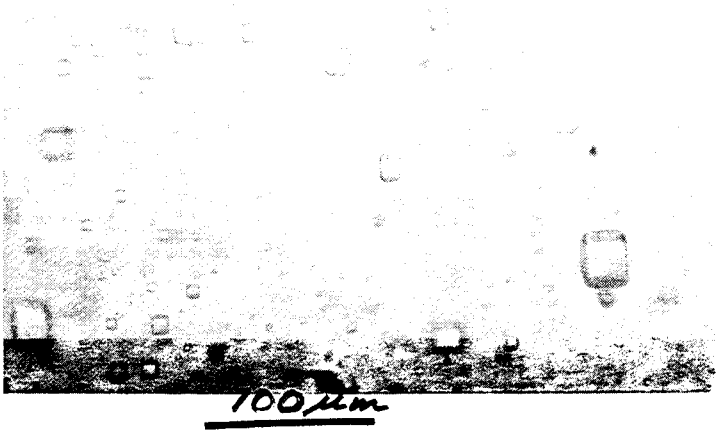

Plate 7.18 Detail of one of the cloudy areas in Plate 7.17, showing high concentration of tiny type A inclusions. Most of these inclusions are < 1µm (see Plate 7.19).

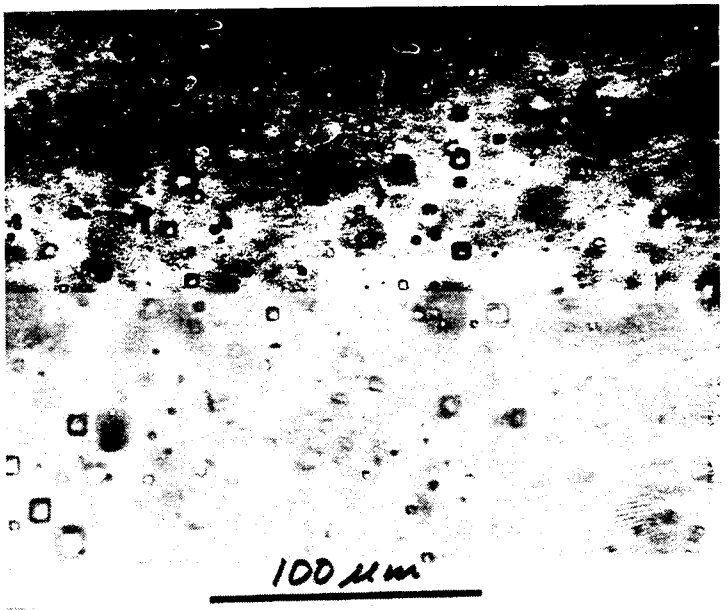

Plate 7.19 Detail of portion of Plate 7.18 that is relatively free of larger inclusions. The smallest inclusions are ≈ 0.5µm. All are type A. None of these inclusions contain a bubble.

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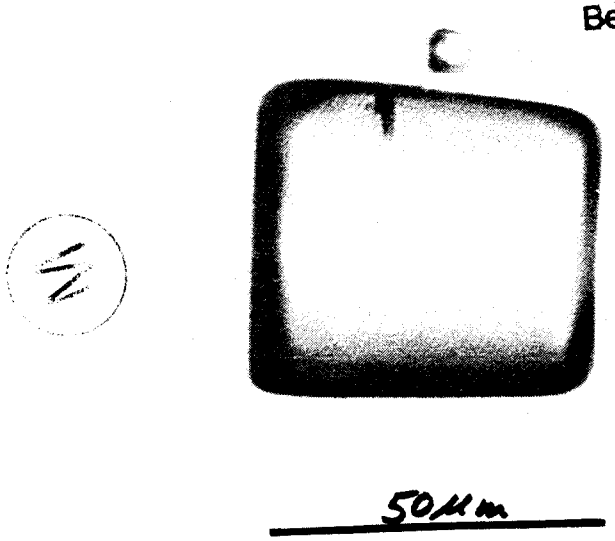

Plate 7.20 Inclusion in sample 2272.5 that contains only liquid, with no bubble, even though fairly large. Type B.

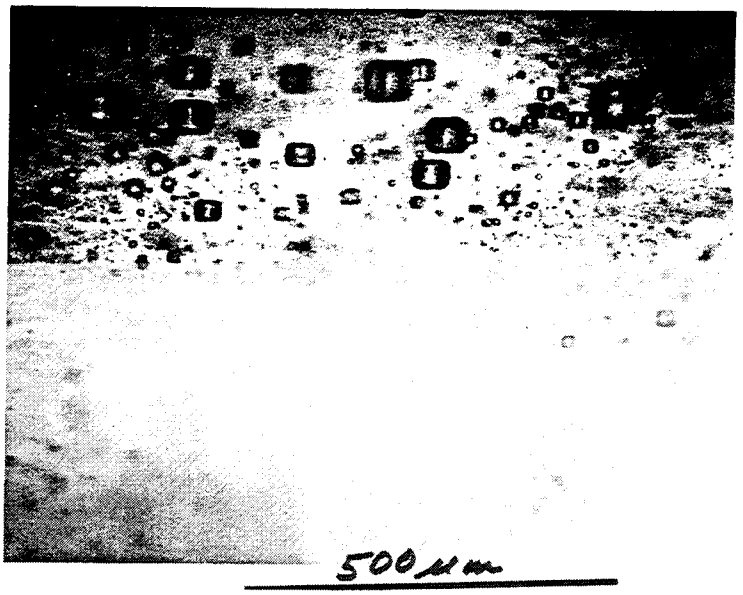

Plate 7.21 Unrecrystallized part of sample 1902 showing primary cubic growth zone feature, delineated by a cloud of tiny type A primary inclusions.

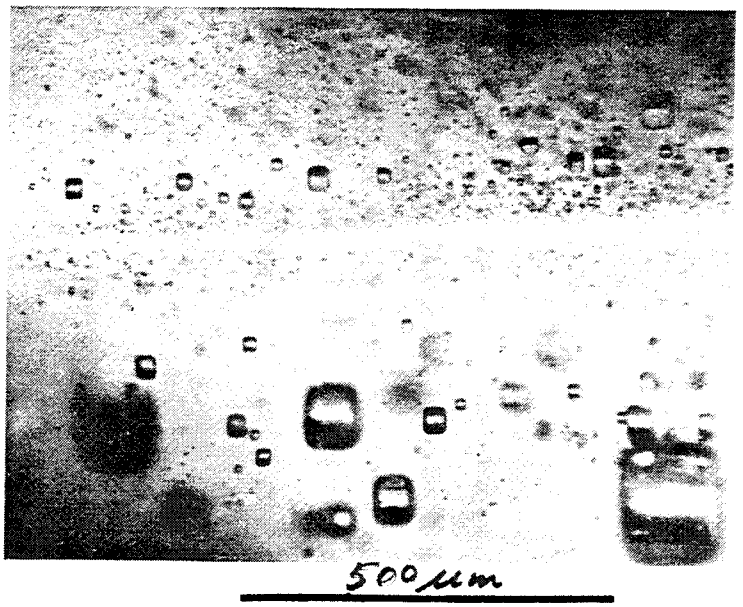

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Plate 7.22 Unrecrystallized part of sample 1902 showing thin inclusion-free zone through dense cloud of tiny type A primary inclusions.

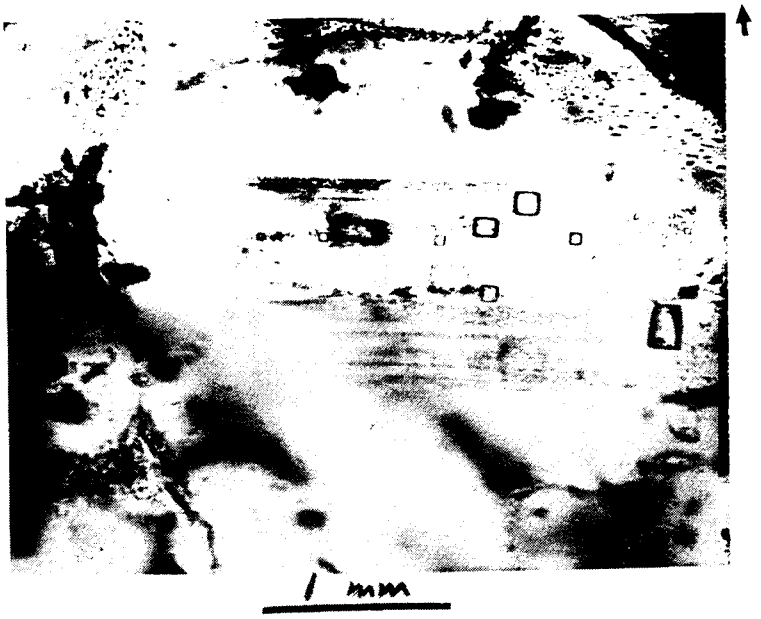

Plate 7.23 Oval grain of salt from sample 2760 containing unrecrystallized core with tiny type A primary inclusions. See Plate 7.24 for detail. Top of core is shown by arrow.

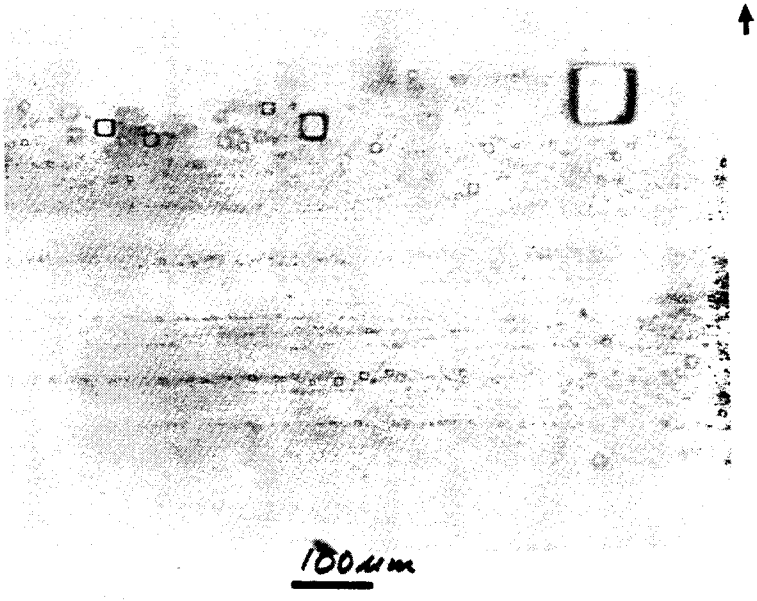

Plate 7.24 Enlgarged view of right central portion of Plate 7.23, showing extremely fine banding of primary type A inclusions, with inclusion-free zones between. Top of core is shown by arrow.

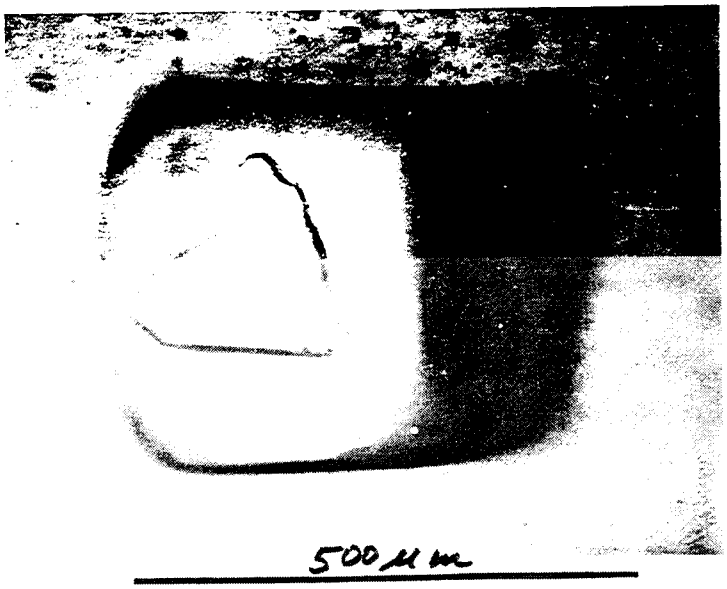

Plate 7.25 Inclusion (type B) in sample 1902 showing twinned birefringent daughter crystal of unidentified phase.

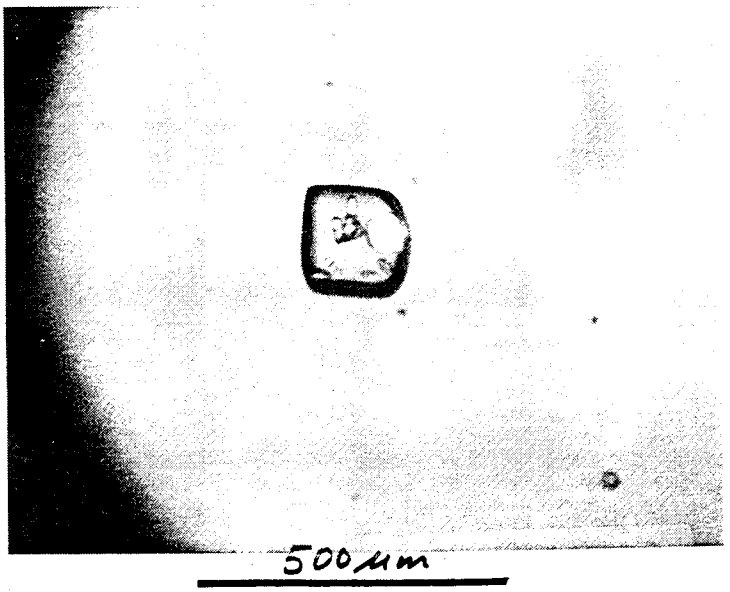

Plate 7.26 Daughter crystals of unidentified phase in type B inclusion in sample 1902.2, with partly crossed polarizers. Note twinning in largest crystal. Many inclusions in this same sample have no daughter crystal or just a few tiny crystals (see Plate 7.28).

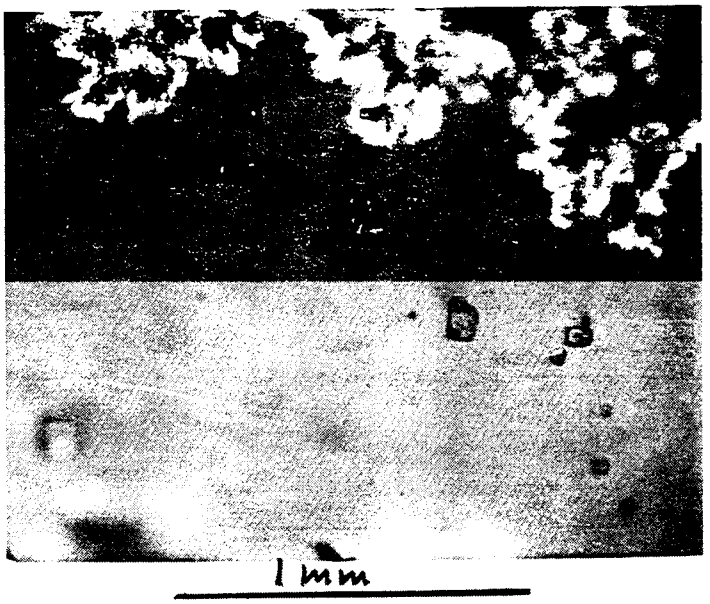

Plate 7.27 Plane of type B liquid inclusions each with a large number of unidentified bladed birefringent daughter crystals, just 400 μm below another plane of inclusions with no daughter crystals (Plate 7.28). Inclusion in Plate 7.26 with daughter crystals is similar in phase ratio but not in same plane (out of focus in lower left here). Sample 1902.2 partly crossed polarizers; birefringent mass embedded in salt crystal at top may be the same phase.

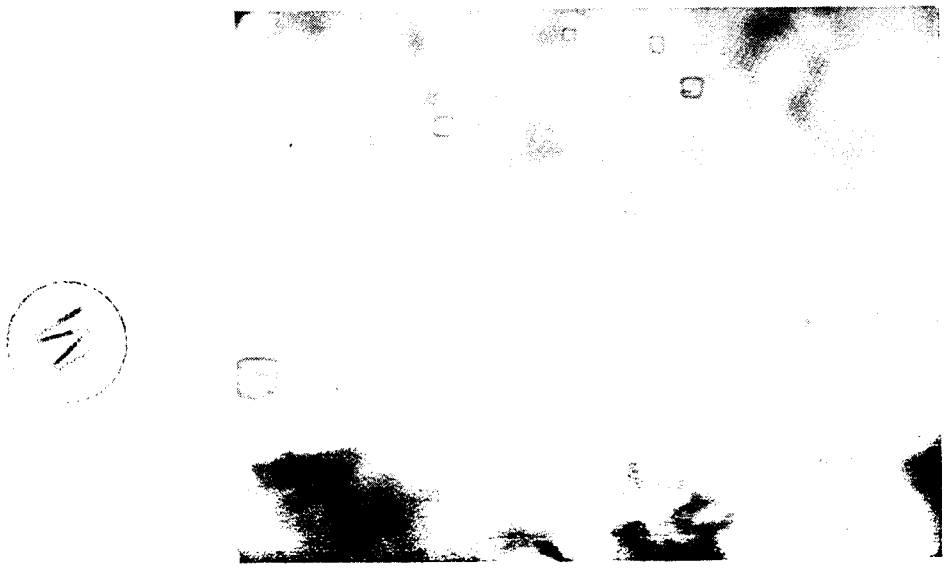

Plate 7.28 Plane of liquid type B inclusions, several with bubble, but without daughter crystals, about 400 μm above a plane of type B inclusions with a large number of unidentified daughter crystals (Plate 7.27). This lower plane is visible but out of focus. Sample 1902.2. Inclusion of Plate 7.26 is visible in lower left.

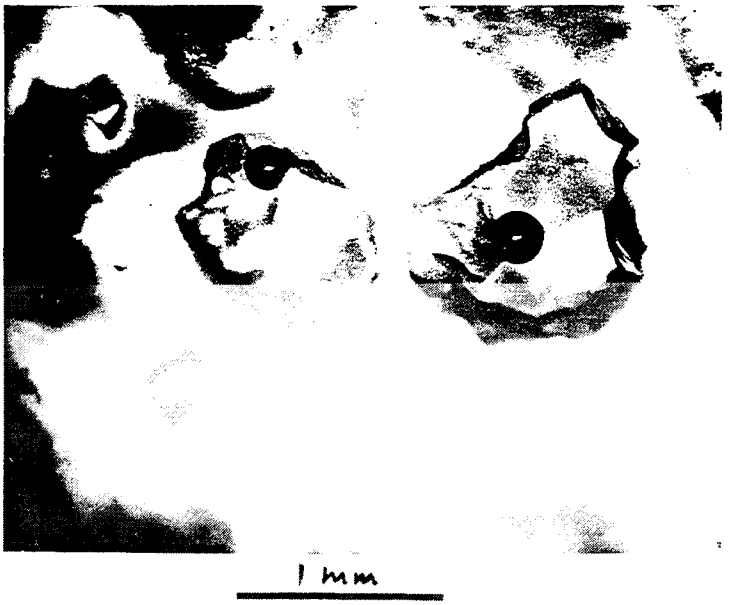

Plate 7.29 Large irregular type C inclusions in sample 2065 with "too large" bubbles.

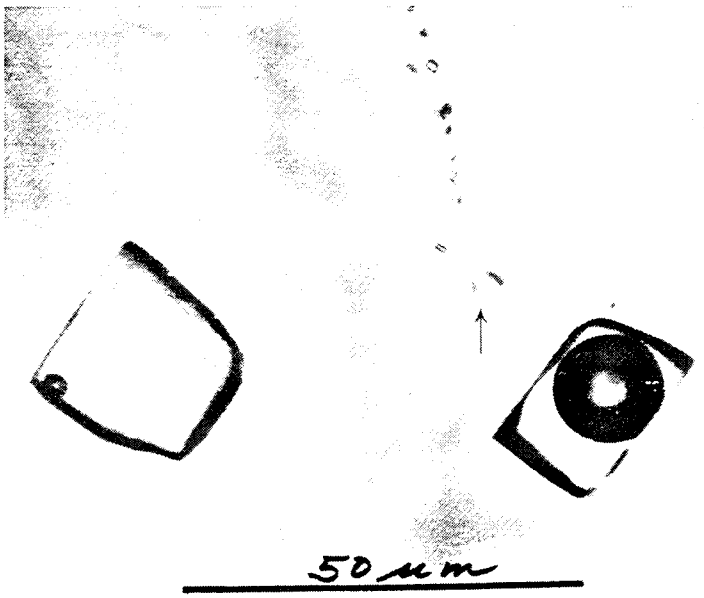

Plate 7.30 Pair of inclusions in sample 1902. The one on left (Type B) with small bubble is typical of those in this sample; that on right (Type C) is on a healed fracture (see arrow) and has apparently been opened and the original fluid replaced with a gas-rich mixture under pressure.

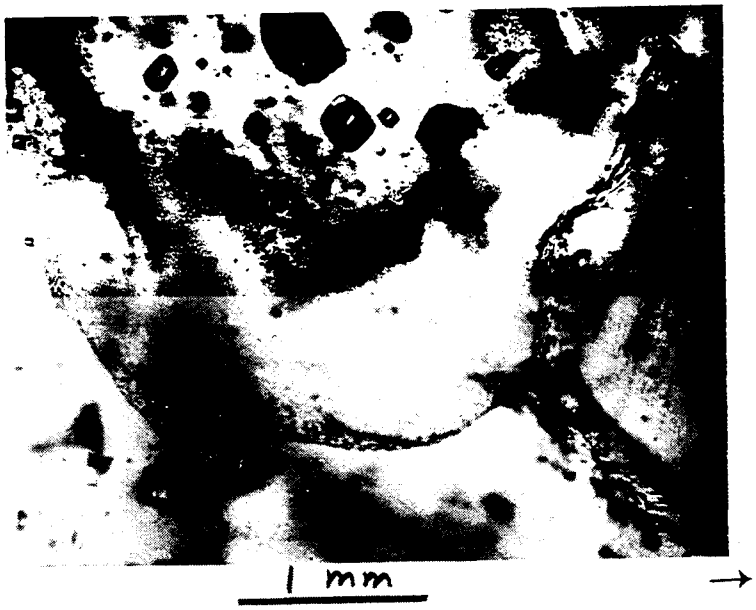

Plate 7.31 Single crystal of salt in sample 2760 with curving planes, outlined by type D inclusions, separating it from adjacent grains. Note also large type B inclusions and mass of tiny type A primary inclusions in central core of crystal. Sample has probably undergone two stages of recrystallization (see text). Top of core is shown by arrow.

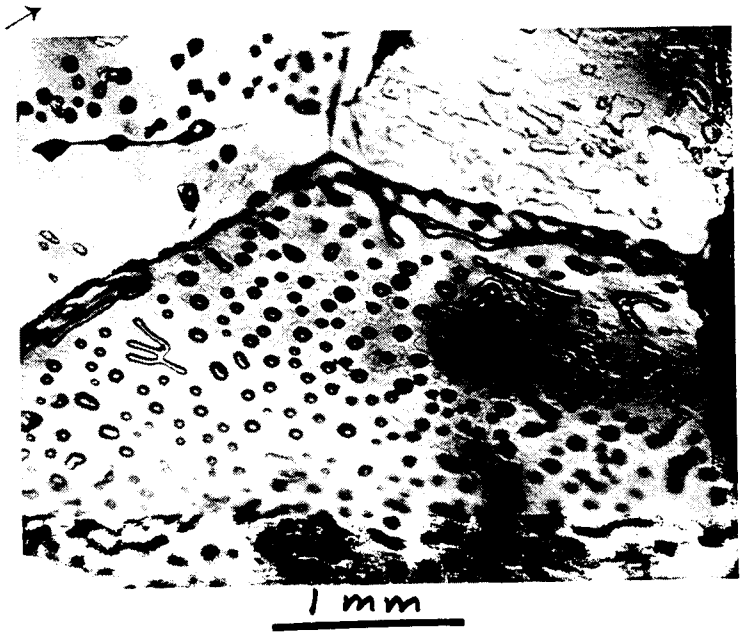

Plate 7.32 Fluid inclusions (gas; type D) on interface between recrystallized salt crystals in sample 2760. Note 120° junction. Top of core is shown by arrow.

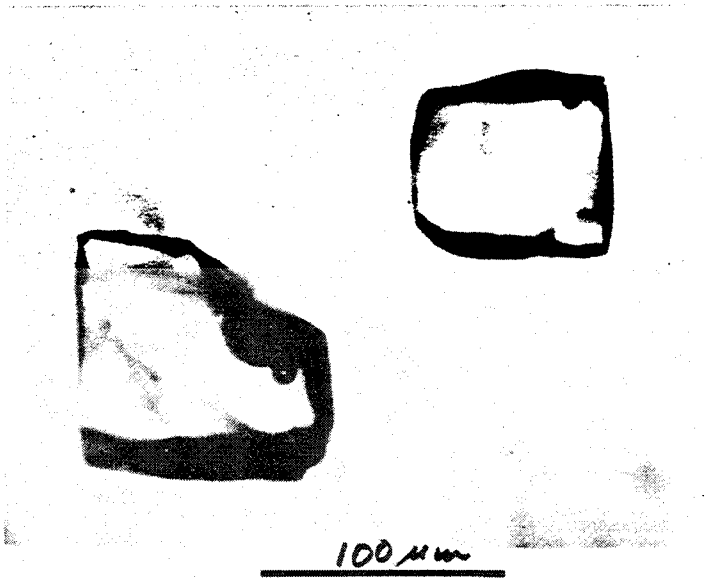

Plate 7.33 Large type B inclusions in sample 1799.1 homogenizing at 20.5°C (lower left) and 21°C (upper right). Photographed at ≈ 19°C.

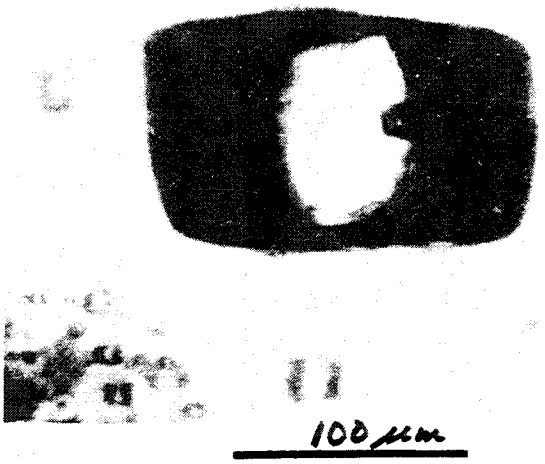

Plate 7.34 Large type B inclusion in sample 2760.1 homogenizing at 20.5°C. Photographed at ≈ 19°C.

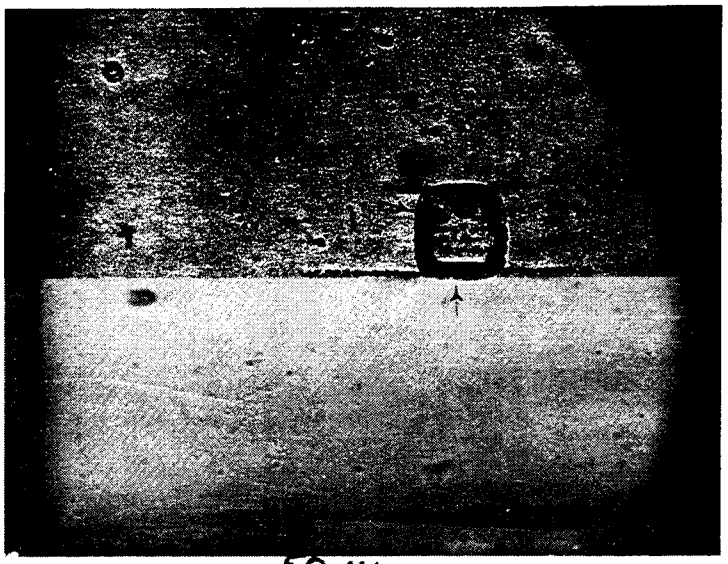

Plate 7.35 Inclusion (type B) in sample 1902 after freezing run, showing horizontal crack formed by expansion on freezing, that is now a plane of tiny secondary fluid inclusions; larger bubble than originally was present (due to volume increase); and rounded halo of tiny inclusions formed during freezing run (arrows), as a result of water in inclusion reacting with halite of walls to form $NaCl \cdot 2H_2O$, thus increasing inclusion volume. See text.

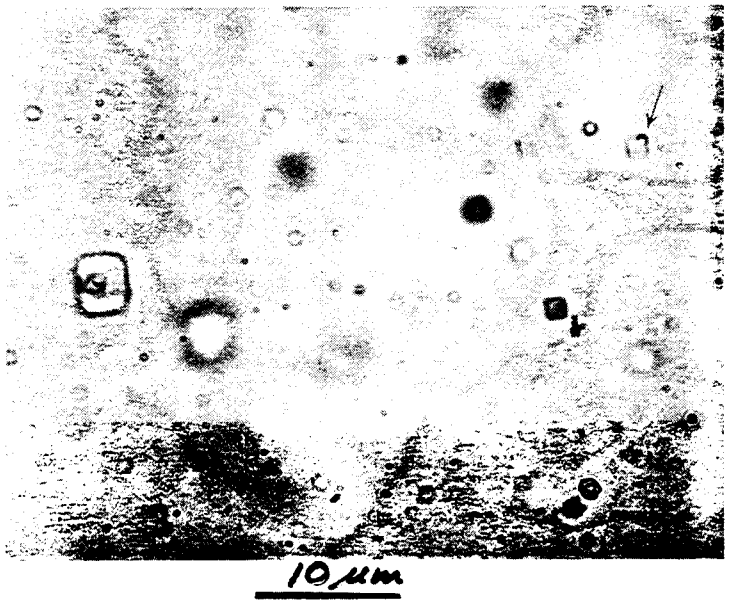

Plate 7.36 Minute primary inclusion in unrecrystallized salt from sample 1902 at high magnification (1560 X). The inclusion in upper right is about 1.8 µm on an edge, and contains a bubble of <0.5µm. Resolution of bubble is poor as it is generally in rapid motion even with an IR filter in optical system and exposures must be long. Many inclusions with no bubble area are ≈ 0.5µm on an edge.

Plate 7.37 Sequence of photographs of type B inclusions in sample 2095.3 taken at the temperatures indicated during a freezing run. At -75.5°C the inclusions contain a partly opaque mixture of solid grains of ice and salts. No change was visible on warming to -34.5°C, but at -32.2°C the mixture suddenly became more translucent and the grain size started to increase, indicating first melting. Extensive melting occurred around -4°C, and the remaining crystals decreased to ≈ 20-25% at 0°C. These were probably a hydrate but not all Nacl $2H_2O$, since a few were present at +12°, and the last dissolved at +15°C. The room temperature photo was taken after the run. The bubble size varies with phases present and temperature.

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Plate 7.38 Inclusion from sample 2760, as found, with large bubble, viewed on crushing stage. The bubble contains gas under pressure (see Plate 7.39).

Plate 7.39 Same inclusion as seen in Plate 7.38, on crushing stage, after fracture has reached it. The bubble has expanded approximately 270% (vol) on pressure release.

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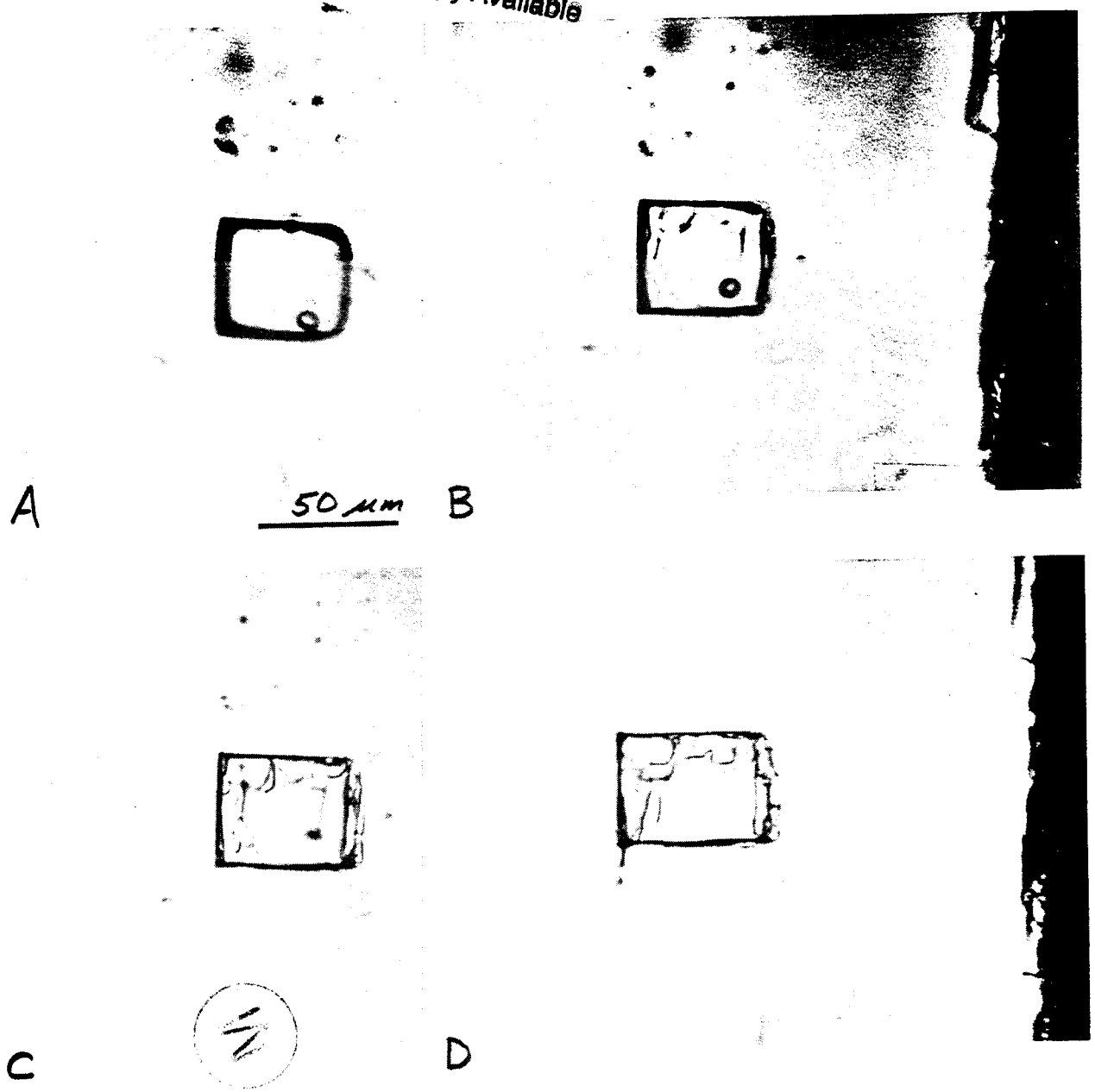

Plate 7.40 Sequence of photographs of inclusion in sample 2760 on crushing stage. A shows the inclusion as found. The sample was then stressed and immediately cracked (at right in B), but the area of inclusion was still under stress, since changes took place along edges of inclusion during next 10 minutes at constant stress (photo B). After 16 minutes at constant stress (C) changes are more pronounced and bubble is smaller; after 18 minutes bubble is gone (D).

In each of the following plates, the length of the scale bar is 100 μm.

Plate 7.41 (Photo 1) Group of small primary hopper-growth inclusions in ERDA-9 sample 2699.8-2700.0, after 250°C decrepitation run. These inclusions probably had no bubble originally, and now have one as a result of plastic deformation of the host salt. They now homogenize at temperatures as high as 273°C (Table 7.17).

Plate 7.42 (Photo 2) Solid phases (daughter crystals?) in inclusion in Kerr-McGee mine sample MB-76-4. The small rod-like crystal has parallel extinction, and the large cubic(?) crystal (KCl?) appears isotropic.

Plate 7.43 (Photo 3) Dense gas inclusion in Kerr-McGee mine sample MB-77-8, photographed at the approximate temperatures indicated (°C). See text, subchapter 7.5.

Plates 7.44 and 7.45 (Photos 4 and 5) Steam inclusions (arrows) in Kerr-McGee mine samples MB-76-3 (7.44) and MB-77-8 (7.45), now containing essentially vacuum, before (a) and after (b) being intersected by a fracture during crushing tests. The surrounding oil has filled the inclusions completely in (b).

Plates 7.46 and 7.47 (Photos 6 and 7) Gas inclusions in Kerr-McGee mine sample MB-77-8 containing gas at less than one atmosphere pressure, before (a) and after (b) being intersected by a fracture during crushing tests.

Plate 7.48 (Photo 8) High pressure gas inclusion in Kerr-McGee mine sample MB-76-4 before (a) and after (b) being intersected by a fracture during crushing.

Plates 7.49, 7.50 and 7.51 (Photos 9, 10, and 11) High pressure gas inclusions in Kerr-McGee mine samples MB-77-8 (7.49 and 7.51) and MB-76-3 (7.50), before (a) and after (b) being intersected by a fracture during crushing. The approximate volume expansion is 30-fold in 7.49, 40-fold in 7.50, and 100-fold in 7.51. Two bubbles formed in 7.49, and one in 7.50 (arrows).

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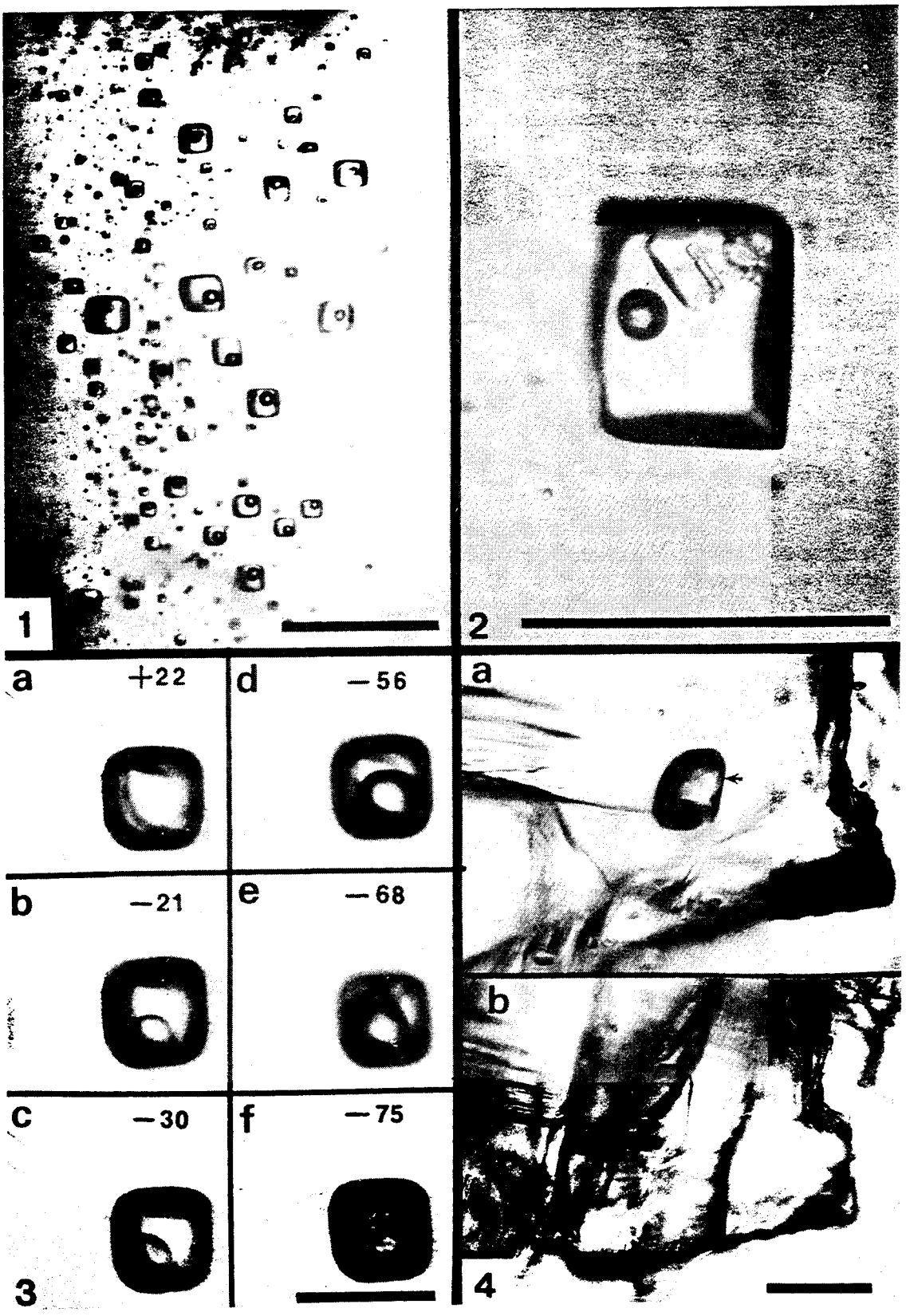

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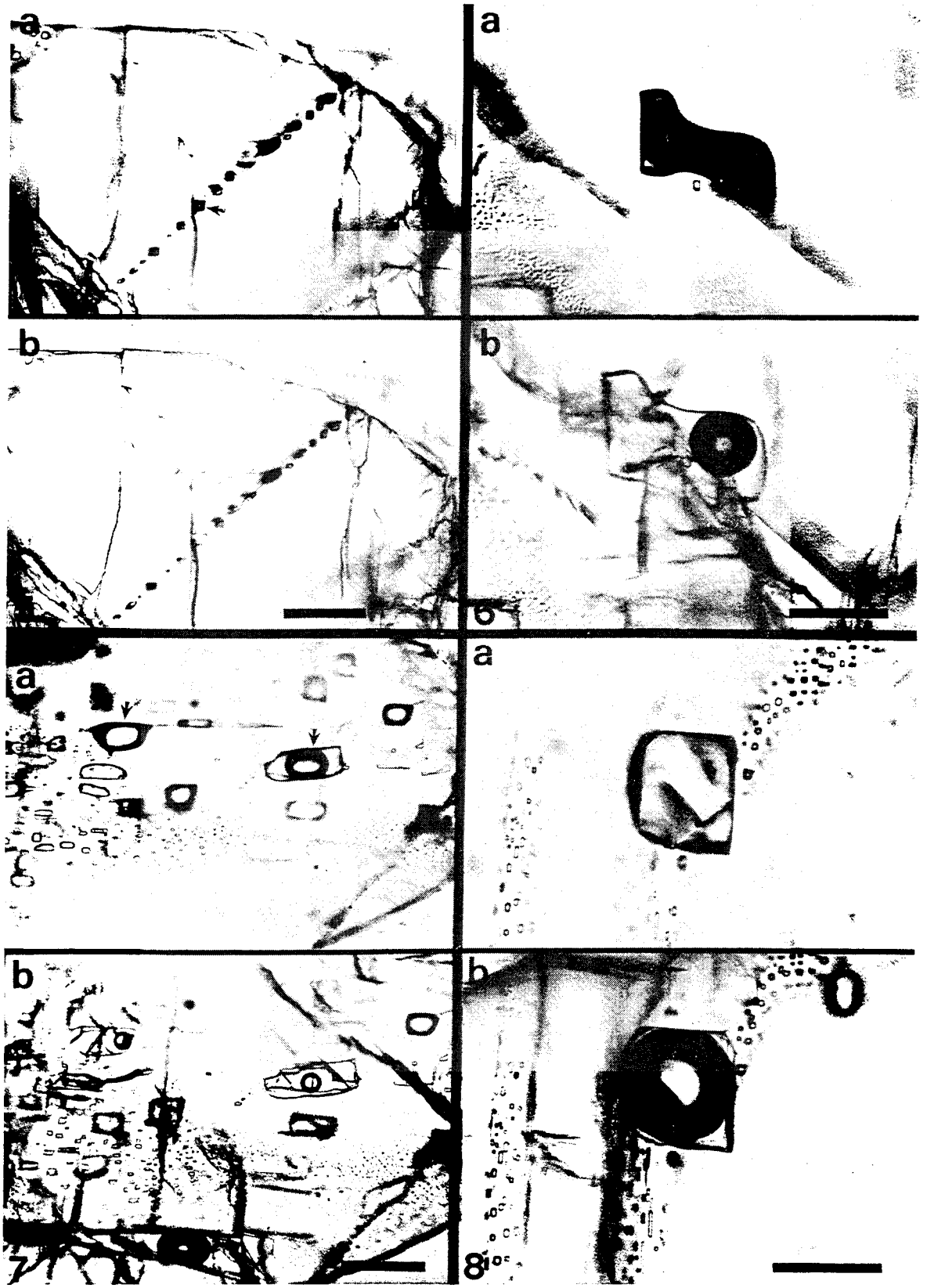

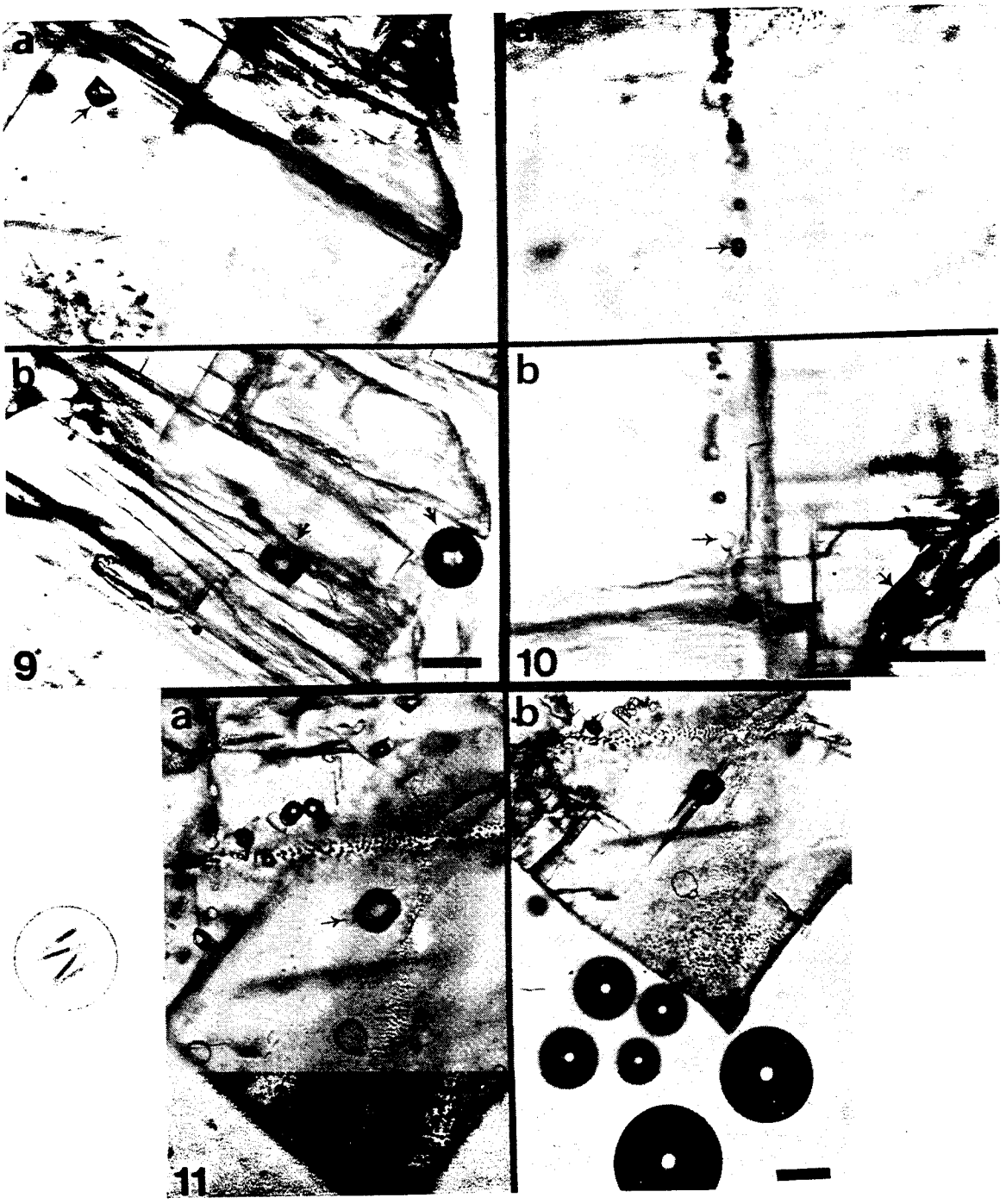
a
b
9
a
b
10
a
b
11

PLATE CAPTION

Plate 7.52 and Overleaf: Core fragments from Castile anhydrite serving as host rock for the ERDA No. 6 brine reservoir. Depths of origin, uranium contents and $^{234}U/^{238}U$ ratios are given in the overleaf for various parts of the core fragments.

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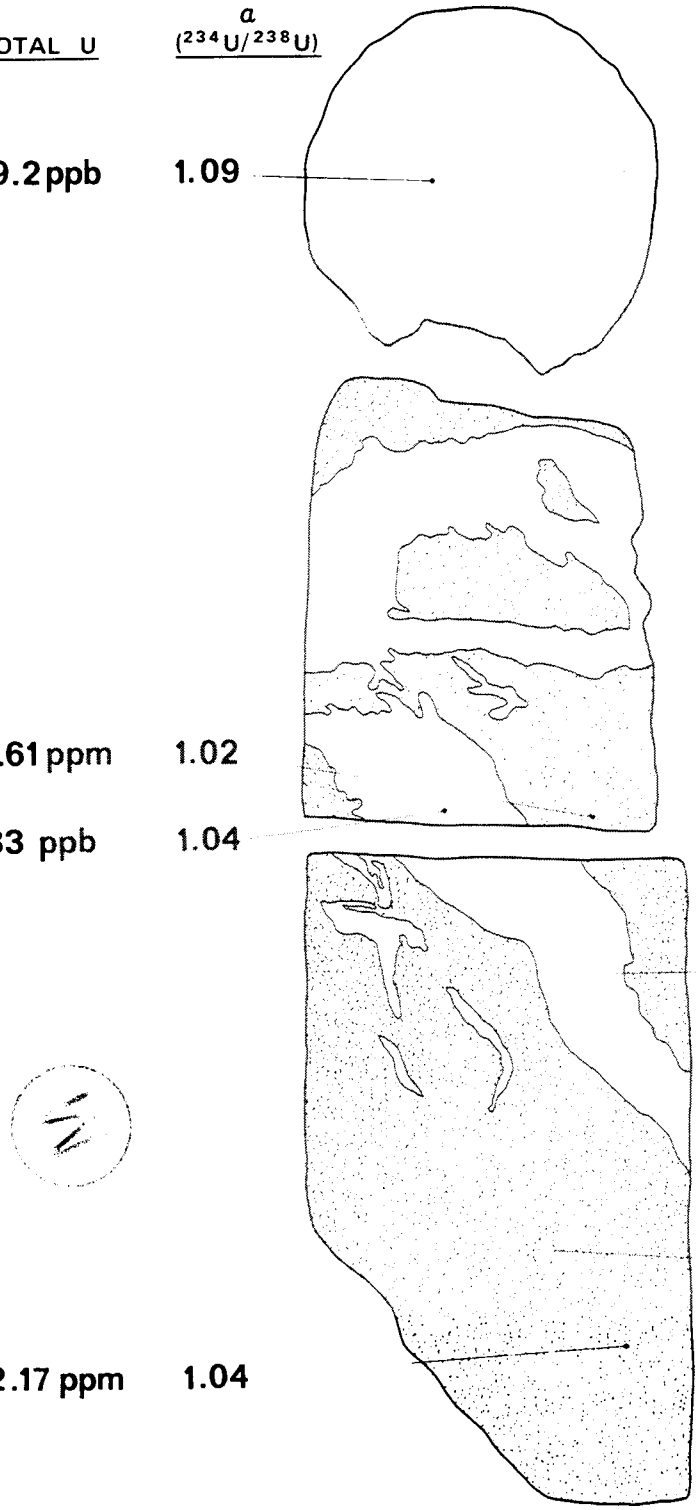
TOTAL U	α ($^{234}U/^{238}U$)	DEPTH (Ft.)
19.2 ppb	1.09	2708
1.61 ppm	1.02	
33 ppb	1.04	2709.4
2.17 ppm	1.04	2709.9



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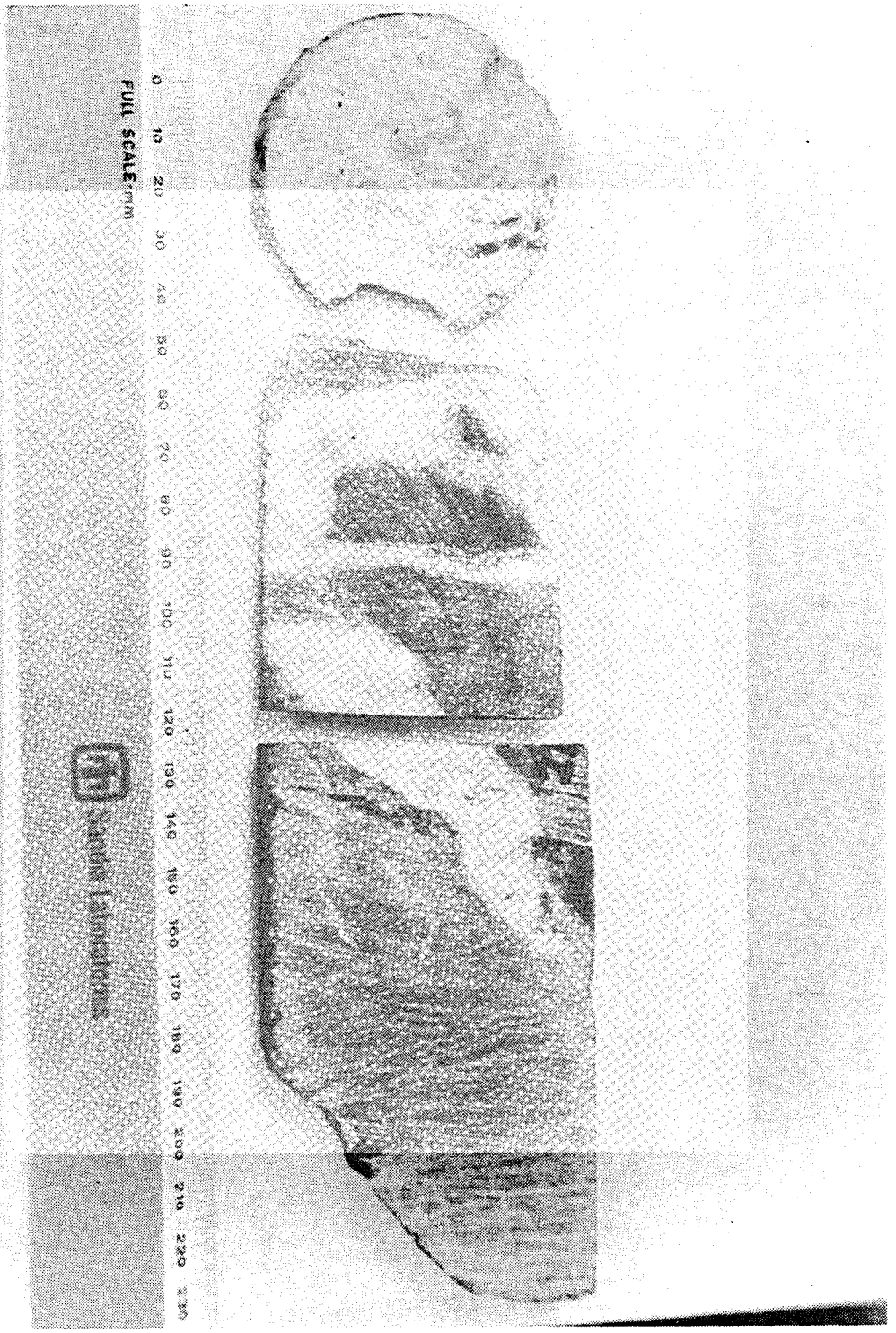

PLATE 7.52

GCR CHAPTER 8

RESOURCES

8.1 INTRODUCTION

The northern portion of the Delaware Basin is known for production of potassium salts and fluid hydrocarbons. An effort was made to select a location for the WIPP that would minimize conflict with these resources. It is likely, however, that some of these potash and hydrocarbon resources underlie the site. The extent of potash mineralization has been fairly well established because the potash mining industry has released information concerning their exploratory drilling in the area. Those findings were supplemented by information from 21 additional holes drilled by the Department of Energy. Site selection criteria described in Chapter 2 prescribe that the site be no closer than one mile from a deep drill hole. This means that the potential hydrocarbon resource must be evaluated by inference utilizing subsurface information from surrounding areas. An investigation was also carried out to determine the significance of other possible industrial minerals such as caliche, gypsum, salt, uranium, sulfur, and lithium at or very near the WIPP site. Table 8-1 summarizes the principal findings of resource studies. Only potash and natural gas are considered to be significant exploitable deposits as shown in Table 8-2. The economic resources denied in Zones I-III are shown in Table 8-3.

8.2 ORGANIZATIONS INVOLVED IN RESOURCE EVALUATION, AND THEIR REPORTS

Numerous contractors representing both government and private companies were engaged in the resource evaluation at the WIPP site. An outline of work accomplished during this phase of the site characterization is given in Table 8-4.

The listed studies quantify in-place resources and evaluate what portion of those resources would be extractable. A legal determination is now under way to establish values to the various mineral and oil and gas

lease holders within the site area. However, these studies deal with the present value of specific land tracts and as such are not pertinent to site chacterization.

8.3 POTENTIAL RESOURCES IN RELATIONSHIP TO STRATIGRAPHY AT THE WIPP SITE

Resource evaluation at the WIPP site took into consideration the existing stratigraphy of the site area. Each formation was evaluated for mineral deposits that were either known or that could exist based on the characteristics of the sediments present.

A stratigraphic column is given in Table 8-5 that indicates where in the geologic section specific types of deposits are considered to have a reasonable likelihood of occurrence. The table briefly describes the character, thickness, and median depth of each formation.

8.4 RESOURCE DESCRIPTION BY SPECIFIC COMMODITIES

The description of resources commences with the shallowest formation and proceeds down the stratigraphic column to the Precambrian.

8.4.1 Caliche

A thin layer of caliche (a whitish, calcium carbonate-rich material) underlies most of the site area. Exposures are normally obscured by dune sand, but it has been estimated that the caliche blanket covers approximately 80% of the site area. The average thickness is 4.3 feet, and the total resource has been estimated at 185 million tons (Siemers et al., 1978). The quality of caliche as determined by insoluble content (ranging from 21 to 69%) appears to be typical for caliche for this region.

Caliche is often used to surface dirt roads in southeast New Mexico. Small quarries dot the landscape, and several provided material for road construction to various drill locations within the WIPP site. This is the sole use for caliche in this region. Caliche is so extensive in this region that it can not be considered as either a limited resource or one that has significance to road construction of surrounding areas if land is withdrawn for the WIPP site.

8.4.2 Uranium

Uranium could occur in sediments such as those of the Gatuna, Santa Rosa or Dewey Lake Formations. However, no significant occurrence of uranium has been found within the Delaware Basin. Reducing environments favoring uranium deposition are absent as evidenced by the lack of organic debris, pyrite or humates in these formations. No signal indicative of economic or even marginal uranium concentrations was observed on gamma ray logs of the 36 holes drilled through these beds during site evaluation. The conclusion is that significant uranium deposits are most unlikely, even in beds which are considered to be the most favorable.

8.4.3 Gypsum

Dissolution of salt from the Rustler Formation has occurred over much of the site area. Waters accompanying this dissolution have caused partial conversion of anhydrite within the Rustler to gypsum. The conversion is not complete, however, and it is doubtful that high-quality gypsum would be persistent in any single bed. The maximum amount that could be present, assuming an aggregate thickness of 40 feet, amounts to 1.3 billion tons (Siemers et al., 1978). The quality and bed thickness are inferior to those in beds west of the WIPP site. Still farther west and south, extensive outcrops of high quality gypsum of the Castile Formation occur. The nearby availability of superior quality gypsum that can be mined by open pit methods leads to the conclusion that gypsum in the Rustler Formation can not be considered a likely economic resource.

8.4.4 Halite (Salt)

Halite is the dominant constituent of the Ochoan evaporites. The shallowest salt is in the Rustler, but dissolution of this formation has removed much of the Rustler salt except in the southeast quadrant of the WIPP site. On the other hand, salt beds persist under the site in the Salado and Castile Formations. The thickest and purest salt beds in the region are in the Castile. The State Bureau of Mines and Mineral Resources estimated 118 billion tons of salt in the Salado within the WIPP boundary (Siemers et al., 1978). The Castile Formation would add approximately 80 billion tons of additional salt resource.

As with gypsum and caliche, the immense halite deposits are not considered to have economic significance because of the prevalence of these deposits throughout the general area and the existence of adequate supplies closer to areas where salt is in demand.

8.4.5 Sulfur

A significant deposit of native sulfur is being exploited by the Frasch process approximately 50 miles south of the WIPP site in northeastern Culberson County, Texas. The occurrence is associated with brecciated and carbonatized anhydrite beds of the Castile Formation. Considerable exploration has been under way since discovery of the Culberson deposit, but that exploration has been aligned along the southern and western parts of the Delaware Basin where the Castile Formation either lacked halite during deposition or the halite has been removed by dissolution. The genesis of the deposits is believed to depend on a combination of bacterial action, induced fracture permeability and a source of hydrocarbons (presumably from upward escape of natural gas or crude oil along fractures from the Delaware Mountain Group). The closest analogy to such a setting in the northern part of the Delaware Basin and the vicinity of the WIPP site would be either "breccia pipes" or H_2S-laden brine reservoirs. Careful attention was given in selecting the WIPP site to avoid such structures; further investigation has not revealed any such structures, therefore, no sulfur deposits are expected.

8.4.6 Lithium

Lithium occurs in a concentration of 140 mg/L in a saturated brine reservoir that was encountered during the drilling of ERDA 6. The hole was located 2 miles northeast of the outer boundary of the WIPP site. A similar reservoir was found in the Belco Hudson Federal No.1 gas well 1/4 mile outside Zone IV on the southwest side of the site. No analyses were done for lithium in the latter well, but both reservoirs were at equivalent stratigraphic positions (middle Castile), contained H_2S, and were fully saturated brines. The concentration of 140 ppm lithium in ERDA 6 verges on being economically extractable if the reservoir is of sufficient size. Griswold (1977) estimated the reservoir volume at ERDA 6 to be on the order of 100,000 to 1 million bbl. If reservoirs are limited to this size, they would not warrant development. At current market price the in-place value of the lithium would not exceed $1 million.

There has been a deliberate attempt to locate the WIPP site in an area free of brine reservoirs in the Castile. Extensive seismic surveys have been run across the area to ensure that no anomalous structures occur in the Castile Formation. The occurrences at ERDA 6 and at the Belco well are associated with complex anticlinal structures and are easily recognizable on seismic survey traces.

8.4.7 Potash

Method of Evaluation. Sylvite (KCl) and langbeinite ($K_2Mg_2(SO_4)_3$) exist under portions of the WIPP site (see Figures 8.2, 8.3, 8.4). Although an attempt was made to avoid such deposits during the site selection process, it was not possible to do so completely because other site selection factors such as avoiding deep oil and gas test wells and the desire for uniform and thick salt beds at reasonable depth took precedence.

The potash evaluation commenced in August, 1976, after the site was chosen for detailed characterization. When chosen, the site was located mostly outside the Known Potash Area defined by the Conservation Division of the U.S. Geological Survey. Considerable potash exploratory drilling had been done on the flanks of the site area by private industry, but it is a requirement that the results of that drilling be held in confidence by the USGS. However, Sandia Laboratories contacted each mining company that had drilled in the vicinity and was granted access to the drill records on a private basis. These records indicated that deposits of commercial quality probably extended into the site area. The Department of Energy (then ERDA) authorized an exploratory drilling program to evaluate the potash deposits within the WIPP site. Technical direction of this exploratory drilling program was given to the USGS. The drilling program commenced in August and was completed by the end of November, 1976.

The Roswell, New Mexico, office of the Conservation Division of the USGS was given the task of determining potash resources by combining the results of DOE-sponsored drilling with records of drilling in the vicinity of the site. Findings have been reported by John et al. (1978).

The DOE also engaged the services of the U.S Bureau of Mines (USBM) to evaluate the extent to which the resources defined by the USGS could be produced at a profit using existing mining and beneficiation practices. The results of the study have been reported by the USBM (1977). The essential conclusion was that langbeinite in the 4th ore zone could be profitably mined in the northeast quadrant of the WIPP site. A band of sylvite, contained mostly within the 10th ore zone on the north and west sides of the sites, verged on being economically exploitable. Profitable mining of the sylvite would require a higher price for muriate (KCl) than current market value ($52/ton versus a current price of $43/ton).

Description of the Potash Exploration Drilling Phase. Figure 8-1 is a map showing a land block, centered on the WIPP site, that measures 8 miles on a side. This land block constitutes the area investigated by

the USGS and USBM. All locations of drill holes are shown from which information was available as to the depth, thickness, grade, and mineral suite of ore beds. Note that a different symbol is used to denote holes drilled by DOE from those drilled by mining companies. Examination of the distribution of hole locations reveals that the drilling plan directed by the USGS included testing the entire WIPP area on a spacing of not less than one hole per square mile. The objective was to completely cover the site area following industry practice for reconnaisance exploration. The density of the holes is judged to be quite adequate for resource appraisal.

Drilling closely followed standard industry practices (Jones, 1978). Rotary techniques were used from the surface down to a point just above the uppermost ore zone. Drilling operations were then converted to coring using a brine saturated with potassium chloride as the drilling fluid. Core recovery was excellent in all 21 holes. The core recovered was examined, and zones of interest were "split" for chemical analysis. Routine check analyses were done by an independent laboratory. All cores, including the remaining half of sample splits and sample rejects (excess after assay), have been permanently stored.

The results of the analyses of the 21 exploratory holes are attached as Appendix 8A. Included in the list are hole AEC 8 (drilled at the old ORNL site) and 17 holes for which information is available for release either by permission of the mining company involved or because the lease or permit on which the hole was drilled has expired.

Calculation of Potash Resource Distribution, Volume and Grade. As previously stated, calculation of the in-place volume and grade was undertaken by the Roswell office of the Conservation Division of the USGS. Technical assistance was also provided by the Special Projects Branch of the USGS.

There are 61 exploratory holes in the 8 x 8 mile land block shown in Figure 8-1. Ore intercept information was available to the USGS on all

of these holes. Thus, while their calculations used all available data, some specific information pertaining to 22 industry drilled holes is not reported in Appendix 8A to protect proprietary information of individual companies as they so requested.

The reserve calculation commenced with assigning depth intercepts to significant mineralization within the various ore zones. There are 11 such ore zones within the McNutt member of the Salado Formation (see Figure 4.3-3b). The next step consisted of extrapolating continuity of individual ore zones between holes. The final step was to calculate the volume and grade for continuous blocks of mineralization. In addition, the Conservation Division utilized criteria they have established for classifying resources as either measured, indicated, unevaluated, or barren. The criteria are:

Measured potash reserves - Tonnage is computed from dimensions revealed in workings and drill holes. The grade is computed from the results of detailed sampling and analyses. A minimum of three data points in any one ore zone meeting quality and thickness standards, no more than 1 1/2 miles (2.4 km) apart, have been used to delineate measured reserves.

Indicated potash reserves - Tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Unevaluated potash areas - Tonnage and grade have not been computed due to low density drilling and sampling, but are surrounded by measured and (or) indicated reserves.

Barren and/or minor potash mineralization areas - Subeconomic resources that would require a substantially higher market value or a major cost-reducing technology for economical production.

Subeconomic resources also include other bittern minerals not presently being recovered.

Potash resources were then quantified at three minimum grade and thickness levels. Standard conditions for each class are shown in Table 8.6.

The intermediate conditions, termed "lease", conform with established policy of the Department of Interior that any area known to contain potash mineralization meeting or exceeding that standard and located on Federal land can be acquired only through competitive bid. The standard is based on judgment along with recognition that ores as low as these grades have been successfully treated from time to time at one or more of the potash refineries in the Carlsbad district. The conditions termed "high" are roughly equivalent to the grade of langbeinite and sylvite ores currently being mined in the district.

Results of the USGS Resource Estimate. The essential results of the USGS resource calculations are best shown by three consecutive maps (Figures 8-2, 3 and 4) which commence with the lowest resource grade standards and progress to the highest. For simplicity, measured and indicated resources were combined. The majority of the resource meets the criteria for "measured" because the entire WIPP site has been drilled on one mile centers. The resource maps do not segregate the several mineralized ore zones, and at times they are "stacked", e.g. the 4th and 10th may be mineralized in the same area in plan even though they are stratigraphically separated by about 180 feet.

Most of the WIPP site area is underlain by potash resources that meet the low standards. No significant planimetric change occurs on raising the standard to lease grades. However, at the high standard, which is roughly equivalent to the current standard of producing mines, the WIPP is nearly clear of potash deposits of interest (particularly Zones I-III). Mining operations may be allowed in Zone IV, the outer boundary of the WIPP site, under controlled conditions.

As grade standards are increased, the potash resources reduce, at more rapid rate on a mass weight basis than on a planimetric basis. Table 8-7 lists the tonnage of by ore zone, type, and location by Zone boundaries within the WIPP site.

For ease in interpretation, the data in Table 8-7 has been charted on Figures 8-5 and 8-6 for langbeinite and sylvite resources, respectively. The USGS recognized the 4th ore zone (langbeinite) and the 10th (mainly sylvite) as the two major mineralized ore zones in the WIPP site area (John et al., 1977). At lease grade, the 4th ore zone contains 115.4 million tons of langbeinite resource, of which only 24 million tons (21%) lies inside the outer boundary of Zone III. At the higher grade (8% K_2O as langbeinite) the tonnage under the WIPP reduces to 59 million tons, of which only 14.6 million tons (25%) lies inside the outer boundary of Zone III.

The 10th ore zone contains mostly sylvite, but a mixed assemblage containing both langbeinite and sylvite exists on the east side of the withdrawal area. At present only one operator in the Carlsbad district has a refinery capable of handling such ores. This operator is the leaseholder over part of this mixed ore zone. However, the langbeinite in the 10th ore zone would be difficult to beneficiate according to the USBM study (USBM, 1977, p.103). Therefore, the 10th ore zone is considered to be viable only for its sylvite content. With this restriction, the 10th ore zone contains 53.5 million tons of ore at lease standard under the entire WIPP site, of which 30.4 million tons (57%) are located within the outer boundary of Zone III. At the high standard, the total tonnage reduces to 38.8 million tons, of which only 9.8 million tons (25%) are inside Zone III.

Results of the USBM Valuation of Potash Resources. The USBM has performed an economic assessment of the potash resources that were defined by the USGS. The USBM study included beneficiation testing to determine the amenability of the various mineral assemblages to refining into marketable products. The USBM engineers visited most of the mines in the district to gather data concerning mining and refining techniques, power consumption, water use, etc. Then, knowing the location and grade

of potash deposits in the WIPP site area, they devised conceptual designs of various mining and processing facilities that would provide both the highest profit and efficient recovery of marketable products from the potash deposits. The approach followed what private industry would do in an evaluation of a potash prospect. No restriction was placed as to where physical mining could be done, or problems related to land acquisition or permitting. Resources adjacent to the WIPP site were considered in the mine development plans. In all, the USBM conceived 12 different conceptual plans for exploiting potash in this area. Each plan, called a mining unit, was evaluated leading to a conclusion that 8 were worthy of full cost analysis. The full findings have been reported by the USBM (1977).

The USBM concluded that only one mining unit (Unit B-1) could be considered economic under existing market conditions and technology (see Table 8.8).

Unit A-1 almost meets the economic requirement of 15% rate of return on invested capital set by the USBM. To make it viable one needs a price of $52.04 per ton of muriate without any increase in production costs. Muriate is currently selling at $43.40 for standard grade containing 62% K_2O (Source: July 1978 issue of Engineering and Mining Journal); however, the price for muriate has exceeded $60 per ton in the past.

Data within the USBM report indicate that the langbeinite resources associated with the Unit B-1 that lie within the boundary of WIPP amount to 48.46 million tons, of which only 13.33 million tons (27.5%) lie inside the outer boundary of Zone III. For Unit A-1 the corresponding numbers are 27.41 million and 0.9 million tons.

Summary of Conclusions Concerning Potash Resources in the WIPP Site. The site contains economically mineable reserves of langbeinite and possibly sylvite. If total rights withdrawal is a requirement to satisfy waste isolation, then the relevant quantities of potash resources are much greater than if mining is allowed in the Zone IV, the outer buffer zone. The relevant quantities are presented in Table 8-9.

The USGS has estimated that potash resources in southeast New Mexico (excluding the WIPP site) that meet lease standards are on the order of 5000 million tons of combined sylvite and langbeinite ores. Therefore, total withdrawal of potash lease rights at the WIPP site would account for about 7% of those resources; withdrawal of Zone I, II, and III rights would account for about 2%. No data are available for the Carlsbad potash district regarding what percentage of these resources would meet the standards deemed by the USBM to be mineable under today's conditions. In addition, the principal potash resource at the WIPP site consists of langbeinite. No estimates, either by USGS or USBM standards, are available for this ore alone. The Carlsbad district is the only area mining langbeinite in the free world. Langbeinite equivalent is produced in quantity, however, by combining sulfates of potassium and magnesium obtained from brine lakes. When the site was initially selected, most of the WIPP lay outside the Known Potash Area, however the 21 hole drilling program conducted as part of the WIPP potash evaluation resulted in discoveries sufficient to warrant expansion of that boundary (see Figure 8-1). The expansion conforms with USGS policy that potash resources meeting the lease standard must be placed within the enclave.

8.4.8 Hydrocarbons

Method of Evaluation. The WIPP site selection criteria dictated that deep drill holes (defined as those that penetrate through the Ochoan) be excluded from Zones I, II, and III. The objective was to maintain a one mile buffer between deep holes and Zone II, the zone in which waste is to be stored. This particular criterion is restrictive, because much of the Delaware Basin has been penetrated by wildcat test holes with an average density of about one hole per square mile. The present site is one of the few remaining portions of the Delaware Basin in New Mexico which will satisfy the criterion pertaining to deep holes. The absence of extensive drilling is due in part to the great depth (greater than 10,000 feet) to potentially favorable gas formations. In addition, potash deposits north and west of the site area precluded oil and gas exploration in those directions. Federal and State regulations have set aside potash

ineralized areas to protect underground mining operations from accidental entrance of methane gas. Therefore, most of the WIPP site is untested for deep reservoirs that might contain crude oil and natural gas. The evaluation must rely on projection of surrounding subsurface geologic information into the site area. There are four petroleum test holes in Zone IV of the WIPP site. Three holes tested the Delaware sands and were unproductive. The fourth was a deep gas test (15,000 feet) that was also unproductive.

The State Bureau of Mines and Mineral Resources performed a regional evaluation of the hydrocarbon resources in southeast New Mexico which was then used to further evaluate a four township area centered on the original ORNL site (Foster, 1974). This report is useful for the current WIPP site because, as indicated in Figure 8-7, the present site is still within the area studied.

Data contained in Foster's report provide a basis for estimating total hydrocarbon resources that might underlie the site area. By using a statistical approach, Foster arrived at a possible hydrocarbon content for each potential productive zone, commencing with the "Ramsey Sand," down to the top of the Precambrian basement. The Ramsey, the first potential pay zone, is located in the upper part of the Delaware Mountain Group. The lowest zones he considered to be potentially productive were dolomitic reservoirs in the Silurian/Devonian. His estimate was based on full development of any prospective area; therefore, total resources were estimated rather than the economics associated with their extraction. His resource estimate was based on the premise that geologic conditions beneath the site were as favorable as elsewhere in the study area and that each potential zone beneath an untested section would contain a proportionate share of the statistical average of hydrocarbons for that zone. The average was derived from success ratios and a conservative estimate of primary recovery of hydrocarbons as established by past exploration, development and production.

A consulting petroleum engineering firm, Sipes, Williamson and Aycock, Inc (SW&A), was engaged by Sandia Laboratories to conduct an economic evaluation of hydrocarbons in the site area. Based on known drilling costs and market conditions, they made a judgment as to what portion and which formations under the site were worthy of testing. The basic criterion was reasonable prospect for discovery with an economic reward to the operator of at least 10% return on his investment plus full recovery of costs. The essential conclusion of the SW&A study was that the Morrow unit has a high potential for successful discovery of natural gas. All other formations present were considered too high a risk to be the objective of a prudent wildcat test. Naturally, once a Morrow well was drilled it could encounter shallower productive pay zones, but the odds of such happening were deemed too speculative to be considered in the overall economics. The full findings of this study have been reported by Keesey (1976).

Structure maps of several horizons beneath the Ochoan evaporites have been compiled from seismic surveys that were either purchased from existing surveys or conducted as part of the WIPP site study. While the main purpose of these seismic surveys has been to understand the geologic aspects of the site area, they are also valuable for interpretation of potential hydrocarbon reservoirs. These structure maps were not available to Foster for his 1974 study, but they were to SW&A during their 1976 evaluation. The seismic studies have been reported by McMillan (1976) and G. J. Long & Associates (1976). Updated structural interpretations based on later seismic studies are now available. The recent changes have had little impact on the overall hydrocarbon evaluation.

Total Hydrocarbon Resources at the WIPP Site. The New Mexico Bureau of Mines study forms the basis of the evaluation of the total hydrocarbon resources in the site area (Foster, 1974). We assume there is a reasonable probability that Foster's estimated resources could exist under the site. However, this probably represents the upper bound of exploitable hydrocarbons.

The validity of the resource estimate rests on the subsurface geology and statistical probability. The geologic setting under the Ochoan evaporites is considered to be quite typical for this portion of the Delaware Basin; therefore the chance of finding oil or gas should approximate what has been found in similar areas near the site which have been more fully tested. However, since it is a regional statistical approach, it is possible that much more or much less than the average expected resource would be found if the site was actually drilled. The hydrocarbon evaluation is not as definitive as that for potash, which was actually confirmed by exploratory drilling. This would be self-defeating in the case of the deeper hydrocarbon resources since the area was selected to avoid such deep drill holes.

Foster's evaluation (Foster, 1974) took into account the occurrence of all known oil and gas accumulations in much of southeast New Mexico (Figure 8-7). The statistical base encompassed about 42 full townships equivalent to almost 1 million acres. The reserves for each oil pool or gas reservoir were estimated from the standpoint of actual or, where possible, projected production. Areas were then classed as developed or undeveloped based on the density and depth of drilling. From these data, Foster (1974) then determined the expected resource per section of land by assuming that the success of future drilling would have the same success ratio as in the past. A coincident assumption was that, while past wildcat drilling avoided the current WIPP site, the past economic incentive for drilling was low. Also, drilling restrictions pertaining to the Known Potash Enclave have prevented drilling, particularly on the west side of the WIPP area. There were more attractive areas available throughout the basin that satisfied the availability of private venture for exploration capital. These past constraints do not enter into the hydrocarbon potential estimates because the characterization of the site must take into consideration the long-term needs for mineral resources.

Figure 8-8 is taken from Foster (1974). Formations that he considered as potentially productive are shown opposite the stratigraphic column of sedimentary rocks underlying the Ochoan evaporites. Table 8-10 then

shows the potential resource he assigned to the various specific intervals but which were composited to more gross intervals. Further explanation is required pertaining to "wildcat" and "acreage" assignment of reserves.

The acreage method tests the success ratio of producing acreage versus the acreage considered to have been tested by wildcat drilling. The wildcat method considered a field, regardless of the number of wells in that field, as a single discovery. A success ratio was then determined by dividing the number of wildcat discoveries by the number of dry holes that were drilled to that formational depth. The acreage method normally results in a higher success ratio and, therefore, higher reserve estimates. In-place hydrocarbon resources for each zone within the WIPP site can be readily calculated from Foster's data by combining his estimate of in-place hydrocarbon resources per section (640 acres) with the known area for each zone of the WIPP site. The acreage method was used to prepare Table 8-11.

While the quantities given in Table 8-11 may appear large, they are brought into perspective by stating that all of the nearby region, i.e., the area studied by Foster, would contain 51 times the resource quantity under the WIPP site. The factor is simply the ratio of the total area evaluated by Foster (1512 square miles) divided by the area of the WIPP site (29.62 square miles). In addition, if hydrocarbon development is allowed in Zone IV, e.g., by deviated drilling, then the resource that would be withdrawn is reduced in proportion to the excluded area, i.e., from 29.62 square miles down to 12.73 square miles for a 43% reduction in restricted resources. The hydrocarbon resources remaining in Zones I, II, and III would account for only 0.84% of the total hydrocarbon resources Foster has estimated in the area immediately surrounding the WIPP site.

Estimate of the Economically Recoverable Hydrocarbon Resources. Sipes, Williamson, and Aycock, Inc. (SW&A) estimated the potentially economic hydrocarbon resources (Keesey, 1976). Their approach was to review the

existing geologic information pertaining to the area in and around the site and then to determine if the probability of oil and gas occurrences justified the risk of drilling and completing a well. The base area studied by SW&A consisted of a 20 x 20 mile block centered on the WIPP site (Figure 8-7). All available data were evaluated on each test that had been drilled within this 400 square mile area, with particular emphasis placed on deliverability and recoverable reserves.

SW&A found that 60 wells in this area were producing oil and/or gas from reservoirs in the Delaware Mountain, Bone Spring, Wolfcamp, Strawn, Atoka and Morrow. With the exception of the Atoka and Morrow, all other zones were considered as presenting too high a risk to justify the cost of wildcat drilling. Furthermore, even though an Atoka reservoir is being produced from a well located near the southwest corner of the WIPP site, SW&A concluded that that particular reservoir is being effectively drained by the single well. Offset drilling would enhance recovery rate but not total recovery.

The Morrow was considered to be worthy of testing, because of the high success ratio of wells drilled to that formation in the area around the site. Of 26 wells drilled to sufficient depth to test the Morrow, 23 were successfully completed as gas wells. A study of these wells revealed that the projected ultimate recovery ranged from insignificant to as much as 5.20 billion cubic feet (bcf) of natural gas. From the distribution of recoveries they concluded that the average successful Morrow well would recover 2.074 bcf of gas. This is in fair agreement with Foster's estimate for Pennsylvanian gas wells; he estimated 3.2 bcf per Morrow gas well if spaced at 320 acres per well.

Drilling and completion costs were then estimated for wells drilled to the Morrow (approximately 14,000 ft.). The estimate was $1.4 million. Using discounted cash flow analysis and the expected delivery rate and current gas price ($1.42 per 1,000 cu. ft. with 4% yearly escalation) they concluded that if a well produced 0.7 bcf over its lifetime it would

recover costs. Since the average well was more than twice this production, it was apparent that drilling in the site area could be justified.

Use was then made of the structure map on a limestone reflector horizon in the Morrow based on data from seismic surveys (Figure 8-9) (Long, 1976). Tentative drilling sites were picked with weight given to the flanks of anticlines because local experience indicates that productive sand lenses would more likely occur at such localities. A total of 20 drill sites was selected (Figure 8-9). In favorable structural areas wells were placed on a spacing of 320 acres per well. This spacing is standard practice for wells of this depth in New Mexico. Depending on proximity to producing wells and structural favorability, the 20 wells were ranked as proven, probable or possible. The proven category was limited to locations that would offset producing wells in the Los Medanos field. Two locations were designated as proven, nine as probable, and nine as possible.

The ultimate recovery of wells was adjusted to take into account the risk factor associated with wildcat drilling. Proven wells were assigned production of 2.07 bcf, probable wells 1.64 bcf, and possible wells 1.33 bcf per well for the southwest quadrant of the WIPP site. The estimated reserves for locations in other parts were placed at 2.09 bcf for probable and 1.67 bcf for possible reserves. No locations could be considered as proven. The higher reserves assigned to these locations were considered justifiable because shallower pay zones may be discovered on the way down to the Morrow. This calculation yielded a total reserve of 36.85 bcf of natural gas under the WIPP site (Table 8-12). Some distillate would accompany this gas production. Foster (1974) estimated that Pennsylvanian gas is accompanied by 14,950 barrels of distillate per bcf of natural gas produced. Therefore, the 36.85 bcf of reserve under the site should be expected to be accompanied by 550,900 bbl distillate.

Of the 20 drilling sites selected, 7 lie in Zone IV, 2 of which are ranked as proven, 4 as probable, and 1 as possible. The aggregate

reserve of these 7 wells is 13.38 bcf of natural gas and 200,000 bbl of distillate. If drilling is allowed into Zone IV these hypothetical reserves could be recovered. The net balance that would be non-recoverable because of restrictions on drilling in Zones I, II, and III is 23.47 bcf of natural gas and 350,000 bbl of distillate.

Summary of Conclusion Concerning Hydrocarbon Resources. Table 8-13 summarizes the findings of the New Mexico Bureau of Mines resource study and the SW&A economic evaluation of the part of those resources considered attractive enough to be developed by the petroleum industry at 1977 prices and drilling costs.

The hydrocarbon resources remaining under the WIPP, if Zone IV is developed, amount to about 0.84% of that projected by Foster for the vicinity of the WIPP site. The total economic reserve, including Zone IV, amounts to approximately 90 days production of dry gas from southeast New Mexico.

8.4.9 Metalliferous Deposits in the Precambrian

Even the deepest oil/gas test near the WIPP site has not penetrated deep enough to encounter the Precambrian basement. A regional survey of test holes has been done by Foster and Stipp (1961). The basement may consist of slightly metamorphosed rhyolites and tuffs known as the Panhandle Volcanic Complex (Flawn, 1954). Such rocks hold potential for sulfide deposits. Geophysical techniques (induced polarization or electromagnetics) have a detection capability scarcely exceeding 1000 feet, while the Precambrian is at median depth of 18,000 feet beneath ground level at the WIPP site. No evaluation, therefore, is feasible for sulfide deposits. The depth is greater by a factor of almost two over the deepest mines in the world. Therefore, resources in the basement rocks, should they exist, are not likely to be attractive targets for exploitation.

8.5 SUMMARY

Potassium salts and fluid hydrocarbons are the only two resources thought to be economically significant in the WIPP site area. The depth, volume and richness of the deposits are the principal factors which will determine when and if they might be exploited by a free-enterprise system. Such economic evaluation has been conducted and reported in the WIPP Environmental Impact Statement. Because economic aspects change, they are not so relevant to site characterization as they are to assessing the impacts of constructing the WIPP facility. Hence, in this chapter, amounts and types of resources will be discussed rather than their present economic value. The principal findings of resource studies are summarized in Table 8-1.

If reasonable technologic and economic restraints are considered for extracting, processing and marketing the resources then both the amounts and types of exploitable deposits are greatly reduced. Only potash and natural gas are considered to be significant in this respect (see Table 8.2). Even these reduced quantities should be considered as upper estimates because of these assumptions: 1) complete mineral lease ownership by a single company and 2) no conflict between the simultaneous development of the shallow potash deposits and the deep gas reservoirs.

Economic resources are further reduced by allowing the mining of potash and recovery of oil and gas by deviated drilling in Zone IV, the outer buffer zone. If this is the case, then economic resources lying in the inner zones are limited to those given in Table 8-3.

Caliche, salt, and gypsum are also present, but the abundance of these minerals throughout the region leads to the conclusion that land withdrawal for the WIPP will have little effect on present or future requirements for them. Consideration was also given to the possible presence of uranium in redbed-type sediments that overlie the evaporites. The conclusion is that no significant uranium deposit exists. Lithium occurs in a brine reservoir within the Castile Formation

northeast of the present site and may be present in a similar reservoir to the southwest. However, care has been taken to avoid such brine reservoirs within the site area. Consideration was also given to the possible existence of metalliferous deposits in the Precambrian basement under the site. However, the depth (about 18,000 feet below the ground surface) to Precambrian rocks would preclude mining even if mineral concentrations were present. No geologic or geophysical evidence exists to suggest that deposits are any more likely in the basement rock of the WIPP area than elsewhere in the region.

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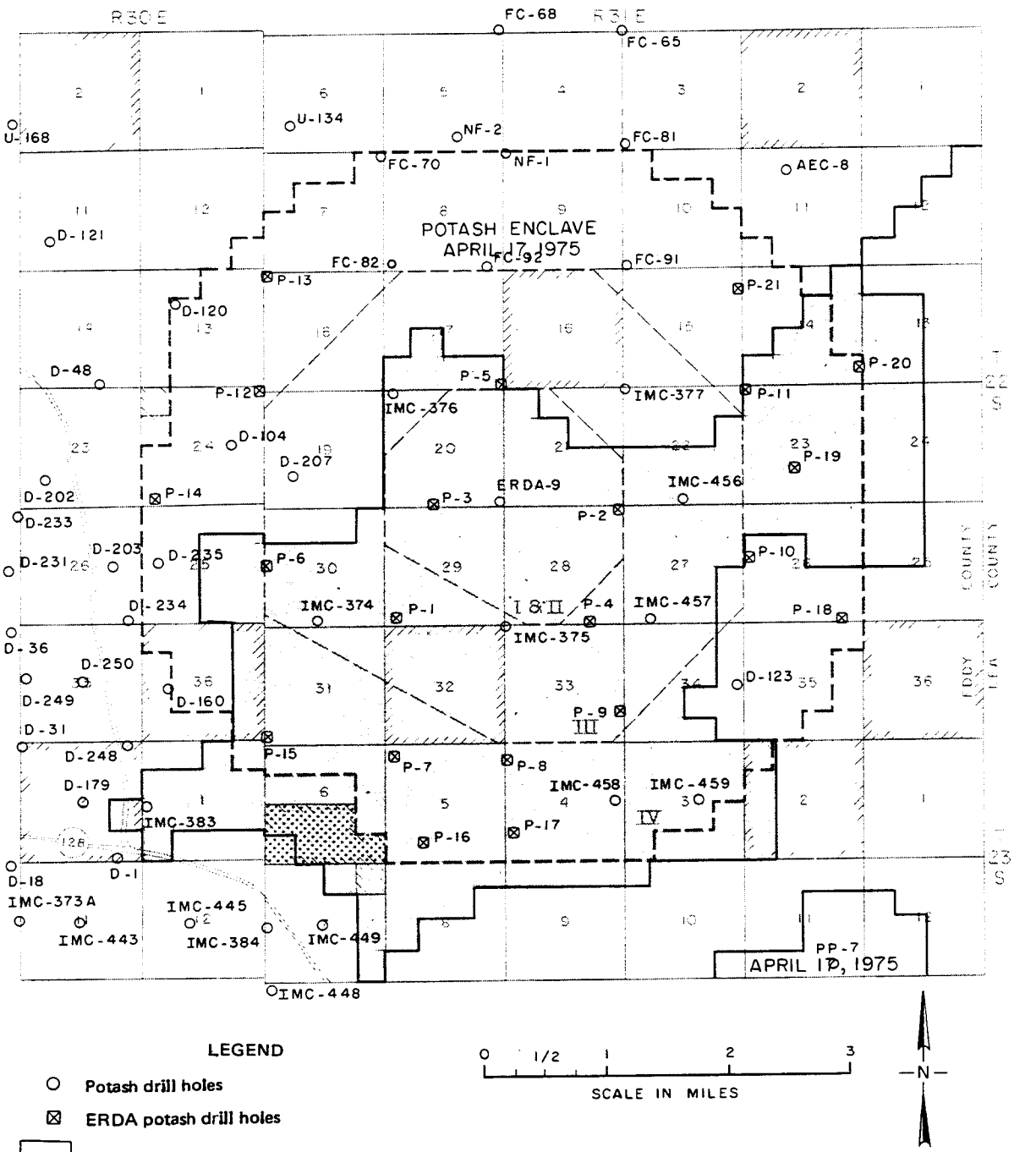

LEGEND

- ○ Potash drill holes
- ⊠ ERDA potash drill holes
- Federal surface and mineral rights
- State surface and mineral rights
- Private surface and mineral rights
- Potash Enclave Boundary Extension, July, 1977
- Private surface, all mineral rights owned by Federal Government
- Private surface and mineral rights, except oil and gas federally owned
- ———. Proposed WIPP site outline
- ———— Zone boundaries and areas provided by ERDA

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SCALE IN MILES

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FIGURE 8-1

LOCATION OF POTASH EXPLORATION DRILL HOLES

IN THE VICINITY OF WIPP SITE

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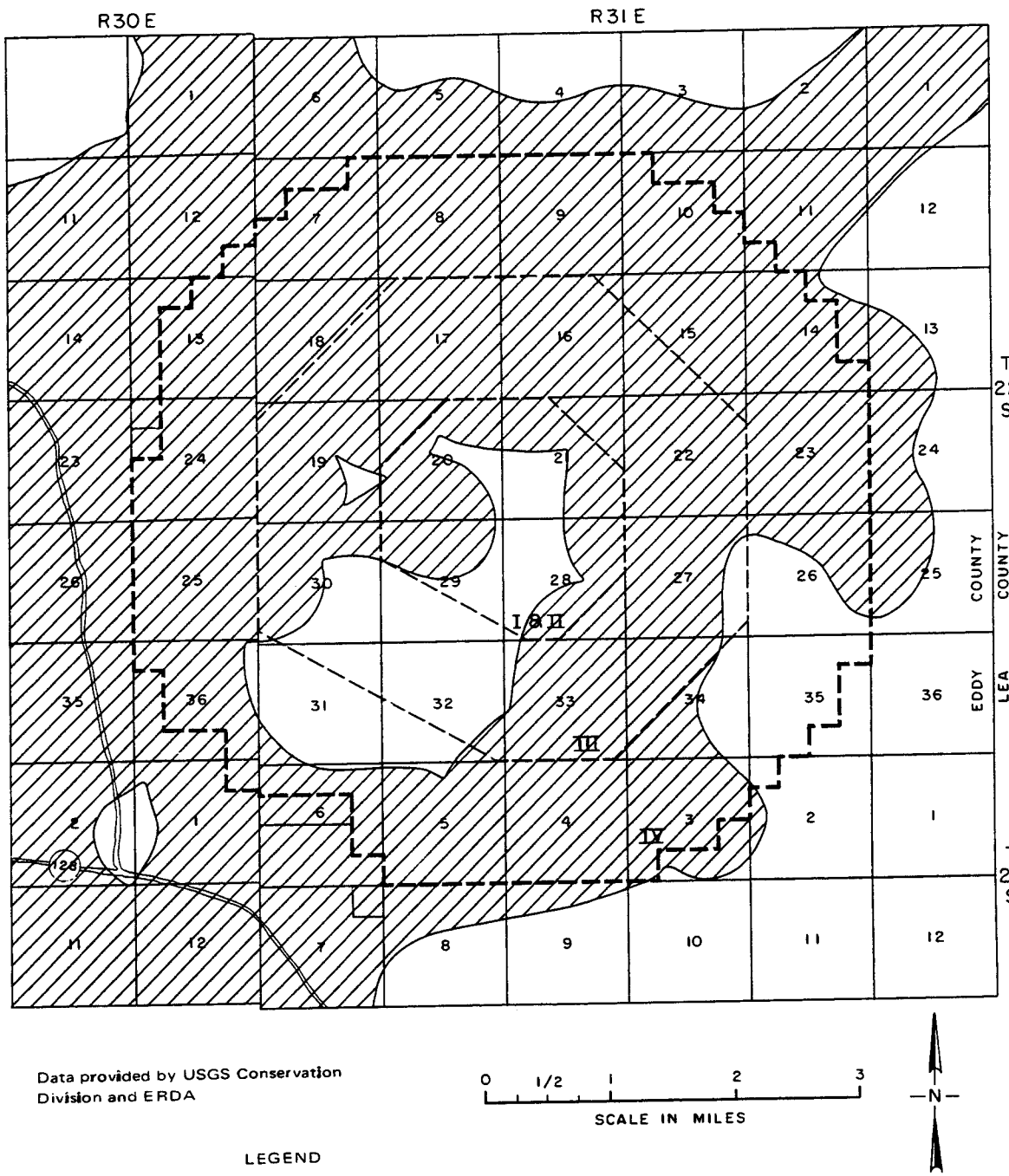

FIGURE 8-2 LOW STANDARD POTASH RESOURCES

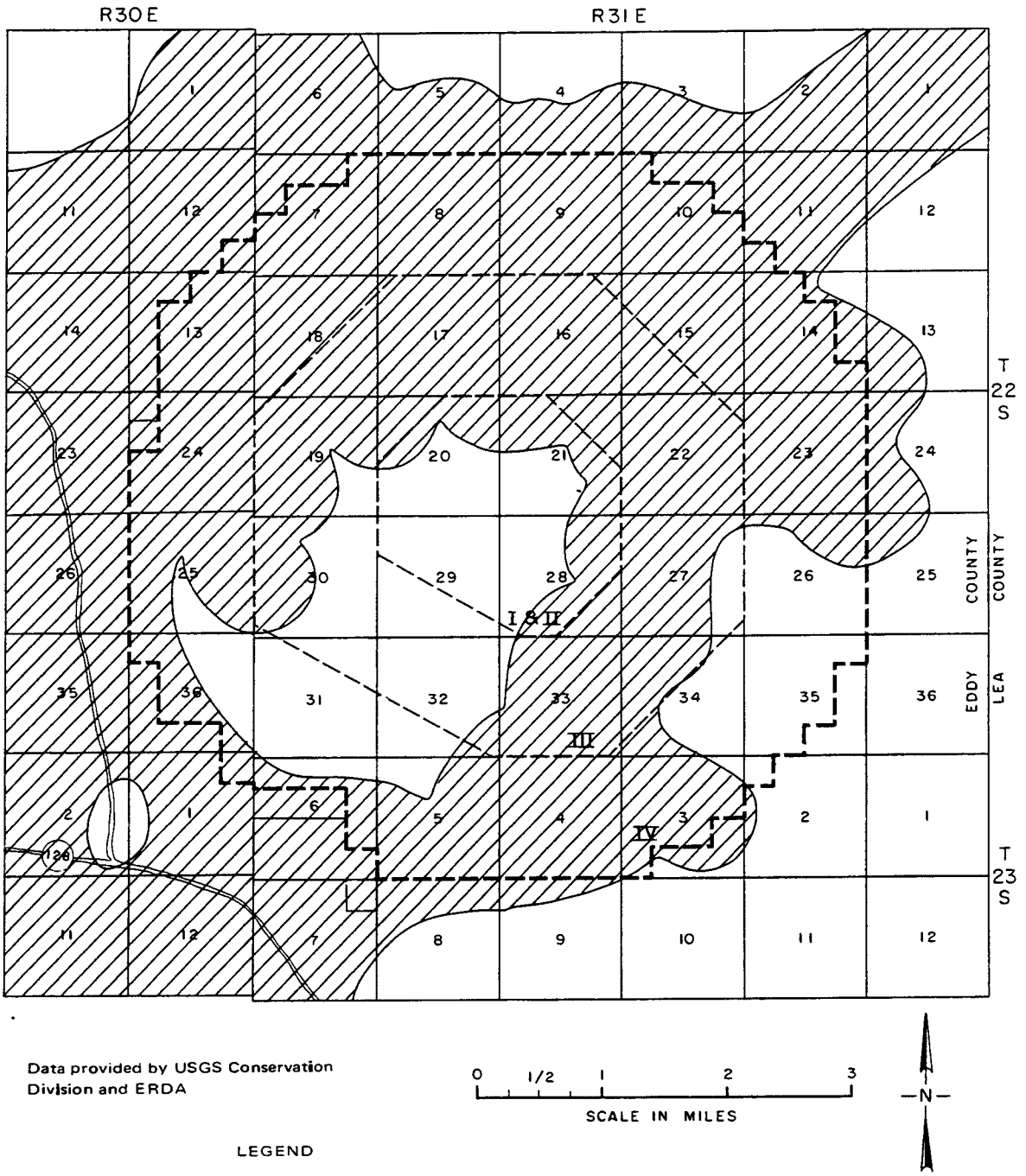

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FIGURE 8-3 LEASE STANDARD POTASH RESOURCES

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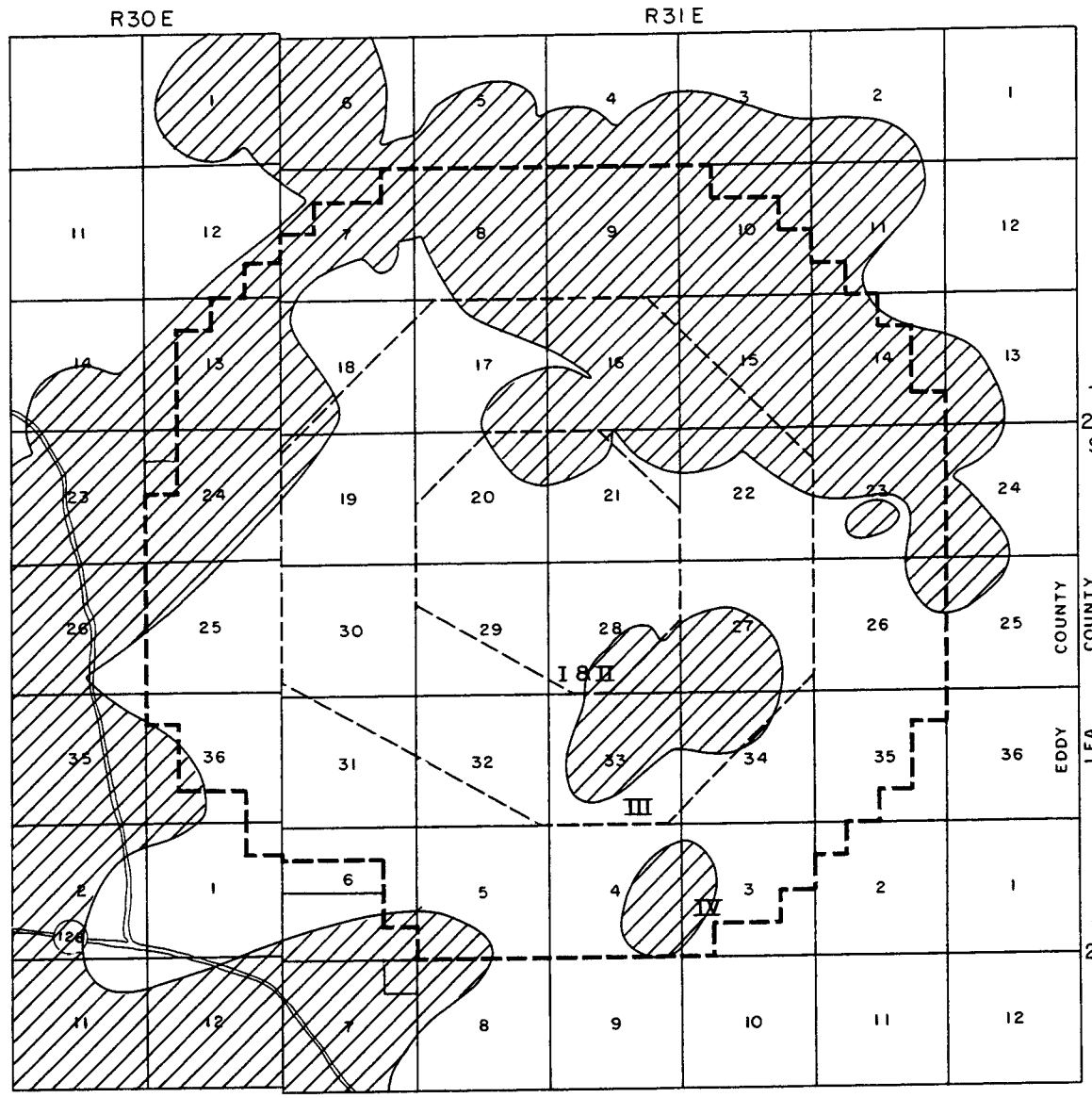

FIGURE 8-4 HIGH STANDARD POTASH RESOURCES

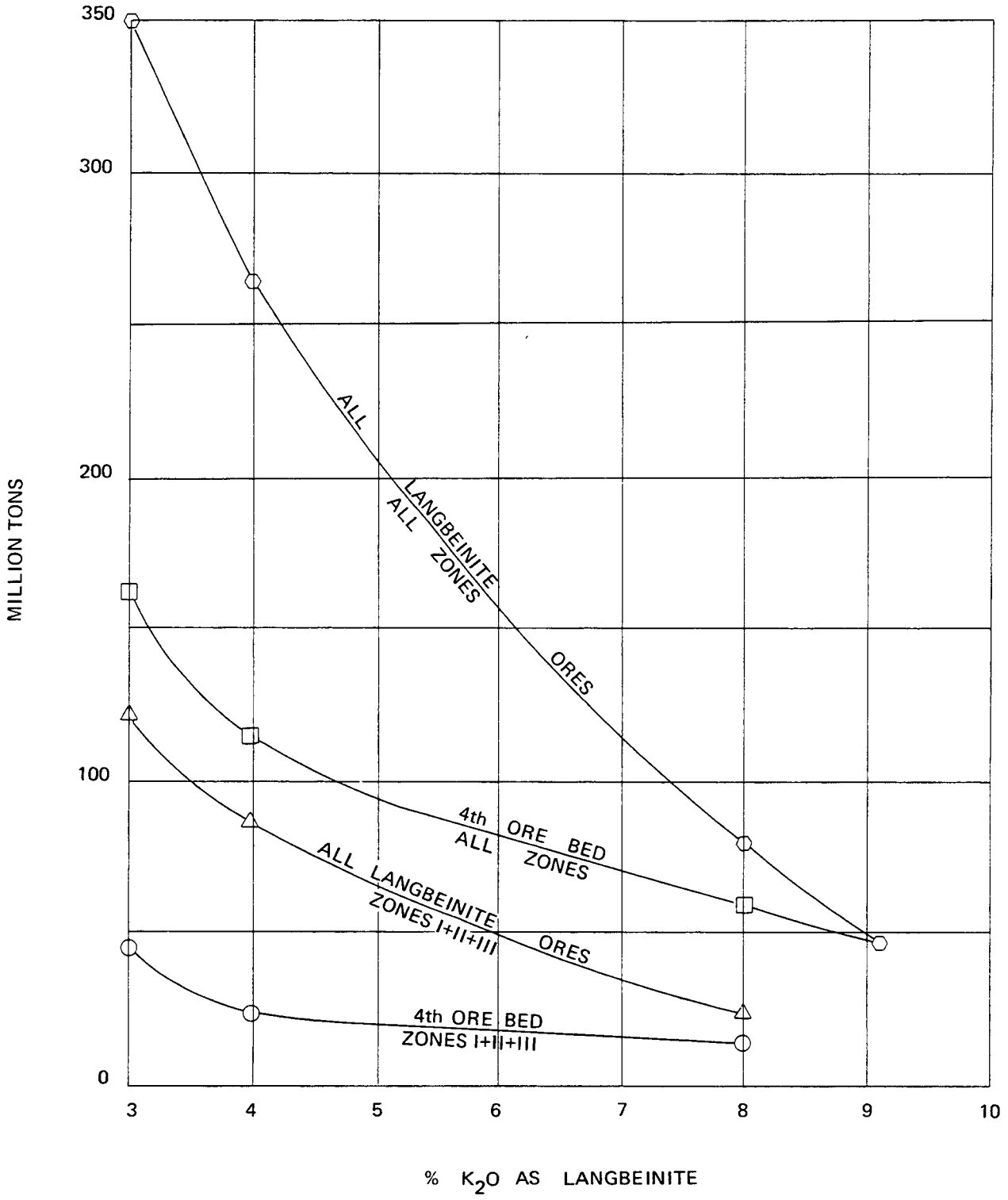

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FIGURE 8-5. LANGBEINITE RESOURCES

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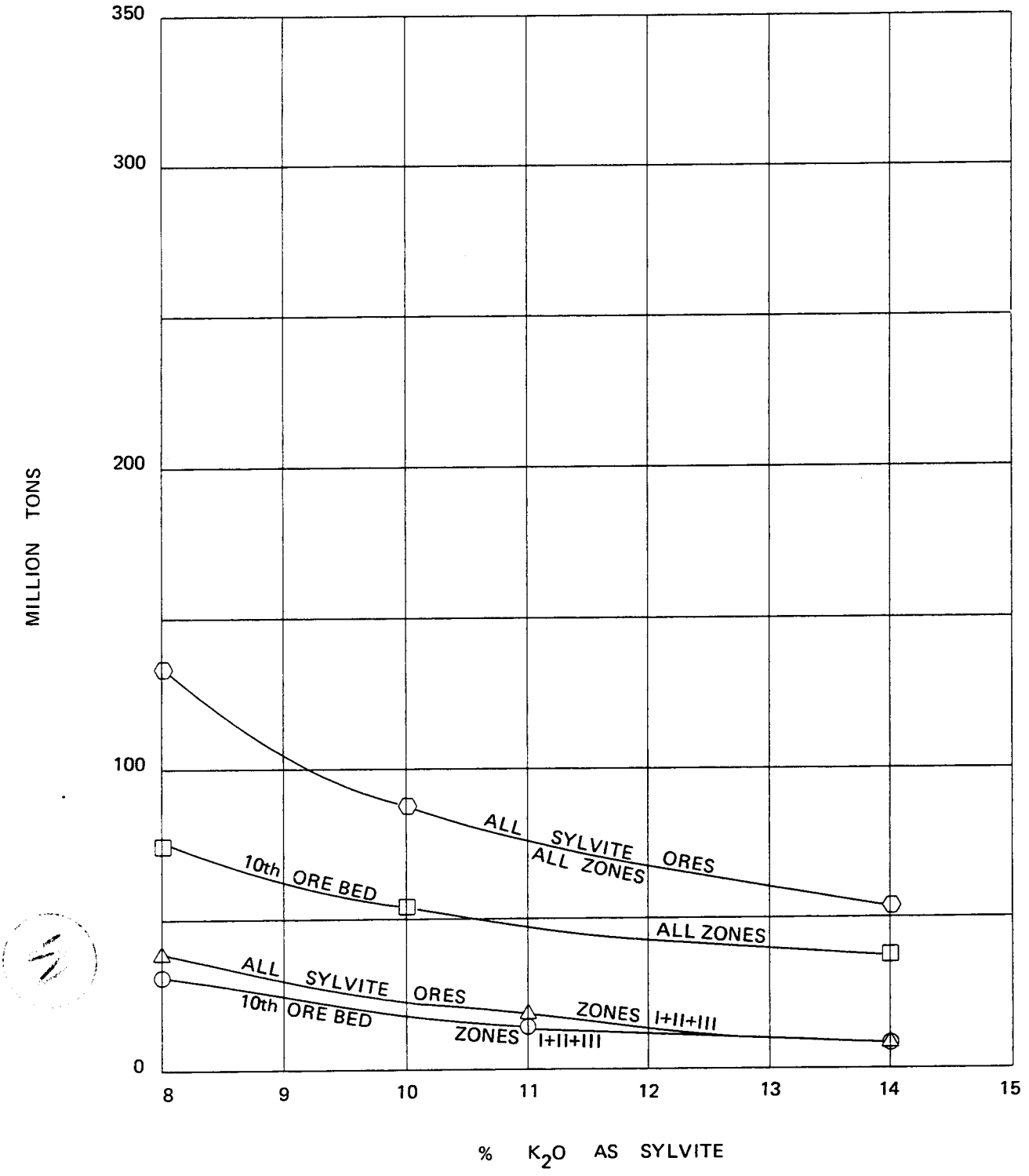
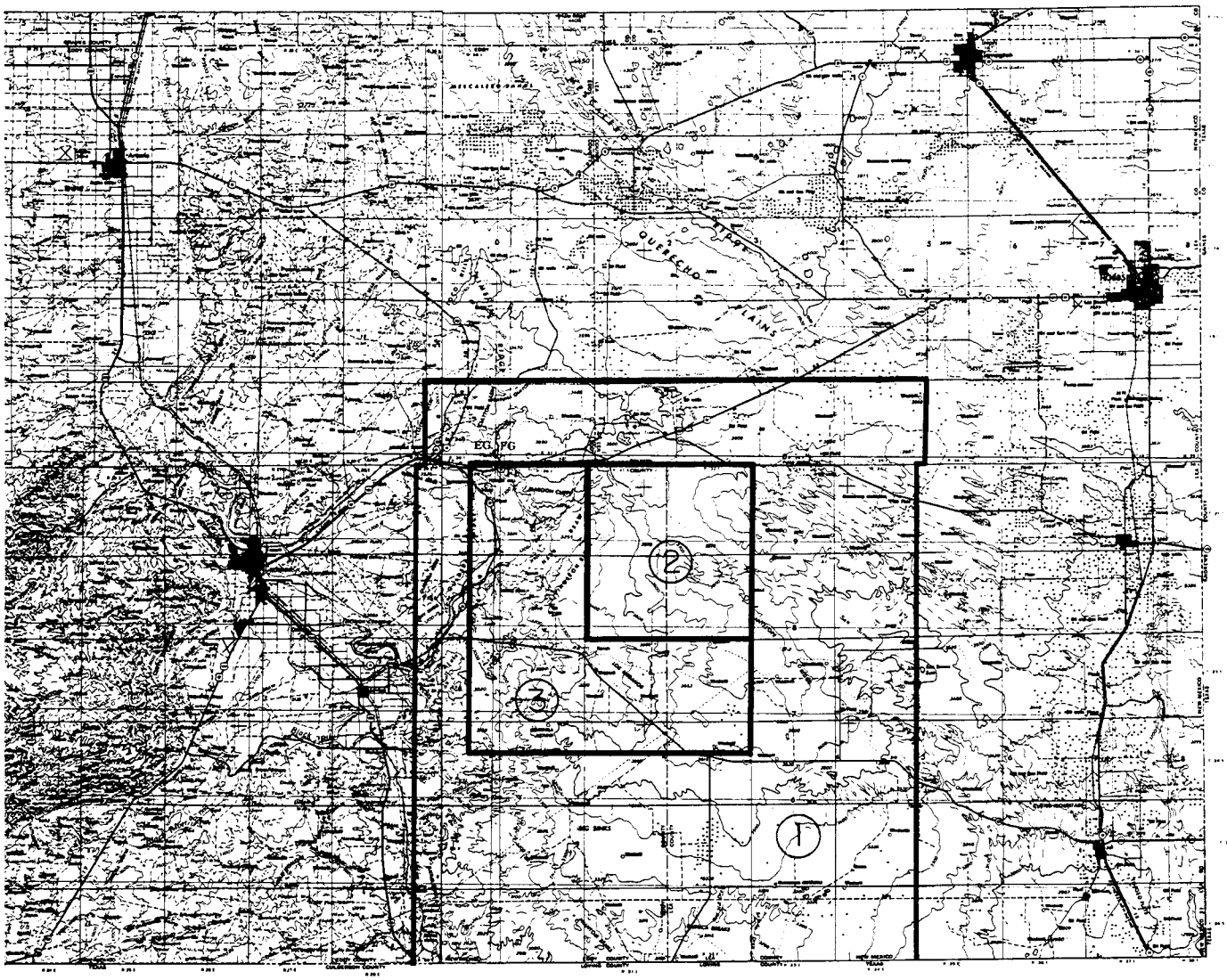


FIGURE 8-6. SYLVITE RESOURCES



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(1) NEW MEXICO BUREAU OF MINES STUDY AREA

(2) NEW MEXICO BUREAU OF MINES DETAILED STUDY CENTERED ON OLD ORNL SITE

(3) SIPES, WILLIAMSON AND AYCOCK STUDY AREA CENTERED ON WIPP SITE

FIGURE 8-7

LOCATION OF HYDROCARBON RESOURCE STUDY AREAS

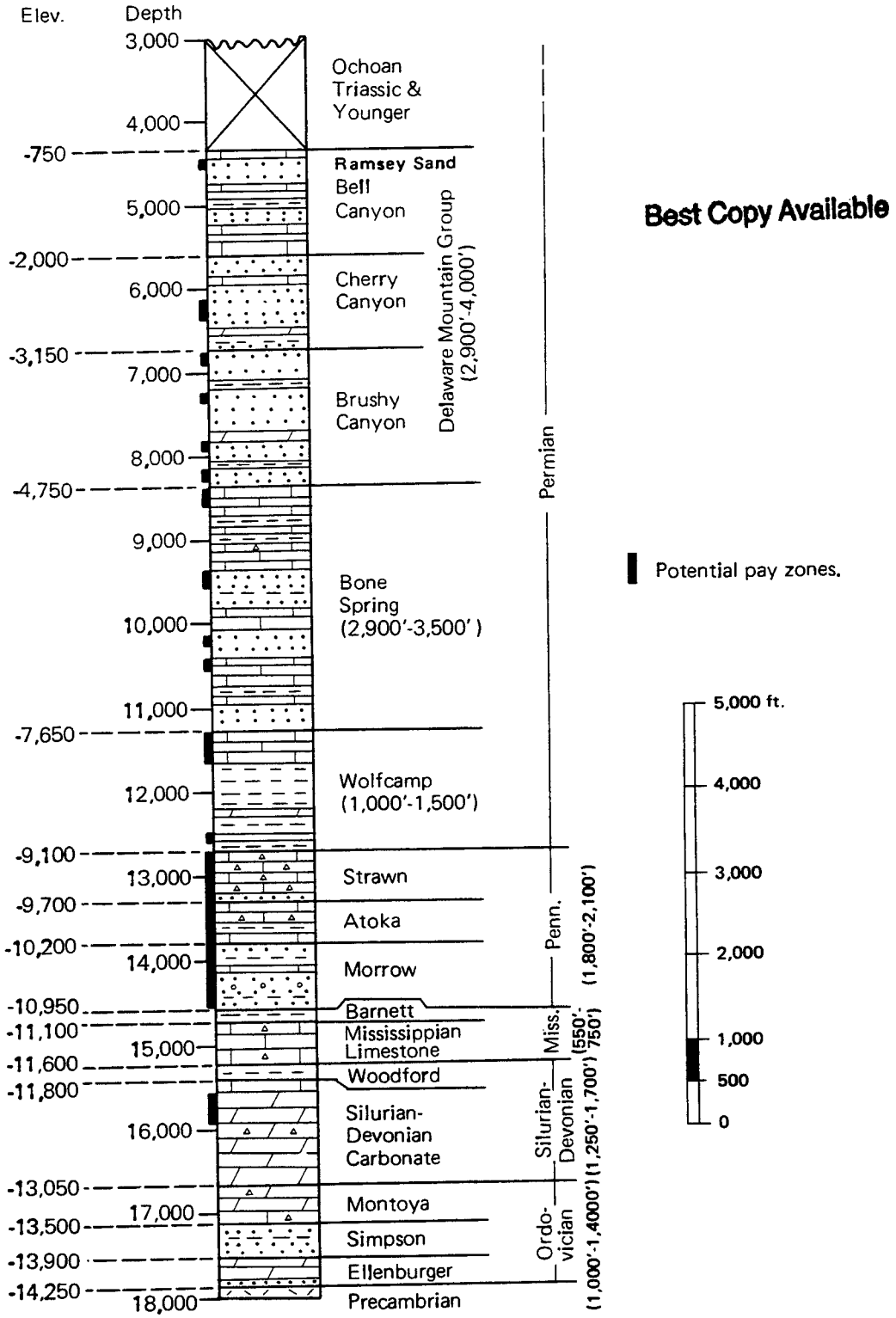

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FIGURE 8-8. GEOLOGIC COLUMN AND POTENTIAL HYDROCARBON RESERVOIRS (ADAPTED FROM FOSTER, 1974)

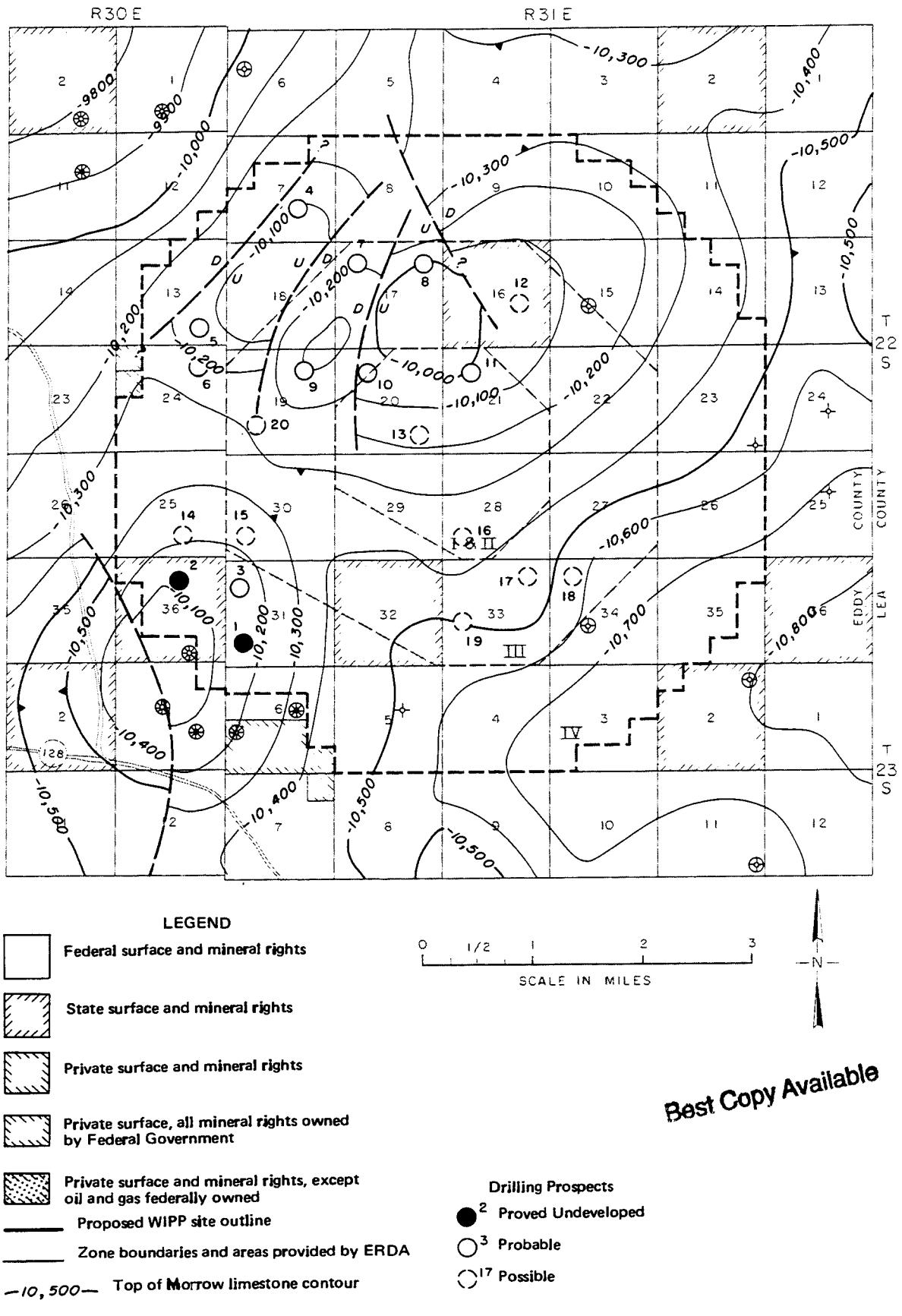

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FIGURE 8-9

HYPOTHETICAL DRILLING SITES TO DEVELOP POTENTIAL MORROW GAS RESERVOIRS

TABLE 8-1

TOTAL ESTIMATED RESOURCES AT WIPP SITE

Resource	Quantity	Depth	Richness
Caliche	185×10^6 tons	at surface	21-69% Insol.
Gypsum	1.3×10^9 tons	300-1,500 feet	Pure to mixed
Salt	198×10^9 tons	500-4,000 feet	Pure to mixed
Sylvite	88.5×10^6 tons	1600 feet	11.8 K_2O
Langbeinite	264.8×10^6 tons	1800 feet	6.10 K_2O
Crude Oil	37.7×10^6 bbls	4,000-20,000 feet	31-46° API
Natural Gas	490×10^9 cu. ft.	4,000-20,000 feet	1100 BTU/cu ft
Distillate	5.72×10^6 bbls	4,000-20,000 feet	53-56° API

TABLE 8-2

POTENTIAL ECONOMIC RESOURCES AT WIPP SITE

Resource	Quantity	Depth	Richness
Sylvite	27.43×10^6 tons	1,600 feet	13.33% K_2O
Langbeinite	48.46×10^6 tons	1,800 feet	9.11% K_2O
Natural Gas	36.85×10^9 cu ft	14,000 feet	1,100 BTU/cu ft
Distillate	0.55×10^6 bbls	14,000 feet	53° API

TABLE 8-3

ECONOMIC RESOURCES WITHIN ZONE I, II AND III AT WIPP SITE

Resource	Quality	Depth	Richness
Langbeinite	10×10^6 tons	1,800 feet	10% K_2O
Natural Gas	20×10^9 cu ft	14,000 feet	1,100 BTU/cu ft
Distillate	132×10^3 bbls	14,000 feet	53° API

TABLE 8-4

ORGANIZATIONS RESPONSIBLE FOR RESOURCE EVALUATION AND KEY REPORTS CONCERNING RESOURCES

Organization	Responsibility	Reports
U.S. Geol Surv.	Potash Resources as related to ore grade and volume	John et al. (1978) Jones (1978)
U.S. Bur. of Mines	Determination as to what extent the potash resources reported by U.S.G.S could be economically mined and refined under today's technology and market	USBM (1977)
N.M. Bur. of Mines	Definition of resources and economics for caliche, salt, gypsum, brine, sulfur and uranium	Siemers et al. (1978)
N.M. Bur. of Mines	Oil and gas resources of a four township area which includes the WIPP site	Foster (1974)
Sipes, Williams and Aycock, Inc.	Determination of the economic viability of hydrocarbons under the WIPP site	Keesey (1976)
G.J. Long & Assoc. Inc., Permain Exploration Co.	Intrepretation of structure of Paleozoic sediments beneath Ochoan evaporites. These studies were useful in evaluation of hydrocarbons	Long (1976), McMillan (1976)

Table 8-5

POTENTIAL RESOURCES CORRELATED WITH STRATIGRAPHY

Formation	Thickness (ft)	General Character	Potential Resources	Evaluation
Mescalero Sand	0-15	Dune sand, fine grained	None	No resource
Caliche	0-5	Limestone, chalky	Caliche (in road construction)	Caliche is abundant throughout the area
Gatuna	0-375	Sandstone and siltstone	Uranium	Conditions apparently were oxidizing during deposition, and no uranium is apt to occur in the vicinity
Santa Rosa Sandstone		Sandstone	Uranium	Conditions apparently were oxidizing during deposition, and no uranium is apt to occur in this vicinity
Dewey Lake	487	Siltstone and sandstone some claystone	Uranium	Minor occurrences have been reported outside the WIPP site area. Gamma ray logs of 36 holes drilled within the site area showed no anomalies.
Rustler	310	Anhydrite and rock salt with subordinate dolomite, sandstone, claystone and polyhalite	Gypsum and salt	Abundant throughout the area, no advantage for site resources.
Salado	1976	Rock salt with subordinate anhydrite, polyhalite, potassium ores sandstone, and magnesite	Potassium salts, salt and gypsum	Langbeinite and sylvite occur in commercial quantities

Table 8-9 (Continued)

Formation	Thickness(ft)	General Character	Potential Resources	Evaluation
Castile	1400	Anhydrite and rock salt with subordinate limestone	Sulfur, salt, lithium in brine reservoirs	Salt is abundant throughout the area. Lithium concentration in brine is subeconomic today. Care has been taken to exclude brine reservoirs from site. Conditions and structures for sulfur deposits not known to exist at site.
Delaware Mtn. Group	3800	Fine grained sandstone (possibly a siltstone), shale, limestone, and dolomite	Oil and associated gas. Most favorable zone is the Ramsey sand	Reservoirs may exist, but small in comparison with the Morrow Formation
Bone Spring	3400	Limestone, fine-grained sandstone, and black shale	Oil and associated gas	Reservoirs may exist, but are small in comparison to the Morrow Formation
Wolfcamp (Hueco)	1480	Limestone, black shale, red or green shale, sandstone, and conglomerate	Oil and gas	Reservoirs may exist, but are small in comparison to the Morrow Formation
Strawn	300	Limestone, oolitic limestone and gray to black shale	Oil and associated gas	Reservoirs may exist, but are small in comparison to the Morrow Formation
Atoka	640	Limestone, oolitic limestone and gray to black shale	Natural gas	Commercial gas is being produced from near site. Atoka reservoirs are restricted in size, therefore, small likelihood of existence under the site
Morrow	1300	Limestone, oolitic limestone, gray to black shale, and sandstone	Natural	Commercial quantities of gas probably exist

Table 8-5 (Continued)

Formation	Thickness (ft)	General Character	Potential Resources	Evaluation
Mississippian	740	Black, angillaceous shale, black calcareous shale or shaly limestone, some sandstone	None	None likely
Siluro Ordovician	2100	Limestone, dolomite, chert, shale, black shale with rounded quartz grain inclusions, and small amounts of sandstone	Oil and gas. Most favorable zone is beneath the Woodford Shale	Oil and gas may be present in anticlinal situations
Precambrian		Not tested with in the WIPP site locality. Regional inference is that it consists of acidic volcanics or metasediments	Sulfide deposits	Considered too deep to exploit.

References: Siemers et al., 1978; Foster, 1974.

TABLE 8-6
STANDARD CONDITIONS FOR POTASH RESOURCES

Class	Type Ore	% K_2O	Thickness, ft
Low	Langbeinite	3	4
	Sylvite	8	4
Lease	Langbeinite	4	4
	Sylvite	10	4
High	Langbeinite	8	4
	Sylvite	14	4

Reference: John et al, 1978.

Table 8-7

POTASH RESOURCES, TONS x 10^6

I. Sylvite Ores

Ore Zone	Low Grade			Lease Grade			High Grade		
	I+II+III	IV	Total	I+II+III	IV	Total	I+II+III	IV	Total
10	30.4	44.4	74.8	16.5	37.2	53.7	9.8	28.9	38.7
9	3.7	6.6	10.3	1.2	4.8	6.0	--	0.7	0.7
8	5.0	43.1	48.1	1.0	27.8	28.8	--	13.7	13.7
Total	39.1	94.1	133.2	18.7	69.8	88.5	9.8	43.3	53.1

II. Langbeinite Ores

Ore Zone	Low Grade			Lease Grade			High Grade		
	I+II+III	IV	Total	I+II+III	IV	Total	I+II+III	IV	Total
10	25.0	30.6	55.6	24.6	24.8	49.4	9.7	0.9	8.8
5	11.6	14.6	26.2	10.9	13.3	24.2	--	1.6	1.6
4	46.5	114.5	161.0	24.0	91.4	115.4	14.6	44.4	59.0
3	14.6	19.9	34.5	9.6	16.0	25.6	--	--	--
2	24.2	49.5	73.7	18.7	31.5	50.2	1.9	7.9	9.8
Total	121.9	229.1	351.0	87.8	177.0	264.8	24.4	54.8	79.2

III. All Ores

Ore Zone	Low Grade			Lease Grade			High Grade		
	I+II+III	IV	Total	I+II+III	IV	Total	I+II+III	IV	Total
10	55.4	75.0	130.4	41.1	62.0	103.1	17.7	29.8	47.5
9	3.7	6.6	10.3	1.2	4.8	6.0	--	0.7	0.7
8	5.0	43.1	48.1	1.0	27.8	28.8	--	13.7	13.7
5	11.6	14.6	26.2	10.9	13.3	24.2	--	1.6	1.6
4	46.5	114.5	161.0	24.0	91.4	115.4	14.6	44.4	59.0
3	14.6	19.9	34.5	9.6	16.0	25.6	--	--	--
2	24.2	49.5	73.7	18.7	31.5	50.2	1.9	7.9	9.8
Total	161.0	323.2	484.2	106.5	246.8	353.3	34.2	98.1	132.3

Reference: John et al., 1978.

Table 8-8

ECONOMIC POTASH RESOURCES, TONS x 10^6

Mining Unit	Products	Recoverable Ore in Mining Unit	Recoverable Ore in WIPP Site	Percent in Zones I,II,III	Price[1] that Provides a 15 Percent ROR[2], $
B-1	Langbeinite	79.78	48.46	27.5	35.00
	Sulphate			27.5	88.50
A-1	Muriate	57.60	27.41	3.2	52.04
D-2	Langbeinite	87.93	23.57	0.7	36.51
	Sulphate			0.7	92.31
A-2	Muriate	98.32	51.80	7.6	61.73
C-2	Muriate	57.19	36.49	54.2	61.74
D-3	Langbeinite	140.27	42.45	23.5	42.26
	Sulphate			23.5	106.86
C-3	Muriate	70.64	52.87	57.5	67.52
A-3	Muriate	135.02	73.77	14.9	70.28

[1]Market price assuming no increase in production costs. Estimated weighted average annual price per ton of product, f.o.b., Carlsbad, New Mexico, used for evaluation.

[2]Rate of return

Reference: U.S. Bureau of Mines, 1977.

Table 8-9

SUMMARY OF POTASH RESOURCES, 10^6 TONS

	In Place Resources (USGS Study)				Mineable Today (USBM Study)	
	Lease Standard		High Standard			
	Langbeinite	Sylvite	Langbeinite	Sylvite	Langbeinite	Sylvite
Total Withdrawal	264.8	88.5	79.2	53.1	48.46	27.41*
Mining Permitted in Zone IV	87.8	18.7	24.4	9.8	13.35	0.9

*The USBM does not consider the sylvite contained in Unit A-1 to be mineable under today's market. To do so would require the price for muriate to be $52.04 per ton, or the investor must be willing to accept a rate of return less than 15%.

Table 8-10

POTENTIAL HYDROCARBON RESOURCES
EXPECTED IN VARIOUS FORMATIONS WITHIN THE DELAWARE BASIN

Stratigraphic Unit	Rating Geological Oil	Rating Geological Gas	Rating Statistical Oil	Rating Statistical Gas	P.O.F.	Production Estimate Section (640 Acres) Acreage Oil (bbls)	Acreage Assoc. Gas (MCF)	Acreage Dist. (bbls)	Acreage Gas (MFC)	Wildcat Oil (bbls)	Wildcat Assoc. Gas (MFC)	Wildcat Dist. (bbls)	Wildcat Gas (MCF)	Adjusted Rating Oil	Adjusted Rating Gas
Ramsey	IV		V		62	472,350	756,324			75,052	120,141			IV	
Delaware Mtn. Gp.	II		II		21	51,686	19,546			34,462	13,029			II	
Bone Spring	III		IV		39	193,952	379,738			88,170	172,610			III	
Wolfcamp	III	III	II	II	23	20,800	228,462	32,544	633,984	20,475	224,953	19,530	383,969	III	III
Pennsylvania	III	V	III	V	88	265,455				299,788	1,784,799	94,596	6,441,672	IV	IV
Mississippian	I	I	I	I	14										
Silurian/ Devonian	III	III	IV	IV	72	1,368,330	656,676	36,720	4,244,310	343,422	164,804	36,562	4,225,491	I	IV
Ordovician	I	II	I	III	63										

Table 8-10 (Continued)

Stratigraphic Unit	Adjusted Production Estimate Section (640 Acres) Oil (bbls)	Assoc. Gas (MCF)	Dist. (bbls)	Gas (MFC)	Oil (bbls)	Assoc. Gas (MFC)	Dist. (bbls)	Gas (MCF)
Ramsey	472,350	756,324			75,052	120,141		
Delaware Mtn. Gp.	25,843	9,773			17,231	6,515		
Bone Spring	145,464	284,804			66,128	129,458		
Wolfcamp	15,600	171,347	24,408	475,488	15,356	168,715	14,648	287,979
Pennsylvanian	265,455	1,580,826	132,440	8,857,200	299,788	1,784,799	118,245	8,052,090
Mississippian								
Silurian Devonian	342,083	164,169	36,720	4,244,310	85,856	41,201	36,562	4,225,495
Ordovician								
	1,266,795	2,967,243	193,568	13,576,998	559,411	2,250,829	169,455	12,565,558

	Ratings	Calculated %
I:	Very low	25
II:	Low	50
III:	Moderate	75
IV:	High	100
V:	Very High	125

Taken from: R. W. Foster, 1974

Table 8-11

IN PLACE HYDROCARBON RESOURCES AT WIPP SITE*

Formation	Zone I+II+III			Zone IV			Total		
	Oil (bbls)	Nat. Gas (C.F.) ($\times 10^9$)	Dist. (bbls)	Oil (bbls)	Nat. Gas (C.F.) ($\times 10^9$)	Dist. (bbls)	Oil (bbls)	Nat. Gas (C.F.) ($\times 10^9$)	Dist. (bbls)
Ramsey	6.0×10^6	9.6		8.0×10^6	12.8		14.0×10^6	22.4	
Delaware Group	3.3×10^5	0.1		4.4×10^5	0.2		7.7×10^5	0.3	
Bone Spring	1.9×10^6	3.6		2.5×10^6	4.8		4.4×10^6	8.4	
Wolfcamp	2.0×10^5	8.2	3.1×10^5	2.6×10^5	10.9	4.0×10^5	4.6×10^5	19.1	7.1×10^5
Pennsylvanian	3.4×10^6	132.9	1.7×10^6	4.5×10^6	176.3	2.2×10^6	7.9×10^6	309.2	3.9×10^6
Mississippian									
Silurian/ Devonian	4.4×10^6	56.1	4.7×10^5	5.8×10^6	74.5	6.3×10^5	10.2×10^6	130.6	1.1×10^6
Ordovician									
Total	16.2×10^6	210.5	2.5×10^6	21.5×10^6	279.5	3.2×10^6	37.7×10^6	490.0	5.7×10^6

* Based on Adjusted Production Estimate per Section (640 acres), Acreage method, Table 8-10. WIPP site contains 29.6 square miles or sections.

TABLE 8-12
ESTIMATE OF ECONOMIC HYDROCARBON RESOURCES AT WIPP SITE

Well Number	Natural Gas (BCF) Zone I, II, III			Natural Gas (BCF) Zone IV			Natural GAS (BCF) Total		
	Proven	Probable	Possible	Proven	Probable	Possible	Proven	Probable	Possible
1	---	---	---	2.07	---	---	2.07	---	---
2	---	---	---	2.07	---	---	2.07	---	---
3	---	---	---	---	1.64	---	---	1.64	---
4	---	---	---	---	2.09	---	---	2.09	---
5	---	---	---	---	2.09	---	---	2.09	---
6	---	---	---	---	2.09	---	---	2.09	---
7	---	2.09	---	---	---	---	---	2.09	---
8	---	2.09	---	---	---	---	---	2.09	---
9	---	2.09	---	---	---	---	---	2.09	---
10	---	2.09	---	---	---	---	---	2.09	---
11	---	2.09	---	---	---	---	---	2.09	---
12	---	---	1.67	---	---	---	---	---	1.67
13	---	---	1.67	---	---	---	---	---	1.67
14	---	---	---	---	---	1.33	---	---	1.33
15	---	---	1.33	---	---	---	---	---	1.33
16	---	---	1.67	---	---	---	---	---	1.67
17	---	---	1.67	---	---	---	---	---	1.67
18	---	---	1.67	---	---	---	---	---	1.67
19	---	---	1.67	---	---	---	---	---	1.67
20	---	---	1.67	---	---	---	---	---	1.67
	---	10.45	13.02	4.14	7.91	1.33	4.14	18.36	14.35
		Total	23.47		Total	13.38		Total	36.85
	Plus Distillate 350,900 BBLS			Plus Distillate 200,000 BBLS			Plus Distillate 550,960 BBLS		

Reference: Keesey, 1976.

TABLE 8-13
SUMMARY OF IN-PLACE AND ECONOMIC HYDROCARBON RESOURCES AT THE WIPP

	IN PLACE RESOURCES (NMBM STUDY)			ECONOMIC RESOURCES (SW&A STUDY)		
	Zone I,II,III	Zone IV	Total	Zone I,II,III	Zone IV	Total
Crude Oil 10^6BBLS	16.2	21.5	37.7	---	---	---
Natural Gas 10^9CUFT	210.5	279.5	490	23.47	13.38	36.85
Distillate 10^6BBLS	2.5	3.2	5.7	0.35	0.20	0.55

GCR Chapter 9

SPECIAL STUDIES

9.1 INTRODUCTION

The special studies presented in Chapter 9 cover issues of particular interest because the site is being characterized for radioactive waste isolation (the WIPP). The first special study presented is that of determining the thermophysical behavior of Southeastern New Mexico (SENM) rocks for mine design and the effects of heat-producing wastes, if placed in the WIPP. The second special study is to determine the site-specific sorptive capacities of SENM rocks for radionuclides flowing with SENM groundwaters. Characterization of the sorptive capacities of SENM rocks is required for safety assessment analysis of hypothetical failure events, not for site selection. Both of these studies are by no means complete and are continuing. The information presented here is an indication of the status of these studies in midyear 1978. Tabulations of test data are left to the references and future reports on specific subjects.

9.2 THERMOPHYSICAL PROPERTIES

9.2.1 Introduction

The thermophysical properties of New Mexico rock salt are being investigated to support the structural mine design and to evaluate the overall stability of bedded salt for the WIPP. A goal of this program is to develop constitutive relations which can be used in design and long-term stability calculations, commonly by finite element analyses (Dawson and Tillerson, 1977). Specific concerns are the stability of the facility during its life, the influence of ground motions on waste retrieval capabilities, and the effect of waste emplacement on the long term containment potential. The program was initiated in 1975.

Rock salts are weak, anelastic geological materials. They exhibit nonlinear response under practically all loading conditions at temperatures and pressures normally encountered in mining. Since salt

can experience large strains prior to failure, openings even at very shallow depths have been known to completely close and heal (Baar, 1977).

In long-established active mining districts, careful in situ observations and measurements have provided a basis for making reasonably reliable predictions of room deformation and failure (Baar, 1977). Some of this knowledge is applicable to the WIPP, although it cannot be directly applied to the WIPP because the behavior of rock salt is dependent upon the site, facility design, temperature and time involved. The rock mechanics program considers the particular problems posed by the longevity of the WIPP and by the unusual combination of mechanical and thermal loading anticipated in the repository.

Laboratory experiments have been severely criticized by some for not realistically representing in situ conditions, (Baar, 1977). However, laboratory experiments on rock salt are a useful step in material characterization, to establish limits of behavior. Ultimately, laboratory and in-situ test data coupled with modeling should lead to representative descriptions of material and structural behavior. As the WIPP is developed, in situ monitoring should enhance the validity of laboratory and modeling results.

The thermophysical behavior of rock salt has been modeled through various approaches, (e.g., Bradshaw and McClain, 1975; Fossum, 1977; Langer, 1967; Mraz, 1978; St. John, 1978; Serata, 1966, 1968, 1970; Serata and Cundey, 1978; Thompson and Ripperger, 1964; Thoms et al., 1973; Wahi et al., 1978). A widely accepted model which can translate laboratory data into a prediction of in situ salt behavior has not been developed.

Three broad areas were studied to identify the relative and site specific importance of various southeast New Mexico rock salt thermophysical properties. These three areas of study consist of: 1) petrography relevant to physical and mechanical properties, 2) general physical properties (density, moisture content, resistivity, etc.), and 3) thermal-mechanical properties (quasi-static and creep parameters).

Petrographic studies were conducted on mineralogically characterized core from AEC 7, AEC 8 and ERDA 9 to investigate structural petrographic changes between natural and experimentally-deformed samples (Callender & Ingwell, 1977). Identification of failure mechanisms by petrographic analyses will assist in selecting models to describe rock behavior.

Physical properties being measured for selected core include density, moisture content, porosity, permeability, electrical resisitivity, ultrasonic velocity, and thermal conductivity. Additional gas and brine permeability measurements are in progress at Sandia both on experimentally undeformed and deformed samples.

The following mechanical properties are being measured: uniaxial compressive strength, indirect (Brazilian) tensile strength, stress-strain behavior and ultimate stress in quasi-static triaxial compression, elastic moduli, principal strain ratios, elastic limit ("yield" stress), and creep rates. Additional tests address the effects of specimen machining, specimen aging due to stress relief during and after core retrieval, and specimen size, all of which could limit the field applicability of laboratory-determined results. The influence of sample size may be partially inferred from published data (e.g., Uhlenbecker, 1968; Dreyer, 1972; Szeki, 1978).

The data base for physical and thermal properties determined from core from the WIPP study area is still being compiled, and tests are continuing. Moreover, most of the results obtained to date pertain to rock salt alone, as opposed to other members of the stratigraphic column above and below the proposed repository horizons.

9.2.2 Petrography

Approximately 35 samples of experimentally undeformed and deformed salt were macroscopically and microscopically examined for mineralogy, fabric, and induced structure by J.F. Callender and T. Ingwell of the University of New Mexico (1977). Mineralogy of rock salt from southeast New Mexico has been described in detail in Chapter 7.

Between the depths of 1,000 and 2,000 feet, the samples are predominantly halite (NaCl) (range 47-98 percent) with lesser amounts of anhydrite ($CaSO_4$) (range 0-15 percent), polyhalite ($K_2MgCa_2(SO_4)_4.2H_2O$) (range 0-18 percent), and clay and silt (range 0-44 percent). Halite is usually present in the core, except in samples from anhydrite layers and polyhalite seams. Anhydrite, clay and silt are generally present, while polyhalite occurs less commonly. Detailed stratigraphy of the WIPP study area is presented in the ERDA 9 corehole lithologic log, Figure 4.3.3.b.

Fabric In general, the undeformed rock salt specimens do not show well-developed linear or planar fabrics, aside from uncommonly-observed bedding. Locally, however, halite crystals show a faint to strong elongation, probably due to readjustment to local stresses. Certain fabric features within the cores may presumably have important local effects on salt deformation. These features include bubble trains, hopper crystals, cleavage, glide planes, grain boundaries, and clay zones (Callender and Ingwell, 1977).

Bubble trains are commonly aligned along cleaveage traces or grain boundaries in halite. The bubbles generally contain fluid, although some may also be gas or partially solid-filled (see section 7.6). Fracturing in experimentally deformed cores locally follows the bubble trains, and they are likely the site of small-scale structural weaknesses within halite. Once such fractures heal, the zones they followed become stronger than before (section 7.6) Hopper crystals, generally filled with clay, also tend to grow and be aligned along halite cleavage planes. In a number of samples, small-scale fracturing, induced by sample preparation or by disturbance during the coring operation in the field, is associated with zones of hopper crystals.

Cleavage, and fracture related to cleavage, is observed in halite. In euhedral, generally recrystallized, halite, the cleavage direction and grain boundary are coincident. In these cases, deformation along trends parallel to grain boundaries should certainly be facilitated. Similar relations, though less common, exist in subhedral halite. Translation

glide in halite is an important dislocation mechanism and has been described in the literature (c.f., Buerge, 1930; Clabaugh, 1962). Two glide planes, (110) and (001), have been recognized in both undeformed and deformed salt.

In summary, a local concentration of discrete fabric elements (e.g., hopper crystals, bubble trains) may be as statistically significant as planar or linear elements (such as bedding, cleavage alignment, or elongation) for the structural evaluation of the core, and local zones in deformed salt may play an important role in establishing fracture patterns.

Fracture. Analyses of fracture patterns in salt to date have been complicated by induced fracture during sample preparation and the field coring procedures used to obtain samples. The recognition of these induced fractures is generally fairly straightforward; however, the persistent question of local induced fracture arises during detailed study, and is a problem which cannot be easily resolved. Fortunately for the petrographer, many fractures are filled with clay, anhydrite, and polyhalite; these filled fractures give some insight into patterns in material before laboratory testing since they are clearly not a result of sample handling.

In general, fracture in undeformed salt core is relatively minor and is commonly associated with cleavage or grain boundary adjustments. It appears that fractures may have remained open at some stages of diagenesis for a sufficiently long period of time to be filled by sulfate or other solutions. A few unusual fracture geometries have been noted: en echelon fractures, generally with their major trend parallel to cleavage; circular fractures commonly around hopper crystals; fracture refraction across grain boundaries; jog and kink fractures; and fracture and local extension along glide planes. The number of fractures observed in the laboratory resulting from relief of the in situ confining stresses is unknown. Clay, anhydrite, and polyhalite have apparently flowed in some undeformed samples. Perhaps the best evidence for this statement is

local well-defined linear fabric in polyhalite and anhydrite, and the inclusion of halite in clay along grain boundaries.

In samples severely deformed by laboratory testing, fracture patterns are easily observed. In one sample a well-defined zone of cleavage and glide-plane fracture developed at about 40° to the compressional axis. Apparently, a network of interconnected fractures has been established in this zone which respects neither grain boundaries nor grain size. In contrast, another sample suggests that local fabric elements, particularly clay-rich zones, may affect fracture geometry and that planar fracture fabrics may not be as well-developed in clay-rich samples.

Fracturing of halite can be generated in the laboratory at relatively low confining pressures ($\leq$ 1500 psi) and moderately high strains (5 to 12 percent); this fracturing induces a fracture porosity in the material. At higher confining pressures, rock salt displays ductile behavior and it is difficult to induce fracturing. The position of the fracture pattern observed in the laboratory is related to both the stress direction and the local fabric elements. In addition, the crystal lattice of halite permits, through defects and crystallographic constraints (c.f., Hirth and Lothe, 1968), a complex dislocation system to develop.

9.2.3 Physical Properties

Measurements of physical properties of rock salt pertinent to the design of the WIPP have been conducted by several investigators. Some representative data are summarized in Table 9.2.3-1.

Density and Resistivity. Measurements were made on full dimension (4-1/2 inch diameter) core. The density determinations were performed following conventional laboratory procedures for determing bulk rock densities utilizing the buoyancy method. Commercial grade kerosene was used for buoyancy measurements. Direct current resistivity determinations were made using current densities of less than 0.20 microamperes per square centimeter (Elliot, 1976), and by downhole geophysical measurements (Griswold, 1977).

Volatile Mass Loss. Total volatiles, including water, were obtained by heating samples of Salado salt from the proposed repository levels to 300°C in several stages. Static weight loss determinations were made at each stage of heating (Kopp & Combs, 1975) and were reported in section 7.5.3.. In addition, thermogravimetric analyses were made by suspending powdered samples from a microbalance while dry nitrogen flowed over the sample. The samples were heated at 5°C/minute until the temperature reached 500°C and held there until gas evolution had ceased (see section 7.5.2 for details and data).

Permeability. Gas permeability of SENM rock salt has been measured for pressures up to 5000 psi and at room temperature to determine the tightness of the host rock to any gases evolved in the WIPP. The data developed by Sutherland (1978), are for argon gas at confining pressures to 2000 psi. A plot of permeability test results is shown on Figure 9.2.3-1. Sutherland's data demonstrate the influence of confining pressure (crack closure and healing) on permeability. Preloading of samples to near lithostatic confining pressures is required to obtain reproducible data in laboratory experiments. Other gases (air, nitrogen, argon) were measured by Core Labs (1977), Terra Tek (1978), and Shelby (1978). The Core Labs' tests followed API standards, however, they did not allow for crack healing. Shelby tested single crystal NaCl. The results of these measurements illustrate the following:

(1) There is no correlation between measured permeabilities for as-received (stress-relieved) core samples;

(2) Samples behave as if they are "healing" when subjected to a confining pressure on the order of their original in situ pressure (illustrated on Figure 9.2.3-1).

(3) After an initial "healing" or "consolidation" period, the polycrystalline samples tested by Sutherland (1978) and Terra Tek (1978) have measured permeabilities of less than 0.05 microdarcys (the limit of resolution of their permeability measurement systems);

(4) There is little or no gas flow through the salt single crystals (less than 1 picodarcy) in the single crystal test apparatus of Shelby (1978). Therefore, the preferred flow channels through a core sample are believed to be along crystalline boundaries.

Thermal Conductivity. The thermal conductivity of several rock salt samples from core of AEC 8 were determined by a longitudinal heat flow apparatus. This apparatus was designed specifically for use with geologic core sections. Constant power is supplied to a heater at one end of the specimen until thermal equilibrium is established. The heat flux transducer and thermocouple outputs are then recorded allowing the thermal conductivity to be calculated from the readings (Acton, 1977). A plot of test results is shown on Figure 9.2.3-2.

Sonic Pulse Velocity. Measurements of compressional wave velocity were made both on laboratory samples (Kent and Wawersik, 1976) and by down hole geophysical methods (Griswold, 1977). Laboratory measurements were made both parallel and perpendicular to the core axis. No signficant variations (less than 0.02 Km/sec) were observed between the axial and transverse values of twenty measurements. The laboratory data were within 15% of the downhole geophysical values.

Summary of Data. Some physical properties are summarized in Table 9.2.3-1. In addition, permeability data are plotted on Figure 9.2.3-1 and thermal properties are shown in Figure 9.2.3-2. The experimental data are presented in the referenced documents.

9.2.4 Thermomechanical Properties

Introduction. It is the goal of laboratory stress-strain tests to develop constitutive relations which can be used in structural calculations. As the program progresses, a combination of finite element calculations using data obtained in the laboratory, empirical mine design methods and in-situ validation studies will serve to evaluate, in detail, certain aspects of the final WIPP design.

To achieve a valid and practical description of the behavior of rock salt from experiments in the laboratory, several programs are being conducted. These are: (1) Measurement of the mechanical response of SENM rock salts and other nearby rocks (e.g., anhydrite) over the domain of stresses and temperatures which may be expected in the WIPP; (2) Development of general models based on test results that are applicable to differing stress deformation and/or temperature histories; (3) Determination of mechanisms governing salt response in sufficient detail to allow the extrapolation of laboratory measurement in time; and finally (4) Establishment of relationships between laboratory samples of rock salt and salt masses in-situ.

This report summarizes the first series of laboratory tests, consisting primarily of short term "quasi-static" tests. These tests served to compare the response of WIPP salt with rock salts from other horizons and locations and to effectively scope the rock behavior for planning the long term creep tests. It is recognized that short term test behavior may be only partially indicative of long term behavior. Not all of the data developed is presented, particularly where detailed information has been published elsewhere. Instead, test values have been selected which are felt to best represent the behavior of the WIPP rock salt. Too few repetitive tests have been performed thus far to determine statistical significance of the data. This is due to the long times required to perform tests and the limited amount of rock salt core available to this test program from specific horizons of interest to WIPP.

A deliberate attempt was made to encompass a broad range of parameter variations including confining pressure and principal stress difference, i.e., mean stress and deviator stress, as well as temperature, time, loading rate, loading path, handling history, and specimen size. These variations covered a wider spectrum than might ordinarily be required to support the design of conventional mines or solution cavities. The approach is predicated on the unusual combination of anticipated mechanical and thermal loadings associated with WIPP. The experimental program plan also tried to address specific questions, for example,

concerning the effect of loading path, which were raised by critics of conventional quasi-static experiments in the past (Baar, 1977).

Testing was primarily conducted on rock salt samples from three horizons in the Salado Formation. The two horizons at 2,100+ feet and 2,600 to 2,700 feet represent the relatively pure halite from the proposed contact-handling (CH) and remote-handling (RH) levels, while the third horizon at 1,900 feet was chosen for study because it is clay rich salt.

The testing program through the summer of 1978 was generally divided into two segments, quasi-static tests and creep tests. Quasi-static properties were generated over a range of loading rates from d/dt $(\sigma_1 - \sigma_3)$ of 150 to 215 psi/min (RE/SPEC Inc. data, Gnirk et al., 1973, Hansen and Mellegard, 1977) to loading rates of 30 to 60 psi/min (Sandia data, Wawersik, 1977, 1978c). The 30 psi/min loading rate was chosen to match that of published data (Dreyer, 1972, Menzel and Schreiner, 1977). Creep tests were carried over a range of confining pressure $0 \leq \sigma_3 \leq$ 3,000 psi, deviator stresses $1{,}500 \leq (\sigma_1 - \sigma_3) \leq$ 6,000 psi, and temperatures of $24^{\circ} \leq T \leq 100^{\circ}$C with a duration of up to 70 days. These loading rates were arbitrarily chosen as a means of scoping the behavior of SENM rock salt under conditions that may be encountered in the WIPP.

Apparatus, Experiments, Capabilities, and Data Handling. To support the determination of material properties of WIPP site rocks, a new triaxial facility was developed (Wawersik et al., 1976). Based on earlier experience (Wawersik and Brown, 1973; Gnirk et al., 1973; Wawersik, 1975), the present apparatus has the following capabilities.

The apparatus accepts cylindrical specimens up to 4-1/4 inches diameter by 8.5 inches in length to accomodate the coarse grain size or rock salt.

The system has a pressure rating of 10,000 psi; this is adequate to perform variable load path tests, for example, in triaxial compression, in triaxial extension, at constant maximum compression, etc.

The equipment is suitable to conduct both quasi-static tests and creep experiments.

Specimens can be heated uniformly to approximately 250°C in short-term tests and to 200°C to 220°C in long-term experiments.

Controlled, known temperature gradients can be applied for studies of fluid migration.

The equipment provides access to both specimen ends for possible venting or for measurements of pore pressure and permeability and for application of pore pressure, etc.

It provides both axial and radial deformation measurements. For uniform lateral deformation, this combination of strain measurements yields shear and volumetric strains.

The apparatus is equipped with multiple feed-throughs for use of instrumentation inside the pressure vessel.

Normally, hydrostatic and deviatoric loading are decoupled so that the hydrostatic response of all specimens can be defined and, more importantly, so that linear and bulk thermal expansion measurements can be determined as a function of temperature and pressure.

The apparatus and procedures allow for large, relatively unrestrained sample deformation.

Details of the test equipment (ranges, calibration procedures and precisions) are discussed elsewhere (Wawersik, 1975; Wawersik et. al., 1977; Wawersik, 1978a).Material and Test Specimens - The rock salt studied was machined from 4-1/4 inch diameter core obtained from zones at depths of 1,900 feet, 2,100 feet and 2,600 to 2,700 feet. Sample machining consisted of cylindrical and flat-end grinding following documented procedures which were designed to minimize the thickness of any shatter zones at the specimen surfaces. Alternatively, specimens were obtained by means of standard coring tools. Final specimen dimensions were nominally 2 inches or 4 inches in diameter, with a

length-to-diameter ratio of at least two. After machining, the cylindrical surfaces of all samples were coated with a protective layer of RTV silastic.

Quasi-static Rock Salt Properties. Quasi-static testing was conducted on WIPP salt under hydrostatic pressures to 5,000 psi. Deviatoric loading tests were performed to 3000 psi confining pressure and to temperatures of 200°C. Variables of interest were: pressure (confining pressure, mean stress), principal stress difference (deviator stress), time (loading rate), temperature and load path. A separate study of the role of the intermediate principal stress will also be initiated. The importance of the foregoing variables was suggested by prior mine measurements and by existing laboratory data (for example Schmidt, 1937; U.S. Corps of Engineers, 1963; Le Comte, 1965; Hofer and Thoms, 1968; Schlichta, 1969; Carter and Heard, 1970; Bradshaw and McClain, 1971; Dreyer, 1972; Heard, 1972, Serata et al., 1972; Kern, 1973; Menzel and Schreiner, 1977; Baar, 1977).

The term quasi-static is used in the conventional sense to denote a fixed slow rate of loading. To avoid misunderstandings and undue generalizations of these data, it is emphasized that most quasi-static experiments were carried out at particular loading rates, e.g., 30 psi/min. It is important to realize that any data concerning the mechanical behavior of WIPP rock salt under different loading conditions must be inferred with proper regard to the time-dependent nature of the material (Wawersik and Hannum, 1978).

Quasi-static data available to date include approximately 75 uniaxial compression and indirect Brazilian tension tests at ambient temperature on core from drill holes AEC 7 and 8 (Hansen and Gnirk, 1975). These experiments were performed under the direction of Oak Ridge National Laboratory prior to June, 1975. They include approximately 20 experiments on anhydrite and 5 tests on polyhalite. More recent quasi-static data include approximately 50 tests on selected specimens from the potential WIPP repository horizons (Wawersik et al., 1976;

Hansen, 1977; Hansen and Mellegard, 1977, Wawersik and Hannum, 1978). Samples were machined from core of drill holes AEC 7 and ERDA 9. Emphasis was placed on the response of rock salt from the storage horizon at 2600 feet because of the added complexities of elevated temperatures if heat producing wastes are placed in WIPP.

Selected representative mechanical properties in uniaxial compression and indirect tension are listed in Table 9.2.4-1.

Quasi-static Triaxial Properties - Representative triaxial data are listed on Table 9.2.4-2 for a range of confining pressures and temperatures. Note that both tables 9.2.4.1 and 9.2.4-2 list secant moduli (stress/total strain) and principal strain ratios ($\varepsilon_3/\varepsilon_1$) rather than the elastic constants, that is, Young's modulus, E, and Poisson's ratio. To calculate the intrinsic elastic constants it is necessary to separate the nonelastic portion from the total deformation or to move through stress states where elastic response dominates. This was accomplished for New Mexico rock salt recently during unload/reload cycles.

The constants obtained were $4.55 \times 10^6 \leq \varepsilon \leq 5.2 \times 10^6$ psi and $0.17 \leq \nu \leq 0.24$ (Wawersik and Hannum, 1978). These values agree to within 15% with those which were determined from borehole geophysical data.

During initial deviatoric loading in the laboratory, nearly all deformation of WIPP salt was nonelastic (Wawersik and Hannum, 1978). The actual magnitude of this nonelastic deformation is likely to be sensitive to the magnitude of the deviatoric stress which the core experienced during drilling (Wawersik and Hannum, 1978), associated core damage and subsequent core "relaxation" during core storage and handling. Combinations of these factors probably account for the variations in secant moduli and principal strain ratios in tables 9.2.4-1 and 9.2.4-2.

It is common practice in engineering to plot triaxial test data in the form of Mohr's circles at the ultimate stress. The plots are made in the

stress space (σ,T) where σ and T denote normal and shear stresses, and an envelope is drawn tangent to the circles representing the ultimate shear stress of any value of confining pressure.

When the data from Tables 9.2.4-1 and 9.2.4-2 are plotted, three Mohr's circles which are normal for SENM rock salt are obtained in Figure 9.2.4-2A in stress space (σ,T) . The ultimate stresses can be approximated by a straight line (Coulomb) envelope of the form $T = C + \sigma \tan \phi$. In conventional engineering terminology, C is called the cohesion and ϕ , the angle of internal friction. In this case, at ambient temperatures, rock salt from the 2,700 foot level has an apparent cohesion of approximately 1,000 psi and an angle of internal friction of 33°. Similar data for other rocks are being used for mine pillar design. However, it should be recognized that the validity of these ultimate stress analyses rests on two assumptions: (1) failure is independent of the intermediate principal stress, and (2) failure is defined solely in terms of stresses and independent of strain, strain rate and time. Both of these assumptions are currently being evaluated for rock salt.

In contrast to other rocks, it is important to remember that rock salt undergoes large deformations long before the ultimate stress is reached. Since these deformations can exceed 15% even at ambient temperature, it is conceivable that a practial failure condition might incorporate a maximum deformation criterion. To illustrate this case, a Coulomb envelope was constructed (Figure 9.2.4-2B) which defines the stress magnitudes at an arbitrarily chosen constant value of strain ($\varepsilon_1 = 2.5\%$). This value is the average strain at the ultimate stress of samples tested in uniaxial compression at ambient temperature and a loading rate of 30 psi/min. It can be seen that Figure 9.2.4-2B is different from the ultimate stress envelope in Figure 9.2.4-2A. Clearly, the shapes of the Mohr envelopes are highly dependent on failure criteria. The values obtained also depend on the manner in which the Mohr's envelope is drawn. In Figure 9.2.4-2A, a "best fit" straight line tangent to the circles was drawn; while in B, a parabola was drawn tangent to the circles.

Detailed Quasi-static Stress-Strain Relationships. Elastic constants, ultimate stresses, and stress or strain envelopes are useful for conventional failure stability analyses where rock is treated either as an elastic or as an elastic-plastic material. While such analyses have proven valuable in combination with careful engineering judgement, they are not always accurate. In view of the time-dependent nature of rock salt it is especially important that design calculations be based on a more comprehensive constitutive model. To initiate the development of such a model, detailed short-term quasi-static stress strain observations were made to identify the effects of pressure, deviatoric stress, (shear stress), temperature, and loading history. The influence of time as a discrete parameter is mainly considered in creep experiments.

Deviatoric Loading at Constant Confining Pressure. Deviatoric loading at constant confining pressure is the process of increasing the principal stress difference (deviator stress) from an initial state of hydrostatic compression. It is a necessary condition to induce substantial salt flow.

Typical quasi-static deviatoric loading data are shown in Figures 9.2.4-3 through 9.2.4-15. The key to these curves indicates sample depth in feet and (confining pressure in ksi and temperature in degree C). These stress strain curves depict complete continuous experimental records which indicate the manner in which all specimens were loaded. Deviator stress was applied incrementally rather than continuously. Actual force was raised quickly by some predetermined amount and then held constant for between 4 and 15 minutes while axial and lateral strains ε_1 and ε_2 $(= \varepsilon_3)$ were monitored in time. The stepwise loading procedure made it relatively easy to control the mean applied loading rate while monitoring time dependent strains during load hold periods with a minimum of experimental error (Wawersik and Hannum, 1978). In most figures, these details of loading are omitted. As illustrated by the curve for sample 9-2601 in Figure 9.2.4-3, where smooth fits are made to the endpoints of each step in the actual stress strain record. Note that large changes in specimen cross sectional area at constant force during

all load hold intervals lead to considerable decreases in principal stress difference with time (Wawersik et al., 1977, 1978c). Conventional plots $(\sigma_1 - \sigma_3)$ versus ε_1 such as Figure 9.2.4-3 relate the present data to virtually all similar results for rock salt in the literature (for example, Schmidt, 1937; Heard, 1972; Dreyer, 1972, Menzel and Schreiner, 1977).

Considering Figures 9.2.4-3 through 9.2.4-6, three observations are particularly noteworthy.

1. Laboratory specimens of New Mexico rock salt have an initial elastic limit close to zero. Furthermore, this initial elastic limit appears to be the same following all hydrostatic pressure histories up to 5000 psi (Wawersik and Hannum, 1978).

2. Pressure appears to have a considerable effect on all properties of New Mexico rock salt except the elastic constants (Wawersik and Hannum, 1978). Specifically pressure controls the strain magnitudes, the ultimate stress and the relationships between the principal strain (Figures 9.2.4-5 and 9.2.4-6). Pressure effects are particularly evident at $(\sigma_1 - \sigma_3)$ greater or equal 1200 psi.

3. New Mexico rock salt subjected to quasi-static laboratory compression can undergo substantial dilatancy which is associated with cataclasis, i.e., microfracturing. The magnitudes of the observed volume changes were significant particularly at low confining pressure and amounted to sizeable fractions of the observed shear strains near the ultimate stress (Wawersik and Hannum, 1978). Isovolumetric conditions of deformation are approached only at 3000 psi confining pressure. However, data at elevated temperature demonstrate that even comparatively minor amounts of dilatancy can have a considerable effect on the rate at which New Mexico rock salt deforms (Wawersik and Hannum, 1978).

Elevated Temperature Data. Elevated temperature experiments were carried out in two groups. First, the influence of temperature was considered at fixed confining pressures, for example, 500 psi (Figs. 9.2.4-7, 8 and 9). Then, the effect of pressure was evaluted at 200°C (Figs. 9.2.4-10, 11 and 12). As expected (Bradshaw and McClain, 1971; Heard, 1972: Dreyer, 1972), temperature reduced the ultimate stress and increased the ductility (Fig. 9.2.4-7). Increasing the temperature is qualitatively equivalent to increasing confining pressure at ambient temperature. Cataclastic effects with considerable dilatancy are suppressed in favor of deformation modes which proceed at constant, or nearly constant, volume (Figs. 9.2.4-8 and 9.2.4-9). (Wawersik and Hannum, 1978)

Influence of Loading History. Effects of loading history are noted in several studies in the literature (for example, Schmidt, 1937; Sereta et al., 1972; Baar, 1977). To consider such effects, three sets of experiments were performed early in the experimental program. First, the influence of differing hydrostatic loading histories was tested. The results indicated no measurable effects on the behavior of rock salt from southeastern New Mexico during subsequent deviatoric loading (Wawersik and Hannum, 1978).

In the second group of experiments, quasi-static strains were measured as a function of load path in a conscious effort to separate the influences of load path and loading history as much as possible. The load paths employed are shown in Figure 9.2.4-15. They consist of:

1. Conventional triaxial tests at constant confining pressure (load path I).

2. Triaxial loading at constant mean stress ($\sigma m = \frac{1}{3}(\sigma_1 + \sigma_2 + \sigma_3)$ load path II).

3, Deviatoric loading at approximately constant maximum compression (load path III).

Figure 9.2.4-13 also identifies one test which combined load path III and I passing through points A, D, E, G, and H (Wawersik and Hannum, 1978). Table 9.2.4-3 provides a comparison of strains at several common stress states of Figure 9.2.4-13 with the strains ε_1 and ε_3 are numerically greatest along the path of constant confining pressure (load path I). The smallest ε_1 and ε_3 were obtained along the path of maximum pressure, either confining pressure or mean stress (load path III) (Wawersik and Hannum, 1978).

To evaluate load history even further, a third set of tests was performed. In these experiments, one sample was deformed in three successive stages at 3000, 500, and again at 3000 psi confining pressure. The response of this specimen was then compared with the strain behavior of individual samples which had been loaded deviatorically at 3000 psi and 500 psi confining pressure (Wawersik and Hannum, 1978). The results of the latter tests are shown in Figures 9.2.4-14 and 9.2.4-15. Notice particularly, that the stress strain record for the third load cycle of sample 7-2740.5 does not immediately converge to the stress strain records of specimens 7-2745 and 9-2601.5. Differences in results are obviously due to the influence of loading history (Wawersik and Hannum, 1978).

Interpretation of Quasi-static Data - In view of the quasi-static testing to date, as illustrated in the figures, the following observations were made repeatedly and establish broad guidelines which should be observed in modeling the thermomechanical behavior of New Mexico rock salt up to fracture and/or massive flow (ε_1 greater or equal 20%).

Rock salt from SENM in the laboratory is nonlinear under all loading conditions with an initial elastic limit ($\sigma_1 - \sigma_3$) approximately zero. Its intrinsic elastic properties can be evaluated accurately only in load/unload/reload cycles provided restrictions are imposed either on the loading (strain) rate or on the range of deviator stresses. However, given comparatively nonelastic strains, the intrinsic elastic behavior does not appear to be very important.

In the low confining pressure domain $\sigma_3 \leq 3000$ psi, rock salt behavior depends strongly on pressure and temperature. Both dependencies are reflected in ductility, ultimate stresses and in the variation between maximum and minimum principal strains or in the variations between volumetric strains and shear strains (Figures 9.2.4-4, 5, 8, 11, and 15).

A brittle mode of deformation (microfracturing) dominates rock salt deformation at ambient temperature, low confining pressure, and deviator stress in excess of approximately 1000 to 1500 psi. Accordingly, the overriding pressure effect under these conditions is pressure dependent dilatancy (Figures 9.2.4-4, 6 and 9). Brittle fracture, including creep fracture, i.e., macroscopic collapse and loss in load bearing ability are possible. At low (less than 1,000 to 1,500 psi) deviator stress, high temperature, and/or high pressure, salt deformation proceeds in a predominantly ductile manner at nearly constant volume. Particularly at high temperatures, pressure does not appear to further influence the nature of the governing deformation mechanisms. This is indicated by a pressure invariance (Figure 9.2.4-11) of the relationship between maximum and minimum compressive strains (shear and volumetric strains). However, observed differences in induced strain rate at a fixed loading rate but different confining pressures indicate that pressure influences the rate at which the governing deformation mechanisms, cataclastic or ductile flow, proceed.

It is recognized that available quasi-static stress strain data do not necessarily describe the properties of New Mexico rock salt over long periods of time. However, for lack of other information, quasi-static tests have been used to define the matrices of future creep experiments and to anticipate phenomena which might occur during creep. For example, emphasis is being placed on triaxial creep experiments as opposed to uniaxial tests. Simultaneous measurements are being made of both volumetric strains and shear strains in creep. Similar tests are not conducted routinely elsewhere and the apparatus to perform these tests is at the state-of-the-art in experimental rock mechanics.

Creep of Rock Salt Creep tests on rock salt are continuing to evaluate the long-term time-dependent behavior of New Mexico rock salt. Since August, 1977, two sets of triaxial creep tests have been performed on core from drill holes AEC 7 and ERDA 9, emphasizing the interval of 2600 to 2800 feet depth. Experiments were carried out over the range

$$0 \leq \sigma_3 \leq 3000 \text{ psi}, \; 1500 \leq (\sigma_1 - \sigma_3) \leq 6000 \text{ psi}, \text{ and } 24^{\circ} \leq T \leq 130^{\circ}\text{C}.$$

Results indicate that in principle WIPP salt can undergo both transient and steady state creep. Furthermore, limited data suggest that steady state creep rates lie in the range from 10^{-10} sec^{-1} to 10^{-7} sec^{-1}, depending strongly on stress state and temperature. Steady state creep may have to be considered in WIPP design calculations; it was not included in earlier wastes repository analyses which were conducted in conjunction with in situ experiments during Project Salt Vault, Kansas (Bradshaw and McClain, 1971).

To evaluate the nature of transient creep of the WIPP salt, 34 tests were carried out on NX sized (two inch nominal diameter) core. Tests durations vary between 0.5 and 500 hours (Hanson, 1977, and Hanson and Mellegard, 1977). Initial efforts served to evaluate the significance of transient creep on the possible repository conditions, to establish upper (conservative) bounds for steady state creep rates at relatively low deviator stress and temperature, and to test the applicability of a pillar creep formula which has been widely used (Bradshaw and McClain, 1971):

$$E(t) = A(\sigma_1 - \sigma_3)^{a} T^{b} t^{c} \qquad (9.1)$$

The results of present transient creep data demonstrate significant pressure effects which are consistant with all quasi-static observations but are not predicted by equation 9.1.

Beyond that, however, at least one block of data appears to support equation 9.1 which in its generalized form is:

$$\varepsilon = F_1(p)F_2(\sigma_1-\sigma_3)F_3(T)F(\text{strain or time}) \quad (9.2)$$

Work is now in progress to estimate the error magnitudes which are associated with the use of equation 9.2 even under restricted conditions, e.g., $(\sigma_1 - \sigma_3) \leq 2{,}500$ psi and $\sigma_3 \leq 1{,}000$ psi. To accomplish this, numerical simulations are compared with the results of independent laboratory experiments which combine multiple creep runs with intermittent short-term stress variations at two different temperatures.

Time Dependent Fracture. To determine the long term strength of New Mexico rock salt, two approaches are being take. First, long-term laboratory creep tests are conducted to establish a relationship between strength and time. Obviously such tests are time consuming. Second, failure times may be calculated from creep flow and from estimates of the amount of nonelastic strain at the point of fracture. The nonelastic failure strain can be estimated by means of an empirical procedure which establishes a relationship between creep, time dependent fracture and quasi-static post failure characteristics (Wawersik, 1972). If this technique is applied to New Mexico rock salt, it appears that the range of stable creep prior to fracture at ambient temperature is:

$$\varepsilon_1 \leq 2.5 \text{ to } 6\% \text{ at } \sigma_3 = 0 \text{ psi}$$

$$\varepsilon_1 \leq 17 \text{ to } 20\% \text{ at } \sigma_3 = 500 \text{ psi}$$

Substantially greater stable creep occurs at σ_3 = 3000 psi confining pressure (Wawersik 1977). On Figure 9.2.4-18, photographs of core samples from ERDA #9 are shown that were deformed during triaxial testing (Hansen and Mellegard, 1977). Notice the large amount of strain test Numbers 6 and 7 have undergone without apparent major physical damage.

Applicability of Laboratory Measurements. Several investigations are underway to define the qualitative and quantitative applicability of laboratory experiments on WIPP salt to in-situ design predictions. Apart from numerical validation studies, measurements are in progress to determine the relaxation of core after drilling and to assess whether rock salt is damaged during field coring, recovery and storage. The latter efforts are supported by repeated tests on specimens with known laboratory stress histories to further define the effects of stress history, aging and specimen machine. In addition, numerical simulation are being conducted to balance the magnitude of deviatoric loading of salt core during drilling.

9.2.5 Summary and Conclusions

Data from the petrographic and physical properties studies show the WIPP horizon rock salt has low moisture content ($< 0.5\%$), is essentially impermeable ($< 5 \times 10^{-8}$ darcy) and has a high thermal conductivity ($\simeq 5.75$ watts/m^{o}k). These properties along with the studies of fabric and fracture indicate this rock salt is ideally suited from a physical standpoint for the storage of high temperature nuclear waste.

The initial elastic limit is close to zero for rock salt for any confining pressure. Although strengths for rock salt are substantial (unconfined compressive strength to 3700 psi and modulus to 2×10^{6} psi) the load bearing ability is dependent on time, temperature and confining pressure.

It has been shown that rock salt can experience large creep strains (25%) prior to loss of load bearing capacity. Gradual creep is an acceptable feature in the design of underground openings in rock salt as it allows the structure to close without a sizeable reduction in bearing strength and without the physical damage which is associated with fracture.

Laboratory testing is continuing to develop a constitutive model to describe the behavior of SENM rocks. The model will be used in computer codes to study the structural response of the geologic media to WIPP.

9.3 RADIONUCLIDE SORPTION ON WIPP ROCKS

9.3.1 Introduction

An important mechanism in retarding nuclide movement in groundwater is sorption. In the following discussion, this term will be used to encompass all mechanisms pertinent to interaction between nuclides and geomedia which include ion exchange, adsorption, and precipitation.

The ability of rocks to adsorb radionuclides and hinder their migration away from a geologic repository for radioactive waste is not a factor in site selection criteria (Chapter 2). Also, since sorptive affinity is not a fundamental invariant property of a rock sample, such as is mineralogy or total volatile content, radionuclide sorption properties were not discussed in Chapter 7 (Geochemistry). Nevertheless, quantification of rocks' affinities for radionuclide sorption, however, is NOT a generic problem which can be solved simply for all rocks. Since the only rational approach to the problem is to conduct experiments to determine radionuclide sorption properties for site-specific rocks and site-specific aqueous solutions, preliminary results of such experiments are reported as special studies. The results of special studies of radionuclide sorption are entirely dependent upon experimental conditions, just as in the measurement of quasistatic mechanical properties.

In some safety assessment modeling scenarios described for the escape of radionuclides from WIPP repository horizons, groundwters contact and leach the waste form, and eventually find their way out of the salt deposit into the surrounding rock and mineral strata. During this exit, the nuclide-bearing liquid would contact clay-containing halite in the repository horizon, polyhalite formations, anhydrite formations, and

finally the sandstone and dolomite formations which are the bounds of the evaporites. To a rough approximation, the concentration per unit mass of a given nuclide, sorbed on a solid mineral phase C_{solid} can be related to the concentration per unit volume, in the liquid phase C_{liquid}, by the relation:

$$C_{solid} = KC_{liquid}$$

where K is generally known as the distribution coefficient, Kd, with units of ml/g. The use of the term Kd implies an equilibrium condition for a given reaction which is both instantaneous and reversible. In the interaction of a nuclide with a complex mineral assemblage, neither condition may apply and the nuclide sorption observed can result from one or more sorption phenomena on one or more phases. To prevent confusion in nomenclature, the term Kd is used in this report, but with the understanding that what is being measured is a sorption coefficient which applies only to the system described and for the particular set of conditions used in making the measurement. Thus, the measurement of "Kd" does not reflect a fundamental thermodynamic property of rocks and/or solutions; it is rather a function of the experiment in which it is measured.

Ideally, sorptive affinities for radionuclides would be measured in situ in the geological formation of interest using long path lengths and available groundwater. This is not generally feasible and must be supplanted with data generated in a laboratory. Most of this section is an extract of SAND78-0297, "Interaction of Radionuclides with Geomedia Associated with the Waste Isolation Pilot Plant (WIPP) site in New Mexico" by R. G. Dosch and A. W. Lynch. It provides the results of a series of laboratory Kd measurements for various radionuclides and samples of different geological media from the vicinity of the WIPP site, and a discussion of the conditions used in making the measurements. The nuclides chosen for study have either a high potential for leaching and/or migration, a high radiotoxicity, or a chemistry similar to that of a nuclide with these properties. They included ^{137}Cs, ^{85}Sr, ^{131}I, ^{125}Sb, ^{144}Ce, ^{152}Eu, ^{153}Gd, ^{106}Ru, ^{243}Am, ^{244}Cm and ^{238}Pu.

A given set of conditions including pH, Eh, particle size, nuclide concentrations, and brine and/or groundwater simulant composition was defined prior to starting the work and maintained throughout. The Kd values reported are considered to be a set of preliminary baseline data for use in evaluating the effects of changes in those conditions which will undoubtedly be necessary as more information about the WIPP site itself and interactions of the waste forms with bedded salt become available.

The results of some parametric studies with lanthanide elements are also given. Significant differences in Kd's were observed as a result of varying pH and nuclide concentrations, and from the addition of trace quantities of organic contaminants to simulant solutions.

9.3.2 Geological Media

Sample Selection. The geological samples used in this work were taken from four inch diameter core samples from AEC #8 and ERDA #9 boreholes. (See Chapters 4 and 7 for descriptions of stratigraphy and mineralogy.) These include three samples from various rock formations (including the water-bearing rocks above and below the evaporites), four halite samples from the Salado Formation, and samples of polyhalite and Cowden anhydrite also from the Salado Formation.

The selection of the geological media for study was based on both the hydrology of the WIPP site and surrounding area and on a reasonable scenario for radionuclide transport from a bedded salt repository. The Magenta, Culebra, and Bell Canyon formations represent actual or potential aquifers.

Any path to the biosphere for water which may have contacted and leached a waste form would involve migration through halite formations, and also through anhydrite and polyhalite strata interspersed in the halite. Thus, these materials, along with the clay contained in the halite, are included in this study as they represent potential barriers to nuclide migration.

Sample Preparation. Culebra, Magenta, Bell Canyon, polyhalite, and anhydrite samples were reduced to a powder prior to use. Clays from the halite samples were obtained by dissolving core samples in deionized water, filtering and washing the insoluble residue, and drying at ambient temperature in air or vacuum.

9.3.3 Brine and Groundwater Simulants

The bulk of the Kd measurements reported herein were done using simulated brines and groundwater of the compositions given in Table 9.3-1. The Brine A composition is based on that expected in an aqueous solution in contact with potash deposits found in the vicinity of the WIPP site. The Brine B composition is typical of water in contact with halite deposits in the repository horizons. The groundwater Solution C composition is based on analyses of shallow groundwaters from the Los Medanos area (Lambert, 1978) above the evaporites and is intended to represent an "average" composition.

In determining Kd values for halite particles, saturated brines prepared from the particular core sample from which the halite had been taken were used as the liquid phase.

9.3.4 Solution Chemistry

Solutes. The use of simulated brines became necessary as both naturally occurring brines and core samples from repository horizons are currently available in very limited quantities. Simulants do offer the advantage of providing a reproducible matrix which allows for direct comparison of Kd data generated in different laboratories.

Potential problems in using simulants could arise from the absence of trace constituents which may be present in natural waters. If these are common inorganic species, the effect on Kd's would probably be negligible. However, trace quantities of organic compounds or dissolved gases such as hydrogen sulfide could produce significant changes in Kd

values should they tend to form stable complexes with some nuclides. The effect of trace quantities of organics which may be introduced into the repository as radwaste is being addressed and is discussed in Section 9.3.8.

Oxidation Potential. In aqueous migration from a deep geologic storage site, nuclides would most likely encounter both anoxic and aerobic conditions, in that order, as the biosphere is approached. The potential effect on Kd values could be many orders of magnitude; however, this should be limited to nuclides such as U, Np, and Pu which may undergo oxidation-reduction reactions in the potential range encountered.

Oxidizing conditions have been used to date as they are believed to produce the "worst case" with respect to migration, i.e., the higher valence states of the previously mentioned actinides tend to have lower Kd's, and they will be encountered in any scenario leading to contamination of the biosphere.

Hydrogen Ion Activity. The effect of the pH is believed to be extremely important in both the solution chemistry and the adsorption mechanism involved in the Kd for a given geological media. Problems encountered in determining Kd values in systems where solution pH is varying are discussed in Section 9.3.8. Changes in the adsorption characteristics of clays, oxides, and some zeolite materials as a function of pH are well documented (Amphlett, 1964).

The initial pH values of 6.5, 6.5 and 7.5 for Brine A, Brine B and solution C simulants, respectively, were chosen as being representative of field pH measurements of natural brines and groundwaters in the Los Medanos area.

Radionuclide Concentation. Ideally, a distribution coefficient should be independent of concentration. This condition usually exists only over a narrow concentration range and, therefore, nuclide concentrations should be chosen which are somewhat representative of those expected in a

repository. The problem lies in the fact that little or no data exists to aid in estimating leaching rates under conditions expected after closure of a repository. These include glass or other waste forms at elevated temperature (70-200°C) and lithostatic pressure (2000 psi) in contact with "wet" salt or brine. Another presently unknown variable is the effect of radiolysis on leaching mechanisms and rates. Available leaching data primarily result from laboratory leaching experiments with simulated waste in distilled water at ambient temperature.

In order to simplify both sampling and counting operations in the initial work, an activity of approximately 1 μCi/ml was used for all determinations unless stated otherwise. The corresponding nuclide concentrations based on the suppliers' analyses of the isotopes used are listed in Table 9.3-2.

Unless otherwise stated, all distribution coefficient measurements were made using a single nuclide in the brines or groundwater to eliminate competing ion effects. The effect of the nuclide concentration on Kd's is of concern and some initial work in this regard is presented in Section 9.3.8.

9.3.5 Experimental Procedures

Apparatus, Sample Size and Sampling. Samples of rock, clay, anhydrite, polyhalite, or halite were weighed directly into polyethylene dropping bottles volumes of doped brine or groundwater were added. The ratio of liquid to solid was typically in the range of 30 to 35. Due to limited quantities of the clay samples, higher ratios (50-150) were used in experiments with clays.

The bottles were sealed by placing a piece of polyethylene film over the opening and replacing the bottle top. Agitation was provided by orbital, reciprocating, or wrist-action shakers. Samples for analysis were taken by replacing the polyethylene film with a 0.8 μ pore size Gelman filter, tightening the dropping bottle top down over the filter, and squeezing

the bottle to force 0.5 to 1.0 ml volumes into pre-weighed polyethylene vials. Quantitative volumes were determined from weight and density measurements. The filters were replaced with polyethylene film and the agitation continued.

Portions of all "feed" solutions were put in identical polyethylene dropping bottles, agitated, and sampled at the same time and in the same manner. The activity in the filtered "feed" samples were used as the initial solution activity in the Kd calculations.

Analyses. The activity in solutions containing ^{137}Cs, ^{85}Sr, ^{106}Ru, ^{131}I, ^{125}Sb, ^{152}Eu, ^{144}Ce, or ^{153}Gd was determined by x-ray spectroscopy. A Harshaw 3" x 3" NaI(Tl) scintillation crystal or an Ortec VIP Series Coaxial Ge(Li) solid state detector was used. Data was accumulated and processed by a PDP-11/20 computer system. ^{99}Tc beta activity was measured using a mica end-window Geiger tube or by liquid scintillation counting. Alpha activities were determined by liquid scintillation counting. Since only relative activities are needed to determine Kd's, units of cpm/ml were used in all calculations.

Equilibration Time. Samples of fission product nuclides were generally taken after 14-20 and 30-35 day equilibration periods. In some instances, more frequent sampling was done. Variation in Kd's between the two sampling times were generally within a factor of two and are believed to result from changes in concentration due to adsorption on container walls, filters, or pH changes in both the sample and feed solutions rather than from rock-nuclide sorption kinetics.

Equilibration times of 170 days were used in the actinide experiments. This extended period was dictated by delays in acquiring laboratory facilities rather than by experimental design.

9.3.6 Kd Data

The results of Kd measurements using the conditions described in previous sections are given in Tables 9.3-3 through 9.3-11. Each table represents a different geological sample and contains th Kd's determined for the various brine/groundwater-nuclide combinations listed and a pH range including the initial feed pH and final sample pH values. The Kd ranges given for the fission product nuclides include two or more measurements made during the course of the experiment. Error associated with these measurements is certainly the most significant at the high ($>10^4$) and low (<1) ends of the Kd range, where background to signal ratios are high or calculations are based on small differences in large numbers. Two-to-fivefold variations of Kd's between duplicate analyses in these regions were not uncommon. Another obvious source of uncertainty is sampling, both in picking a section of core to represent a geological formation and in taking small samples to represent the core. The magnitude of error due to heterogeneity in a given core sample is unknown, as multiple samples were not used in this survey.

9.3.7 Discussion of Kd Data

Cesium. Cesium adsorption from brines "A" and "B" on Culebra and Magenta samples, representing a potential aquifer region overlying the repository horizons, is minimal or non-existent with Kd's ranging from 0 to 2. Adsorption from groundwater C is slightly higher (Kd's from 4 to 10). In the potential aquifer underling the repository, the Bell Canyon Formation, Cs adsorption is significantly higher in the groundwater "C" simulant than in brine "B". This trend tends to support an ion exchange mechanism for Cs adsorption.

Similar results are observed on the samples associated with the repository horizons, with the exception of the polyhalite sample, which did not adsorb Cs from any of the solutions used.

Strontium. The adsorption of Sr on the rock samples from potential aquifer regions was very low with a Kd of 5 being the highest value observed in both brines and groundwater simulant.

Of the materials associated with the repository horizons, only the polyhalite sample showed any appreciable adsorption of Sr from the brine solutions that would be associated with the region.

The interstitial clay in the halite formation shows no tendency to adsorb Sr from the brine solutions (Tables 9.3-6 and (.3-9), and this may be attributed in part to the relatively high concentration of stable Sr used in the simulants. However, the same behavior was observed in an experiment where a brine prepared by dissolving a halite core and doped with < 0.3 ppm ^{85}Sr was cycled through a column of the halite particles from the same core (Tables 9.3-1 and 9.3-11). In this case, only a slight reduction in Sr activity was observed (which may have resulted from adsorption on the glass column or Tygon tubing used to circulate the brine), while ^{144}Ce was quantitatively removed by the halite.

Europium, Gadolinium and Cerium. These nuclides have been grouped together for discussion because their chemistries are very similar, particularly with respect to hydrolysis, and secondly, because they exhibited similar behavior in their interactions with the geomedia from the WIPP site.

With the exception of polyhalite samples, Kd's of greater than 10^3 for these nuclides were observed on all the geological samples with which they were contacted. Any interpretation of these data with respect to mechanism or comparison of the effects of different brines or geological media is difficult because of the contribution of hydrolysis and subsequent precipitation to the overall adsorption observed in the experiments.

For example, the polyhalite sample which was singled out as having Kd's of less than 10^3 for these nuclides (Table 9.3-7), also had final pH values which were lower than the rock or clay samples. Thus, the

apparent difference in Kd's may be a hydrolysis effect rather than be related to the polyhalite. The effect of hydrolysis is further discussed in Section 9.3.8.

Technetium and Iodine. Both of these nuclides are expected to exist as anionic species in natural groundwaters or brines and were used in the form of pertechnetate, TcO_4, and iodide, I, in this work.

Natural ion exchangers typically exhibit extremely low anion capacities, particularly in neutral or basic solution. In this work, the only material which showed significant adsorption of pertechnetate and iodide was a clay sample taken from a halite core (Table 9.3-9). The adsorption was observed in Brine A and groundwater C, but neither species appeared to be adsorbed from Brine B. The relatively high concentration of Tc used may have far exceeded the anion exchange capacity of some or all of the samples and this possibility is being investigated.

Ruthenium and Antimony. Difficulty was encountered in preparing the doped "A", "B", and "C" solutions due to the high concentrations of stable Ru and acid (4NHCl) in the ^{106}Ru solution used. Adjustment of pH after doping resulted in precipitation of > 95% of the Ru. The final feed solutions were estimated to contain approximately 0.10 μCi/ml of ^{106}Ru in "B" and "C" or 25 ppm total Ru.

General trends observed in the Kd measurements include: 1) higher Kd's for the clay minerals than for the rock samples, 2) higher Kd's in simulants "B" and "C" than observed in "A". The latter effect may be the result of brine composition, but more likely is a hydrolysis effect as the final equilibrium pH of "B" and "C" is higher than that in the "A" brine.

Antimony was added to the group of nuclides being studied late in this work, and there are not sufficient data available on which to base any general statements.

Actinides. The actinides used in this work were supplied as Am(III), Cm(III), and Pu(IV) solutions and used at face value. No attempts were made to determine the Pu species present in the simulant solutions after doping. The nominal activity of the actinides in the solutions used in this work was 1 μCi/ml, however, the final activities in the "feed" solutions were lower. The doping was done by adding the isotope solutions to containers and evaporating to dryness at room temperature. The brines or groundwater solutions were then added to the containers and the solutions were set aside for several days. The amount of isotope used was sufficient to provide an activity of 1.0 μCi per milliliter of solution if the entire amount was dissolved.

In general, the actinide concentrations in groundwater "C" at a pH of 7.3-7.4 are greater than those in the brine solutions in the 6.9-7 pH range. This is particularly true for ^{244}Cm, where the concentrations are 2 to 3 orders of magnitude lower in the brine solutions.

Kd values for the actinides of 300 or greater are observed for all the geological samples if the halite Kd's are based on weight of insoluble material rather than the weight of the total halite sample. In general, the Kd values in the groundwater "C" are higher than in Brine "B" which could result from hydrolysis due to higher pH in the "C" solutions; however, there are some cases where this Kd order is reversed.

The reasonably good agreement between the Kd values for the clay samples (Table 9.3-6) and the halite containing interstitial clay particles (Tables 9.3-5 and 9.3-11) suggests that the halite in the vicinity of the repository can serve as a barrier to actinide migration.

9.3.8 Parametric Effects

pH and Nuclide Concentration Effects on Kd. The first investigation into the contribution of the pH of the aqueous phase and effect of nuclide concentration on the sorption coefficient involved ^{152}Eu sorption from brines A and B and groundwater C on samples from the Magenta and Culebra Formations.

The experimental procedure used was the same as that described previously, except two blank samples of each feed solution were included instead of one. At the end of a two week equilibration period, the pH of the samples and feed solutions were measured. One of the feed B and C solutions was then adjusted so that its pH was equal to that observed in sample solutions containing that feed. A sodium carbonate solution was used for the pH adjustment, which was done over a period of three days. By the time analytical samples of the adjusted feeds were taken, the pH of some of them had increased and was higher than the corresponding sample. The pH of the Brine A feeds was not adjusted as the final values were the same as those in the samples.

The pH of the adjusted feeds decreased significantly during the first three months, probably due to adsorption of atmospheric carbon dioxide (Garrels and Christ, 1965). The pH of the solutions contacting the rock also varied with some increasing and others decreasing; however, the change was consistent within a given set of samples containing the same rock and solution.

Distribution coefficients calculated from both the feed activities and pH adjusted feed activities after two week and three month periods are listed in Table 9.3-12.

Europium is apparently more soluble in Brine A than in Brine B at the same pH or in the C composition at higher pH. The effect of adjusting the pH in B and C solutions definitely resulted in hydrolysis and formation of some species which did not pass through a 0.8μ filter. It is also of interest that significant decreases in activity in the pH-adjusted feeds were observed for all Eu concentrations used.

The Effect of Trace Organic Contaminants of Kd's of ^{152}Eu, ^{153}Gd and ^{144}Ce. One of the concerns in estimating migration rates of radionuclide in aqueous media is the ionic form of the nuclide of interest. Experiments have shown that the simple ionic forms of most polyvalent cations interact quite readily with geologic media from the

WIPP site via ion exchange or other sorption phenomena. These interactions serve to retard the movement of the ionic species relative to the aqueous matrix containing them.

The extent of the nuclide-geologic media interaction can be significantly altered by changes in the ionic form of the nuclide. Examples of such changes are redox reactions which may result in species of zero or negative charge types and reactions with available inorganic or organic ligands to form complex species with different chemical properties. One such change in properties might be enhanced mobility over that of the bare ion.

Investigations of the sorption changes due to complexation between organic ligands and radionuclides have been initiated by Robert T. Paine of the University of New Mexico. One source of organic ligands which may be present in large quantities in the repository is the plywood used in containers for shipping TRU waste. Samples of these containers are being refluxed in synthetic Brine B at 70°C, the maximum temperature expected in the transuranic (TRU) waste horizon in the repository. The initial samples of this brine, subsequently referred to as B*, were taken after 5 weeks of refluxing.

Although no significant physical degradation of the plywood was observed after this time period, chemical leaching did occur as evidenced by the coffee brown appearance of the brine. Gas chromatograph-mass spectrometer analysis of the brine indicated the presence of organic material, but identificaton was inconclusive. Infrared spectroscopy was used to examine carbon tetrachloride and benzene-acetone extracts from the brine. The extracted organic material fell into the general class of esterified rosin compounds, but no specific indentification was possible. Qualitative observation indicated that the brine contained extremely small amounts of organic material. Neither solvent system extracted the colored species from the brine.

The effect of plywood extract on lanthanide distribution coefficients (Kd's) was determind by measuring Kd's for ^{153}Gd, ^{144}Ce and ^{152}Eu between five geologic media from the WIPP site and the brine B* containing the plywood extract, and comparing these values with Kd's obtained in identical experiments using pure Brine B. The results are given in Table 9.3-13.

Although both the B and B* brines were doped initially with the same concentrations of tracers, there is a significant difference in the activity of the final samples taken. This could result from adsorption on the polyethylene containers or hydrolysis and subsequent filtration of hydrated oxides of the tracer elements through the 0.8 μ filters. In either case, the effect occurs to a significantly lesser extent in the brine B*, which is probably the result of interaction between the tracers and some ligand extracted from the plywood to form complexes which are less susceptible to hydrolysis.

The difference in Kd values could also result from complex formation. The complexing ligand may be a rosin derivative, many of which form very stable compounds with heavy metals. It may also be the species which causes the brown coloration of the brine. Observation of the analytical samples taken from the brine B* samples showed that the clay material had completely decolorized the brine. The other materials decolorized the B* samples to varying degrees, as given below in order of decreasing color intensity remaining in solution:

Feed > Magenta > Culebra ≈ Bell Canyon > Cowden > Clay solution

Similar work will be done using extracts which are being prepared from other organic materials expected to be associated with TRU waste such as rubber gloves, swipes, detergents, etc. Based on lanthanide results, an experimental matrix will be designed to study the actinide elements.

The Effect of Oxidation State on Radionuclide Sorption. An additional approach to understanding the behavior of actinides under site specific conditions in WIPP is the study of the behavior of various oxidation

states of the actinides (particularly plutonium) in the presence of various components of the WIPP strata. This work is being performed at Argonne National Laboratory by Sherman Fried and Arnold Friedman.

Relatively concentrated solutions of actinides (0.01 M) whose oxidation states were determined by inspection of their optical absorption spectra were prepared and allowed to react with saturated WIPP brines, and with rocks from the WIPP site. Since it was assumed that in the final stages of a WIPP repository oxygen might be absent in the rock salt, the preparations were made in vacuo to identify species present under such conditions.

Solutions of plutonium were prepared in such a way that samples sealed in optical absorption cells at approximately 10^{-6} atmosphere of O_2 could be examined from time to time to observe changes in absorption peaks (if any) and thus determine the stability of the particular oxidation state as a function of time.

In the case of plutonium preparations, the isotope ^{242}Pu was employed. This was done to minimize radiolysis effects (specific activity Pu^{242} = 4.5×10^3 d/m/μg vs. $1/15 \times 10^5$ d/m/μg for ^{239}Pu). It is felt that while the behavior of plutonium in these concentrated solutions may be substantially different than tracer Pu migrating in an aquifer where the radiation field will be much less, it is nevertheless a good approximation to the conditions immediately in the vicinity of the canister when an amount of radioactivity has just leached out.

The various oxidation states of Pu were prepared by electrolytic means or oxidation by ozone as the case required, in order to avoid the introduction of extraneous ions which might affect the results.

The solutions of Pu compounds ($PuCl_3$, $PuCl_4$, and PuO_2Cl_2) were prepared directly in the absorption cell. The concentrations were generally of the order of 0.01 M. In a typical case, 4 ml of saturated WIPP brine "A" (Table 9.6-1) was introduced into the optical cell and

evaporated to dryness in a stream of nitrogen. After this operation, the proper amount of Pu compound was pipetted in the cell and evaporated to dryness with the salts from the WIPP brine.

The cell was attached to the vacuum line and evacuated until the pressure was $\sim 10^{-6}$ atm. De-aerated water was then distilled under vacuum until the amount of solution equals that which originally pipetted into the cell.

These samples of various Pu compounds were examined from time to time observing any changes in intensity or wavelength of absorption peaks corresponding to the oxidation state in question.

The resulting samples prepared for measurement of changes in intensity of the optical absorption spectra are Pu(III), Pu(IV) and Pu(VI) in water, and in saturated WIPP brine solution.

No definite changes in absorption peaks corresponding to changes in oxidation state were observed. The Pu(IV) solutions were so dilute, because of precipitation from the hydrolysis of Pu(IV), that little or no characteristic absorption peaks could be observed at all. The Pu(III) solutions, whose absorption peak is at about 6000 Å , also showed little or no detectable change over the time interval of the experiment (2-4 months).

The Pu(VI) as PuO_2Cl_2, surprisingly, is insoluble in saturated WIPP brine. The level of solubility is so small that no absorption peaks could be seen at all. In order to be sure that this case is not one of very slow rate of solution, the sealed absorption cells are being rotated with periodic abosorption spectrum determinations.

Some absorption studies have already been carried out with Pu(IV) and Am(III) on anhydrite and dolomite from the WIPP site (see previous sections).

Work is presently underway with the Argonne National Laboratory Analytical Chemistry Group to develop procedures for the determination of the oxidation potential of WIPP salt, dolomite and anhydrite slurries, particularly those employing oxidation-reduction indicators.

Crude reaction rates and K_D values of Pu(III) and Am(III) with Magenta and Culebra dolomites in waters that have been equilibrated with the individual rock are in the table.

Rock Type	Radionuclide	Reaction Time (hr)	K_D
Magenta (gypsiferous dolomite)	Pu	50	41
	Am	400	47
Culebra (silty dolomite	Pu	1	19
	Am	1	84

It should be understood that these reaction rates are crude and that the K_D values are somewhat indeterminable because of varying quantities of radionuclides "plating out" on the walls of the containers. These experiments will be repeated as a function of temperature. Since these determinations were made on tablets of rock of known dimensions, the surface absorption coefficients can be calculated, these perhaps being more applicable to migration along fissures and cracks, where the surface absorption coefficient is

$$S_c = \frac{\text{activity/ml liquid}}{\text{activity/cm}^2 \text{ solid}}$$

The installation of a controlled atmosphere box has made it possible to study the absorption of the various oxidation states of Pu without the perturbing effects of atmospheric oxygen.

9.3.9 Summary

A survey of the potential of geological media from the vicinity of the Waste Isolation Pilot Plant site in Southeastern New Mexico for retardation of radionuclide migration via an aqueous carrier has been completed. Solution simulants representing water in equilibrium with potash minerals or halite zones and a typical groundwater were spiked with radionuclides and contacted with geological samples to obtain sorption coefficients, Kd's. The samples were taken from potential aquifers above and below the repository horizons and from bedded salt deposits in the repository horizons. The nuclides chosen for study represent those with a high potential for leaching and/or migration, high radiotoxicity, or those with a chemistry similar to nuclides with the aformentioned properties. They included ^{137}Cs, ^{85}Sr, ^{131}I, ^{99}Tc, ^{125}Sb, ^{144}Ce, ^{152}Eu, ^{153}Gd, ^{106}Ru, ^{243}Am, ^{244}Cm and ^{238}Pu.

A very general summation of the Kd results in brine simulants is as follows: Anionic species, TcO_4^- and I^-, showed little or no tendency to adsorb on any of the geological media (Kd's $\leq$ 1), with the possible exception of a clay material from a halite stratum (Kd < 5). Cs and Sr Kd's were also generally less than 1, but values in the range of 10-20 were observed on several minerals. Ru Kd's ranged from 25 to $>10^3$, depending on the brine and geological materials. The lanthanide and actinide Kd's were typically > 10^3, with only polyhalite showing significantly lower adsorption.

In the groundwater simulant, Tc and I showed the same behavior. The Kd's of the other nuclides were slightly higher, particularly those of Cs and Sr. This would be expected if the sorption were due to an ion exchange mechanism, but, in the case of the lanthanides and actinides, may also result from an increased contribution of hydrolysis to the Kd due to the higher pH of the groundwater simulant.

Important parameters in Kd measurements include solid sample form, simulant compositon, Eh and pH, and radionuclide concentration. In the Kd survey measurements, an initial set of these parameters was selected and, wherever possible, was used throughout the work. Parametric studies with Eu involving pH, trace organic constituents in the simulant solutions, and radionuclide concentrations have shown that significant differences in Kd's can be observed by varying any of those parameters.

A general observation which can be made from data obtained to date is that a Kd represents an empirical value for nuclide adsorption, which includes the effects of physical adsorption, ion exchange, and hydrolysis or other precipitation processes. The utility of a given Kd value is unambiguous only for that set of conditions used in making the measurement. Kd information which is used in modeling radionuclide migration should be in the form of a range of values generated in parametric studies under the variety of conditions postulated for a specific repository site.

For the WIPP site, rock salt, anhydrite, polyhalite and water-bearing dolomites and sandstones show an affinity for radionuclide sorption. Sorptive capacity as measured by batch Kd experiments generally expressed $Kd > 0$. Even small values of Kd ($0 < Kd < 1$) are effective in retarding the movement of radionuclides in groundwater.

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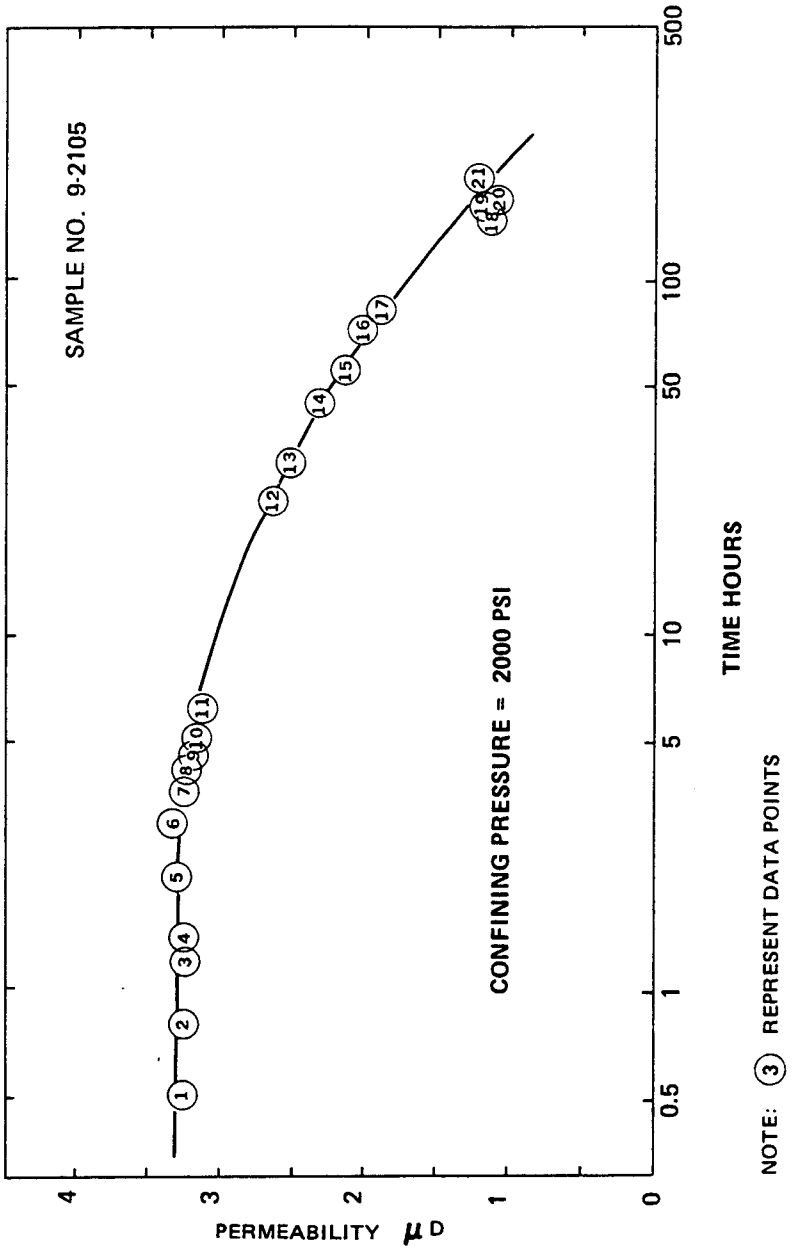
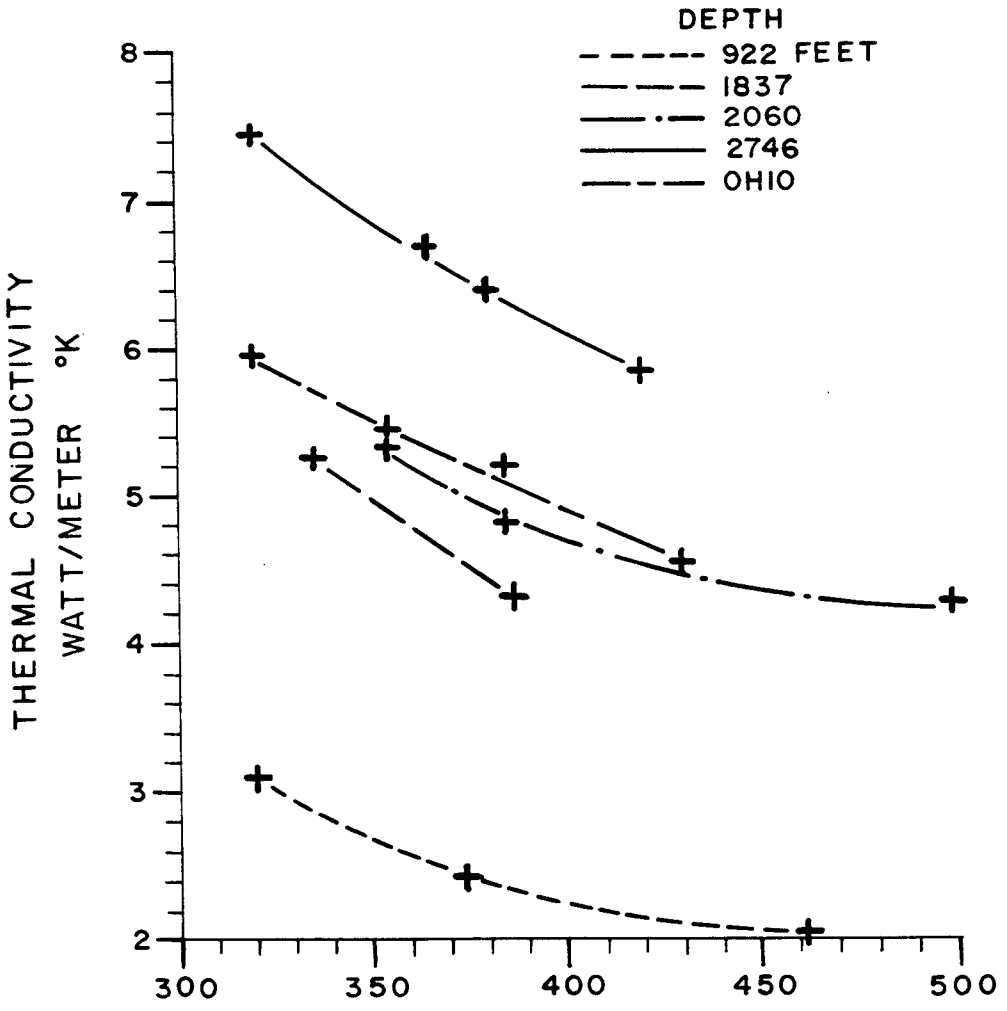


ARGON PERMEABILITY OF ROCK SALT SAMPLE AT 2000 PSI CONFINING PRESSURE

FROM: SUTHERLAND, 1978

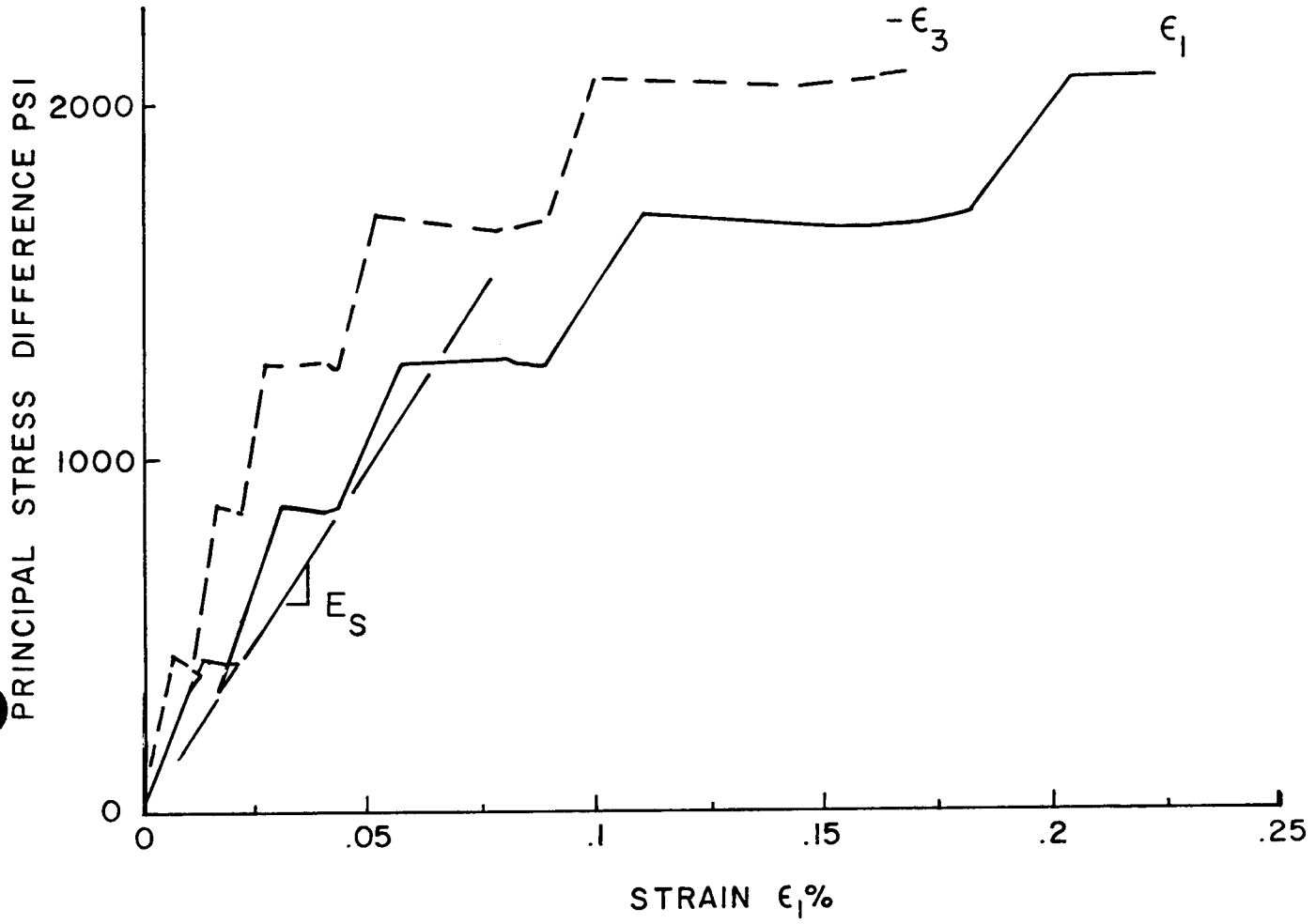
FIGURE 9.2.3-1



THERMAL CONDUCTIVITY OF ROCKSALT CORE SECTIONS CONTAINING 50% OR MORE HALITE, WELL AEC 8

From: Acton, 1977

FIGURE 9.2.3-2



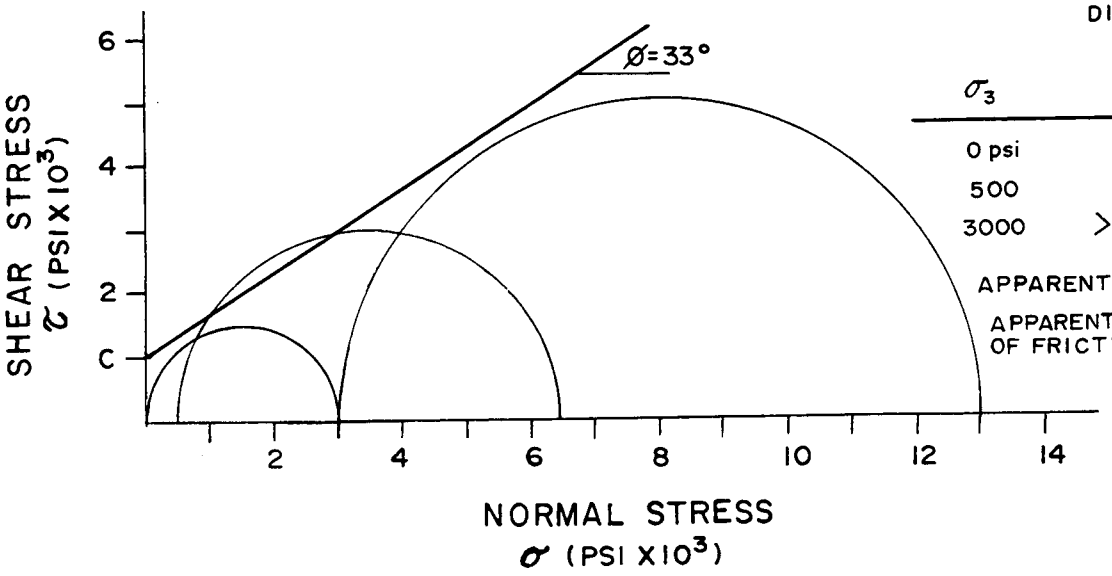
KEY

7-2745 (3.0, 23)
Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)

TRIAXIAL STRESS-STRAIN CURVES IN REGIME OF SMALL PRINCIPAL STRESS DIFFERENCES AND STRAIN

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-1

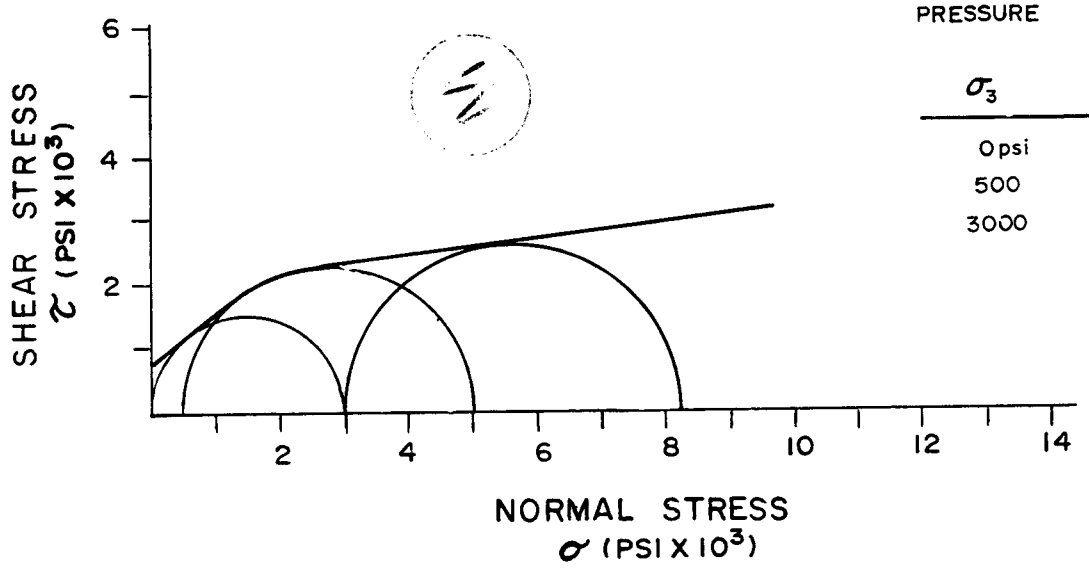


CONFINING PRESSURE σ_3	PRINCIPAL STRESS DIFFERENCE $(\sigma_1-\sigma_3)$	AXIAL STRAIN AT FAILURE ε_1
0 psi	3000psi	2.5%
500	6000	15
3000	>10,000	>20

APPARENT COHESION C=1000psi

APPARENT ANGLE OF FRICTION Ø = 33°
T = 23°

A. MOHR'S ENVELOPE AT ULTIMATE STRENGTH



CONFINING PRESSURE σ_3	PRINCIPAL STRESS DIFFERENCE $(\sigma_3-\sigma_1)$	AXIAL STRAIN ε_1
0psi	3000psi	2.5%
500	4500	2.5
3000	5250	2.5

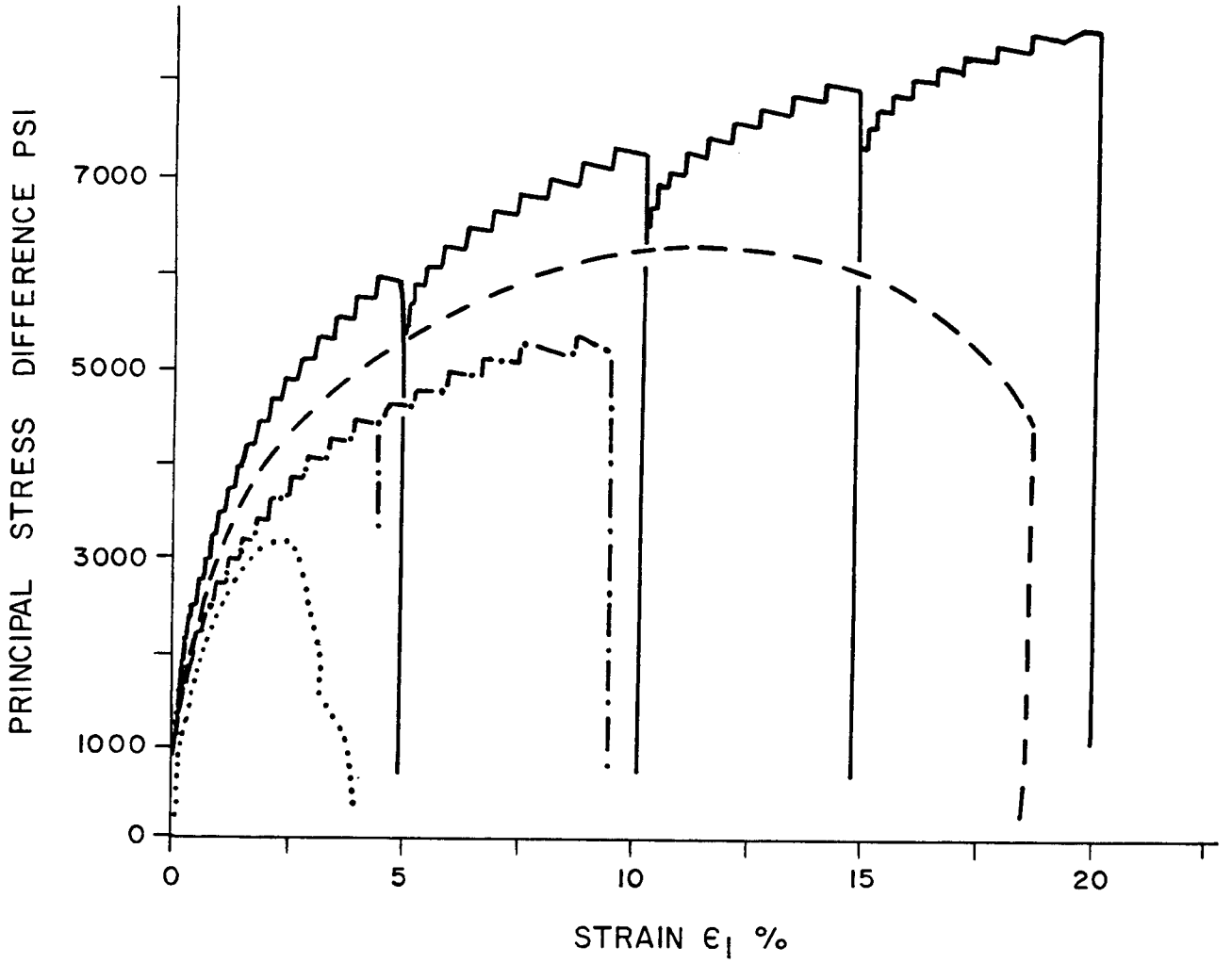
T = 23°

B. MOHR'S ENVELOPE AT CONSTANT STRAIN

NOTES:

1. THE SAME TEST DATA WERE USED TO GENERATE BOTH ENVELOPES. (TABLE 9 III, 9 IV; WAWERSIK, 1977)
2. THESE QUASI-STATIC PROPERTIES DO NOT ACCOUNT FOR ANY STRENGTH DETERIORATION WITH TIME.

FIGURE 9.2.4-2



KEY

..... 9-2676 (0, 23)

Hole No. – Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)

— · — 7-2837 (.25, 23)

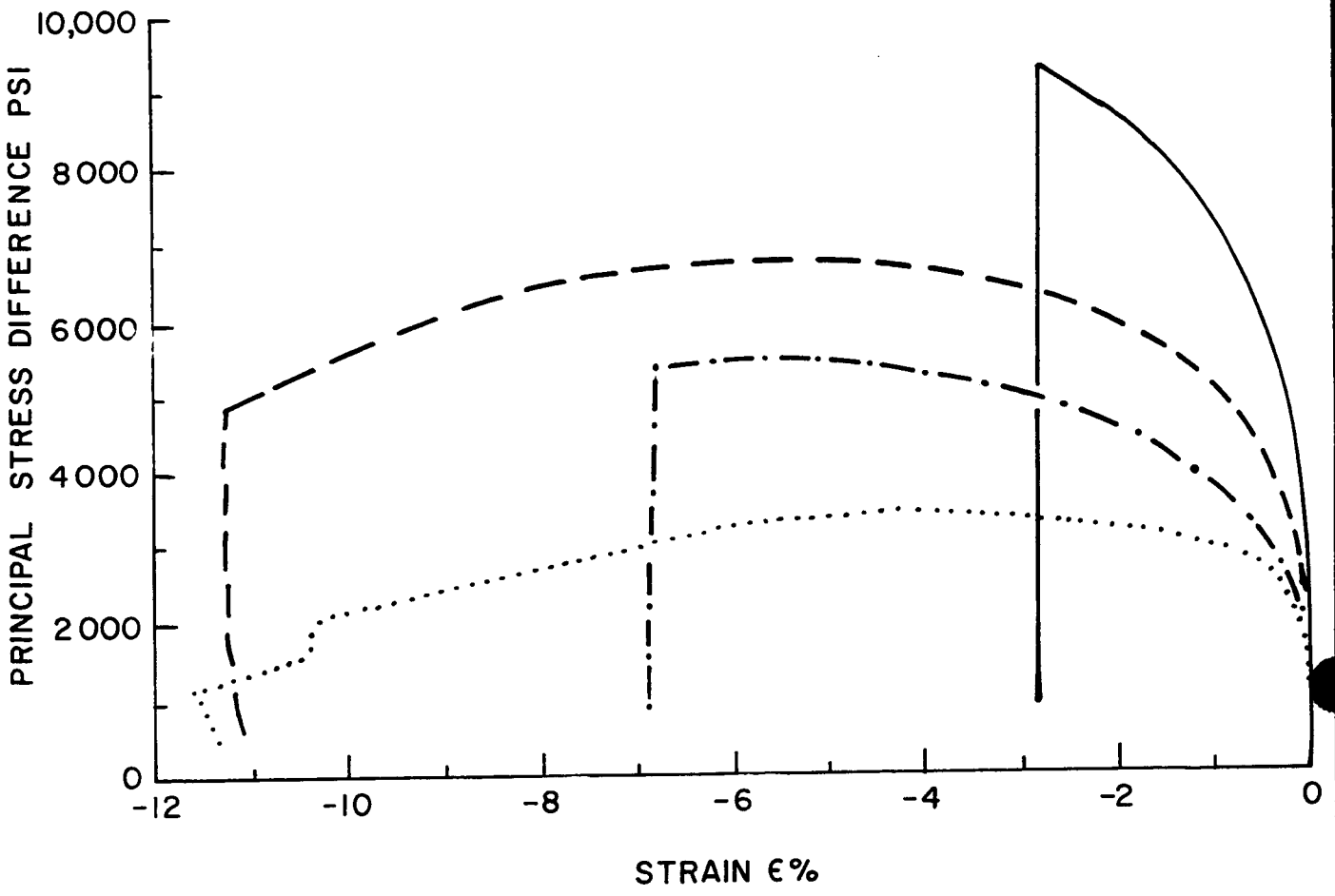
— — 9-2601 (.50, 23)

——— 9-2601.5 (3.0, 23)

CONVENTIONAL QUASI-STATIC TRIAXIAL STRESS-STRAIN DATA AT AMBIENT TEMPERATURE EFFECT OF PRESSURE

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-3



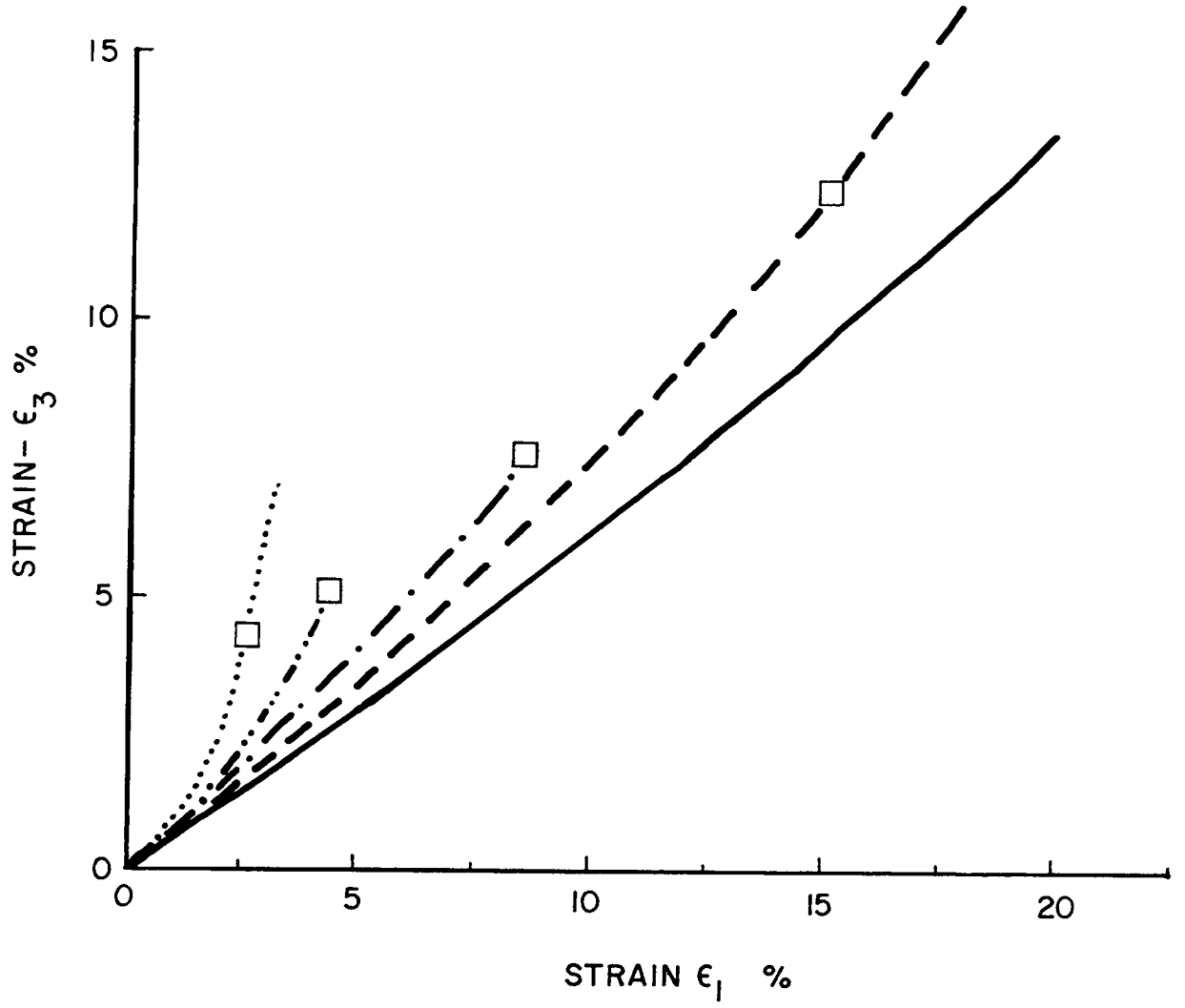
KEY

.....	9-2676 (0, 23)
	Hole No. – Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
— · —	7-2837 (.25, 23)
— —	9-2601 (.50, 23)
———	9-2601.5 (3.0, 23)

PRINCIPAL STRESS DIFFERENCE VS. VOLUMETRIC STRAIN FOR TEST OF FIGURE 9.2.4-3

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-4



KEY

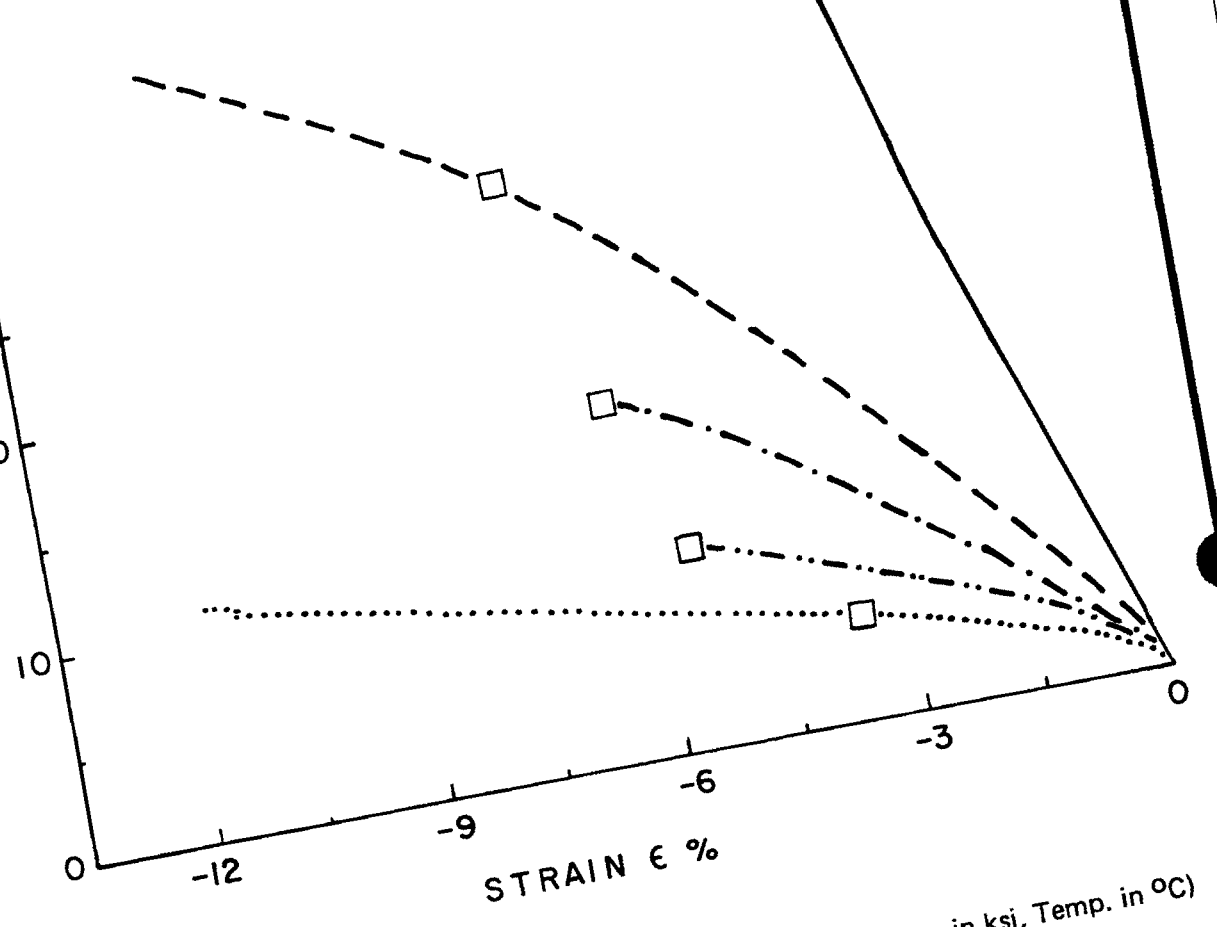
.....	9-2676 (0, 23)
	Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
—··—	9-2689 (.10, 23)
—·—	7-2837 (.25, 23)
— —	9-2601 (.50, 23)
———	9-2601.5 (3.0, 23)

NOTE: Open squares identify approximate strains at ultimate stresses.

TRIAXIAL VARIATION OF LATERAL STRAIN VS. AXIAL STRAIN FOR TEST OF FIGURE 9.2.4-3

From : Wawersik and Hannum, 1978

FIGURE 9.2.4-5



KEY

- 9-2676 (0, 23)
- —·—·— 9-2689 (.10, 23)
- —·—·— 7-2837 (.25, 23)
- — — — 9-2601 (.50, 23)
- ——— 9-2601.5 (3.0, 23)

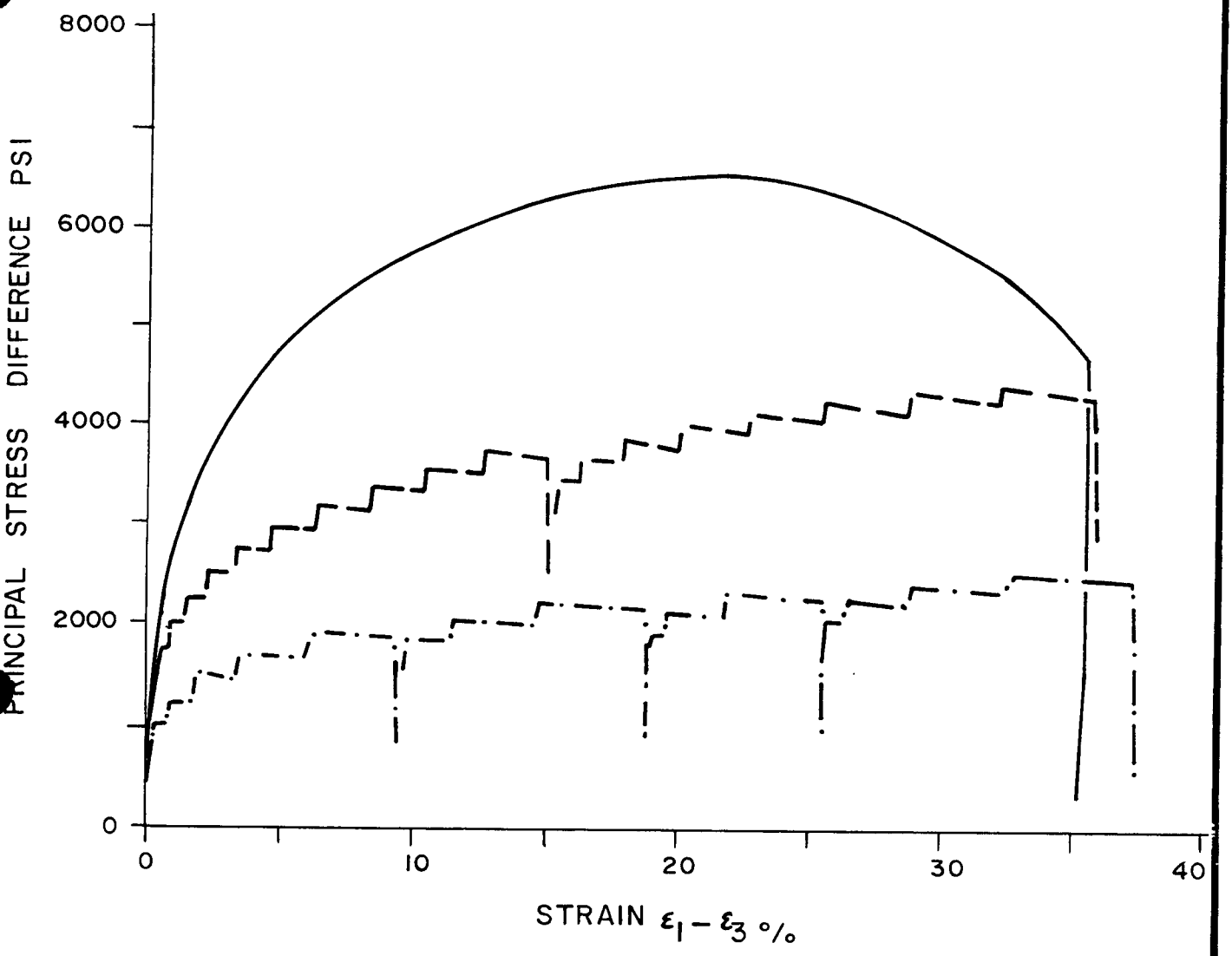
Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)

NOTE: Open squares identify approximate strains at ultimate stresses.

TRIAXIAL VARIATION OF SHEAR STRAIN VS VOLUMETRIC STRAIN FOR TESTS OF FIGURE 9.2.4-3

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-6



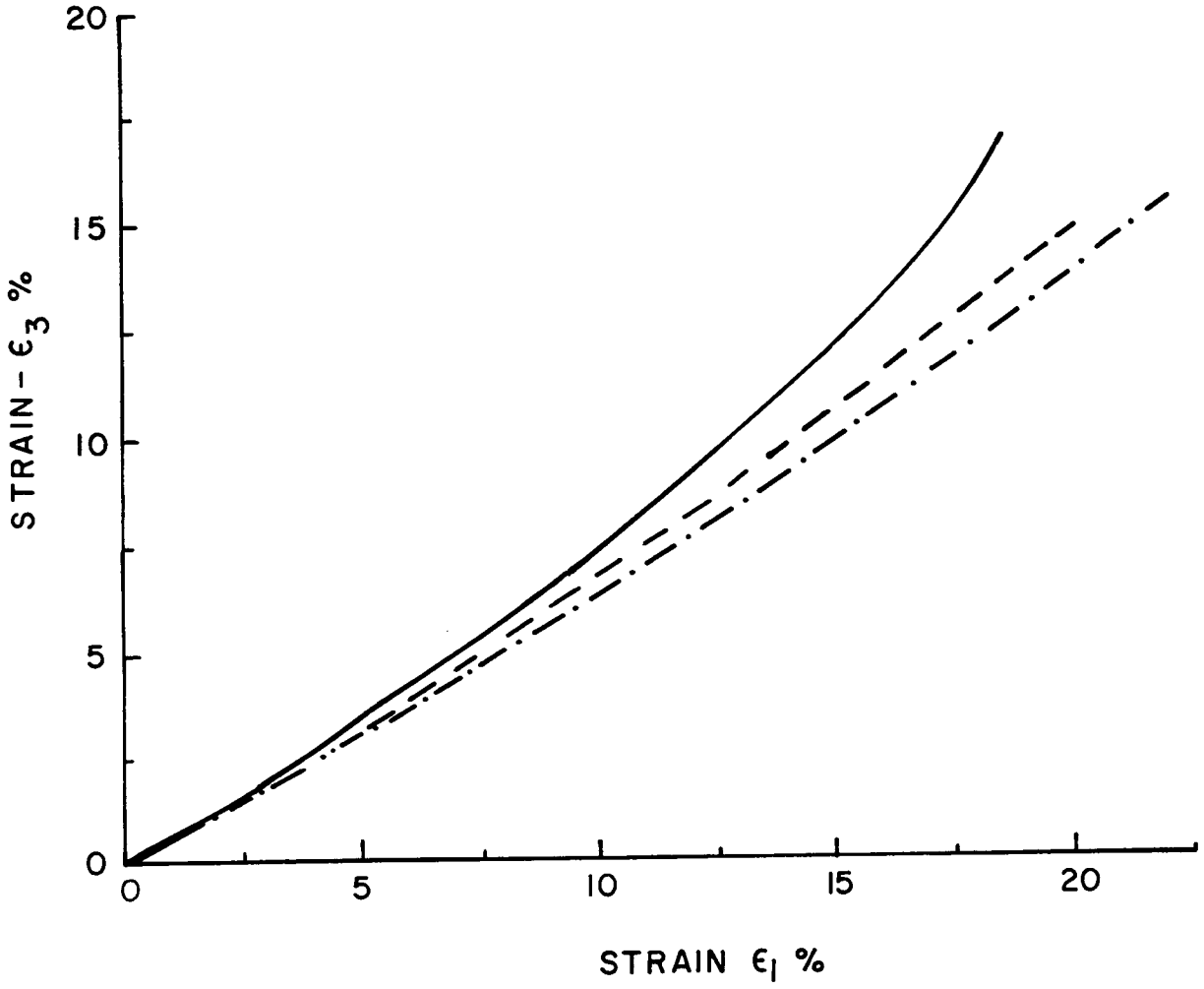
KEY

9-2601 (.50, 23)
Hole No. – Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
9-2673.4 (.50, 100)
9-2604 (.50, 200)

TRIAXIAL STRESS-STRAIN CURVES AS A FUNCTION OF TEMPERATURE AT CONSTANT CONFINING PRESSURE

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-7



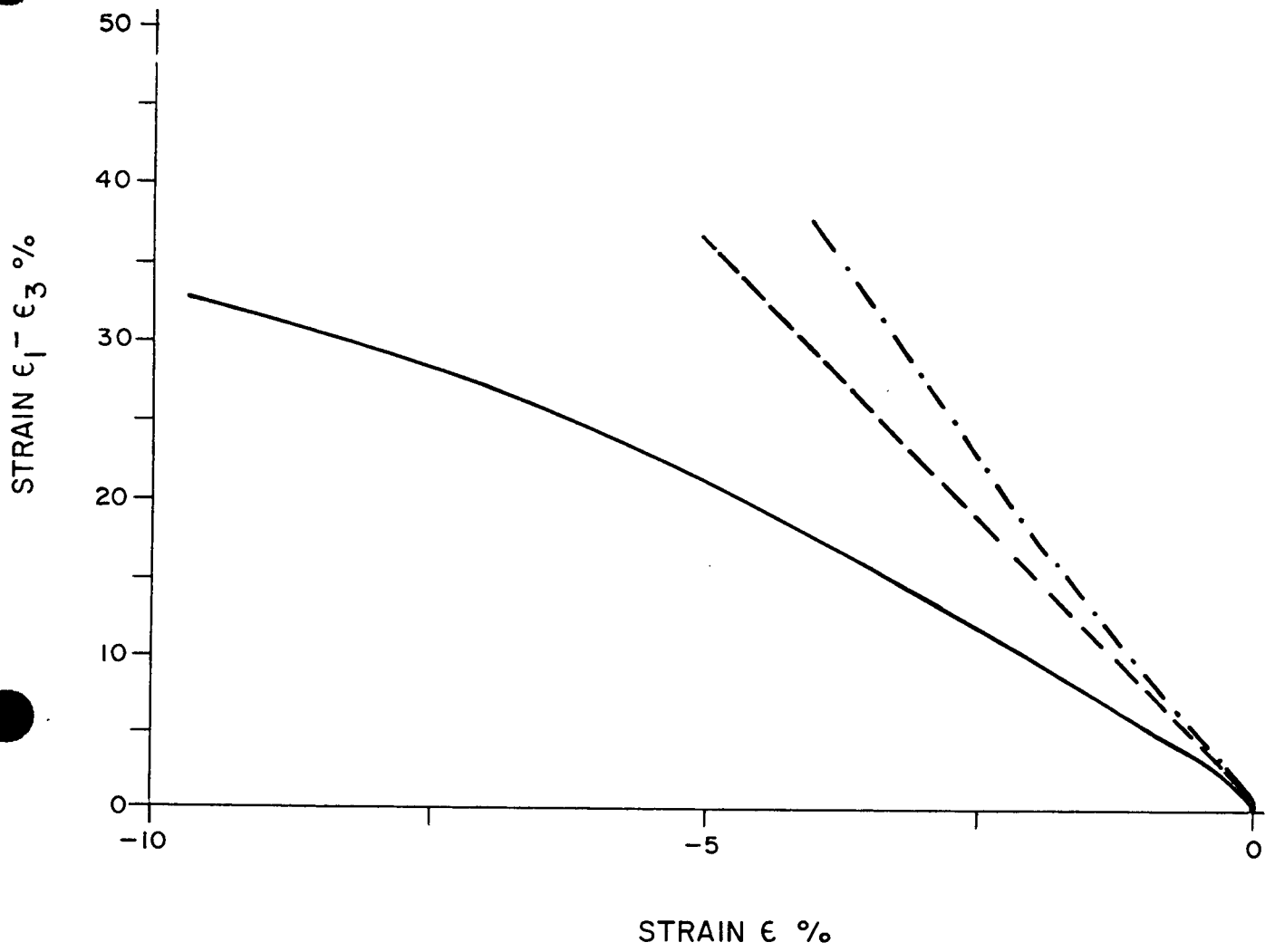
KEY

——— 9-2601 (.50, 23)
Hole No. – Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
— — 9-2673.4 (.50, 100)
—·— 9-2604 (.50, 200)

VARIATION OF LATERAL VS. AXIAL STRESS FOR TESTS OF FIGURE 9.2.4-7

From: Wawersik and Hannum, 1978

FIGURE 9.2.4 - 8



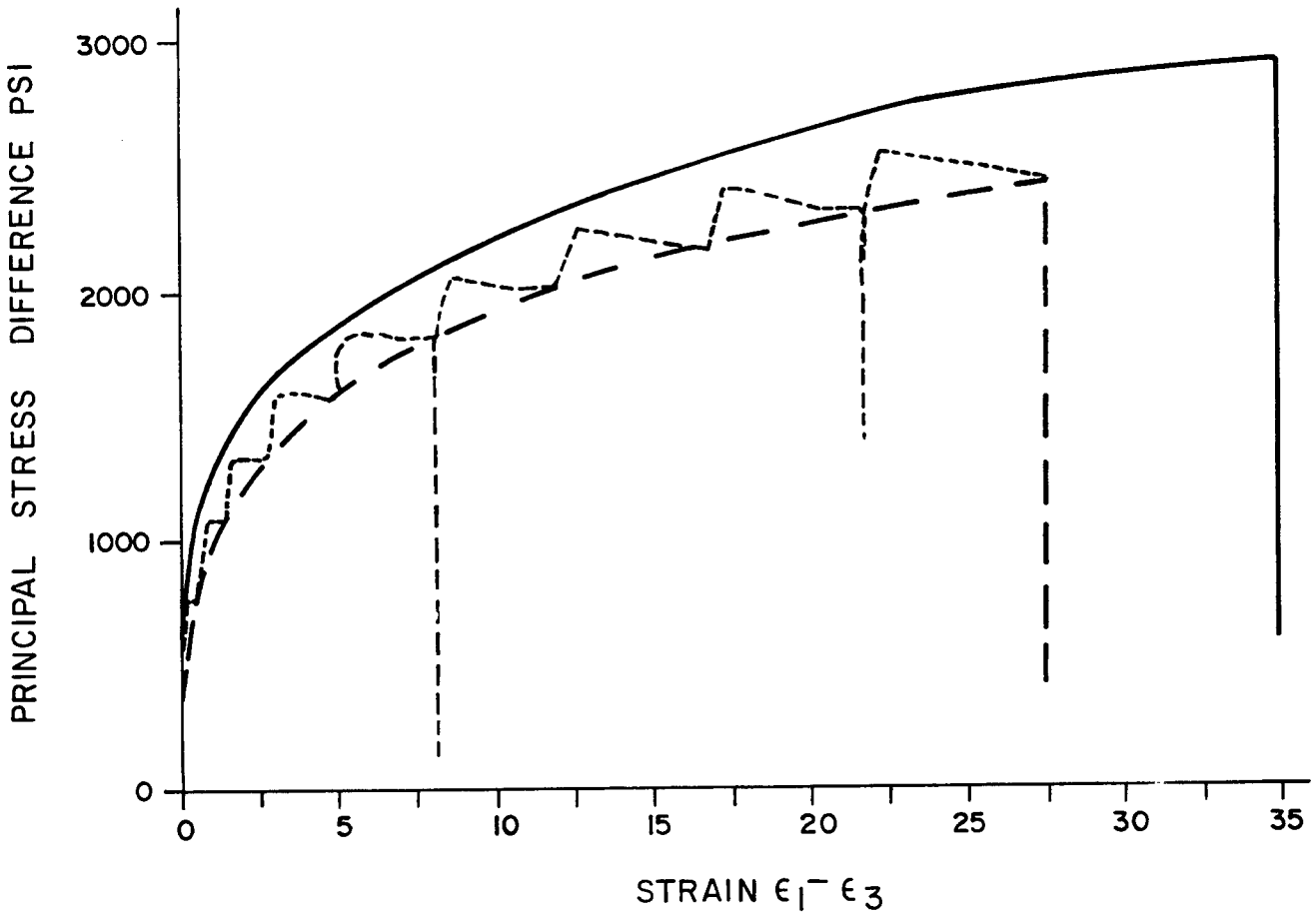
KEY

9-2601 (.50, 23)
Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
9-2673.4 (.50, 100)
9-2604 (.50, 200)

VARIATION OF SHEAR-STRAIN VS. VOLUMETRIC STRAIN FOR TESTS OF FIGURE 9.2.4-7

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-9



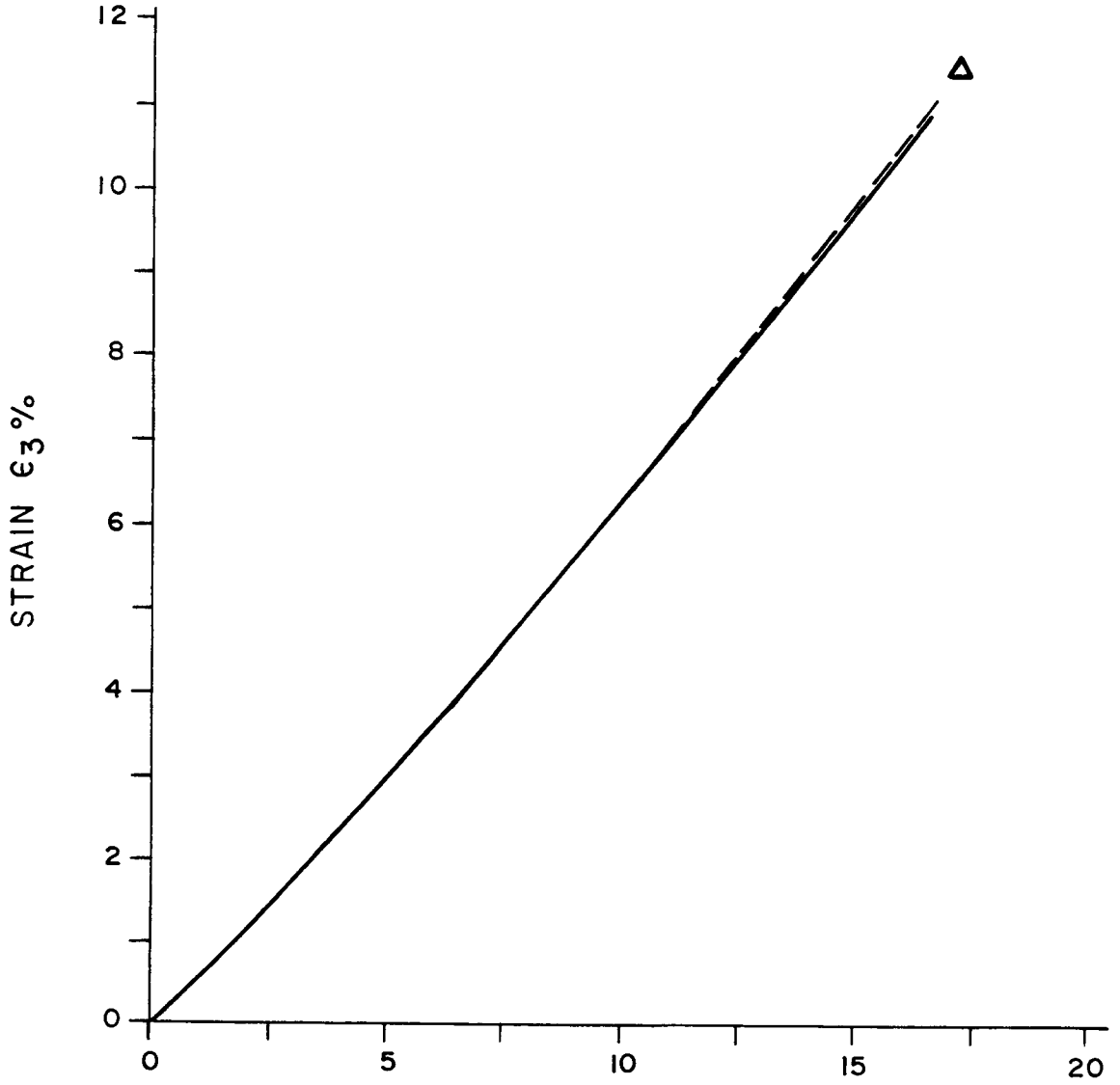
KEY

7-2740 (.50, 200)
Hole No. – Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
7-2744 (3.0, 200)
Actual load path

TRIAXIAL STRESS STRAIN CURVES AS A FUNCTION OF CONFINING PRESSURE AT 200°C

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-10



KEY

Δ 7-2836 (0, 200)
Hole No. – Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)

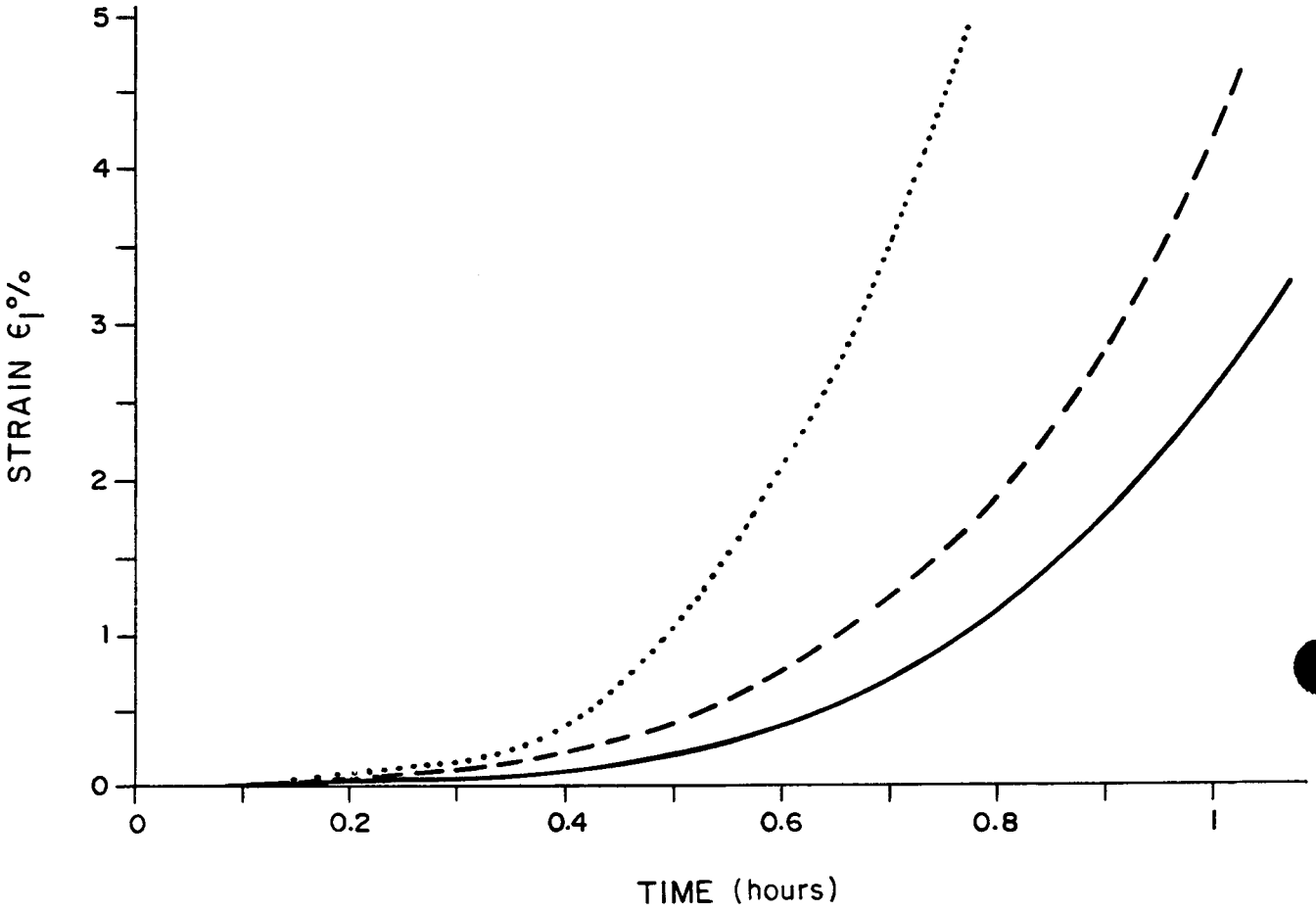
——— 7-2740 (.50, 200)

– – – 7-2744 (3.0, 200)

VARIATION OF LATERAL STRAIN VS. AXIAL STRAIN FOR TESTS OF FIGURE 9.2.4-10 (PLUS ONE ADDITIONAL TEST IN UNIAXIAL COMPRESSION)

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-11



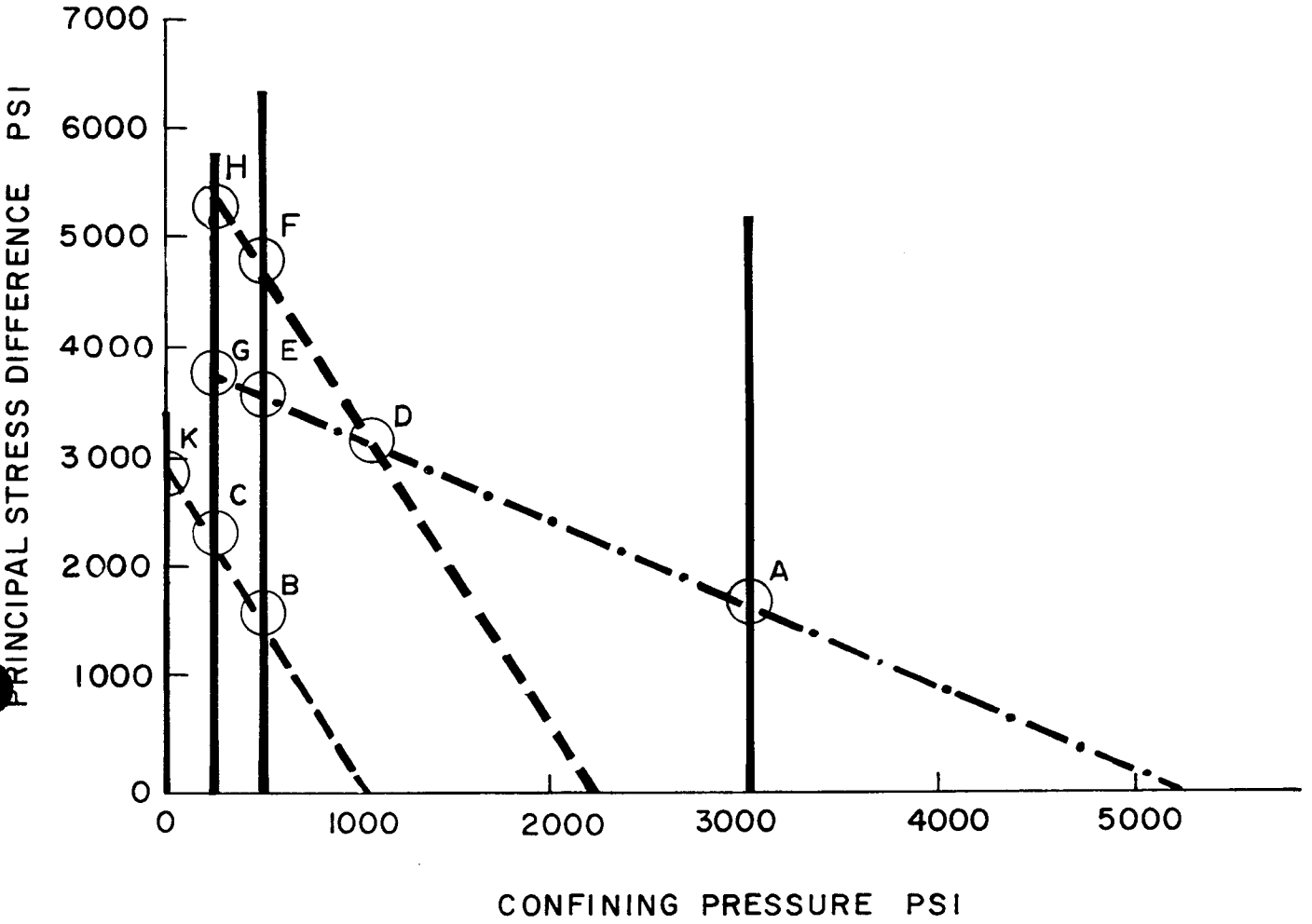
KEY

..... 7-2836 (0, 200)
Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
— — 7-2740 (.50, 200)
——— 7-2744 (3.0, 200)

AXIAL STRAIN VS. TIME FOR TEST OF FIGURES 9.2.4-10 AND 9.2.4-11

From: Wawersik and Hannum, 1978

FIGURE 9.2.4-12



KEY

Load Path I ($\sigma_2 = \sigma_3$ = const.)

Load Path II (σ_m = const.) $\sigma_m = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$

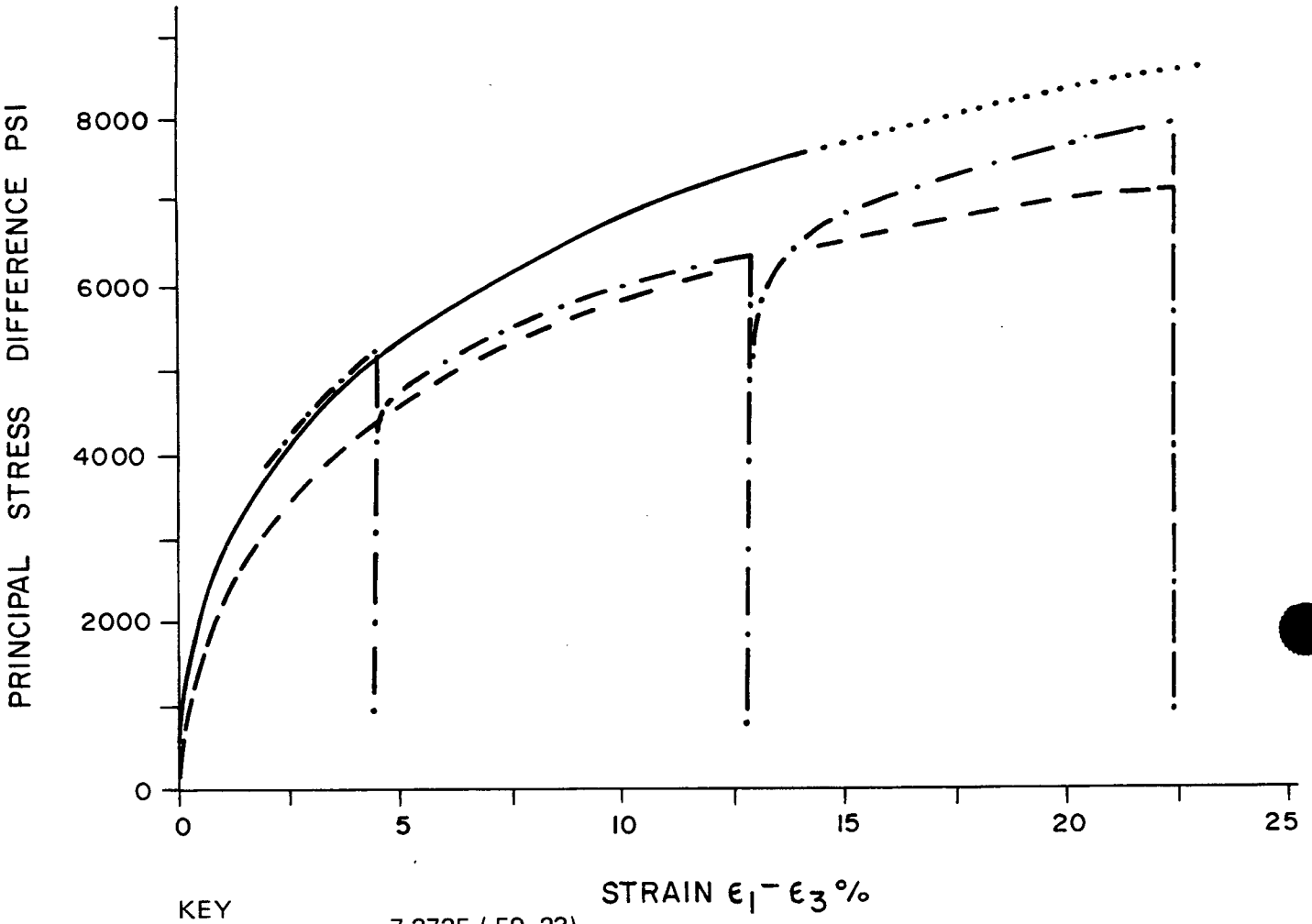
Load Path III ($\sigma_1 \approx$ const.)

NOTE: See table 9.2.4-3 for tabulated data.

MAP OF THREE NON-PROPORTIONAL LOAD PATHS AND COMMON STRESS STATES (POINTS A THROUGH K)

From : Wawersik and Hannum, 1978

FIGURE 9.2.4-13



KEY

- 7-2725 (.50, 23)
  Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
- 7-2745 (3.0, 23)
- 7-2740.5 (3.0/.50/3.0, 23)
- 9-2601.5 (3.0, 23)

NOTE: The partial code 3.0/.50/3.0 identifies prevailing confining pressures between $(\sigma_1 - \sigma_3) = 0$ and first unload/reload cycle, first and second unload/reload cycle, and between second unload/reload cycle and final unloading trace.

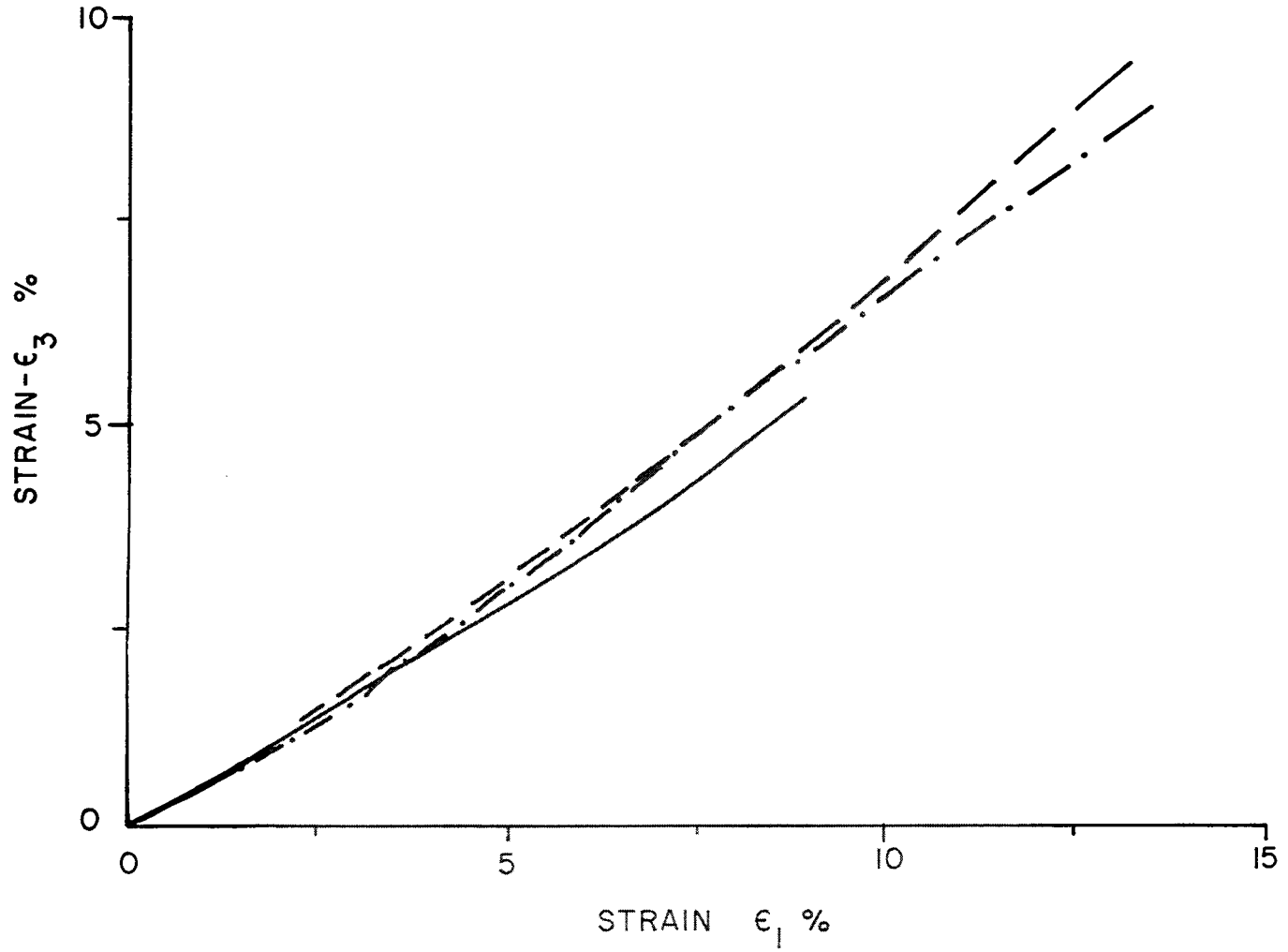
STRESS-STRAIN CURVES

FOR SAMPLE SUBJECTED TO

ONE OR MORE CONFINING PRESSURES

From : Wawersik and Hannum, 1978

FIGURE 9.2.4 - 14



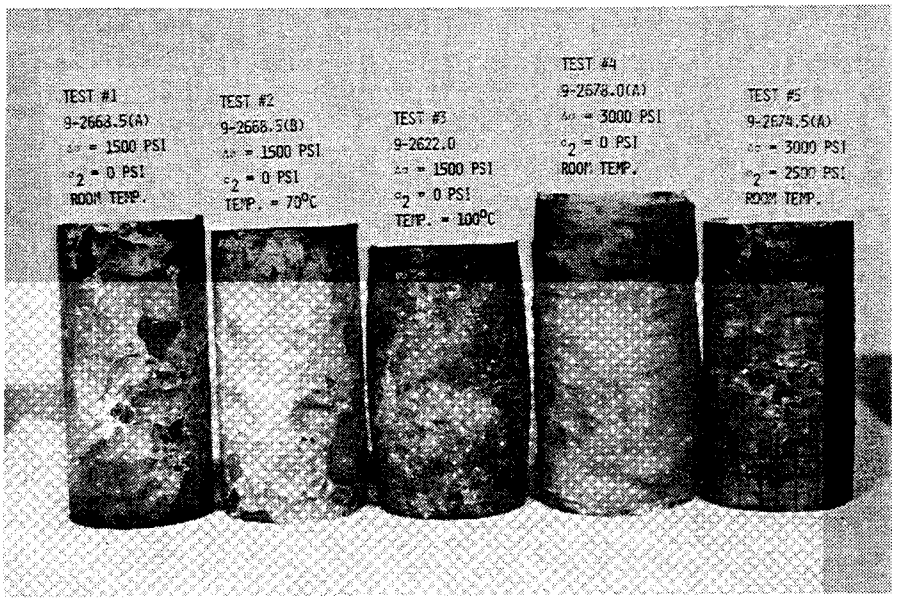
KEY

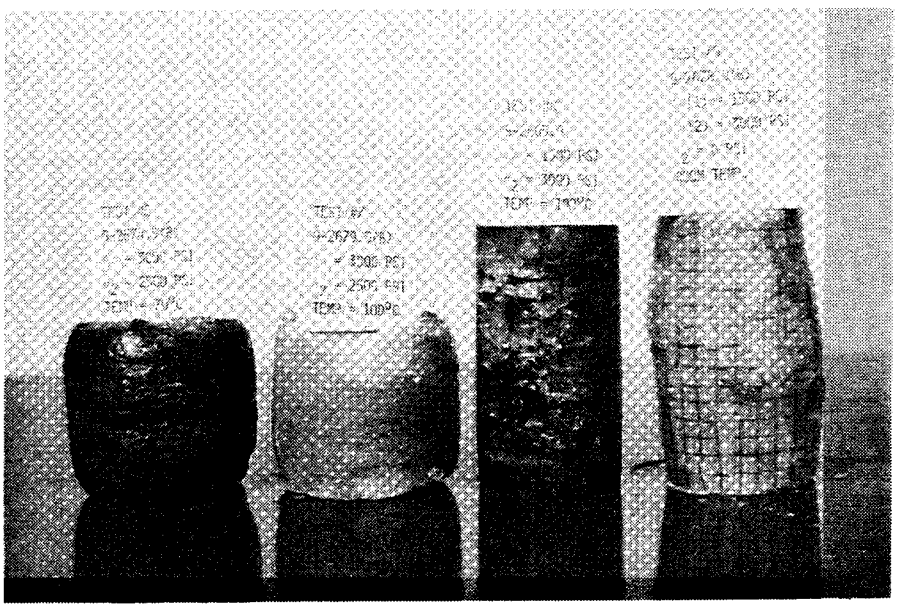
— — 7-2725 (.50, 23)
Hole No. — Sample depth in ft. (Conf. pressure in ksi, Temp. in °C)
——— 7-2745 (3.0, 23)
—·— 7-2740.5 (3.0/.50/3.0, 23)

VARIATION OF LATERAL STRAIN VS. AXIAL STRAIN FOR TESTS OF FIGURE 9.2.4-14

From : Wawersik and Hannum, 1978

FIGURE 9.2.4-15





DEFORMED CORE SAMPLES OF ROCK SALT
FROM DRILL HOLE ERDA #9

FROM: HANSEN and MELLEGARD, 1977

FIGURE 9.2.4–16

Table 9.2.3-1: Physical properties of rock from WIPP study area

Material	Depth (ft)	Density (gm/cc)	Avg. Porosity (Range) (%)	Mass (Moisture) Loss (% to $\leq$ 300°C)	Resistivity in Ohm Meters	Avg. Air Permeability (Range) in (md)[2]	(P) Wave[3] Velocity (Km/sec)
Rock Salt	2000-2100	2.18	0.4 (0.1-0.8)	N[1] - 1.0	58,100	0.01 (0.0003-0.17)	(4.42-4.62)
Rock Salt	2600-2700	2.18	0.5 (0.3-0.7)	N - 0.4	(4,900-230,000)	-	-
Anhydrite		2.80	-	-	-	-	-
Polyhalite	-	2.70	-	-	-	-	-
Siltstone	-	2.26	-	-	-	-	-

[1]N - None Measured

[2]Core Labs Data; see also Figure 9.2.3-1

[3]Note: P Wave velocities determined in the lab agree to 15% with those measured downhole on borehole ERDA 9 (Griswold, 1977).

Table 9.2.4.-1 - Representative unconfined mechanical properties of rock salt from the WIPP study area

Material	Drillhole/ Approx. Depth (ft)	Uniax. Compr. Strength (psi)	Strain at failure percent	Brazilian Tensile Strength (psi)	Initial Elastic Limit $(\sigma_1 - \sigma_3)$ (psi)	Secant Modulus $x10^6$ (psi)	Principal Strain Ratio	Principal Strain Ratio, $\varepsilon_3/\varepsilon_1$ at Failure
Rock Salt	AEC 7,8/1900	2450	$\geq$ 1.7	200	$\leq$ 750	1.94	0.33	-
Rock Salt	AEC 7,8/2700	3700	3.6	240	$\leq$ 750	1.94	0.34	-
Rock Salt	ERDA 9/2100	2400	1.6	-	< 200	-	-	1.6
Rock Salt	ERDA 9/2700	3300	2.9	-	< 200	-	-	2.1

Note: Loading rates - $30 \leq \frac{d}{dt} (\sigma_1 - \sigma_3) \leq 215$ psi/min

1 Megapascal (MPa) equals about 145 psi
Symbols < and > denote experimental uncertainty.

Table 9.2.4-2 - Representative triaxial compression data for rock salt from the WIPP study area

Drillhole/ Depth (ft)	Confining Pressure (psi)	Temp. (^{o}C)	Ultimate (max) Princ. Stress Diff. (psi)	Ultimate (max) Strain, ε_1 Percent	Initial Elastic Limit ($\sigma_1 - \sigma_3$) (psi)	Secant Modulus x10^6 (psi)	Principal Strain "Poissons'" Ratio	Max. Obs. Princ. Strain Ratio
ERDA 9/2100	500	23	6000	12	$\leq$100	2.7	0.20	- 0.72
ERDA 9/2100	3000	23	> 9000	>20	$\leq$100	2.7	0.20	- 0.65
ERDA 9/2600-2700	500	23	6300	15	$\leq$100	2.7	0.20	- 0.80
ERDA 9/2600-2700	3000	23	> 8900	>20	$\leq$100	2.7	0.20	- 0.67
AEC 7/2700-2800	500	23	> 6200	>13	$\leq$100	2.7	0.21	- 0.71
AEC 7/2700-2800	500	100	$\approx$ 4200	$\geq$18	$\leq$100	-	-	- 0.69
AEC 7/2700-2800	500	200	$\approx$ 2400	>17	$\leq$100	2.4	-	- 0.68
AEC 7/2700-2800	300	200	> 2750	>17	$\leq$100	-	-	-
ERDA 9/2600	500	200	> 2500	>22	$\leq$100	-	-	- 0.68

Note: Loading rate d/dt ($\sigma_1 - \sigma_3$) = 30 to 60 psi/min.

Table 9.2.4-3 Deviatoric Load Path Data For Figure 9.2.4-13

Reference Point In Figure 15	Load Path	$(\sigma_1 - \sigma_3)$ PSI	$\sigma_2=\sigma_3$ PSI	σm PSI	ε_1 %	$-\varepsilon_3$ %
A	I	1600	2970	3550	0.17	0.07
	III	1640	3020	3570	0.075	0.05
B	I	1520	520	1015	0.357	0.175
	II	1500	520	1015	0.3	0.168
C	I	2200	260	1040	o.782	0.441
	II	2250	250	1015	0.769	0.476
D	II	3190	1120	2180	1.35	0.786
	III	3150	1120	2160	0.73	0.454
E	I	3540	520	1670	1.38	0.828
	II	3580	510	1700	1.12	0.705
F	I	4700	490	2090	4.04	2.434
	II	4740	510	2120	3.92	2.430
G	I	3840	250	1490	2.486	1.85
	III	3780	250	1500	1.49	1.01
H	I	5240	250	1990	8.58	7.81
	III & I	5140	260	2000	6.41	5.46
	II	5320	276	2070	5.71	3.79
K	I	2950	0	990	1.49	1.47
	II	2950	15	1000	1.58	1.19

Table 9.3-1

REPRESENTATIVE BRINES/SOLUTIONS FOR WIPP EXPERIMENTATION

Ion	Brine "A" (mg/liter) (± 3%)	Brine "B" (mg/liter) (± 3%)	Solution "C" (mg/liter) (± 3%)
Na^+	42,000	115,000	100
K^+	30,000	15	5
Mg^{++}	35,000	10	200
Ca^{++}	600	900	600
Fe^{+++}	2	2	1
Sr^{++}	5	15	15
Li^+	20	-	-
Rb^+	20	1	1
Cs^+	1	1	1
Cl^-	190,000	175,000	200
SO_4^{--}	3,500	3,500	1,750
B (BO_3^{---})	1,200	10	-
HCO_3^-	700	10	100
NO_3^-	-	-	20
Br^-	400	400	-
I^-	10	10	-
pH (adjusted)	6.5	6.5	7.5
specific gravity	1.2	1.2	1.0

Table 9.3-2

Nominal Concentration of Nuclides Used in Kd Measurements

Nuclide	Concentration, ppm
^{137}Cs	0.012
Stable Cs	1.0
^{85}Sr	0.03 - 0.3
Stable Sr	5 - 15
^{106}Ru	2500
^{99}Tc	59
^{152}Eu	0.1 - 1.0
^{144}Ce	3×10^{-4}
^{131}I	5×10^{-5}
^{153}Gd	0.2 - 2.0
^{125}Sb	≤ 0.01
^{243}Am	5.4
^{244}Cm	0.012
^{238}Pu	0.058

Table 9.3-3

Distribution Coefficients on Samples From the Magenta Dolomite

Fission Product
Distribution Coefficients

	pH range	Cs	Sr	I,Tc	Eu,Gd	Ru
Brine A	6.5 - 6.9	< 1	1	0 - 1.5	$> 5 \times 10^3$	40-50
Brine B	6.5 - 7.5	< 1	1	< 1	$> 5 \times 10^3$	500-600
Sol'n C	7.5 - 8.2	4	5	0 - 1.5	$> 10^4$	400-550

Actinide
Distribution Coefficients

	pH range	Pu	Am	Cm
Brine B	6.5 - 7.8	5.4×10^3	3.1×10^2	1.3×10^3
Sol'n C	7.5 - 8.2	2.4×10^3	2.4×10^3	4.2×10^4

Table 9.3-4

Distribution Coefficients on Samples From the Culebra Dolomite

Fission Product
Distribution Coefficients

	pH range	Cs	Sr	I,Tc	Eu,Gd	Ru
Brine A	6.5 - 6.9	< 1	< 1	< 1	$> 10^4$	25 - 35
Brine B	6.5 - 7.6	1-2	1-2	< 1	$> 10^4$	640 - 660
Sol'n	7.5 - 8.2	7-10	4-5	< 1	$> 10^4$	240 - 400

Actinide
Distribution Coefficients

	pH range	Pu	Am	Cm
Brine B	6.5 - 7.8	2.1×10^3	2.6×10^3	1.2×10^4
Sol'n C	7.5 - 8.3	7.3×10^3	2.2×10^4	1.1×10^5

Table 9.3-5

Distribution Coefficients on Halite From The 2056' Horizon of ERDA #9 Borehole

Actinide Distribution Coefficients [1]

pH range	Pu	Am	Cm
7.0 - 7.1	17	306	354
	(1.0×10^4)	(1.8×10^5)	(2.1×10^5)

1) The Kd values in parentheses were calculated from the weight of water insoluble material in the halite. The lower values are based on the total weight of halite taken.

Table 9.3-6

Distribution Coefficients on Samples of Clay From The 2186.6' Horizon of AEC #8 Borehole

Fission Product Distribution Coefficients

	pH range	Cs	Sr	I,Tc	Gd,Eu	Ru
Brine A	6.5 - 7.0	< 1	< 1	< 2	$> 2.5 \times 10^3$	150-180
Brine B	6.5 - 7.7	4-6	< 1	< 1	$> 10^4$	$> 2 \times 10^3$
Sol'n C	7.5 - 7.8	80-120	3-6	< 1	$> 10^4$	$> 1 \times 10^3$

Actinide Distribution Coefficients

	pH range	Am	Pu	Cm
Brine B	6.5 - 8.0	1.1×10^3	4×10^4	1.9×10^4
Sol'n C	7.5 - 8.4	3.5×10^3	1.8×10^5	4.2×10^5

Table 9.3-7

Distribution Coefficients on Samples of Polyhalite From the 2304' Horizon of ERDA #9 Borehole

Fission Product Distribution Coefficients

	pH range	Cs	Sr	Eu,Ce [1]	Sb	Tc
Brine A	6.5 - 7.0	< 1	5-10	10-20	< 1	< 1
Brine B	6.5 - 7.2	< 1	19-22	430-700, 50-55	0.9-1.5	< 1
Sol'n C	7.5 - 7.6	< 1	35-40	100-200, 40-60	3-4	< 1

1) Where two ranges of values are given, the first refers to Eu and the second to Ce.

Table 9.3-8

Distribution Coefficients on Sample of Cowden Anhydrite
From the 2562' Horizon of AEC #8 Borehole

Fission Product
Distribution Coefficients

	pH range	Gd,Eu,Ce
Brine B	6.5 - 7.9	$> 10^3$

Actinide Distribution
Coefficients

	pH range	Am	Pu	Cm
Brine B	6.5 - 7.9	2.9×10^2	6.7×10^3	4.2×10^3
Sol'n C	7.5 - 8.2	2.2×10^3	7.7×10^4	1.8×10^5

Table 9.3-9

Distribution Coefficients on Samples of Clay from the 2725' Horizon of AEC #8 Borehole

Fission Product
Distribution Coefficients

	pH range	Cs	Sr	Eu,Gd [1]	Tc,I [1]	Ru
Brine A	6.6 - 7.0	4-9	< 1	$> 10^3$, $2.8\text{-}4 \times 10^2$	3.5-4.5, 0-3.5	90-120
Brine B	6.7 - 7.4	3-6	< 1	$> 10^4$	< 1	$> 10^3$
Sol'n C	7.5 - 8.0	34-40	30-45	$> 10^4$, $> 3 \times 10^3$	0.7-1.5, 0.5-4	$> 10^3$

Actinide
Distribution Coefficients

	pH range	Am	Pu	Cm
Brine B	6.5 - 7.8	310	7.2×10^4	2.7×10^3
Sol'n C	7.4 - 8.4	2.3×10^3	4.0×10^4	1.6×10^5

1) Where two ranges of values are given, the first refers to the first element listed and the second range is for the second element listed.

Table 9.3-10

Distribution Coefficients on Samples of Bell Canyon Formation

Fission Product
Distribution Coefficients

	pH range	Cs	Sr	Eu	Sb	Tc
Brine B	6.5 - 7.4	14-16	< 1	$> 10^4$	5-8	< 1
Sol'n C	7.5 - 7.9	130-140	1-5	$> 10^4$	20-25	< 1

Table 9.3-11

Distribution Coefficients on Halite Samples From the 2611' Horizon of ERDA #9 Borehole

Column Experiment

Column Bed: 7.5 g of Halite in 1 cm diameter column

Solution: Saturated Halite Solution, 200 ml

Flow: 1 Bed volume/min.

Time (days)	% of Initial Activity in Solution	
	^{85}Sr	^{144}Ce
0	100	100
1	98.0	26.7
4	96.8	0.9
8	98.4	0

Actinide Distribution Coefficients(1)

pH range	Am	Pu	Cm
7.0 - 7.3	11	59	56
	(3.8×10^3)	(2.11×10^4)	(2×10^4)

(1) The Kd values in parentheses were calculated using the weight of water insoluble material in the clay. The lower values are based on the weight of halite taken.

Table 9.3-12

^{152}Eu Distribution Coefficients (Kd's)

Rock	Simulant	Nominal ^{152}Eu(μCi/ml)	Kd(1) 2 week	Kd(1) 3 month	Kd(2) 2 week	Kd(2) 3 month
Culebra	A	0.01	1.7×10^{4}	1.5×10^{4}	--	--
"	A	0.1	3.6×10^{4}	2.1×10^{4}	--	--
"	A	1.0	1.8×10^{4}	4.3×10^{4}	--	--
"	B	0.01	3.4×10^{3}	1.6×10^{3}	--	7.6×10^{3}
"	B	0.1	1.1×10^{4}	3.6×10^{3}	--	1.3×10^{3}
"	B	1.0	3.7×10^{3}	3.9×10^{3}	8.8×10^{2}	1.4×10^{3}
"	C	0.01	2.8×10^{4}	1.3×10^{4}	--	1.1×10^{4}
"	C	0.1	2.7×10^{4}	2.6×10^{4}	--	1.9×10^{4}
"	C	1.0	2.0×10^{4}	1.4×10^{4}	1.2×10^{3}	9.6×10^{3}
Magenta	A	0.01	1.4×10^{4}	6×10^{3}	--	--
"	A	0.1	1.9×10^{4}	2.0×10^{4}	--	--
"	A	1.0	1.2×10^{4}	1.4×10^{4}	--	--
"	B	0.01	2.8×10^{3}	8.6×10^{2}	--	4×10^{2}
"	B	0.1	8.3×10^{3}	3.7×10^{3}	--	1.3×10^{3}
"	B	1.0	1.1×10^{3}	1.2×10^{3}	3.5×10^{2}	4.0×10^{2}
"	C	0.01	2.0×10^{4}	1.7×10^{4}	--	1.3×10^{4}
"	C	0.1	3.6×10^{4}	2.2×10^{4}	--	1.6×10^{4}
"	C	1.0	1.4×10^{4}	1.5×10^{4}	7.7×10^{2}	1.3×10^{4}

(1) Kd based on activity in feed solutions.

(2) Kd based on activity in pH adjusted feed solutions.

Table 9.3-13

Comparison of ^{153}Gd, ^{144}Ce, and ^{152}Eu Kd's in Brine B and Brine B* Containing Plywood Extract

14 Day Equilibration

Sample	Brine	^{153}Gd cpm/ml	^{153}Gd Kd	^{152}Eu cpm/ml	^{152}Eu Kd	^{144}Ce cpm/ml	^{144}Ce Kd
Feed	B	24,200	-	20,230	-	5,120	-
Feed	B*	38,090	-	38,090	-	7,080	-
Culebra	B		4.2×10^3		9.9×10^3		1.5×10^3
"	B*		6.3×10^2		6.6×10^2		6.0×10^2
Magenta	B		2.5×10^3		3.4×10^3		1.4×10^3
"	B*		6.5×10^1		7.0×10^1		1.1×10^2
Bell Canyon	B		3.4×10^3		3.4×10^3		3.2×10^3
"	B*		1.3×10^2		1.5×10^2		2.3×10^2
Cowden	B		2.6×10^3		2.2×10^4		2.2×10^3
"	B*		3.7×10^2		4.0×10^2		5.1×10^2
High Clay	B		6.8×10^3		8.5×10^4		1.2×10^3
"	B*		8.7×10^3		2.8×10^4		2.5×10^3

28 Day Equilibration

Sample	Brine	^{153}Gd cpm/ml	^{153}Gd Kd	^{152}Eu cpm/ml	^{152}Eu Kd	^{144}Ce cpm/ml	^{144}Ce Kd
Feed	B	23,260	-	20,170	-	4,800	-
Feed	B*	33,350	-	35,210	-	5,910	-
Culebra	B		4.3×10^3		8.3×10^3		3.3×10^3
"	B*		2.1×10^3		1.8×10^3		1.3×10^3
Magenta	B		3.5×10^3		2.5×10^3		$\geq 10^4$
"	B*		1.4×10^2		1.6×10^2		2.5×10^2
Bell Canyon	B		4.2×10^3		2.7×10^3		3.2×10^3
"	B*		1.5×10^2		1.7×10^3		3.2×10^2
Cowden	B		$\geq 10^5$		5.4×10^3		1.8×10^3
"	B*		4.7×10^2		4.8×10^2		5.3×10^2
Hi Clay	B		6.5×10^3		8.7×10^3		6.1×10^3
"	B*		1.9×10^4		3.2×10^4		5.9×10^3

GCR CHAPTER 10
CONTINUING STUDIES

10.1 INTRODUCTION

Continuing studies for the WIPP primarily encompass those geological processes that need to be understood in order to more quantitatively assess the safety of converting the WIPP to a repository. The processes of importance are tectonic, geochemical, hydrologic, and climatic. The studies indicated within this chapter generally relate to these major processes. In addition, a few studies indicated in this chapter relate to minor continuing efforts of site characterization. This chapter will serve to enumerate issues which remain to be addressed relevant to the safety of converting WIPP to a repository. It is not intended here that specific plans and schedules be presented.

The organization of Chapter 10 follows that of previous chapters.

10.2 SITE SELECTION

In line with the differentiation made in Chapter 2 between site selection, site characterization, and site confirmation, the activities of site selection and site characterization are nearly complete. The confirmation of the WIPP site for a repository will necessitate the continuing studies indicated in Sections 10.3 through 10.9.

10.3 REGIONAL GEOLOGY

Continuing studies of the regional geology focus mainly on the processes of tectonics and climate through studies of paleoclimates and various manifestations of past tectonic activity.

10.3.1 Paleoclimatology

The purpose of paleoclimatic studies in southeastern New Mexico is to develop the local timing and magnitude of past climatic changes and their relation to observed geology to help assess the possible effects of future changes on a repository.

The primary method of paleoclimatic study is to examine cores of Pleistocene or Recent sediments for fauna and flora which are indicative of past climatic conditions. In addition, organic matter or ash falls may, if suitable, be dated radiometrically to provide time control.

Studies of paleoclimate are underway with preliminary analysis of core taken in San Simon Sink from borehole WIPP 15. Fauna and flora are being separated from the sediment for paleontological analyses, and suitable organic material is being separated for radiocarbon analysis. These studies of the San Simon material will be completed in 1979 to yield an initial profile of climatic changes. Further coring in other locations may be undertaken at that time, if necessary, to supplement the record. The final stage of this study will be to integrate the local climatic changes into the information about regional climates and to determine the relationship between climatic changes and related processes such as subsurface salt dissolution and resultant subsidence (see Section 10.6).

10.3.2 Regional Tectonic Studies

The purpose of various studies of regional tectonics is to assess the long-term effects of tectonic forces on a repository.

Several studies together contribute to information about regional tectonics and include the seismological studies discussed in Section 10.5.

LANDSAT. A preliminary examination of LANDSAT photos has been completed and is reported in Chapter 3. In addition, the WIPP site and surrounding regions will be re-examined in 1979 with more sophisticated image

enhancement to determine the presence and location of more subtle lineaments. Field evaluation of the interpretations will be undertaken as required.

Leveling Surveys. Releveling of some existing first-order vertical control lines was carried out in 1977, and about 300 km of new lines were established. These new lines, some of which traverse Nash Draw and the WIPP site, will be periodically releveled to establish a data base for separating regional tectonic effects from local effects perhaps due to dissolution (see Section 10.6).

West Texas Salt Flats Graben. Releveling and seismology studies indicate active tectonic displacement on the west Texas salt flats graben. Seismic reflection records will be examined and test coring conducted in 1979 to determine if the sediments will yield a record of tectonic disturbance that will contribute to information about the tectonic forces likely to affect a repository located in the Delaware Basin.

10.4 SITE GEOLOGY

The purpose of continuing studies of site geology are to refine the data base for assessment of the safety of a repository there, and to contribute some additional details of site characterization. The methods and studies as such are quite varied.

10.4.1 Geologic Mapping

Geologic mapping continues on the WIPP site and in the area, particularly under a study of the stability of the WIPP site. This study, being conducted by the USGS, is concerned with mapping caliche and related sediments to provide more conclusive data on the length of time the area has been stable, and the rates at which areas around the site have been disturbed.

10.4.2 Aeromagnetic Survey

A very high resolution aeromagnetic survey will be initiated during FY79 to examine the WIPP site and several special features. The survey of the site will primarily be to determine if any dikes have intruded the evaporites at the site since dikes might form a pathway for fluid flow. Several of the domal features mentioned in Chapters 3, 4, and 6, two of which are considered to be breccia pipes, will be examined to determine if a magnetic signature is associated with disturbance of the magnetic red beds. The tool, if proven applicable, might then be used for prospecting to support continuing studies of breccia pipes as indicated in 10.6.

10.5 SEISMOLOGY

The purpose of continuing seismological studies is to provide data for facility design and to expand the data base contributing to an understanding of tectonic processes affecting a repository in the Delaware Basin. Seismological studies are supported by arrays of stations near points of interest.

10.5.1 Near-Site Activity

The careful characterization of near-site background activity, as indicated in Chapter 5, is the dominant seismic issue affecting the WIPP site. Station CLN has been operating near the site since 1974, and continues to operate. It is planned to augment this station so that at least three stations will be operating at the site to better define near-site seismicity.

10.5.2 Central Basin Platform

An array of stations has been operating near Kermit, Texas, since 1976 to evaluate the seismic activity on the Central Basin Platform and to explore the relationship, if any, between this activity and the massive

fluid injection for secondary oil recovery operations occurring in that area. This array will continue to operate both for this purpose and because the assessment of seismic activity at the WIPP site may partly depend on an understanding of the relationship between fluid injection and seismic activity should injection occur in oil fields near the site.

10.6 CONTINUING STUDIES IN HYDROLOGY

10.6.1 Introduction

Hydrology is a major consideration when examining the feasibility for locating a nuclear waste disposal site. Two factors are directly related to hydrology: (1) the geologic stability of the formation in which the waste products will be stored, and (2) the occurrence of water as a transport medium for radionuclides. Unsaturated waters migrating along the surfaces of the salt beds will dissolve salt; therefore, an examination of magnitude and direction of fluid flow and fluid chemistry in formations above and below the salt is necessary. Additionally, the direction and rate of fluid movement both above and below the storage horizon should be evaluated to predict the movement of radionuclides should they be accidentally discharged into the aquifers.

10.6.2 Purpose of Hydrologic Testing

Two hydrology-related questions are to be answered in evaluating the suitability of the proposed WIPP site.

1. What is the geologic stability of the Salado Formation?

2. Should the primary containment barrier (the salt) fail or an accident occur, where and how rapidly will radionuclides be transported by groundwater?

Three factors need to be investigated to examine the integrity of the Salado within the site: (1) the Rustler-Salado contact is to be examined

geophysically and petrologically within the WIPP area to determine if dissolution is presently occurring, (2) the dissolution front (as defined by the edge of the shallow dissolution zone in the Nash Draw) needs to be located more precisely, (3) the estimated rate of dissolution is to be refined.

The hydraulic gradients and rates of fluid movement in the series of fluid bearing zones that overlie the Salado require further definition. Estimates of concentrations of aqueous species (and when and where they might appear) may then be refined for specific safety-assessment modeling scenarios describing radionuclide escape into these groundwater systems and migration out of the area. In addition, formations which do not presently contain water but exhibit some degree of permeability are to be tested to see what rates of movement would be, should they contain water or other fluids at some later time.

10.6.3 Direction and Rate of Fluid Migration

If radionuclides were to reach fluid bearing zones in the Rustler, they would be transported away from the site by the groundwater system. To evaluate the impact of such an accident on the surrounding area, hydraulic gradients and hydraulic conductivities of fluid bearing zones overlying the salt beds will be determined or modified. Data for these determinations will be acquired by pumping tests on hydrologic test holes or measurements of the recovery time of fluid levels in bailed holes. Tracer tests will be conducted where they may contribute useful information.

A series of hydrologic tests is planned in holes placed near the periphery of the proposed land withdrawal area. After additional testing of some existing holes, control points for the potentiometric surfaces and for hydraulic conductivities will have been established for the periphery with a spacing of 2 to 3 miles. These data will allow construction of more detailed potentiometric surface maps for the site area. The potentiometric contours will be meshed with the results from

the Nash Draw program to the west. Consequently, the potentiometric surface and hydraulic conductivity data required for modeling efforts of long-term safety assessment will be obtained for an area extending from the northeast part of the study area to Malaga Bend on the Pecos River (an area of about 200 square miles).

The borehole plugging program requires data from both laboratory and *in situ* permeability measurements. These permeability measurements, both in the evaporites and in aquifers, will provide additional data for the safety assessment work.

10.6.4 Dewey Lake Redbeds

The Rustler Formation and the shallow dissolution zone in Nash Draw have demanded the attention of this program because they are fluid-bearing. The Dewey Lake Redbeds are also of some significance since fluids are present in sandstone lenses. Although the redbeds are only locally saturated, two possibilities exist for additional water to enter the formation: a climatic change to a high rainfall period, or migration of fluids from below into the redbeds.

Tests in two types of holes are being considered: existing holes, and at least one new hole specifically designed for Dewey Lake testing. The casing in existing holes will be perforated opposite permeable zones as identified from analyses of logging and drilling records.

The standard hydrologic testing procedures will allow calculation of the transmissivity of fluid bearing strata in the Dewey Lake Redbeds or other permeable zones that might be expected to contain fluids at some future time.

10.6.5 Long-Term Monitoring

The peripheral hydrologic test holes, which now include four potash holes, will be configured for long-term monitoring. This long-term

monitoring may show what changes are taking place in the hydraulic gradients which in turn may indicate increased or decreased flow, and variations in rates of recharge or discharge. Moreover, depending on the extent of the monitoring system, a warning network for information on fluid threats to the integrity of the repository is obtained.

The Dewey Lake Redbed hole(s) can be monitored to detect fluid movement that may not be present except during high precipitation cycles of long or short duration.

The test holes drilled in Nash Draw would be monitored to detect changes in the hydrologic regime along the Rustler-Salado contact. Because the Culebra is the main producer of water west and south of the WIPP area, it is desirable to monitor this fluid-bearing strata to determine its relationship with the shallow dissolution zone and to provide additional data for modeling the safety assessment modeling scenarios.

10.6.6 Surface Hydrology

Surface hydrology must be examined climatologically with the aid of surface mapping. Records of annual rainfall and intensity and duration of storms (particularly high intensity, 24 hour, 50 and 100 year recurring storms) are available. This information, in conjunction with surface mapping (from aerial photographs, topographic maps, or both) of contributory drainage will provide the basis to estimate amounts of runoff and amounts of infiltration in the study area. Because of the high evapotranspiration and the caliche layer below surficial sands, infiltration estimates are expected to be only a small portion of the calculated recharge.

Photogrammetric and field mapping is planned to locate and describe springs which may issue from the Dewey Lake Redbeds or the shallow dissolution zone. Several springs are suspected to be located west of the site, and discharge measurements could aid in the identification of the formations from which they issue. Geochemical monitoring of many

such springs, including the Malaga Bend seeps and the Pecos River salt load, will add to this overall understanding of hydrologic system dynamics.

10.6.7 Overview of Deep Hydrologic Testing

Three objectives for deep aquifer testing to complement the site-specific shallow aquifer investigations in the WIPP study area are:

(1) To obtain static bottom-hole pressure measurements in the deep aquifer zones, for the refinement of previous estimates of local potentiometric surfaces, hydraulic gradients, and hydraulic conductivities.

(2) To determine the bounds of the formational reservoirs.

(3) To obtain fluid samples for geochemical analyses.

Three wells suitable for hydrologic testing (Badger, Cabin-Baby, Cotton-Baby) are located within the site area. Each well will have to be re-entered and plugged, in accordance with methods now under study, or maintained as monitoring wells. Deep hydrologic data will be developed from these well to obtain site-specific information on the Delaware zones. Testing outside the study area involves two additional wells (AEC No. 8 and ERDA No. 6).

10.6.8 Long-Term Monitoring of Deep Wells

A number of wells could be equipped for long-term monitoring of the Delaware zone to show what changes, if any, are taking place in the hydraulic gradient, which in turn indicate fluid movement in the reservoir. Periodic fluid samples can be obtained to identify increased flow or chemical changes in the ground water system.

10.6.9 Continuing Studies in Salt Dissolution and Overburden Subsidence

Program Objectives. The program of investigation of dissolution and subsidence has four fundamental purposes, and one special-case consideration:

1. To correlate surficial collapse features and deposits with subsurface dissolution, in order to develop criteria for an evolutionary pattern of collapse.

2. To characterize subsurface dissolution products adjacent to the WIPP site.

3. To determine the behaviour of fluids in dissolution products adjacent to the WIPP site.

4. To analyze potential impacts of evolution of dissolution products at and near the WIPP site with respect to repository breachment and radionuclide transport.

The special case is to determine the nature of subsidence over mines in salt, and its effects on the overlying groundwater system.

An elaboration of these purposes follows.

Nash Draw Investigations. Nash Draw is believed to have originated by some combination of surface erosion and subsidence following subsurface dissolution. If the process of formation is overwhelmingly erosion, then the potential for removal of overburden at the WIPP site is probably about the same as it has been in Nash Draw. If, however, the process is overwhelmingly dissolution of salt and subsequent collapse of the overburden, the potential extension of Nash Draw toward the WIPP by dissolution will be more quantitatively described. At present, there is no conclusive way of defining an instantaneous rate of growth of Nash Draw toward the WIPP site; therefore, the only alternative is to

understand the processes which have resulted in Nash Draw, and incorporate their implications into the mathematical modeling efforts directed toward safety assessment involving the WIPP site in general, and radionuclide escape and migration in particular.

First, the Nash Draw program is a series of core holes, which will be geophysically logged. This operation will obtain data to serve three purposes: 1) reveal the subsurface of Nash Draw stratigraphy at carefully chosen points, 2) reveal the relationships between the subsurface structure and surface features and deposits, 3) reveal how much halite and anhydrite (or gypsum) has been removed by dissolution.

Second, the Nash Draw program is a source of geologic material for petrographic and geochemical examination. Examination of thin sections of recovered rock will allow the mineralogy of dissolution products to be determined, i.e. identification of what was dissolved and what remains. Mineralogy and textures of dissolution residues and cemented collapse fill can then be compared with those of dissolution features sampled in other programs, such as the one to investigate the cemented rubble chimneys (often called "karstic domal features" or "breccia pipes"). Geochemical analyses of core materials for trace constituents will reveal their degree of interaction with groundwaters, and possibly an age of formation. Also, permeabilities to fluids can be obtained from cores.

Third, the Nash Draw core holes will become a series of hydrology test holes. The brine flow underlying Nash Draw has been attributed responsibility for much of the dissolution and collapse observed today. The safety assessment scenarios for radionuclide escape and migration involve movement from WIPP into Rustler Formation waters into the shallow dissolution zone and out at Malaga bend on the Pecos River. It behooves us to understand the hydrologic relationships between the shallow dissolution zone and the Rustler water-bearing rocks in Nash Draw in order to verify that models of radionuclide transport are representative of the physical system.

Cemented Rubble Chimney Investigations. One of the "karstic domal features" described by J. D. Vine (called Hill "C") was encountered at the level of the McNutt potash zone by Mississippi Chemical Corporation. It was found to be a chimney in the Salado Formation filled with clay-cemented brecciated rock belonging to strata above the McNutt. Similarly a breccia-filled chimney was encountered in drilling near a circular hill near the Wills-Weaver Mine. There are numerous other erosion-breached domes such as Vine's Hill "C" in the vicinity of Nash Draw; the subsurface expression of them, if any, is virtually unknown. It is desirable that a hole be drilled to a depth at which no more brecciated rock is found. Hydrologic observation (including water sampling and static water-level measurements) in fluid-bearing zones of the structure itself and in "bedrock" and in nearby rocks will help to determine the degree of hydraulic connection of the structure with aquifers of regional extent.

Petrographic analyses of recovered core will allow comparisons to be made with dissolution products recovered from Nash Draw investigations, described previously. Such material also lends itself to geochemical analyses for the determination of rock-water interaction history and age. Similarly, fluid analyses will provide an indication of how the fluids have interacted with their host rocks, helping to determine the processes at work in such structures.

Since modeling of radionuclide escape and migration must take into account fluid movement, cemented rubble chimneys should be evaluated for their potential as paths for such movement. They should also be evaluated as members of the evolutionary pattern of dissolution and collapse features, and might be generically related to the development of Nash Draw. Consequently, it is desirable to measure in situ the permeability of the structure. In addition, the hydrologic relationships between the chimney and surrounding rocks should be understood in order to formulate a complete hydrologic model for risk assessment.

Mine Subsidence Investigations. The potash producers in southeastern New Mexico mine in two stages -- the primary recovery which leaves rooms separated by large pillars, and the secondary recovery in which they may "rob the pillars" and ultimately remove almost 95% of the ore. Second-mining requires abandonment almost immediately thereafter, because there is no longer a large enough local pillar system to hold up the roof. And so, the roof slowly sags, and subsidence is propagated to the surface.

While investigations of subsidence over mines do not bear directly on the four program objectives, mining is certainly a particular cause of subsidence and perhaps an indirect agent for initiating dissolution. If subsidence over a mine causes fracturing of water bearing rocks above, locally increased permeability might allow circulation of groundwater to underlying evaporites through the fractures to start dissolution.

The amount of subsidence and its potential for enhancement of salt dissolution of the Salado Formation over the WIPP if the McNutt potash zone were to be mined is unknown. If this subsidence program were to lead to a satisfactory means to predict subsidence and its effects, in particular dissolutioning, the control zone restrictions currently prescribed around the WIPP could possibly be relaxed. It is possible that minor subsidence will occur over the closed WIPP mine because it will not be possible to backfill the repository to the same packing density as original rock. Therefore, it is desirable to evaluate the effect of mining and subsequent subsidence on the local groundwater system in the subsiding overburden.

10.6.10 Modeling of Regional Hydrology

Hydrologic modeling has one basic objective, to support risk assessment work by describing the movement of fluids in this region in as much detail as possible. The movement of fluids affects the expected period of integrity of the repository and the movement of radionuclides from the repository. To fulfill this objective, the modeling emphasizes several

aspects. The first aspect is interpretation and explication of the data collected in field programs designed to delineate the regional flows. The second is to suggest where data are insufficient and more field or laboratory work is required. The third aspect is the simulation of experiments which cannot be performed in the field. Two examples for simulations are: consequences of perturbations to regional flow patterns caused by the existence of a repository, and consequences of changes in regional flow patterns due to alterations in rainfall patterns or due to man's activities.

The fourth aspect is prediction of the movement and concentrations of radionuclides consistent with fluid movement determined in part by the release scenarios developed for WIPP.

Implementation is based on the modification and use of certain 2-D and 3-D computer codes available for hydrologic modeling. Code verification based on field data already collected is in process. Supporting laboratory programs designed to provide parameters as absorption coefficients, permeabilities, etc., are already underway.

10.7 CONTINUING STUDIES IN GEOCHEMISTRY

10.7.1 Introduction

Detailed accounts of geochemical data reported in Chapter 7 have provided the pressing need of fundamental information for (1) conceptual design of WIPP operational facilities, and (2) formulation of site-specific process scenarios to be used in the consequence safety assessment effort. An evaluation of the available data has shown that the completed studies are not entirely sufficient to support WIPP experimental programs. These programs include borehole plugging, laboratory rock mechanics, in-mine rock mechanics, in-mine heater experiments, in-mine high-level waste emplacement experiments, laboratory waste-rock interaction experiments, radionuclide transport through rocks, and waste encapsulation studies.

In addition, the long-term safety assessment effort has lacked information about geological processes associated with so-called "geological anomalies" such as igneous dikes and cemented rubble chimneys.

10.7.2 Mineralogy and Petrology

The data concerning assemblages of evaporite minerals in the Salado Formation which were presented in Chapter 7 have addressed the types of minerals found and their relative (qualitative) abundances. While this has been useful in selection of candidate horizons for waste emplacement, it has been of limited use to the quantitative measurements of thermal and physical properties of evaporite rocks (see Chapter 9).

It has been found that a small change in the quantitative mineralogical proportions in a rock sample has a large non-linear effect on thermal properties, for example. Chapter 7, together with its executive summary in Chapter 1, has pointed out the variability in the mineralogical composition of rocks in the Permian evaporite section.

In addition, quantitative mineralogy and petrology is required for development of materials to be used in the plugging of shafts and boreholes. The long-term thermodynamic stability of a grout plug, for example, cannot be evaluated without an intimate knowledge of mineral phases in both grout and rock, so that free energy calculations can be made for degradation reactions which might occur between the two. Compatibility of grout with rock and groundwater will be an essential factor requiring thorough evaluation to provide confidence in the long-term sealing of boreholes and shafts which penetrate from surface to repository horizons.

10.7.3 Volatiles Characterization

Chapters 7 and 9 have alluded to the variability in volatile content of evaporites and how the variation affects fundamental rock properties. Chapter 7 has addressed the volatile component in detail mostly in view

of mass loss experienced by heated rock. The entire mass loss cannot be ascribed to water alone. Indeed, Chapter 7 briefly addressed the chemical species which were found in a few selected rock samples, and even so, considerable variation was observed. Experiments are planned to simulate high-level-waste-canister heat in a potash mine, in order to quantize the devolatilization products. Unambiguous interpretations of the experimental results derived therefrom require an understanding of the volatile components native to the rock before heating begins. Furthermore, the interpretations also require an understanding of the fundamental differences between potash ore zones and actual repository zones, since the results of devolatilization in one will certainly not be directly applicable to the other without taking into consideration the native differences.

10.7.4 Origins of Evaporite Assemblages

It was pointed out in Chapter 7 that many of the evaporite mineral assemblages observed in the Permian section cannot have precipitated from a seawater-like solution. Furthermore, the thermodynamic properties of some minerals, such as the almost ubiquitous polyhalite, are virtually unknown. Similarly its mode of origin is entirely unknown, and has been long regarded wholly as a product of recrystallization, commonly replacing anhydrite.

The present assemblages not only contain non-primary evaporite minerals, but also have a magnesium deficiency relative to other evaporites in the world. The sink for this magnesium presumably lost during recrystallization has not been identified. The observations of Chapter 7 urge that a thermodynamic understanding of the environments and processes of evaporite recrystallization be sought. In this way the water loss that the evaporites have experienced (during recrystallization) can be estimated, and confidence can be gained regarding what mineralogical changes (if any) are likely to take place in response to waste emplacement.

The techniques used in deducing the origins of evaporite assemblages include chemical quantitative analyses of minerals, petrographic paragenetic examination, and stable isotope, radioisotope and trace element analyses.

10.7.5 Igneous Dike

In Chapter 4, there was mention of a northeast-trending igneous dike intruding the evaporites on the west side of Nash Draw west of the WIPP study area. The characterization of the dike was based on the Yeso Hills and Kerr-McGee mine occurrences, together with an aeromagnetic survey. In order to come to an understanding of the marginal effects (i.e., dike-salt-fluid interactions), the following pursuits are recommended:

1. Collection and study of additional samples from farther away from the Kerr-McGee dike occurrence.
2. Determination of:
   a. K-Ar ages of the alteration micas in the dikes
   b. Drilling angle holes with coring at appropriate intervals, to sample the dike and the effects of the dike upon the host rock system.

The dike appears to be a natural laboratory experiment involving high-temperature interactions among salts, groundwaters, and "alien" mineralogies such as emplaced waste would also represent.

10.7.6 Trace Elements and Age-Dating

A continued effort is desirable in age-dating and trace element studies, in order to support investigative efforts contemplated for the so-called "geologic anomalies." The activities are, specifically:

1. Chemical and isotopic study of exposed collapse structure in underground workings of Mississippi Chemical Mine.

a. If waters have percolated through this structure in very recent times then this may be reflected in oxygen isotopic study of grain coatings, etc. Rb-Sr studies of clay minerals should give an indication of Rb, Sr and ($^{87}Sr/^{86}Sr$) redistribution relative to clay minerals removed from the collapse structure.

b. Scanning electron microscope/microprobe study of grain boundaries: supplemented by instrumental neutron activation analysis (INAA) for adsorbed elements (alkalies, alkaline earths, rare earth elements).

c. Rare Earth Elements (REE) distribution in all primary and secondary phases most likely to have been affected by solutions.

2. REE (and other key trace element) abundance in major facies of drill core from WIPP site. At present trace element data are very sporadic and obtained by different techniques so that real differences due to analytical precision and accuracy are suspect. Detailed INAA study of various phases from the same stratigraphic horizons over a wide lateral extent are desirable to establish realistic background data for the REE (i.e. because the REE are commonly used as analogues for the transuranics) so that REE data from dike-salt contact zones and elsewhere can be proprly assessed. If the REE distribution is extremely variable then local variations due to solution, recrystallization, contact effects will be difficult to interpret; if the REE show a more or less uniform distribution pattern and abundance then such effects can be closely scrutinized.

3. Dike-evaporite contact effects. Samples from the lamprophyre dike (T = ~ 35 MYBP) which is observed in the underground workings of the Kerr-McGee Mine offers a unique chance to examine the effects of a local, high temperature source in contact with several evaporite phases.

10.7.7 Reef and Back-Reef Waters

There is at present some degree of confusion surrounding the source and discharge of water in the Capitan Reef surrounding the Delaware Basin. Chapter 7 has shown that the greater portion of the water in the Reef cannot have come from direct infiltration into outcrops in the Guadalupe and Glass Mountains, nor from rocks in the Basin. Therefore, the relationships between the Reef and its lagoonal facies (back-reef) stratigraphic equivalents are likely source and sink candidates. These relationships are best deduced by combinations of stable isotope, uranium isotope, and solute analyses of reef and back-reef waters. An extensive water-sampling of these areas is required for this. The results of this geochemical mapping of regional groundwater flow would be used in the long-term safety assessment modelling effort and the final publication of the regional groundwater mathematical model.

10.7.8 Future Work on Fluid Inclusions

In addition to the obvious necessity of making studies on samples from the actual strata to be used for high level waste storage, a variety of approaches need to be explored. Fluid inclusions near the waste canisters might decrepitate in the thermal pulse; the conditions under which this will occur can and should be explored experimentally. (studies are continuing of inclusions in a suite of salt samples collected at various distances from a dike penetrating the salt horizons; this provides a natural analog.) The identification of the daughter minerals in some inclusions, and their thermal behavior, as well as bubble movement in a thermal gradient, will provide additional compositional information. The gases released on crushing or heating should be explored, as well as the leakage of gases (or water) out of inclusions. This would be pertinent both for interpretation of K/Ar ages and in corrosion problems. The actual chemical composition of the larger inclusions and their isotopic composition (particularly H/D and O^{16}/O^{18}) can be determined by existing methods. This would help in

understanding the complex sequence of interactions of pore (and inclusion) fluid with the original salt beds to yield the present mineralogy.

10.8 RESOURCES

Sandia Laboratories has no continuing studies of resources at the WIPP site.

10.9 SPECIAL STUDIES

10.9.1 Purpose. The objective of thermophysical and radionuclide sorption studies on SENM rocks is to determine their characteristics as required by the structural mine design, in situ experimental, and long-term safety analyses programs. As with other continuing studies, these special studies are a means to an end, not an end in themselves.

10.9.2 Thermophysical Properties

Scope. A continuing assessment of the thermophysical properties of SENM rocks is envisioned because of the broad range of questions posed about radioactive waste isolation. These problems range from the plasticity of salt to the migration of brine in salt; many are not answered by a cursory investigation. Establishing a data base, for instance, for the analyses of long-term creep, is time consuming. It is not anticipated that evaluation of physical rock properties will be pivotal in mine, experiment or repository design; however, that is intrinsically impossible to guarantee. Such evaluations may very well be pivotal in considerations of retrievability of high-level waste experiments, in which high temperatures tend to accelerate creep. Thus, physical rock property determinations, such as the micromechanics of rock deformation, are a prudent pursuit to provide additional confidence in geologic isolation.

Continuing Studies. The primary object of the continuing experimental rock mechanics program is to understand and model the thermomechanical behavior of the WIPP salt. This will be accomplished through studies of transient creep data at pressures exceeding 1500 psi and at a principal stress difference less than 2000 psi where there is a paucity of data. In addition, petrographic investigations will continue to identify the governing deformation mechanisms.

Other studies relevant to the long-term stability of the WIPP include measurements of gas and brine permeabilities on previously deformed core and measurements of gas permeabilities at elevated temperatures. Studies are also planned in the area of thermal expansion coefficients and brine migration in salt under thermal gradients. Migration of fluid inclusions is being given attention, because of the brine's corrosive potential and because the capacity of fluid inclusions to carry radionuclides through rock salt is not known.

Rock mechanic programs will also be initiated to determine the mechanical properties of the WIPP site rock other than rock salt. These studies will be directed toward the engineering performance and construction characteristics of the non-salt rock which will influence the design and construction of shafts to the repository levels.

Mineralogic and petrographic studies will be conducted on core to support the physical rock properties determinations as required. This information is required to determine the phase systems in the rocks being investigated. A similar set of studies support the geochemical analyses, Chapter 7. The variations in mineral assemblage, grain size, fluid inclusion content, and petrofabric which have been observed in evaporite rocks have also given rise to variations in physical properties, which could only qualitatively be taken into account in the investigations reported here.

The arbitrary separation of mineralogical and physical rock properties from geology and hydrology that has often occurred in other studies is

being avoided in the comprehensive studies being performed for the WIPP. The relations of rocks found at the proposed repository horizons to those found in an in situ test bed located elsewhere (e.g., nearby potash mine) are being evaluated. Quite possibly, mineralogic and fabric changes may cause discrepancies in results from one site to another.

10.9.3 Radionuclide Sorption Properties

Scope. A continuing assessment of WIPP rocks ability to inhibit the migration of radionuclides away from the repository is envisioned to augment the batch Kd determinations, which were used in preliminary calculations of radionuclide travel time in site-specific escape scenarios. A realistic approach to safety assessment requires data to be generated (mostly in the laboratory) under simulated physiochemical conditions anticipated in subsurface evaporites and related rocks of southeast New Mexico. The laboratory experiments in radionuclide migration would ultimately be evaluated by SENM field experiments involving the emplacement and observation of movement of non-radioactive tracers which are chemically analogous to radionuclides.

Continuing Studies. Whereas previous "Kd" measurements reflect the degree to which radionuclide soprtion on rocks takes place in static, closed systems, scenarios involving the entrainment of radionuclides in moving groundwater imply that a variety of physiochemical conditions will be encountered in the subsurface.

Now that the radionuclides of interest have been identified, different oxidation states of those radionuclides which might give rise to different mobilities in WIPP environments will next be identified. Investigations of effects on sorption of parameters such as pH, radionuclide concentration in solution, and oxidation potential will then proceed with the oxidation states of species of interest. These parameterization experiments will culminate in the simulation of radionuclide migration in flow-through experiments involving actual WIPP rocks and solutions, at the anticipated physiochemical conditions.

Appendix 7.A (Ref. sec. 7.3)

Whole Rock Chemical Analyses, Soluble-Insoluble Fractions, Mineralogy, and Weight Losses upon Heating.

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1044.2 FEET

SOLUBLE = 99.72 %
INSOLUBLE = 0.28 %

COMPONENT	WT %
SO3	0.55
NA	38.56
NA2O	0.0
K	0.03
K2O	0.0
MGO	0.04
CAO	0.43
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	60.40
WEIGHT LOSS ON HEATING	
70	0.10
HI TEMP	0.0
TOTAL	100.39

MAJOR: HAL
MINOR: ANH
TRACE: CARN

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1107.5 FEET

SOLUBLE = 69.47 %
INSOLUBLE = 30.53 %

COMPONENT	WT %
SO3	20.88
NA	20.28
NA2O	6.63
K	0.0
K2O	4.48
MGO	4.57
CAO	1.84
SIO2	8.30
FE2O3	0.27
AL2O3	1.24
CL	30.78
WEIGHT LOSS ON HEATING	
70	0.12
125	0.10
200	0.40
350-400	1.37
TOTAL	101.26

MAJOR: HAL
MINOR: POLY, LANG, KFELD, TALC, QTZ
TRACE: CHLOR, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1171.5 FEET

SOLUBLE = 37.10 %
INSOLUBLE = 62.90 %

COMPONENT	WT %
SO3	39.73
NA	12.56
NA2O	0.88
K	1.91
K2O	0.0
MGO	0.70
CAO	25.13
SIO2	0.63
FE2O3	0.06
AL2O3	0.0
CL	18.87
WEIGHT LOSS ON HEATING	
70	0.14
300-400	0.58
425	0.08
TOTAL	101.27

MAJOR: HAL, ANH
MINOR: POLY
TRACE: SYL, BLOED, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1221.0 FEET

SOLUBLE = 99.51 %
INSOLUBLE = 0.49 %

COMPONENT	WT %
SO3	2.02
NA	38.79
NA2O	0.0
K	0.06
K2O	0.0
MGO	0.10
CAO	0.88
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	58.31
WEIGHT LOSS ON HEATING	
70	0.30
100-200	0.14
375-425	0.07
TOTAL	101.17

MAJOR: HAL
MINOR: ANH
TRACE: POLY, LANG, QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1343.0 FEET

SOLUBLE = 99.74 %
INSOLUBLE = 0.36 %

COMPONENT	WT %
SO3	0.99
NA	38.60
NA2O	0.0
K	0.35
K2O	0.0
MGO	0.15
CAO	0.66
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	59.40
WEIGHT LOSS ON HEATING	
70	0.27
300-350	0.16
TOTAL	100.95

MAJOR: HAL
MINOR: ANH, POLY
TRACE: QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1402.5 FEET

SOLUBLE = 99.97 %
INSOLUBLE = 0.03 %

COMPONENT	WT %
SO3	0.11
NA	39.67
NA2O	0.0
K	0.06
K2O	0.0
MGO	0.06
CAO	0.02
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	59.78
WEIGHT LOSS ON HEATING	
70	0.19
400-500	0.12
TOTAL	100.04

MAJOR: HAL
MINOR:
TRACE: POLY

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1468.5 FEET

SOLUBLE = 93.66 %
INSOLUBLE = 6.34 %

COMPONENT	WT %
SO3	2.88
NA	34.44
NA2O	0.0
K	0.37
K2O	0.07
MGO	1.85
CAO	0.19
SIO2	2.15
FE2O3	0.24
AL2O3	0.07
CL	53.61
WEIGHT LOSS ON HEATING	
70	1.27
100-150	0.36
175	0.10
250	0.07
375	0.34
400-500	0.45
TOTAL	98.46

MAJOR: HAL
MINOR: KAIN, KIES
TRACE: POLY, KFELD, TALC, QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1534.0 FEET

SOLUBLE = 99.86 %
INSOLUBLE = 0.14 %

COMPONENT	WT %
SO3	1.67
NA	36.10
NA2O	0.0
K	0.52
K2O	0.0
MGO	0.22
CAO	0.64
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	57.76
WEIGHT LOSS ON HEATING	
70	0.22
200	0.01
400-500	0.24
TOTAL	97.53

MAJOR: HAL
MINOR: POLY
TRACE: KAIN, QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1615.0 FEET

SOLUBLE = 98.69 %
INSOLUBLE = 1.31 %

COMPONENT	WT %
SO3	4.56
NA	35.06
NA2O	0.0
K	1.05
K2O	0.0
MGO	0.71
CAO	1.47
SIO2	0.23
FE2O3	0.04
AL2O3	0.07
CL	55.95
WEIGHT LOSS ON HEATING	
70	0.34
100	0.09
350-400	0.37
TOTAL	99.94

MAJOR: HAL
MINOR: POLY, KAIN
TRACE: CHLOR, MONT

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1698.0 FEET

SOLUBLE = 95.35 %
INSOLUBLE = 4.65 %

COMPONENT	WT %
SO3	0.58
NA	36.47
NA2O	0.0
K	0.06
K2O	0.07
MGO	1.20
CAO	0.34
SIO2	2.07
FE2O3	0.25
AL2O3	0.61
CL	58.35
WEIGHT LOSS ON HEATING	
70	0.82
350	0.03
TOTAL	100.85

MAJOR: HAL
MINOR: ANH, CARN, KIES
TRACE: POLY, ILL, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1755.0 FEET

SOLUBLE = 99.60 %
INSOLUBLE = 0.40 %

COMPONENT	WT %
SO3	0.65
NA	38.12
NA2O	0.0
K	0.23
K2O	0.0
MGO	0.13
CAO	0.08
SIO2	0.02
FE2O3	0.0
AL2O3	0.0
CL	59.54
WEIGHT LOSS ON HEATING	
70	0.19
200	0.04
300-400	0.05
TOTAL	99.45

MAJOR: HAL
MINOR:
TRACE: LEON, QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1952.5 FEET

SOLUBLE = 99.30 %
INSOLUBLE = 0.70 %

COMPONENT	WT %
SO3	3.18
NA	37.14
NA2O	0.0
K	0.75
K2O	0.03
MGO	0.54
CAO	0.79
SIO2	0.34
FE2O3	0.03
AL2O3	0.05
CL	57.00
WEIGHT LOSS ON HEATING	
70	0.14
350-450	0.44
TOTAL	100.43

MAJOR: HAL
MINOR: POLY
TRACE: LEON, CHLOR, KFELD, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1954.0 FEET

SOLUBLE = 97.46 %
INSOLUBLE = 2.54 %

COMPONENT	WT %
SO3	0.73
NA	37.94
NA2O	0.0
K	0.18
K2O	0.06
MGO	0.56
CAO	0.52
SIO2	1.34
FE2O3	0.09
AL2O3	0.23
CL	58.38
WEIGHT LOSS ON HEATING	
70	0.32
350-400	0.09
TOTAL	100.44

MAJOR: HAL
MINOR: POLY
TRACE: ANH, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1957.5 FEET

SOLUBLE = 99.16 %
INSOLUBLE = 0.84 %

COMPONENT	WT %
SO3	1.72
NA	38.38
NA2O	0.0
K	0.36
K2O	0.01
MGO	0.41
CAO	2.18
SIO2	0.37
FE2O3	0.04
AL2O3	0.11
CL	59.00
WEIGHT LOSS ON HEATING	
70	0.20
300-400	0.12
TOTAL	102.90

MAJOR: HAL
MINOR: ANH
TRACE: POLY, CHLOR, KFELD, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1961.0 FEET

SOLUBLE = 99.10 %
INSOLUBLE = 0.90 %

COMPONENT	WT %
SO3	0.49
NA	39.14
NA2O	0.0
K	0.21
K2O	0.01
MGO	0.25
CAO	0.19
SIO2	0.42
FE2O3	0.04
AL2O3	0.08
CL	58.83
WEIGHT LOSS ON HEATING	
70	0.07
100	0.16
150-200	0.16
TOTAL	100.05

MAJOR: HAL
MINOR: POLY
TRACE: CHLOR, KFELD, TALC, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1967.0 FEET

SOLUBLE = 99.94 %
INSOLUBLE = 0.06 %

COMPONENT	WT %
SO3	3.03
NA	39.58
NA2O	0.0
K	0.90
K2O	0.0
MGO	0.23
CAO	0.94
SIO2	0.0
FE2O3	0.01
AL2O3	0.0
CL	58.74
WEIGHT LOSS ON HEATING	
70	0.20
300-350	0.28
450-500	0.65
TOTAL	104.62

MAJOR: HAL
MINOR: POLY
TRACE: FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1969.0 FEET

SOLUBLE = 98.05 %
INSOLUBLE = 1.95 %

COMPONENT	WT %
SO3	0.32
NA	38.76
NA2O	0.0
K	0.08
K2O	0.0
MGO	0.22
CAO	0.08
SIO2	0.15
FE2O3	0.02
AL2O3	0.04
CL	60.60
WEIGHT LOSS ON HEATING	
70	0.43
100	0.08
400-500	0.20
TOTAL	100.98

MAJOR: HAL
MINOR:
TRACE: ANH, KAIN, CHLOR, TALC, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1973.0 FEET

SOLUBLE = 98.63 %
INSOLUBLE = 1.37 %

COMPONENT	WT %
SO3	0.26
NA	38.46
NA2O	0.0
K	0.06
K2O	0.03
MGO	0.53
CAO	0.07
SIO2	0.66
FE2O3	0.01
AL2O3	0.13
CL	59.58
WEIGHT LOSS ON HEATING	
70	0.19
170	0.07
380	0.02
450+	0.12
TOTAL	100.19

MAJOR: HAL
MINOR: POLY, KIES
TRACE: KAIN, CHLOR, FKELD, TALC, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1975.0 FEET

SOLUBLE = 99.93 %
INSOLUBLE = 0.07 %

COMPONENT	WT %
SO3	0.19
NA	38.93
NA2O	0.0
K	0.06
K2O	0.0
MGO	0.07
CAO	0.09
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	60.38
WEIGHT LOSS ON HEATING	
70	0.17
400-500	0.07
TOTAL	100.03

MAJOR: HAL
MINOR:
TRACE: ANH, KAIN

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1978.5 FEET

SOLUBLE = 91.07 %
INSOLUBLE = 8.93 %

COMPONENT	WT %
SO3	2.82
NA	32.52
NA2O	1.96
K	0.44
K2O	0.13
MGO	2.62
CAO	0.98
SIO2	2.89
FE2O3	0.37
AL2O3	1.06
CL	51.89
WEIGHT LOSS ON HEATING	
70	0.36
200	0.04
300-400	0.17
450-550	1.10
TOTAL	99.35

MAJOR: HAL
MINOR: POLY, CHLOR
TRACE: ANH, LANG, BLOED, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1983.0 FEET

SOLUBLE = 100.00 %
INSOLUBLE = 0.0 %

COMPONENT	WT %
SO3	1.11
NA	36.00
NA2O	0.0
K	0.61
K2O	0.0
MGO	0.40
CAO	0.46
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	59.20
WEIGHT LOSS ON HEATING	
70	0.29
125	0.03
275	0.05
350-400	0.14
TOTAL	98.30

MAJOR: HAL
MINOR: DOLY, KAIN
TRACE: QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1986.5 FEET

SOLUBLE = 99.71 %
INSOLUBLE = 0.29 %

COMPONENT	WT %
SO3	0.17
NA	38.20
NA2O	0.0
K	0.04
K2O	0.0
MGO	0.03
CAO	0.21
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	60.66
WEIGHT LOSS ON HEATING	
70	0.10
TO 500	0.0
TOTAL	99.71

MAJOR: HAL
MINOR: ANH, POLY
TRACE: KAIN, QTZ

TOTAL ANALYSIS

HOLE # 7
DEPTH = 1993.5 FEET

SOLUBLE = 99.55 %
INSOLUBLE = 0.45 %

COMPONENT	WT %
SO3	2.96
NA	38.25
NA2O	0.0
K	1.68
K2O	0.0
MGO	0.79
CAO	2.30
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	53.81
WEIGHT LOSS ON HEATING	
70	0.19
100	0.05
350--400	0.80
TOTAL	101.28

MAJOR: HAL
MINOR: POLY
TRACE:

TOTAL ANALYSIS

HOLE # 7
DEPTH = 2537.0 FEET

SOLUBLE = 91.43 %
INSOLUBLE = 8.57 %

COMPONENT	WT %
SO3	46.62
NA	0.93
NA2O	4.93
K	0.90
K2O	0.0
MGO	13.02
CAO	4.37
SIO2	13.98
FE2O3	1.13
AL2O3	3.26
CL	2.63
WEIGHT LOSS ON HEATING	
70	0.47
100	0.09
TO 500	0.0
HI TEMP	8.68
TOTAL	109.58

MAJOR: ANH
MINOR: HAL, KIES
TRACE: BLOED, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 2703.0 FEET

SOLUBLE = 98.97 %
INSOLUBLE = 1.03 %

COMPONENT	WT %
SO3	1.46
NA	38.36
NA2O	0.0
K	0.02
K2O	0.01
MGO	0.26
CAO	0.79
SIO2	0.25
FE2O3	0.06
AL2O3	0.05
CL	58.89
WEIGHT LOSS ON HEATING	
70	0.24
150	0.03
550	0.12
TOTAL	100.54

MAJOR: HAL
MINOR: ANH
TRACE: POLY, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 7
DEPTH = 2716.3 FEET

SOLUBLE = 99.63 %
INSOLUBLE = 0.37 %

COMPONENT	WT %
SO3	0.44
NA	39.44
NA2O	0.0
K	0.01
K2O	0.0
MGO	0.01
CAO	0.18
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	61.00
WEIGHT LOSS ON HEATING	
70	0.22
350	0.04
TOTAL	101.72

MAJOR: HAL
MINOR: ANH
TRACE: POLY, TALC

TOTAL ANALYSIS

HOLE # 7
DEPTH = 2736.0 FEET

SOLUBLE = 99.67 %
INSOLUBLE = 0.33 %

COMPONENT	WT %
SO3	0.42
NA	39.75
NA2O	0.0
K	0.01
K2O	0.0
MGO	0.06
CAO	0.51
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	59.88
WEIGHT LOSS ON HEATING	
70	0.08
TO 450	0.03
TOTAL	101.08

MAJOR: HAL
MINOR: ANH
TRACE:

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1391.5 FEET

SOLUBLE = 98.99 %
INSOLUBLE = 1.01 %

COMPONENT	WT %
SO3	1.14
NA	39.34
NA2O	0.0
K	0.31
K2O	0.02
MGO	0.27
CAO	0.53
SIO2	0.40
FE2O3	0.27
AL2O3	0.10
CL	58.07
WEIGHT LOSS ON HEATING	
70	0.04
110	0.03
350-400	0.19
TOTAL	100.71

MAJOR: HAL
MINOR: POLY
TRACE: CHLOR, ILL, QTZ, FLUX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1495.3 FEET

SOLUBLE = 99.83 %
INSOLUBLE = 0.17 %

COMPONENT	WT %
SO3	1.12
NA	38.00
NA2O	0.0
K	0.12
K2O	0.0
MGO	0.13
CAO	1.62
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	59.97
WEIGHT LOSS ON HEATING	
70	0.05
200	0.03
TOTAL	101.22

MAJOR: HAL
MINOR:
TRACE: CARN

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1573.0 FEET

SOLUBLE = 97.72 %
INSOLUBLE = 2.28 %

COMPONENT	WT %
SO3	5.11
NA	34.63
NA2O	0.0
K	0.18
K2O	0.02
MGO	1.71
CAO	0.45
SIO2	0.02
FE2O3	0.0
AL2O3	0.01
CL	54.11
WEIGHT LOSS ON HEATING	
70	0.04
100	0.20
160	0.09
350-450	0.85
TOTAL	97.42

MAJOR: HAL
MINOR: (?) POLY, KIES
TRACE: (?) ILL

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1652.0 FEET

SOLUBLE = 48.61 %
INSOLUBLE = 51.39 %

COMPONENT	WT %
SO3	51.04
NA	4.07
NA2O	4.24
K	18.59
K2O	0.99
MGO	4.58
CAO	3.93
SIO2	0.35
FE2O3	0.07
AL2O3	0.04
CL	7.35
WEIGHT LOSS ON HEATING	
70	0.09
300+	4.43
TOTAL	99.77

MAJOR: HAL
MINOR: POLY-(?) SYL, LEON, GLAS
TRACE: ILL, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1705.0 FEET

SOLUBLE = 99.71 %
INSOLUBLE = 0.29 %

COMPONENT	WT %
SO3	1.18
NA	38.79
NA2O	0.0
K	0.35
K2O	0.0
MGO	0.17
CAO	0.44
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	58.64
WEIGHT LOSS ON HEATING	
70	0.15
170	0.02
400-500	0.15
TOTAL	100.19

MAJOR: HAL
MINOR:
TRACE: POLY

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1770.0 FEET

SOLUBLE = 98.79 %
INSOLUBLE = 1.21 %

COMPONENT	WT %
SO3	1.95
NA	35.75
NA2O	0.33
K	0.56
K2O	0.02
MGO	0.55
CAO	1.75
SIO2	0.48
FE2O3	0.0
AL2O3	0.12
CL	57.29
WEIGHT LOSS ON HEATING	
70	0.09
170	0.06
400	0.20
TOTAL	99.15

MAJOR: HAL
MINOR: ANH, KAIN
TRACE: ILL, QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1787.0 FEET

SOLUBLE = 99.43 %
INSOLUBLE = 0.57 %

COMPONENT	WT %
SO3	3.01
NA	37.24
NA2O	0.0
K	0.69
K2O	0.01
MGO	0.54
CAO	0.70
SIO2	0.21
FE2O3	0.03
AL2O3	0.04
CL	58.00
WEIGHT LOSS ON HEATING	
70	0.32
100	0.04
300-400	0.23
TOTAL	101.06

MAJOR: HAL
MINOR: POLY, KAIN
TRACE: CHLOR, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1794.5 FEET

SOLUBLE = 75.34 %
INSOLUBLE = 24.66 %

COMPONENT	WT %
SO3	0.70
NA	29.75
NA2O	1.16
K	0.42
K2O	0.63
MGO	6.65
CAO	0.04
SIO2	7.80
FE2O3	0.46
AL2O3	1.91
CL	45.14
WEIGHT LOSS ON HEATING	
70	0.44
150	0.27
425+	4.70
TOTAL	100.07

MAJOR: HAL
MINOR: CARN, CHLOR, KFELD, TALC, QTZ
TRACE: POLY, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1804.0 FEET

SOLUBLE = 99.74 %
INSOLUBLE = 0.26 %

COMPONENT	WT %
SO3	0.28
NA	39.43
NA2O	0.0
K	0.06
K2O	0.0
MGO	0.04
CAO	0.70
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	59.94
WEIGHT LOSS ON HEATING	
70	0.02
200	0.05
TOTAL	100.79

MAJOR: HAL
MINOR: ANH
TRACE: CARN

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1829.0 FEET

SOLUBLE = 99.03 %
INSOLUBLE = 0.97 %

COMPONENT	WT %
SO3	0.02
NA	39.87
NA2O	0.0
K	0.05
K2O	0.02
MGO	0.29
CAO	0.01
SIO2	0.29
FE2O3	0.04
AL2O3	0.08
CL	58.81
WEIGHT LOSS ON HEATING	
70	0.16
200	0.23
TOTAL	99.87

MAJOR: HAL
MINOR:
TRACE: ANH, CARN, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1838.0 FEET

SOLUBLE = 97.53 %
INSOLUBLE = 2.47 %

COMPONENT	WT %
SO3	0.80
NA	37.58
NA2O	0.0
K	0.26
K2O	0.10
MGO	0.48
CAO	0.05
SIO2	0.13
FE2O3	0.16
AL2O3	0.27
CL	58.38
WEIGHT LOSS ON HEATING	
70	0.39
TO 500	0.0
TOTAL	98.60

MAJOR: HAL
MINOR:
TRACE: POLY, SLY, LEON, CHLOR, KFELD, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1856.7 FEET

SOLUBLE = 99.96 %
INSOLUBLE = 0.04 %

COMPONENT	WT %
SO3	2.70
NA	36.08
NA2O	0.0
K	1.62
K2O	0.0
MGO	0.03
CAO	1.56
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	56.66
WEIGHT LOSS ON HEATING	
70	0.07
350	0.03
TOTAL	98.79

MAJOR: HAL
MINOR: ANH, SYL, POLY
TRACE:

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1875.0 FEET

SOLUBLE = 70.94 %
INSOLUBLE = 29.06 %

COMPONENT	WT %
SO3	0.42
NA	25.64
NA2O	0.0
K	0.31
K2O	2.28
MGO	9.55
CAO	0.63
SIO2	15.30
FE2O3	1.23
AL2O3	3.00
CL	40.92
WEIGHT LOSS ON HEATING	
70	0.22
125-200	0.42
TOTAL	99.92

MAJOR: HAL
MINOR: CARN, KFELD, TALC
TRACE: POLY, CHLOR

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1884.0 FEET

SOLUBLE = 80.58 %
INSOLUBLE = 19.42 %

COMPONENT	WT %
SO3	3.76
NA	27.10
NA2O	0.0
K	6.98
K2O	1.80
MGO	5.09
CAO	1.66
SIO2	9.02
FE2O3	0.60
AL2O3	1.99
CL	44.06
WEIGHT LOSS ON HEATING	
70	0.36
350-400	0.44
TOTAL	102.86

MAJOR: HAL
MINOR: ANH, CARN, KFELD, TALC, FEOX
TRACE: CHLOR

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1890.0 FEET

SOLUBLE = 99.98 %
INSOLUBLE = 0.02 %

COMPONENT	WT %
SO3	0.77
NA	36.78
NA2O	0.0
K	0.10
K2O	0.0
MGO	0.10
CAO	0.95
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	59.33
WEIGHT LOSS ON HEATING	
70	0.05
300-400	0.08
TOTAL	100.18

MAJOR: HAL
MINOR:
TRACE: ANH, CARN

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1894.3 FEET

SOLUBLE = 95.43 %
INSOLUBLE = 4.57 %

COMPONENT	WT %
SO3	0.12
NA	37.90
NA2O	0.0
K	0.06
K2O	0.13
MGO	0.74
CAO	0.03
SIO2	2.43
FE2O3	0.20
AL2O3	0.43
CL	57.78
WEIGHT LOSS ON HEATING	
70	0.30
TO 500	0.0
TOTAL	100.12

MAJOR: HAL
MINOR: QTZ
TRACE: ANH, CARN, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1898.5 FEET

SOLUBLE = 98.53 %
INSOLUBLE = 1.47 %

COMPONENT	WT %
SO3	0.55
NA	38.81
NA2O	0.71
K	0.07
K2O	0.01
MGO	0.26
CAO	0.12
SIO2	0.45
FE2O3	0.02
AL2O3	0.07
CL	57.97
WEIGHT LOSS ON HEATING	
70	0.16
TO 500	0.0
TOTAL	99.20

MAJOR: HAL
MINOR:
TRACE: POLY, BLOED, CHLOR, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1900.0 FEET

SOLUBLE = 99.96 %
INSOLUBLE = 0.04 %

COMPONENT	WT %
SO3	3.20
NA	38.14
NA2O	0.0
K	0.98
K2O	0.0
MGO	0.47
CAO	0.39
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	57.60
WEIGHT LOSS ON HEATING	
70	0.17
300-400	0.64
TOTAL	101.63

MAJOR: HAL
MINOR: LEON
TRACE: POLY

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1905.0 FEET

SOLUBLE = 96.98 %
INSOLUBLE = 3.02 %

COMPONENT	WT %
SO3	0.20
NA	38.67
NA2O	0.0
K	0.13
K2O	0.03
MGO	0.93
CAO	0.45
SIO2	0.91
FE2O3	0.14
AL2O3	0.25
CL	57.91
WEIGHT LOSS ON HEATING	
70	0.36
375	0.26
TOTAL	100.24

MAJOR: HAL
MINOR:
TRACE: POLY, CHLOR, KFELD, TALC

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1910.0 FEET

SOLUBLE = 99.02 %
INSOLUBLE = 0.98 %

COMPONENT	WT %
SO3	0.53
NA	39.64
NA2O	0.0
K	0.0
K2O	0.30
MGO	0.31
CAO	0.44
SIO2	0.34
FE2O3	0.04
AL2O3	0.08
CL	59.04
WEIGHT LOSS ON HEATING	
70	0.06
375	0.04
TOTAL	100.82

MAJOR: HAL
MINOR: POLY
TRACE: ANH, CHLOR, KFELD, TALC, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1913.1 FEET

SOLUBLE = 97.71 %
INSOLUBLE = 2.29 %

COMPONENT	WT %
SO3	0.06
NA	38.48
NA2O	0.0
K	0.06
K2O	0.05
MGO	0.55
CAO	0.01
SIO2	0.91
FE2O3	0.13
AL2O3	0.21
CL	59.27
WEIGHT LOSS ON HEATING	
70	0.11
120	0.03
260	0.03
400+	0.04
TOTAL	99.94

MAJOR: HAL
MINOR:
TRACE: KAIN, CHLOR, KFELD, TALC, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1916.2 FEET

SOLUBLE = 99.85 %
INSOLUBLE = 0.15 %

COMPONENT	WT %
SO3	0.92
NA	38.48
NA2O	0.0
K	0.21
K2O	0.0
MGO	0.13
CAO	0.44
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	57.71
WEIGHT LOSS ON HEATING	
70	0.13
250	0.02
350-400	0.10
TOTAL	98.29

MAJOR: HAL
MINOR: POLY
TRACE: ANH

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1923.0 FEET

SOLUBLE = 98.30 %
INSOLUBLE = 1.70 %

COMPONENT	WT %
SO3	1.06
NA	38.03
NA2O	0.0
K	0.05
K2O	0.08
MGO	0.09
CAO	0.20
SIO2	0.60
FE2O3	0.10
AL2O3	0.16
CL	58.43
WEIGHT LOSS ON HEATING	
70	0.19
300	0.06
450+	0.24
TOTAL	99.29

MAJOR: HAL
MINOR: POLY
TRACE: KAIN, CHLOR, ILL, KFELD, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1930.0 FEET

SOLUBLE = 98.99 %
INSOLUBLE = 1.01 %

COMPONENT	WT %
SO3	2.81
NA	35.71
NA2O	0.08
K	1.03
K2O	0.01
MGO	0.46
CAO	0.20
SIO2	0.18
FE2O3	0.07
AL2O3	0.04
CL	56.74
WEIGHT LOSS ON HEATING	
70	0.05
350-400	0.42
TOTAL	97.80

MAJOR: HAL
MINOR: POLY
TRACE: LEON, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1933.0 FEET

SOLUBLE = 99.62 %
INSOLUBLE = 0.38 %

COMPONENT	WT %
SO3	0.78
NA	38.03
NA2O	0.0
K	0.15
K2O	0.0
MGO	0.09
CAO	0.65
SIO2	0.01
FE2O3	0.01
AL2O3	0.0
CL	59.61
WEIGHT LOSS ON HEATING	
70	0.19
200	0.09
TOTAL	100.19

MAJOR: HAL
MINOR: ANH, POLY, KAIN
TRACE: QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1938.0 FEET

SOLUBLE = 99.86 %
INSOLUBLE = 0.14 %

COMPONENT	WT %
SO3	2.91
NA	35.63
NA2O	0.0
K	0.68
K2O	0.0
MGO	0.84
CAO	1.02
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	59.45
WEIGHT LOSS ON HEATING	
70	0.13
125	0.14
275	0.05
350-400	0.17
TOTAL	101.16

MAJOR: HAL
MINOR: POLY, KAIN
TRACE:

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1953.2 FEET

SOLUBLE = 99.91 %
INSOLUBLE = 0.09 %

COMPONENT	WT %
SO3	2.30
NA	39.50
NA2O	0.0
K	0.30
K2O	0.0
MGO	0.42
CAO	1.23
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	57.63
WEIGHT LOSS ON HEATING	
70	0.05
250	0.05
375	0.03
425	0.29
TOTAL	101.90

MAJOR: HAL
MINOR: ANH, POLY
TRACE: BLOED, TALC

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1967.0 FEET

SOLUBLE = 95.13 %
INSOLUBLE = 4.87 %

COMPONENT	WT %
SO3	1.25
NA	35.99
NA2O	2.73
K	0.57
K2O	0.09
MGO	1.21
CAO	0.41
SIO2	0.76
FE2O3	0.10
AL2O3	0.20
CL	57.52
WEIGHT LOSS ON HEATING	
70	0.28
190	0.04
400-500	0.20
TOTAL	101.35

MAJOR: HAL
MINOR: POLY, KAIN, TALC
TRACE: CHLOR, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 1986.0 FEET

SOLUBLE = 36.72 %
INSOLUBLE = 63.28 %

COMPONENT	WT %
SO3	60.87
NA	0.36
NA2O	5.83
K	0.0
K2O	26.07
MGO	1.83
CAO	5.12
SIO2	0.54
FE2O3	0.17
AL2O3	0.85
CL	0.15
WEIGHT LOSS ON HEATING	
70	0.07
300-400	5.81
TOTAL	107.67

MAJOR: (?) GLAS, ANH, LEON
MINOR:
TRACE: HAL, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2006.0 FEET

SOLUBLE = 99.50 %
INSOLUBLE = 0.50 %

COMPONENT	WT %
SO3	2.37
NA	37.59
NA2O	0.0
K	1.03
K2O	0.0
MGO	0.31
CAO	0.06
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	57.17
WEIGHT LOSS ON HEATING	
70	0.20
350-400	0.29
450	0.13
475	0.04
TOTAL	99.70

MAJOR: HAL
MINOR: KAIN, BLOED
TRACE: POLY, QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2017.0 FEET

SOLUBLE = 95.20 %
INSOLUBLE = 4.80 %

COMPONENT	WT %
SO3	0.62
NA	35.66
NA2O	0.0
K	0.06
K2O	0.04
MGO	0.53
CAO	1.02
SIO2	2.02
FE2O3	0.28
AL2O3	0.70
CL	57.09
WEIGHT LOSS ON HEATING	
70	0.22
100	0.02
300-400	0.17
ORGANIC	1.59
TOTAL	100.02

MAJOR: HAL
MINOR: ANH
TRACE: SYL, CAIN, CHLOR, FEOX, ILL

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2039.0 FEET

SOLUBLE = 98.94 %
INSOLUBLE = 1.06 %

COMPONENT	WT %
SO3	5.50
NA	35.02
NA2O	0.0
K	1.56
K2O	0.03
MGO	0.70
CAO	1.58
SIO2	0.27
FE2O3	0.07
AL2O3	0.05
CL	54.01
WEIGHT LOSS ON HEATING	
70	0.21
100	0.05
300-400	0.49
425	0.27
TOTAL	99.81

MAJOR: HAL
MINOR: POLY, KAIN
TRACE: KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2050.0 FEET

SOLUBLE = 28.61 %
INSOLUBLE = 71.39 %

COMPONENT	WT %
SO3	54.99
NA	8.00
NA2O	4.90
K	0.05
K2O	0.04
MGO	0.31
CAO	7.10
SIO2	0.33
FE2O3	0.0
AL2O3	0.0
CL	12.44
WEIGHT LOSS ON HEATING	
70	0.11
475	0.68
TOTAL	88.95

MAJOR: ANH
MINOR: HAL
TRACE: QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2068.0 FEET

SOLUBLE = 98.84 %
INSOLUBLE = 1.16 %

COMPONENT	WT %
SO3	2.49
NA	37.41
NA2O	0.0
K	0.08
K2O	0.01
MGO	0.31
CAO	0.89
SIO2	0.38
FE2O3	0.05
AL2O3	0.07
CL	55.99
WEIGHT LOSS ON HEATING	
70	0.04
250	0.10
TOTAL	97.82

MAJOR: HAL
MINOR: ANH, TALC, BLOED
TRACE: POLY, CHLOR, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2084.0 FEET

SOLUBLE = 92.00 %
INSOLUBLE = 8.00 %

COMPONENT	WT %
SO3	2.64
NA	34.46
NA2O	1.87
K	1.02
K2O	0.19
MGO	1.48
CAO	0.73
SIO2	2.07
FE2O3	0.25
AL2O3	0.37
CL	52.19
WEIGHT LOSS ON HEATING	
70	0.17
140	0.05
350-400	0.27
450-550	0.22
TOTAL	97.98

MAJOR: HAL
MINOR: CHLOR, TALC, QTZ
TRACE: KFELD, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2130.0 FEET

SOLUBLE = 99.61 %
INSOLUBLE = 0.39 %

COMPONENT	WT %
SO3	2.31
NA	37.79
NA2O	0.0
K	0.42
K2O	0.0
MGO	0.25
CAO	0.75
SIO2	0.03
FE2O3	0.0
AL2O3	0.0
CL	57.16
WEIGHT LOSS ON HEATING	
70	0.11
125	0.07
350-400	0.10
TOTAL	99.38

MAJOR: HAL
MINOR: POLY
TRACE: ANH, QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2162.0 FEET

SOLUBLE = 98.90 %
INSOLUBLE = 1.10 %

COMPONENT	WT %
SO3	1.56
NA	36.77
NA2O	0.55
K	1.23
K2O	0.03
MGO	0.65
CAO	0.93
SIO2	0.23
FE2O3	0.06
AL2O3	0.05
CL	59.99
WEIGHT LOSS ON HEATING	
70	0.14
300-400	0.48
TOTAL	102.67

MAJOR: HAL
MINOR: ANH, POLY, SYL
TRACE: KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2217.0 FEET

SOLUBLE = 99.78 %
INSOLUBLE = 0.22 %

COMPONENT	WT %
SO3	0.0
NA	39.14
NA2O	0.0
K	0.07
K2O	0.0
MGO	0.02
CAO	0.12
SIO2	0.01
FE2O3	0.0
AL2O3	0.0
CL	59.75
WEIGHT LOSS ON HEATING	
70	0.04
300-400	0.40
TOTAL	99.77

MAJOR: HAL
MINOR:
TRACE: ANH, POLY, SLY, QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2280.0 FEET

SOLUBLE = 100.00 %
INSOLUBLE = 0.0 %

COMPONENT	WT %
SO3	0.39
NA	37.91
NA2O	0.0
K	0.12
K2O	0.0
MGO	0.09
CAO	0.25
SIO2	0.02
FE2O3	0.0
AL2O3	0.0
CL	60.23
WEIGHT LOSS ON HEATING	
70	0.19
350	0.08
TOTAL	99.28

MAJOR: HAL
MINOR: ANH, CARN
TRACE: POLY, QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2326.0 FEET

SOLUBLE = 95.44 %
INSOLUBLE = 4.56 %

COMPONENT	WT %
SO3	0.18
NA	37.83
NA2O	0.0
K	0.06
K2O	0.03
MGO	1.39
CAO	0.17
SIO2	1.15
FE2O3	0.12
AL2O3	0.25
CL	57.93
WEIGHT LOSS ON HEATING	
70	0.11
100-150	0.03
450+ MIN	0.56
TOTAL	99.81

MAJOR: HAL
MINOR: TALC
TRACE: HAL, CARN, CHLOR, FLUX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2366.3 FEET

SOLUBLE = 31.37 %
INSOLUBLE = 68.63 %

COMPONENT	WT %
SO3	47.32
NA	0.62
NA2O	3.76
K	0.0
K2O	10.67
MGO	6.40
CAO	3.37
SIO2	10.68
FE2O3	0.01
AL2O3	1.57
CL	1.17
WEIGHT LOSS ON HEATING	
70	0.43
200-375	4.81
375-500	1.60
TOTAL	92.41

MAJOR:
MINOR: KAIN, KFELD, TALC, QTZ
TRACE: HAL, SYL

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2427.5 FEET

SOLUBLE = 99.36 %
INSOLUBLE = 0.64 %

COMPONENT	WT %
SO3	2.58
NA	39.42
NA2O	0.0
K	0.01
K2O	0.01
MGO	0.05
CAO	0.35
SIO2	0.10
FE2O3	0.01
AL2O3	0.01
CL	59.88
WEIGHT LOSS ON HEATING	
70	0.03
300-400	0.40
TOTAL	102.85

MAJOR: HAL
MINOR: ANH
TRACE: POLY, BLOED, KFELD, TALC, QTZ, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2460.0 FEET

SOLUBLE = 99.21 %
INSOLUBLE = 0.79 %

COMPONENT	WT %
SO3	1.14
NA	38.75
NA2O	0.0
K	0.03
K2O	0.01
MGO	0.20
CAO	0.62
SIO2	0.19
FE2O3	0.03
AL2O3	0.06
CL	57.00
WEIGHT LOSS ON HEATING	
70	0.17
125	0.05
350	0.08
450	0.07
TOTAL	98.40

MAJOR: HAL
MINOR: ANH
TRACE: KAIN, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2519.6 FEET

SOLUBLE = 99.36 %
INSOLUBLE = 0.64 %

COMPONENT	WT %
SO3	0.17
NA	40.42
NA2O	0.0
K	0.02
K2O	0.0
MGO	0.01
CAO	0.03
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	60.31
WEIGHT LOSS ON HEATING	
70	0.08
480	0.06
TOTAL	101.74

MAJOR: HAL
MINOR:
TRACE: POLY

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2563.0 FEET

SOLUBLE = 7.11 %
INSOLUBLE = 92.89 %

COMPONENT	WT %
SO3	40.59
NA	1.47
NA2O	6.06
K	0.05
K2O	0.54
MGO	14.73
CAO	24.37
SIO2	6.25
FE2O3	0.96
AL2O3	1.86
CL	1.05
WEIGHT LOSS ON HEATING	
70	1.87
100-150	0.19
175	0.07
450+ MIN	0.11
TOTAL	100.17

MAJOR: ANH
MINOR: CHLOR, KFELD, TALC, FEOX
TRACE: HAL, LANG

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2615.5 FEET

SOLUBLE = 99.74 %
INSOLUBLE = 0.26 %

COMPONENT	WT %
SO3	0.86
NA	38.58
NA2O	0.0
K	0.05
K2O	0.0
MGO	0.02
CAO	0.58
SIO2	0.0
FE2O3	0.01
AL2O3	0.0
CL	59.37
WEIGHT LOSS ON HEATING	
70	0.21
300-350	0.06
TOTAL	100.00

MAJOR: HAL
MINOR: ANH
TRACE: POLY, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2665.5 FEET

SOLUBLE = 99.08 %
INSOLUBLE = 0.92 %

COMPONENT	WT %
SO3	0.98
NA	36.68
NA2O	0.0
K	0.02
K2O	0.01
MGO	0.22
CAO	0.35
SIO2	0.23
FE2O3	0.04
AL2O3	0.06
CL	59.14
WEIGHT LOSS ON HEATING	
70	0.25
400-500	0.48
TOTAL	100.46

MAJOR: HAL
MINOR: ANH, CHLOR
TRACE: POLY, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2706.0 FEET

SOLUBLE = 98.75 %
INSOLUBLE = 1.25 %

COMPONENT	WT %
SO3	1.13
NA	37.09
NA2O	0.64
K	0.03
K2O	0.03
MGO	0.19
CAO	0.68
SIO2	0.27
FE2O3	0.27
AL2O3	0.07
CL	58.60
WEIGHT LOSS ON HEATING	
70	0.16
300	0.05
380	0.75
400+	0.70
TOTAL	100.66

MAJOR: HAL
MINOR: ANH
TRACE: POLY, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2758.0 FEET

SOLUBLE = 99.22 %
INSOLUBLE = 0.78 %

COMPONENT	WT %
SO3	1.70
NA	37.20
NA2O	0.83
K	0.08
K2O	0.01
MGO	0.18
CAO	1.14
SIO2	0.06
FE2O3	0.01
AL2O3	0.02
CL	58.07
WEIGHT LOSS ON HEATING	
70	0.11
250	0.05
TOTAL	99.46

MAJOR: HAL
MINOR: ANH
TRACE: POLY, CHLOR, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2779.0 FEET

SOLUBLE = 99.62 %
INSOLUBLE = 0.38 %

COMPONENT	WT %
SO3	1.09
NA	37.41
NA2O	0.0
K	0.01
K2O	0.0
MGO	0.03
CAO	1.80
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	58.53
WEIGHT LOSS ON HEATING	
70	0.21
HI TEMP	0.0
TOTAL	99.46

MAJOR: HAL
MINOR: CARN, ANH
TRACE:

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2794.0 FEET

SOLUBLE = 99.79 %
INSOLUBLE = 0.21 %

COMPONENT	WT %
SO3	0.99
NA	37.86
NA2O	0.0
K	0.02
K2O	0.0
MGO	0.01
CAO	0.68
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	60.58
WEIGHT LOSS ON HEATING	
70	0.18
HI TEMP	0.0
TOTAL	100.53

MAJOR: HAL
MINOR: ANH
TRACE: POLY

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2802.5 FEET

SOLUBLE = 99.55 %
INSOLUBLE = 0.45 %

COMPONENT	WT %
SO3	1.76
NA	38.39
NA2O	0.0
K	0.02
K2O	0.0
MGO	0.01
CAO	0.22
SIO2	0.0
FE2O3	0.0
AL2O3	0.0
CL	58.19
WEIGHT LOSS ON HEATING	
70	0.10
170	0.02
375	0.02
TOTAL	99.18

MAJOR: HAL
MINOR: ANH
TRACE: BLOED, POLY

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2809.0 FEET

SOLUBLE = 99.09 %
INSOLUBLE = 0.91 %

COMPONENT	WT %
SO3	2.02
NA	38.56
NA2O	0.0
K	0.01
K2O	0.01
MGO	0.04
CAO	1.09
SIO2	0.04
FE2O3	0.0
AL2O3	0.01
CL	59.70
WEIGHT LOSS ON HEATING	
70	0.15
150-200	0.09
400	0.24
TOTAL	101.96

MAJOR: HAL
MINOR: ANH
TRACE: POLY, BLOED, POLY, KFELD, QTZ

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2820.5 FEET

SOLUBLE = 99.46 %
INSOLUBLE = 0.54 %

COMPONENT	WT %
SO3	1.67
NA	38.42
NA2O	0.0
K	0.01
K2O	0.0
MGO	0.03
CAO	0.29
SIO2	0.06
FE2O3	0.0
AL2O3	0.0
CL	58.50
WEIGHT LOSS ON HEATING	
70	0.18
400+	0.18
TOTAL	99.34

MAJOR: HAL
MINOR: THEN, ANH
TRACE: POLY, TALC

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2879.0 FEET

SOLUBLE = 96.41 %
INSOLUBLE = 3.59 %

COMPONENT	WT %
SO3	4.15
NA	32.65
NA2O	0.93
K	0.02
K2O	0.01
MGO	0.13
CAO	1.54
SIO2	0.13
FE2O3	0.01
AL2O3	0.01
CL	55.79
WEIGHT LOSS ON HEATING	
TO	0.06
TO 500	0.0
500+	3.31
TOTAL	98.74

MAJOR: HAL
MINOR: GLAUB, ANH
TRACE: POLY, KFELD, TALC, FEOX

TOTAL ANALYSIS

HOLE # 8
DEPTH = 2948.0 FEET

SOLUBLE = 97.32 %
INSOLUBLE = 2.68 %

COMPONENT	WT %
SO3	5.34
NA	37.30
NA2O	0.0
K	0.01
K2O	0.01
MGO	0.03
CAO	0.79
SIO2	0.06
FE2O3	0.01
AL2O3	0.0
CL	55.51
WEIGHT LOSS ON HEATING	
70	0.20
150	0.02
450	0.02
500	0.02
TOTAL	99.32

MAJOR: HAL
MINOR: GLAUB, ANH
TRACE: LANG, TALC, QTZ, FEOX

Appendix 7.B (Ref. sec. 7.3)

Whole Rock Chemical Analyses in Soluble and Insoluble Fractions & Moles times 1000

HOLE # 7
DEPTH = 1044.2 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.55	6.87
NA	38.56	1677.25
NA2O	0.0	0.0
K	0.03	0.77
K2O	0.0	0.0
MGO	0.04	0.99
CAO	0.43	7.67
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.40	1703.61

HOLE # 7
DEPTH = 1107.5 FEET

SOLUBLE
69.47 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	9.24	115.41
NA	20.28	882.12
NA2O	0.0	0.0
K	0.0	0.0
K2O	3.70	39.28
MGO	2.24	55.57
CAO	1.61	28.71
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.01	0.10
CL	30.78	868.26
SUBTOTAL	67.86 %	
MEASURED =	69.47	

HOLE # 7
DEPTH = 1107.5 FEET

INSOLUBLE
30.53 WT % OF TOTAL

WT %	MOLES
11.63	145.27
0.0	0.0
6.63	106.97
0.0	0.0
0.77	8.17
2.33	57.80
0.23	4.10
8.30	138.13
0.27	1.69
1.24	12.16
0.0	0.0
31.40 %	
30.53	

HOLE # 7
DEPTH = 1171.5 FEET

SOLUBLE
37.10 WT % OF TOTAL

HOLE # 7
DEPTH = 1171.5 FEET

INSOLUBLE
62.90 WT % OF TOTAL

COMPONENT	WT %	MOLES	WT %	MOLES
SO3	1.92	23.98	37.81	472.27
NA	12.56	546.32	0.0	0.0
NA2O	0.0	0.0	0.88	14.20
K	1.91	48.85	0.0	0.0
K2O	0.0	0.0	0.0	0.0
MGO	0.47	11.66	0.23	5.71
CAO	1.65	29.42	23.48	418.69
SIO2	0.01	0.17	0.62	10.32
FE2O3	0.0	0.0	0.06	0.38
AL2O3	0.0	0.0	0.0	0.0
CL	18.87	532.30	0.0	0.0
SUBTOTAL	37.39 %		63.08 %	
MEASURED =	37.10		62.90	

HOLE # 7
DEPTH = 1221.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	2.02	25.23
NA	38.79	1687.26
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.10	2.48
CAO	0.88	15.69
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.31	1644.85

HOLE # 7
DEPTH = 1343.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.99	12.37
NA	38.60	1678.99
NA2O	0.0	0.0
K	0.35	8.95
K2O	0.0	0.0
MGO	0.15	3.72
CAO	0.66	11.77
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.40	1675.60

HOLE # 7
DEPTH = 1402.5 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.11	1.37
NA	39.67	1725.53
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.06	1.49
CAO	0.02	0.36
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.78	1686.32

HOLE # 7
DEPTH = 1468.5 FEET

SOLUBLE
93.66 WT % OF TOTAL

HOLE # 7
DEPTH = 1468.5 FEET

INSOLUBLE
6.34 WT % OF TOTAL

COMPONENT	WT %	MOLES	WT %	MOLES
SO3	0.98	12.24	1.89	23.61
NA	34.44	1498.04	0.0	0.0
NA2O	0.0	0.0	0.0	0.0
K	0.37	9.46	0.0	0.0
K2O	0.0	0.0	0.07	0.74
MGO	0.52	12.90	1.32	32.75
CAO	0.18	3.21	0.01	0.18
SIO2	0.03	0.50	2.12	35.28
FE2O3	0.0	0.0	0.24	1.50
AL2O3	0.0	0.0	0.07	0.69
CL	53.61	1512.27	0.0	0.0
SUBTOTAL	90.13 %		5.72 %	
MEASURED =	93.66		6.34	

HOLE # 7
DEPTH = 1534.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	1.67	20.86
NA	36.10	1570.25
NA2O	0.0	0.0
K	0.52	13.30
K2O	0.0	0.0
MGO	0.22	5.46
CAO	0.64	11.41
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.76	1629.34

HOLE # 7
DEPTH = 1615.0 FEET

SOLUBLE
98.69 WT % OF TOTAL

HOLE # 7
DEPTH = 1615.0 FEET

INSOLUBLE
1.31 WT % OF TOTAL

COMPONENT	WT %	MOLES	WT %	MOLES
SO3	3.58	44.72	0.98	12.24
NA	35.06	1525.01	0.0	0.0
NA2O	0.0	0.0	0.0	0.0
K	1.05	26.85	0.0	0.0
K2O	0.0	0.0	0.0	0.0
MGO	0.69	17.12	0.02	0.50
CAO	1.39	24.79	0.08	1.43
SIO2	0.03	0.50	0.21	3.49
FE2O3	0.0	0.0	0.03	0.19
AL2O3	0.0	0.0	0.07	0.69
CL	55.95	1578.28	0.0	0.0
SUBTOTAL	97.75 %		1.39 %	
MEASURED =	98.69		1.31	

	HOLE # 7 DEPTH = 1698.0 FEET SOLUBLE 95.35 WT % OF TOTAL		HOLE # 7 DEPTH = 1698.0 FEET INSOLUBLE 4.65 WT % OF TOTAL	
COMPONENT	WT %	MOLES	WT %	MOLES
SO3	0.58	7.24	0.0	0.0
NA	36.47	1586.34	0.0	0.0
NA2O	0.0	0.0	0.0	0.0
K	0.06	1.53	0.0	0.0
K2O	0.0	0.0	0.07	0.74
MGO	0.28	6.95	0.92	22.82
CAO	0.33	5.88	0.01	0.18
SIO2	0.04	0.67	2.03	33.78
FE2O3	0.0	0.0	0.25	1.57
AL2O3	0.0	0.0	0.61	5.98
CL	58.35	1645.98	0.0	0.0
SUBTOTAL	96.11 %		3.89 %	
MEASURED =	95.35		4.65	

HOLE # 7
DEPTH = 1755.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.65	8.12
NA	38.12	1658.11
NA2O	0.0	0.0
K	0.23	5.88
K2O	0.0	0.0
MGO	0.13	3.23
CAO	0.08	1.43
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.54	1679.55

HOLE # 7
DEPTH = 1952.5 FEET

SOLUBLE
99.30 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	3.03	37.85
NA	37.14	1615.49
NA2O	0.0	0.0
K	0.75	19.18
K2O	0.0	0.0
MGO	0.42	10.42
CAO	0.78	13.91
SIO2	0.01	0.17
FE2O3	0.01	0.06
AL2O3	0.0	0.0
CL	57.00	1607.90
SUBTOTAL	99.14 %	
MEASURED =	99.30	

HOLE # 7
DEPTH = 1952.5 FEET

INSOLUBLE
0.70 WT % OF TOTAL

WT %	MOLES
0.15	1.87
0.0	0.0
0.0	0.0
0.0	0.0
0.03	0.32
0.12	2.98
0.01	0.18
0.33	5.49
0.02	0.13
0.05	0.49
0.0	0.0
0.71 %	
0.70	

HOLE # 7
DEPTH = 1954.0 FEET

SOLUBLE
97.46 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.73	9.12
NA	37.94	1650.28
NA2O	0.0	0.0
K	0.18	4.60
K2O	0.0	0.0
MGO	0.17	4.22
CAO	0.51	9.09
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.38	1646.83
SUBTOTAL	97.93 %	
MEASURED =	97.46	

HOLE # 7
DEPTH = 1954.0 FEET

INSOLUBLE
2.54 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.06	0.64
0.39	9.68
0.01	0.18
1.33	22.13
0.09	0.56
0.23	2.26
0.0	0.0
2.11 %	
2.54	

HOLE # 7
DEPTH = 1957.5 FEET

SOLUBLE
99.16 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.32	16.49
NA	38.38	1669.42
NA2O	0.0	0.0
K	0.36	9.21
K2O	0.0	0.0
MGO	0.24	5.95
CAO	2.18	38.87
SIO2	0.03	0.50
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.00	1664.32
SUBTOTAL	101.51 %	
MEASURED =	99.16	

HOLE # 7
DEPTH = 1957.5 FEET

INSOLUBLE
0.84 WT % OF TOTAL

WT %	MOLES
0.41	5.12
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.17	4.22
0.0	0.0
0.35	5.82
0.04	0.25
0.10	0.98
0.0	0.0
1.08 %	
0.84	

HOLE # 7
DEPTH = 1961.0 FEET

SOLUBLE
99.10 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.49	6.12
NA	39.14	1702.48
NA2O	0.0	0.0
K	0.21	5.37
K2O	0.01	0.11
MGO	0.07	1.74
CAO	0.19	3.39
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.83	1659.52
SUBTOTAL	98.95 %	
MEASURED =	99.10	

HOLE # 7
DEPTH = 1961.0 FEET

INSOLUBLE
0.90 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.18	4.47
0.0	0.0
0.42	6.99
0.04	0.25
0.08	0.78
0.0	0.0
0.73 %	
0.90	

HOLE # 7
DEPTH = 1967.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	3.03	37.85
NA	39.58	1721.62
NA2O	0.0	0.0
K	0.90	23.02
K2O	0.0	0.0
MGO	0.23	5.71
CAO	0.94	16.76
SIO2	0.0	0.0
FE2O3	0.01	0.06
AL2O3	0.0	0.0
CL	58.74	1656.98

HOLE # 7
DEPTH = 1969.0 FEET

SOLUBLE
98.05 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.32	4.00
NA	38.76	1685.95
NA2O	0.0	0.0
K	0.08	2.05
K2O	0.0	0.0
MGO	0.11	2.73
CAO	0.08	1.43
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.60	1709.45
SUBTOTAL	99.96 %	
MEASURED =	98.05	

HOLE # 7
DEPTH = 1969.0 FEET

INSOLUBLE
1.95 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.11	2.73
0.0	0.0
0.14	2.33
0.02	0.13
0.04	0.39
0.0	0.0
0.31 %	
1.95	

HOLE # 7
DEPTH = 1973.0 FEET

SOLUBLE
98.63 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.26	3.25
NA	38.46	1672.90
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.13	3.23
CAO	0.06	1.07
SIO2	0.03	0.50
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.58	1680.68
SUBTOTAL	98.58 %	
MEASURED =	98.63	

HOLE # 7
DEPTH = 1973.0 FEET

INSOLUBLE
1.37 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.03	0.32
0.40	9.92
0.01	0.18
0.62	10.32
0.01	0.06
0.13	1.28
0.0	0.0
1.20 %	
1.37	

HOLE # 7
DEPTH = 1975.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.19	2.37
NA	38.93	1693.35
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.07	1.74
CAO	0.09	1.60
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.38	1703.24

HOLE # 7
DEPTH = 1978.5 FEET

SOLUBLE
91.07 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.74	34.22
NA	32.52	1414.53
NA2O	0.0	0.0
K	0.44	11.25
K2O	0.0	0.0
MGO	0.37	9.18
CAO	0.96	17.12
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	51.89	1463.75
SUBTOTAL	88.92 %	
MEASURED =	91.07	

HOLE # 7
DEPTH = 1978.5 FEET

INSOLUBLE
8.93 WT % OF TOTAL

WT %	MOLES
0.08	1.00
0.0	0.0
1.96	31.62
0.0	0.0
0.13	1.38
2.25	55.82
0.02	0.36
2.89	48.09
0.37	2.32
1.06	10.40
0.0	0.0
8.76 %	
8.93	

HOLE # 7
DEPTH = 1983.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	1.11	13.86
NA	36.00	1565.90
NA2O	0.0	0.0
K	0.61	15.60
K2O	0.0	0.0
MGO	0.40	9.92
CAO	0.46	8.20
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.20	1669.96

HOLE # 7
DEPTH = 1986.5 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.17	2.12
NA	38.20	1661.59
NA2O	0.0	0.0
K	0.04	1.02
K2O	0.0	0.0
MGO	0.03	0.74
CAO	0.21	3.74
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.66	1711.14

HOLE # 7
DEPTH = 1993.5 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	2.96	36.97
NA	38.25	1663.77
NA2O	0.0	0.0
K	1.68	42.97
K2O	0.0	0.0
MGO	0.79	19.60
CAO	2.30	41.01
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	53.81	1517.91

HOLE # 7
DEPTH = 2537.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	46.62	582.31
NA	0.93	40.45
NA2O	4.93	79.54
K	0.90	23.02
K2O	0.0	0.0
MGO	13.02	323.00
CAO	4.37	77.92
SIO2	13.98	232.65
FE2O3	1.13	7.08
AL2O3	3.26	31.97
CL	2.63	74.19

HOLE # 7
DEPTH = 2703.0 FEET

SOLUBLE
98.97 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.73	9.12
NA	38.36	1668.55
NA2O	0.0	0.0
K	0.02	0.51
K2O	0.0	0.0
MGO	0.06	1.49
CAO	0.78	13.91
SIO2	0.04	0.67
FE2O3	0.01	0.06
AL2O3	0.0	0.0
CL	58.89	1661.21
SUBTOTAL	98.89 %	
MEASURED =	98.97	

HOLE # 7
DEPTH = 2703.0 FEET

INSOLUBLE
1.03 WT % OF TOTAL

WT %	MOLES
0.74	9.24
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.20	4.96
0.01	0.18
0.21	3.49
0.05	0.31
0.05	0.49
0.0	0.0
1.27 %	
1.03	

HOLE # 7
DEPTH = 2716.3 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.44	5.50
NA	39.44	1715.53
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.18	3.21
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	61.00	1720.73

HOLE # 7
DEPTH = 2736.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.42	5.25
NA	39.75	1729.01
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.06	1.49
CAO	0.51	9.09
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.88	1689.14

HOLE # 8
DEPTH = 1391.5 FEET

SOLUBLE
98.99 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.07	13.36
NA	39.34	1711.18
NA2O	0.0	0.0
K	0.31	7.93
K2O	0.0	0.0
MGO	0.21	5.21
CAO	0.52	9.27
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.07	1638.08
SUBTOTAL	99.52 %	
MEASURED =	98.99	

HOLE # 8
DEPTH = 1391.5 FEET

INSOLUBLE
1.01 WT % OF TOTAL

WT %	MOLES
0.07	0.87
0.0	0.0
0.0	0.0
0.0	0.0
0.02	0.21
0.06	1.49
0.01	0.18
0.39	6.49
0.27	1.69
0.10	0.98
0.0	0.0
0.92 %	
1.01	

HOLE # 8
DEPTH = 1495.3 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	1.12	13.99
NA	38.00	1652.89
NA2O	0.0	0.0
K	0.12	3.07
K2O	0.0	0.0
MGO	0.13	3.23
CAO	1.62	28.89
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.97	1691.68

HOLE # 8
DEPTH = 1573.0 FEET

SOLUBLE
97.72 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	3.40	42.47
NA	34.63	1506.31
NA2O	0.0	0.0
K	0.18	4.60
K2O	0.0	0.0
MGO	1.65	40.93
CAO	0.29	5.17
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	54.11	1526.38
SUBTOTAL	94.26 %	
MEASURED =	97.72	

HOLE # 8
DEPTH = 1573.0 FEET

INSOLUBLE
2.28 WT % OF TOTAL

WT %	MOLES
1.71	21.36
0.0	0.0
0.0	0.0
0.0	0.0
0.02	0.21
0.06	1.49
0.16	2.85
0.02	0.33
0.0	0.0
0.01	0.10
0.0	0.0
1.98 %	
2.28	

HOLE # 8
DEPTH = 1652.0 FEET

SOLUBLE
48.61 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	19.80	247.31
NA	4.07	177.03
NA2O	0.0	0.0
K	18.59	475.45
K2O	0.0	0.0
MGO	4.12	102.21
CAO	0.19	3.39
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	7.35	207.33
SUBTOTAL	54.12 %	
MEASURED =	48.61	

HOLE # 8
DEPTH = 1652.0 FEET

INSOLUBLE
51.39 WT % OF TOTAL

WT %	MOLES
31.24	390.21
0.0	0.0
4.24	68.41
0.0	0.0
0.99	10.51
0.46	11.41
3.74	66.69
0.34	5.66
0.07	0.44
0.04	0.39
0.0	0.0
41.12 %	
51.39	

HOLE # 8
DEPTH = 1705.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	1.18	14.74
NA	38.79	1687.26
NA2O	0.0	0.0
K	0.35	8.95
K2O	0.0	0.0
MGO	0.17	4.22
CAO	0.44	7.85
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.64	1654.16

HOLE # 8
DEPTH = 1770.0 FEET

SOLUBLE
98.79 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.78	22.23
NA	35.75	1555.02
NA2O	0.0	0.0
K	0.56	14.32
K2O	0.0	0.0
MGO	0.52	12.90
CAO	1.75	31.21
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.29	1616.08
SUBTOTAL	97.66 %	
MEASURED =	98.79	

HOLE # 8
DEPTH = 1770.0 FEET

INSOLUBLE
1.21 WT % OF TOTAL

WT %	MOLES
0.17	2.12
0.0	0.0
0.33	5.32
0.0	0.0
0.02	0.21
0.03	0.74
0.0	0.0
0.47	7.82
0.0	0.0
0.12	1.18
0.0	0.0
1.14 %	
1.21	

HOLE # 8
DEPTH = 1787.0 FEET

SOLUBLE
99.43 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	3.01	37.60
NA	37.24	1619.84
NA2O	0.0	0.0
K	0.69	17.65
K2O	0.0	0.0
MGO	0.40	9.92
CAO	0.70	12.48
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.00	1636.11
SUBTOTAL	100.05 %	
MEASURED =	99.43	

HOLE # 8
DEPTH = 1787.0 FEET

INSOLUBLE
0.57 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.14	3.47
0.0	0.0
0.21	3.49
0.03	0.19
0.04	0.39
0.0	0.0
0.43 %	
0.57	

HOLE # 8
DEPTH = 1794.5 FEET

SOLUBLE
75.34 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.70	8.74
NA	29.75	1294.04
NA2O	0.0	0.0
K	0.42	10.74
K2O	0.0	0.0
MGO	0.44	10.92
CAO	0.03	0.53
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	45.14	1273.34
SUBTOTAL	76.50 %	
MEASURED =	75.34	

HOLE # 8
DEPTH = 1794.5 FEET

INSOLUBLE
24.66 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
1.16	18.72
0.0	0.0
0.63	6.69
6.20	153.81
0.01	0.18
7.78	129.47
0.46	2.88
1.91	18.73
0.0	0.0
18.15 %	
24.66	

HOLE # 8
DEPTH = 1804.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.28	3.50
NA	39.43	1715.09
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.04	0.99
CAO	0.70	12.48
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.94	1690.83

HOLE # 8
DEPTH = 1829.0 FEET

SOLUBLE
99.03 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.02	0.25
NA	39.87	1734.23
NA2O	0.0	0.0
K	0.05	1.28
K2O	0.0	0.0
MGO	0.06	1.49
CAO	0.01	0.18
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.81	1658.96
SUBTOTAL	98.83 %	
MEASURED =	99.03	

HOLE # 8
DEPTH = 1829.0 FEET

INSOLUBLE
0.97 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.02	0.21
0.23	5.71
0.01	0.18
0.29	4.83
0.04	0.25
0.08	0.78
0.0	0.0
0.67 %	
0.97	

HOLE # 8
DEPTH = 1856.7 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	2.70	33.72
NA	36.08	1569.38
NA2O	0.0	0.0
K	1.62	41.43
K2O	0.0	0.0
MGO	0.03	0.74
CAO	1.56	27.82
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	56.66	1598.31

HOLE # 8
DEPTH = 1838.0 FEET

SOLUBLE
97.53 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.80	9.99
NA	37.58	1634.62
NA2O	0.0	0.0
K	0.26	6.65
K2O	0.0	0.0
MGO	0.11	2.73
CAO	0.05	0.89
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.38	1646.83
SUBTOTAL	97.19 %	
MEASURED =	97.53	

HOLE # 8
DEPTH = 1838.0 FEET

INSOLUBLE
2.47 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.10	1.06
0.37	9.18
0.0	0.0
0.12	2.00
0.16	1.00
0.27	2.65
0.0	0.0
1.02 %	
2.47	

HOLE # 8
DEPTH = 1884.0 FEET

SOLUBLE
80.58 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	3.76	46.96
NA	27.10	1178.77
NA2O	0.0	0.0
K	6.98	178.52
K2O	0.0	0.0
MGO	1.44	35.72
CAO	1.65	29.42
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	44.06	1242.88
SUBTOTAL	85.00 %	
MEASURED =	80.58	

HOLE # 8
DEPTH = 1884.0 FEET

INSOLUBLE
19.42 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
1.80	19.11
3.65	90.55
0.01	0.18
9.01	149.94
0.60	3.76
1.99	19.52
0.0	0.0
17.06 %	
19.42	

HOLE # 8
DEPTH = 1875.0 FEET

SOLUBLE
70.94 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.42	5.25
NA	25.64	1115.27
NA2O	0.0	0.0
K	0.31	7.93
K2O	0.0	0.0
MGO	0.33	8.19
CAO	0.43	7.67
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	40.92	1154.30
SUBTOTAL	68.06 %	
MEASURED =	70.94	

HOLE # 8
DEPTH = 1875.0 FEET

INSOLUBLE
29.06 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
2.28	24.20
9.22	228.73
0.20	3.57
15.29	254.45
1.23	7.70
3.00	29.42
0.0	0.0
31.22 %	
29.06	

HOLE # 8
DEPTH = 1890.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.77	9.62
NA	38.78	1686.82
NA2O	0.0	0.0
K	0.10	2.56
K2O	0.0	0.0
MGO	0.10	2.48
CAO	0.95	16.94
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.33	1673.62

HOLE # 8
DEPTH = 1894.3 FEET

SOLUBLE
95.43 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.12	1.50
NA	37.90	1648.54
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.08	1.98
CAO	0.03	0.53
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.78	1629.90
SUBTOTAL	95.97 %	
MEASURED =	95.43	

HOLE # 8
DEPTH = 1894.3 FEET

INSOLUBLE
4.57 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.13	1.38
0.66	16.37
0.0	0.0
2.43	40.44
0.20	1.25
0.43	4.22
0.0	0.0
3.85 %	
4.57	

HOLE # 8
DEPTH = 1898.5 FEET

SOLUBLE
98.53 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.55	6.87
NA	38.81	1688.13
NA2O	0.0	0.0
K	0.07	1.79
K2O	0.0	0.0
MGO	0.08	1.98
CAO	0.11	1.96
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.97	1635.26
SUBTOTAL	97.60 %	
MEASURED =	98.53	

HOLE # 8
DEPTH = 1898.5 FEET

INSOLUBLE
1.47 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.71	11.46
0.0	0.0
0.01	0.11
0.18	4.47
0.01	0.18
0.44	7.32
0.02	0.13
0.07	0.69
0.0	0.0
1.44 %	
1.47	

HOLE # 8
DEPTH = 1900.0 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	3.20	39.97
NA	38.14	1658.98
NA2O	0.0	0.0
K	0.98	25.06
K2O	0.0	0.0
MGO	0.47	11.66
CAO	0.39	6.95
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.60	1624.82

HOLE # 8
DEPTH = 1905.0 FEET

SOLUBLE
96.98 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.20	2.50
NA	38.67	1682.04
NA2O	0.0	0.0
K	0.13	3.32
K2O	0.0	0.0
MGO	0.10	2.48
CAO	0.44	7.85
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.91	1633.57
SUBTOTAL	97.45 %	
MEASURED =	96.98	

HOLE # 8
DEPTH = 1905.0 FEET

INSOLUBLE
3.02 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.03	0.32
0.83	20.59
0.01	0.18
0.91	15.14
0.14	0.88
0.25	2.45
0.0	0.0
2.17 %	
3.02	

HOLE # 8
DEPTH = 1910.0 FEET

SOLUBLE
99.02 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.53	6.62
NA	39.64	1724.23
NA2O	0.0	0.0
K	0.0	0.0
K2O	0.29	3.08
MGO	0.10	2.48
CAO	0.44	7.85
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.04	1665.44
SUBTOTAL	100.05 %	
MEASURED =	99.02	

HOLE # 8
DEPTH = 1910.0 FEET

INSOLUBLE
0.98 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.20	4.96
0.0	0.0
0.33	5.49
0.04	0.25
0.08	0.78
0.0	0.0
0.66 %	
0.98	

HOLE # 8
DEPTH = 1913.1 FEET

SOLUBLE
97.71 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.06	0.75
NA	38.48	1673.77
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.06	1.49
CAO	0.0	0.0
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.27	1671.93
SUBTOTAL	97.94 %	
MEASURED =	97.71	

HOLE # 8
DEPTH = 1913.1 FEET

INSOLUBLE
2.29 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.05	0.53
0.48	11.91
0.0	0.0
0.90	14.98
0.13	0.81
0.21	2.06
0.0	0.0
1.77 %	
2.29	

HOLE # 8
DEPTH = 1916.2 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.92	11.49
NA	38.48	1673.77
NA2O	0.0	0.0
K	0.21	5.37
K2O	0.0	0.0
MGO	0.13	3.23
CAO	0.44	7.85
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.71	1627.93

HOLE # 8
DEPTH = 1923.0 FEET

SOLUBLE
98.30 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.10	1.25
NA	38.03	1654.20
NA2O	0.0	0.0
K	0.05	1.28
K2O	0.0	0.0
MGO	0.05	1.24
CAO	0.08	1.43
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.43	1648.24
SUBTOTAL	96.75 %	
MEASURED =	98.30	

HOLE # 8
DEPTH = 1923.0 FEET

INSOLUBLE
1.70 WT % OF TOTAL

WT %	MOLES
0.95	11.87
0.0	0.0
0.0	0.0
0.0	0.0
0.08	0.85
0.03	0.74
0.12	2.14
0.59	9.82
0.10	0.63
0.16	1.57
0.0	0.0
2.03 %	
1.70	

HOLE # 8
DEPTH = 1930.0 FEET

SOLUBLE
98.99 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.81	35.10
NA	35.71	1553.28
NA2O	0.0	0.0
K	1.03	26.34
K2O	0.0	0.0
MGO	0.33	8.19
CAO	0.19	3.39
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	56.74	1600.56
SUBTOTAL	96.81 %	
MEASURED =	98.99	

HOLE # 8
DEPTH = 1930.0 FEET

INSOLUBLE
1.01 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.08	1.29
0.0	0.0
0.01	0.11
0.13	3.23
0.01	0.18
0.18	3.00
0.07	0.44
0.04	0.39
0.0	0.0
0.52 %	
1.01	

HOLE # 8
DEPTH = 1933.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	0.78	9.74
NA	38.03	1654.20
NA2O	0.0	0.0
K	0.15	3.84
K2O	0.0	0.0
MGO	0.09	2.23
CAO	0.65	11.59
SIO2	0.01	0.17
FE2O3	0.01	0.06
AL2O3	0.0	0.0
CL	59.81	1687.17

HOLE # 8
DEPTH = 1938.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	2.91	36.35
NA	35.63	1549.80
NA2O	0.0	0.0
K	0.68	17.39
K2O	0.0	0.0
MGO	0.84	20.84
CAO	1.02	18.19
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.45	1677.01

HOLE # 8
DEPTH = 1953.2 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	2.30	28.73
NA	39.50	1718.14
NA2O	0.0	0.0
K	0.30	7.67
K2O	0.0	0.0
MGO	0.42	10.42
CAO	1.23	21.93
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.63	1625.67

HOLE # 8
DEPTH = 1967.0 FEET

SOLUBLE
95.13 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.25	15.61
NA	35.99	1565.46
NA2O	0.0	0.0
K	0.57	14.58
K2O	0.0	0.0
MGO	0.23	5.71
CAO	0.40	7.13
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.52	1622.57
SUBTOTAL	95.96 %	
MEASURED =	95.13	

HOLE # 8
DEPTH = 1967.0 FEET

INSOLUBLE
4.87 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
2.73	44.05
0.0	0.0
0.09	0.96
0.98	24.31
0.0	0.0
0.76	12.65
0.10	0.63
0.20	1.96
0.0	0.0
4.86 %	
4.87	

HOLE # 8
DEPTH = 1986.0 FEET

SOLUBLE
36.72 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	22.99	287.16
NA	0.36	15.66
NA2O	0.0	0.0
K	0.0	0.0
K2O	14.68	155.84
MGO	0.62	15.38
CAO	0.87	15.51
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	0.15	4.23
SUBTOTAL	39.67 %	
MEASURED =	36.72	

HOLE # 8
DEPTH = 1986.0 FEET

INSOLUBLE
63.28 WT % OF TOTAL

WT %	MOLES
37.88	473.15
0.0	0.0
5.83	94.06
0.0	0.0
11.39	120.91
1.20	29.77
4.25	75.78
0.54	8.99
0.17	1.06
0.85	8.34
0.0	0.0
62.11 %	
63.28	

HOLE # 8
DEPTH = 2006.0 FEET

TOTAL

COMPONENT	WT %	MOLES
SO3	2.37	29.60
NA	37.59	1635.06
NA2O	0.0	0.0
K	1.03	26.34
K2O	0.0	0.0
MGO	0.31	7.69
CAO	0.06	1.07
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.17	1612.69

HOLE # 8
DEPTH = 2017.0 FEET

SOLUBLE
95.20 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.55	6.87
NA	35.66	1551.11
NA2O	0.0	0.0
K	0.06	1.53
K2O	0.0	0.0
MGO	0.08	1.98
CAO	0.96	17.12
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.09	1610.44
SUBTOTAL	94.42 %	
MEASURED =	95.20	

HOLE # 8
DEPTH = 2017.0 FEET

INSOLUBLE
4.80 WT % OF TOTAL

WT %	MOLES
0.07	0.87
0.0	0.0
0.0	0.0
0.0	0.0
0.04	0.42
0.44	10.92
0.06	1.07
2.01	33.45
0.28	1.75
0.70	6.87
0.0	0.0
3.60 %	
4.80	

HOLE # 8
DEPTH = 2039.0 FEET

SOLUBLE
98.94 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	4.88	60.95
NA	35.02	1523.27
NA2O	0.0	0.0
K	1.56	39.90
K2O	0.0	0.0
MGO	0.50	12.40
CAO	1.57	28.00
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	54.01	1523.55
SUBTOTAL	97.54 %	
MEASURED =	98.94	

HOLE # 8
DEPTH = 2039.0 FEET

INSOLUBLE
1.06 WT % OF TOTAL

WT %	MOLES
0.62	7.74
0.0	0.0
0.0	0.0
0.0	0.0
0.03	0.32
0.21	5.21
0.01	0.18
0.26	4.33
0.07	0.44
0.05	0.49
0.0	0.0
1.25 %	
1.06	

HOLE # 8
DEPTH = 2050.0 FEET

SOLUBLE
28.61 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	3.92	48.96
NA	8.00	347.98
NA2O	0.0	0.0
K	0.05	1.28
K2O	0.0	0.0
MGO	0.02	0.50
CAO	0.55	9.81
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	12.44	350.92
SUBTOTAL	24.98 %	
MEASURED =	28.61	

HOLE # 8
DEPTH = 2050.0 FEET

INSOLUBLE
71.39 WT % OF TOTAL

WT %	MOLES
51.08	638.02
0.0	0.0
4.90	79.06
0.0	0.0
0.04	0.42
0.29	7.19
6.55	116.80
0.33	5.49
0.0	0.0
0.0	0.0
0.0	0.0
63.19 %	
71.39	

HOLE # 8
DEPTH = 2068.0 FEET

SOLUBLE
98.84 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.49	31.10
NA	37.41	1627.23
NA2O	0.0	0.0
K	0.08	2.05
K2O	0.0	0.0
MGO	0.03	0.74
CAO	0.87	15.51
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	55.99	1579.41
SUBTOTAL	96.89 %	
MEASURED =	98.84	

HOLE # 8
DEPTH = 2068.0 FEET

INSOLUBLE
1.16 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.28	6.95
0.02	0.36
0.37	6.16
0.05	0.31
0.07	0.69
0.0	0.0
0.80 %	
1.16	

HOLE # 8
DEPTH = 2084.0 FEET

SOLUBLE
92.00 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.05	25.61
NA	34.46	1498.91
NA2O	0.0	0.0
K	1.02	26.09
K2O	0.0	0.0
MGO	0.35	8.68
CAO	0.72	12.84
SIO2	0.01	0.17
FE2O3	0.01	0.06
AL2O3	0.0	0.0
CL	52.19	1472.21
SUBTOTAL	90.81 %	
MEASURED =	92.00	

HOLE # 8
DEPTH = 2084.0 FEET

INSOLUBLE
8.00 WT % OF TOTAL

WT %	MOLES
0.59	7.37
0.0	0.0
1.87	30.17
0.0	0.0
0.19	2.02
1.13	28.03
0.01	0.18
2.07	34.45
0.24	1.50
0.37	3.63
0.0	0.0
6.47 %	
8.00	

HOLE # 8
DEPTH = 2130.0 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	2.31	28.85
NA	37.79	1643.76
NA2O	0.0	0.0
K	0.42	10.74
K2O	0.0	0.0
MGO	0.25	6.20
CAO	0.75	13.37
SIO2	0.03	0.50
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.16	1612.41

HOLE # 8
DEPTH = 2162.0 FEET

SOLUBLE
98.90 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.31	16.36
NA	36.77	1599.39
NA2O	0.0	0.0
K	1.23	31.46
K2O	0.0	0.0
MGO	0.45	11.16
CAO	0.93	16.58
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.99	1692.24
SUBTOTAL	100.68 %	
MEASURED =	98.90	

HOLE # 8
DEPTH = 2162.0 FEET

INSOLUBLE
1.10 WT % OF TOTAL

WT %	MOLES
0.25	3.12
0.0	0.0
0.55	8.87
0.0	0.0
0.03	0.32
0.20	4.96
0.01	0.18
0.23	3.83
0.06	0.38
0.05	0.49
0.0	0.0
1.38 %	
1.10	

HOLE # 8
DEPTH = 2217.0 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	0.0	0.0
NA	39.14	1702.48
NA2O	0.0	0.0
K	0.07	1.79
K2O	0.0	0.0
MGO	0.02	0.50
CAO	0.12	2.14
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.75	1685.47

HOLE # 8
DEPTH = 2280.0 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	0.39	4.87
NA	37.91	1648.98
NA2O	0.0	0.0
K	0.12	3.07
K2O	0.0	0.0
MGO	0.09	2.23
CAO	0.25	4.46
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.23	1699.01

HOLE # 8
DEPTH = 2326.0 FEET

INSOLUBLE
4.56 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.0	0.0
NA	0.0	0.0
NA2O	0.0	0.0
K	0.0	0.0
K2O	0.03	0.32
MGO	1.31	32.50
CAO	0.03	0.53
SIO2	1.14	18.97
FE2O3	0.12	0.75
AL2O3	0.25	2.45
CL	0.0	0.0
SUBTOTAL	2.88 %	
MEASURED =	4.56	

HOLE # 8
DEPTH = 2366.3 FEET

SOLUBLE
31.37 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	16.19	202.22
NA	0.62	26.97
NA2O	0.0	0.0
K	0.0	0.0
K2O	7.47	79.30
MGO	2.77	68.72
CAO	0.16	2.85
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	1.17	33.00
SUBTOTAL	28.39 %	
MEASURED =	31.37	

HOLE # 8
DEPTH = 2366.3 FEET

INSOLUBLE
68.63 WT % OF TOTAL

WT %	MOLES
31.13	388.83
0.0	0.0
3.76	60.66
0.0	0.0
3.19	33.86
3.63	90.05
3.21	57.24
10.67	177.57
0.01	0.06
1.57	15.40
0.0	0.0
57.17 %	
68.63	

HOLE # 8
DEPTH = 2427.5 FEET

SOLUBLE
99.36 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.22	27.73
NA	39.42	1714.66
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.31	5.53
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.88	1689.14
SUBTOTAL	101.85 %	
MEASURED =	99.36	

HOLE # 8
DEPTH = 2427.5 FEET

INSOLUBLE
0.64 WT % OF TOTAL

WT %	MOLES
0.36	4.50
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.04	0.99
0.04	0.71
0.09	1.50
0.01	0.06
0.01	0.10
0.0	0.0
0.56 %	
0.64	

HOLE # 8
DEPTH = 2460.0 FEET

SOLUBLE
99.21 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.14	14.24
NA	38.75	1685.52
NA2O	0.0	0.0
K	0.03	0.77
K2O	0.0	0.0
MGO	0.03	0.74
CAO	0.62	11.06
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	57.00	1607.90
SUBTOTAL	97.57 %	
MEASURED =	99.21	

HOLE # 8
DEPTH = 2460.0 FEET

INSOLUBLE
0.79 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.17	4.22
0.0	0.0
0.19	3.16
0.03	0.19
0.06	0.59
0.0	0.0
0.46 %	
0.79	

HOLE # 8
DEPTH = 2519.6 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	0.17	2.12
NA	40.42	1758.16
NA2O	0.0	0.0
K	0.02	0.51
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.03	0.53
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.31	1701.27

HOLE # 8
DEPTH = 2563.0 FEET

SOLUBLE
7.11 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.49	18.61
NA	1.47	63.94
NA2O	0.0	0.0
K	0.05	1.28
K2O	0.0	0.0
MGO	0.07	1.74
CAO	0.60	10.70
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	1.05	29.62
SUBTOTAL	4.73 %	
MEASURED =	7.11	

HOLE # 8
DEPTH = 2563.0 FEET

INSOLUBLE
92.89 WT % OF TOTAL

WT %	MOLES
39.10	488.38
0.0	0.0
6.06	97.77
0.0	0.0
0.54	5.73
14.66	363.68
23.77	423.86
6.25	104.01
0.96	6.01
1.86	18.24
0.0	0.0
93.20 %	
92.89	

HOLE # 8
DEPTH = 2615.5 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	0.86	10.74
NA	38.58	1678.12
NA2O	0.0	0.0
K	0.05	1.28
K2O	0.0	0.0
MGO	0.02	0.50
CAO	0.58	10.34
SIO2	0.0	0.0
FE2O3	0.01	0.06
AL2O3	0.0	0.0
CL	59.37	1674.75

HOLE # 8
DEPTH = 2665.5 FEET

SOLUBLE
99.08 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	0.98	12.24
NA	38.68	1682.47
NA2O	0.0	0.0
K	0.02	0.51
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.35	6.24
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.14	1668.27
SUBTOTAL	99.19 %	
MEASURED =	99.08	

HOLE # 8
DEPTH = 2665.5 FEET

INSOLUBLE
0.92 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.21	5.21
0.01	0.18
0.22	3.66
0.04	0.25
0.06	0.59
0.0	0.0
0.55 %	
0.92	

HOLE # 8
DEPTH = 2706.0 FEET

SOLUBLE
98.75 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.12	13.99
NA	37.09	1613.31
NA2O	0.0	0.0
K	0.03	0.77
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.68	12.13
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.60	1653.03
SUBTOTAL	97.54 %	
MEASURED =	98.75	

HOLE # 8
DEPTH = 2706.0 FEET

INSOLUBLE
1.25 WT % OF TOTAL

WT %	MOLES
0.01	0.12
0.0	0.0
0.64	10.33
0.0	0.0
0.03	0.32
0.18	4.47
0.0	0.0
0.27	4.49
0.27	1.69
0.07	0.69
0.0	0.0
1.47 %	
1.25	

HOLE # 8
DEPTH = 2758.0 FEET

SOLUBLE
99.22 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.70	21.23
NA	37.20	1618.10
NA2O	0.0	0.0
K	0.08	2.05
K2O	0.0	0.0
MGO	0.01	0.25
CAO	1.14	20.33
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.07	1638.08
SUBTOTAL	98.20 %	
MEASURED =	99.22	

HOLE # 8
DEPTH = 2758.0 FEET

INSOLUBLE
0.78 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.83	13.39
0.0	0.0
0.01	0.11
0.17	4.22
0.0	0.0
0.06	1.00
0.01	0.06
0.02	0.20
0.0	0.0
1.10 %	
0.78	

HOLE # 8
DEPTH = 2779.0 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	1.09	13.61
NA	37.41	1627.23
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.03	0.74
CAO	1.80	32.10
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.53	1651.06

HOLE # 8
DEPTH = 2794.0 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	0.99	12.37
NA	37.86	1646.80
NA2O	0.0	0.0
K	0.02	0.51
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.68	12.13
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	60.58	1708.89

HOLE # 8
DEPTH = 2802.5 FEET
TOTAL

COMPONENT	WT %	MOLES
SO3	1.76	21.98
NA	38.39	1669.86
NA2O	0.0	0.0
K	0.02	0.51
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.22	3.92
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.19	1641.47

HOLE # 8
DEPTH = 2809.0 FEET

SOLUBLE
99.09 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.02	25.23
NA	38.56	1677.25
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.96	17.12
SIO2	0.0	0.0
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	59.70	1684.06
SUBTOTAL	101.26 %	
MEASURED =	99.09	

HOLE # 8
DEPTH = 2809.0 FEET

INSOLUBLE
0.91 WT % OF TOTAL

WT %	MOLES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.03	0.74
0.13	2.32
0.04	0.67
0.0	0.0
0.01	0.10
0.0	0.0
0.22 %	
0.91	

HOLE # 8
DEPTH = 2820.5 FEET

SOLUBLE
99.46 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	1.30	16.24
NA	38.42	1671.16
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.10	1.78
SIO2	0.03	0.50
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	58.50	1650.21
SUBTOTAL	98.37 %	
MEASURED =	99.46	

HOLE # 8
DEPTH = 2820.5 FEET

INSOLUBLE
0.54 WT % OF TOTAL

WT %	MOLES
0.37	4.62
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.25
0.19	3.39
0.03	0.50
0.0	0.0
0.0	0.0
0.0	0.0
0.60 %	
0.54	

HOLE # 8
DEPTH = 2879.0 FEET

SOLUBLE
96.41 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	2.17	27.10
NA	32.65	1420.18
NA2O	0.0	0.0
K	0.02	0.51
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.59	10.52
SIO2	0.02	0.33
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	55.79	1573.77
SUBTOTAL	91.25 %	
MEASURED =	96.41	

HOLE # 8
DEPTH = 2879.0 FEET

INSOLUBLE
3.59 WT % OF TOTAL

WT %	MOLES
1.97	24.61
0.0	0.0
0.93	15.00
0.0	0.0
0.01	0.11
0.12	2.98
0.95	16.94
0.12	2.00
0.01	0.06
0.01	0.10
0.0	0.0
4.12 %	
3.59	

HOLE # 8
DEPTH = 2948.0 FEET

SOLUBLE
97.32 WT % OF TOTAL

COMPONENT	WT %	MOLES
SO3	3.41	42.59
NA	37.30	1622.45
NA2O	0.0	0.0
K	0.01	0.26
K2O	0.0	0.0
MGO	0.01	0.25
CAO	0.54	9.63
SIO2	0.01	0.17
FE2O3	0.0	0.0
AL2O3	0.0	0.0
CL	55.51	1565.87
SUBTOTAL	96.79 %	
MEASURED =	97.32	

HOLE # 8
DEPTH = 2948.0 FEET

INSOLUBLE
2.68 WT % OF TOTAL

WT %	MOLES
1.92	23.98
0.0	0.0
0.0	0.0
0.0	0.0
0.01	0.11
0.02	0.50
0.25	4.46
0.05	0.83
0.01	0.06
0.0	0.0
0.0	0.0
2.26 %	
2.68	

Appendix 7.C (Ref. sec. 7.4)

Selected x-ray diffraction traces of EDTA-insoluble residues from the ERDA-9 core.

I-2. MB-CS-42: Serpentine and saponite; the sharp maxima at 12.2 and 24.5°2θ are basal spacings of serpentine's 7Å periodicity. The broad peak at 7.25°2θ (air-dried) becomes a broad weak shoulder at ∿5°2θ upon glycol saturation and is saponite.

A. <2μm EDTA-insoluble residue, air-dried.
B. Bulk EDTA-insoluble residue, glycol-saturated.

I-3. MB-CS-15: Talc and smectite (saponite); sharp peaks at 9.5 and 28.5°2θ are basal spacings of talc's 9.5Å periodicity; they do not shift with glycol-saturation. The broad low-angle peak again is saponite; accessory amounts of serpentine also present.

A. <2μm EDTA-insoluble residue, air-dried.
B. Bulk EDTA-insoluble residue, glycol-saturated.

I-4. MB-CS-17: Regularly interstratified mixed-layer chlorite-saponite (corrensite); distinct strong superlattice reflection at 2.9°2θ (air-dried) which expands to 2.7°2θ with glycol-saturation. The peak at 6.4°2θ (air-dried) expands to 5.6°2θ.

A. <2μm EDTA-insoluble residue, air-dried.
B. <2μm EDTA-insoluble residue, glycol-saturated.

I-5. JL-CS-9: Randomly interstratified mixed-layer chlorite-saponite; air-dried peak at 6.1°2θ expands to 5.5°2θ with glycol saturation. Illite (8.7, 17.6, and 26.6°2θ), minor serpentine (12.3 and 13.1°2θ), and minor feldspar (27.4°2θ) also present.

A. <2μm EDTA-insoluble residue, air-dried.
B. <2μm EDTA-insoluble residue, glycol-saturated.

I-6. MB-CS-13: Saponite; reflections at 6.1 and 27.3°2θ which expand to 5.2° 2θ upon glycol saturation. A small quantity of a regularly interstratified mixed-layer clay (small superlattice peak at 2.4°2θ) also present.

A. <2μm EDTA-insoluble residue, air-dried.
B. <2μm EDTA-insoluble residue, glycol saturated.

I-7. JL-CS-2: Randomly interstratified mixed-layer clay, either talc-saponite or illite-saponite; single strong maximum at 8.6°2θ becomes pronounced doublet at 9.6 and 7.6°2θ with glycol saturation.

A. <2μm EDTA-insoluble residue, air-dried.
B. <2μm EDTA-insoluble residue, glycol-saturated.

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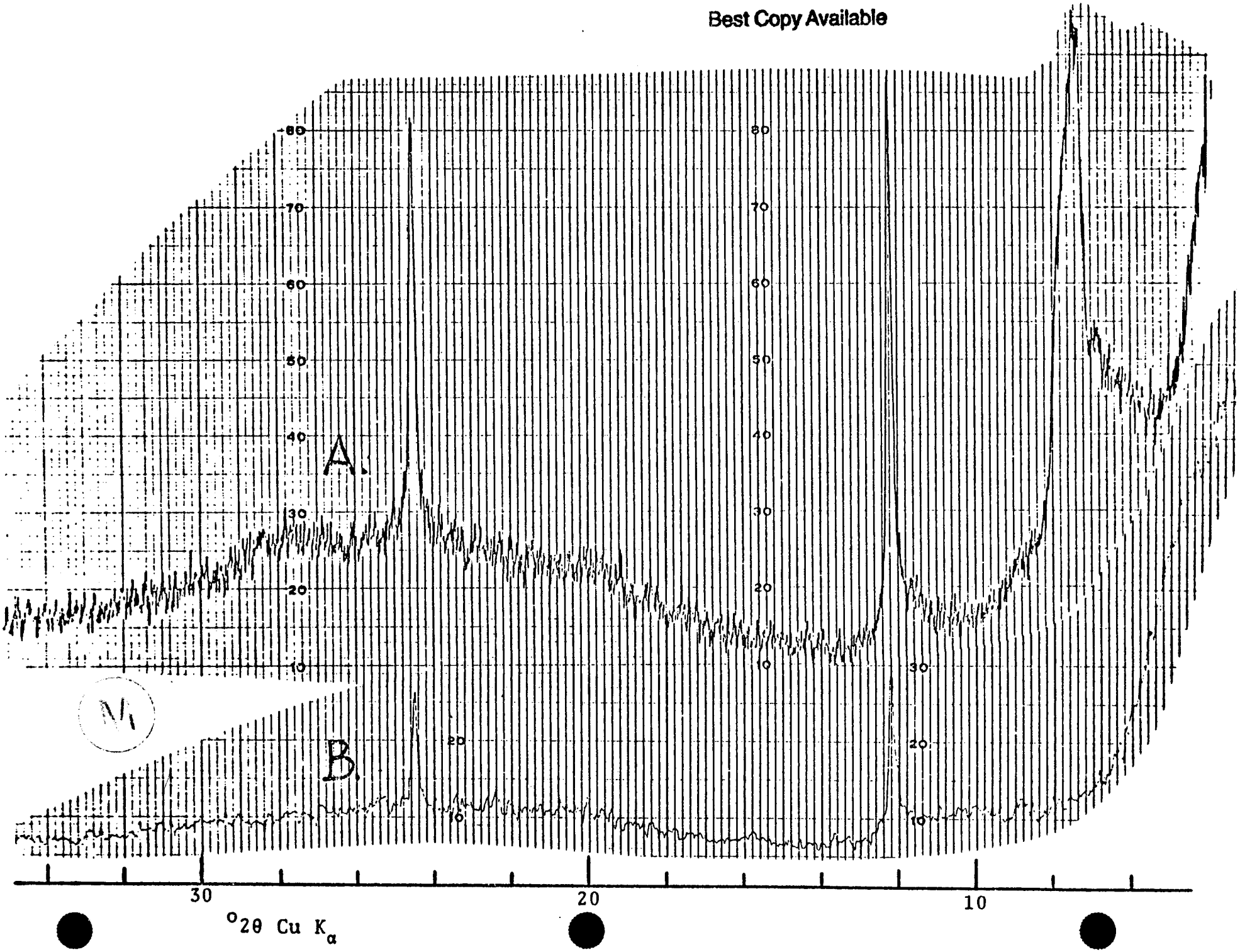

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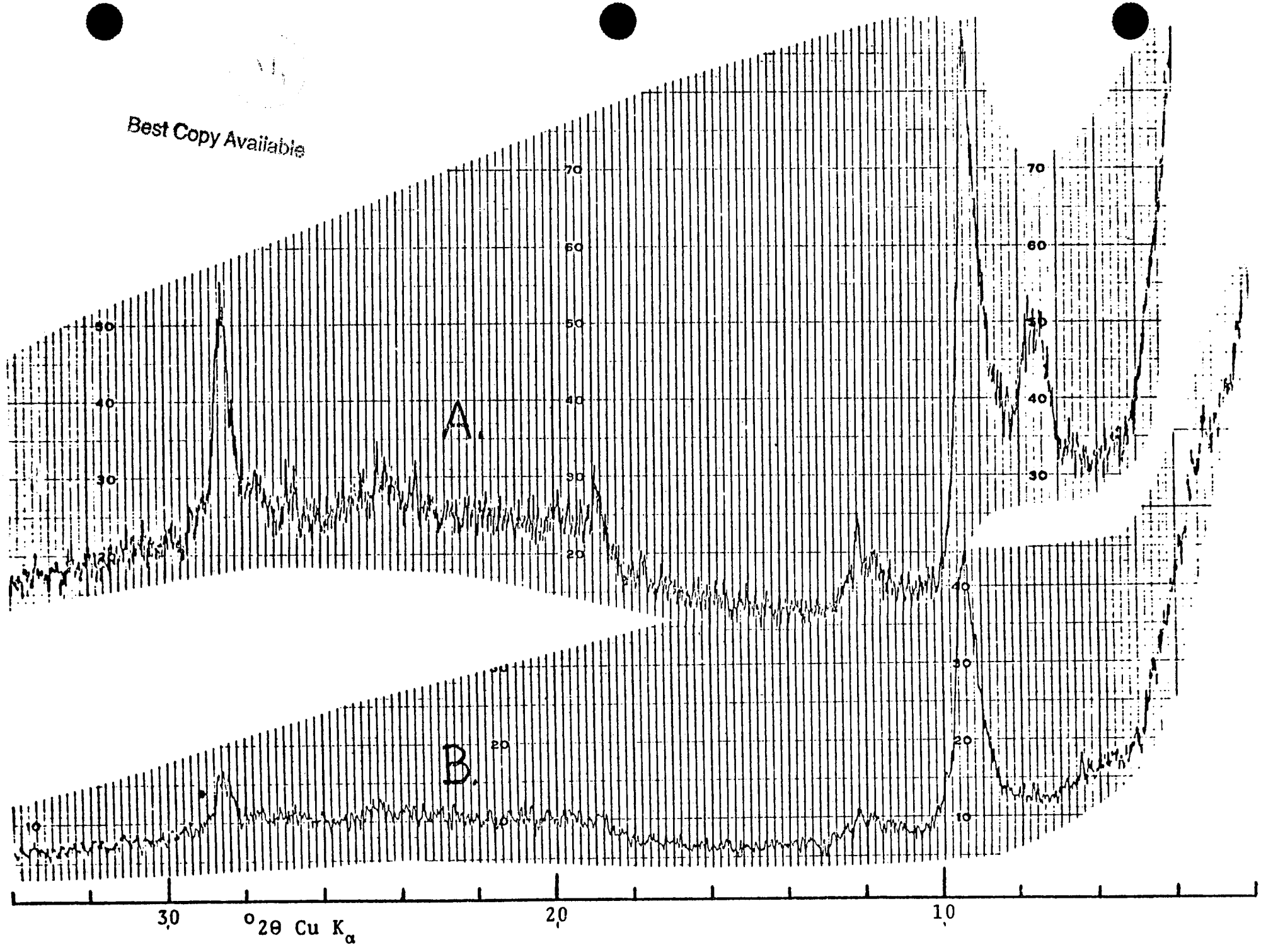

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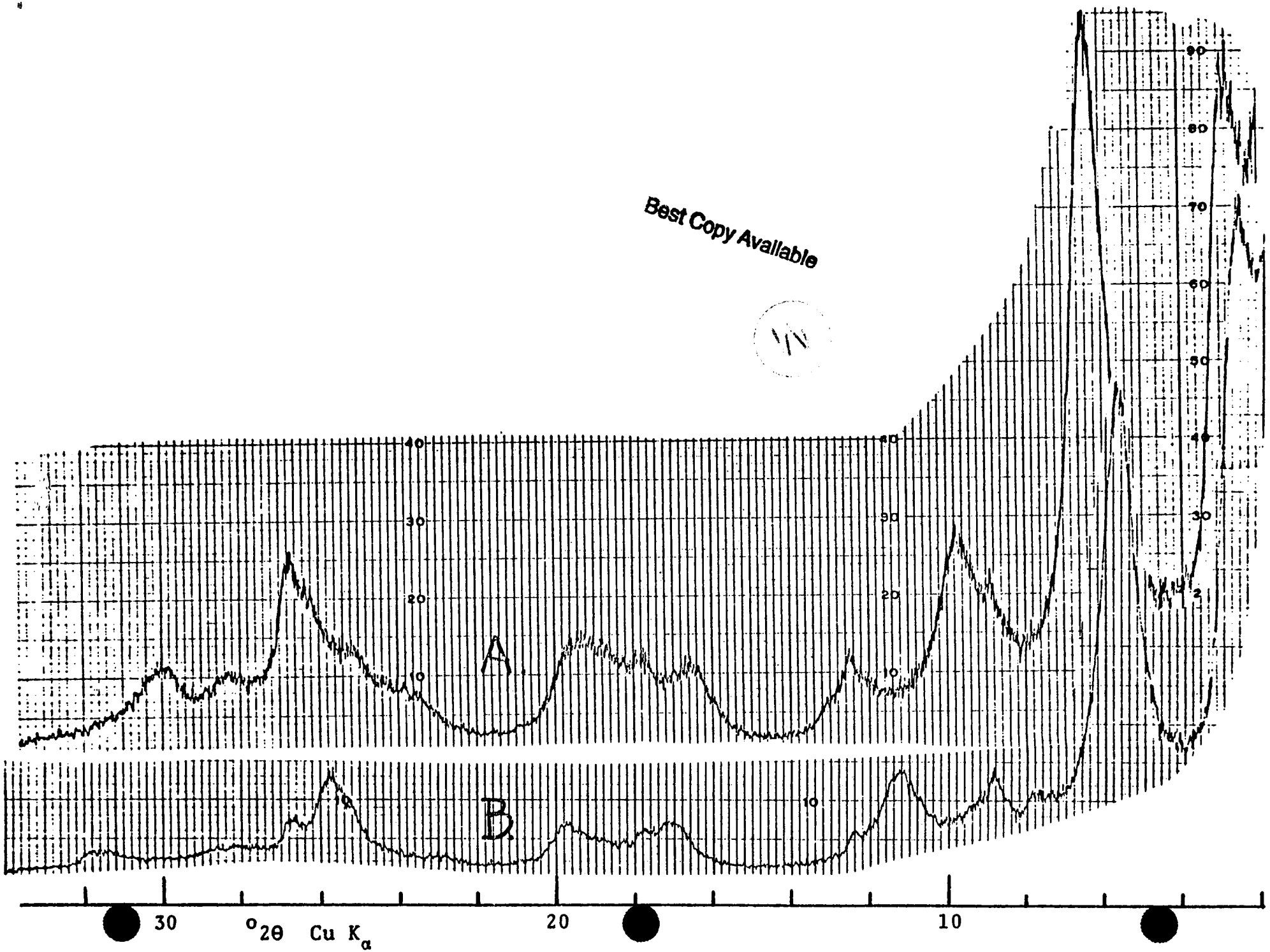

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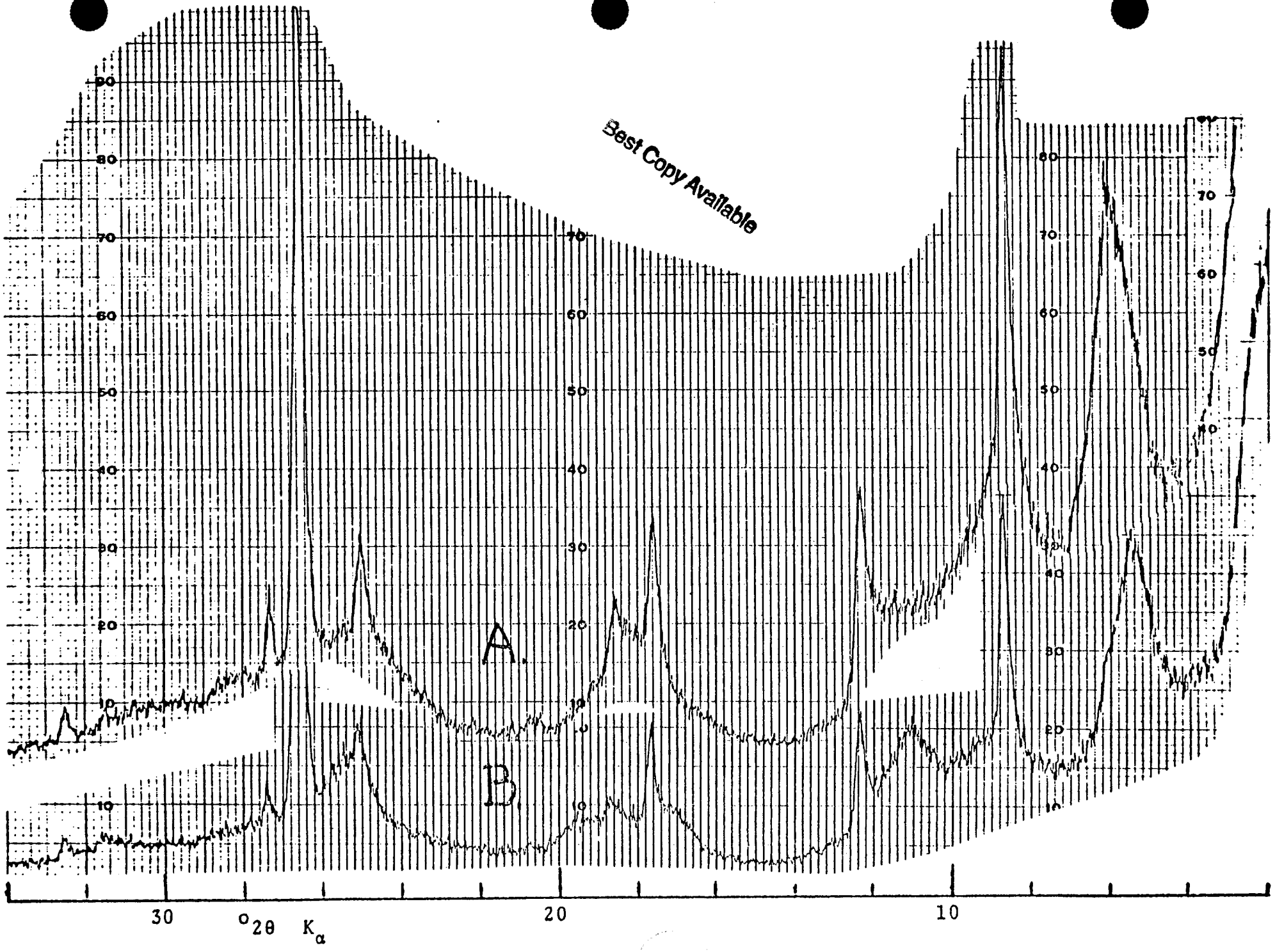

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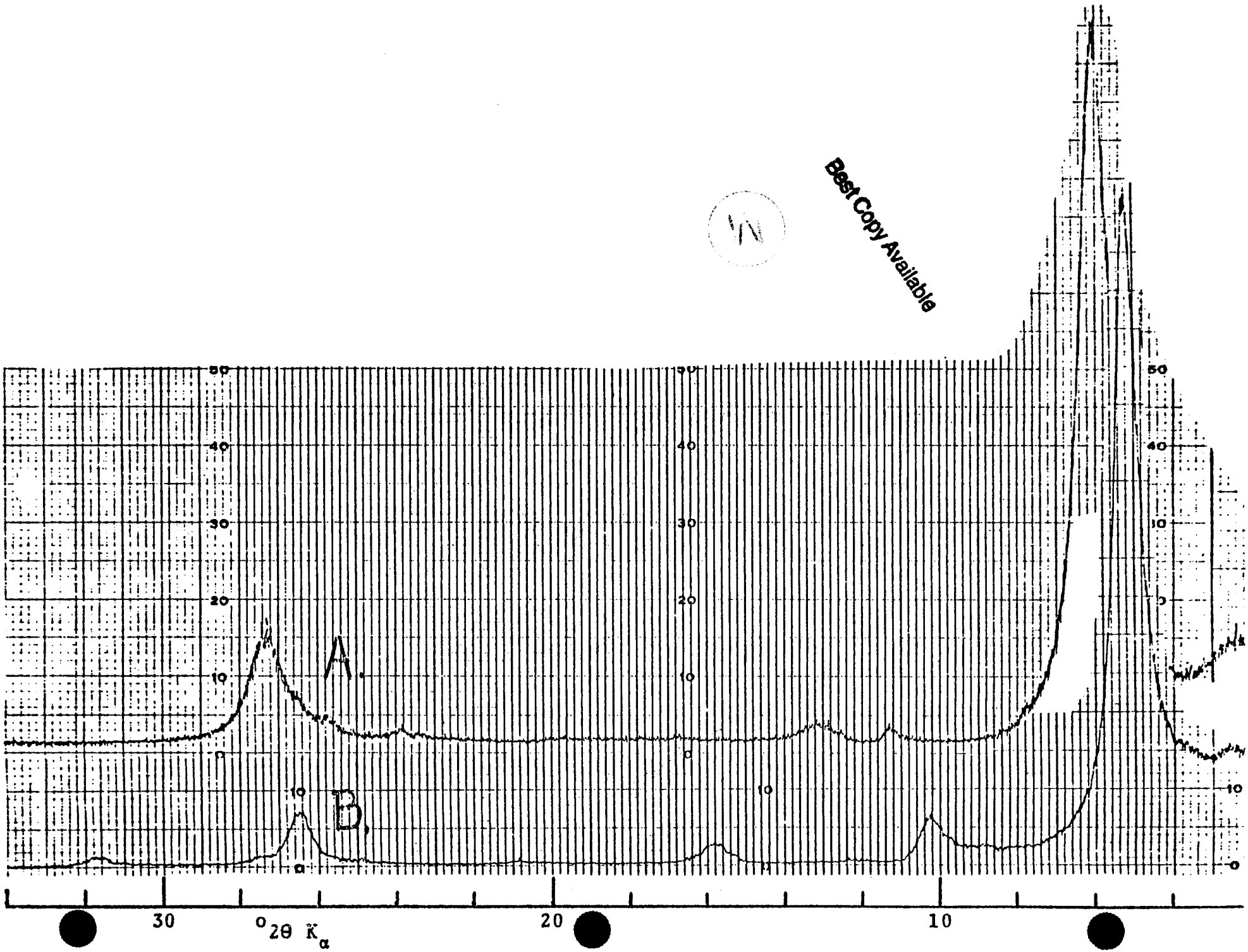

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APPENDIX 7.b (Ref. sec. 7.4)

Core Footage (Sandia Core Photo #), Informal Lithology and Detailed Macroscopic Core Description

FI in left column indicates abundant fluid inclusions.

† just to left of right column indicates description incorporates stratigraphic variation within that interval.

Abbreviations and Meanings used in Core Description (right column)

anhy or anhyd	anhydrite
ave	average
brwn	brown
dom	dominant
fg	fine grained or finely crystalline
inc	increasing
irreg	irregular
L	length
lams	laminae or laminations
lite or lt	light
loc	local or locally
max	maximum
repl	replacement
struc	structure
thk	thick or thickness
W	Width
w/	with
Xtals or Xtalline	crystals or crystalline
μX	microcrystalline

Core Footage (Sandia Photo #)	Informal Lithology	Macroscopic (aided by binocular microscope) Core Description
1162.7 (27) 1163.7	Halite	lite brwn, clear, anhedral Xtals (1cm), sharp Xtal boundaries of halite minor 1-4mm thk, lenses of lite gray, μX, anhydrite rimmed with polyhalite
1165.2 (28) 1166.6	Anhydrite w/ halite "crystal growth"	dominantly gray, μX anhydrite w/ slight color banding (gray-lite gray) with: lenses (1/2 to 1 cm thk.) of brown, clear to opaque, poorly defined anhedral Xtals of halite layers (1 to 4 cm thk) of vertically elongate (L/W=2 to 3, L=2mm to 3 1/2 cm), locally swallow-tail, Xtals of halite
1167.3 (28) 1168	Banded Anhydrite	banding of dominantly gray, μX anhydrite laminae (5-10mm thk) with white, thin (<1mm) laminae of μX magnesite locally a few anhedral (some swallow tail) Xtals of halite, locally vertically elongate or radiating
1168 (29) 1168.25	Anhydrite	similar to 1165.2 - 1166.6 but including laminae (~1mm thick) of magnesite
1168.25 (29) 1169.9	brick-red Polyhalite and Halite	dominantly anhedral (rare euhedral) 1/2 cm Xtals of halite, clear to cloudy with red, μX polyhalite between and in halite crystals
1172.6 (30) 1173.5	Banded Polyhalite	prominant banding but mineralogy obscure - "brown mineral" typically opaque, microcrystalline or massive halite, orange to orange brown poorly bounded anhedra ~1/2 cm - silty claystone or anhydrite? locally contorted banding

Core Footage (Sandia Phote #)	Informal Lithology	Macroscopic (aided by binocular microscope) Core Description
1173.5 (31) 1174.7	Halite	halite - clear to red, anhedral Xtals (ave 1/2 cm, max 2 cm) red from polyhalite stain; minor anhydrite
1404.7 (103) 1405.7	11th ore zone (leonite, kainite?)	polyhalite (± halite?) white & cloudy to blood red, massive w/ irreg. patches of dark gray claystone and irreg patches of pale yellow mineral (kainite-leonite?) massive patches are both vertically and horizontally elongate
1418 (106-107) 1418.8	Marker Bed 117, polyhalite plus mud	dominantly massive red polyhalite (w/ microscopic granular texture) laminations 1/2 to 1 1/2 cm thk alternating w/ clay laminae (<2mm thk) which are black & wavy [near 1418 - claystone w/ poor horizontal fissility plus "brown mineral" which looks like halite but has bitter taste]
1584 (160) 1584.9	5th ore zone, very dirty	dominantly halite - clear anhedra ~1 cm (max 2 cm) locally stained by "brown mineral" μXtalline coatings & locally patches a few mm in size; minor patches of gray μX anhydrite
1609.1 (168) 1610.3	Clear Halite (~2 ft above polyhalite)	dominantly halite - brwn (due to polyhalite stain?) indistinct anhedral about 1 1/2 cm; minor evenly dispersed polyhalite stain, and patches (~2mm) of gray material (anhydrite or clay?)
1632 (175) 1632.8	Mudstone	near top: banded anhydrite - claystone; anhydrite dark gray, μX - laminae up to 2mm thk, locally vertically elongate masses or Xtals; claystone lite grey, laminae from 1/2mm to 1/2 cm (thk inc. upward) near base: polyhalite w/ gray clay

Core Footage (Sandia Photo #)		Informal Lithology		Macroscopic (aided by binocular microscope) Core Description
1648.5 (180-181) 1649.7		4th ore zone halite, bloedite, vanthoffite		dominantly halite - lite brown anhedra ~3/4 cm locally red, μXtal polyhalite as stain & repl. of halite - some lenses and Xtal coatings of gray μX anhydrite?
2034.3 2037.3		Halite	† †	dominantly halite: finely crystalline & clayey near top - coarsely crystalline & banded anhydrite &/or polyhalite near center - finely crystalline & banded w/ anhydrite near base
2065.2 2067.6		Halite		dominantly coarsely Xtalline (~2 cm) clear, anhedral halite w/ patches, lenses & stains of "brown material" (polyhalite, carnallite, glauberite?) loc w/ radiating acicular texture
2301.6 (384) 2302.7		lite colored Polyhalite		dominantly red, μX polyhalite - locally crinkly flakes & irreg. patches of white fg. material
2413.6 (418-419) 2415.7	FI	pure & impure Polyhalite	†	dominantly poorly thickly banded polyhalite w/ sub-equal lenses of anhydrite & halite polyhalite: pinkish brown to red, μX halite: med. to coarsely Xtal, usually anhedral but some euhedra, typically clear anhydrite: layers, lenses and interXtalline patches, gray, μX, locally brown
2512 (450) 2512.5		dirty Halite		dominantly halite-gray, clear to cloudy, anhedral, 1 cm Xtal; minor light gray anhydrite as interXtalline patches
2515.6 (452+) 2519.2		typical massive Cowden Anhy.	† †	(halite above 2516.9) faintly banded gray, μX, anhydrite w/ wispy lenses of magnesite very minor halite

Core Footage (Sandia Photo #)	Informal Lithology	Macroscopic (aided by binocular microscope) Core Description
2527.7 (456+) 2529.2	typical laminated Cowden Anhy.	laminations of gray, μX, anhydrite - lam up to 1 1/2 cm (some needle like & loc radiating into magnesite) white, opaque μX magnesite lams, wavy, <1mm to 3mm thk
2538.5 (459) 2539.4	base of Cowden Anhy.	top: faintly banded (color) μX anhydrite, minor patches of halite ↑ dominantly coarsely Xtalline (~1 cm) clear, anhedral halite w/ lenses & interXtalline anhydrite base: similar to middle but halite Xtal size decreases to ~1mm
2541 (460) 2542.5	dirty halite just below Cowden	dominantly halite - gray, clear to cloudy, anhedral Xtals (ave 1 cm, <1mm to 3 cm) minor anhydrite (or magnesite?) - interXtalline patches (1 or 2 cm by 2mm)
2606.5 2608.8	Halite	dominantly halite - typically clear but some cloudy, white to gray anhedra typically ~1 cm but three 3 cm thk zones of ave size ~2mm which tend to be gray; minor anhydrite - interXtalline gray, μX
2614.7 2615.6	Halite	dom. halite - clear white euhedra & subhedra, most anhedra, ave 2 cm (<1mm to 4 cm); minor anhydrite - lt gray to white, μX, interXtalline
2615.9 FI 2619.5	Halite	↑ 15.9 - 16.5 dom halite - clear, white to gray, anhedra, ave 2 cm (1/2 - 6 cm) w/ v minor gray-white, μX, interXtalline anhyd or magnesite 16.5 - 18.4 dom halite - clear to cloudy, white to gray anhedra, ave 1 cm (<1mm - 2 cm) locally "chevron struc" within (& across) Xtals w/ minor gray-white, μX, interXtalline anhyd or magnesite ↑ 18.4 - 19.5 similar to 15.9 - 16.5

Core Footage (Sandia Photo #)	Informal Lithology	Macroscopic (aided by binocular microscope) Core Description
(2705.7) 2704.8 (509) (2706.8) 2706.5	mottled Anhy & Halite	dominantly halite - coarsely Xtalline (1 to 1 1/2 cm) anhedral, clear to white cloudy cut at ~45° by zones more finely Xtalline halite and mixed w/ up to 30% interXtalline gray, μX, anhydrite (w/ minor magnesite)
2758 (526) 2759.3	dirty Halite	dom halite - light to dk gray, anhedra, ave ~1 cm (<1mm to 3 cm) w/ minor anhydrite - dk gray, μX (but some microlites) as interXtall material
2819.1 (545) 2819.8	clean Halite, slightly banded	dom halite - cloudy, white to lt. gray, anhedral; faint banding by ave Xtal size variation from 1/2 to 1 cm, finer Xtalline tends to be whiter; minor thin horizontal lenses (rare patches), white, μX (rare microlites)
2819.9 (545) 2820.9A	see above	dom anhydrite - lt gray to dk gray (locally banded), μX; subordinate halite - irreg lenses & patches (frequently thin & horiz elongate) unusually sharp contacts between anhydrite & halite
2820 B (545-546) 2820.6B	see above	same as 19.9 - 20.9A except anhydrite locally brown and may contain magnesite
2820.6B (546) 2821.9	see above	dom halite - cloudy, white, anhedral, ave 1 cm (<1mm to 2 cm); very rare lense of wh to lt gray, μX anhydrite possibly w/ magnesite
2826.5 2827.5	dirty Halite	dom halite - poorly developed banding from clear, to cloudy white, to opaque dk gray, anhedral crystals ave 1/2 - 1 cm some magnesite (or anhydrite) - thin irreg seams & wavy lams (both horiz), white, μX

Core Footage (Sandia Photo #)	Informal Lithology	Macroscopic (aided by binocular microscope) Core Description
2845.6	massive light Anhydrite (in Castile)	dom anhydrite - mottled from clear to white & cloudy to gray to dk gray
2846.4		sub. magnesite - thin seams and irreg patches, µX
2847.8	banded light Anhydrite	dom anhydrite - banded from clear, to white & cloudy, to gray to dk gray, to black; clear tends to occur in laminae & lenses, locally "enterolithic" contortions and w/ smooth lower contacts & irreg "swallow-tail" upper contacts; subordinate magnesite
2849.1		

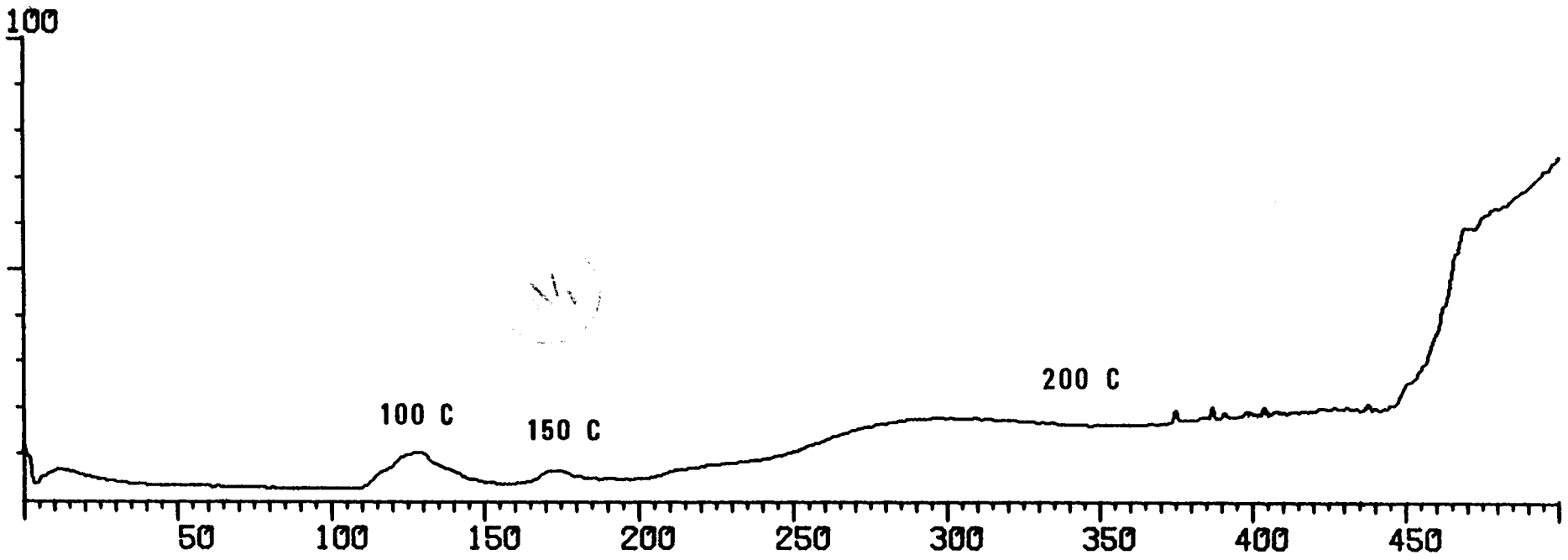
Appendix 7.E (Ref. sec. 7.5)

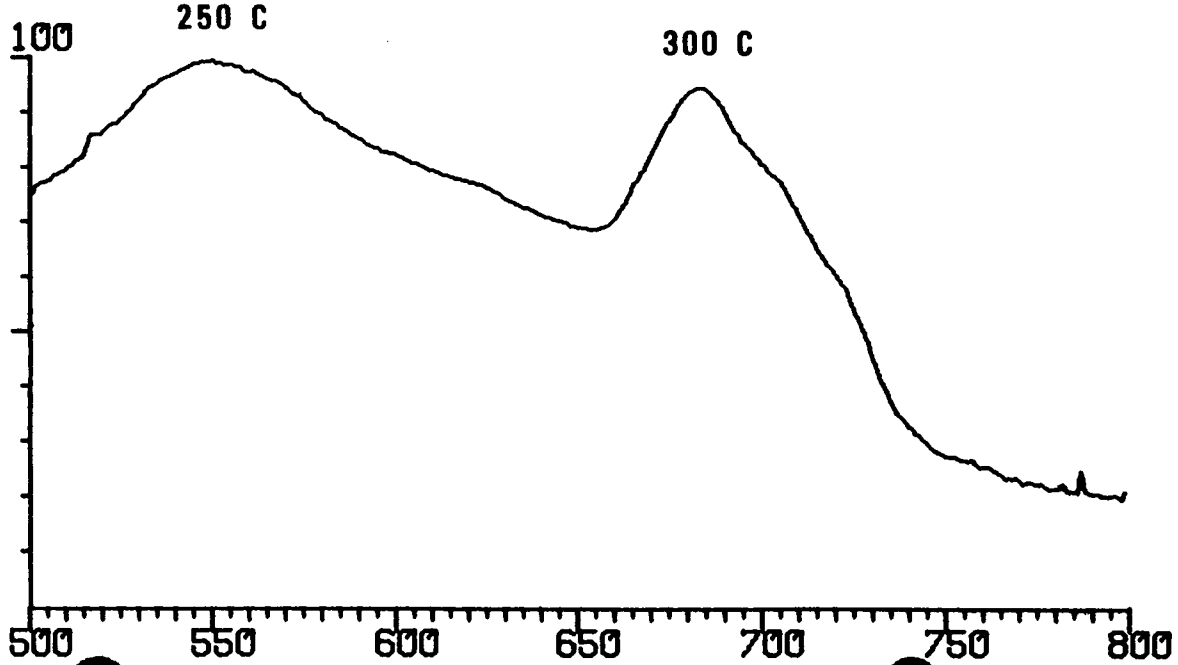
Gas Chromatograms and Mass Spectra
of Volatiles from Selected Samples
of Core from ERDA No. 9

Mass spectra are reported as intensity (normalized to the highest mass peak) as a function of mass/charge ratio (in atomic mass units).
Gas chromatograms are reported as intensity of elution peaks (normalized to the highest elution peak) as a function of relative elution time (in arbitrary units).

SALT SAMPLE 2302.6

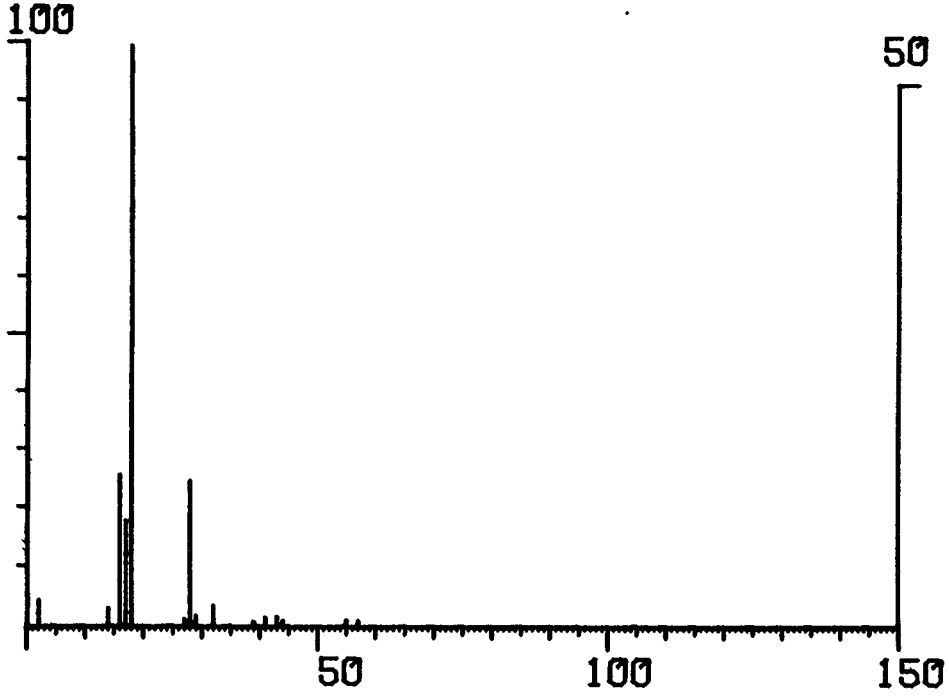
TOTAL ION CHROMATOGRAM X6





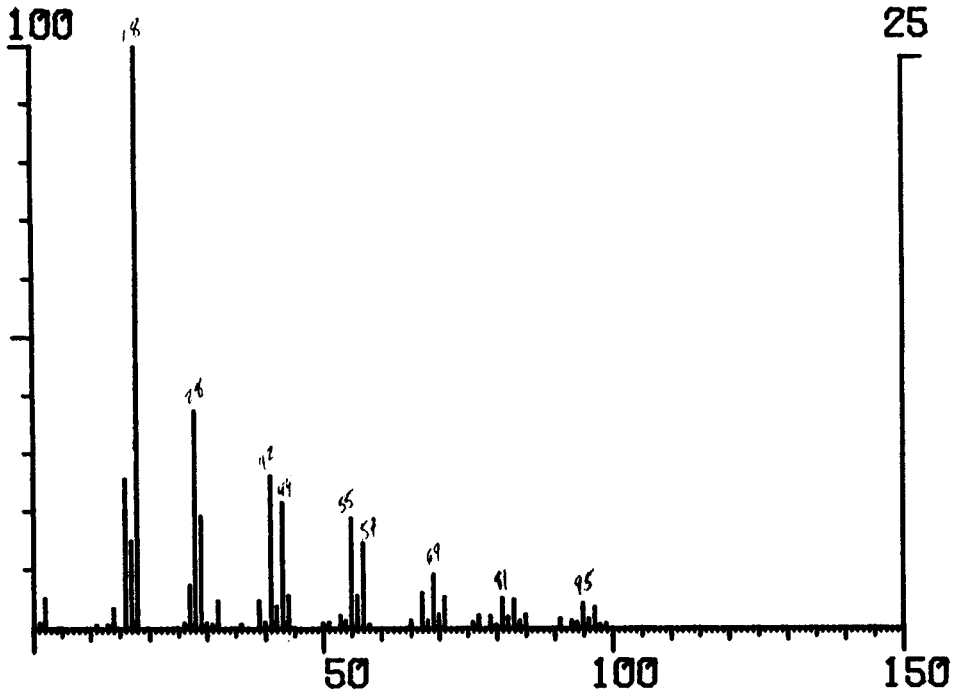
SALT SAMPLE 2302.6

12 MASS SPECTRA 50C X3



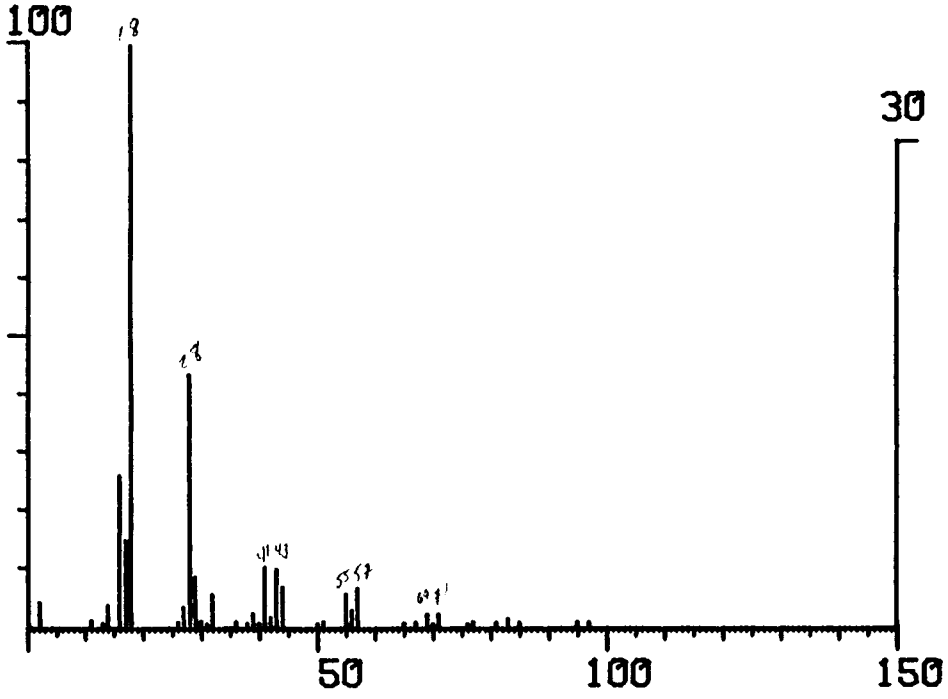
SALT SAMPLE 2302.6

128 MASS SPECTRA 100C X3



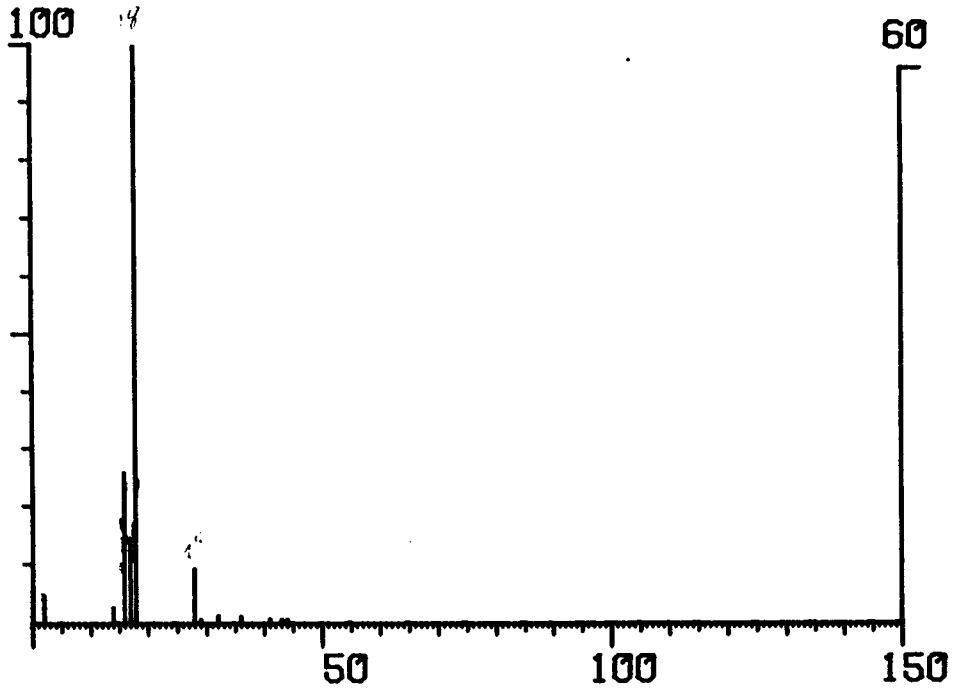
SALT SAMPLE 2302.6

174 MASS SPECTRA 150C X3



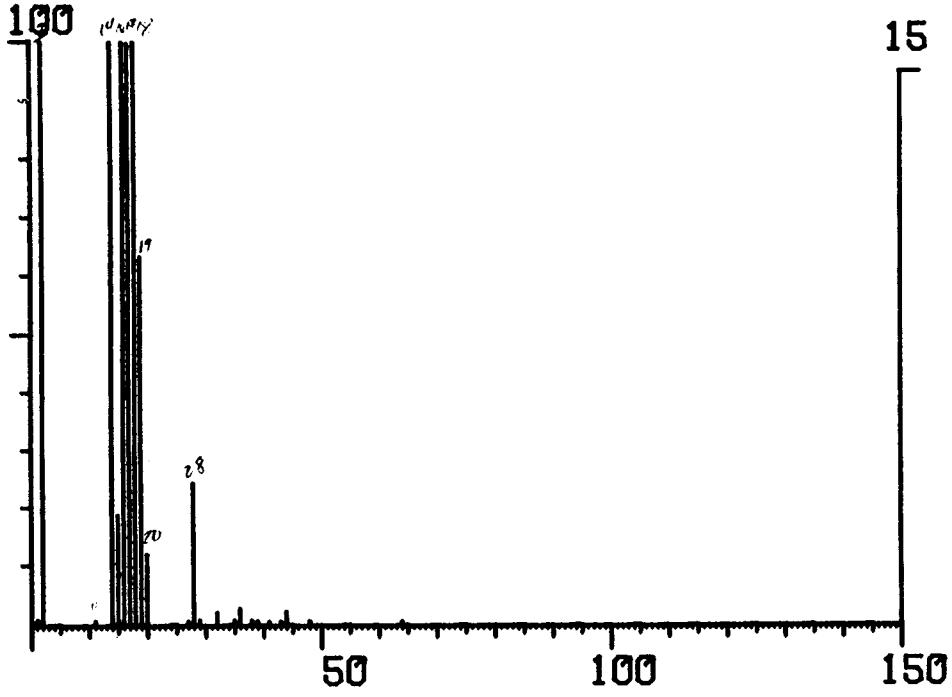
SALT SAMPLE 2302.6

297 MASS SPECTRA 200C X4



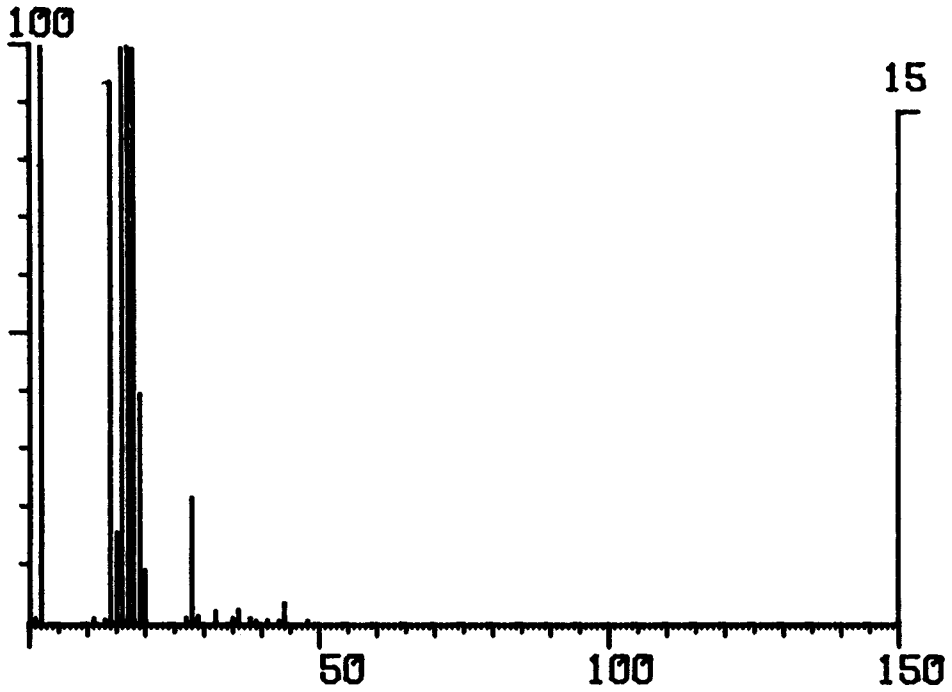
SALT SAMPLE 2302.6

550 MASS SPECTRA 250C X4



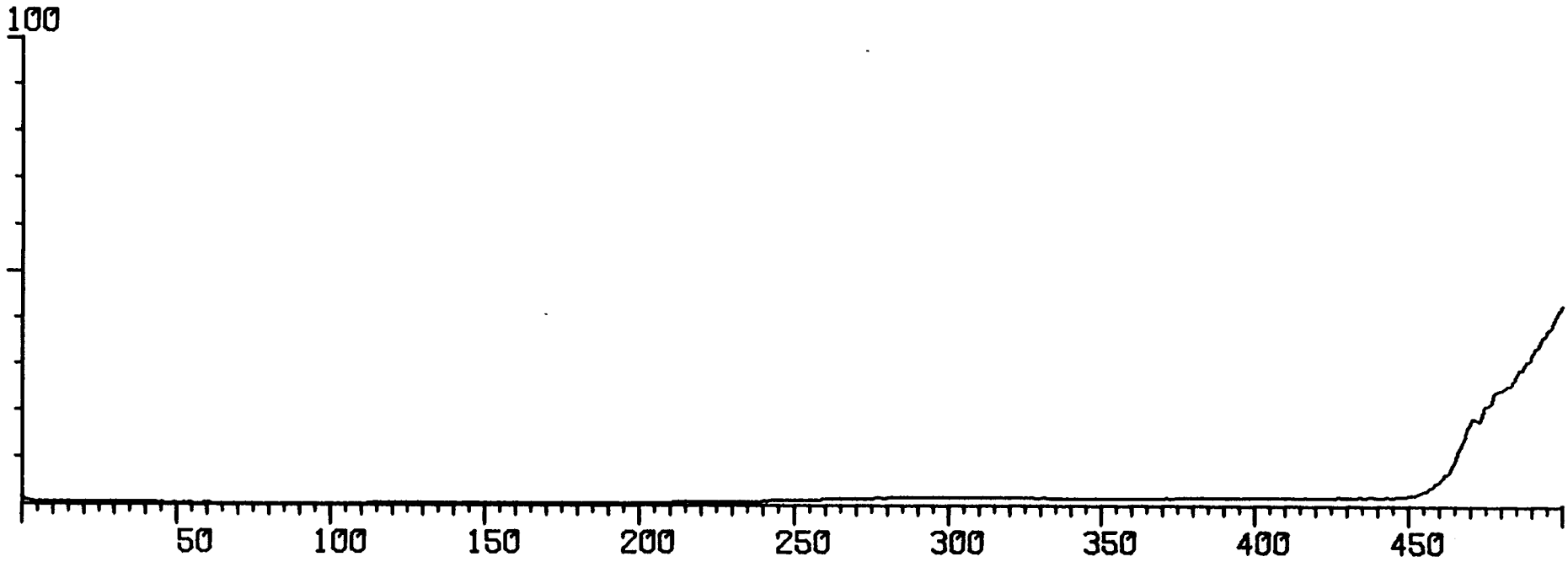
SALT SAMPLE 2302.6

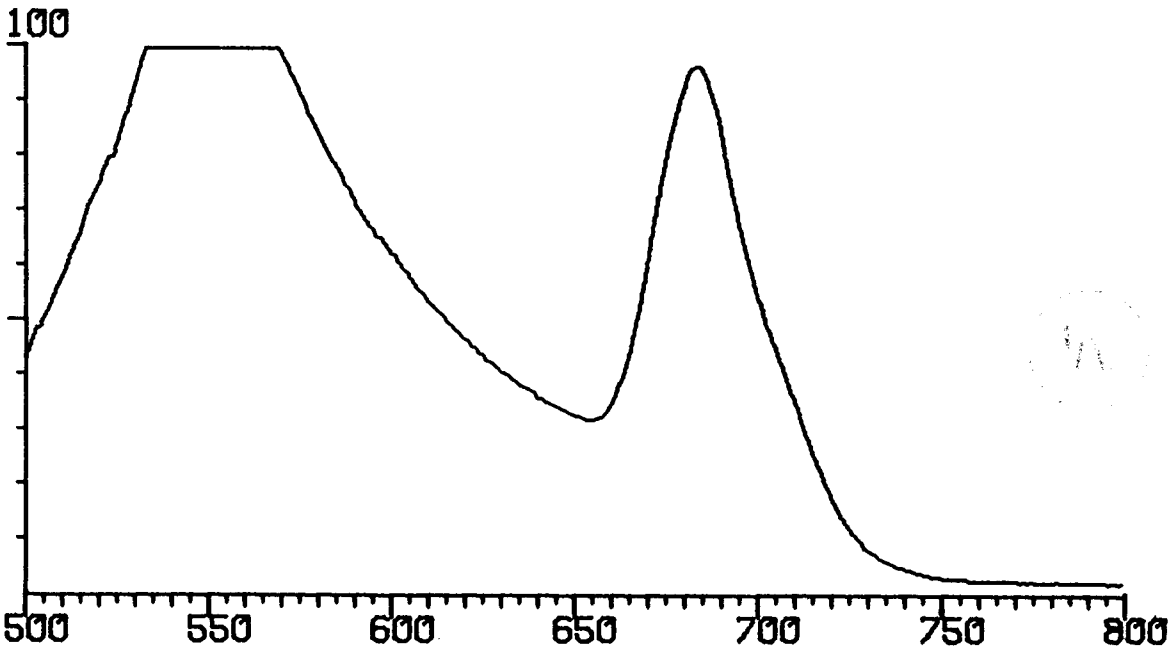
686 MASS SPECTRA 300C X4



SALT SAMPLE 2302.6

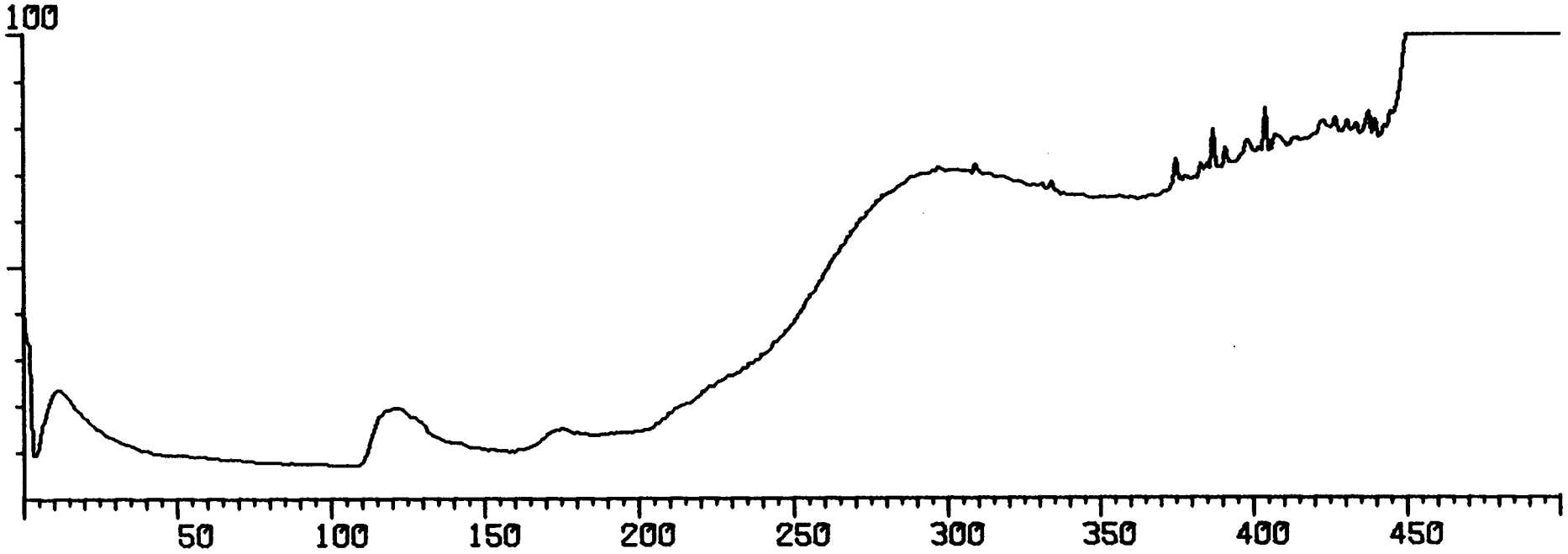
MASS 14 SEARCH X5

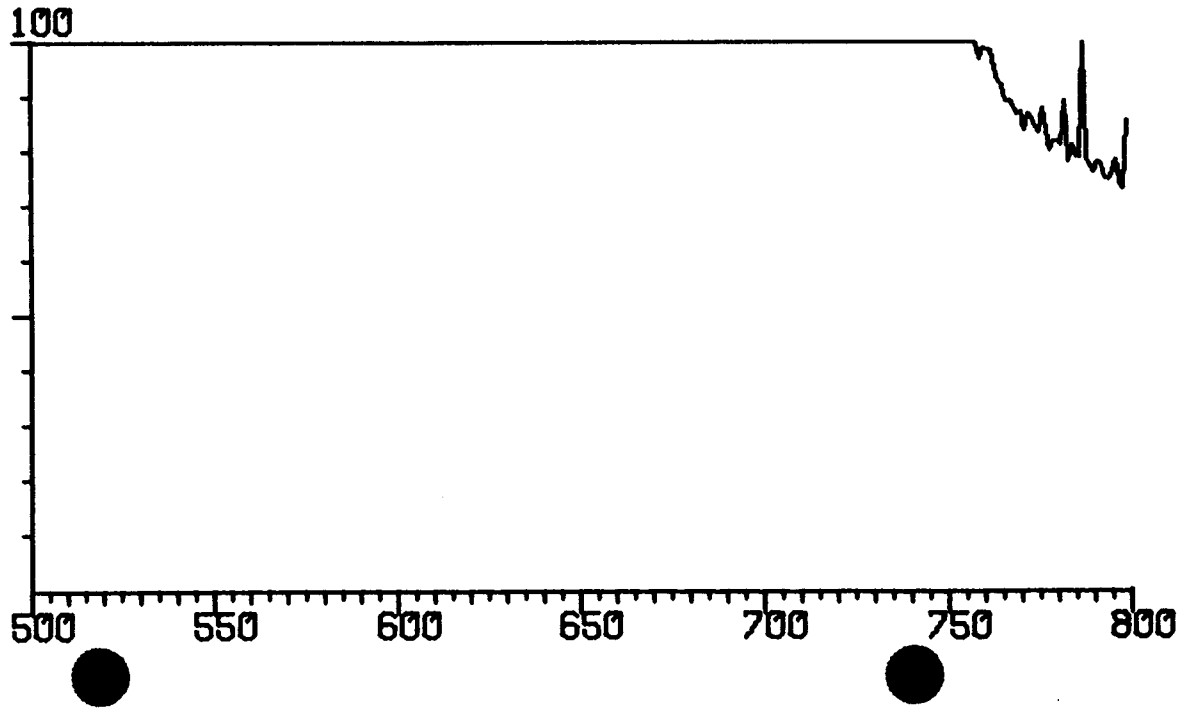




SALT SAMPLE 2302.6

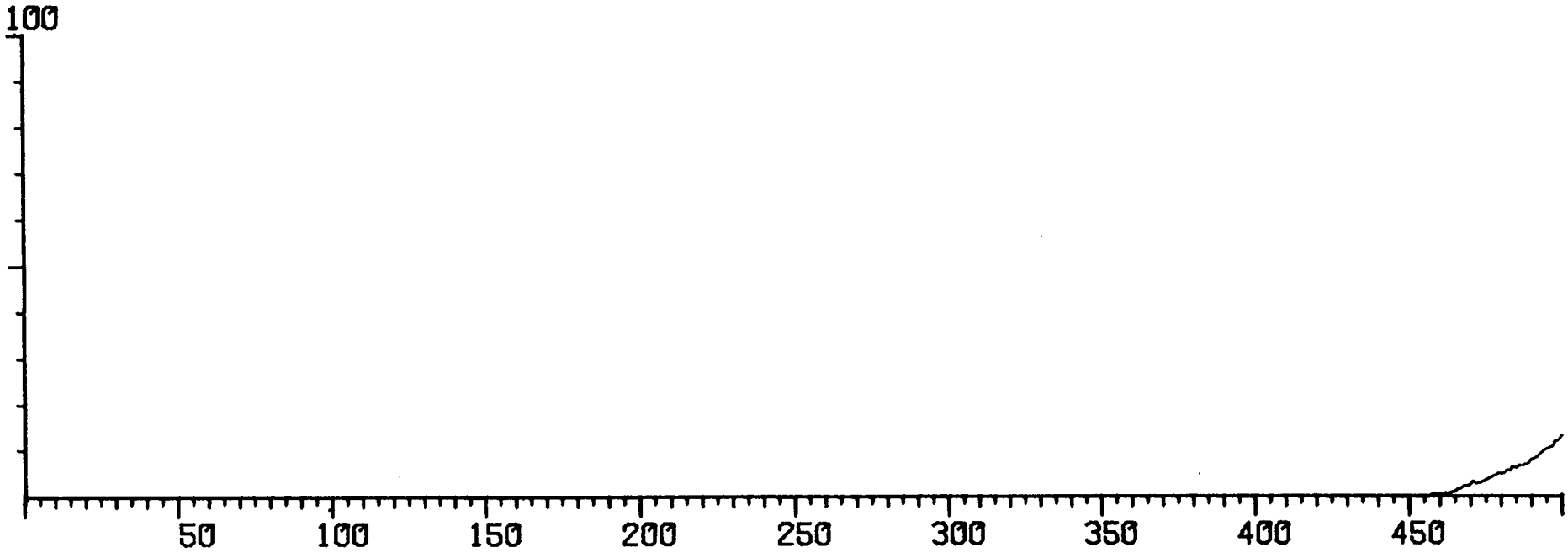
MASS 18 SEARCH X4

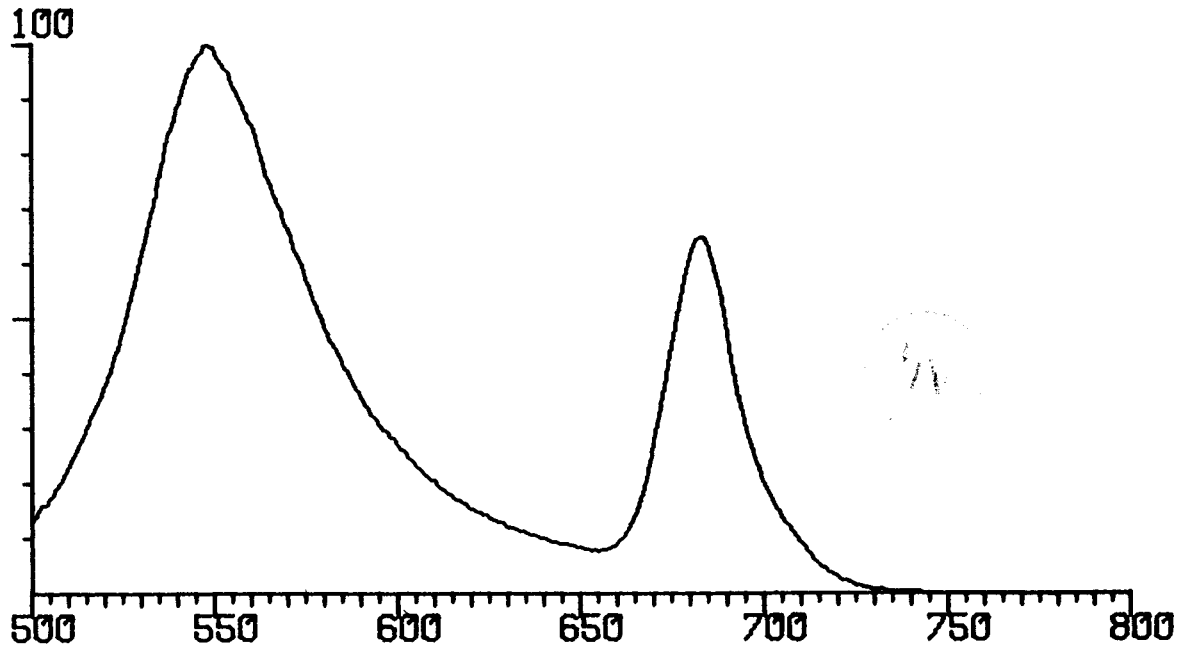




SALT SAMPLE 2302.6

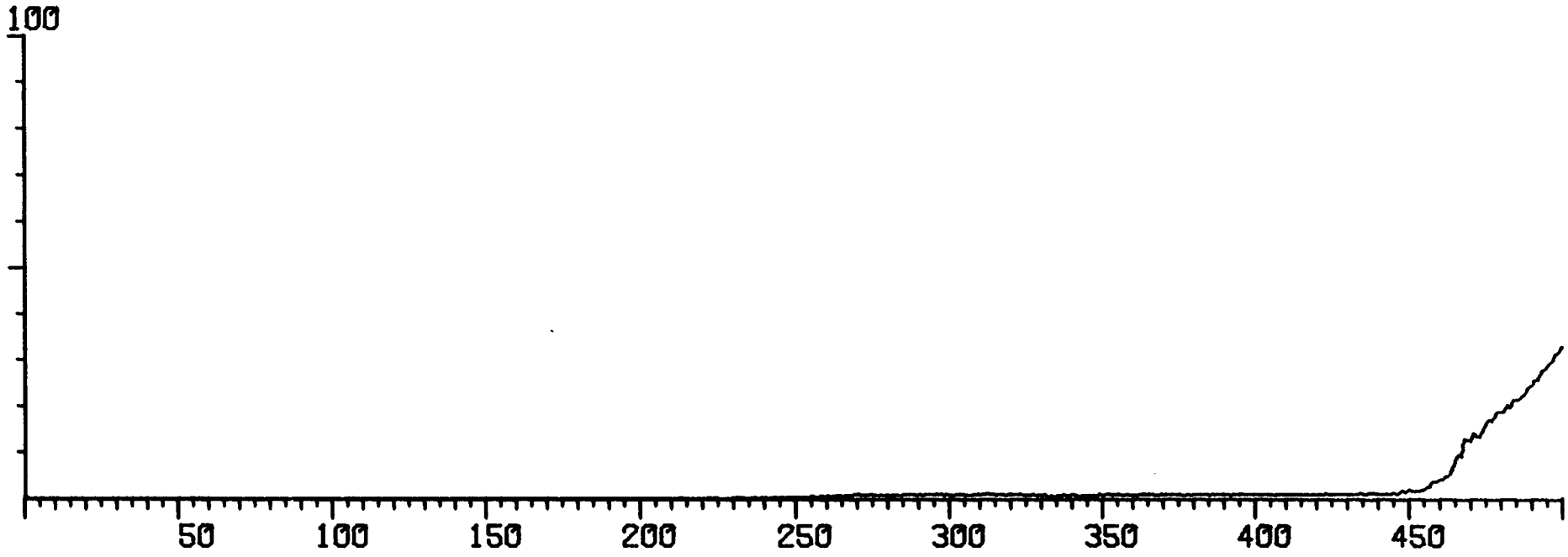
MASS 19 SEARCH X4

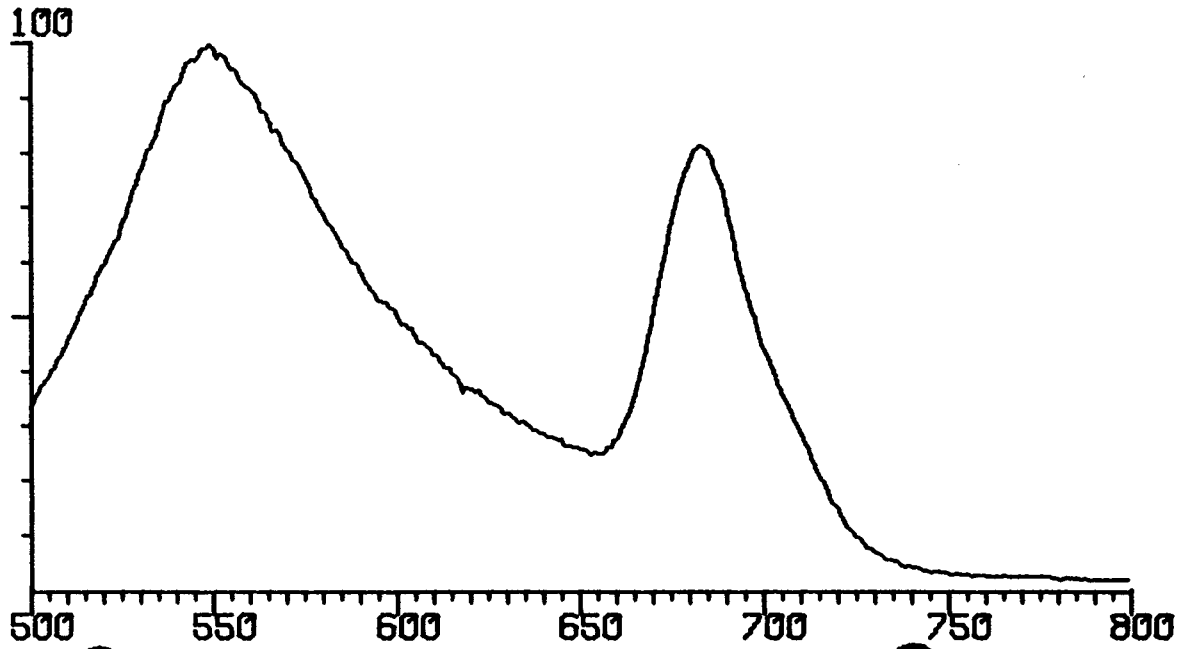




SALT SAMPLE 2302.6

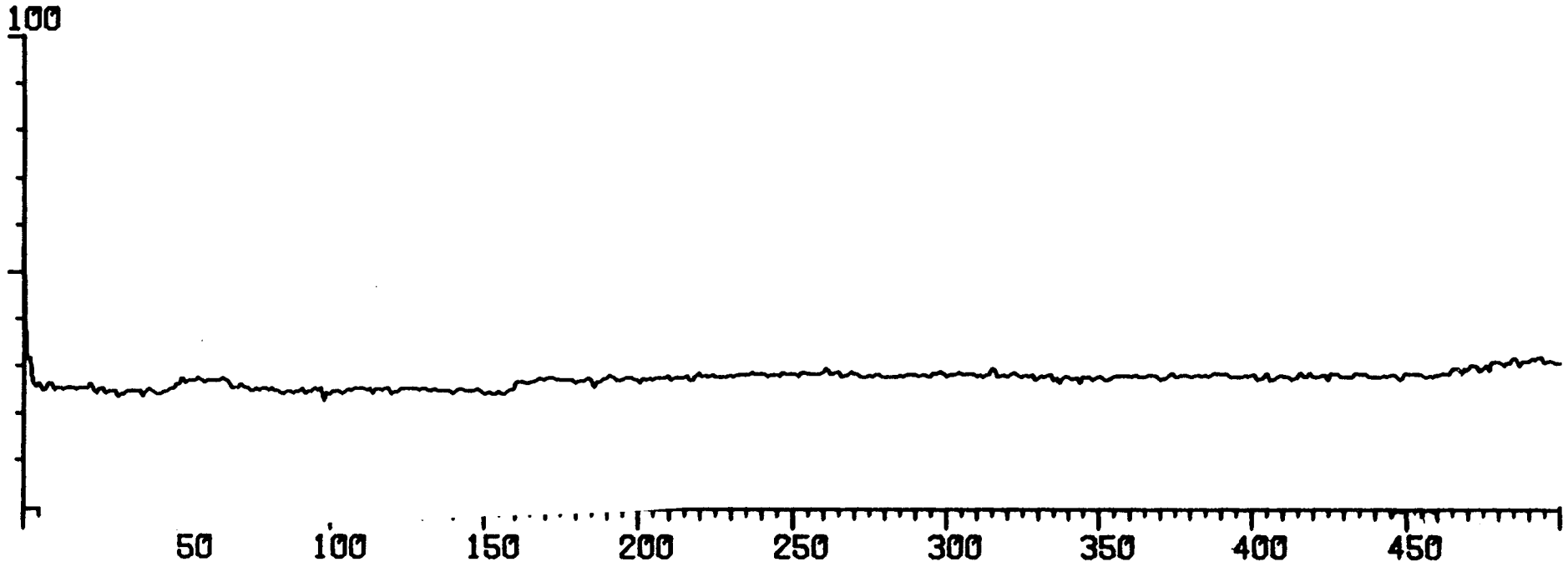
MASS 20 SEARCH X3

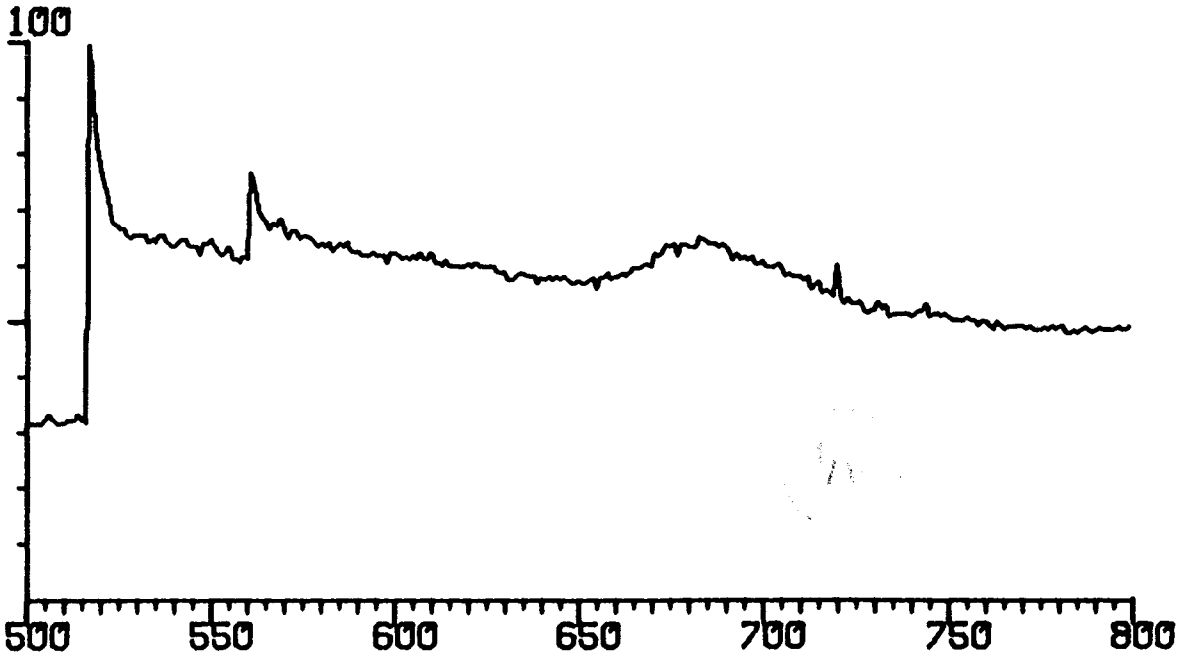




SAL SAMPLE 2302.6

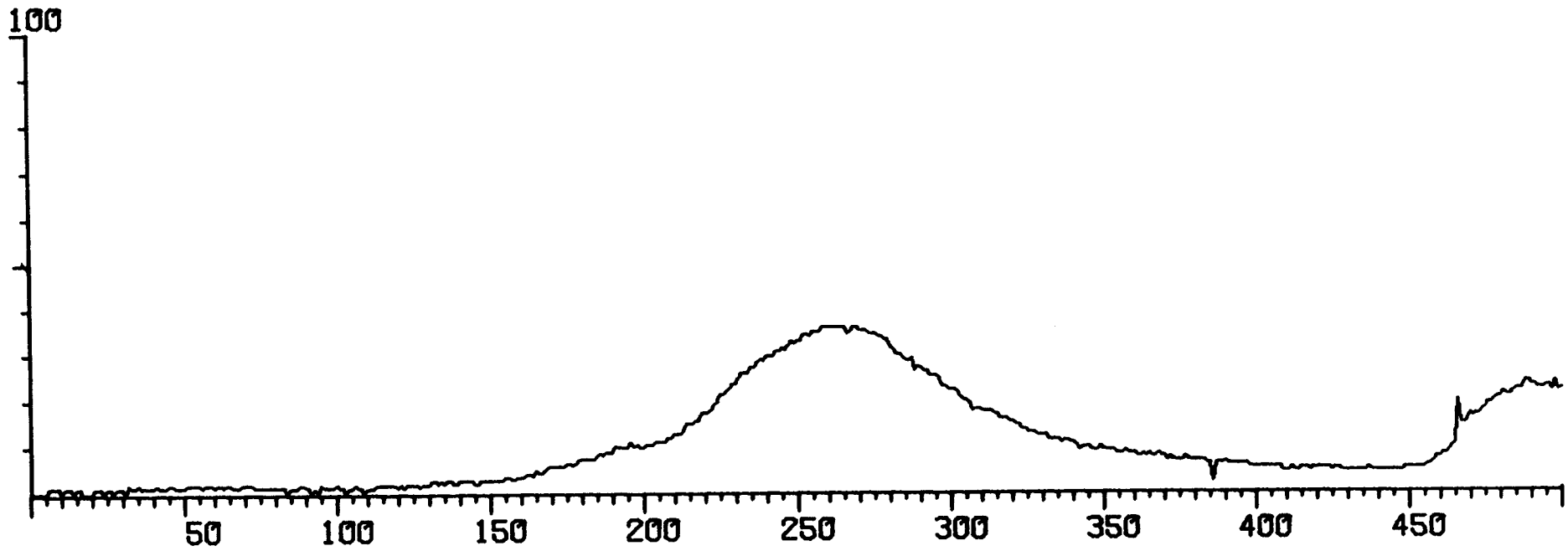
MASS 32 SEARCH X2

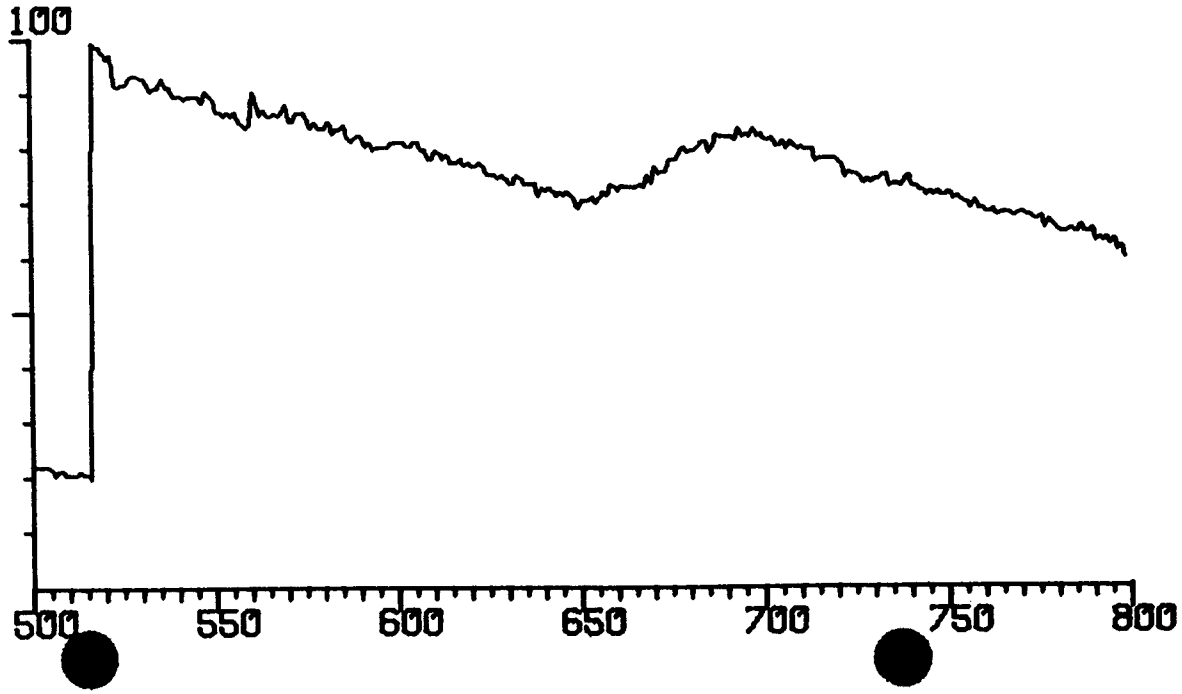




SALT SAMPLE 2302.6

MASS 36 SEARCH X2





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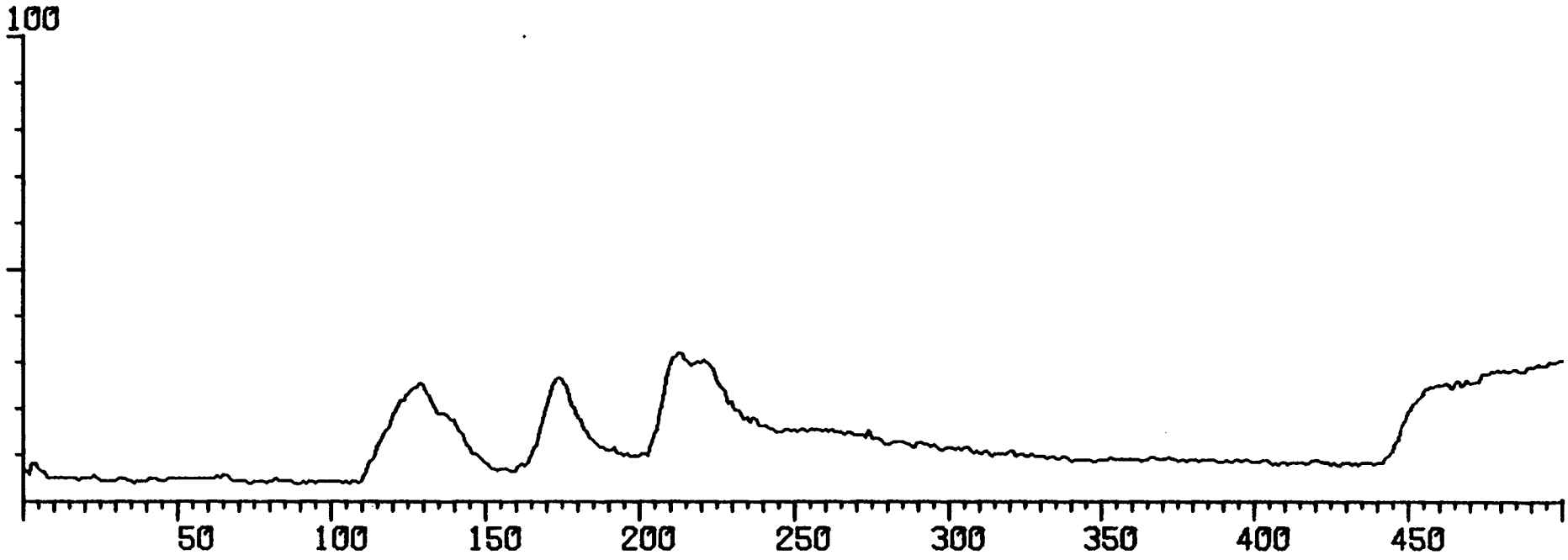
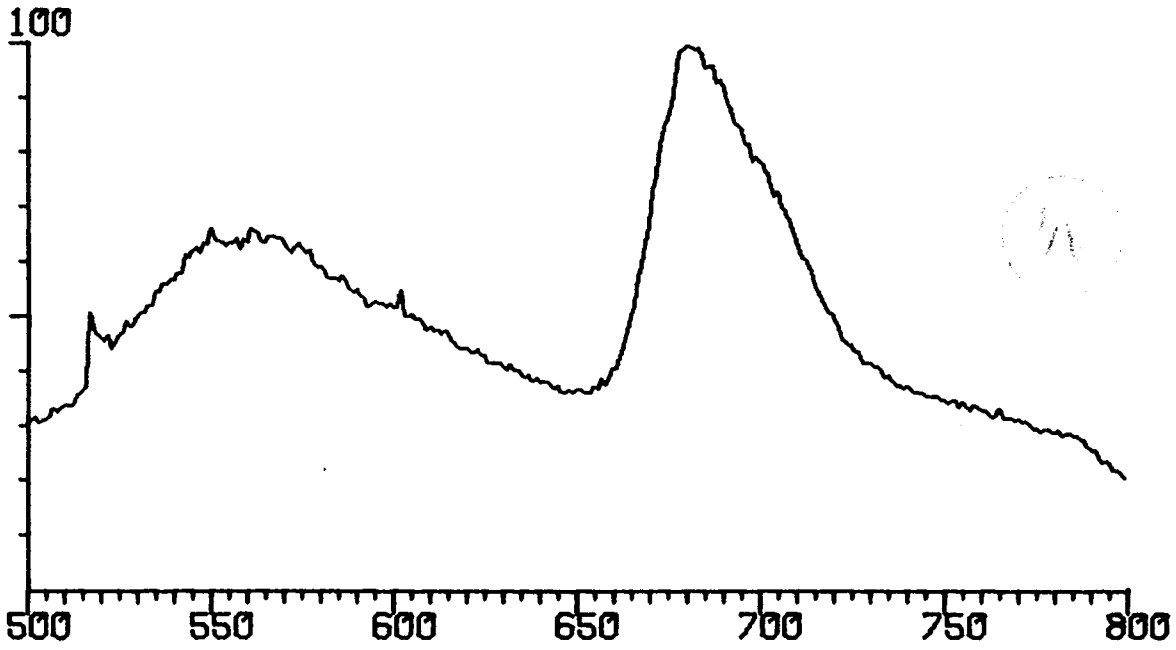
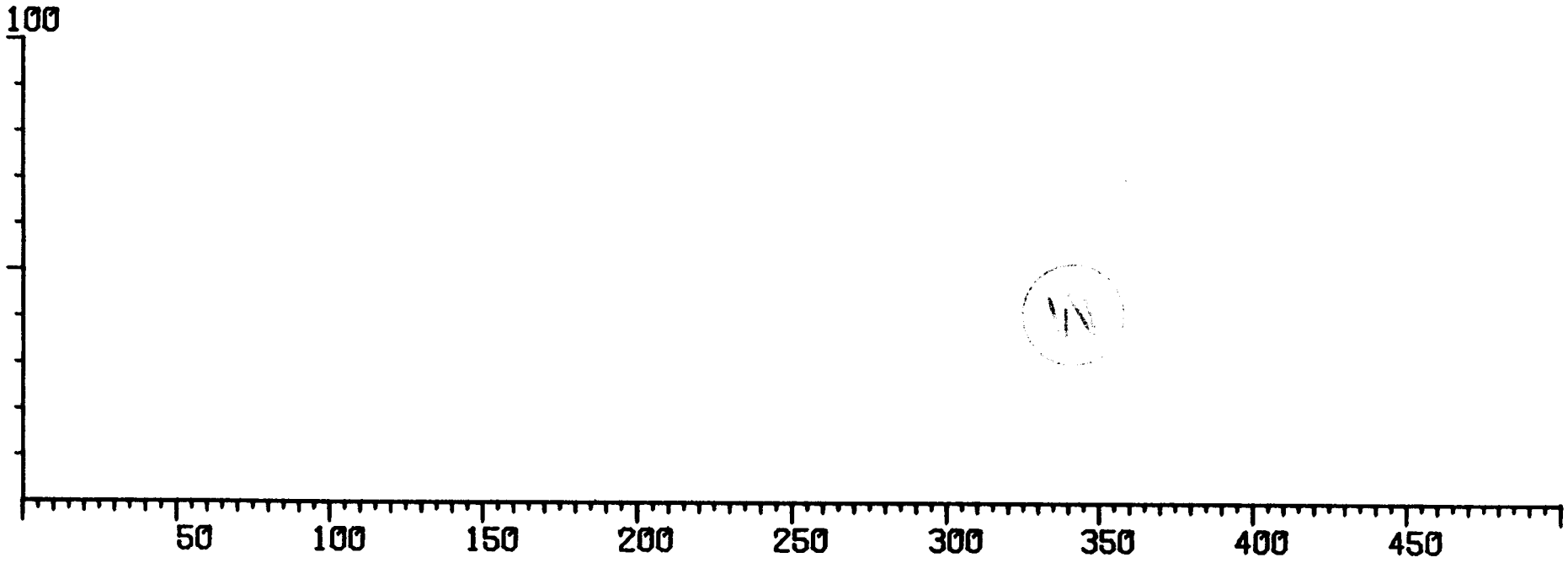
MASS 44 SEARCH X2

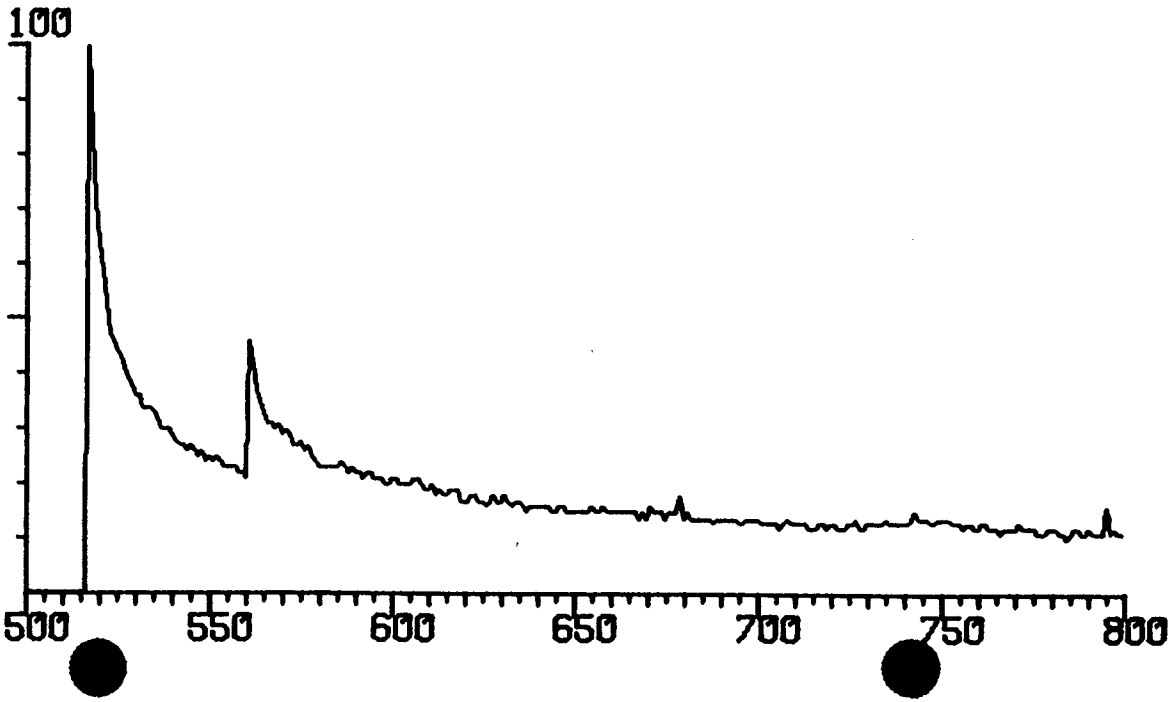




SALT SAMPLE 2302.6

MASS 48 SEARCH X1





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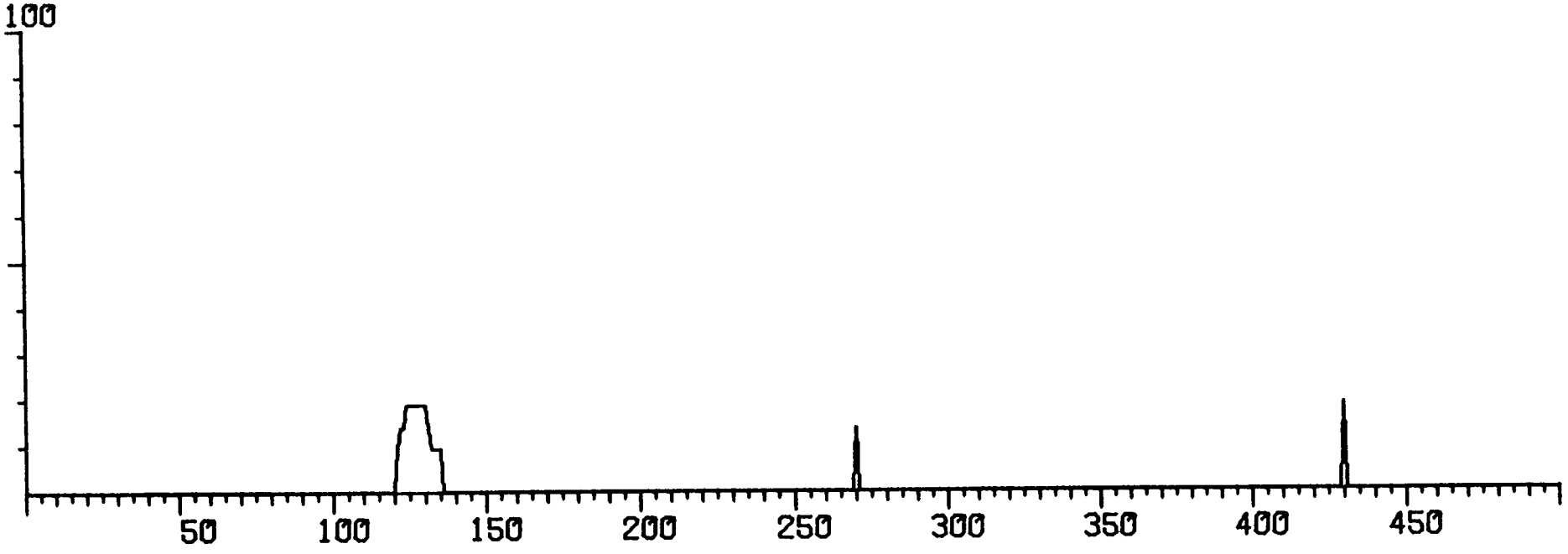
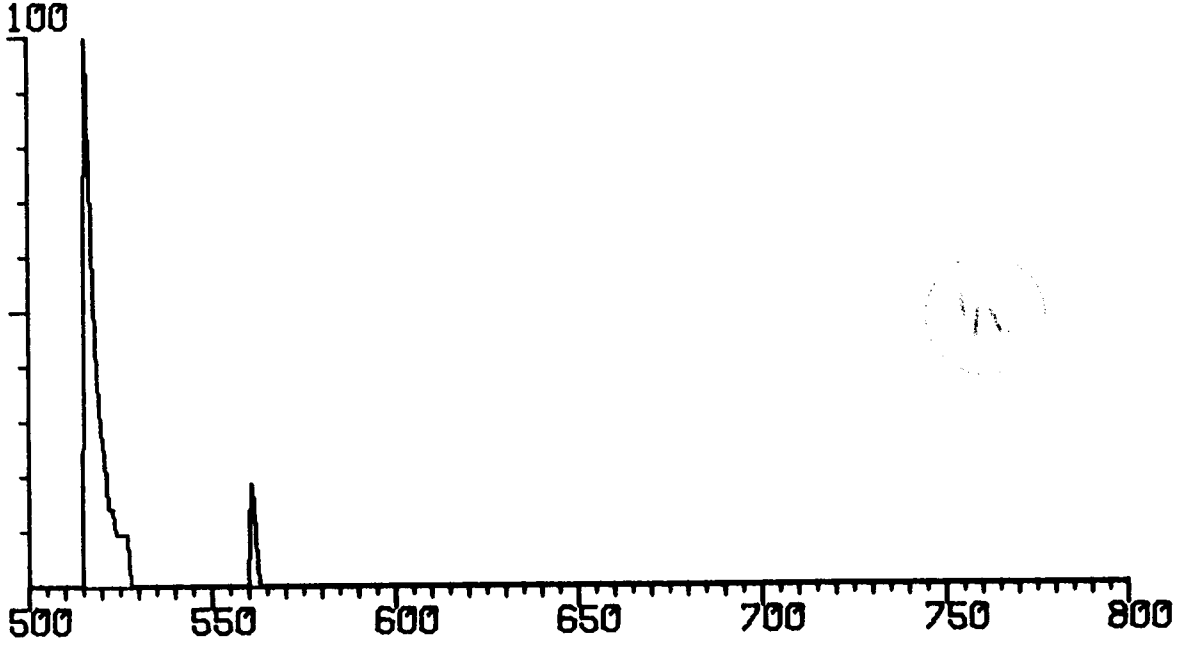
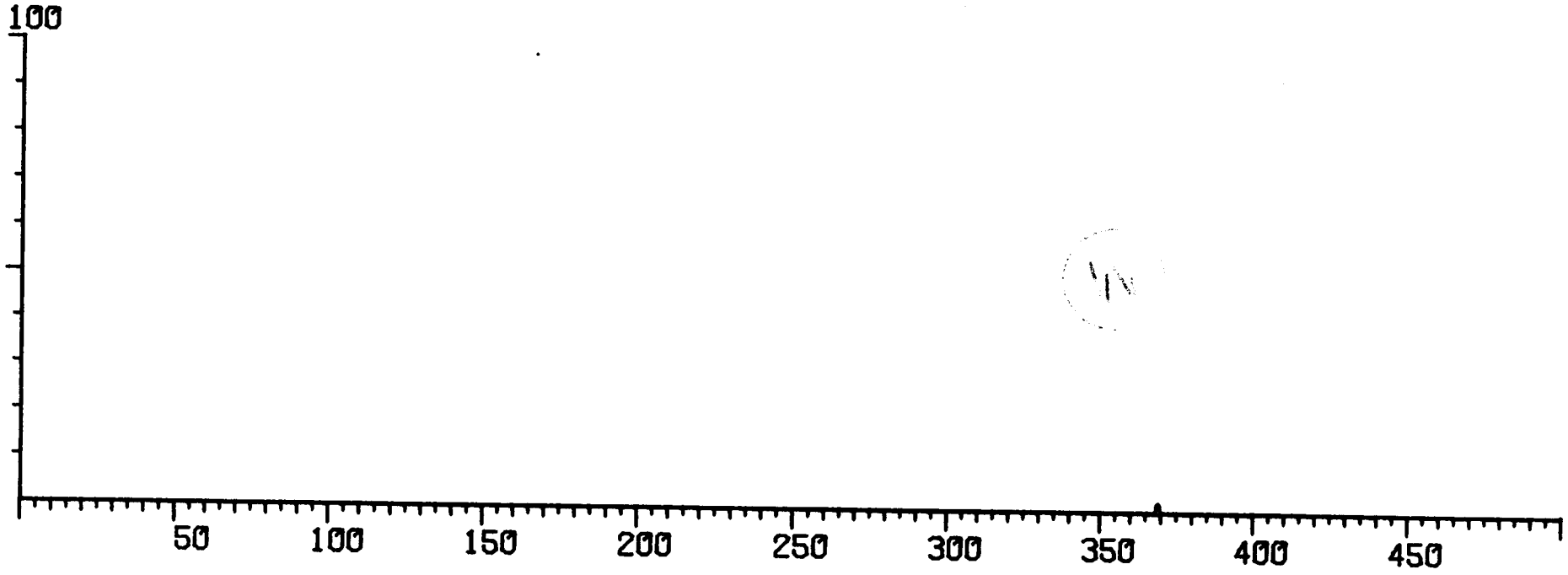
MASS 80 SEARCH X1

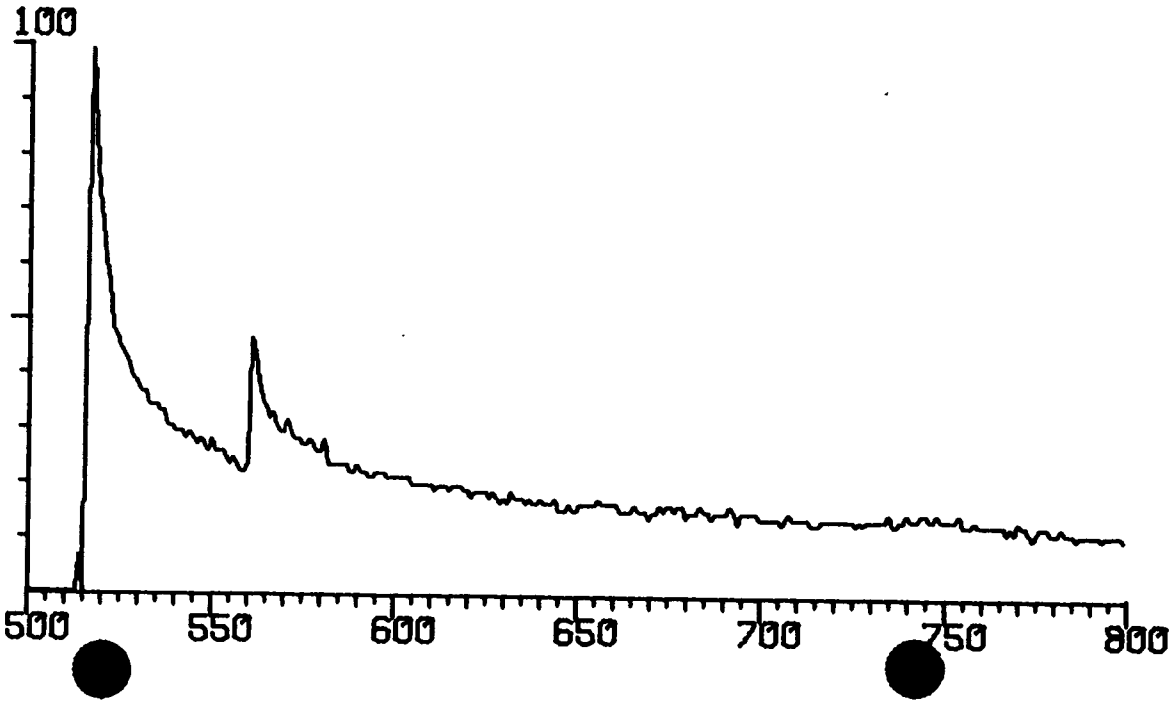




SALT SAMPLE 2302.6

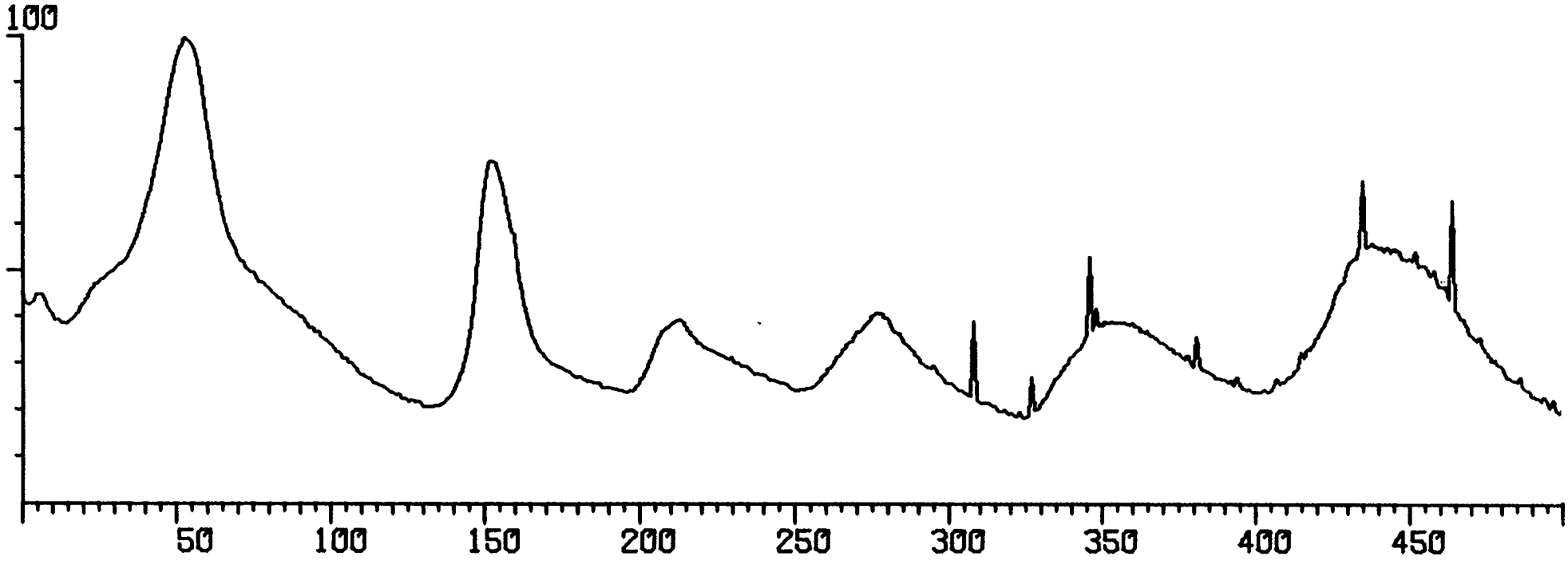
MASS 64 SEARCH X1





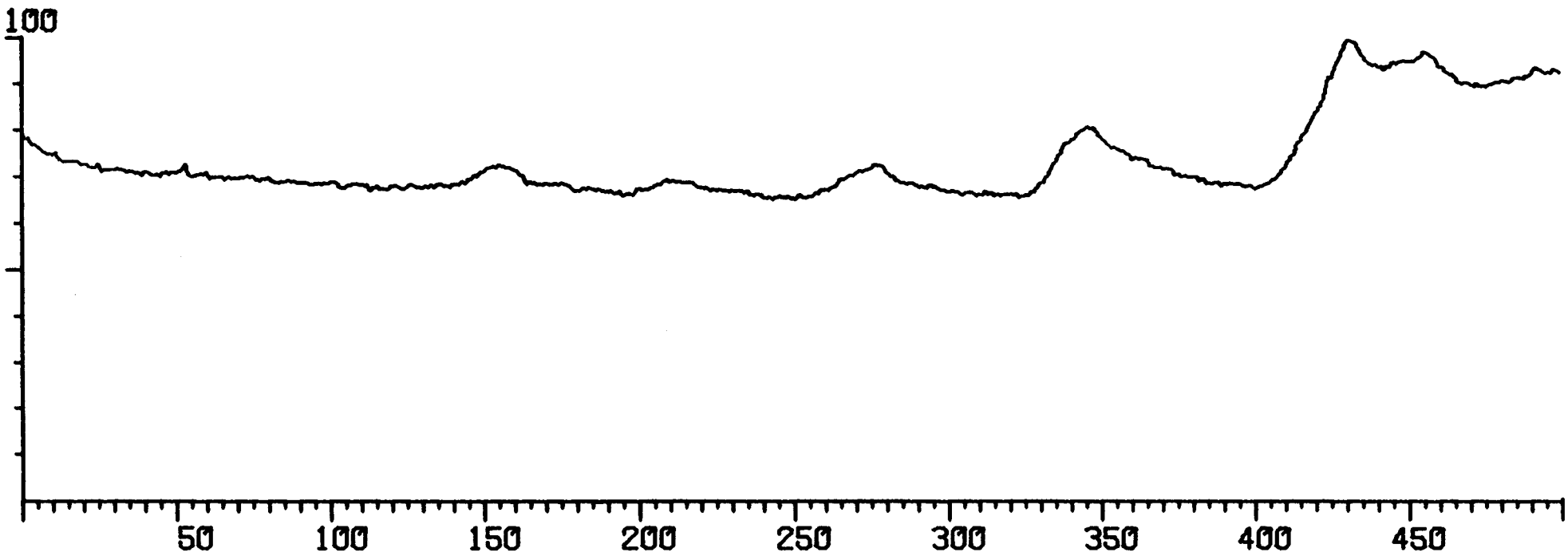
SALT SAMPLE 2516.3

MASS 18 SEARCH X3



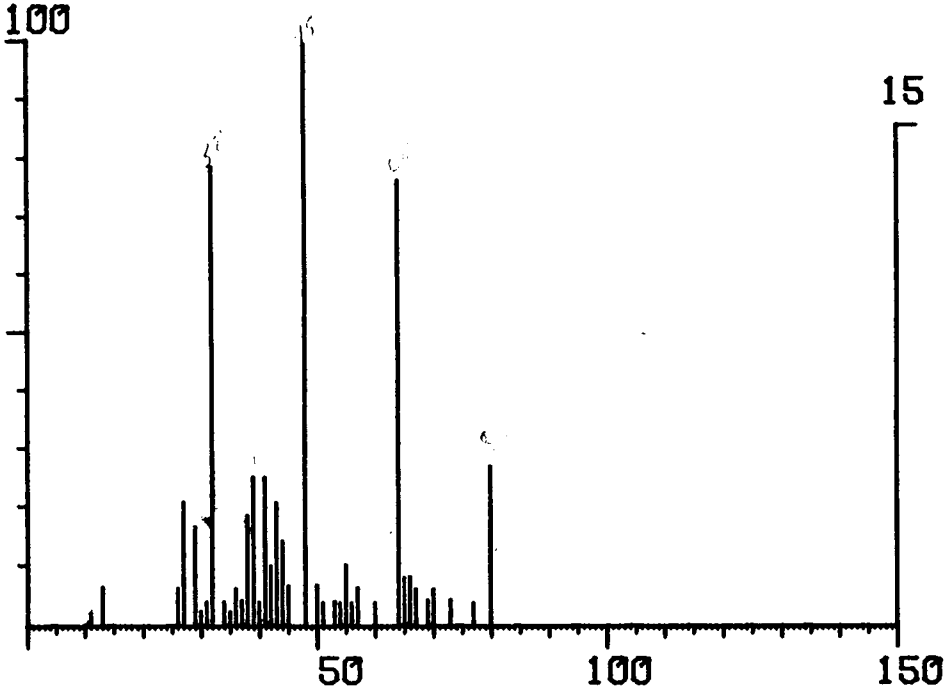
SALT SAMPLE 2516.3

MASS 28 SEARCH X3



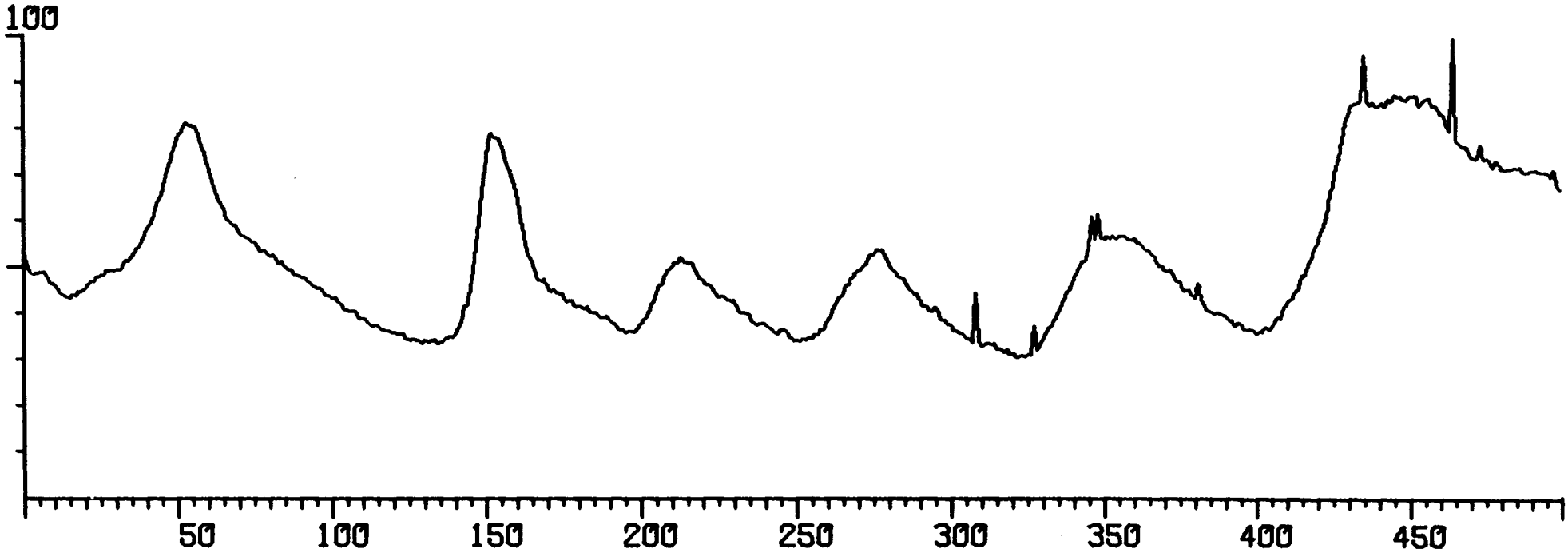
SALT SAMPLE 2302.6

517 CH 517 - CH 522 X1



SALT SAMPLE 2516.3

TOTAL ION CHROMATOGRAM



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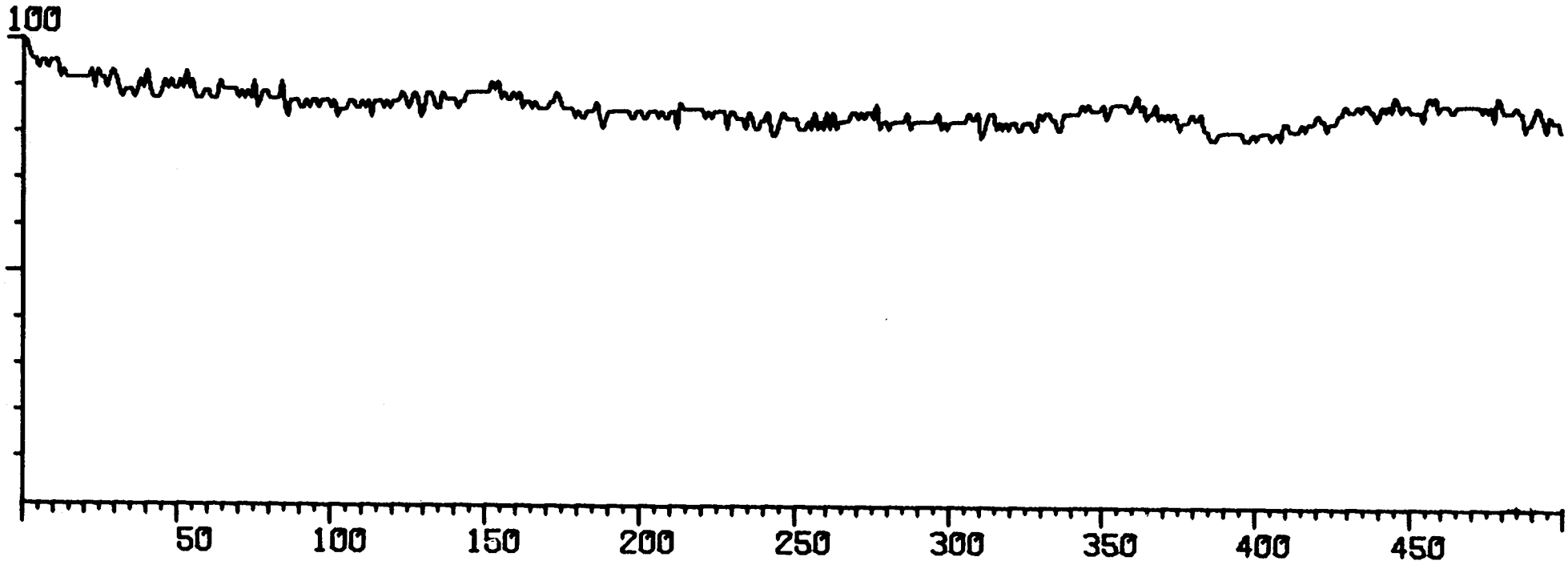
MASS 32 SEARCH X2



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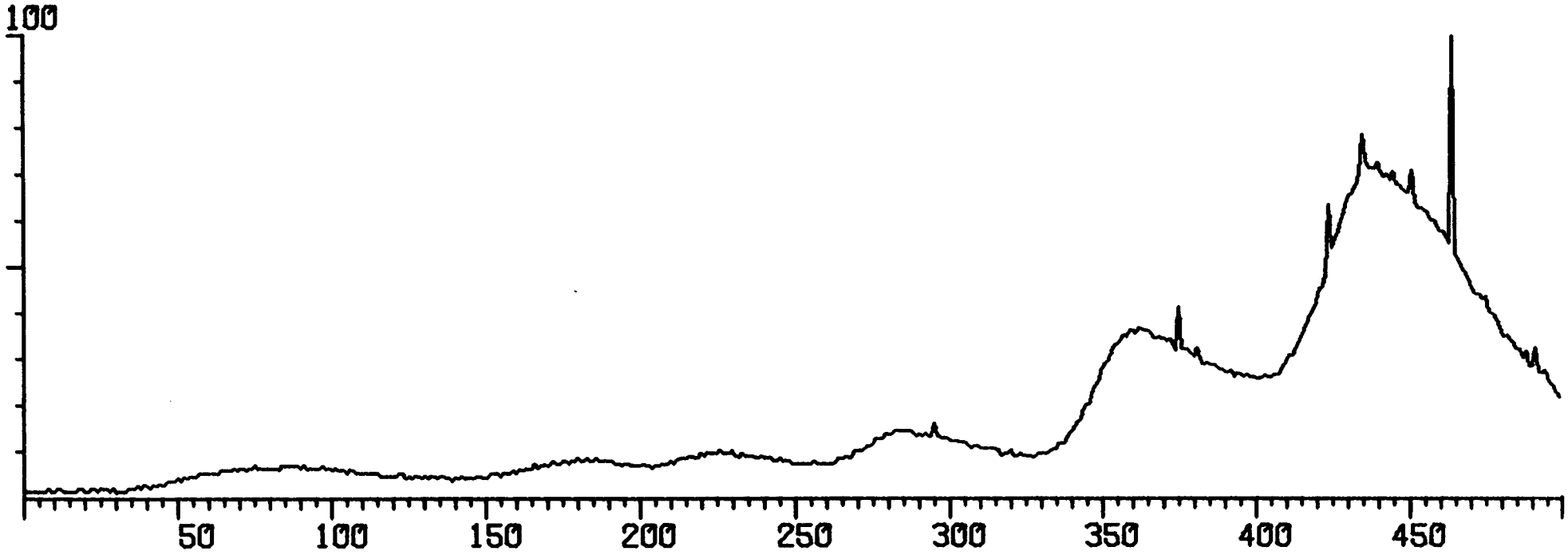
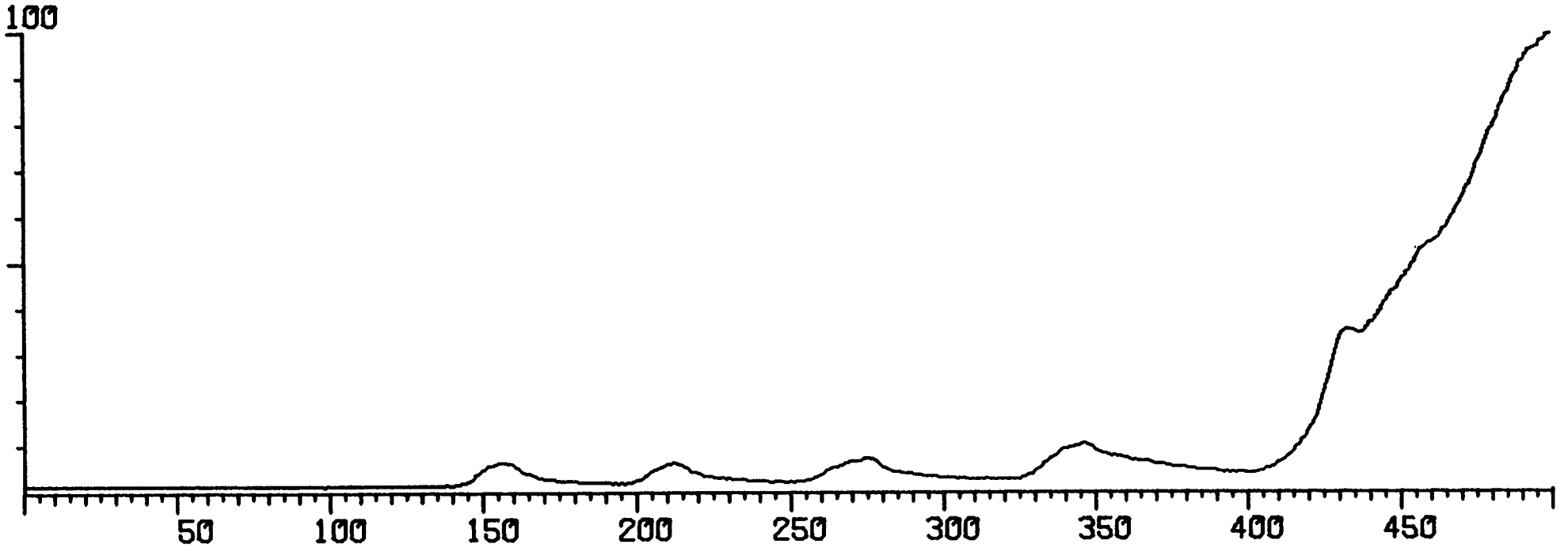
MASS 36 SEARCH X2



SALT SAMPLE 2516.3

MASS 44 SEARCH X3



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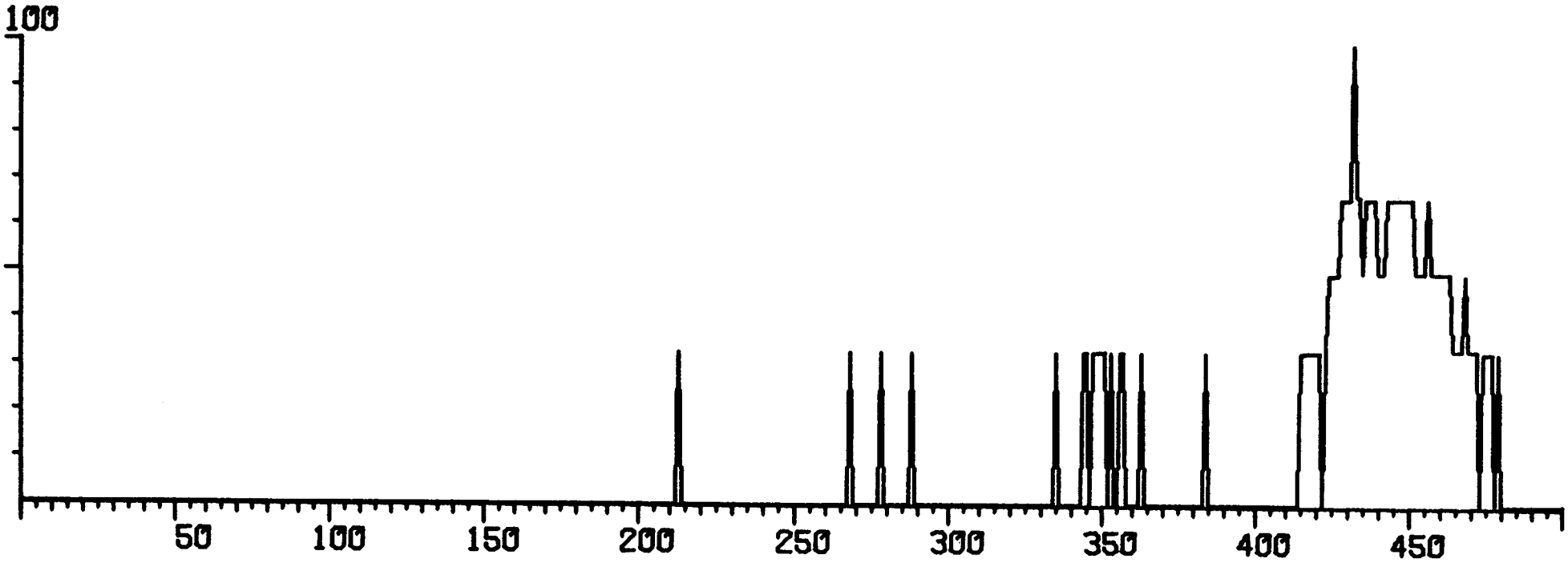
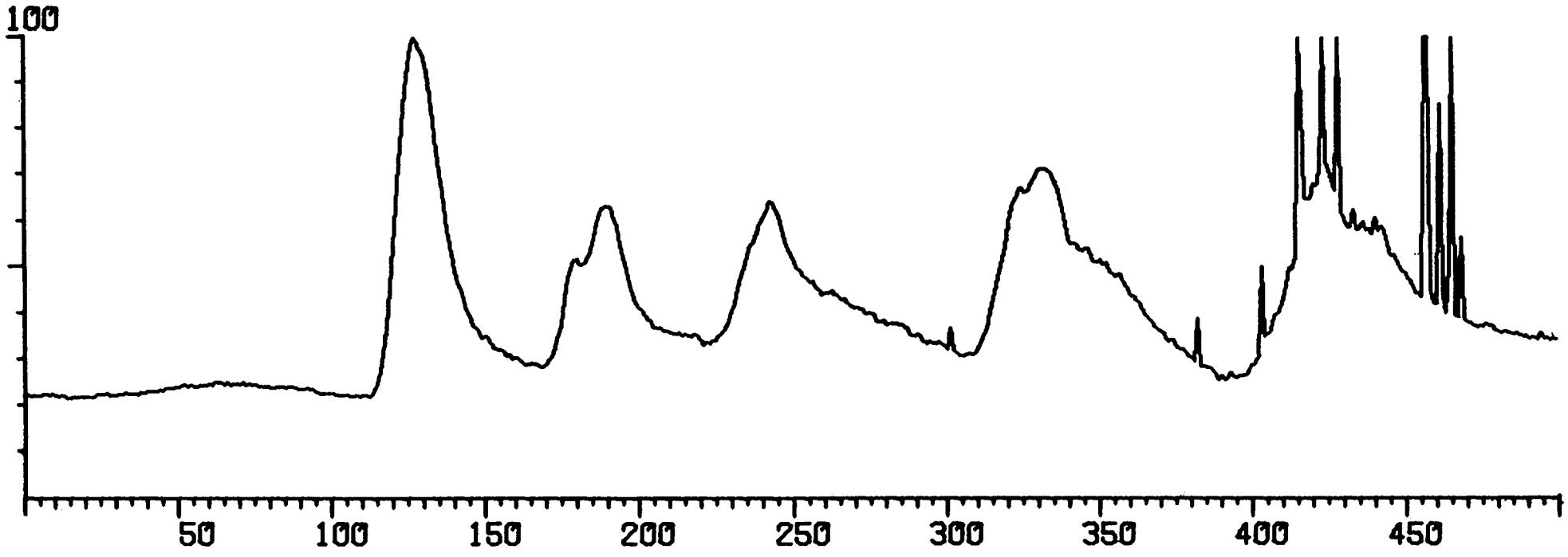
MASS 48 SEARCH X1



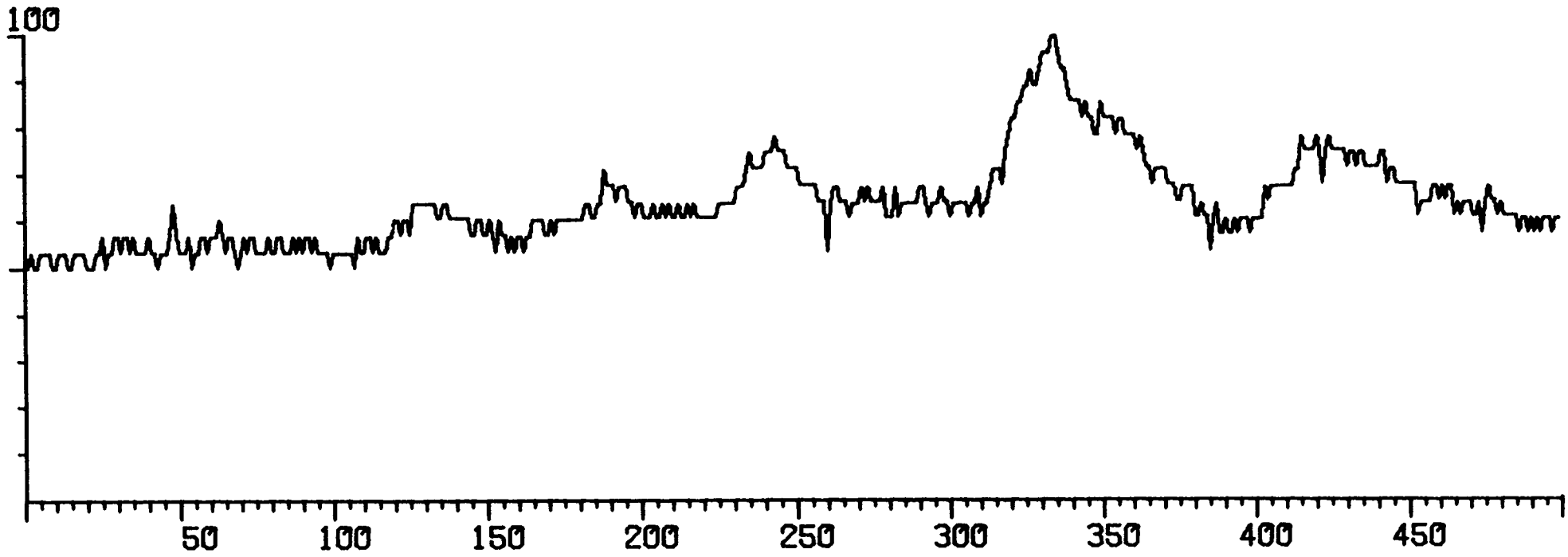
SALT SAMPLE 2658.5

TOTAL ION CHROMATOGRAM



SALT SAMPLE 2658.5

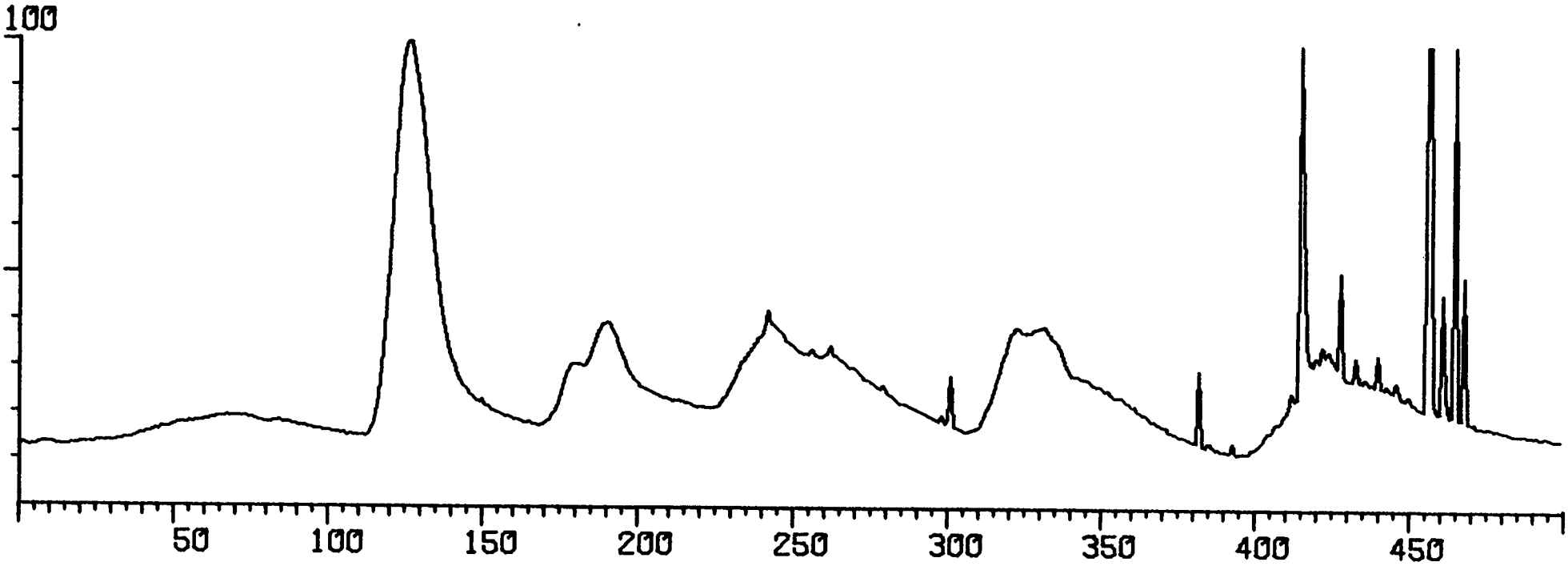
MASS 14 SEARCH X1



SALT SAMPLE

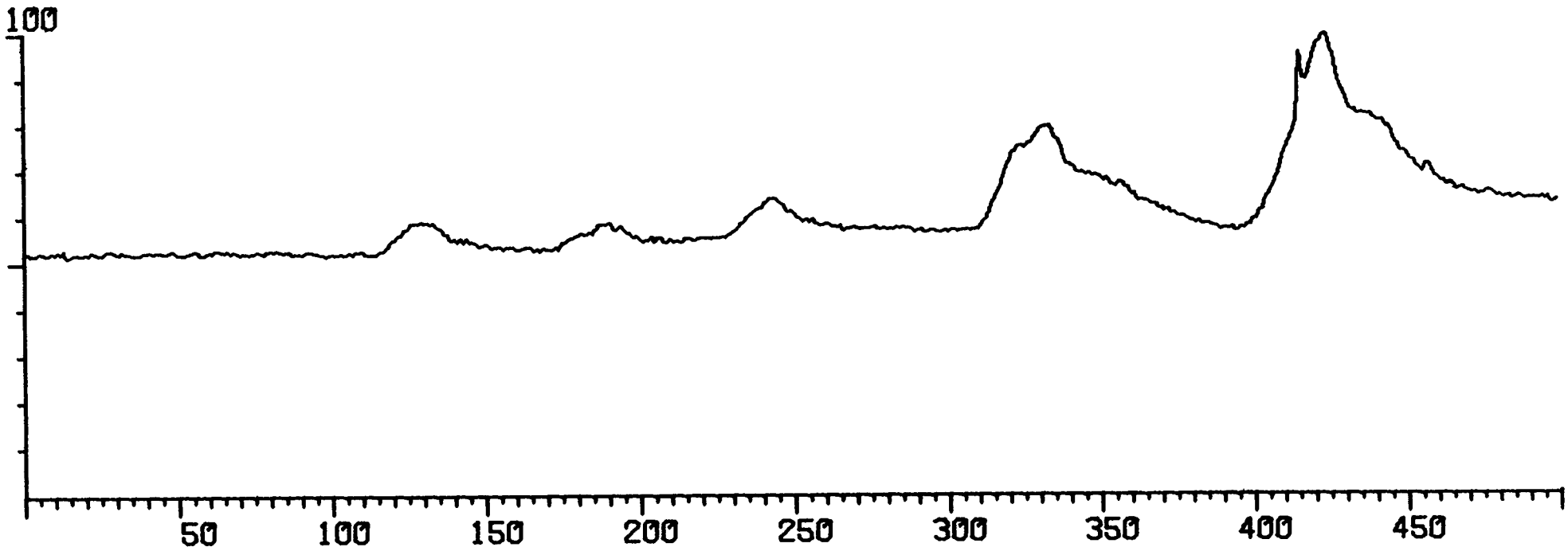
2658.5

MASS 18 SEARCH X4 (CH 127 = 100%)



SALT SAMPLE 2658.5

MASS 28 SEARCH X3



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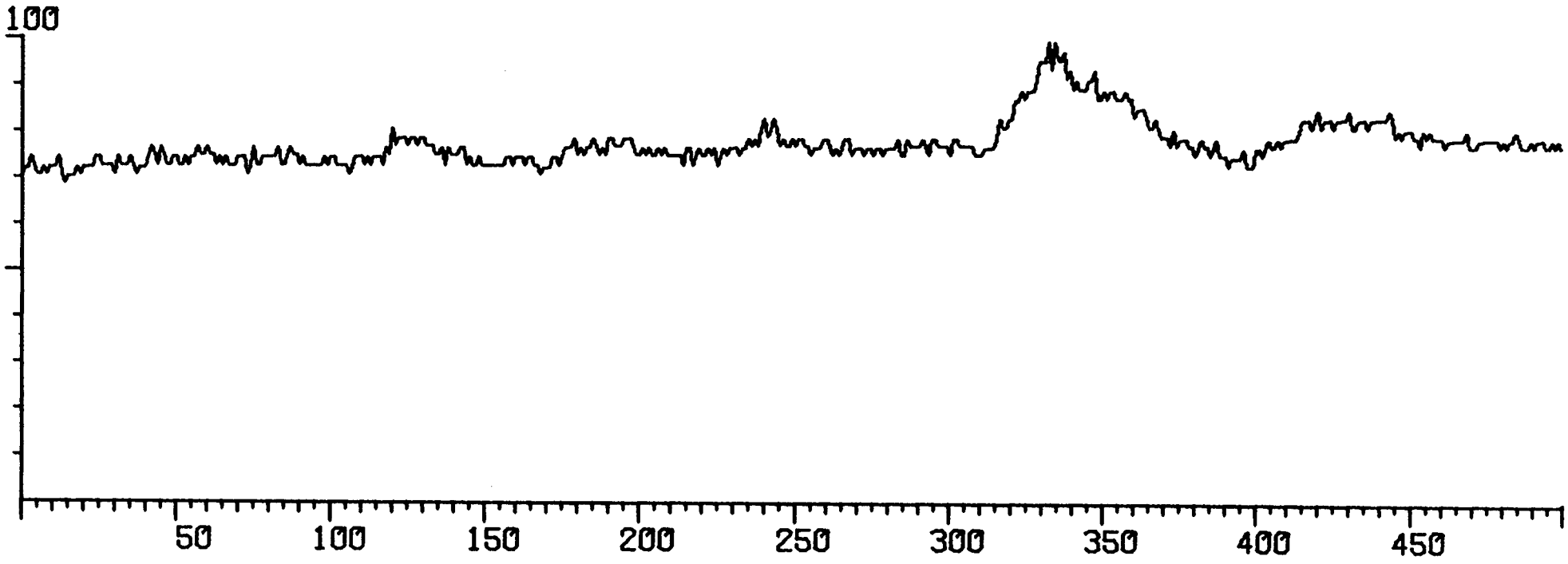
MASS 32 SEARCH X1



SALT SAMPLE 2658.5

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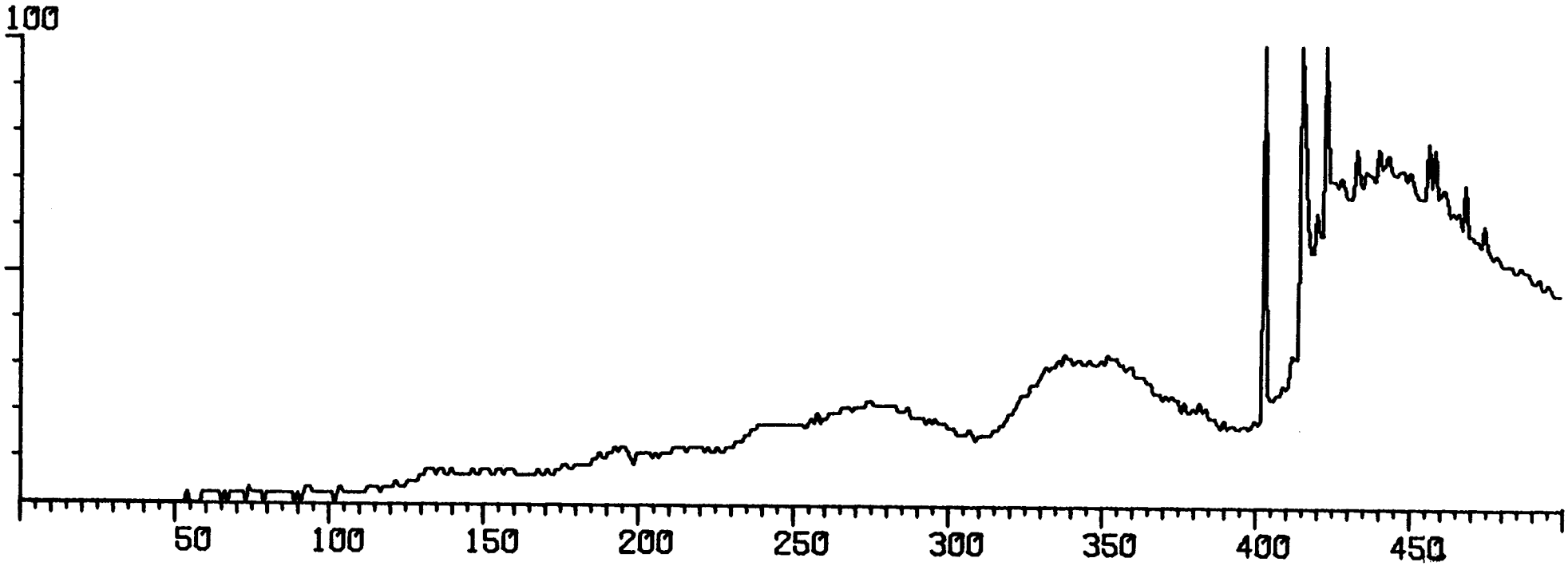
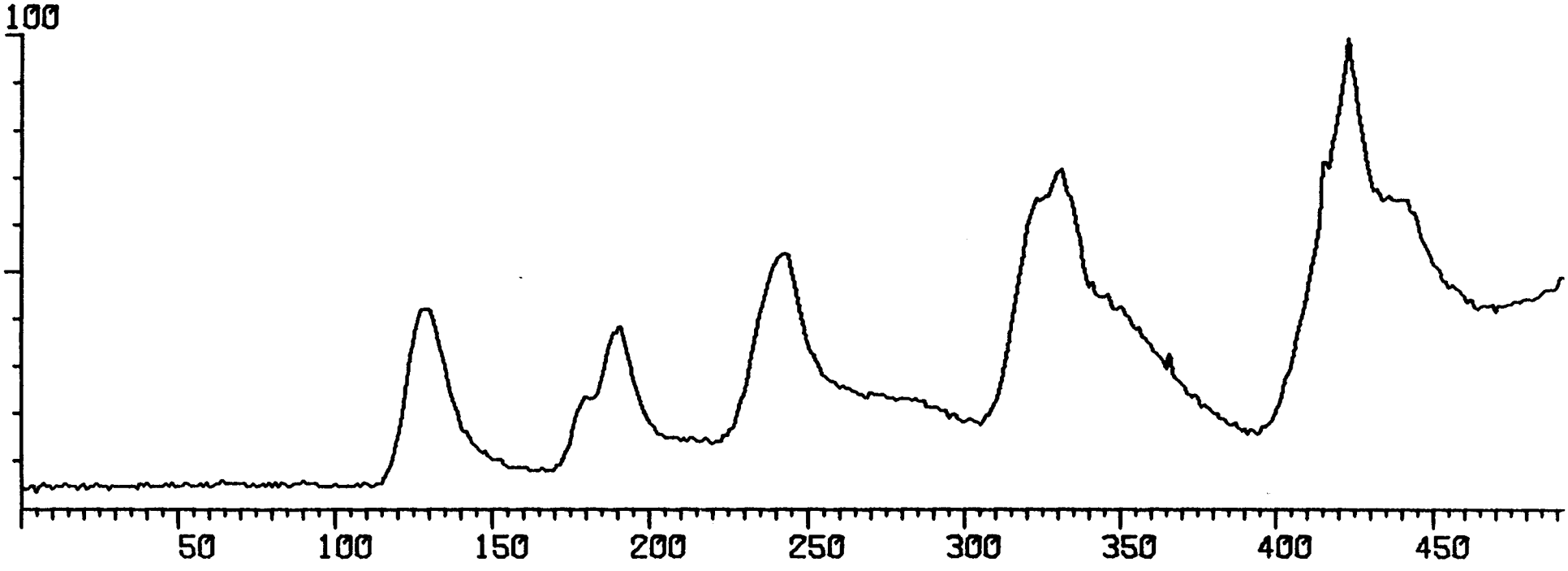


SALT SAMPLE 2658.5

MASS 44 SEARCH X2



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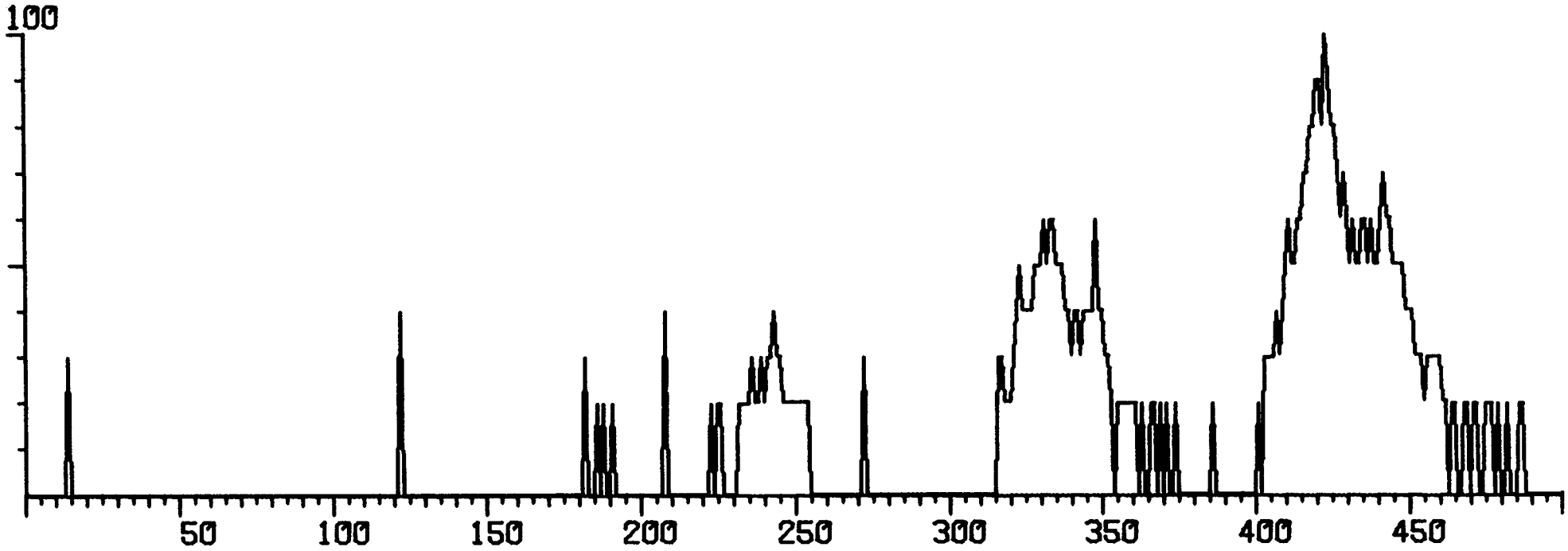
MASS 48 SEARCH X1



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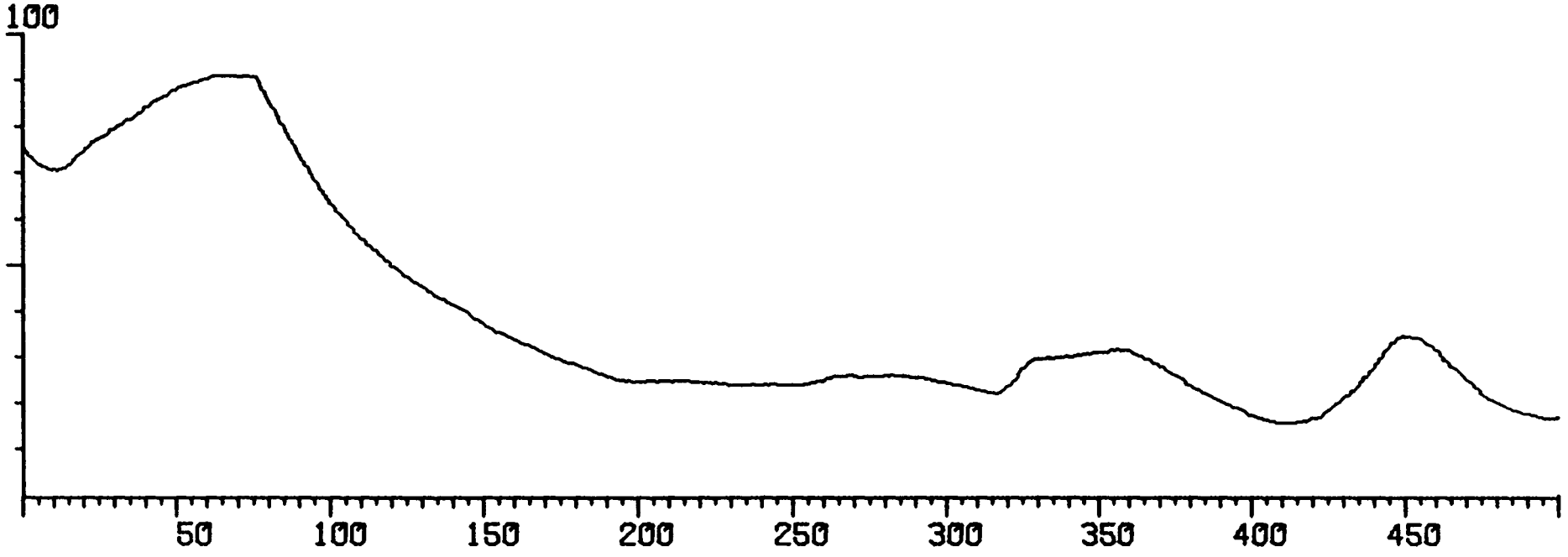
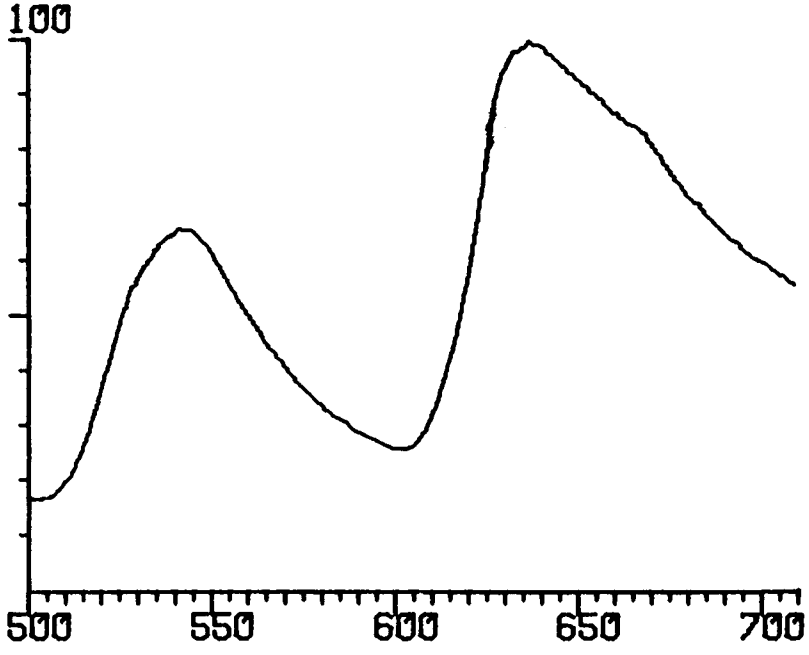
TOTAL ION CHROMATOGRAM





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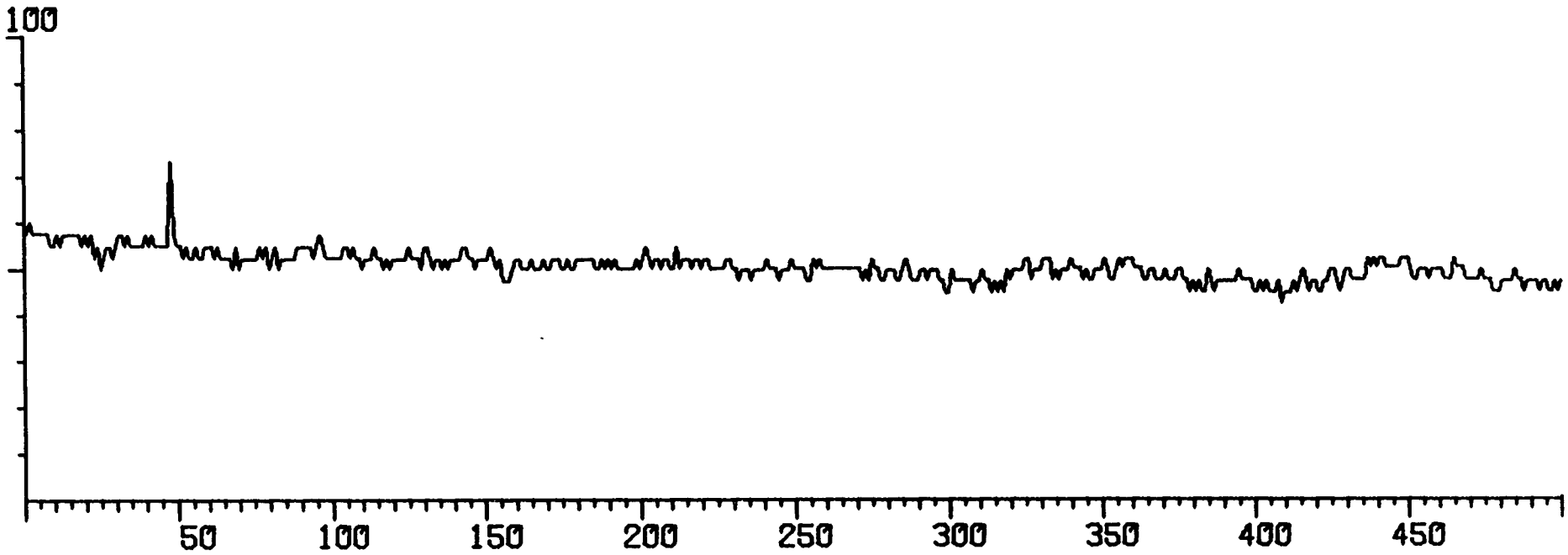
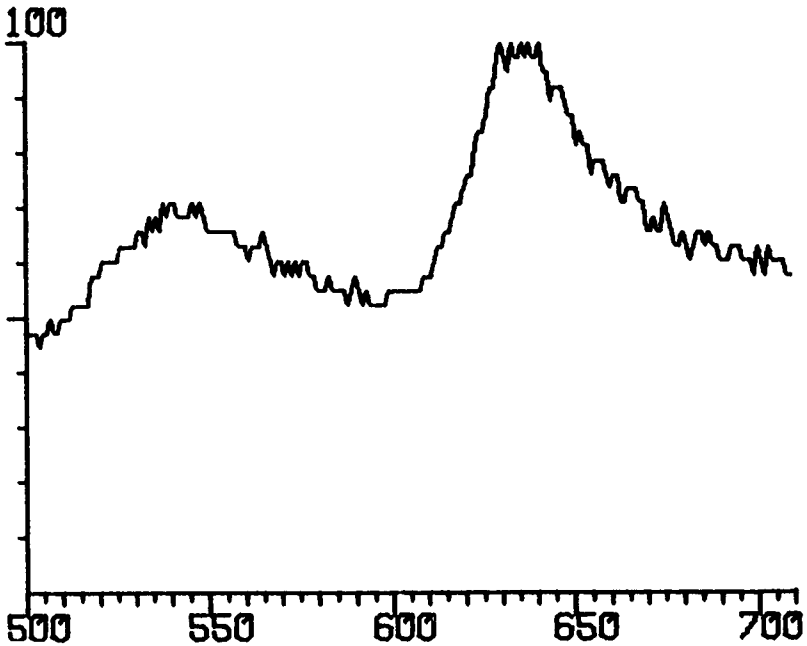
MASS 14 SEARCH X1





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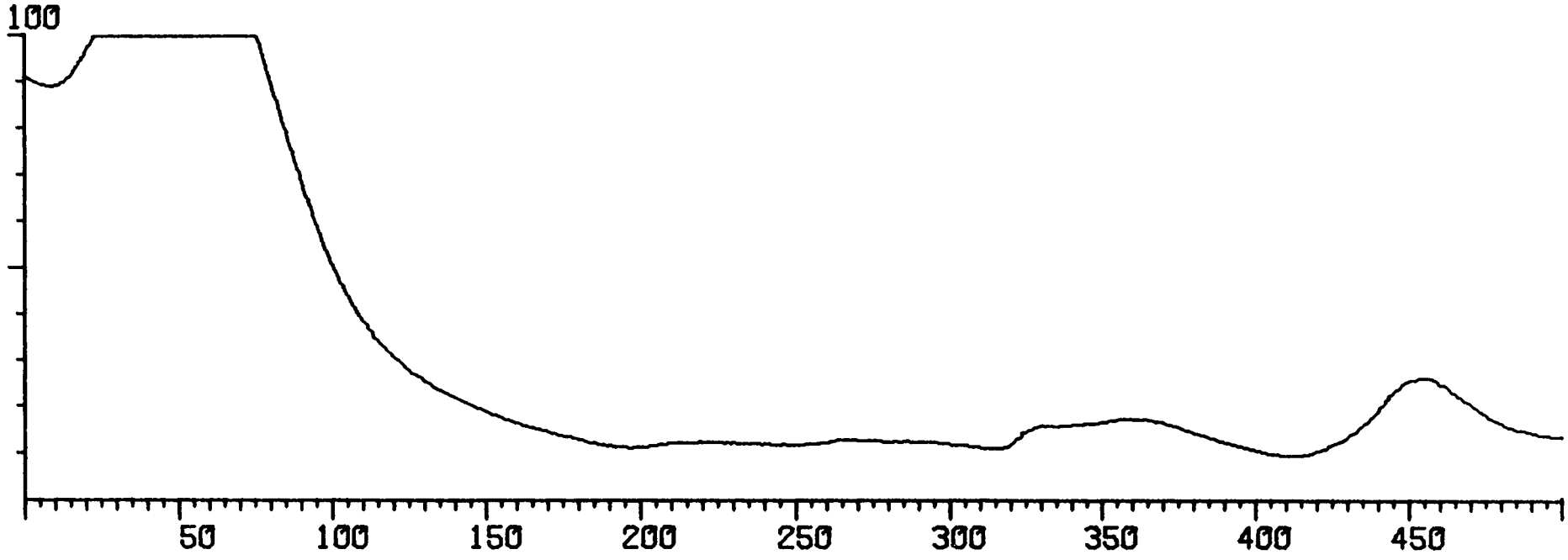
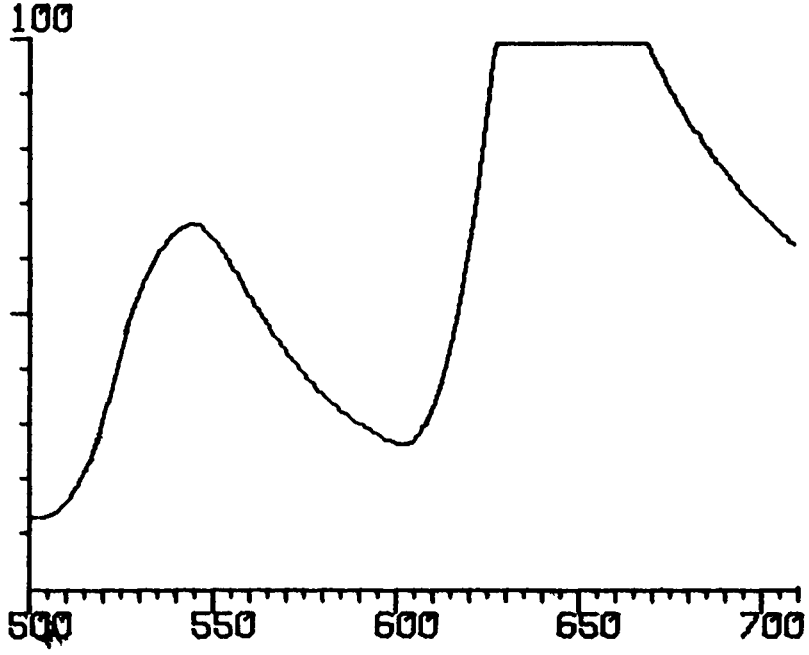
MASS 18 SEARCH X4





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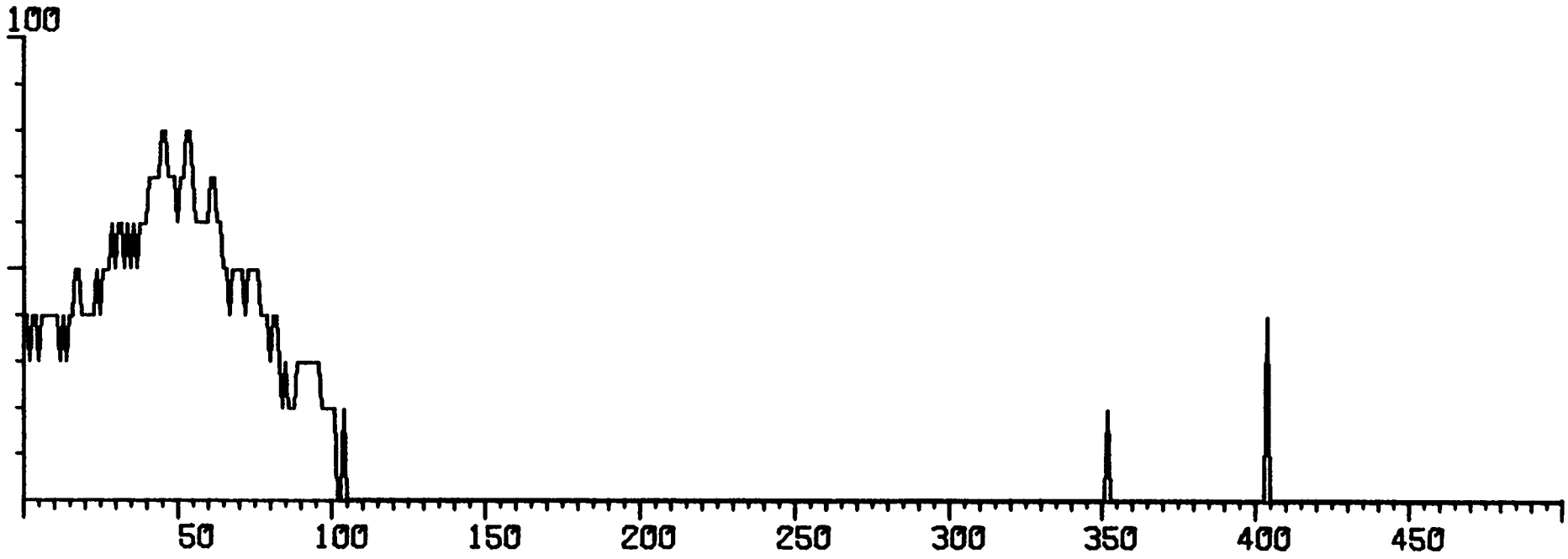

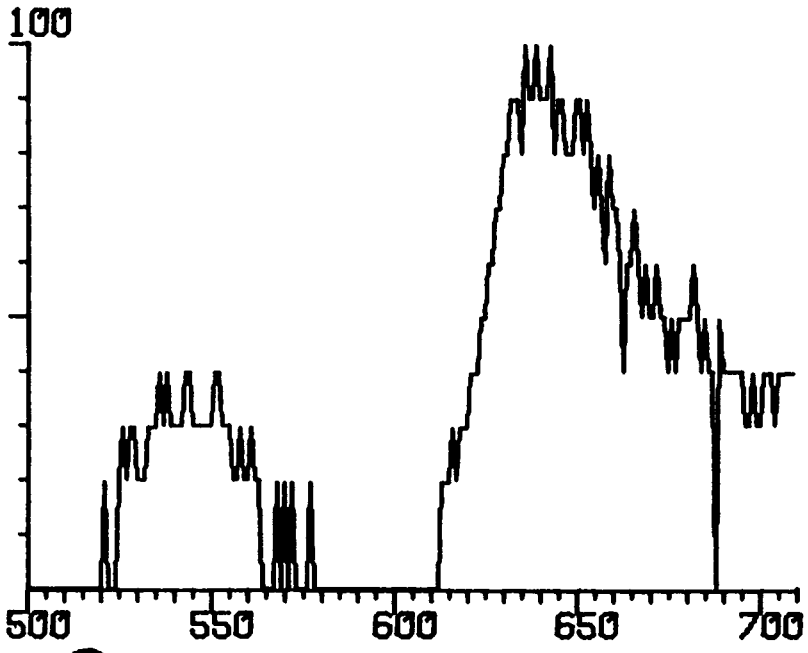

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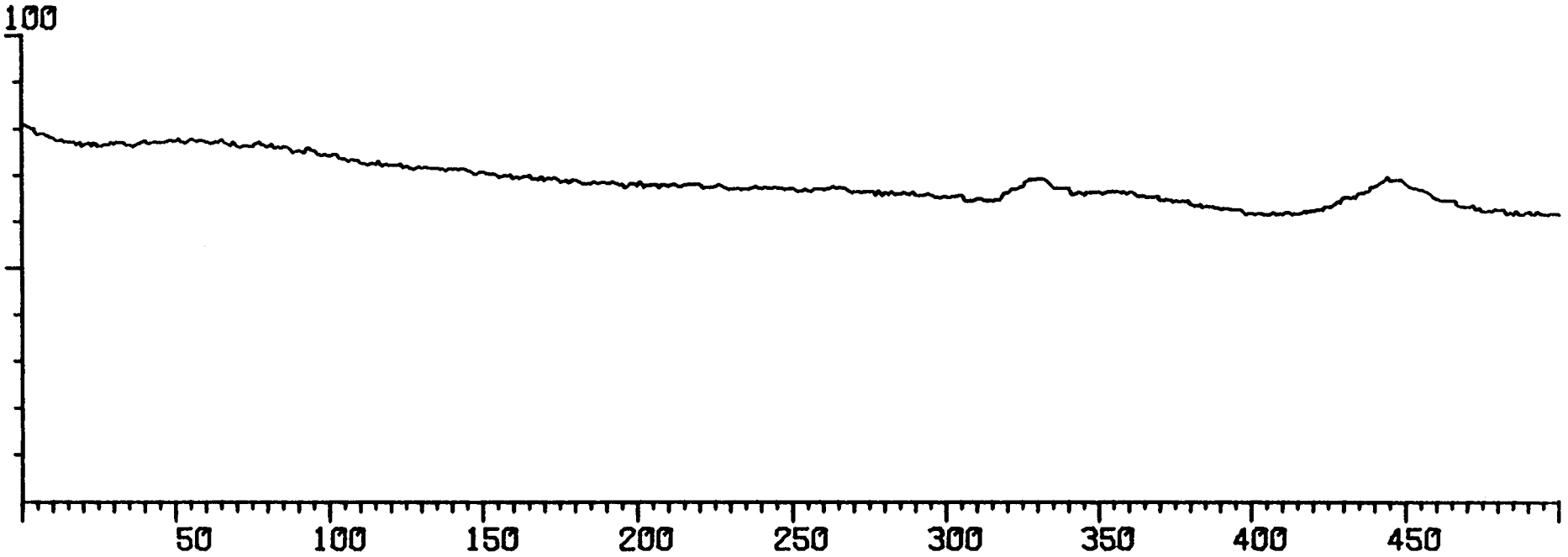
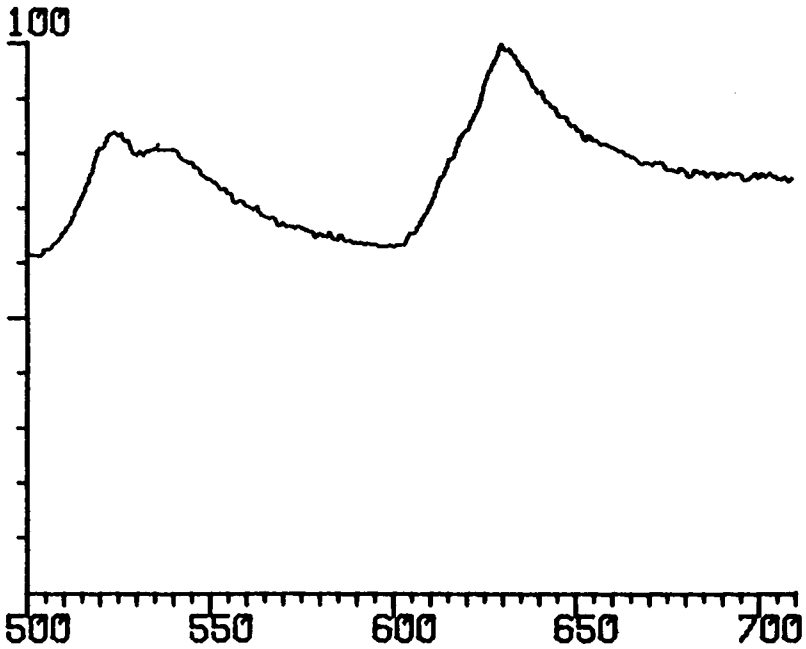
MASS 28 SEARCH X3





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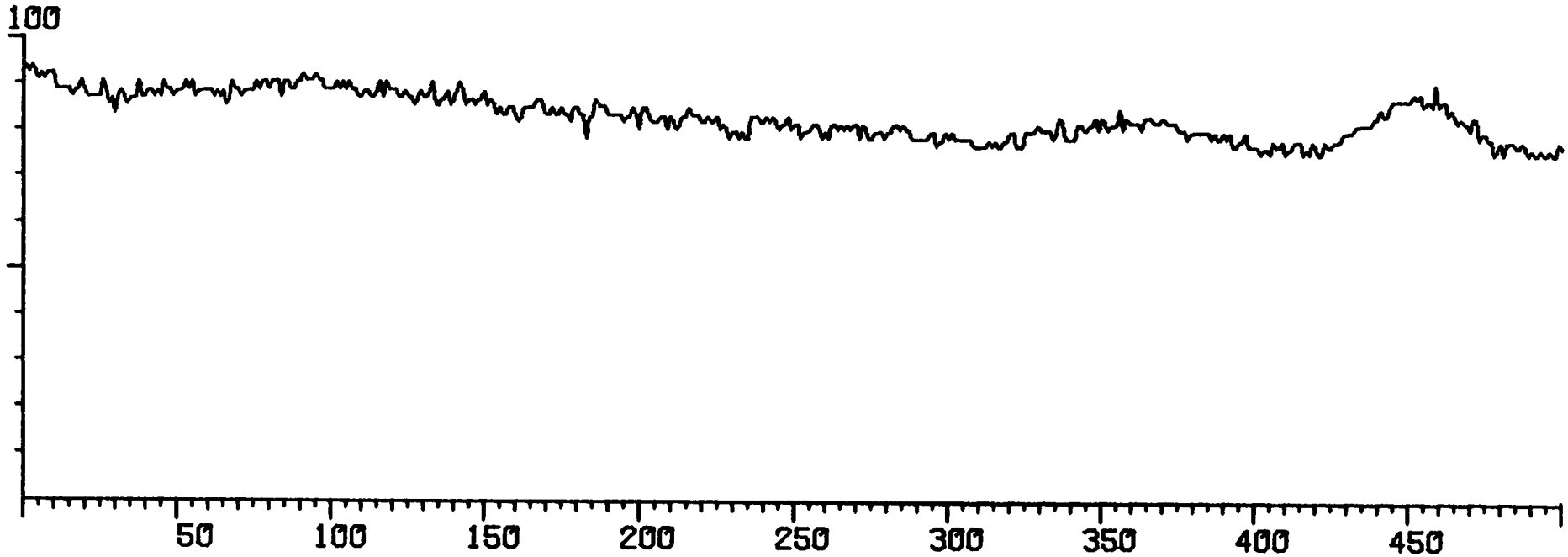
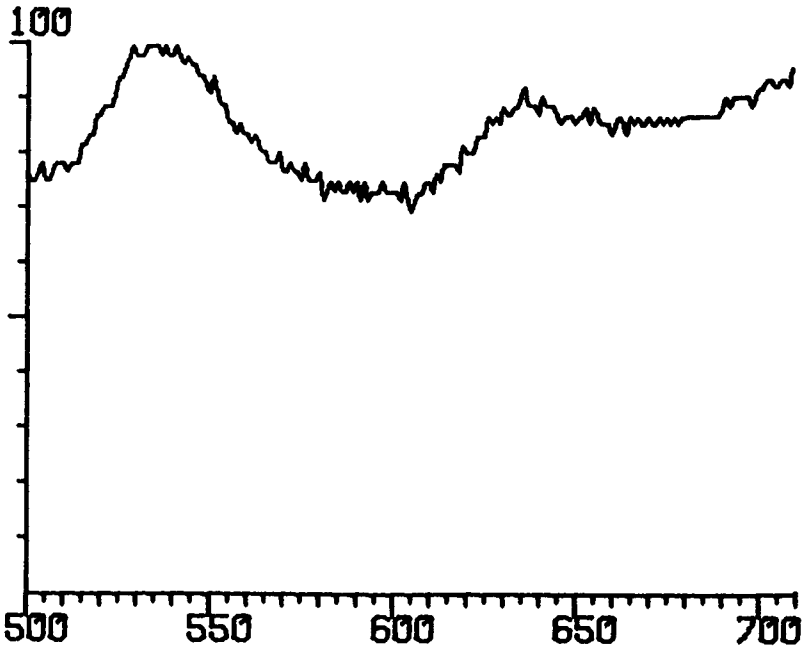
MASS 32 SEARCH X1





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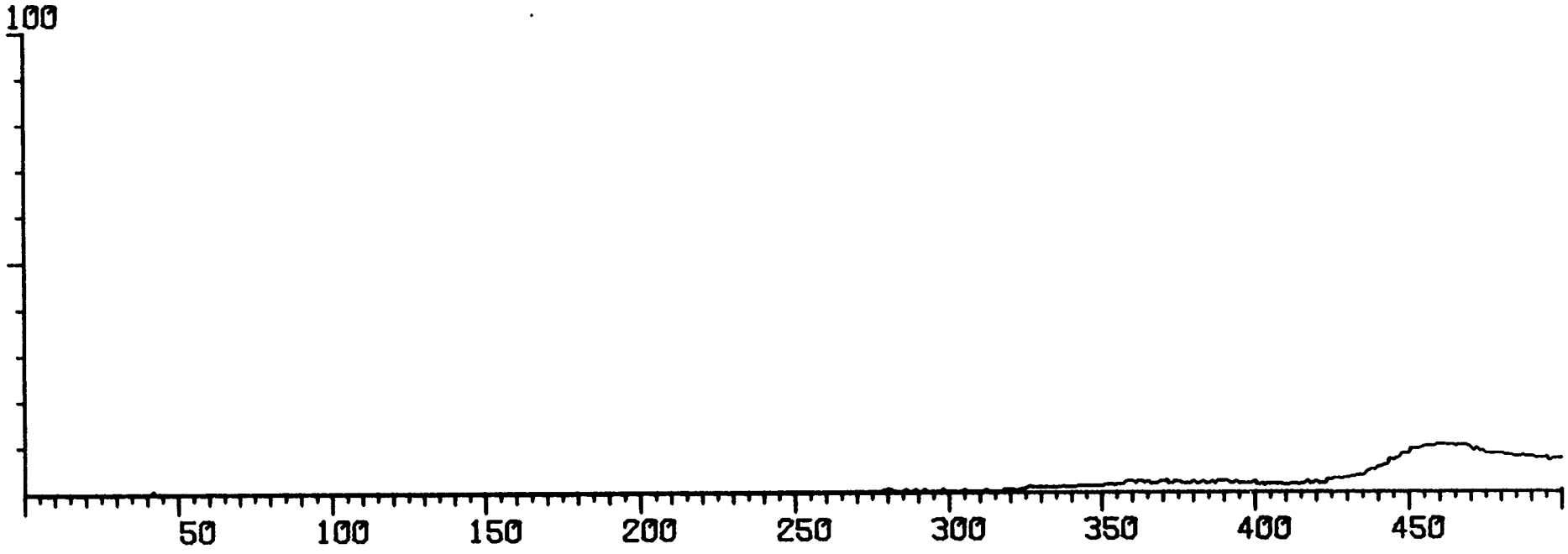
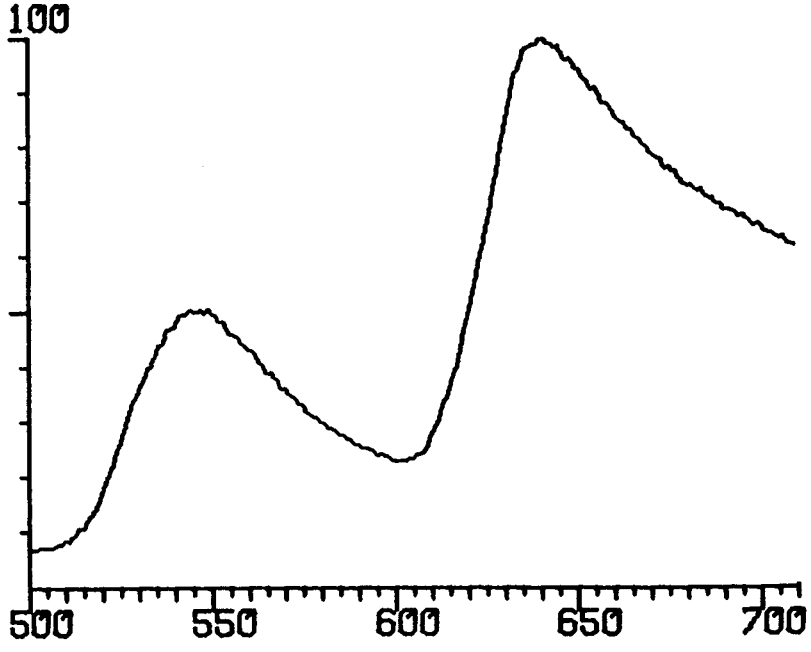
MASS 36 SEARCH X2





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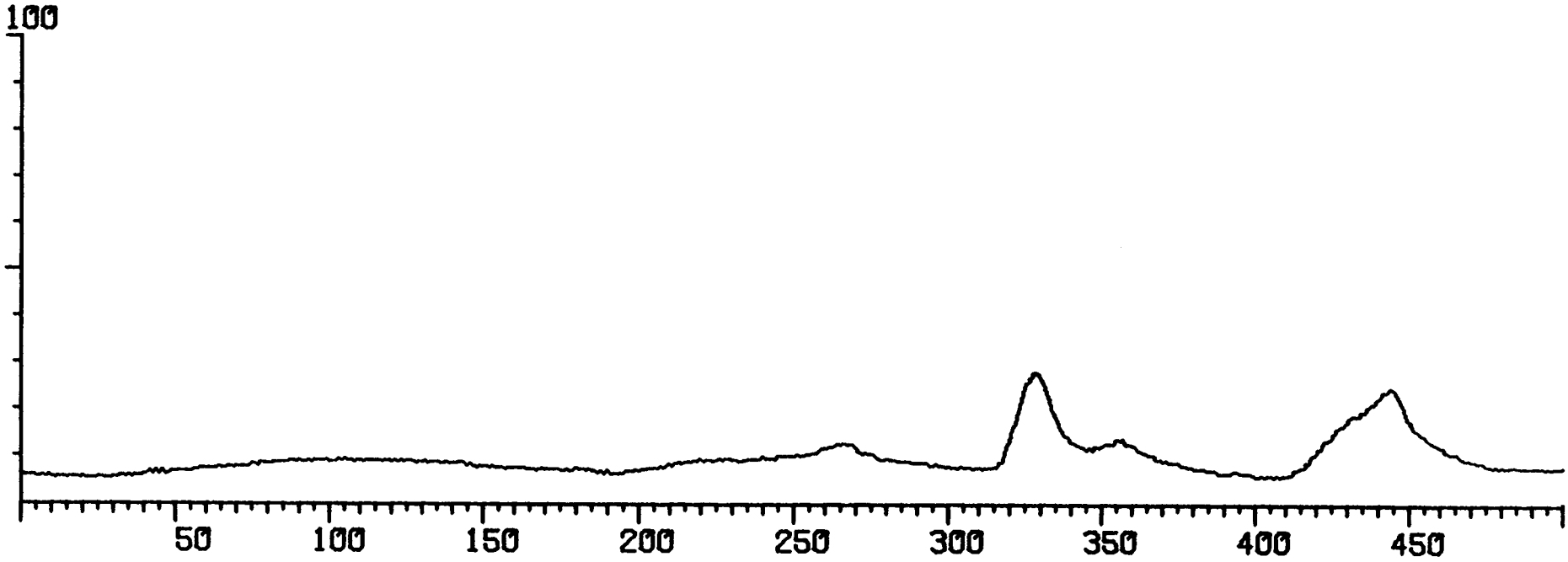
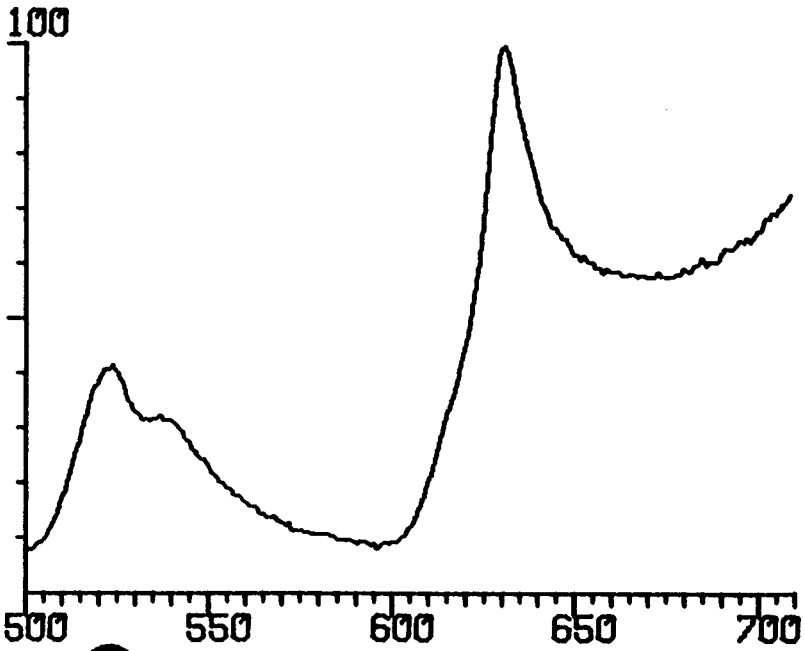
MASS 44 SEARCH X2





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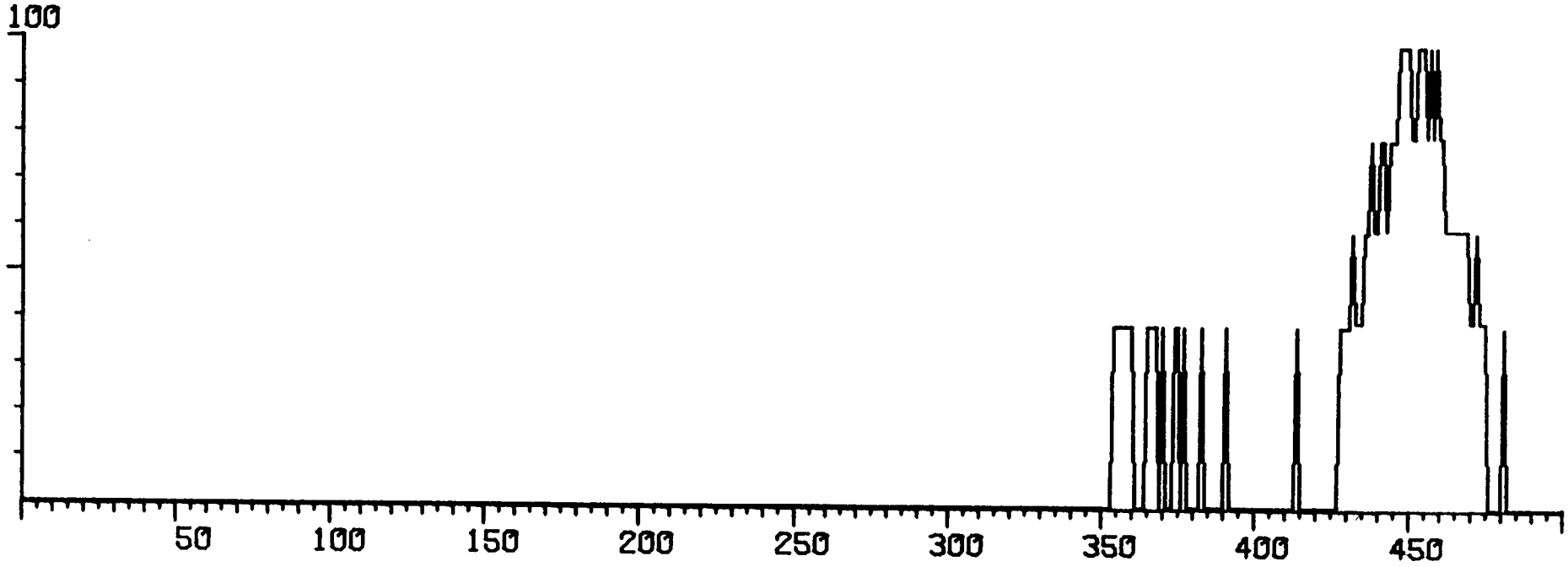

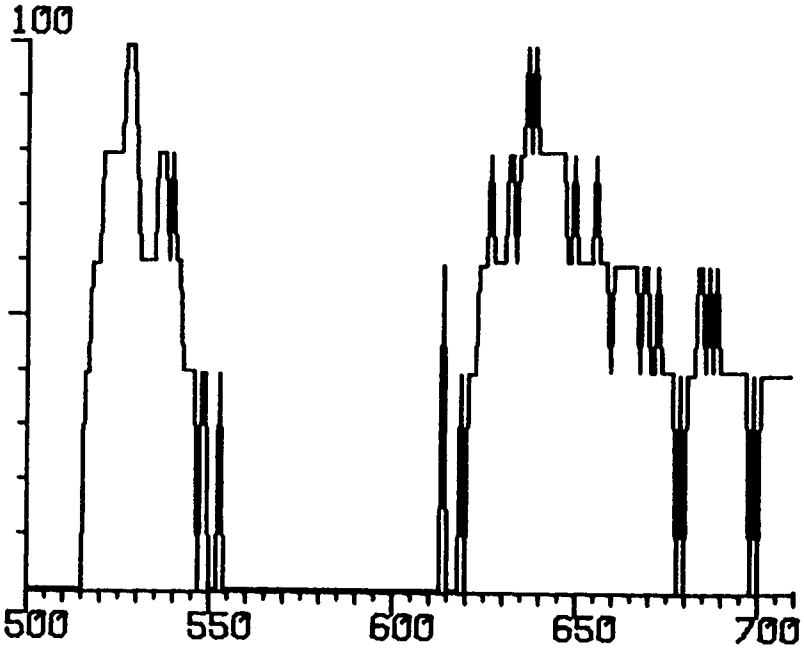

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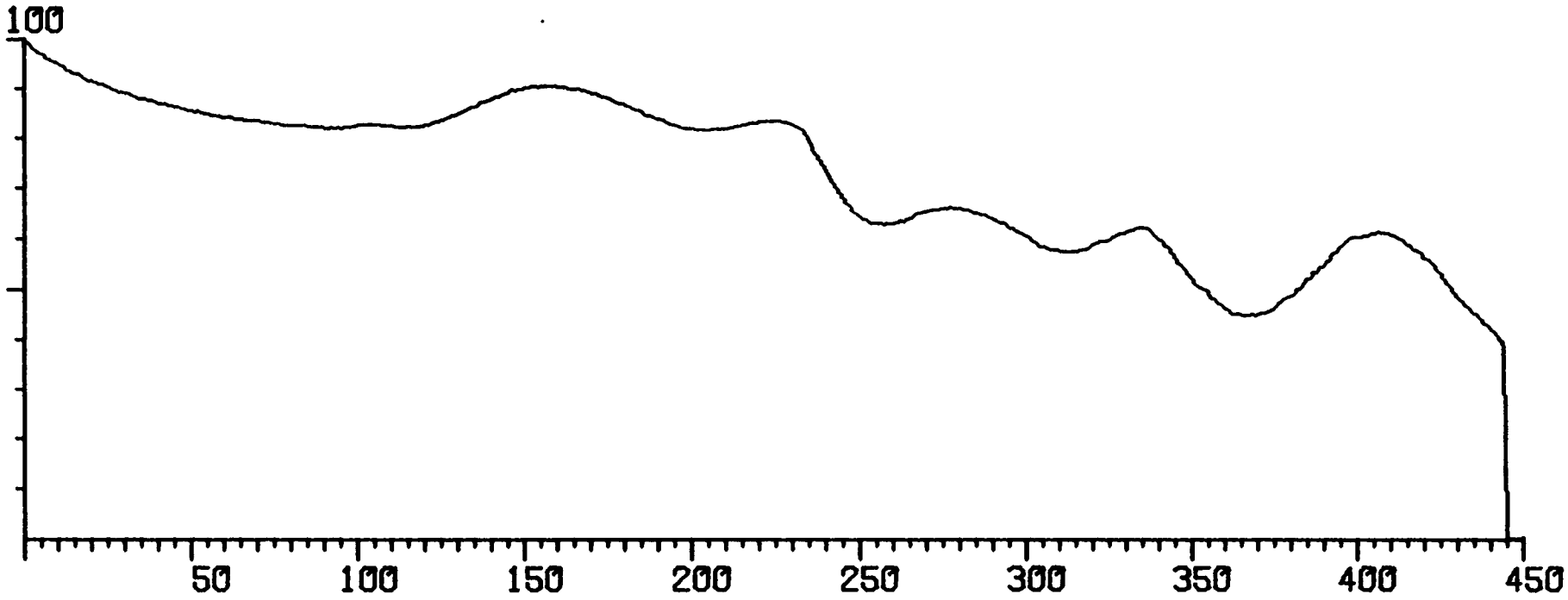
TOTAL ION CHROMATOGRAM



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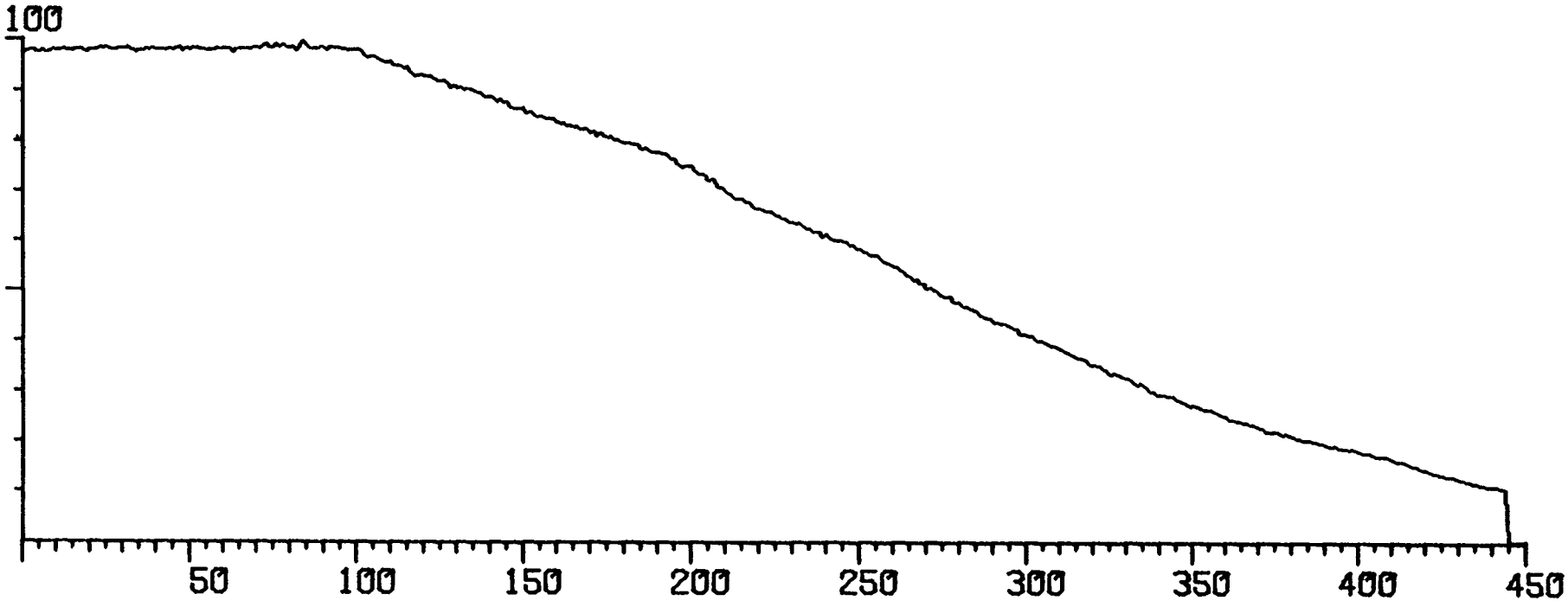
MASS 14 SEARCH X3



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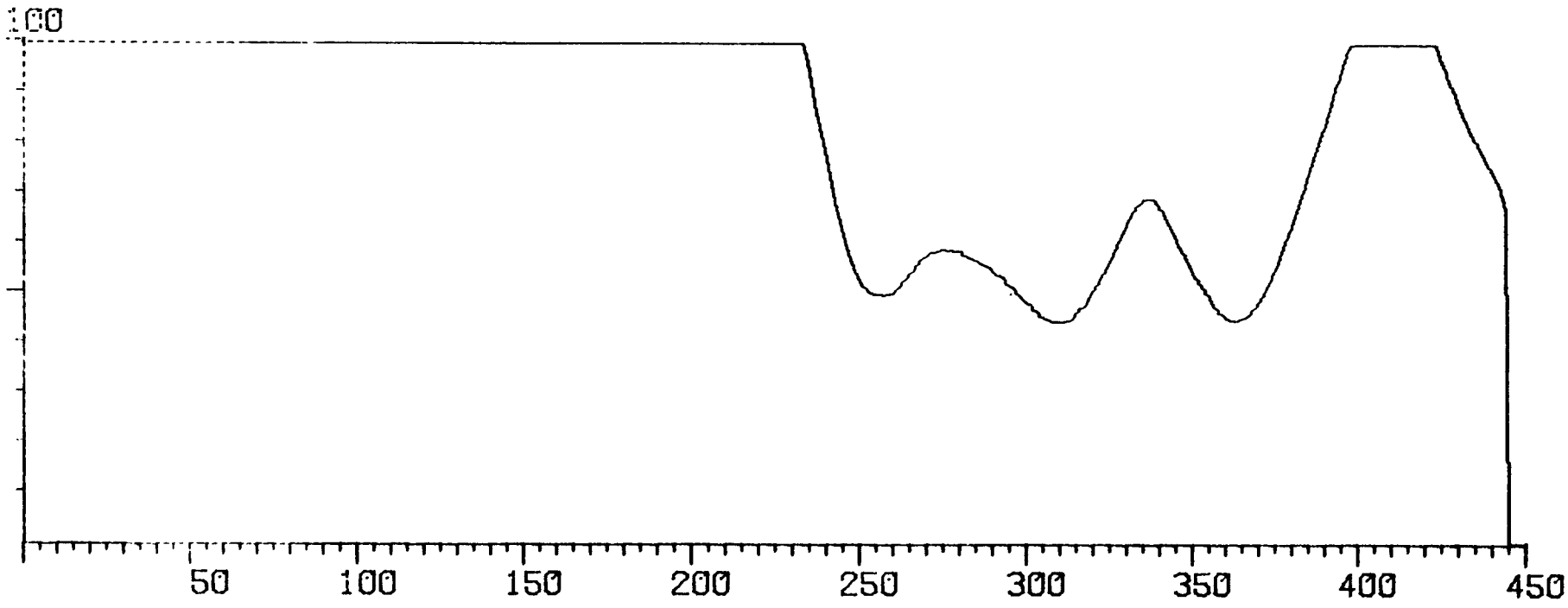

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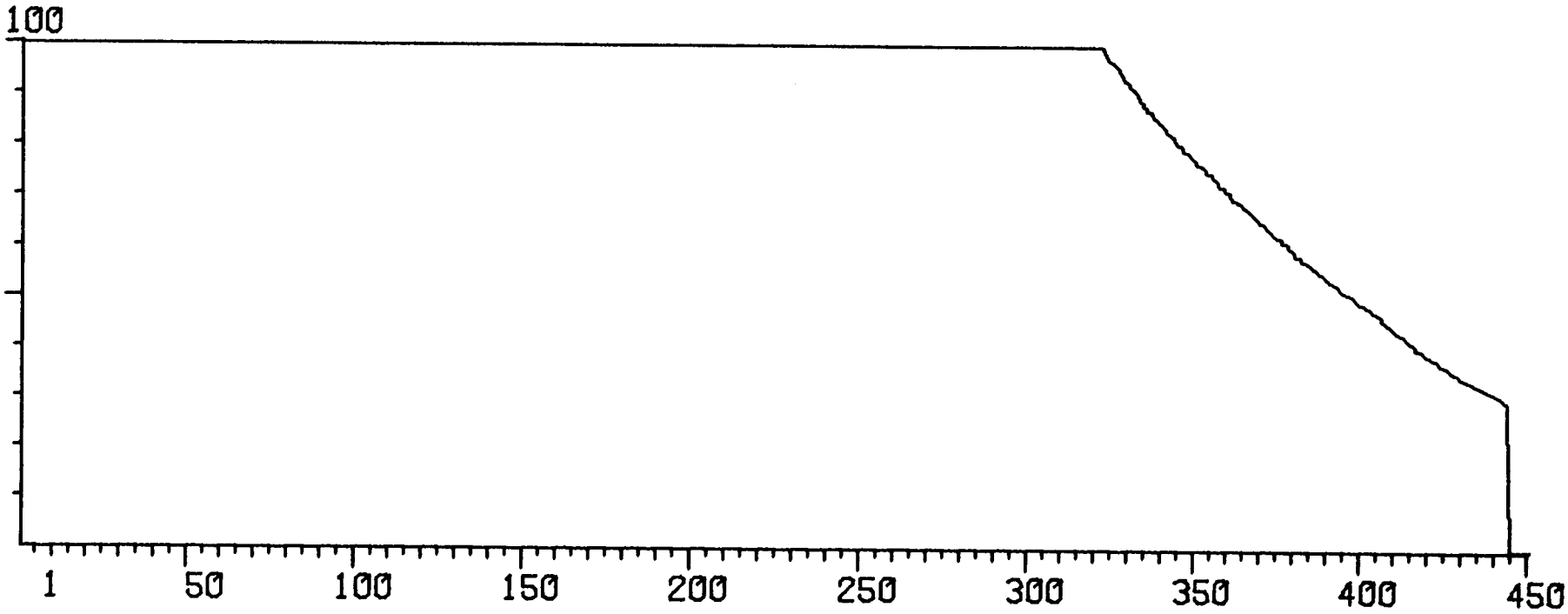
MASS 28 SEARCH X4



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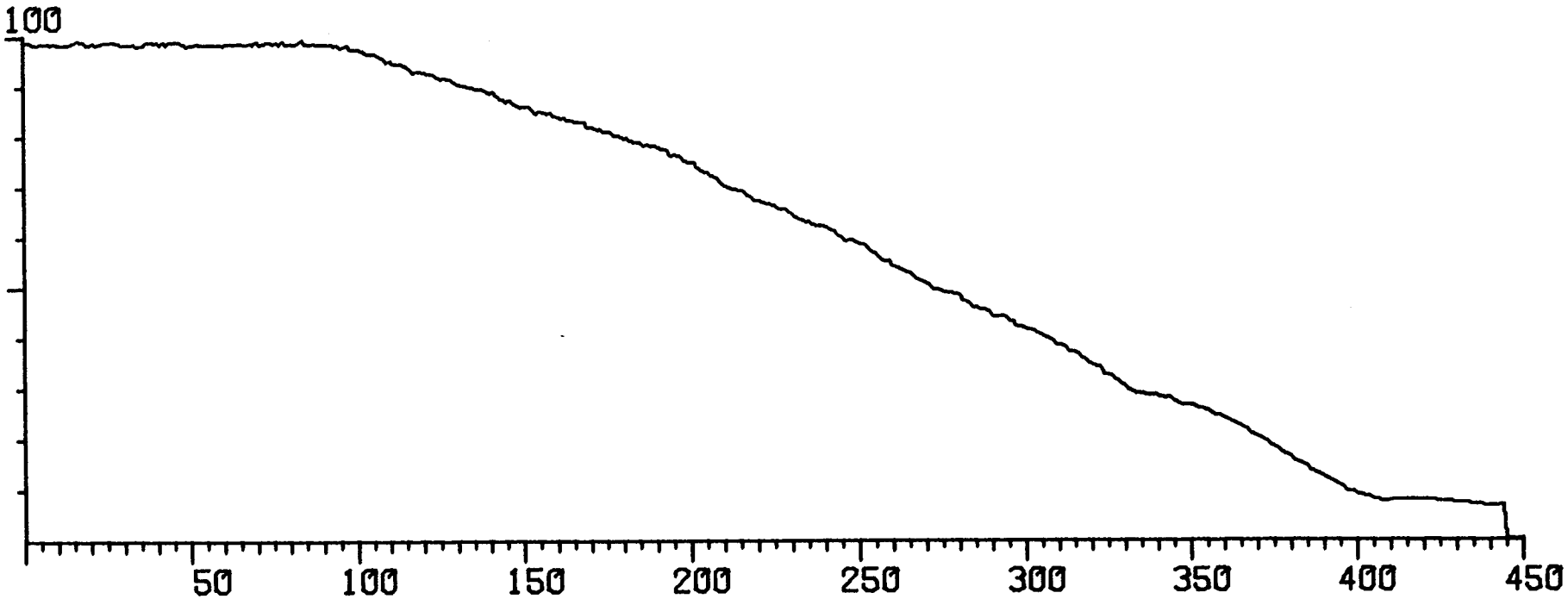

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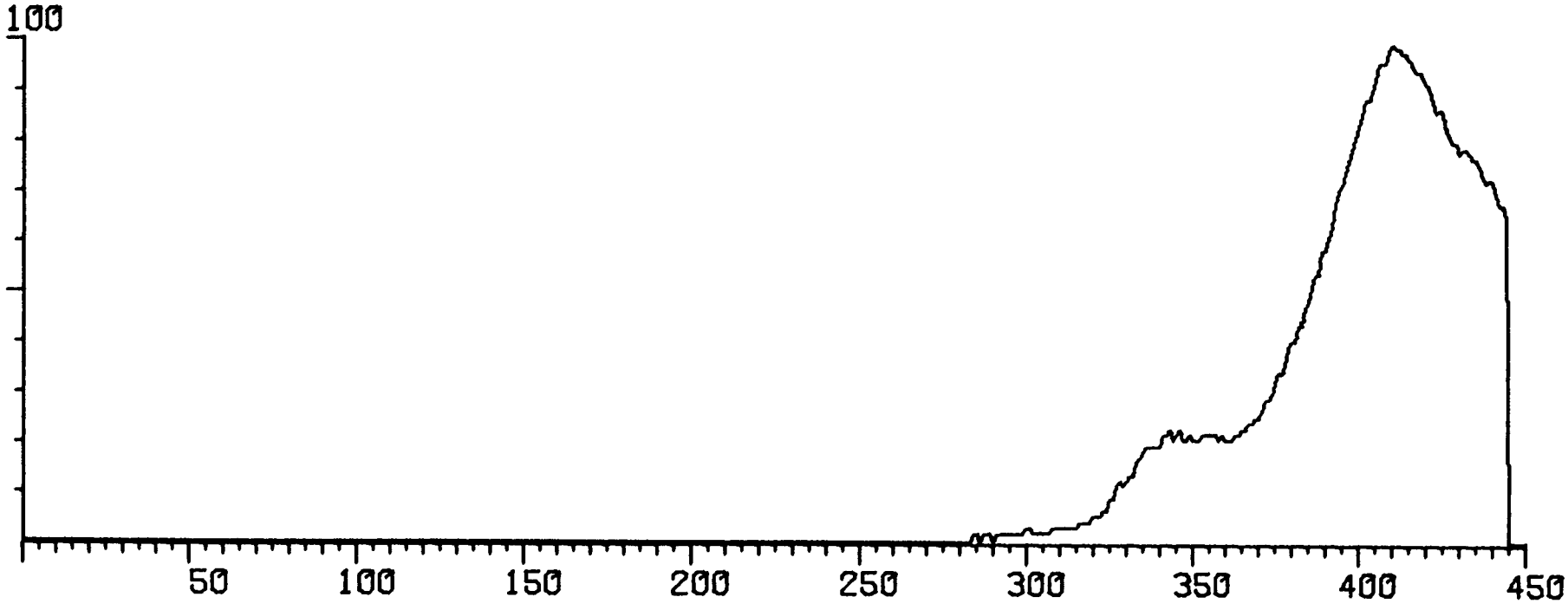

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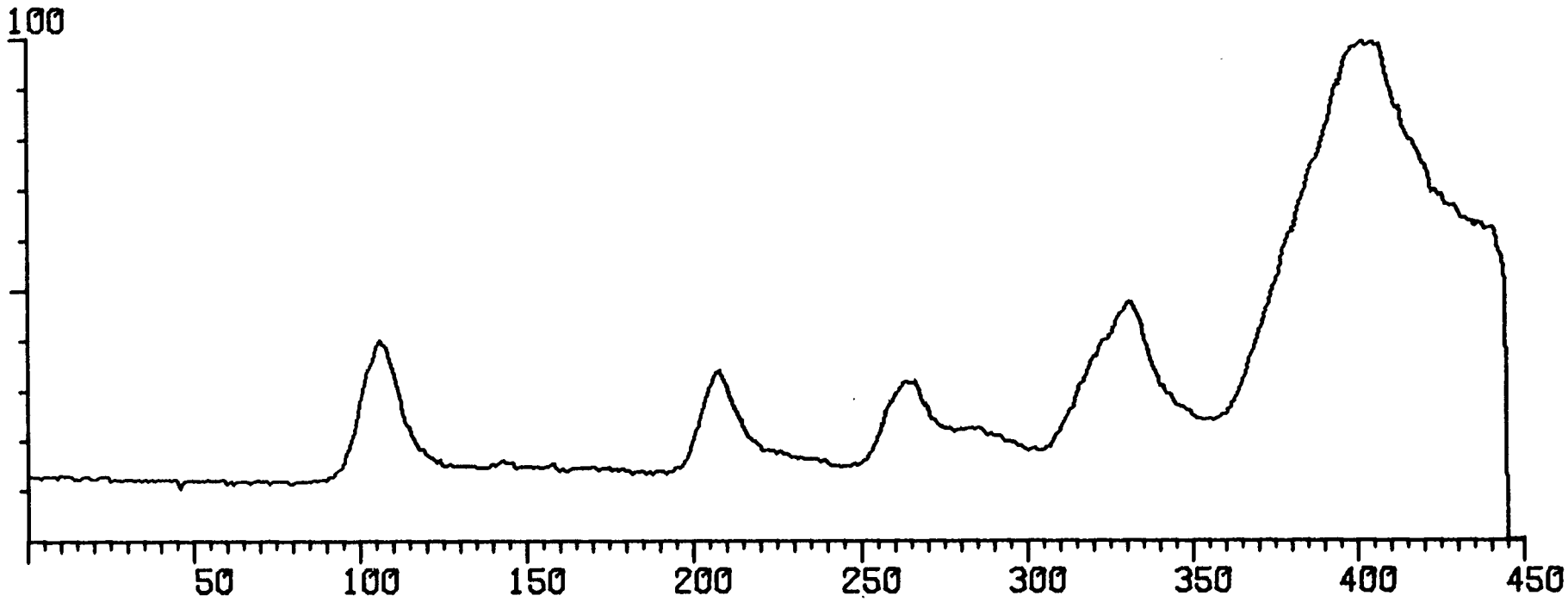

APPENDIX 7.F. Analytical Precision. (Ref. Sec. 7.5)

1. General statement concerning sample sizes, weighing errors, etc.

The sample weights used in this study ranged from approximately 0.5 to 2.5 grams, but typically were from 1.5 to 2.0 grams. The sample bottles were weighed before each new batch of samples was prepared, and both the sample bottles and the combined sample bottle and sample were weighed two times or more. Replicate weighings errors should result in a precision of no worse than $\pm$0.1 to 0.2 weight %.

2. Results of triplicate analyses on selected samples.

Triplicate analyses were performed on separate splits taken from the sample vial using different initial sample weights each time. The results are tabulated below:

Sample	Weight Losses Determined (Wt. %)			Mean to Nearest 0.1%
7-1044	0.1	0.1	0.3	0.2
7-1296	1.3	0.9	1.3	1.2
8-1794	1.2	1.4	1.2	1.3
8-1986	0.0	0.0	0.1	0.0
8-2563	2.0	2.3	1.9	2.1
8-2616	0.0	0.0	0.0	0.0

The results of these analyses indicate that most weight losses determined from replicate samples (taken from the same sample bottle) fall within ±0.2 to 0.3 of the mean value. Because of vertical and lateral variation in mineral content typical of sedimentary rocks the range anticipated for different samples of the same core would be larger, but it is not possible to estimate the precision under such non-reproducible conditions. In the case of relatively uniform samples (such as some halite or anhydrite beds) the precision might be anticipated to remain fairly good. On the other hand, samples which contain varying amounts of clays or other hydrous minerals might be expected to show much larger variations in their weight losses upon heating.

APPENDIX 7.G. Weight Loss Data for Cores #7 and #8, Carlsbad, New Mexico, Including Comparisons with the Data of Section 7.3. (Ref. Sec. 7.5)

1. Core #7.

Sample (ft)	Depth (m)	Weight Losses at 102 ± 5°C (Wt.%)	@70°C	Data from Section 7.3 To 200°C	To Above 400°C
1044	318.2	0.1	0.10	0.10	0.10
1107	337.4	1.0	0.12	0.22	1.99
1171	356.9	0.1	0.14	0.14	0.80
1221	372.2	0.2	0.30	0.44	0.51
1342	409.0	0.2	0.27	0.27	0.43
1402	427.3	0.1	0.19	0.19	0.31
1468	447.4	2.2	1.27	1.73	2.59
1533	467.3	0.1	0.22	0.23	0.47
1615	492.3	0.2	0.34	0.43	0.80
1697	517.2	3.4	0.82	0.82	0.85
1755	534.9	0.2	0.19	0.23	0.28
1952	595.0	0.0	0.14	0.14	0.58
1954	595.6	0.6	0.32	0.32	0.41
1958	596.8	0.2	0.20	0.20	0.32
1960	597.4	0.1	0.07	0.39	0.39
1967	599.5	0.1	0.20	0.20	1.13
1969	600.2	0.2	0.43	0.51	0.71
1973	601.4	0.3	0.19	0.26	0.40
1975	602.0	0.2	0.17	0.17	0.24
1978	602.9	0.8	0.36	0.40	1.67
1983	604.4	0.0	0.29	0.32	0.51
1986	605.3	0.0	0.10	0.10	0.10
1993	607.5	0.0	0.19	0.24	1.04
2702	823.6	0.0	0.24	0.27	0.39
2716	827.8	0.2	0.22	0.22	0.26
2736	833.9	0.1	0.08	0.08	0.11

APPENDIX 7.G. Weight Loss Data, Continued.

2. Core #8

Sample (ft)	Depth (m)	Weight Losses at 102 ± 5°C (Wt.%)	Data from Section 7.3 @70°C	To 200°C	To Above 400°C
1391	424.0	0.1	0.04	0.07	0.26
1495	455.7	0.1	0.05	0.08	0.08
1573	479.5	0.2	0.04	0.33	1.18
1652	503.5	0.1	0.09	0.09	4.52
1705	519.7	0.0	0.15	0.17	0.32
1769	539.2	0.1	0.09	0.15	0.35
1787	544.7	0.2	0.32	0.36	0.59
1794	546.8	1.4	0.44	0.71	5.41
1804	549.9	0.0	0.02	0.07	0.07
1829	557.5	0.1	0.16	0.39	0.39
1838	560.2	0.3	0.39	0.39	0.39
1857	566.0	0.1	0.07	0.07	0.10
1875	571.5	1.2	0.22	0.64	0.64
1884	574.2	0.9	0.36	0.36	0.80
1890	576.1	0.1	0.05	0.05	0.13
1894	577.3	0.4	0.30	0.30	0.30
1899	578.8	0.1	0.16	0.16	0.16
1900	579.1	0.1	0.17	0.17	0.81
1905	580.6	1.0	0.36	0.36	0.62
1911	582.5	0.2	0.06	0.06	0.10
1913	583.1	0.2	0.11	0.14	0.21
1916	584.0	0.0	0.13	0.13	0.25
1923	586.1	0.1	0.19	0.19	0.49
1930	588.3	0.4	0.05	0.05	0.47
1933	589.2	0.1	0.19	0.28	0.28
1938	590.7	0.0	0.13	0.27	0.49
1953	595.3	0.1	0.05	0.10	0.42
1967	599.5	0.5	0.28	0.32	0.52
1986	605.3	0.0	0.07	0.07	5.81

APPENDIX 7.G. Weight Loss Data, Continued.

2. Core #8

Sample (ft)	Depth (m)	Weight Losses at 102 ± 5°C (Wt.%)	Data from Section 7.3 @70°C	To 200°C	To Above 400°C
2006	611.4	0.1	0.20	0.20	0.66
2017	614.8	0.2	0.22	0.24	0.41
2039	621.5	0.1	0.21	0.26	1.02
2050	624.8	0.0	0.11	0.11	0.79
2068	630.3	0.1	0.04	0.04	0.14
2084	635.2	0.3	0.17	0.22	0.71
2130	649.2	0.0	0.11	0.18	0.28
2162	659.0	0.1	0.14	0.14	0.62
2217	675.7	0.1	0.04	0.04	0.44
2280	694.9	0.0	0.19	0.19	0.27
2326	709.0	0.1	0.11	0.14	0.70
2366	721.2	1.9	0.43	0.43	6.84
2427	739.7	0.0	0.03	0.03	0.43
2460	749.8	0.0	0.17	0.22	0.37
2519	767.8	0.0	0.08	0.08	0.14
2563	781.2	2.3	1.87	2.13	2.24
2616	797.4	0.0	0.21	0.21	0.27
2666	812.6	0.0	0.25	0.25	0.73
2707	825.1	0.6	0.16	0.16	1.66
2758	840.6	0.0	0.11	0.11	0.16
2779	847.0	0.2	0.21	0.21	0.21
2793	851.3	0.0	0.18	0.18	0.18
2803	854.4	0.0	0.10	0.12	0.14
2809	856.2	0.0	0.15	0.24	0.48
2821	859.8	0.2	0.18	0.18	0.36
2879	877.5	0.2	0.06	0.06	3.37
2948	898.6	0.1	0.20	0.22	0.26

APPENDIX 7.G. Weight Loss Data, Continued.

3. Weight losses determined at higher temperatures for selected samples from Core #8.

Sample (ft)	Depth (m)	Weight Losses (+ 0.1 to 0.2 Weight %) 102 ± 5°C	170 ± 5°C	300 ± 10°C
1804	549.9	0.0	0.0	0.2
1829	557.5	0.1	0.2	0.4
1875	571.5	1.2	1.8	2.2
1884	574.2	0.9	1.0	1.5
1923	586.1	0.1	0.1	0.2
1967	599.5	0.5	0.5	1.4
2050	624.8	0.0	0.0	0.7
2366	721.2	1.9	2.0	7.4
2948	898.6	0.1	0.0	0.2

Note: In this set of weight loss determinations, one split from each sample selected was heated to successively higher temperatures.

APPENDIX 7.H. Mineralogy and Petrology of Core #7 and #8.

1. Abbreviations used.

Minerals In the summaries which follow the approximate amounts of the minerals present are indicated by upper and lower case letters. AN + MAJOR (> 25%); An + Minor (5 to 25%); an = trace (< 5%. Often less than 1%)

AN	=	Anhydrite	HA	=	Halite
CAR	=	Carnallite	KAIN	=	Kainite
CEL	=	Celestite	PH	=	Polyhalite
CSSM	=	Clay and silt-sized minerals (often magnesitic)	QTZ	=	Quartz
			SYL	=	Sylvite
FELD	=	Feldspar(s)			
GLAU	=	Glauconite			
GYP	=	Gypsum			

Grain Sizes

fg	=	Fine grained (< 1 mm)
mg	+	medium grained (1 mm to 1 mm)
cg	=	coarse grained (> 1 cm)

With the exception of halite, which shows a wide range of grain sizes, most of the minerals observed are fine grained.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

2. Core #7

Depth (ft)	Description
1044	cg HA with An and cssm in patches and stringers. An also in isolated crystals and crystal clusters.
1107	fg to mg HA with mg gyp which is partially replaced by An. fg to mg ph in patches and stringers along with cssm.
1171	Appears macroscopically bedded. Primarily vuggy AN. Voids filled with radial ("starbursts") of ph and also with ha and cssm.
1221	cg HA. Patches and stringers filled with ph (radial in part) and an. Some evidence of ph replacing an.
1296	mg to cg HA with Cssm, ph and possibly some an in patches and stringers. Some of the Cssm appears intergranular among HA crystals. May represent subaerial deposition.
1342	mg to cg HA with ph and cssm in patches and stringers.
1402	mg HA. ph (radial in part) and an in patches and stringers and as crystal clusters.
1468	mg HA with much intergranular Cssm. Possibly represents subaerial deposition. Trace an and ph as isolated crystals and crystal clusters. Some authigenic quartz and feldspar.
1533	mg to cg HA with poorly preserved hoppers. Ph in patches and stringers, some possibly intergranular with HA. Trace Cssm associated with the Ph.
1615	mg to cg HA with hoppers. fg to mg An and ph in patches and stringers. ph appears to be replacing An, some of which may be psuedomorphic after gypsum.
1697	Appears to be macroscopically bedded. Large, nodular masses of AN (possibly pseudomorphic after gypsum nodules) with voids filled with Cssm, Ph, ha and syl. Ph associated with Cssm; syl associated with Ph.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

2. Core #7, continued

Depth (ft)	Description
1755	mg to cg Ha with poorly preserved hoppers. ph and an in patches and stringers. ph replaces an in part. Perhaps a little syl is present.
1952	Appears macroscopically bedded. mg to cg HA with hoppers. Ph and an in patches, stringers and as isolated crystals and clusters. Ph replacing an in part.
1954	mg to cg HA with Cssm in patches and stringers. Some Cssm is intergranular with HA. May represent subaerial deposition. Some isolated crystals and clusters of ph associated with Cssm.
1958	mg to cg HA. cssm in patches and stringers. (Some cssm may be intergranular). ph and possible an in patches and stringers associated with cssm and also in isolated crystals and clusters.
1960	Possibly macroscopically bedded. fg to cg HA with hoppers. Intergranular Cssm with associated authigenic qtz and feld. May represent suberial deposition. Some isolated crystals and clusters of ph and an.
1967	mg to cg HA with poorly preserved hoppers. ph in patches and stringers shows some evidence of flow or deformation. A few isolated crystals and clusters of an.
1969	fg to cg HA with poorly preserved hoppers. Intergranular Cssm with associated authigenic qtz and feld. Isolated crystals and clusters of an and lesser ph.
1973	cg HA with very few patches and stringers of cssm, ph and even some ha crystals.
1975	cg HA with ph, cssm and an in patches and stringers. ph appears to be replacing an. ph associated with cssm.
1978	mg to cg HA with intergranular Cssm and ph. May represent subaerial deposition. Some ph in patches and stringers and as isolated crystals and clusters. Some ph is mg. Isolated crystals of an are associated with the ph.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

2. Core #7, continued

Depth (ft)	Description
1983	mg to cg HA with hoppers. Ph and an in patches and stringers Ph replacing an.
1986	mg to cg HA with small amounts of ph, an and cssm in patches and stringers.
1993	cg HA with hoppers. Ph and an in patches and stringers. (Some Ph and an may be intergranular). Ph appears to replace an.
2702	mg to cg HA with An and cssm in patches and stringers.
2716	mg to cg HA with hoppers. an and cssm in patches and stringers, some possibly intergranular with HA. May represent subaerial deposition.
2736	mg to cg HA with hoppers. An and cssm in patches and stringers, some possibly intergranular with HA. May represent subaerial deposition.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

3. Core #8

Depth (ft)	Description
1391	cg HA with ph and possibly some an in patches and stringers.
1495	mg to cg HA with hoppers. Ph associated with cssm in patches and stringers. Some may be intergranular. Ph shows evidence of flowage or deformation.
1573	Appears macroscopically bedded. mg to cg HA with Ph and fg to mg An in large patches. Ph appers to be replacing An.
1652	Appears macroscopically bedded. fg to mg AN with Ph. mg Ha in patches or voids. Some syl associated with Ph. Algal laminations may be present in the An.
1705	fg to cg HA with hoppers. Ph in patches and stringers; some may be intergranular. Small amount of an associated with Ph.
1769	mg to cg HA with poorly preserved hoppers. fg to mg Ph in patches and stringers and intergranular with HA. In part, Ph appears to be replacing HA. Some gyp (?) may be present in very small amounts. There also may be trace amounts of cel (?).
1787	mg to cg HA with hoppers. Ph in patches and stringers and some intergranular with HA. Some mg, acicular an crystals and mg, acicular cel (?) crystals noted. There may be a small amount of gyp (?) present in this slide.
1794	Appears macroscopically bedded. fg to mg HA with hoppers. CSSM is intergranular with HA. May represent subaerial deposition. Also noted: a few isolated ph crystals, some authigenic qtz and feld, and a trace of glau (?).
1804	fg to cg HA with poorly presrved hoppers. CSSM is intergranular with HA. May represent subaerial deposition. ph in isolated crystals and cluters.
1829	cg HA with hoppers. Cssm in patches and stringers and some intergranular. Possible subaerial deposition. Trace of ph.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

3. Core #8, continued

Depth (ft)	Description
1838	fg to mg HA with poorly preserved hoppers. Cssm intergranular with HA. Ph and An in patches and stringers and associated wtih the Cssm. May represent subaerial deposition.
1857	cg HA with poorly preserved hoppers. ph along stringers.
1875	Apperas macroscopically bedded. fg to mg HA intergranular with CSSM. May represent subaerial deposition. Isolated crystals and clusters of ph and fg to mg an. Traces of authigenic qtz and feld.
1884	fg to mg HA with hoppers, intergranular with CSSM. May represent subaerial deposition. Some isolated crystals and clusters of fg to mg an (some may be pseudomorphic after gyp). Possible trace of syl.
1890	mg to cg HA with hoppers. ph and an in patches and stringers.
1894	mg to cg HA with poorly preserved hoppers. ph and an in patches and stringers. cssm in patches and stringers with authigenic qtz and feld.
1900	fg to cg HA with hoppers. Ph, An and cssm in patches and stringers and some intergranular with HA. May represent subaerial deposition. Some Ph appears to be deformed or to have flowed.
1905	mg to cg HA with patches and stringers and some intergranular Cssm. (May represent subaerial deposition). Scattered, isolated crystals of ph and an.
1910	mg to cg HA with poorly preserved hoppers. Ph, an and cssm intergranular with HA and in patches and stringers. Ph apperas to be replacing an.
1911	mg to cg HA with hoppers. Ph, An and cssm in patches and stringers, some intergranular with HA. (May represent subaerial deposition). Ph appears to be replacing an.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

3. Core #8, continued

Depth (ft)	Description
1913	fg to cg HA with intergranular Cssm. Inclusions of ha in Cssm. May represent subaerial deposition. Isolated crystals of ph. A few authigenic grains of qtz and feldspar.
1916	cg HA with poorly preserved hoppers. ph and an in patches and stringers.
1923	fg to cg HA with intergranular Cssm. May represent subaerial deposition. ph and an in patches and stringers and as isolated crystals. Trace authigenic feld.
1930	mg to cg HA with poorly presrved hoppers. Ph and an in patches and stringers, some as isolated crystals. cssm in patches and stringers. Possible trace gyp (?).
1933	cg HA with hoppers. cssm, ph and an in patches and stringers. Small amounts of authigenic qtz and feld (?).
1938	cg HA with poorly preserved hoppers. Ph and an in patches and stringers.
1953	fg to mg HA with hoppers. Cssm intergranular with HA and in patches and stringers. May represent subaerial deposition. Isolated crystals and clusters of ph and an.
1967	fg to cg HA with hoppers. Cssm intergranular with HA and in patches and stringers. May represent subaerial deposition. Isolated crystals and clusters of ph and an.
1986	Appears cross-bedded. PH with mg AN. Ph appeas to be replacing AN. Some fine laminations may be algal lamination or traces of cssm seams. ha in patches or filling void places.
2006	fg to cg HA with hoppers. Ph and an in patches and stringers. Trace of syl associated with Ph.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

3. Core #8, continued

Depth (ft)	Description
2017	mg to cg HA with hoppers. Ph and an in patches and stringers. Ph appears to be replacing an. cssm in patches.
2039	mg to cg HA with hoppers. Ph and an with cssm in patches and stringers. Much of the Ph is radial. Ph appears to be replacing an.
2050	mg AN with numerous inclusions. AN apperas to be replacing ha with former cubic crystal outlines preserved.
2068	fg to cg HA. Patches and stringers and intergranular An, cssm and possible ph (?). May represent subaerial deposition.
2084	fg to cg HA with much intergranular Cssm, ph and poissible an (?). May represent subaerial deposition. Some Ha crystals appear to be growing in the Cssm.
2130	fg to mg HA with intergranular An and minor cssm. Some ph (?) may be replacing An.
2162	cg HA with intergranular Cssm and Ph. May represent subaerial deposition. Trace of an associated with Ph. Trace of syl associated with Ph.
2217	cg HA with patches and stringers of Ph and an. Some Ph radial and replacing an. Possible syl associated with Ph.
2280	fg to cg HA with patches and stringers of Ph and an. POssible trace of kain (?).
2326	fg to cg HA with poorly preserved hoppers. Cssm intergranular with HA. May represent subaerial deposition. Isolated crystals and clsuters of ph and an. Trace authigenic feld (?).
2366	Possibly macroscopically bedded. fg, radial PH with minor an. cssm scattered throughout.

APPENDIX 7.H. Mineralogy and Petrology, Continued.

3. Core #8, continued

Depth (ft)	Description
2427	fg to cg HA with poorly preserved hoppers. An and cssm in patchers, stringers, and intergranular with HA. May represent subaerial deposition, in part. Possible fossil (bryozoan) fragment.
2460	mg to cg HA with hoppers. Patches, stringers, and intergranular An and cssm. mg an in isolated crystals and clusters along the margins of the patches and stringers.
2519	mg to cg HA with poorly preserved hoppers. Patches, stringers and intergranular an ofter associated with cssm. May represent subaerial deposition.
2563	Possibly macroscopically bedded. Nodular AN with patches of Cssm. Possible mudcrack or burrow along one edge of slide normal to the bedding.
2616	fg to mg HA with poorly preserved hoppers. An intergranular with HA and as patches and stringers. May represent subaerial deposition.
2666	fg to cg HA with poorly preserved hoppers. Patches, stringers, and intergranular Cssm and an. May represent subaerial deposition.
2707	cg HA with hoppers. Patches and stringers of Cssm and an.
2758	fg to mg HA with poorly preserved hoppers. An associated wtih cssm in patches, stringers (some intergranular). May represent subaerial deposition. Some An in isolated crystals.
2779	fg to cg HA with hoppers. An and cssm in patches, stringers and intergranular with HA. May represent subaerial deposition.
2793	fg to cg HA with trace evidence of hoppers. Intergranular AN and cssm. May represent subaerial deposition. Patches and stringers of An. Traces of ph and authigenic qtz (?).

APPENDIX 7.H. Mineralogy and Petrology, Continued.

3. Core #8, continued

Depth (ft)	Description
2803	fg to cg HA with hoppers. Intergranular An and cssm. Some An in patches with possible ph (?). A few large, isolated crystals of An. May represent subaerial deposition.
2809	fg to mg HA with trace evidence of hoppers. An and cssm in patches, stringers and as intergranular material. May represent subaerial deposition.
2821	mg to cg HA with hoppers. Intergranular An and cssm. Some An in patches and stringers. May represent subaerial deposition.
2879	Possible macroscopic evidence of bedding. fg to mg HA with hoppers. Patches and stringers of An and cssm. POssible trance of ph (?). An unknown minerals with lower birefringence and positive relief was observed. Also present are some large, isolated crystals of An.
2948	Possible macroscopic evidence of bedding. mg to cg HA with hoppers. Some patches and stringers of An present. Some may be nodular (?) (possibly pseudomorphic after gyp). a few isolated crystals of ph (?) were noted.

APPENDIX 8A

Analyses of Potash for Department of Energy
(then ERDA) and Industry Boreholes in the WIPP Area

Source is Table 3, John et al., 1978

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral

[Drill-hole no.: Drill-hole designations; P, Energy Research and Development Administration; FC, Farm Chemical Res. Dev. Corp; IMC, International Minerals and Chemical Corp; NFU, Farmers Edu. and Coop. Union of America; D, Duval Sulphur and Potash Co.; U, U.S. Potash Co., Inc. Arc, arcanite; Bs, bischofite; Bl, bloedite; C, carnallite; Gl, glaserite; Gu, glauberite; Ka, kainite; Ki, kieserite; L, langbeinite; Le, leonite; Lo, loewite; S, sylvite; Va, vanthoffite.]

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
P-1	5	9	1440.47-1441.35	0.88	8	76	---	15.0	Tr/Ka[1]	3.4/L	
	5	10	1441.35-1442.30	0.95	9	86	---	4.4		1.0/L	
	5	11	1442.30-1443.50	1.20	---	79	---	---	14.0/Ka Tr/Bl[1]	---	
	5	12	1443.50-1444.35	0.85	---	95	---	2.34	---	0.53/L	
	5	13	1444.35-1445.30	0.95	1	79	---	17.07	---	3.87/L	4.83-1.67/L
P-2	10	14	1627.15-1628.35	1.20	1	39	---	39.9	1.9/Ka 5.0/Le	9.05/L	
	10	15	1628.35-1629.52	1.17	1	46	---	43.1	2.6/Ka 0.5/Le	9.78/L	2.37-9.41/L
	4	5	1802.70-1804.00	1.30	1	39	---	38.0	12.9/Ka	8.6/L	
	4	6	1804.00-1805.00	1.00	6	80	---	---	---	---	
	4	7	1805.00-1805.85	0.85	5	89	---	---	---	---	
	4	8	1805.85-1806.30	0.45	6	60	---	20.0	4.0/Ka 3.7/Le	4.54/L	3.60-3.67/L
	2	1	1833.08-1834.00	0.92	2	79	---	4.4	1.9/Ka	3.14/L	
	2	2	1834.00-1834.50	0.50	---	38	---	52.9	0.5/Ka	12.0/L	1.42-6.26/L
P-3	4	3	1596.30-1597.60	1.30	2	72	---	24.7	0.5/Ka	5.6/L	
	4	4	1597.60-1598.70	1.10	2	62	---	18.6	0.5/Ka	4.22/L	
	4	5	1598.70-1599.53	0.83	34	38	---	23.4	---	5.31/L	3.23-5.06/L
P-4	10	2	1572.60-1574.97	2.37	1	56	46.0	---	---	29.40/S	
	10	3	1574.97-1576.17	1.20	4	64	27.6	---	---	17.48/S	
	10	4	1576.17-1577.77	1.60	3	86	7.0	---	---	4.32/S	
	10	5	1577.77-1578.69	0.92	4	64	28.0	---	---	17.46/S	6.09-18.66 /S
P-5	10	6	1546.69-1548.65	1.96	6	65	28.0	---	---	18.28/S	
	10	7	1548.65-1549.66	1.01	4	76	13.3	---	---	8.42/S	
	10	8	1549.66-1551.40	1.74	3	60	21.0	---	---	13.41/S	
	10	9	1551.40-1552.75	1.35	2	65	14.5	---	---	9.14/S	6.06-13.2/S
P-6	4	12	1476.00-1477.45	1.45	6	74	---	22.0	1.0/Ki	5.01/L	
	4	13	1477.45-1478.37	0.92	1	83	2.0	8.0	6.0/Ki	1.90/L 1.26/S	
	4	14	1478.37-1480.00	1.63	3	84	---	12.0	---	2.78/L	4.00-3.39/L
	2	18	1510.50-1511.32	0.82	1	37	2.0	54.0	6.0/Ki	12.31/L	
	2	19	1511.32-1512.10	0.78	---	53	---	42.0	---	9.65/L	
	2	20	1512.10-1513.05	0.95	7	79	3.0	1.0	8.6/Ka	0.19/L	2.55-6.98/L
P-7	4	2	1479.73-1481.20	1.47	2	65	1.0	29.0[4]	---	6.53/L[4]	
	4	3	1481.20-1483.00	1.80	---	89	2.0	3.0[4]	---	0.75/L	
	4	4	1483.00-1483.48	0.48	3	69	2.0	3.8	5.7/Ka 1.0/Le 1.0/Bl	3.8/L	3.75-3.41/L
P-8	10	2	1363.70-1365.00	1.30	---	52	29.0	25.0	---	18.45/S 5.62/L	
	10	3	1365.00-1366.72	1.72	1	46	3.0	45.0	4.0/Ka 2.0/Le	10.3/L 1.65/S	
	10	4	1366.72-1368.05	1.33	1	86	---	14.0	---	8.23/L	4.35-6.74/L 4.35-6.17/S mixed ore equivalent: 4.35-9.2/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of intervals (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
P-9	10	8	1522.56-1523.41	0.85	1	42	7.0	48.0	0.67/Ka	4.73/S 10.8/L	
	10	9	1523.41-1524.07	0.66	1	93	2.0	---	3.0/Ki	0.96/S	
	10	10	1524.07-1524.70	0.63	2	17	7.0	63.37	---	4.42/S 14.37/L	
	10	11	1524.70-1526.04	1.34	3	95	---	1.10	---	0.24/L	
	10	12	1526.04-1526.74	0.70	2	65	---	31.31	---	7.1/L	4.18-5.63/L 2.14-3.48/S mixed ore equivalent: 4.18-6.34/L
	4	17	1703.65-1705.23	1.58	2	70	---	28.70	---	6.51/L	
	4	18	1705.23-1705.65	0.42	1	89	---	6.80	3.0/Ka	1.55/L	2.00-5.47/L
P-10	11	1	1650.38-1651.22	0.84	6	89	1.8	---	1.0/Ka	1.13/S	
	11	2	1651.22-1652.03	0.81	7	81	6.1	---	2.0/Ki	3.83/S	
	11	3	1652.03-1653.83	1.80	5	85	7.7	---	1.0/Ki	4.85/S	3.45-3.70/S
	11	4	1653.83-1654.58	0.75	6	94	---	---	---	---	
P-11	11	2	1601.90-1603.56	1.66	---	56	5.0	---	3.60/Ki 1.0/C	3.34/S	
	11	3	1603.56-1604.64	1.08	3	61	2.0	---	31.0/Ka 3.0/C	1.48/S	
	11	4	1604.64-1605.38	0.74	4	84	3.0	---	7.0/Ka 2.0/C	2.20/S	3.48-2.52/S
	10	7	1670.70-1671.84	1.14	1	71	19.0	8.0	1.0/Ki	12.0/S 1.82/L	
	10	8	1671.84-1673.42	1.58	2	66	10.0	18.0	1.0/Ki	6.32/S 3.98/L	
	10	9	1673.42-1674.70	1.28	3	71	16.7	---	1.0/Ki	10.53/S	4.00-9.29/S 2.72-3.07/L mixed ore equivalent: 4.00-14.51/S
	9	14	1688.72-1689.60	0.88	3	76	22.0	---	---	13.74/S	
	9	15	1689.60-1690.89	1.29	1	64	36.9	---	---	23.30/S	
	9	16	1690.89-1691.95	1.06	1	71	21.3	---	2.0/C	13.43/S	
	9	17	1691.95-1693.28	1.33	2	92	2.0	---	1.0/C	1.24/S	4.56-12.73/S
	4	19	1840.60-1842.35	1.75	1	58	---	40.0	5.0/Ki	9.14/L	
	4	20	1842.35-1843.40	1.05	4	76	5.0	4.9	---	1.11/L 2.98/S	2.80-6.0/L
	2	22	1868.67-1870.28	1.61	1	38	2.0	60.0	2.0/Ki	13.65/L	
	2	23	1870.28-1871.10	0.82	---	54	5.0	45.0	1.0/Ki	13.53/L	
	2	24	1871.10-1872.30	1.20	---	27	---	58.3	8.0/Ka[1] Tr/Bl&Lo	13.24/L	3.63-13.49/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
P-12	10	2a[4]	1344.97-1345.27	0.3	4	36	62.3[2]	---	1.0/Ki	39.38/S	
	10	2b[4]	1345.27-1345.90	0.63	---	10	24.0[2]	---	59.0/Ki	15.08/S	
	10	3	1345.90-1346.95	1.05	1	59	18.0	---	18.0/Ki	11.39/S	
	10	4	1346.95-1348.90	1.95	3	64	18.0	---	19.0/Ki	11.36/S	
	10	5	1348.90-1349.91	1.01	7	44	20.0	---	8.6/Ki 8.7/Ka	12.63/S	
	10	6	1349.91-1350.80	0.89	3	67	16.0[3]	---	2.0/Ka	10.42/S	5.83-13.29/S
	8	14	1390.19-1390.97	0.78	4	80	15.5	---	---	9.77/S	
	8	15	1390.97-1392.66	1.69	7	88	7.0	---	---	4.12/S	
	8	16	1392.66-1394.29	1.63	4	88	10.3	---	---	6.47/S	
	8	17	1394.29-1394.90	0.61	8	51	35.5	---	---	22.42/S	4.71-8.24/S
	4	21	1520.00-1521.55	1.55	1	22	23.0	45.0	9.0/Ki	14.47/S 10.13/L	2.39-7.08/L
	4	22	1521.55-1522.39	0.84	10	48	7.0	6.0	16.0/Ka 10.0/Le	1.44/L 4.42/S	2.39-10.94/S mixed ore equivalent: 4.00-8.23/L
	3	26	1533.50-1535.05	1.55	---	40	11.0	49.0	---	7.0/S 8.59/L	
	3	27	1535.05-1535.59	0.54	34	86	1.0	8.0	1.0/Ki	1.80/L 0.62/S	3.51-5.98/L
	3	28	1535.59-1537.01	1.42	2	47	10.0	21.0	---	4.72/L 6.32/S	3.51-5.74/S mixed ore equivalent: 3.51-8.27/L
	2	34	1549.79-1550.65	0.86	3	85	---[4]	11.0	2.42/L	0.54/L	
	2	35a	1550.65-1551.29	0.64	---	20	5.0	70.0	1.0/Ka Tr/Le[1]	15.93/L	
	2	35b	1551.29-1551.61	0.32	---	21	5.0	30.0	18.0/Ka 19.0/Le 17.0/Bl	12.48/L	1.82-8.05/L
P-13	10	29	1318.02-1319.00	0.98	1	46	49.5	---	---	31.32/S	
	10	30	1319.00-1320.22	1.22	1	62	17.0	2.0	15.0/Ki	10.92/S	
	10	31[4]	1320.22-1320.88	0.66	3	97	---	---	---	---	
	10	32[4]	1320.88-1321.87	0.99	1	30	20.0	10.0	30.0/Ki 10.0/Ka	12.6/S 2.27/L	3.85-14.67/S
	9	36	1334.82-1336.38	1.56	2	94	2.0	---	---	1.12/S	
	9	37	1336.38-1337.32	0.94	2	62	34.8	---	---	21.99/S	
	9	38	1337.32-1338.64	1.32	---	90	3.8	---	---	2.41/S	3.82-6.7/S
	8	21	1359.65-1360.63	0.98	2	67	30.2	---	---	19.13/S	
	8	22	1360.63-1361.70	1.07	8	80	9.14	---	---	4.97/S	2.05-11.74/S
	4	2	1480.20-1481.73	1.53	2	82	2.0	9.0	3.0/Ki	2.03/L	
	4	3	1481.73-1482.78	1.05	1	63	---	33.2	0.4/Le	7.53/L	3.53-4.06/L
	4	4	1482.78-1483.73	0.95	1	64	---	7.0	7.0/Bl	1.59/L	

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
	3	8	1493.23-1493.88	0.65	2	86	---	7.0	---	1.59/L	
	3	9	1493.88-1494.58	0.70	---	15	---	53.0	---	12.06/L	
	3	10	1494.58-1495.50	0.92	3	86	---	10.0	---	2.21/L	2.27-5.07/L[5] 4.00-2.88/L[5]
P-14	10	2	1255.24-1255.64	0.40	---	41	57.0	---	---	36.03/S	
	10	3	1255.64-1257.56	1.92	---	41	57.0	---	---	36.06/S 8.84/S	
	10	4	1257.56-1259.07	1.51	3	64	14.0	18.0	Tr/Ka[1]	3.99/L	
	10	5	1259.07-1260.15	1.08	4	74	7.0	22.0	---	4.36/S 4.88/L	
	10	6	1260.15-1261.05	0.90	2	55	12.0[6]	---	16.0/Ka	6.21/S	5.81-18.47/S 2.59-4.36/L mixed ore equivalent: 5.81-23.33/S
	5	10	1364.44-1366.11	1.67	5	74	5.0	15.0	1.0/Ka	3.35/L 3.00/S	
	5	11	1366.11-1367.86	1.75	3	83	---	19.0	Tr/Ka[1]	4.3/L	
	5	12[6]	1367.86-1369.26	1.40	1	80	---	13.0	Tr/Ka[1]	3.03/L	4.82-3.60/L 1.67-3.0/S mixed ore equivalent: 4.82-4.02/L
	4	18	1440.79-1441.98	1.19	4	46	6.0	38.5	---	8.74/L 3.99/S	
	4	19	1441.98-1442.84	0.86	5	95	---	---	---	---	
	4	20	1442.84-1443.98	1.14	16	56	4.0	23.0	Tr/Le 2.0/Ka	5.22/L 2.53/S	
	4	21	1443.98-1444.61	0.63	3	88	---	11.0	---	2.50/L	3.82-4.69/L 3.19-2.39/S
P-15	4	7	1371.94-1372.81	0.87	6	76	---	25.0	---	5.59/L	
	4	8	1372.81-1374.77	1.96	8	89	---	4.0	---	1.00/L	
	4	9	1374.77-1375.80	1.03	9	64	---	28.0	---	6.30/L	3.86-3.45/L
	2	13	1399.66-1400.38	0.72	3	64	---	32.0	4.0/Ka	7.18/L	
	2	14	1400.38-1401.51	1.13	---	78	---	17.0	3.0/Ka 3.0/Le	4.28/L	1.85-5.41/L
P-16	10	4	1301.94-1302.57	0.63	3	93	0.7	4.0	---	0.47/S 0.89/L	
	10	5	1302.57-1303.91	1.34	3	79	---	21.0	---	4.77/L	
	10	6	1303.91-1304.39	0.48	---	61	---	34.0	8.1/Ka 8.0/Le Tr/Ki[1]	7.77/L	2.45-4.63/L
	4	10	1476.76-1478.40	1.64	---	36	2.0	53.0	Tr/Ka&Le[1]	12.01/L 1.26/S	
	4	11	1478.40-1478.95	0.55	2	86	---	8.7	---	1.98/L	2.19-9.49/L
	4	12	1490.12-1491.00	0.88	1	83	1.0	14.1[7]	---	4.94/L	
	4	13	1491.00-1491.56	0.56	0	39	7.0	19.7[7]	---	4.40/L 4.12/S	
	4	14	1491.56-1492.64	1.08	7	79	---	12.0	---	2.75/L	
	4	15	1492.64-1493.89	1.25	2	56	3.0	31.0	6.0/Le 2.0/Ka	7.05/L 2.09/S	3.77-4.93/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
P-16	2	19	1526.90-1528.00	1.10	1	51	1.0	42.0	2.0/Ka	9.05/L	1.10-9.60/L
P-17	10	2	1365.60-1367.20	1.6	1	27	---	68.8	---	15.61/L	
	10	3	1367.20-1368.45	1.25	3	76	---	12.6	2.0/Ka	2.87/L	
	10	4	1368.45-1369.70	1.25	3	44	---	6.64	30.0/Le 9.0/Ka	1.51/L	4.10-7.43/L
	4	8	1542.90-1543.68	0.78	---	48	---	38.0	13.0/Le Tr/Ka[1]	8.62/L	
	4	9	1543.68-1544.46	0.78	---	43	---	53.0	3.0/Le	12.03/L	1.56-10.33/L
	2	18	1591.39-1592.71	1.32	1	44	---	46.0	1.0/Ka	10.46/L	
	2	19	1592.71-1594.21	1.50	4	83	---	2.4	2.0/Ka	0.53/L	2.82-5.18/L
P-18	10	3	1728.40-1728.78	0.38	1	41	33.0	35.0	---	22.83/S 7.94/L	
	10	4	1728.78-1730.45	1.67	3	86	9.0	---	---	5.61/S	
	10	5	1730.45-1731.49	1.04	6	80	0.72	---	---	0.45/S	
	10	6	1731.49-1732.29	0.80	4	74	0.81	---	---	0.51/S	3.89-4.86/S 0.38-7.94/L mixed ore equivalent: 3.89-6.8/S
P-19	10	7	1741.80-1742.35	0.55	1	55	6.70	36.0	---	4.23/S 8.24/L	
	10	8	1742.35-1743.72	1.37	1	26	2.0	59.0	---	1.20/S 13.39/L	
	10	9	1743.72-1745.09	1.37	4	81	1.0	15.0	---	0.62/S 3.40/L	
	10	10	1745.09-1746.00	0.91	2	53	---	30.0	8.4/Le 2.0/Ka	9.21/L	4.20-8.03/L
	4	21	1925.20-1925.90	0.70	1	74	---	11.0	12.0/Ki	2.50/L	
	4	22	1925.90-1926.70	0.80	1	27	---	57.0	2.0/Ka 9.0/Ki	12.93/L	
	4	23	1926.70-1927.94	1.24	2	62	---	3.6	5.0/Ka Tr/Le[1]	0.82/L	2.74-4.79/L
	2	26	1956.40-1957.36	0.96	6	64	1.0	16.0	15.0/Ki	3.74/L	
	2	27	1957.36-1958.71	1.35	1	29	---	65.0	Tr/Ka[1]	14.83/L	
	2	28	1958.71-1959.21	0.50	0.5	61	---	25.0	Tr/Ka[1]	5.72/L	2.81-9.42/L
P-20	10	2	1725.00-1726.15	1.15	2	72	21.2	Tr/L[4]	---	13.43/S	
	10	3	1726.15-1728.10	1.95	4	64	7.0	35.0	---	4.42/S 8.01/L	
	10	4	1728.10-1729.62	1.52	3	60	28.0[6]	---	6.0/Ka	17.69/S	1.95-8.01/L
	10	5	1729.62-1731.48	1.86	3	60	34.0	---	---	21.48/S	6.51-14.03/S mixed ore equivalent: 6.51-20.03/S
	4	10	1898.80-1900.45	1.65	5	53	1.0	37.0	5.0/Ka	8.35/L	
	4	11	1900.45-1901.77	1.32	16	85	---	1.3	---	0.30/L	
	4	12	1901.77-1903.35	1.58	10	74	---	17.7	---	4.0/L	4.55-4.5/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
P-20	2	14[4]	1925.08-1926.30	1.22	3	95	---	0.88	---	0.2/L	
	2	15	1926.30-1927.75	1.45	1	61	---	35.5	---	8.05/L	2.67-4.46/L
P-21	10	2	1644.03-1644.84	0.81	4	80	17.0	---	---	10.82/S	
	10	3	1644.84-1646.00	1.16	4	81	11.8[6]	---	2.0/Ki	7.46/S	
	10	4	1646.00-1646.33	0.33	1	28	20.2[6]	---	42.0/Ki	12.76/S	
	10	5	1646.33-1647.20	0.87	1	41	25.5[6]	---	18.0/Ki	16.14/S	
	10	6	1647.20-1648.22	1.02	1	62	29.5[2]	---	1.0/Ki	18.66/S	
	10	7	1648.22-1649.23	1.01	3	64	31.3	---	---	19.81/S	5.20-14.37/S
	8	15	1685.17-1686.48	1.31	0	55	45.0[6]	---	---	28.4/S	
	8	16	1686.48-1687.20	0.72	4	83	6.0[6]	---	---	3.72/S	
	8	17	1687.20-1688.24	1.04	5	92	3.0	---	---	1.95/S	
	8	18	1688.24-1688.77	0.53	4	95	0.8	---	---	0.52/S	
	8	19	1688.77-1690.19	1.42	6	86	9.9	---	---	6.24/S	
	8	20	1690.19-1691.26	1.07	8	90	1.0	---	---	0.75/S	
	8	21	1691.26-1692.40	1.14	3	65	33.0	---	---	21.16/S	
	8	22	1692.40-1693.34	0.94	5	65	13.0	---	---	8.18/S	8.17-10.24/S
	4	24	1809.90-1811.50	1.60	0	31	3.0	64.0	2.5/Ka 3.9/Le	14.60/L	1.92-14.69/L[5]
	4	25	1811.50-1811.82	0.32	0	18	5.0[2]	54.66	9.0/Ka 10.60/Le	15.12/L	4.00-7.05/L[5]
	4	30	1815.51-1816.10	0.59	11	51	5	27.0	9.0/Ki	6.08/L	
	4	31	1816.10-1817.25	1.15	3	42	5	44.0	8.0/Ka	9.95/L	1.74-8.64/L[5] 4.00-3/76/L[5]
AEC-8	10	10	1589.10-1589.70	0.60	1	85	5	---	5/Ki 2/An	2.97/S	
	10	11[6]	1589.70-1591.70	2.00	---	43	16	---	40/Ki	10.32/S	
	10	12[6]	1591.70-1592.20	0.50	---	37	24	---	6/C 30/Ki 0.1/An	15.16/S	
	10	13[6]	1592.20-1594.50	2.30	---	49	32	---	7/C 9/Ka 0.8/An	20.31/S	
	10	14	1594.50-1594.70	0.20	---	38	4	---	51/C 9/Ka 1/Ki 0.1/An	2.34/S	
	10	15[6]	1594.70-1595.50	0.80	2	85	3	---	4/C 2/Ki 9/Ka 0.9/An	2.18/S	6.4-12.33/S
	4	2	1752.70-1753.40	0.70	---	95	---	4	---	0.86/L	
	4	3	1753.40-1754.00	0.60	1	69	2	33	3/Ka	7.39/L	
	4	4	1754.00-1755.00	1.00	---	33	2	63	2/Ka	13.90/L	
	4	5	1755.00-1756.70	1.70	---	24	---	69	3/Le	15.38/L	4-11.27/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
FC-70	10	2	1377.67-1379.00	1.33	2	65	11.2[6]	---	20.0/Ki	7.11/S	
	10	3	1379.00-1381.00	2.00	2	51	39.1[6]	---	1.0/Ki	24.72/S	
	10	4	1381.00-1382.00	1.00	2	64	19.4[6]	---	3.0/C 3.0/Ki	12.29/S	4.33-16.44/S
	9	6	1391.50-1393.00	1.50	1	53	28.00	---	---	17.74	1.5-17.74/S
	8	7	1415.08-1415.75	0.67	2	70	25	---	Tr/Ki[1]	16.10/S	
	8	8	1415.75-1416.50	0.75	5	89	2	---	Tr/Ki[1]	1.35/S	
	8	9	1416.50-1418.00	1.50	2	97	1	---	1.0/Ka Tr/Ki[1]	0.57/S	
	8	10	1418.00-1419.50	1.50	3	91	3	---	---	1.62/S	
	8	11	1419.50-1420.42	0.92	2	80	16	---	1.0/Ka Tr/Ki[1]	10.04/S	
	8	12	1420.42-1421.50	1.08	1	71	16	---	1.0/Ka	10.21/S	6.42-5.5/S
	5	16	1466.00-1467.58	1.58	---	72	---	19.6	---	4.43/L	
	5	17	1467.58-1469.00	1.42	1	53	---	40.7	---	9.22/L	
	5	18	1469.00-1469.67	0.67	1	70	---	24.2	---	5.49/L	3.67-6.48/L
	4	19	1529.92-1531.42	1.50	1	36	---	52.6[6]	---	11.93/L	
	4	20	1531.42-1532.42	1.00	---	45	---	33.0[6]	---	7.42/L	2.5-10.13/L
FC-81	8	7	1564.17-1564.92[8]	0.75	2	58	36.6	---	2.0/C	23.16/S	
	8	8	1564.92-1566.13	1.21	2	79	15.3	---	4.0/C	9.71/S	
	8	9	1566.13-1567.38	1.25	5	66	8.9	6.1	10.0/C	5.62/S 1.38/L	3.21-11.26/S 3.21-0.54/L mixed ore equivalent: 3.21-12.61/S
	4	10	1687.00-1688.21	1.21	---	20	---	74.0	4.0/Ka Tr/Va[1]	16.71/L	
	4	11	1688.21-1689.46	1.25	1	25	---	67.0	Tr/Va[1]	15.31/L	2.46-16.0/L
	2	15	1712.88-1714.46	1.58	1	40	---	56.0	2.2/Le	12.7/L	
	2	16	1714.46-1715.46	1.00	---	65	---	30.3	3.0/Ka Tr/Le[1]	6.9/L	
	2	17	1715.46-1716.00	0.54	4	45	---	42.8	Tr/Le[1]	9.71/L	3.12-10.4/L
FC-82	5	1	1541.42-1541.79	0.37	---	17	---	72.2	2.0/Le 6.0/C	16.34/L	
	5	2	1541.79-1542.29	0.50	---	85	7.0	7.2	---	1.63/L	
	5	3	1542.29-1543.96	1.67	2	5	---	49.8	4.0/Lo 20.9/C	11.3/L	
	5	4	1543.96-1544.50	0.54	1	59	5.0	20.0	Tr/Le[1]	4.54/L	3.08-9.37/L
	4	5	1613.42-1615.08	1.66	---	17	---	63.0	9.3/Ki Tr/Lo[1]	14.3/L	
	4	6	1615.08-1615.92	0.84	1	48	0.7	12.8	17.7/Le 12.0/Ki	2.9/L	2.5-10.52/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
FC-82	3	7	1624.33-1625.58	1.25	2	57	---	31.1	3.5/Bl 3.7/Ka	7.06/L	
	3	8	1625.58-1627.00	1.42	2	67	---	29.9	0.6/C	6.78/L	
	3	9	1627.00-1627.75	0.75	1	28	---	62.2	Tr/Bl[1] 5.0/Gl	14.11/L	3.42-8.49/L
FC-91	4	34	1712.25-1712.66	0.42	1	18	---	50.0	11.0/Ka 7.5/Le 6.0/Ki	11.35/L	
	4	35	1712.66-1713.08	0.42	---	62	---	---	5.0/Ka 3.4/Ki	---	
	4	36	1713.08-1714.17	1.08	1	25	---	64.6	5.0/Ki	14.66/L	
	4	37	1714.17-1714.75	0.58	2	32	---	58.7	5.0/Ka 1.3/Ki	13.32	
	4	38	1715.75-1715.75	1.00	20	38	---	47.0	5.0/Ka Tr/Gu[1]	10.66	
	4	39	1715.75-1716.33	0.58	6	31	---	54.0	6.2/Ka 4.0/Gl 1.2/Ki	12.25/L	4.08-11.3/L
	4	40	1718.66-1719.42	0.75	3	81	---	8.0	3.0/Ka 9.0/Bs	1.82/L	
	4	41	1719.42-1720.75	1.33	2	37	---	59.5	---	13.5/L	
	4	42	1720.75-1722.00	1.25	---	60	---	37.08	Tr/Gu 3.4/Bs	8.41/L	
	4	43	1722.00-1722.58	0.58	---	71	---	13.5	0.4/Ka 6.0/Bs Tr/Gu[1]	3.06/L	3.91-8.08/L
	2	44	1742.75-1743.25	0.50	---	15	---	62.0	8.8/Ka Tr/Va[1]	14.07/L	
	2	45	1743.25-1744.25	1.00	---	47	---	30.5	10.0/Ki 10.0/Va	6.92/L	
	2	46	1744.25-1745.00	0.75	---	61	---	1.0	3.2/Ka 10.1/Ki 24.0/Va[1] Tr/Gu[1]	0.73/L	2.25-6.44/L
FC-92[9]	8	5	1604.92-1606.04	1.12	1	51	47	Tr[1]	Tr/C[1]	29.0/S	
	8	6	1606.04-1606.50	0.46	---	50	49	Tr[1]	Tr/C[1]	31.0/S	
	8	7	1606.50-1606.75	0.25	---	60	29	1	5.7/C	18.5/S	1.83-28/S
	4	57	1740.66-1741.58	0.92	1	51	---	46.7	---	10.6/L	
	4	58	1741.58-1742.25	0.66	1	36	---	61.0	---	13.85/L	
	4	59	1742.25-1743.25	1.00	1	36	---	61.2	0.1/Ki	13.89/L	
	4	60	1743.25-1744.08	0.83	1	34	---	61.3	---	13.91/L	
	4	61	1744.08-1745.00	0.92	2	38	---	48.8	1.8/Ki	11.07/L	4.33-12.6/L
	2	62	1769.42-1770.08	0.66	1	42	---	55.4	3.0/Va	12.57/L	
	2	63	1770.08-1771.42	1.33	1	51	---	45.7	2.0/Va 1.0/Arc	10.37/L	
	2	64	1777.42-1772.08	0.66	---	39	---	33.0	17.0/Va 8.0/Ki 1.0/Gu	7.49/L	
	2	65	1772.08-1772.58	0.5	---	73	---	1.5	14.0/Va 1.0/Gu	0.34/L	3.16-8.64/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
IMC-374	4	8	1430.70-1432.10	1.40	6	86	0.7	2.0	0.7/Ki 0.3/Ka	0.46/L 0.44/S	
	4	9	1432.10-1433.10	1.00	13	68	1.0	6.4	1.35/Le	1.46/L 0.63/S	2.4-0.88/L 2.4-0.51/S
IMC-375	4	7	1627.90-1629.00	1.10	2	78	---	6.6	2.0/Ka	1.50/L	
	4	8	1629.00-1630.50	1.50	4	70	2.0	13.2	2.0/Le 1.0/Ka	3.0/L 1.3/S	2.5-2.46/L 1.5-1.3/S
IMC-376	10	2	1427.00-1427.70	0.7	---	60	38.4	---	---	24.3/S	
	10	3	1427.70-1428.30	0.6	---	98	0.2	---	---	0.1/S	
	10	4	1428.30-1429.20	0.9	1	96	0.4	---	---	0.26/S	
	10	5	1429.20-1431.00	1.8	2	86	11.2	---	---	7.1/S	4.0-7.52/S
	5	13	1528.00-1528.90	0.9	2	89	1.0	2.8	---	0.63/L	
	5	14	1528.90-1530.90	2.0	0	45	---	51.3	1.0/Le	11.65/L	3.7-6.5/L
	5	15	1530.90-1531.70	0.8	2	93	1.0	1.05	---	0.25/L	(4.0-6.03/L)[5]
NFU-1[10]	8		1536.25-1540.17	3.92	---	---	---	---	---	19.67/S	3.92-19.67/S
	4		1646.75-1649.08	2.33	---	---	---	---	---	11.96/L	2.33-11.96/L
NFU[10]	10		1441.08-1445.17	4.08	---	---	---	---	---	0.8/S	4.08-0.8/S
	8		1479.80-1483.80	4.00	---	---	---	---	---	9.1/S	4.0-9.1/S
	4		1598.50-1602.70	4.20	---	---	---	---	---	13.1/L	4.2-13.1/L
D-120[10]	10		1248.30-1249.80	1.50	---	---	---	---	---	31.63/S	
	10		1249.80-1251.10	1.30	---	---	---	---	---	10.4/S	
	10		1251.10-1252.50	1.40	---	---	---	---	---	7.34/S	4.2-15.3/S
	4		1419.60-1421.30	1.70	---	---	---	---	---	13.8/S	2.2-10.7/S
	4		1421.30-1421.80	0.50	---	---	---	---	---	0.5/S	2.2-7.5/L mixed ore equivalent: 2.2-29.45/S
D-48[10]	10		1236.60-1240.60	4.00	---	---	---	---	---	---	4.0-11/S 4.0-2.1/L (visual estimate)
	8		1280.52-1289.78	9.26	---	---	---	---	---	---	9.26-17.37/S
	4		1414.20-1416.20	2.00	---	---	---	---	---	---	2.0-8.8/L (visual estimate)

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
D-207	10	24	1358.60-1359.60	1.00	4	87	5	---	2/Ka	3.34/S	
	10	25	1359.60-1360.20	0.60	4	89	5	1	2/Ka	3.34/S 0.25/L	
	10	26[4]	1360.20-1360.60	0.40	1	75	4	1	6/Ka	0.31/L	
	10	27[4]	1360.60-1361.20	0.60	1	47	6	16	5/Ka	3.79/S 3.70/L	
	10	28	1361.20-1361.80	0.60	2	69	2	9	2/Ka	2.04/L	
	10	29	1361.80-1362.30	0.50	7	62	5	10	7/Ka	3.34/S 2.31/L	
	10	30	1362.30-1363.10	0.80	6	83	4	---	1/C 3/Ka	2.66/S	4.5-2.54/S 2.7-1.8/L mixed ore equivalent: 4.5-5.24/S
	4	33	1533.10-1533.50	0.40	2	53	36	7	---	1.51/L 22.74/S	
	4	34	1533.50-1533.80	0.30	4	86	2	11	---	2.43/L	
	4	35	1533.80-1534.40	0.60	2	85	1	2	---	0.50/L	
	4	36	1534.40-1534.70	0.30	3	95	---	4	---	0.85/L	
	4	37	1534.70-1535.00	0.30	2	74	4	1	3.0/Ki	0.14/L	
	4	38	1535.00-1539.80	4.80	6	87	2	4	---	0.85/L	6.7-0.90/L 0.4-22.74/S mixed ore equivalent: 6.7-1.44/L
	3	44	1545.90-1546.30	0.40	1	66	---	32.0	0.74/Le	7.2/L	
	3	45	1546.30-1546.66	0.30	1	11	---	73.2	9.0/Ki	16.6/L	
	3	46	1546.66-1548.00	1.40	2	62	---	30.3	3.8/Le	6.89/L	
	3	47	1548.00-1548.60	0.60	1	43	---	54.7	---	12.4/L	2.7-9.24/L
	2	52	1552.20-1553.00	0.80	11	83	---	5.0	---	1.05/L	
	2	53	1553.00-1553.20	0.20	11	45	---	41.5	2.0/Le	9.41/L	
	2	54	1553.20-1553.60	0.40	4	81	---	15.8	---	3.59/L	
	2	55	1553.60-1554.00	0.40	1	47	---	49.4	1.32/Le	11.19/L	
	2	56	1554.00-1554.80	0.80	18	86	1.4	8.8	---	2.0/L 0.9/S	2.6-3.94/L Tr/S[4]
D-104[10]	10		1340.40-1341.70	1.30	---	---	---	---	---	---	
	10		1341.70-1343.20	1.50	---	---	---	---	---	---	
	10		1343.20-1344.00	0.80	---	---	---	---	---	---	
	10		1344.00-1344.70	0.70	---	---	---	---	---	---	6.0-5.5/S
	10		1344.70-1346.40	1.70	---	---	---	---	---	---	3.2-4.71/L mixed ore equivalent: 6.0-11.78/S
	8		1391.10-1392.00	0.90	---	---	---	---	---	---	
	8		1392.00-1395.30	3.30	---	---	---	---	---	---	
	8		1395.30-1396.30	1.00	---	---	---	---	---	---	5.2-10.8/S
	4		1519.90-1522.80	2.90	---	---	---	---	---	---	2.9-9.4/L

Table 3 - Calculated mineral content of selected samples from potassium-bearing intervals with summation of percent K_2O as ore mineral--continued

Drill-hole no.	Ore zone	Sample no.	Depths of interval (feet)	Thickness (feet)	Calculated minerals present (weight percent)					K_2O as ore minerals (percent)	Weighted average K_2O as ore mineral for all intervals in ore zone (feet and percent)
					Polyhalite	Halite	Sylvite	Langbeinite	Other minerals		
D-104[10]	3		1527.50-1528.90	1.40	---	---	---	---	---	---	1.4-5.0/L
	3		1528.90-1530.50	1.60	---	---	---	---	---	---	2.9-11.4/S mixed ore equivalent: 2.9-6.66/L
	2		1539.50-1540.20	1.20	---	---	---	---	---	---	1.2-15.0/L
U-134[10]	10		1319.58-1321.25	1.69	3	---	6.0	---	2.0/Ka 0.7/C	3.79/S	
			1321.25-1322.83	1.58	2	---	---	---	12.5/Ka	17.22/S	3.27-10.28/S
	8		1361.10-1362.17	1.08	---	---	---	---	---	---	
	8		1362.17-1364.50	2.33	---	---	---	---	---	---	
	8		1364.50-1366.50	2.00	---	---	---	---	---	---	6.33-7.89/S
	8		1366.50-1367.42	0.92	---	---	---	---	---	---	(4.0-12.5/S)[5]
	5		1406.75-1409.42	2.66	---	---	---	---	---	14.44/L	
	5		1409.42-1410.00	0.58	---	---	---	---	---	8.03/L	
	5		1410.00-1411.66	1.66	---	---	---	---	---	7.05/L	4.9-11.2/L
	4		1471.66-1474.00	2.33	---	---	---	---	---	8.54/L	2.33-8.54/L
	3		1484.91-1487.33	2.42	---	---	---	---	---	3.6/L	
	3		1487.33-1490.25	2.92	---	---	---	---	---	1.86/L	
	3		1490.25-1491.33	1.08	---	---	---	---	---	8.7/L	6.42-3.7/L[3]

*Values in table for percent mineral and K_2O equivalent are not consistent owing to independent rounding of assays and conversion factors by numerous authors and investigators.

[1] Trace amount; equals 0 to 2.0 percent
[2] Incomplete dissolution of sample
[3] 5.9 percent insolubles, by weight
[4] Incomplete or unreliable assay
[5] Grade adjusted to 4-foot interval
[6] High insoluble content
[7] 7.1 percent potassium assay used
[8] Outside of the ERDA area by 300 feet, included due to influence
[9] Raw data unavailable; these are company figures
[10] Company interval data; raw data unavailable; no sample numbers assigned

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APPENDIX LTHBL

HEALTH-BASED SOIL LEVELS FOR THE LONG-TERM NO-MIGRATION DEMONSTRATION

This appendix presents the methodology for assigning health-based soil concentrations based on cancer slope factors (CSFs), reference doses (RfDs), and other relevant parameters obtained from the Environmental Protection Agency's (EPA's) Integrated Risk Information System (IRIS) database (EPA 1995). The method for determining the health-based levels (HBLs) for soil is described in Appendix E in EPA's proposed ruling on 40 CFR 264 Subpart S: Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (55 FR 30870 through 30871). The equation for calculating the HBL for carcinogenic hazardous constituents is as follows:

$$C = (R*W*LT)/(CSF*I*A*ED)$$

where EPA recommends the following:

- C = soil concentration of the selected constituents (mg/kg)
- R = assumed risk level (Class A - 10^{-6}; Class B - 10^{-6}; Class C - 10^{-5})
- W = assumed body weight (70 kg adult)
- LT = assumed lifetime (70 years)
- CSF = carcinogenic slope factor (mg/kg)/day
- I = assumed intake rate (0.1 g/day)
- A = absorption factor (dimensionless; assume = 1)
- ED = exposure duration (70 years)

CSFs and levels of risk are assigned by the EPA on the basis of evidence obtained from carcinogenicity studies or through EPA work groups, as documented in EPA's IRIS database (EPA 1995). Carcinogenic risk levels are classified as: Class A - known human carcinogen; Class B - probable human carcinogen; Class C - possible human carcinogen; and Class D - not classified for human carcinogenicity.

RfDs are the average daily exposure that the EPA has determined to be unlikely to produce deleterious health effects during the exposure period of the reference human. The calculation of health-based soil levels on the basis of a constituent's systemic toxicity is as follows:

$$C = (RfD*W)/(I*A)$$

where EPA recommends the following:

- C = soil concentration of the selected constituent (mg/kg)
- RfD = reference dose for a particular chemical (mg/kg/day)
- W = assumed body weight (16 kg)

I = assumed intake rate (0.2 g/day)
A = absorption factor (dimensionless; assume = 1)

Tables LTHBL-1 through LTHBL-3 compares carcinogenic and noncarcinogenic health-based soil levels for each constituent. Parameters are taken from the September, 1995 version of the EPA IRIS database, or, in special cases, those published in Appendix F of EPA's proposed rule for 40 CFR 264 Subpart S. The legend of Tables LTHBL-1 through LTHBL-3 is keyed to shaded and bolded entries to signify the origin of the carcinogenic CSFs or noncarcinogenic RfDs for each constituent, whether from the IRIS database or other EPA literature or information.

Table LTHBL-1. Compilation of Cancer Slope Factors, RfDs and Resulting Health-Based Soil Levels Volatile Organic Compounds - EPA IRIS Database (September, 1995)

Volatile Organic Compound	Risk Factor	CSF	Health-Based Soil (mg/kg) CSF-Calculated[1]	RfD	Health-Based Soil (mg/kg) RfD-Calculated[2]	Minimum Health-Based Soil[3] (mg/kg)
Carbon Tetrachloride	$1x10^{-6}$	0.13	5.4	0.0007	56	5.4
1,2-Dichloroethane	$1x10^{-6}$	0.091	7.7	None Reported	N/A[6]	7.7
1,1-Dichloroethylene	$1x10^{-5}$	0.6	11.7	0.009	720	11.7
Tetrachloroethylene	$1x10^{-6}$	***0.051***[4,5]	***13.7***	0.01	800	***13.7***
Benzene	$1x10^{-6}$	0.029	24.1	*None Reported*	*N/A*	24.1
1,1,2,2-Tetrachloroethane	$1x10^{-5}$	0.2	35.0	*None Reported*	*N/A*	35.0
Trichloroethylene	$1x10^{-6}$	***0.011***	***63.6***	*None Reported*	*N/A*	***63.6***
Bromoform	$1x10^{-6}$	0.0079	88.6	0.02	1600	88.6
Methylene Chloride	$1x10^{-6}$	0.0075	93.3	0.06	4800	93.3
Chloroform	$1x10^{-6}$	0.0061	114.8	0.01	800	114.8
1,1,2-Trichloroethane	$1x10^{-5}$	0.057	122.8	0.004	320	122.8
Chlorobenzene	Class D	None	N/A	0.02	1600	1600
1,1,1-Trichloroethane	Class D	None	N/A	***0.09***	***7200***	***7200***
Carbon Disulfide	Listed - No Class	None	N/A	0.1	8000	8000
Toluene	Class D	None	N/A	0.2	16000	16000
Trichlorofluoromethane	Listed - No Class	None	N/A	0.3	24000	24000
Isobutanol	Listed - No Class	None	N/A	0.3	24000	24000
Methyl Ethyl Ketone	Class D	None	N/A	0.6	48000	48000
Z 1,2-Dichloroethylene	Class D	None	N/A	*None Reported*	*N/A*	N/A
Vinyl Chloride	Listed - No Class	*None*	*N/A*	None Reported	N/A	N/A

Note 1: First health-based soil column is based on carcinogenic risk from oral exposure

Note 2: Second health-based soil column is based on systemic toxicity risk from oral exposure

Note 3: Minimum health-based soil concentration (last column) is the limiting concentration

Note 4: Shaded entries represents EPA risk assessment in progress or chemical withdrawn from IRIS listing.

Note 5: Bold shaded numbers signify that an EPA-proposed subpart S corrective level (EPA 1990, Appendix F) is used; a constituent is undergoing risk review or is otherwise withdrawn from IRIS.

Note 6: N/A refers to no data available to make assessment

Table LTHBL-2. Compilation of Cancer Slope Factors, RfDs and Resulting Health-Based Soil Levels Semi-Volatile Organic Compounds - EPA IRIS Database (September, 1995)

Semi-VOC	Risk Factor	CSF	Health-Based Soil (mg/kg) CSF-Calculated[1]	RfD	Health-Based Soil (mg/kg) RfD-Calculated[2]	Minimum Health-Based Soil[3] (mg/kg)
Hexachlorobenzene	$1x10^{-6}$	1.6	0.4	0.0008	64	0.4
2,4-Dinitrotoluene	$1x10^{-6}$	0.68	1.0	*0.002*	*160*	1.0
Pentachlorophenol	$1x10^{-6}$	0.12	5.8	0.03	2400	5.8
Nitrobenzene	Class D	*None*	*N/A*	*0.0005*	*40*	*40*
Hexachloroethane	$1x10^{-5}$	0.014	500	0.001	80	80
Pyridine	Listed - No Class	None	N/A	0.001	80	80
2,4-Dintrophenol	Listed - No Class	None	N/A	0.002	160	160
Cresols (o,m,p)	Class D	None	N/A	***0.05***	***4000***	***4000***
ortho-Dichlorobenzene	Class D	None	N/A	0.09	7200	7200
1,4-Dichlorobenzene	Class D	None	N/A	None Reported	N/A	N/A

Table LTHBL-3. Compilation of Cancer Slope Factors, RfDs and Resulting Health-Based Soil Levels RCRA Metals and Compounds - EPA IRIS Database (September, 1995)

Metal	Risk Factor	CSF	Health-Based Soil (mg/kg) CSF-Calculated[1]	RfD	Health-Based Soil (mg/kg) RfD-Calculated[2]	Minimum Health-Based Soil[3] (mg/kg)
Beryllium	$1x10^{-5}$	4.3	1.6	0.005	400	1.6
Arsenic (inorganic)	$1x10^{-5}$	1.5	4.7	0.0003	24	4.7
Thallium carbonate	Class D	None	N/A	0.00008	6.4	6.4
Thallium chloride	Class D	None	N/A	0.00008	6.4	6.4
Thallium (I) sulfate	Class D	None	N/A	0.00008	6.4	6.4
Thallium nitrate	Class D	None	N/A	0.00009	7.2	7.2
Thallium acetate	Class D	None	N/A	0.00009	7.2	7.2
Antimony	**Class D**	None	N/A	0.0004	32	32
Cadmium	Listed - Class B	None	N/A	0.0005	40	40
Silver	Class D	None	N/A	0.005	400	400

Note 1: First health-based soil column is based on carcinogenic risk from oral exposure
Note 2: Second health-based soil column is based on systemic toxicity risk from oral exposure
Note 3: Minimum health-based soil concentration (last column) is the limiting concentration
Note 4: Shaded entries represents EPA risk assessment in progress or chemical withdrawn from IRIS listing.
Note 5: Bold shaded numbers signify that an EPA-proposed subpart S corrective level (EPA 1990, Appendix F) is used; a constituent is undergoing risk review or is otherwise withdrawn from IRIS.
Note 6: N/A refers to no data available to make assessment

Table LTHBL-3. Compilation of Cancer Slope Factors, RfDs and Resulting Health-Based Soil Levels RCRA Metals and Compounds (continued)

Metal	Risk Factor	CSF	Health-Based Soil (mg/kg) CSF-Calculated[1]	RfD	Health-Based Soil (mg/kg) RfD-Calculated[2]	Minimum Health-Based Soil[3] (mg/kg)
Lead (EPA Recommendation)	Listed - Class B2	None	N/A	N/A	N/A	400
Selenium and Compounds	Class D	None	N/A	0.005	400	400
Chromium (VI)	Listed - Class A	None	N/A	0.005	400	400
Nickel, soluble salts	Listed - No Class	None	N/A	0.02	1600	1600
Zinc cyanide	Listed - No Class	None	N/A	0.05	4000	4000
Barium	Listed - No Class	None	N/A	0.07	5600	5600
Silver cyanide	Listed - No Class	None	N/A	0.1	8000	8000
Chromium (III), insoluble salts	Listed - No Class	*None*	*N/A*	1	80000	80000
Antimony trioxide	Listed - No Class	None	N/A	None Reported	N/A	N/A
Selenium Sulfide	Listed - Class B2	None	N/A	None Reported	N/A	N/A
Thallium selenite	Class D	None	N/A	None Reported	N/A	N/A
Mercury	Class D	None	N/A	*None Reported*	*N/A*	N/A
Chromium (III), soluble salts	Listed - No Class	None	N/A	*None Reported*	*N/A*	N/A
Nickel (Nickel carbonyl)	Listed - Class B2	None	N/A	*None Reported*	*N/A*	N/A
Thallium	Not Listed	None	N/A	Not Listed	N/A	N/A
Nickel cyanide	Listed - No Class	None	N/A	*None Reported*	N/A	N/A

Note 1: First health-based soil column is based on carcinogenic risk from oral exposure
Note 2: Second health-based soil column is based on systemic toxicity risk from oral exposure
Note 3: Minimum health-based soil concentration (last column) is the limiting concentration
Note 4: Shaded entries represents EPA risk assessment in progress or chemical withdrawn from IRIS listing.
Note 5: Bold shaded numbers signify that an EPA-proposed subpart S corrective level (EPA 1990, Appendix F) is used; a constituent is undergoing risk review or is otherwise withdrawn from IRIS.
Note 6: N/A refers to no data available to make assessment

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APPENDIX LTM

Abstract

This report details the techniques and design descriptions that may be used to monitor the long-term performance of the Waste Isolation Pilot Plant (WIPP) repository after the waste is emplaced and the repository is sealed and closed. The current regulatory requirements that govern the monitoring of the facility and the rationale for the proposed technical systems used to monitor the repository are discussed. This report is intended to be used as a technical guide in producing the Long-Term Monitoring (LTM) Plan.

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APPENDIX LTM

LTM.1.0 INTRODUCTION

LTM.1.1 Facility Description

The Waste Isolation Pilot Plant (WIPP) is a research and development facility of the U.S. Department of Energy (DOE), designed to demonstrate the safe transportation, handling, and disposal of defense generated transuranic (TRU) radioactive waste. The facility is located 26 mi (42 km) east of Carlsbad, New Mexico. The repository is in a salt deposit 2,150 ft (655 m) below ground. Figure LTM-1.1 is a diagram of the general WIPP facility layout. The waste will be shipped to the facility and placed in the underground repository for disposal. After the facility is filled with waste, the repository shafts and access ways will be closed and the surface facilities removed. During construction, operation, and closure of the WIPP, operational monitoring will be performed to protect the public, workers, and the environment in accordance with all regulatory and governing requirements. After closure, monitoring will determine if the repository is performing as expected. This report details monitoring technologies that may be used to monitor repository performance after the WIPP is sealed and closed.

The WIPP facility is currently under development, and is scheduled to be permitted and operational in 1998. When operational, the facility will accept waste for approximately 25 years before closure. The facility will then progress through the Decontamination and Decommissioning (D & D) phase and begin the post-closure phase.

LTM.1.2 Scope

The scope of this report is to develop specifications and criteria to direct the design and testing/evaluation of the long-term monitoring (LTM) system. A description of the system will be included in the LTM Plan for the WIPP facility and, as appropriate, the hazardous waste permit application. The scope will be realized by first defining the requirements and then developing specifications for the LTM system. This will also include the development of testing, and quality assurance/quality control (QA/QC) guidelines for this system.

LTM.1.3 Requirements Influencing Long-Term Monitoring

The WIPP is regulated by the U. S. Environmental Protection Agency (EPA) and the state of New Mexico Environment Department (NMED). In addition, the DOE has entered into an agreement with the state of New Mexico for consultation and cooperation regarding the WIPP. Prior to initiating disposal operations, a hazardous waste permit must be granted by the NMED as guided by the Resource Conservation and Recovery Act (RCRA) regulations. Upon receipt and review of the DOE's No-Migration Variance Petition (NMVP), EPA has responsibility for granting or not granting a No-Migration Determination (NMD) in accordance with regulations contained in Title 40 CFR 268.6. In addition, the EPA must certify that the WIPP is in compliance with the provisions of

Title 40 Code of Federal Regulations (CFR) §191 and must make a determination regarding the disposal of TRU radioactive wastes. Included in the effort of obtaining the permit and demonstrating compliance, applicable regulations require a plan which monitors the repository after waste emplacement and closure. Other requirements imposed on LTM are associated with the Agreement of Consultation and Cooperation (C&C) between the State of New Mexico and the DOE. This agreement details specific post-closure environmental monitoring requirements.

This report uses information found in Sandia National Laboratories (SNL) documents, DOE/WIPP documents (including Westinghouse), CFR, and Federal Register (FR) notices that apply to the WIPP LTM.

LTM.1.4 Report Approach to Long-Term Monitoring

To demonstrate compliance with regulatory requirements, a performance assessment (PA) is used to predict the response of the repository during the regulatory time frame of 10,000 years. The PA will construct scenarios which will then be analyzed for effects on repository performance and the resulting estimates of radioactive releases will be incorporated into probability distributions of cumulative releases. A monitoring program to detect substantial and detrimental deviation from the expected performance of the disposal system is required by 40 CFR §191.14(b). "Monitoring activities will be identified during the course of the performance assessment" (WIPP Performance Assessment Department 1992).

The most viable means for monitoring the WIPP after closure is through geophysical methods. Sandia National Laboratories (SNL) has completed several preliminary PAs for the repository. These assessments use experimental data, computer models, and expert judgement to develop predictions for long-term performance at the WIPP. Several possible repository breach scenarios were developed. In its most recently published PA, SNL states that monitoring activities will most likely include monitoring of hydrological, geological, geochemical, and structural performance (WIPP Performance Assessment Department 1992). This report will describe a technique for monitoring the WIPP after closure using geophysical methods.

Post-closure monitoring of the repository will use subsidence monitoring as the initial performance indicator. Subsidence monitoring measures the relative changes in surface elevation. Analytical, empirical, and theoretical calculations can estimate the subsidence above and around the repository over time. Subsidence measurements will be taken over a scheduled period and the results will be compared to the predetermined subsidence estimates (predictions).

An indication that the repository may not be performing as expected occurs when the results of a subsidence survey produce data that are not within the bounds of the prediction. At this time, the data will be evaluated to make a judgement with respect to whether or not the evaluated information represents a "substantial and detrimental

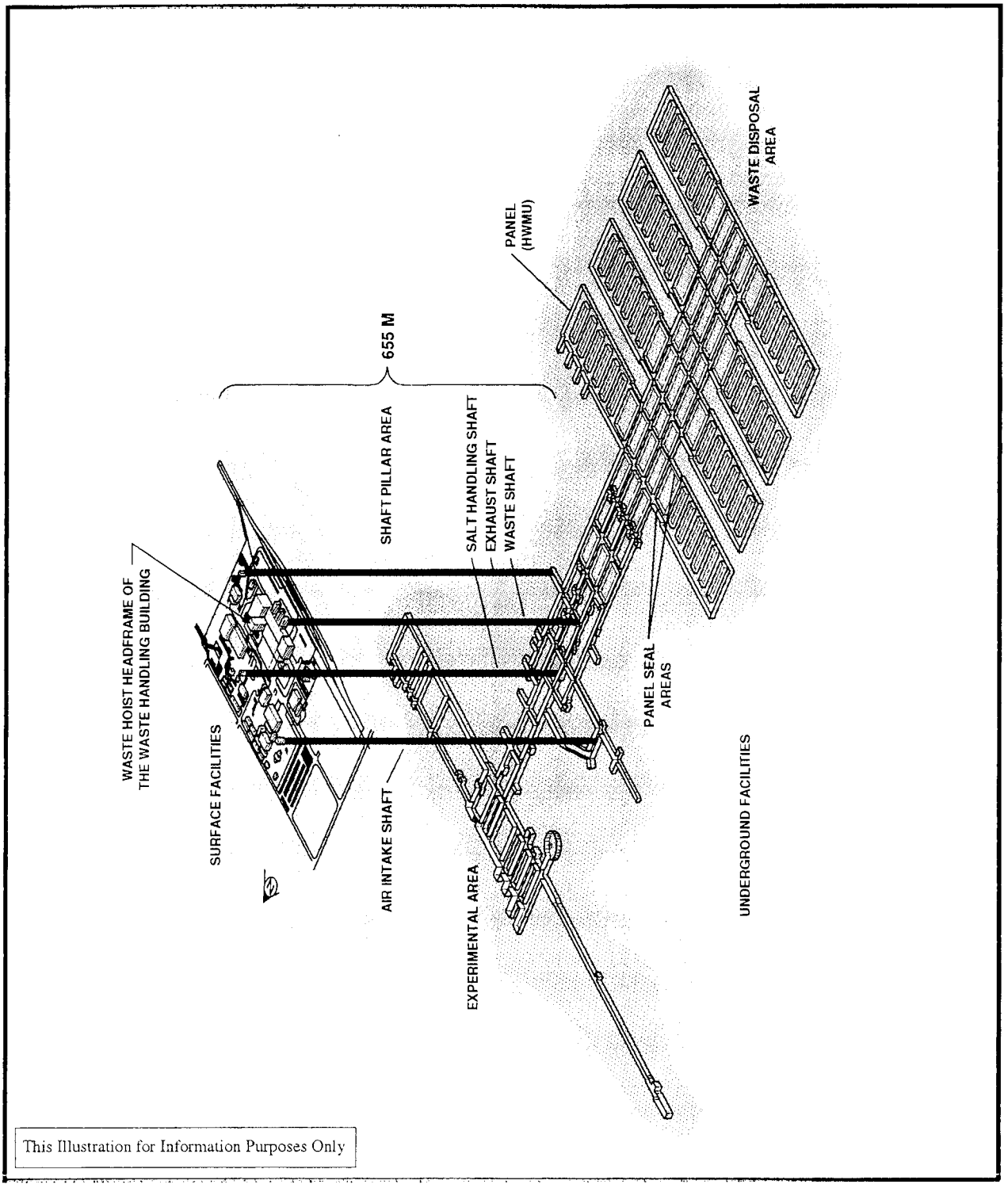

Figure LTM-1. Spatial View of the WIPP Facility

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deviation from expected performance" and if direct repository monitoring and/or intervention is required.

A Baseline Database will be documented consisting of results from surveys and calculations performed during the development and operation of the facility and data from surveys performed shortly after closure of the facility. This database will detail the geomechanical, geochemical, structural, and hydrological characteristics of the repository which are amenable to monitoring. Only survey techniques that are nonintrusive (will not affect the integrity of the repository) will be used. The database will include specific data from experiments performed during the construction and operational phases to provide background information on the facility that will be useful in determining repository performance.

In addition, radiological environmental monitoring will be performed at the same level used during the operational phase for the first two years after decontamination and decommissioning, and, in a limited fashion, environmental monitoring will be conducted for three years thereafter.

LTM.2.0 LONG-TERM MONITORING REQUIREMENTS

LTM.2.1 Regulatory Long-Term Monitoring Requirements

The basis for LTM is found in 40 CFR §191, 40 CFR §268, and 40 CFR §264. The preamble to 40 CFR §191 provides guidance in interpreting the regulations. The regulations were reviewed and the areas that apply to LTM are discussed below. An outline of individual design requirements is provided.

LTM.2.1.1 40 CFR §191.14 EPA Regulation

The regulations found in 40 CFR §191 outline the requirements for the WIPP repository. Section 191.14(b) states, "Disposal systems shall be monitored after disposal to detect substantial and detrimental deviation from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring."

The regulation states in §191.14(a), "Active institutional controls over the disposal sites should be maintained for as long a period of time as practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active controls for more than 100 years after disposal." The regulation defines as an element of Active Institutional Control, "monitoring parameters related to disposal system performance."

The following list summarizes 40 CFR §191 regulations relating to LTM:

- The Disposal Site shall be monitored after disposal to detect substantial and detrimental deviations from expected performance
- The monitoring techniques used must not jeopardize waste isolation
- Monitoring will continue as long as practicable and/or until no significant concerns are to be addressed

LTM.2.1.2 40 CFR §191 Preamble - 50 FR 38066-38089

The preamble to the final rulemaking for 40 CFR §191 is found in 50 FR 38066-38089. This preamble gives insight into the development and intent of the regulation. The preamble states, "The Agency has pursued standards that call for the isolation of the waste through the physical characteristics of the disposal system siting and design, rather than through continuous maintenance and surveillance" (Federal Register 1985). The preamble further details specifications of the LTM by stating, "Monitoring for radionuclide releases to the accessible environment is not likely to be productive. Even a poorly performing geologic repository is very unlikely to allow measurable releases to the accessible environment for several hundreds of years or more." It also states, "A monitoring system based only on detecting radionuclide releases--a system which would almost certainly not be detecting anything for several times the history of the United States -- is not likely to be maintained for long enough time to be of much use" (Federal Register 1985). Thus, radiological monitoring is not suggested for LTM.

The preamble further elaborates, "Disposal systems must be monitored to detect substantial changes from the expected performance until the implementing agency determines that there are no significant concerns to be addressed by further monitoring...A disposal system so designed should still be monitored for a long time after disposal to guard against unexpected failures" (Federal Register 1985). These statements form the basis of the EPA requirement for disposal system monitoring in §191.14 (b).

In summary, the preamble introduces the following insight on LTM:

- Repository design is responsible for waste isolation
- The design of the repository, not monitoring and maintenance, is solely responsible for waste isolation
- Monitoring techniques that only detect radionuclides are not recommended
- Monitoring will be performed until the DOE determines monitoring is no longer required

Monitoring should be used to detect substantial and detrimental deviations from expected performance.

LTM.2.1.3 Resource Conservation and Recovery Act Groundwater Monitoring Regulations

LTM.2.1.3.1 WIPP Groundwater

Previous geological exploration and testing have mapped the geologic strata above and below the repository. Two minor water-bearing units are in the Rustler Formation approximately 540 to 850 ft (164 to 259 m) below ground level. The water quality of these units is classified as poor. Exploratory boreholes and hydrocarbon exploration wells in the vicinity of the WIPP site have located isolated pressurized brine reservoirs below the repository level in the Castile Formation, approximately 2,825 to 4,075 ft (861 to 1,242 m) underground.

LTM.2.1.3.2 Regulatory Groundwater Requirements

Typically, the RCRA regulations require groundwater monitoring in the uppermost aquifer located directly below a Hazardous Waste Management Unit. The EPA allows this requirement to be waived if it can be proven that the hazardous material in excess of health based limits will not migrate past specified boundaries and that monitoring will not be productive in determining compliance.

An EPA RCRA document (U.S. Environmental Protection Agency 1986) provides guidance for developing RCRA permit applications. This document describes hydrological well monitoring at hazardous waste management facilities. In Section LTM.10.3, two LTM items are discussed. The EPA states, "Post-Closure care must provide for a period of at least 30 years after completion of the authorized closure of the repository. If ground-water monitoring systems are utilized during the repository active life, they must also be operated and maintained throughout the post-closure care period" (U.S. Environmental Protection Agency 1986). As stated, monitoring groundwater is not always required, but when monitoring is required and performed during the operational period, the wells must be monitored for 30 years after closure.

The WIPP has installed six groundwater monitoring wells in the Culebra member of the Rustler Formation. Three wells are located upgradient of groundwater flow to provide background information against which to compare downgradient well data. The other three wells are located downgradient. One other well has been installed to sample groundwater in the Dewey Lake Formation. The RCRA specifications are used as guidelines in installing the wells to the extent practicable.

This report assumes groundwater well sampling will be performed during the operational period of the repository. It is further assumed that groundwater sampling wells will be maintained after closure. The DOE will petition the NMED to waive the RCRA groundwater monitoring requirements, since the WIPP facility qualifies for such a waiver. Monitoring for contaminant releases from the repository is not likely to be beneficial, and such activity is not proposed.

LTM.2.1.4 40 CFR §268.6

In §268.6(a)(4), the EPA states, "A monitoring plan that detects migration at the earliest practicable time...." is required when a No-Migration Variance (NMV) is requested.

The WIPP shall petition for a NMV which, as stated in this regulation, requires an LTM Plan. This LTM plan will be the same plan used to satisfy the requirements of 40 CFR §191 for disposal system performance monitoring, because there is no credible pathway for migration to the accessible environment due to the design and deep geologic location of the repository.

LTM.2.2 Agreement for Consultation and Cooperation

The C&C is an agreement between the state of New Mexico and the DOE. This agreement defines specific legal areas of responsibility for the two parties. In the agreement, two specific areas relating to LTM are addressed.

1. "The level of environmental radiological surveillance developed during the operational phase shall be continued during and for at least two years following complete decommissioning and decontamination of the surface facilities. This is to include both the State and the Department of Energy's programs. In addition, increased surface soil and vegetation samples will be collected and analyzed to ensure decontamination standards in effect at the time are met" (State of New Mexico v.s. U.S. Department of Energy 1981).

2. "The final environmental radiological surveillance phase will primarily serve to ensure the public that the re-suspension of contaminated ground surface particles, if any, is not creating a potential long-term inhalation problem. The minimum program projected at this time and to be continued for a period of not less than five (5) years following the termination of the decommissioning and decontamination phase is:

   (A) Intermittent operation of the state-operated high volume air sampling stations.
   (B) Four annual soil surface samples.
   (C) Four annual water samples.
   (D) Thermoluminescent dosimeters (TLDs)" (State of New Mexico v.s. U.S. Department of Energy 1981).

The radiological part of the Environmental Monitoring Plan (EMP) for the WIPP facility fulfills the first requirement (DOE/WIPP 94-024, Section 5.3, Radiological Environmental Monitoring). The total number of samples taken can be increased if the current number is not acceptable. The appropriate section of the EMP can also be used for items (A), (B), and (C). A determination was made by the Environmental Evaluation Group (EEG) to discontinue the environmental thermoluminescent dosimeter (TLD) efforts at and around the WIPP. They determined that environmental TLDs would not detect releases at the site because they are used primarily to detect penetrating radiation.

The waste to be emplaced at the WIPP is mostly alpha emitters (non-penetrating). Therefore, no environmental TLD monitoring will be performed by DOE after closure (U.S. Department of Energy 1984; R. F. Kehrman letter to J.A Mewhinney 1990).

LTM.2.3 Long-Term Monitoring Time Requirements

The LTM plan will not be enacted until after WIPP closure. The repository is scheduled to open in 1998 and will operate until 2023; decontamination and decommissioning (D & D) will be completed within ten years following the final receipt of TRU waste. LTM will not be required until after D & D of the WIPP. Technology will advance during that time span and the requirements governing monitoring may also change. During the 25 years the facility will operate, operational monitoring will have created a vast amount of data. Interpretation and analyses of these data may conclude that part or all further LTM will not be necessary. This decision will be made well into the operational phase of the repository. However, this report assumes that LTM will be required. The LTM plan will include provisions to review the proposed LTM system during the late operational phase to assess advanced monitoring technologies and regulatory requirements and ultimately determine if LTM is required.

LTM.2.3.1 Previous Department of Energy/Waste Isolation Pilot Plant Proposed Monitoring Assumptions

Several DOE/WIPP and SNL documents provide guidance in developing the LTM plan. Provided below is a list of those DOE/WIPP guidance documents.

- WIPP Regulatory Compliance Strategy and Management Plan, DOE-CAO 94-2003
- Compliance Status Report, DOE/WIPP 94-019
- Waste Isolation Pilot Plant Repository Monitoring Program Strategic Plan, DOE/WIPP 93-029 (U.S. Department of Energy 1993)

A review of the listed DOE/WIPP documents was completed. Listed below are the LTM design requirements developed from the assumptions and approaches found in these documents.

- The design of the LTM program will depend in part on the PA results obtained from the operational phase
- Geophysical techniques may be used to identify substantial deviations from expected performance of the repository in the surrounding environment
- Subsidence and seismic monitoring may be used to monitor repository performance

LTM.2.3.2 Institutional Requirements

After closure, all buildings and aboveground facilities will be removed (with the exception of the Hot Cell concrete structure), active controls will be put in place, and the staff will be reduced significantly. LTM techniques shall be designed so that minimal

maintenance and facilities are required. The monitoring techniques shall be as stand-alone as possible, because power may only be available for part of the post-closure period. The LTM systems shall be accessibly located aboveground. Safeguards shall be provided to protect the equipment from vandalism and the environment.

Techniques that obtain useful data at low cost with minimal maintenance over an extended period of time are the most favorable.

In summary, institutional LTM requirements are as follows:

1. The LTM system design shall have a low labor requirement
2. System must endure the natural environment
3. System must be cost-effective
4. System should not require a large support facility
5. System shall require minimal maintenance and power requirements
6. All components susceptible to vandalism should be isolated and/or protected from public access

LTM.3.0 LONG-TERM MONITORING SYSTEM SPECIFICATIONS

All of the LTM system requirements were compiled from Regulatory, Institutional, DOE/WIPP documents, and SNL documents and assumptions to form the LTM specifications. The LTM specifications are listed below:

1. The PA shall identify parameters to monitor repository performance
2. The LTM system shall detect deviations from expected repository performance after closure
3. The monitoring technique(s) used must not jeopardize waste isolation and must be nonintrusive
4. Monitoring will continue as long as practicable, and/or until no significant concerns remain to be addressed, or until the DOE determines monitoring is no longer required
5. Monitoring that detects contaminants is not recommended
6. The radiological aspect of the operational EMP shall be continued for two years past D & D
7. Four annual soil surface samples and four annual water samples shall be taken for five years after D & D
8. The design of the LTM program will depend in part on the results of data obtained during the operational phase
9. Subsidence and seismic monitoring may be used to monitor disposal system performance
10. LTM system design shall require minimal labor
11. System must endure the natural environment
12. System must be cost-effective
13. System should not require a large support facility

14. System should be self-contained
15. All components susceptible to vandalism should be isolated and/or protected from public access

LTM.4.0 SYSTEM DESCRIPTION

The basic requirements listed in the Section LTM.3.0 were used to define an LTM system which would best fulfill all the applicable requirements. After an evaluation of current geophysical and experimental technologies was completed, subsidence monitoring was chosen. Subsidence monitoring was chosen, in part, because it was suggested in EPA, DOE, and SNL documents as being a viable LTM technique that can demonstrate adequate repository performance. Subsidence monitoring is nonintrusive, can detect substantial deviations in repository performance, and meets all the listed requirements in Section LTM.3.0. This monitoring technique is described in Attachment A, along with a discussion on determining repository performance.

Subsidence monitoring is the basic LTM tool that will be supported by several other systems. These systems include a subsidence network, a Long-Term Monitoring Program (LTMP), a Baseline Database, a Closure Review Study (CRS), and a Subsidence Data Study (SDS).

The basic LTM system is composed of a subsidence network, an LTMP, and a Baseline Database. The LTMP is broken down into two subgroups, Subsidence and Environmental/Groundwater monitoring. The overall program is the responsibility of the DOE until it decides, and the regulators concur, that no further monitoring is required. The data collection for both the Baseline Database and subsidence data are verified through a QA/QC program to assure data quality. The monitoring program will be documented through a set of operating procedures that are validated and maintained under the QA/QC program. All actions relating to repository performance indications from the subsidence monitoring program will be resolved through the DOE office overseeing the project.

The LTM system will also consist of any preexisting hydrological wells plus any additional wells deemed useful as the result of the PA. The well monitoring program that was used during the operational phase will be used during the post-closure phase. The frequency of the testing will be modified after closure to include maintenance and well casing replacement, as appropriate. Testing intervals will be lengthened if previous data have been relatively constant during the operational phase. The LTM schedule will be determined by a CRS.

The radiological portions of the operational EMP in place prior to closure will be used in LTM for two years after closure with limited radiological monitoring for the following three years. The PA has determined the most likely release path after closure is not directly to the surface, therefore monitoring releases at the surface level would not be productive (WIPP Performance Assessment Department 1992). Results of D&D

monitoring will be evaluated at closure during the CRS and a determination will be made whether to continue monitoring for aboveground radionuclides and volatile organic compounds (VOC) after the required five-year period.

An SDS will be performed during the developmental and operational phases of the WIPP. This study will provide the subsidence prediction data and gather all data for the Baseline Database. The findings will include the predictions and bounding conditions for repository performance and define scenarios that would characterize the repository's condition when the measured subsidence is out of bounds with the predictions. These scenarios will be used in the Baseline Database to provide guidance during an unpredicted event.

A CRS will be performed during the late operational phase that assesses the condition of the facility at closure. The study will:

- Evaluate the LTM plan, the data generated during the operational and closure phases, and regulatory requirements at the closure date
- Update the LTM program
- Evaluate the necessity for monitoring and determine the appropriate repository parameters to be monitored
- Revise the LTM schedule to account for any impacts on the monitoring frequencies caused by the study findings

In summary, the LTM program will be composed of the following items:

- Subsidence network
- MP
- Baseline Database
- CRS
- SDS

Each item will be discussed in detail below.

LTM.4.1 Subsidence Network

Refer to Attachment A for a description of subsidence, the past work, and the advantages and disadvantages of its use in LTM.

In order to monitor subsidence, a network of benchmarks must be placed over the area of interest. Benchmarks have been installed over and around the general vicinity of the WIPP. These benchmarks are adequate for initial data gathering during the developmental and most of the operational phases. However, the current network is too coarse to provide sufficient data points to accurately measure subsidence over the repository for the long term. From contour plots of expected subsidence in the Backfill Engineering Analysis Report (BEAR), maximum subsidence can occur in a circular area with a radius

as small as 1,000 ft (305 m); most of the current benchmarks are 1,000 ft (305 m) apart. Current benchmark locations are shown on drawing E-2700-1. Reference #8 has recommended placing a network over the repository footprint that would extend 2,000 ft (610 m) past the four mi^2 site boundary shown in Figure A-2 of Attachment A. This would encompass the entire predicted subsidence area for angles of draw up to 45 degrees.

Additional benchmarks shall be placed to increase the density over the repository. These new benchmarks shall be installed after completion of the SDS. The SDS will evaluate and determine the quantity and placement of the benchmarks to best determine subsidence.

After establishing the supplemental benchmark locations, benchmarks will be installed and surveyed that meet the National Geodetic Survey (NGS) Class I, first-order standards. All placement and survey data will be documented in the Baseline Database.

Provisions shall be made to maintain and replace benchmarks when required and to coordinate benchmark placement with the passive markers design. This coordination has been noted in the Permanent Markers Study (PMS).

LTM.4.2 Monitoring Program

The LTM concept assumes substantial work will be performed during the operational phase to gather subsidence information and data. The data may be used in PA calculations to predict subsidence for various scenarios of repository performance. All effects that may influence subsidence over the repository, such as hydrological extraction, petroleum production, mining, and geological subsidence, should be included in these scenarios.

The MP consists of monitoring the subsidence network and, for a limited period, Environmental/Groundwater monitoring. Subsidence monitoring is accomplished with a Class I Leveling Survey. The surveys will be performed every 10 years during the operational phase and thereafter in accordance with the LTM schedule. Environmental/ Groundwater monitoring will be performed for at least five years after closure.

The leveling surveys will be performed as described in a QA/QC procedure to ensure the data is documented and validated. The data will be included in the Baseline Database. A procedure will be developed to implement the LTMP.

The MP will be maintained by the DOE. The CRS will detail the organizational responsibilities and monitoring schedules. This study will also update the LTM plan and define the LTMP requirements.

The MP includes the following:

1. Managing the LTM Program
2. Maintaining monitoring procedures and QA/QC documents
3. Performing all monitoring
4. Maintaining the subsidence network
5. Maintaining the monitoring schedule
6. Maintaining and storing the Baseline Database
7. Performing a data review and performance evaluation
8. Supplemental monitoring when performance is suspect
9. Eventual decommissioning of the LTM program
10. Archiving LTM data

LTM.4.3 Baseline Database

The SDS will generate subsidence predictions and compile the technical information derived from measurements performed during the developmental and operational phases of the WIPP. This data will be included in a Baseline Database. This baseline will also contain data specific to the repository's geophysical, hydrological, geochemical, and structural nature at the end of the disposal phase when the repository is sealed.

The Baseline Database will also contain data from previous monitoring studies and data from specific surveys and monitoring techniques performed immediately after closure of the repository. These surveys will be performed only once after closure to establish the geologic condition of the area at the start of the post-closure phase. These surveys and techniques are described in Attachment A.

The database will provide the guardians of the WIPP facility with easy access to critical data concerning repository performance and LTM.

An evaluation of geophysical methods was performed to determine which methods should be used to establish a baseline for the repository after closure. The following techniques were chosen because they meet the requirements, are specifically nonintrusive, are implemented from the surface, and provide useful data in interpreting the repository's geophysical structural and hydrological condition. All post-closure monitoring techniques that would be physically conducted in the repository were excluded (see Attachment A for discussion on direct repository monitoring).

The following monitoring technologies were chosen to be evaluated as candidates for LTM:

1. Subsidence surveys
2. Seismic surveys
3. Gravitational surveys
4. Electromagnetic surveys
5. Resistivity surveys
6. Aerial radiological surveys

7. Experimental
8. Environmental

Each of these techniques are evaluated in Attachment A. A determination was made to include all past data for geophysical surveys conducted during site selection and operation. At closure, several geophysical surveys will be performed to obtain repository baseline data on the geophysical condition of the repository and surrounding area. Seismic reflection/refraction, gravitational, electromagnetic, and resistivity surveys will be performed. No baseline environmental surveys are required, since a baseline has previously been established. All data and explicit descriptions of the equipment, data reduction techniques, and procedures used will be included in the database. All sensor placements will be surveyed and recorded. Where possible, some of the original survey lines will be used. The CRS will also determine specific survey lines to be included. Monitoring technologies in the experimental phase of development may be evaluated for applicability.

LTM.4.4 Closure Review Study

The initial LTM plan will be written at least 25 years prior to closing the facility. Technology, regulations, site management, safety requirements, and public opinions will advance and change over this time period. It is assumed that the LTM plan will not be updated at regular intervals over the operational phase because it is not cost-effective to do so. A review of the LTM plan prior to closure will be necessary to ensure compliance and safety. This review may result in modification of the LTM plan to reflect the advanced state of repository-specific knowledge resulting from repository operational phase activities.

A CRS will be initiated to evaluate the LTM plan and update all aspects that are not current. This plan will review the data in the Baseline Database and all governing regulatory issues associated with LTM of the facility. The CRS will determine what monitoring is required, what will be monitored, what equipment and techniques will be used, and the area/lines that will be monitored. A feasibility study will evaluate technology available at that time that can be used to accomplish this task.

The CRS will update the LTM schedules and define organizational responsibilities. Monitoring frequencies and dates will be revised in these schedules.

LTM.4.5 Subsidence Data Study

Several subsidence studies have been completed and are included in the following documents:

1. *Final Environmental Impact Statement (FEIS), Waste Isolation Pilot Plant,* DOE/EIS-0026, DOE, 1980.

2. *Final Safety Analysis Report (FSAR), Waste Isolation Pilot Plant*, WP 02-09, WEC, 1990.
3. *Preliminary Comparison with 40 CFR §191, Part B for the Waste Isolation Pilot Plant, December 1991*, SAND91-0893, Vol 1, Methodology and Results, SNL, 1991.
4. *Backfill Engineering Analysis Report* (BEAR), IT Corporation, 1994.
5. *Report on First-Order Leveling Survey for Sandia Laboratories Waste Isolation Pilot Plant (WIPP) Project*, Undated, Rockville, Md. National Geodetic Society
6. *Vertical Movement in the Los Medaños and Nash Draw Areas, New Mexico*, As Indicated by 1977 and 1981 Leveling Surveys, 1982, NOAA Technical Memorandum NOS NGS 37. Rockville, Md. National Geodetic Society.

These reports evaluate the potential for, and predict subsidence due to, the mining of the repository's shafts, drifts, and rooms. These calculations account for a range of waste volumes, waste densities, and backfill types. Subsidence was also calculated for conditions where no backfill would be used.

The BEAR contains the most detailed data on subsidence. Contour maps are included in this report that detail subsidence predictions using influence function and the National Coal Board (NCB) method for scenarios with and without backfill. The maximum subsidence was also calculated using the mass conservation method.

The studies listed above predict the maximum subsidence expected. These studies were not specifically performed to estimate subsidence for long-term repository performance monitoring and do not account for other factors that may influence subsidence, such as local hydrocarbon extraction and local potash mining.

An SDS will include subsidence predictions documented in the BEAR and any subsequent subsidence predictive information that may be developed by the PA. The SDS will also investigate factors that influence subsidence to the extent that these factors are identified in the PA. The goal of the study is to document the most reliable subsidence predictions with respect to time and define the bounding limits that will indicate poor repository performance.

The SDS will define the most favorable positions for any additional benchmarks and oversee their placement in the network.

LTM.5.0 QA/QC REQUIREMENTS

Various QA/QC requirements exist for the WIPP project and many contractor QA/QC programs are in place. The WIPP is a DOE facility, and as such has specific DOE guidelines for QA/QC management. These guidelines are found in the *Quality Assurance Program Document,* CA0-94-1012. The DOE has agreed to adopt QA/QC guidance from the American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA)-1, NQA-2 and NQA-3. The EPA also has imposed QA/QC requirements for the

management of data and the LTM plan; specifically, requirements in 40 CFR §268.6 (b) (4) and 40 CFR §268.6 (c) (1 through 5). The scientific advisor also has a QA/QC program that is used for data collection that impacts LTM.

For this LTM report, the current QA/QC programs in place, which meet NQA-1, 2, and 3, and include sections for data quality, are assumed adequate for data collection. The LTM plan is required to contain the QA/QC plans for LTM management, data collection, analysis, and model validations. These plans will be compiled from the current QA/QC programs.

Other QA issues are associated with 40 CFR §268.6 requirements. This regulation requires the LTM plan to contain detailed records of the LTM system and data collection/recording procedures. Specifically, "All sampling, testing, and analytical data must be approved by the Administrator and must provide data that is accurate and reproducible" (40 CFR §268.6 (c) (5) (i)) and, "A quality assurance and quality control plan addressing all aspects of the monitoring program must be provided to and approved by the Administrator" (40 CFR §268.6 (c) (5) (iii)). An LTM QC plan shall be included as part of the LTM plan.

The overall goal of the QA/QC program associated with LTM is not just to meet all of the regulatory requirement, but to provide a defensible, reproducible monitoring system that effectively assesses repository performance.

LTM.6.0 LONG-TERM MONITORING SCHEDULES

The schedule for the implementation of LTM after D&D will be formalized during the CRS.

The schedule for LTM is composed of four basic monitoring groups; the initial geophysical survey group, the radiological EMP group, the subsidence monitoring group, and the abbreviated radiological environmental monitoring (EM) group. The initial geophysical survey group will be composed of a seismic survey, a resistivity survey, an EM survey, a gravitational survey, and a radiological aerial survey. The radiological EMP group (a continuation of the Operational Environmental Monitoring Program) will be performed for the first two years only. The Subsidence Monitoring group will include a leveling survey in the first and third year and every 10 years thereafter. The last group, the abbreviated radiological EM group, will include only three sample types (airborne particulate, soil, and water) taken on an annual basis for at least three years following cessation of the radiological EMP group. The schedule for the LTM process is detailed in Figure LTM-6.1 and the specific monitoring schedule after closure is shown in Figure LTM-6.2.

LTM.7.0 RECOMMENDATIONS

The LTM requirements are based on regulations, DOE/WIPP, and SNL documentation. From these requirements, physical, chemical, economical, and technical factors must be included in the conceptual approach to designing a LTM system. Such a system can be designed using a monitoring approach composed of a subsidence network, an LTMP, a Baseline Database, a CRS, and an SDS.

The range of periodic measurements from the subsidence network will be compared to the subsidence predictions. If the measured subsidence does not fall within the predictions, the Baseline Database can be used as comparison data to determine the nature, extent, and possible cause and ultimately determine if the repository is performing as expected.

The following describes the LTM monitoring design concept.

1. Create a Baseline Database that includes data from developmental and operational phase activities

2. Perform an SDS

3. Compile subsidence predictions and include any PA-developed scenarios of repository performance that fall outside the baseline subsidence predictions. Develop proper benchmark locations over the repository. The subsidence predictions will be developed from the information available in the BEAR and from any additional information provided by the PA.

4. Create a subsidence network over and around the facility

5. Perform a CRS

6. Perform the listed surveys to establish baseline data for the Baseline Database

   - Seismic survey over the waste panels after closure (once)
   - Resistivity survey over the waste panels after closure (once)
   - EM survey over the waste panels after closure (once)
   - Gravitational survey after closure (once)
   - Subsidence survey (throughout the program lifetime)
   - Obtain and archive core samples from previous core work (once)

7. Initiate the MP after closure. Perform periodic leveling surveys of the subsidence network and develop a schedule for future surveys. Perform the radiological EMP for two years and the abbreviated program for an additional three years

8. Compare leveling survey data to expected results

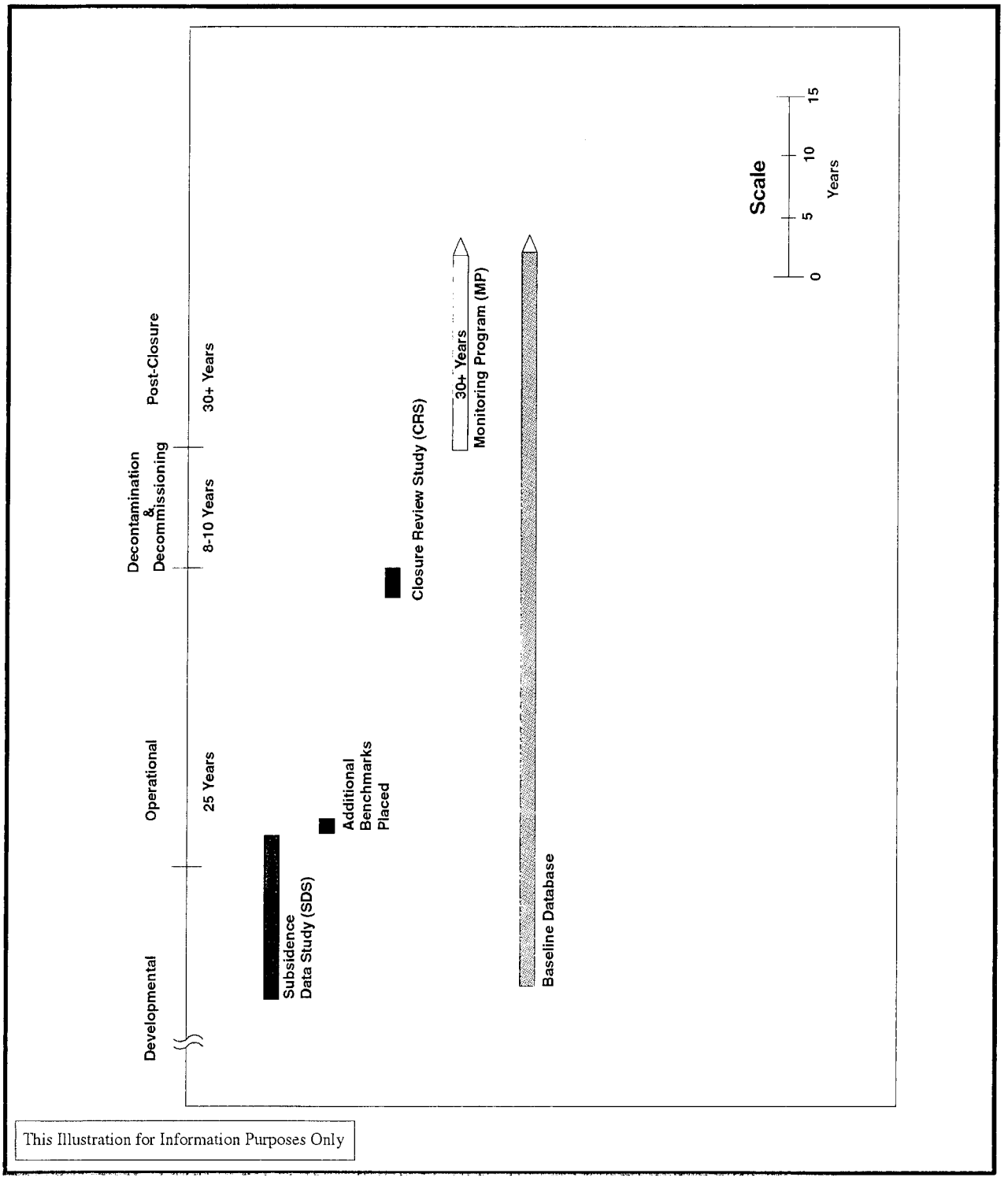

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Figure LTM-2. Long-Term Monitoring Program Conceptual Schedule

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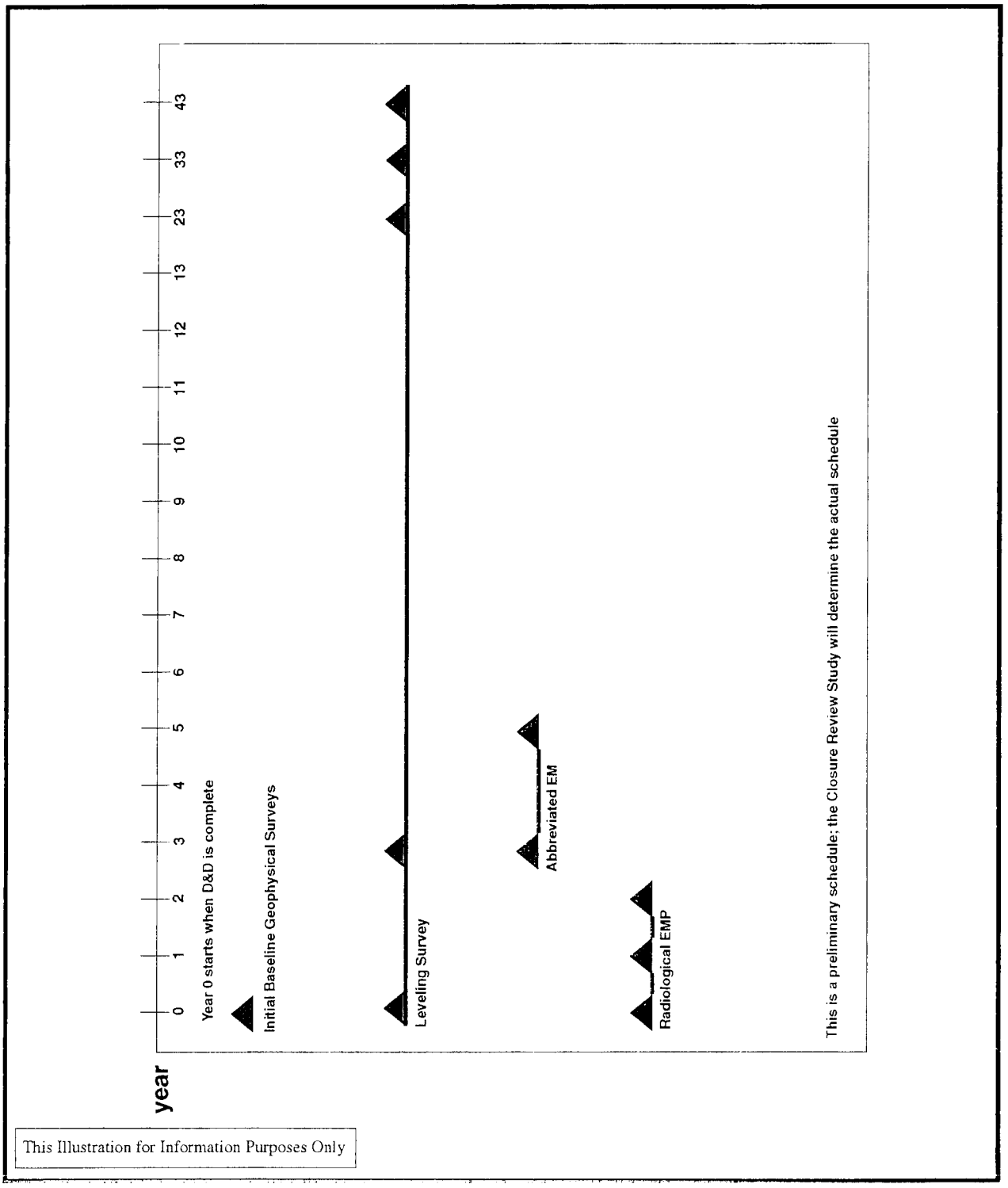

Figure LTM-3. Preliminary LTM Schedule

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9. Perform periodic reviews of the repository performance to determine the monitoring schedule and termination of the monitoring program

10. Perform maintenance on RCRA wells, replacing casings as required or every 25 years until monitoring ceases. Monitor per LTM schedule and LTM Plan requirements

11. Perform maintenance on subsidence network as required (determined during the leveling surveys)

This monitoring concept is based on current technologies and data for monitoring repository performance. The preliminary PA reports specify that monitoring parameters will be developed during the PA, but no specific requirements have been published. Future monitoring during the repository development and operational phases may provide data which indicate that LTM will not be relevant or identify new parameters that must be monitored. Future developments in the regulations may modify monitoring requirements.

The monitoring techniques specified in this report can be used to meet the requirements in the current regulations governing the facility and monitor performance of the facility. This concept provides for a reliable database against which future monitoring results can be compared.

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State of New Mexico v.s. U. S. Department of Energy, *Agreement for Consultation and Cooperation*, Civil action No. 81-0363 JB, July 1981 and supplements, revisions, and modifications dated December 1982, March 1983, November 1984, and March 1988.

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ATTACHMENT A
LONG-TERM MONITORING TECHNICAL STUDY

ATTACHMENT A
LONG-TERM MONITORING TECHNICAL STUDY

A. INTRODUCTION

Geophysical Survey/Monitoring Technology Description

The monitoring technology is defined for each of the technologies listed below. In addition, the past, current, and future work using this technology, as it relates to performance monitoring, is described. Also defined are the advantages, disadvantages, and proposed uses of the technologies in long-term monitoring (LTM) of the repository.

- Subsidence
- Seismic Reflection/Refraction
- Gravitational
- Electromagnetic
- Resistivity
- Direct Repository Monitoring

A.1 Subsidence

A.1.1 Description of Subsidence Monitoring

Subsidence is defined as vertical movement of the land surface anywhere in the subsidence basin. Subsidence monitoring is defined as the measurement of relative vertical movement of the land surface. This movement can be up (uplift) or down (subsidence) and is relative to a fixed reference. This reference is assumed fixed, even though it also moves, and is subjected to the same factors that cause the surface movement. Subsidence monitoring is used to determine the measurable vertical movement of a land mass. The techniques used to monitor subsidence measure the vertical height difference between two or more markers placed on the surface a known distance away from each other and is done with a leveling survey. Usually, one reference benchmark is used as the standard and the relative movement of other stations or benchmarks are measured to detect vertical movement over time. All subsidence measurements are relative, because the reference is not fixed.

The error of the survey is determined by the equipment and distances between the stations. A first order survey has an error of 1 part in 100,000 and a second order survey has an error of 1 part in 20,000. With current technology, several thousandths of an inch vertical movement can be measured.

Subsidence can be caused by a variety of factors. Mining, hydrocarbon extraction, water injection/extraction, geological tilt, and dissolution are major subsidence-causing factors, all of which may be applicable to the Waste Isolation Pilot Plant (WIPP) over the long term.

A.1.2 Advantages of Subsidence Monitoring

Subsidence monitoring is advantageous because it is a passive monitoring technique that is relatively simple to perform and uses well-established technologies. The cost of the survey is low compared to other technologies. This technique requires little system maintenance or monitoring and has no power requirement. The benchmarks are not affected by weather and can last for hundreds of years. Benchmarks can be replaced if required and the data can be offset to account for the change without affecting data quality.

A.1.3 Disadvantages of Subsidence Monitoring

The disadvantages associated with subsidence monitoring are in the benchmark placement. The benchmark should be left undisturbed. Existing benchmarks may be destroyed or moved if new construction occurs over the benchmarks. The permanent markers design may call for large earthen berms around the facility after closure. The placement of the berm may cover up existing benchmarks and may preclude line of sight measurements between existing benchmarks because the berm may be 30 ft (9 m) high. The benchmarks are not protected, and may be destroyed during land use by ranchers, drillers, or developers.

A.1.4 Past Subsidence Work

During the initial site selection process, 195 mi (314 km) of first order, Class 1 leveling survey were performed in 1977 by the National Geodetic Survey (NGS). Later, new survey lines were established that connected the previous first order benchmarks through Carlsbad to second order survey lines through Eunice and Hobbs. Benchmarks were placed over the Nash draw from the north end to the Remuda Basin, over potash mines, the WIPP site, and the San Simon Sink (Powers 1993). Independent of the NGS benchmarks, an additional 52 benchmarks were installed over the WIPP site and surrounding area.

The NGS network was resurveyed in 1981 and the relative movement between Carlsbad and the WIPP site was measured to be about 0.8 in (2 cm). Relative motion across the network was down to the east and up to the west (Powers 1993). The movement across the site can be seen in Figure A-1 and the positions of the benchmarks are shown in Figure A-2 (Balaza 1982). The relationships between subsidence and potash mining in the WIPP vicinity are discussed in Powers (1993). From data in this report, potash mining was shown to have caused significant subsidence at mines close to the WIPP. Two benchmarks over the Mississippi Chemical Corporation mine measured relative to Carlsbad show 10 in (25.4 cm) and 40 in (102.7 cm) movement downward from 1977 to 1981. Powers (1993) also discusses mining effects on surface subsidence at other mines and correlated a relationship between mining and the surface area effects. This effect is

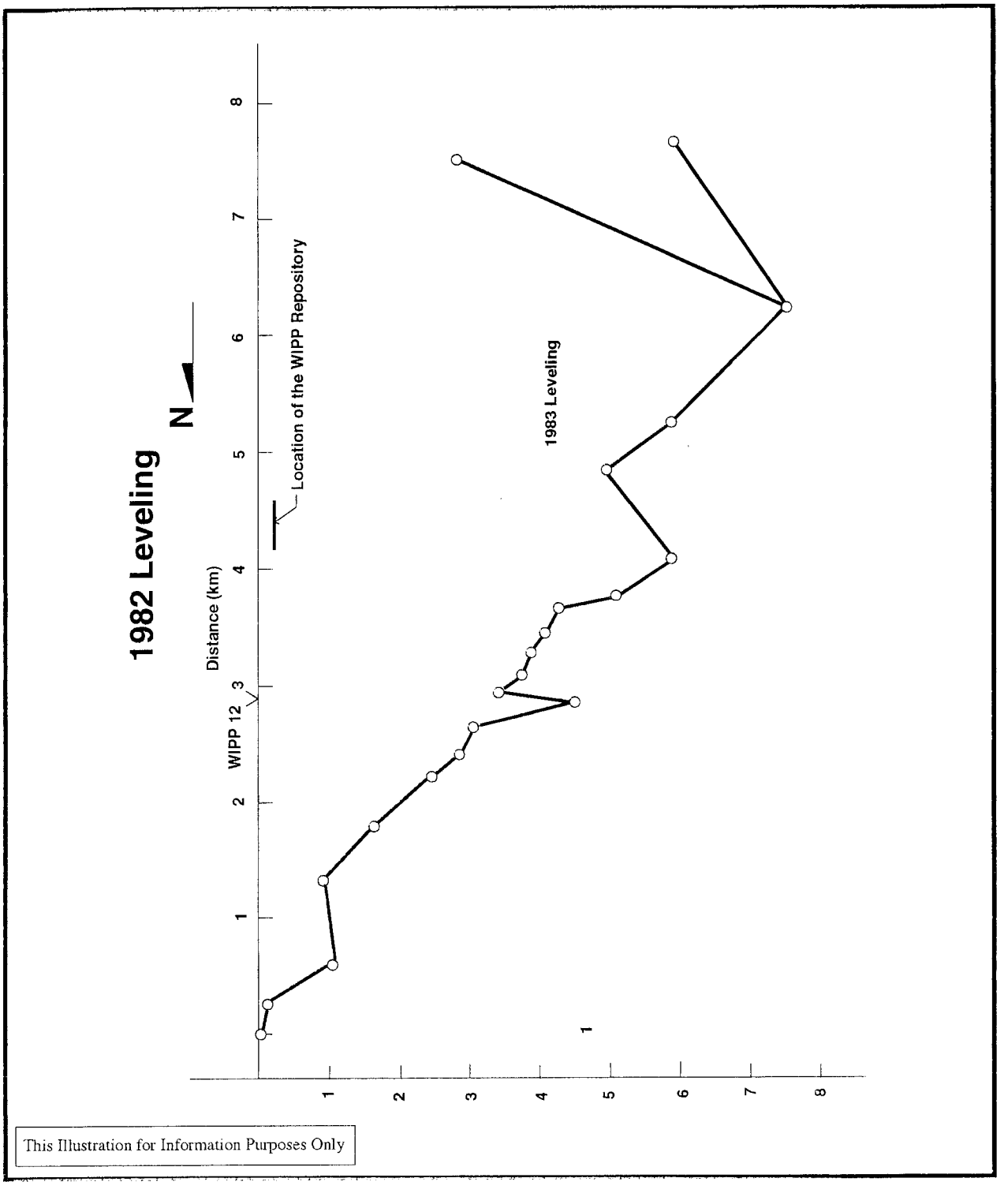

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Figure A-1. Measured Subsidence Across WIPP Site

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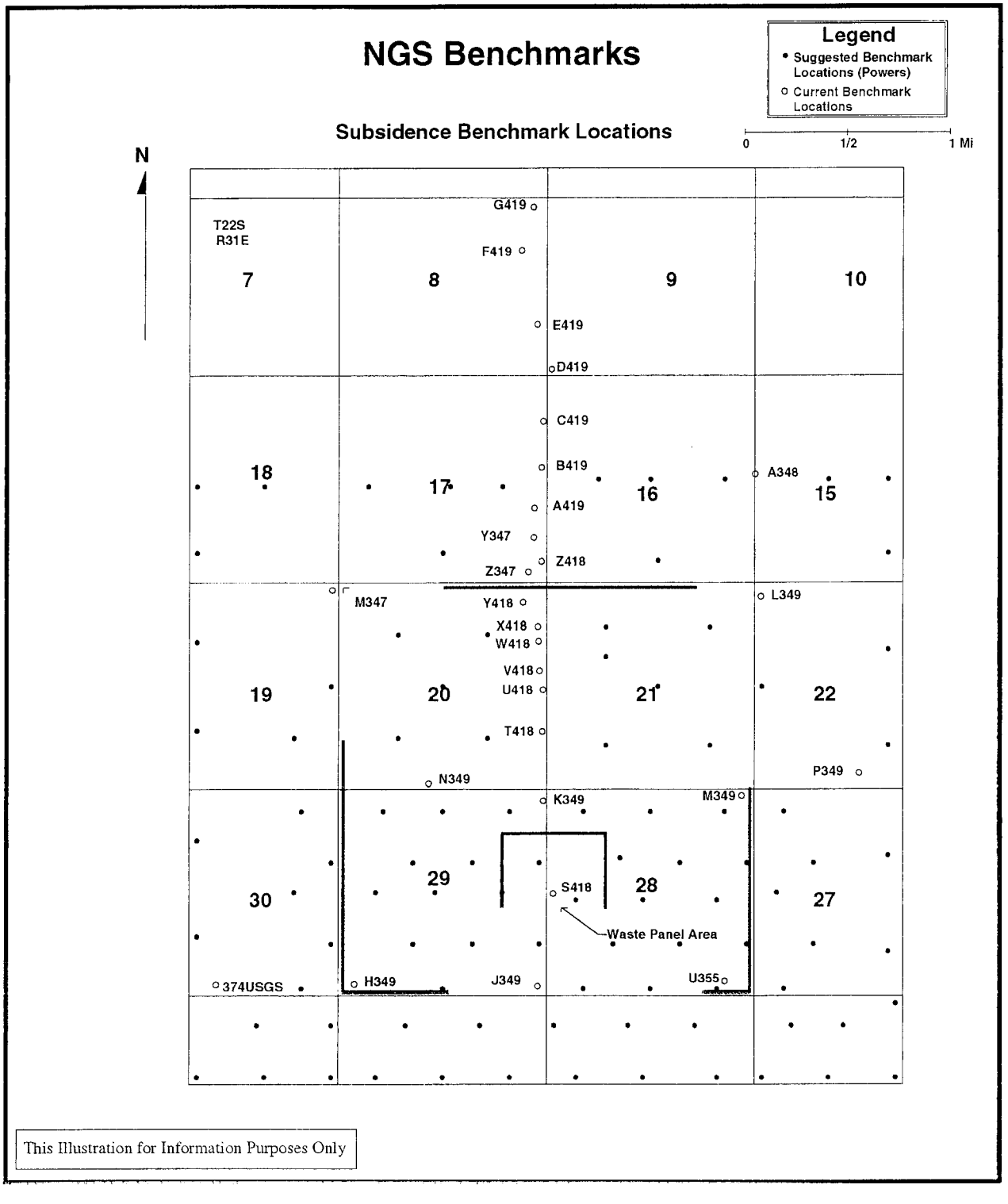

Figure A-2. Subsidence Benchmark Locations

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of importance to WIPP monitoring in that estimations of area mining and WIPP mining can be calculated into the subsidence predictions.

"In May, 1982, the NGS placed and leveled 15 additional high-quality benchmarks along a north-south line across the position of WIPP 12 (1 mile north of WIPP surface facilities) and the underlying brine reservoirs in the Castile Formation" (Powers 1993). After testing and fluid production of approximately 27,058 barrels of brine from the brine reservoir, the NGS resurveyed these benchmarks in January, 1983. "The major difference in elevation across these 15 benchmarks from May, 1982 to January, 1983, is about 6-7 mm between the north end of the line and the approximate position of the WIPP" (Powers 1993). Powers stated that he knows of no known mechanical or numerical simulation that can determine if this deformation is consistent with brine production.

A.1.5 Subsidence Predictions

Subsidence predictions due to mining can also be calculated empirically. Techniques such as mass conservation, National Coal Board (NCB), and profile and influence functions can be used to calculate subsidence caused by mining. The Influence function technique can estimate subsidence from room and pillar type mining, which is the type of mining used at the WIPP (Sutherland and Munson 1983). Four studies have been performed that have calculated subsidence predictions. The results are found in the Final Environmental Impact Statement (FEIS) (DOE 1980), the Final Safety Analysis Report (FSAR) (DOE 1990), Sandia National Laboratories' (SNLs') 1991 comparison with 40 CFR §191 (Preliminary Comparison with 40 CFR §191, Part B for the Waste Isolation Pilot Plant 1991), and the Backfill Engineering Analysis Report (BEAR) (IT Corporation for WEC 1994). The following details each report's maximum subsidence predictions:

MAXIMUM SUBSIDENCE PREDICTIONS

FEIS	
70 percent Backfill density	0.3 meter Subsidence
50 percent Backfill density	0.5 meter Subsidence
No Backfill	1.0 meter Subsidence
FSAR	
Shaft pillar area	0.3 to 0.38 meter Subsidence
(backfill type and amount not specified)	
SNL	
35° angle	0.09 meters Subsidence
25° angle	0.13 meters Subsidence
BEAR	
No Backfill (BF)	0.40 to 0.60 meter Subsidence
Highly Compacted BF	0.30 to 0.52 meter Subsidence

A.1.6 Current Work in Subsidence Monitoring

Current subsidence work includes annual monitoring, a proposed NGS survey, and a satellite positioning survey.

The WIPP currently monitors the benchmarks listed in drawing E-2700-1, on an annual basis (drawing by John West Engineering Co., 1-11-93). This survey is performed by Waste Isolation Division (WID) Personnel.

A.1.7 Future Work on Subsidence Monitoring

A NGS survey has been proposed for FY 1996. The current plan is to resurvey about every ten years. The last NGS survey was performed in 1982.

A.1.8 Define Use of Subsidence Surveys for LTM

This report assumes that substantial work will be performed during the operational phase to gather subsidence information and data. This data will be used to relate expected subsidence over time for various scenarios of repository performance. The effects of petroleum production, mining, and geological subsidence must be accounted for in these scenarios. These estimates would be compared to actual measurements.

During the operational phase, the current benchmarks and new benchmark network will be used to gather baseline data. After the operational phase, however, decommissioning of the surface facilities and erection of active and passive controls will eliminate some of this network. For this reason, during the decommissioning, damaged or lost stations should be replaced. Additional stations may be necessary to take into account the placement of the proposed passive permanent markers. It is expected that analysis may have determined subsidence estimates at specific locations; these locations should be included in the benchmark network.

After decommissioning and renovation of the benchmark network, a Class 1 leveling survey should be performed to determine baseline data. The network should be monitored after closure until monitoring is determined to no longer be necessary. The monitoring frequency has to be determined; however, the preliminary plan is every third year for the first 15 years. During this time, the data should be compared to the previous trends. If no anomalies are found, the monitoring frequencies should be adjusted to ten year intervals.

A.2 Seismic Reflection/Refraction Surveys

A.2.1 Description of Seismic Reflection/Refraction Surveys

Seismic Reflection/Refraction surveys are used to determine the depth, thickness, composition, and physical properties of geologic layers. Data from the survey can locate

specific horizons such as water tables, clay layers, and bedrock. This technology can be used to map the geological structures of large areas at great depths. Survey results are often used by geologists to locate specific geologies that may contain hydrocarbon reserves.

This method uses seismic wave transmissions to determine geologic structure depth and composition. Seismic waves travel at different velocities depending on the soil and rock type. Hard and dense rock have higher wave velocities than soft and less dense rock. Seismic waves can travel through and reflect or refract off of geological structures. Some of the wave energy will travel along the layers. This phenomena is used to determine depth and composition of the strata by measuring the return time of an induced wave generated at the surface and reflected and refracted back from the underlying strata.

This technique measures wave travel times through a sensor array, called geophones, placed over the area of interest. A seismic wave is generated by dropping a weight (anything from a hand sledge to truck mounted ram) or by using high explosives. A seismograph is used to amplify and record the data. By using various seismic wave input energies, sensor array spacings, and numbers, specific depths can be mapped (U.S. Environmental Protection Agency 1986). The map corresponds to a geological profile along the line surveyed. Figure A-3 details the basic seismic surveying technique.

A.2.2 Advantages of Seismic Reflection/Refraction Surveys

One advantage of this technique is the abundance of existing data. Numerous petroleum companies have performed seismic surveys in the area and several other surveys were performed during site selection (Waste Isolation Pilot Plant Repository Monitoring Program Strategic Plan 1993; Powers 1978). This data can be used as a reference to detect changes by comparison with new data. The quality of the data is good for lower structures but are not as useful above the 3,000 ft (910 m) (Powers 1978).

Seismic surveys are nonintrusive and require no permanent devices to be installed at the site. Seismic surveys are relatively inexpensive.

A.2.3 Disadvantages of Seismic Reflection/Refraction Surveys

Basic disadvantages of this technique include data quality and interpretation. This technique is sensitive to noise and equipment set-up. The data must be electronically processed, conditioned, and interpreted by an experienced geologist. Interpretation is an art form and no two interpretations are the same (Griswold 1977). This can create repeatability errors if the surveys are repeated on the same geology. The results are usually compared to core samples to verify the interpretation and validate the results.

Seismic surveys use equipment that allows for many variations in how data is collected. For comparison reasons, surveys must be performed using similar equipment set-ups (i.e. array spacings, line locations, data conditioning, etc.). Any variations in the technique

and equipment must be accounted for in the interpretation of the data to ensure that changes caused when different equipment is used for repeated surveys are not interpreted as geological changes.

Relatively thin strata and layers of similar densities cannot be distinguished. Since the technique is based on wave velocities, layers of material that may have different chemical and geological characteristics, but similar velocity components, cannot be differentiated.

A.2.4 Past Seismic Reflection/Refraction Survey Work

During the siting process for the WIPP, several geophysical techniques were used to gather geological data that would identify a suitable site location.

From 1976 to 1978, SNL conducted three surveys totaling 79 line mi (127 line km) of data, of which 72 line mi (116 line km) were over or near the WIPP site (Hern 1978). The first survey consisted of three lines totaling 24.98 line mi (40.22 line km) of conventional petroleum style data and was collected from petroleum companies. The other two surveys were conducted using short geophone spacing and high signal frequency for better shallow field resolution above 4,000 ft (1,220 m) (Powers 1978). One of these surveys totaled 47.04 line mi (76 line km) involving 13 lines. The third survey included seven and a half line mi (0.8 line km) of profiling run along crossing lines through the site (Griswold 1977; Hern 1978).

Approximately 189 line mi (304 line km) of older (1950s-1960s) seismic surveys performed by Shell Oil Co. were purchased from a brokerage firm (G.J. Long and Associates, Inc. 1976). Exxon allowed 196 line mi (316 line km) of their data to be viewed at their office; Amoco allowed 513 line mi (826 line km) of data to be viewed (G.J. Long and Associates, Inc. 1976). This data was considered proprietary and could not be distributed to other sources. All of the listed data was gathered and interpreted during 1976 (Griswold 1977). Results of the data were used to map the geological layers around the WIPP site. These maps are found in WP 02-9, FSAR Section 2.7.

In 1976, attempts were made to perform a high resolution shallow survey using weight drop techniques. This survey produced data that was not interpretable when compared to known geological information (Hern 1978).

In 1979, an extensive seismic survey was performed that profiled lines directly over the WIPP site boundaries in north-south and east-west patterns. The north-south lines were spaced at one-fourth mi (0.4 km) intervals and the east-west lines were spaced one-half mi (0.8 km) apart in Zone 2. In the areas between Zones 2 and 3, the lines were spaced further apart. The north-south lines were separated by one-half mi (0.8 km) and the east-west lines were spaced at one mi (1.6 km). This survey used the same basic parameters as the original SNL survey, with closer line spacing. The intent was to improve the accuracy of the data above the Salado formation.

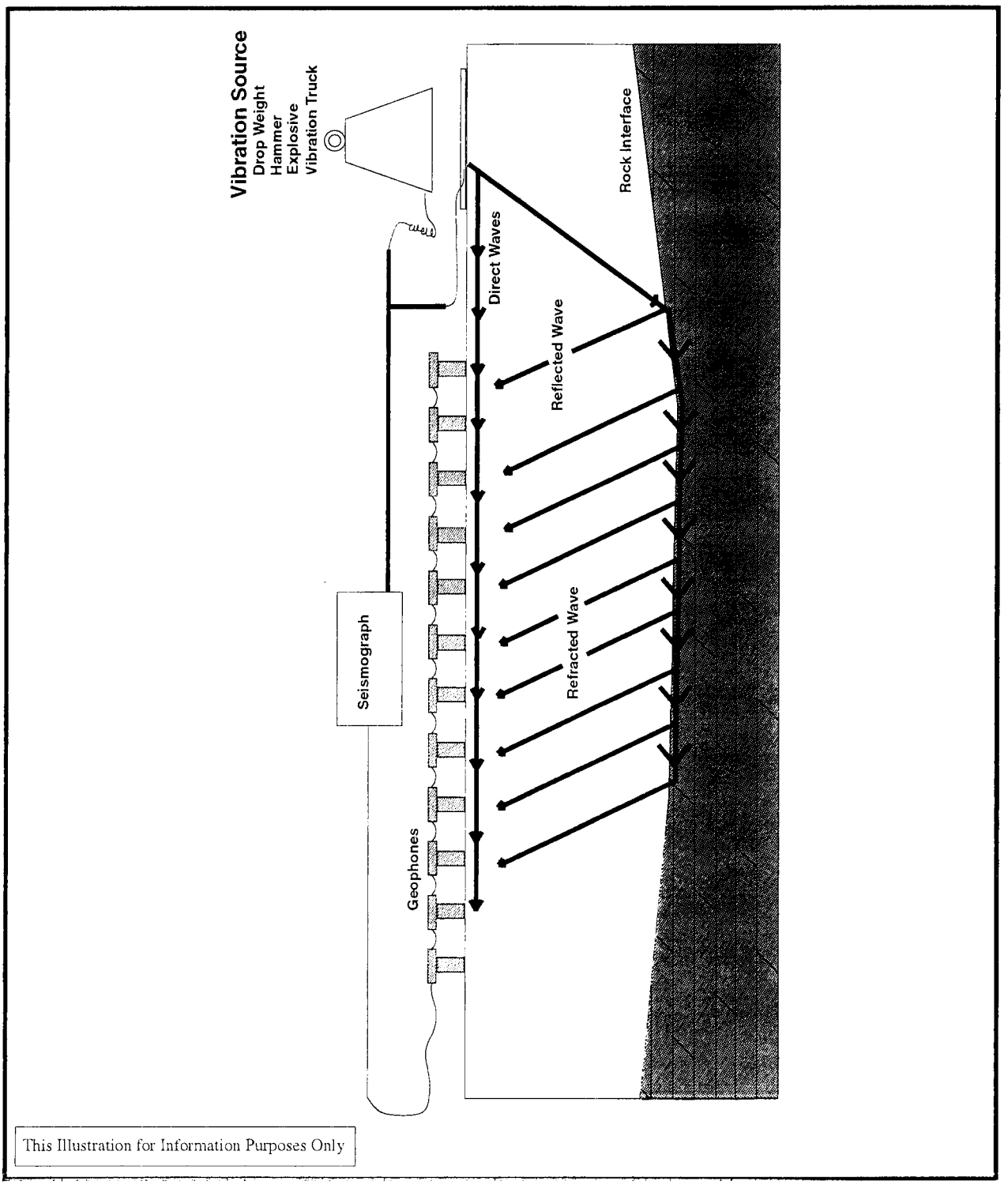

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Figure A-3. Seismic Reflection/Refraction Survey Concept

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A.2.5 Current Seismic Reflection/Refraction Work

No seismic surveys are being performed.

A.2.6 Future Reflection/Refraction Work

No seismic surveying is planned.

A.2.7 Define Uses for Seismic Reflection/Refraction Surveys in LTM

The seismic method determines the difference in geology by measuring the velocity of a wave through the rock. Any physical change in the rock is accompanied by a corresponding change in its velocity. Seismic surveys can be used to map the repository at various times. The specific depths and densities of various formations can be mapped and compared to data generated in the future to evaluate the repository performance. Changes in the strata, such as changes in aquifer depth and strata density changes, could then be determined.

After the repository is sealed and the facility is decommissioned, a seismic survey should be performed over the repository and surrounding area. This survey should be performed to provide good resolution above and below the repository. The survey results and raw data should be well documented and all interpretations of the data should be well defined. The results and data should be archived so baseline data can be used for comparison to future seismic data if the need arises. The baseline data will help identify changes in the geology surrounding the facility which could help determine if the repository performance is acceptable. The survey would only be performed after closure and would not be resurveyed unless new data was required.

The following are requirements for seismic monitoring uses in LTM.

- Archive data in at least two permanent formats
- Reference line surveys to benchmarks in the subsidence network
- Include all data reduction programs in the archive data
- The exact location for the survey (in accordance with the recommendation of an experienced geologist)
- Research methods to improve repeatability in geophone placement

A.3 Gravitational Surveys

A.3.1 Description of Gravitational Surveys

The gravity survey method maps small variations in the earth's gravitational field. These variations result from mass and density difference in the subsurface lithography of the earth's crust. Interpretation of the data from a gravity survey can detect structural displacement in the strata (Barrows 1983). The survey is performed by using a

gravimeter. The instrument measures the gravity intensity at a point. The data is expressed in milligal, where a gal is an acceleration of 1 cm/sec^2. Standard equipment is accurate to within a tenth of a milligal.

A.3.2 Advantages of Gravitational Surveys

This technology is helpful in determining the depth and area of various geological anomalies. Gravity surveys alone are not concise but aid the researcher in determining areas (anomalies) that should be explored using other geophysical techniques to determine the specifics of the anomaly.

The gravity survey is nonintrusive and relatively inexpensive when compared to other geophysical monitoring techniques.

A.3.3 Disadvantages of Gravitational Surveys

Gravity surveys do not provide the type of information that allows a geologist to determine the exact geological description and location of the strata surveyed.

This technique is very dependent on placement of the gravimeter. Placement errors can cause variability in results if the survey is repeated. For repeatability, exact placement of the gravimeter must be recorded and verified. This variation is not as pronounced when the results are mapped over a large area.

The data from the gravimeter is sensitive to surface structure, elevation, geographic latitude, and solar and lunar tides (Barrows 1983). Corrections must be made for the terrain and usually cause an error of ± 0.3 milligal (U.S. Department of the Interior Geologic Survey 1981). Surveying data point position and altitude is half the effort of the gravity survey. This method is prone to human error since manual recording is used. The data is often "edited" by reviewing the data and deleting any suspected transcription errors.

A.3.4 Past Gravitational Survey Work

During the siting phase in 1976, a regional gravity control was purchased from a geophysical company (Griswold 1977, Results of Site Validation Experiments). Over 3,000 mi (4,827 km) of gravity data was collected in the area as part of various hydrocarbon exploration surveys (DOE 1990). Also, two gravity surveys, the Main Site and the Reconnaissance Profiles, were conducted by SNL. Three smaller areas within the Main Site survey were resurveyed in greater detail to provide information on suspected anomalies.

The Main Site survey covered approximately eight and one half mi^2 (22 km^2). The lines were spaced one sixth mi (0.27 km) apart and ran north-south, with the stations spaced at one eighteenth mi (0.09 km) intervals (Barrows 1983). During this survey, an anomaly

was discovered and a borehole was drilled in that area. This area was surveyed in greater detail and covered an area 1,164 ft by 679 ft (355 m by 207 m). The stations were spaced in a grid 97 ft apart. Two other smaller areas were resurveyed to provide enhanced detail.

This data was used to detect anomalies in the strata and develop an interpretation of the disturbed zone (DZ). However, the DZ data was inconclusive (Barrows 1983). Areas surveyed detected some karst development. A gravity contour map of the WIPP site areas surveyed is found in SNL document SAND82-2992 (Barrows 1983).

A.3.5 Current Gravitational Survey Work

No known gravitational survey work is currently being performed.

A.3.6 Future Gravitational Survey Work

No known gravitational surveying is planned.

A.3.7 Define Uses of Gravitational Surveys for LTM

Gravity survey data should be included in the Baseline Database. All past surveys should be included along with extensive documentation defining the equipment, procedures, and data collection and processing techniques used. Surveys should be performed over the repository after closure and decommissioning, to provide baseline data for the repository. The original gravity survey data will not include the influence of over 6,000,000 ft^3 (170,000 m^3) of waste, so a new survey is required to provide a baseline after closure.

A.4 Electromagnetic Conductivity Surveys

A.4.1 Description of Electromagnetic Conductivity Surveys

The term Electromagnetic Conductivity is used by many geological companies to describe various geophysical equipment. For this report, the term is defined as a method that measures subsurface conductivity by low-frequency electromagnetic induction. This method uses a coil placed on the surface that transmits electromagnetic pulses, which induce eddy current loops in the layered strata below the transmitting loop. The induced loop currents are theoretically directly proportional to the resistance of the strata. The induced current produces a secondary field current that can be sensed by a receiving coil placed a fixed distance from the transmitting coil. The reading is a bulk measurement of conductivity of the strata directly below the transmitting loop to the effective depth of the instrument. The instruments effective depth is related to the distance between the transmitting and receiving coils. The electromagnetic system usually measures conductivity of the materials in millimhos per meter and is easily converted to resistivity. Conductivity is the reciprocal of resistivity.

The environmental monitoring system determines the conductivity of the strata which is related to the soil/rock geophysical and geochemical properties. Properties such as porosity, permeability, concentrations of colloids, and dissolved electrolytes in the pores and conductive minerals all influence conductivity, but the most influential factor is water content. Since water is the main factor, aquifers and brine pockets can be detected (U.S. Environmental Protection Agency 1986). Pipes, waste containers, metallic debris, and wire lines can also be detected (U.S. Environmental Protection Agency 1986).

Electromagnetic systems can be used to profile and map strata. Both stationary and mobile systems are available. Mobile systems are capable of taking continuous readings. A diagram of the basic system configuration is shown in Figure A-4.

A.4.2 Advantages of Electromagnetic Conductivity Surveys

The electromagnetic method is nonintrusive and can detect brine occurrences, strata layers with differing physical properties, and aquifers. Mapping of an area can be compared to subsequently acquired data to determine changes such as brine movements. The depth and area of brine pockets can be determined, which can then be used to estimate the volumes of the pockets. Electromagnetic surveys may be used to locate waste after placement.

The EM method does not require ground contact and the measurements can be taken continuously. Methods of this nature have good repeatability. Measurements can be made at ground level or from aerial surveys.

A.4.3 Disadvantages of Electromagnetic Conductivity Surveys

Electromagnetic technology falls short in data interpretation when a highly resistive layer is sandwiched between two highly conductive layers. Strata can have the same relative conductivity but be entirely different geologically. This method is not concise enough to be a stand-alone method but can be used along with other geophysical techniques to interpret the strata.

The results can vary with ground moisture content. Results after substantial rains are different than those performed after prolonged droughts. Interpretation of the data must account for these variations.

A.4.4 Past Electromagnetic Conductivity Survey Work

Several electromagnetic type surveys were performed by SNL. One survey was initiated to map brine occurrences in the strata above and below the repository. The survey measured 36 locations in a 9.3 mi by 6.2 mi (1.5 km by 1 km) grid directly over the repository. Two other measurements were made, one at WIPP-12 borehole and the other at DOE-1 borehole. A calibration measurement was made at ERDA-9. The final interpretation of the survey data details brine occurrences. These results correlated well

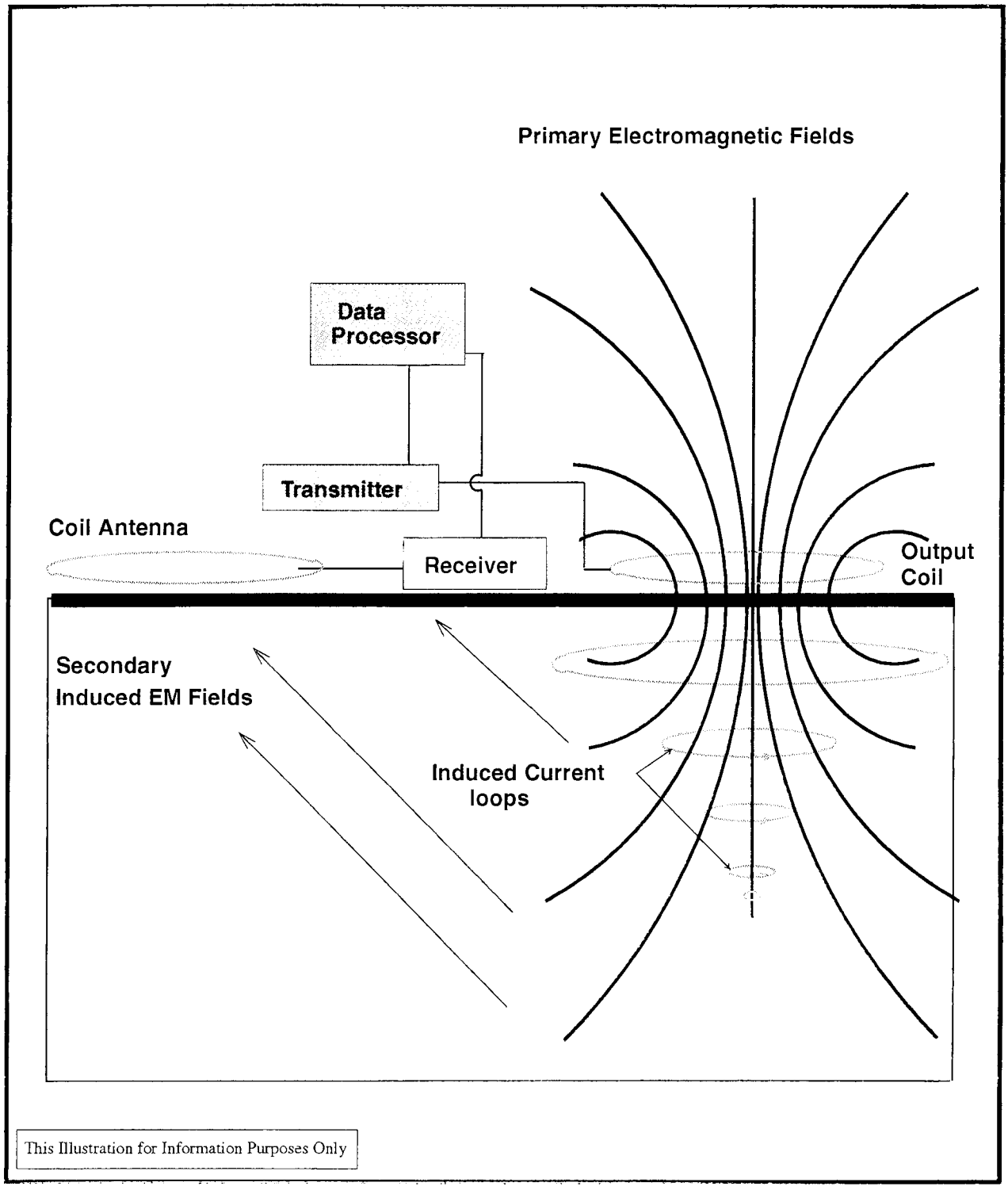

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Figure A-4. Electromagnetic Survey Technique

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with the depths of the brine occurrences found at WIPP-12 and ERDA-9 (Earth Technologies Corporation 1988).

When comparing the results of electromagnetic survey data with borehole logs, the accuracy of determining the depth to brine is better than 246 ft (75 m) at depths between 305 to 460 ft (1,000 to 1,500 m).

Aeromagnetic survey maps are available from the U.S. Geological Survey (Map GP-861, Carlsbad/West Texas) and Aero Service Library (No. 43-6, Carlsbad/West Texas) (Elliot Geophysical Company 1976).

A.4.5 Current Electromagnetic Conductivity Survey Work

No electromagnetic work is currently being performed.

A.4.6 Future Electromagnetic Conductivity Survey Work

No electromagnetic work is planned.

A.4.7 Define Uses of Electromagnetic Conductivity Surveys for LTM

Electromagnetic surveying has the capability of detecting water or brine occurrences, and can differentiate layers with varying physical properties. This technique could be used to monitor the facility after closure to determine if brine has migrated into the shafts, boreholes, and/or repository.

The performance of the shaft, borehole seals, and boreholes could be monitored to determine if they are maintaining the isolation between the aquifers in the Rustler Formation. The repository could be mapped directly after the repository is sealed and included in the baseline data to be used for comparison at a later date.

A.5 Resistivity Surveys

A.5.1 Description of Resistivity Surveys

The Resistivity method is similar in nature to the electromagnetic method. Resistivity measures the resistance of the rock and electromagnetic measures the conductance. Resistance is the reciprocal of conductance. The resistivity of the rock and soil is influenced by the same factors listed in the previous section for conductivity. By varying the electrode spacing geometries and currents, different parameters can be measured. Two specific methods used during WIPP siting are Schlumberger sounding and Gradient array profiling.

The resistivity method uses four sets of electrodes on the surface, spaced in a specific geometry. Two electrodes are energized to create a current through the strata between the

electrodes. The second pair of electrodes measures the potential produced from the first pair. The strata's resistivity can be calculated from the potential and electrode geometry/spacing.

As with the other types of geophysical monitoring methods, resistivity measurements can be used to perform sounding and profiling. Profiling maps the changes in the subsurface resistivity horizontally. Sounding can detect vertical changes in subsurface resistivity. The interpretation of the results can be used to determine the depth and thickness of geologic layers of different resistivity. This method can detect soil thickness and depth to aquifers or brine layers (U.S. Environmental Protection Agency 1986). A diagram describing the basic system configuration is shown in Figure A-5.

A.5.2 Advantages of Resistivity Surveys

The Gradient array profiling method is relatively simple. The electrodes are separated at large distances, which enables economical mapping of large areas.

The advantages of this method are identical to the electromagnetic method.

A.5.3 Disadvantages of Resistivity Surveys

Variations in placement will give differing results if the survey is repeated in the same area. The resistivity surveys require direct ground contact and cannot be performed continuously. The condition of the surface layer can affect the results because variation in the soils moisture content can be detected. Measurements performed shortly after rains will be different than measurements taken after prolonged droughts. This can be accounted for in the interpretation of the results. Resistivity also has the same disadvantages as the electromagnetic method.

A.5.4 Past Resistivity Survey Work

Extensive Resistivity surveys were conducted during the siting of the WIPP from 1976 to 1978. Areas around suspected breccia pipes and sinks (off-site) were surveyed to determine if Resistivity surveys could be used to detect these structures within the WIPP site. All zones of the WIPP site were surveyed. Mining Geophysical Surveys, Inc. performed 53 Schlumberger array soundings and approximately 391 line mi (631 line km) of gradient array profiling (9,880 measurements) (Elliot Geophysical Company 1977).

A.5.5 Current Resistivity Survey Work

No resistivity work is currently being performed.

A.5.6 Future Resistivity Survey Work

No resistivity work is planned.

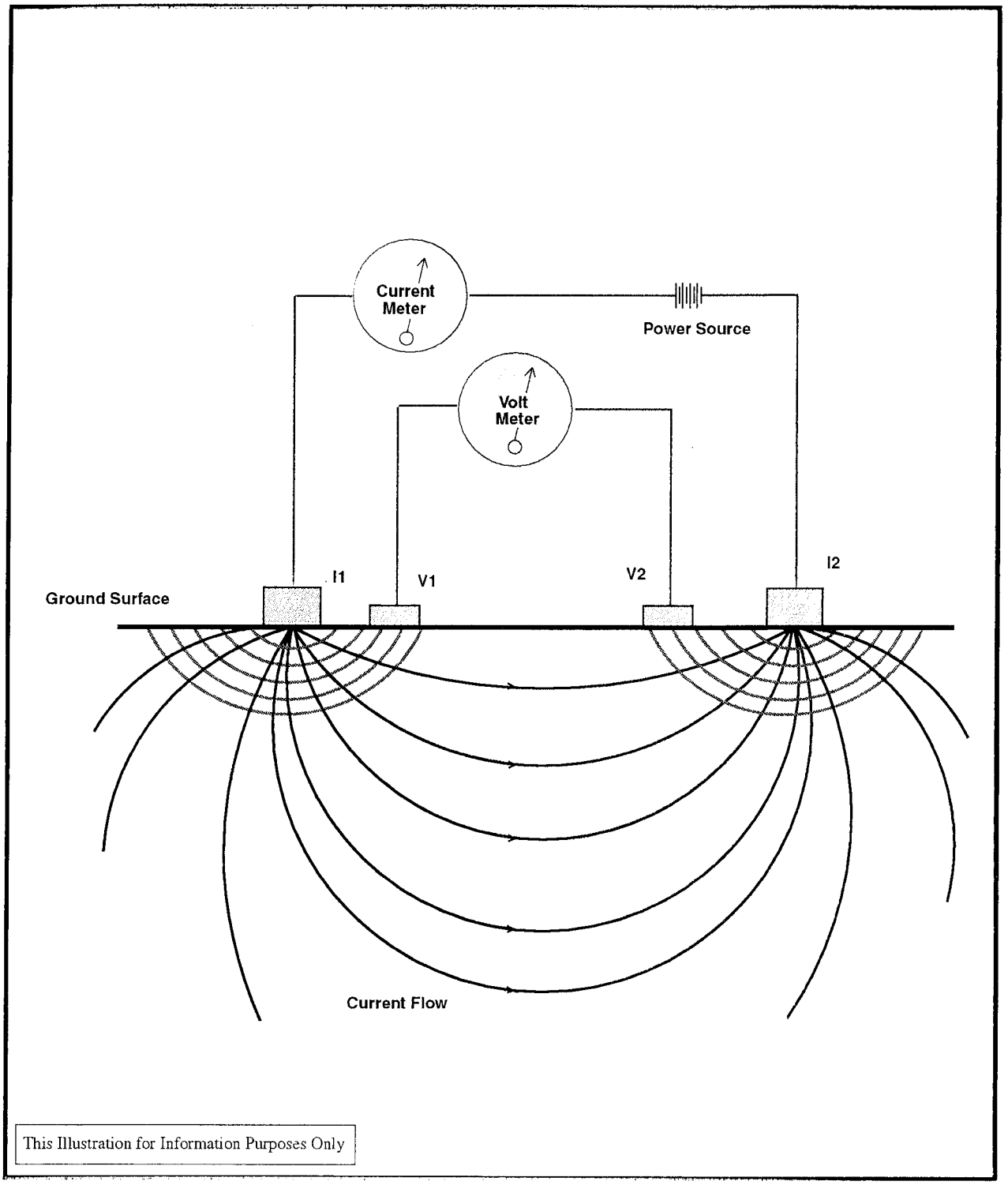

Figure A-5. Resistivity Survey Concept

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A.5.7 Define Uses of Resistivity Surveys for LTM

This technology can be used along with electromagnetic techniques to gather data immediately after the repository is sealed. Both profiling and sounding should be performed to produce geological maps of the strata's resistivity.

When the surveys are made, the exact locations and methods used should be carefully documented. If possible, research may be required to develop a system for electrode placement to ensure good repeatability in the surveys. This data should be documented in the Baseline Database for future comparison.

A.6 Environmental Monitoring

A.6.1 Discussion

Environmental monitoring of the WIPP repository will be performed during the operational and decontamination and decommissioning periods. Regulations require some form of surface, air, and water radiological monitoring during the operation of the repository. However, the use of these systems after closure in detecting timely deviations in the repository's long-term performance is impractical because detection would only serve to assess the severity of the release, not predict its occurrence. The Agreement of Consultation and Cooperation (C&C) between the State of New Mexico and the DOE requires radiological environmental monitoring for at least five years past closure. This agreement specifies that the environmental monitoring program in place during the operational phase must be continued after closure and decommissioning for at least two years, and that an abbreviated program with a limited number of radiological air, soil, water, and background samples be performed for the following two years.

The post-closure environmental monitoring program is required to include the following (Waste Isolation Pilot Plant Environmental Monitoring Plan 1994):

- Radiological Environmental Monitoring (first two years after Decontamination and Decommissioning (D&D))

  - External Radiation
    Continuous Exposure Rate Measurements
  - Airborne Particulate
    Lo-Vol Sampling, eight stations
  - Vegetation
    Four sites
  - Beef
    Annual muscle samples, if available
  - Game Animals
    Annual muscle samples of rabbits and quail

- Soil Samples
  Annual, multiple samples at multiple depths at six locations.
- Surface/Drinking Water
  Annual surface water samples from 12 major bodies of surface water in the vicinity of the site (drinking water will not exist after D&D)
- Groundwater
  Annually, one sample from eight of the wells within the 16 sections boundary taken from the Culebra Dolomite.
- Aquatic Foodstuffs
  Samples of catfish taken from the Pecos River and Brantley Lake, analyzed annually
- Sediment Sampling
  Annual samples taken from the Hill and Indian tank and the Pecos River near Artesia and Malaga, NM

• Abbreviated Radiological Environmental Monitoring (years three, four, and five after D&D)
- Airborne Particulate
  Intermittent operation of the state-operated high volume air sampling stations
- Soil
  Four annual soil surface samples
- Water
  Four annual well water samples

Only the radiological environmental monitoring techniques that apply after closure are included. Items such as effluent monitoring at the Exhaust Shaft were not included because they do not apply after closure.

A.6.2 Past Environmental Monitoring Work

Environmental Monitoring has been an ongoing program since the WIPP's inception. Baseline environmental data was gathered and reported in annual reports and the Environmental Monitoring Plan (EMP) was created. This information is too vast to be included in this report. The current operational EMP is detailed in the "Environmental Monitoring Plan," WIPP/DOE 94-024 and the "Site Environmental Report for the Calendar Year 1993," DOE/WIPP 94-2033. The reference section of these reports list most of the previous environmental monitoring work reports.

A.7 Direct Repository Monitoring

A.7.1 Discussion

As noted in earlier discussions, no proposed LTM techniques include technologies to directly monitor the repository. This is due to the inherent difficulties imposed by the

noninvasive requirement. No wiring or boreholes can be used to connect monitoring equipment in the repository to the surface.

The U.S Bureau of Mines and commercial companies throughout the world are currently researching techniques to communicate through the strata to mine working areas using very-low frequency (VLF) and ultra-low frequency (ULF) electromagnetic radiation. Several companies have developed mine paging systems that use VLF to warn workers within the mine using a system placed on the surface. One system can transmit messages with up to 32 characters to mobile mine pagers. This technology shows promise in remote instrumentation communication that could directly monitor the repository. It has been demonstrated in other salt mines that communication from the surface to the depth of the WIPP repository is possible.

Recently, researchers have started to investigate methods to remotely monitor the sealed rooms and panels. This work uses VLF technology to link sensors and equipment in sealed rooms to the data recorder without a hardwired link. Current work is focused on communication where the link between the transmitter and receiver is only three to ten meters.

The VLF could be used to transmit data from the surface to equipment located in the repository, but the problem lies in communicating the sensor data to the surface. The power required to transmit between the surface and the underground using the current technology is related to the strata conductivity, the output power at the transmitter, and the antenna design. Tests performed in actual mines used large loop antennas on the surface to transmit the signal. Tests have shown that loop diameter is more important in transmission efficiency than output power. Antennas ranging from 98 to over 330 ft (30 to over 100 m) in diameter have been used (U.S. Department of the Interior Bureau of Mines 1991).

There are many problems that must be overcome to directly monitor the repository after closure. Some of these problems are listed below.

- Sensor/transducer calibration
- Sensor longevity in the repository environment
- Data collection and transmission power requirements
- Antenna locations and sizes

A.7.2 Sensor Calibration

Over time, most sensors, such as pressure, gas analyzer, and extensometer sensor/ transducer, experience some change in resolution or drift. Any type of sensor/transducer used would need to operate for 100 years without recalibration. To overcome this problem, redundant sensors, sensor drift calculations, and accessible sensors as standards could be used to limit the induced errors. However, this would not ensure accuracy over the required time frame.

A.7.3 Sensor Longevity

The sensors used for LTM would be required to operate in a salt/brine environment for over 100 years. This imposes the biggest obstacle in Direct Repository Monitoring (DRM). Corrosion, oxidation, and various chemical reactions within the electrical components limit the life span to less than 50 years. Extreme condition research would be required to design a system that could operate for 100 years.

A.7.4 Data Collection and Transmission Power Requirements

A power source that could operate for the time required is not currently available. Battery systems have limited shelf lives and capacities. Lithium type batteries have the longest shelf life of the common battery types. Standard shelf lives of five to ten years at their rated capacity is standard, with some manufactures claiming 80 percent capacity after 15 years. Since the capacity requirements are dependent on the equipment load, the highest current requirement would occur during data transmittal. From experimental work, an estimate of at least 350 watts may be required to transmit to the surface. This can be accomplished with standard power sources for the short-term, but other methods of power generation would be required for the long-term.

One method is power transmission and retention. Power could be transmitted from the surface using ULF energy and an antenna would intercept this energy and store it in capacitors or a special battery. Since the system could be charged for long periods of time between data transmissions, only a small amount of surface transmitted power is required. The problem with this approach is power storage.

The chemical nature of rechargeable batteries limits their life span. The effects of oxidation, outgassing, and heat damage will cause a battery to fail. The life span of most common rechargeable (lead acid, gel, and NiCad) batteries is dependent on the number of recharge cycles, the rate of discharge, and charge rates. Under favorable conditions, most rechargeable batteries can last up to 10 years.

The capacitor is a device that stores energy on two plates separated by an insulator. Capacitors can be designed for this application that would last the required time frame. The problem associated with capacitors is related to power storage capability and size. In comparison, a capacitor and a battery with the same approximate volume do not have the same energy storage capacity. For example, a one μf capacitor charged to 1,000 volt has one-half Joule of energy storage, a 500 mAh NiCad (1.2 volt) of similar volume has 2,160 Joules of energy storage. A capacitor that has this energy storage potential would be extremely large (4,320 times larger).

Satellite power sources use nuclear energy to generate power. These systems would require extensive regulatory groundwork before it could be used. The systems are not considered off-the-shelf technology. However, work is progressing on a Nuclear Heat Power Source using (almost) off-the-shelf technology. One experimental study calls this

type of power source a Powerstick (Chmielewski and Ewell 1994). This theoretical device would use a nuclear heat source and a thermopile to generate an electrical potential. The heat source is a common satellite product used to heat instrumentation. The power source is capable of initially producing 42 milliwatts at 15 volts and would degrade to 37 milliwatts at 14 volts in 10 years. These power sources could be used to slowly charge batteries and/or capacitors that would then be used for a short duration, high demand data transmission cycle, or in parallel for a higher current source.

The regulatory issues associated with nuclear power sources have not been researched. If the remote handled-transuranic (RH-TRU) waste could be used as the heat source, and WIPP receives RH-TRU waste, the regulatory issues may be overcome.

The nuclear/thermopile power source technology has not been proven and there is no prototype as yet. Advances in battery design and the development of this nuclear power source could eventually allow this technology to power a direct repository monitor.

A.7.5 Antenna Location and Size

The size of the antenna may pose a problem in the mine setting. If the antenna is placed inside a room, diameters are limited to a maximum of approximately 33 ft (10 m). If the antenna can be wrapped around a pillar, the antenna would have a radius of approximately 164 ft (50 m), but diameters between 10 and 100 would require special provisions. Also, the effects of the metal in the room will increase the power requirement. These problems can be overcome, but experimentation would be needed to verify the effectiveness of the antenna design.

Currently, no known system is available that could be used to directly transmit data to the surface without a hardwired link. Extensive research and development is needed to develop such a system; however, the system's longevity will be suspect since actual long-term testing could not be accomplished and new technologies are rarely foolproof. For this reason, DRM is not recommended at this time for LTM.

A.8 Conclusion

There is no single geophysical technical exploratory technique that can determine the condition of the surveyed strata. Several techniques are used to gather data to assess the geological structure being examined because interpretation of one technique often uses data from another. For this reason, no one technique should be used to fully assess the repository's condition. One technique can be used as an identifier to alert that a condition may exist and other techniques can be used in unison to assess and validate the condition.

From the review of geophysical survey techniques, the best current monitoring technology that can be used for a LTM identifier is subsidence. This method is the most practical because it is a simple, repeatable, low cost, low maintenance, low technology approach to monitoring the repository. This method should be used as a primary monitor

technique for determining that a possible repository performance problem exists. Other techniques can then be utilized to determine the cause of the problem.

A combination of seismic, electromagnetic, resistivity, and gravitational surveys can be used to assess repository performance. However, it is not practical to perform these on a regular basis, especially if there is good confidence that a performance-related event will not occur. For this reason, an initial collection of surveys could be compiled and used as a standard to assess future data and perform subsidence monitoring to forewarn of changing conditions that may affect repository performance.

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APPENDIX MASS

MASS.1.0 INTRODUCTION

This appendix documents fundamental assumptions underlying the simulation of long-term performance of the disposal unit. Some assumptions discussed in this section are related to Features, Events, and Processes (FEPs) evaluated in the No-Migration Variance Petition (NMVP) uncertainty analyses and Appendix SCR, but requiring a separate justification, as well as an additional level of explanation than assumptions documented elsewhere in the analysis. Chapter 8 of the NMVP provides an overview of assumptions intended as a quick reference describing initial conditions and simplifications necessary to implement the simulation. Other assumptions related to screening FEPs embedded in the selection or calculation of parameter values, or associated with software codes used in the analysis, are addressed within the context of attached appendices (e.g., Appendix SCR, Appendix PAR, Appendix BRAGFLO). Readers are referred to Chapter 8 of the NMVP for a discussion of how the following modeling assumptions discussed in this section relate to the overall analysis:

1. Two-dimensional vertical plane model of the disposal system

2. Convergent and divergent flow to and from the repository

3. Application of Darcy's Law to all modeled media

4. Hydrogen gas as surrogate for waste-generated gas physical properties

5. Salado brine as surrogate for liquid phase physical properties

6. Simplified Salado stratigraphy used in BRAGFLO

7. High threshold pressure for halite-rich Salado rock units

8. Modeled geometry of the repository

MASS.1.1 Two-Dimensional Vertical Plane Model of the Disposal System

The model geometry adopted for the BRAGFLO calculations in this assessment consists of a two-dimensional vertical plane that models flow as convergent to or divergent from the repository. The adequacy of this geometry is evaluated in a model comparison study that compares a slightly simplified BRAGFLO geometry, to a comparable three-dimensional model geometry. The modeling study is documented as "FEP S-1: Verification of 2-D-Radial Flaring Geometry Using 3-D Geometry." Documentation for this study is retained in the Sandia National Laboratories WIPP Central Files.

The study evaluates the effects of flow in the Salado using BRAGFLO. The vertical heterogeneity in the Salado is discretized similarly to the discretization used in the

NMVP. A primary simplification in the comparative study includes coarsening the lateral grid spacing to make direct spatial correlation with the three-dimensional simulations possible. A coarse grid is necessary in three-dimensional simulations to make them computationally feasible.

The comparative study included a fracture model to assess the response of interbeds to high gas pressure and implemented a model configuration similar to that used in the NMVP simulation. The model configuration included a 1-degree regional dip, a five-year start-up period to represent the effects of the operational phase, no consumption of brine, and a 10,000-year simulation period. Two gas generation conditions were considered: Case 1 used a constant gas generation rate of 1.6 moles per drum per year and Case 2 used a constant gas generation rate of 3.2 moles per drum per year.

Performance measures in the study included pressure behavior in the repository and flow of brine up the shaft and out through Salado interbeds in a lateral direction. For both gas generation conditions, the values of performance measures were similar for both two-dimensional and three-dimensional model geometries. From these results it was concluded that the two-dimensional model geometry was an acceptable representation of the disposal system for performance assessment calculations.

MASS.1.2 Convergent and Divergent Flow to and from the Repository

The BRAGFLO geometry for the disposal system is an approximation of an axisymmetric model (i.e., that all flow is convergent to or divergent from a central source or sink). In the BRAGFLO model, the central source or sink for fluids is the repository. The BRAGFLO model is not a pure axisymmetric model, because the repository contains features that need to be distinguished from each other, and thus, the central source or sink is not homogeneous. Superimposed on the axisymmetric BRAGFLO geometry is a 1-degree inclination from north to south representing the regional dip, which is an additional deviation from a true axisymmetric model, and allows gravity to affect flow directions.

The assumption of axisymmetric flow in the Salado with the repository as the axis of symmetry is supported by the preponderance of observations that have been made at the repository horizon at the Waste Isolation Pilot Plant (WIPP) site. Axisymmetric flow would be expected in the Salado if the interbeds are reasonably isotropic under intact conditions, and, if high gas pressure is generated in the repository, induced fractures propagate in all directions from the repository with uniform properties (i.e., properties that are independent of the direction of propagation).

The present-day properties of the interbeds resulted from the processes that formed them and that acted on them following deposition. The deposition of the interbeds occurred in a low-energy environment under conditions that were quite uniform over a wide region. Thus, while some variation in rock composition and fabric can be observed, the lateral variability of these features in the interbeds is small. There is no evidence that

throughgoing textures in the interbeds that might cause anisotropic flow properties (for example, inclined beds) were created during or after deposition.

The interbeds contain partially healed fractures that are likely related to regional tectonic uplift of the basin or changes in overburden thickness related to deposition and erosion of overlying strata. Because the scale of the disposal system is small compared to the area over which these processes acted (i.e., the variation caused by uplift, deposition, and erosion occurred on a scale greater than that of the disposal system), the fractures in the interbeds have similar features throughout the disposal system.

The partially-healed fractures in the disposal system are inclined 10 to 15 degrees on the meter scale, with larger inclinations at very small scale. The direction of these inclinations varies, so that a fracture network composed of multiple, shallow-dip, partially-healed fractures was formed. Because of the geometry of these interconnected fractures, it is reasonable to assume that the fracture network is not associated with anisotropy that would, on the scale of the disposal system, restrict flow to preferred directions in the interbeds. At smaller scales, on the order of meters or tens of meters, flow may occur preferentially in one direction or another due to variation in fracture aperture and fracture connectivity.

High pressure in the repository may induce preexisting fractures to dilate and interconnect by new fracturing or may cause entirely new fractures to form. Because the interbeds have insignificant preexisting lateral anisotropy, the direction in which new fractures form will not be controlled by preexisting rock properties. In nearly horizontal strata with preexisting fractures, new fractures will tend to propagate to uniform distances in all directions from the source of pressure. This occurs because the transmission of energy for fracture propagation to the fracture tip is more difficult as a fracture gets longer, with the result that fractures cannot propagate a long distance in one direction from the source of driving energy before fracturing in another direction becomes preferable. This causes the induced fracturing to propagate radially away from the repository and for the induced fracturing to bridge regions that are unfractured. This process creates a network of induced fractures that is axisymmetric about a point source. The slight dip of the Salado would be expected to influence the radial pattern somewhat, and this is observed in BRAGFLO model results if the conditions occur which activate the interbed fracture submodel.

MASS.1.3 Application of Darcy's Law to All Modeled Media

A mathematical relationship expressing the flux of fluid through porous media as a function of the properties of the rock, fluid, and applied pressure or gravity forces, commonly known as Darcy's Law, is applied to all porous media for all fluid flow calculations. For details about the specific formulation of Darcy's Law used, see Appendix BRAGFLO.

Darcy's Law is generally applicable for flow models if certain conditions are satisfied: (1) the flow is occurring in a porous medium with interconnected porosity, (2) flow

velocities are low enough that viscous forces dominate inertial forces, and (3) a threshold gradient is met.

Hydraulic tests in the Salado (Beauheim et al. 1991, 1993) have been carefully designed to limit the effects of outside influences on the tested interval and provide the best evidence for the controlling flow mechanism in the Salado. The tests influence rock as far as 32 ft (11 m) distant from the test zone and are not thought to significantly alter the pretest conditions of most of the tested region. The stratigraphic intervals tested include halite (both pure and impure) and anhydrite with associated clay seams at distances from 3 ft to 75 ft (1 m to 23 m) from the repository. Because tests close to the repository are within the DRZ, tests farthest from the repository are considered representative of undisturbed conditions.

The tests are interpreted using potentiometric flow models incorporating Darcy's Law. Successful interpretations using these models were obtained and indicate a continuous porous medium that can be hydraulically characterized with permeability, pore compressibility, and porosity parameters. Tests in pure halite yield ambiguous interpretations, indicating either very low permeability or no flow whatsoever (a potential violation of the applicability of Darcy's Law). However, the effects of the pure halite layers on the performance of the repository have been demonstrated to be small (see below). Thus, the regions of importance to the performance of the repository have been tested and do behave as continuous porous media that obey Darcy's Law.

Bear (1972, 125) discusses the balance of viscous and inertial forces in fluid flow. The Reynold's number (Re) is the ratio of inertial to viscous forces. For porous media, Re is calculated as

$$Re = \frac{qd}{\nu}, \qquad (1)$$

where q is the specific discharge, d is some length dimension of the porous matrix, and ν is the kinematic viscosity of the fluid ($\nu = \mu/\rho$, where ρ is fluid density and μ is dynamic viscosity). In principle, d is related to the length of elementary channels in the porous medium. Due to the difficulty of establishing this, however, it is customary to use some measure of the pore grain size for d. Alternatively, Collins (1961) suggests $d = (k/n)^{1/2}$, where k is permeability and n is porosity. The upper limit for application of Darcy's Law is not exceeded if Re is less than some number between 1 and 10.

The specific discharge above which the models of fluid flow might be invalid can be estimated for the WIPP. The maximum d in the domain, by Collins' method, is approximately 2×10^{-4} cm (in the waste region, using an assumed permeability of 1×10^{-12} m^2 = 1×10^{-8} cm^2 and an assumed porosity of 0.2). Salado brine has a dynamic viscosity of 2.1×10^{-2} g cm^{-1} sec^{-1} and a density of 1.22×10^{3} g cm^{-3} for a kinematic viscosity of 0.017 cm^2 sec^{-1}. Taking Re equal to 1 as the critical indicator, the critical specific discharge is the ratio of ν to d, and has a value approaching 100 cm sec^{-1}. As all specific discharges of brine in the BRAGFLO model are significantly less than this value,

viscous forces dominate brine flow in the model, and the upper limit of the validity of Darcy's Law is not exceeded.

For gas in the WIPP, assumed to be hydrogen for this calculation, density is about 8.2×10^{-5} g cm^{-3} and dynamic viscosity is about 89.2×10^{-6} g cm^{-1} sec^{-1}, for a kinematic viscosity of about 1.1 cm^2 sec^{-1}. The critical specific discharge for gas in the BRAGFLO model is greater than 5,000 cm sec^{-1}. In WIPP simulations of gas flow, q for gas remains below this value, indicating that the upper limit for the validity of Darcy's Law for gas is not exceeded.

Bear (1972) proposes that a minimum hydraulic gradient exists below which flow in porous media does not occur (Bear 1972, 128). The minimum gradient may be required to overcome countercurrents that may occur at very low velocities, or may be required to overcome the slight non-Newtonian behavior of the viscosity of water. In general, this behavior is evident in fine-grained, low permeability rock such as clay. Because the WIPP is situated in the low-permeability Salado, flow may not be able to occur through the Salado unless a minimum hydraulic gradient is exceeded. Testing for a minimum hydraulic gradient is extremely difficult, however, and has not been attempted at the WIPP. Corrections to Darcy's Law could be implemented to account for this behavior, had it been observed.

Except for pure halite, all Salado intervals tested at the WIPP have responded to hydraulic testing and test results can be interpreted to high certainty using models based on Darcy's Law without having to make corrections for the existence of minimum hydraulic gradients. This is strong evidence that the standard Darcy's Law is applicable in these units. In hydraulic tests of the pure halite, no hydraulic response to induced pressure change in the test zone was observed. Two explanations are offered for the results observed during the test. Either (1) the pure halite has a permeability low enough that a hydraulic response could not be measured over the duration of the test, or (2) a threshold gradient for fluid flow exists in pure halite and was not exceeded during the test in rock around the test interval.

Even though the reason for pure halite's lack of response during flow tests is not established conclusively, pure halite's behavior can be approximated in continuum models of fluid flow based on Darcy's Law by assigning it an extremely low permeability relative to other rocks units, which effectively prevents flow through the volume representing pure halite. This technique assumes the gradients calculated during modeling in the pure halite interval will not exceed the threshold gradient for flow, if it exists. For this analysis, this assumption is sound given that relatively large gradients were imposed on the unit during hydraulic testing and did not induce flow. Christian-Frear and Webb (1996) did this in an analysis of the effects of the variation in lithologic types, including pure halite, in a model of the Salado surrounding the repository. In their study, they found that the hydrologic response of the Salado to the presence of the repository was adequately represented by the simplified stratigraphic representation that is implemented in BRAGFLO for this NMVP. Thus, even though the lack of hydraulic

response in pure halite units is not conclusively explained, the hydraulic characterization of pure halite intervals is adequate for an accurate assessment of WIPP performance.

Darcy's Law is based on laminar flow theory, which assumes there is no motion of the fluid at the interface between fluid and solid. For liquids, it is reasonable to assume this under most conditions. For gases at low pressure, however, gas molecules near the solid interface may not have intimate contact with the solid and may have finite velocity, not necessarily zero. This results in additional flux of gas above that predicted by application of Darcy's Law. This effect is known as the slip phenomenon, or Klinkenberg Effect (Bear 1972, 128). A standard correction to Darcy's Law for the Klinkenberg Effect is available and is incorporated into the BRAGFLO model (refer to Appendix BRAGFLO for additional details.).

MASS.1.4 Hydrogen Gas as Surrogate for Waste-Generated Gas Physical Properties

The gas phase in the BRAGFLO model is assigned the properties of hydrogen, because that is the gas that will, under most conditions reasonable for the WIPP, be the dominant component of the gas phase, and in almost all cases will be the major component. Hydrogen gas is produced by the corrosion of steel in the repository by water or brine.

Other gases may be produced by processes occurring in the repository. The only gas with potential for the generation of a quantity nearing that of hydrogen is CO_2, which may be produced by microbial degradation of cellulosics and perhaps plastic and rubber constituents in the waste. CO_2 produced, however, is also likely to react with steel or corrosion products to form siderite $FeCO_3$, or react with cementitious materials in the waste to form calcite, $CaCO_3$. It is possible that, due to these competing reactions for the production and consumption of CO_2, very little CO_2 will be present in the gas phase.

Other gases exist in the disposal system. However, for BRAGFLO calculations it is assumed these gases are insignificant, and they are not included in the model.

MASS.1.5 Salado Brine as Surrogate for Liquid-Phase Physical Properties in BRAGFLO Simulation

BRAGFLO models all liquid physical properties needed as those of Salado brine, based on the following reasoning. In the undisturbed performance scenario considered for the NMVP, liquid in the modeled region may be comprised of (1) brine originally in the Salado formation, (2) liquid introduced in the excavation during construction, maintenance and ventilation during the operational phase, and (3) a very small amount of liquid introduced as a component of the waste.

Following repository closure, Salado brine will flow toward the repository at a rate that will depend on the properties of the rock and brine, as well as hydraulic gradients. Because the initial liquid saturation of the repository is low, as discussed below, brine flowing into the repository from the Salado will be the dominant source of liquid in the

repository following closure. For this reason, it is assumed that the properties of brine important in the BRAGFLO model are the same as those of Salado brine.

The origin and significance of non-Salado liquids are discussed below:

- Liquid has been introduced in the repository in the past during construction of the repository and as water spread for dust control. The practice of spreading water for dust control has since been curtailed. As described in DOE/WIPP Brine Sampling and Evaluation Program reports, imported water consisted of groundwater from the Culebra Member of the Rustler Formation. Salado brine is appropriate as a surrogate based on: (1) similar original physical properties of the two high ionic strength solutions, (2) some credit for equilibration of imported water with surrounding rocks, and (3) the relatively small volume of water introduced

- Introduction of liquid through respiration in the repository is also considered insignificant. Due to the dry climate in the region, air drawn in from the surface and circulated through the repository is normally undersaturated in water vapor. In addition, the relative humidity of mine air is less than the equilibrium humidity of water in the mine environment. Thus, this liquid vapor remains vapor until it is removed from the repository through forced circulation up the ventilation shaft

- Analyses reported by Butcher (1996) and Elliot (1993) suggest waste will not be a significant source of free liquid in the waste region. Assuming maximum allowable free liquid (and assuming pure water) in accordance to Waste Acceptance Criteria (WAC), the maximum initial water saturation in the waste region is 1.5 percent, as described below

  Since saturation is dimensionless, it can be computed for a single disposal room and then applied to the entire waste region. Butcher (1993) calculates $V_{wi} = 0.01 \times V_{wst}$, where

  V_{wi} = initial volume of water in a disposal room, and
  V_{wst} = volume of waste in a disposal room.

  The factor 0.01 is the WAC criteria for free liquid as described in Chapter 4 of the NMVP. V_{wst} is equal to 1.416×10^3 m^3, computed as the product of the internal volume of a 55 gal drum (0.2082 m^3) and the projected number of drums in a disposal room (6804). Given $V_{wi} = 14.166$ m^3, the hypothetical maximum initial water saturation of the waste region (S_{wi}) is:

  $S_{wi} = V_{wi} / V_{wv}$, where

  V_{wv} = initial void volume of the waste in the disposal room

  $$V_{wv} = \frac{(\text{waste-drum scale porosity})(\text{solid volume of waste})}{1 - (\text{waste-drum scale porosity})}$$

$$V_{wv} = \frac{0.681\,(451.893\ m^3)}{1 - 0.681}$$

$$V_{wv} = 964.70\ m^3$$

$$S_{wi} = 14.166\ m^3 / 964.70\ m^3$$

$$S_{wi} = 0.147$$

Similarly, Butcher (1996) documents a more reasonable initial 0.06 percent average liquid saturation for the waste-disposal region based on characterization data from over 9,000 drums at the Idaho National Engineering Laboratory (see Elliot 1993).

MASS.1.6 Simplified Salado Stratigraphy used in BRAGFLO

The rock layers of the Salado incorporated in the BRAGFLO model are highly simplified compared to the stratigraphy of the formation in the vicinity of the repository. The BRAGFLO model incorporates impure halite into which is embedded three layers representing Marker Bed 138, anhydrites a and b, and Marker Bed 139.

Christian-Frear and Webb (1996) tested the performance assessment representation of the Salado against a model with explicit representation of the distinct lithologic layers present at the repository horizon. They found the BRAGFLO simplifications decrease the resolution of flow processes and interactions over short distances, but preserve the overall behavior of movement distance and volumes. The stratigraphic representation implemented in BRAGFLO is, thus, adequate for resolving the effects of processes important in performance assessment.

MASS.1.7 High Threshold Pressure for Halite-Rich Salado Rock Units

A parameter typically used to help describe the effects of two-phase flow is threshold pressure, which for a brine-saturated rock is the difference between the pressure that must be attained before gas moves from the repository into the formation and the pressure of the liquid phase occupying the pore space in the formation (Davies 1991). The threshold pressure is important, because it helps determine the quantity of gas that can enter a rock unit.

The threshold pressure, as well as other parameters used to describe two-phase characteristics, has not been measured for halite-rich rocks of the Salado. The Salado, however, is thought to be similar in pore structure to rocks for which threshold pressures have been established (Davies 1991). Based on this observation, Davies (1991) postulated that the threshold pressure of the halite-rich rocks in the Salado could be estimated if an empirical correlation exists between rocks postulated to have similar pore structure.

Davies developed a correlation between threshold pressure and intrinsic permeability that he thought might be applicable to the Salado halites. (A similar correlation was developed for Salado anhydrites; subsequent testing confirmed that the correlation predicted threshold pressures accurately.) The correlation developed by Davies predicts threshold pressures in intact Salado halites on the order of 20 MPa or greater. This threshold pressure predicted by correlation is so high that for all practical and predictive purposes, no gas will flow into intact Salado halites. If pressures were to approach these levels, pressure-release mechanisms, such as anhydrite fracturing, would occur to mitigate pressure build-up.

Because threshold pressure helps control the flow of gas, and because the greatest volume of rock in the Salado is rich in halite, a high threshold pressure effectively limits the volume of gas that can be accommodated in the pore spaces of the host formation. Thus, the assumption of high threshold pressure is considered to be conservative as well as realistic based on available information. If it were demonstrated experimentally that gas can flow into pore spaces of the Salado halite-rich rocks, repository pressures could be reduced significantly.

MASS.1.8 Modeled Geometry of the Repository

The geometry of the repository and shafts has been simplified for modeling, as discussed in Chapter 8 of the NMVP. The modeling is based on the premise that the overall dimensions of repository regions (e.g., waste disposal, operations, and experimental areas) are important in assessing migration, but that resolution of small-scale features of the repository is not. Small-scale features of the repository have not been incorporated into the model geometry mainly because the size and extent of the disposal unit over which no-migration must be demonstrated is large compared to the distinct dimensions of waste-disposal rooms and panels, pillars, drifts, and panel closures. Simplification of the model geometry also improves the computational performance of BRAGFLO.

The difference in stratigraphic position between the northern experimental region and the operations and waste-disposal regions in the southern portion of the repository are believed to be unimportant to the no-migration simulation. The northern experimental region floor is stratigraphically a couple of meters above the floor of the operations and waste disposal regions, and the height of experimental region rooms is greater than the height of waste disposal rooms. For modeling purposes, the experimental region is located in the same stratigraphic horizon as the regions farther south and have the same overall height. The experimental region is modeled at an absolute elevation greater than the regions to the south to account for a southerly regional dip.

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DOE/CAO-96-2160

Final
No-Migration
Variance Petition

June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume VII of VIII

Appendices OUTPUT, PAR, PMR, QAPD, RA, RM, SCR, SER

APPENDIX OUTPUT

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APPENDIX OUTPUT

OUTPUT.1 INTRODUCTION

This appendix contains the output files derived from the BRAGFLO calculations that were used to generate Figures 8-5 through 8-18 in the NMVP. These figures, which are presented in Section 8.4 of the NMVP and display the results of the simulation of long-term brine and gas flow, are reproduced in this appendix. Text describing the interpretation of the figures is provided in Section 8.4 of the NMVP.

Output files are presented as a series of tables, showing values for the specific output parameters at specified times and locations. For values plotted as a function of time, output is given for each BRAGFLO time step, from t_0 to 10,000 years. Figure numbers are unchanged from those given in Section 8.4 of the NMVP.

Unrealistically conservative results occur early into the long-term simulation as a consequence of conservative assumptions designed specifically for the long-term demonstration. In particular, these results tend to greatly overestimate early gas generation and pressure increases in the first 50 to 100 years. Anoxic corrosion reactions are assumed to begin immediately at their full rate, whereas in reality there will be a period of many years in which corrosion is minor, followed by an additional period of several decades during which conditions remain oxic and corrosion does not generate hydrogen. Similarly, microbial reactions are assumed to begin immediately at their full rate. In reality, microbial processes will require considerable mixing of the waste to reach their full potential, bringing reactants such as brine and nutrients in contact with cellulose. Adding additional conservatism to the short-term treatment of gas generation, the entire waste-disposal region is assumed to be sealed five years after excavation, allowing a conservatively small amount of time for removal of brine by evaporation and venting. Furthermore, the extremely small quantity of water initially present in the waste region is all assumed to be available for corrosion. Taken together, these assumptions ensure a reasonably conservative simulation of the long-term gas-generation processes. However, they result in an unrealistic simulation of the short-term processes. This simulation should not be used in detailed evaluations of disposal unit performance during the operational period or during the first 50 to 100 years after closure.

Table OUTPUT-1. Definition of variables used in Figures 8-5 through 8-18

VARIABLE	DEFINITION	FIGURE
BRNPRAVT	Average brine pressure in the repository (MPa)	Figure 8-5
GAS_MOLE	Total moles of gas generated due to corrosion and biodegradation (moles)	Figure 8-6
BRNINTC	Cumulative brine flow into the repository (m^3)	Figure 8-7
POREVOLT	Total pore volume in repository (m^3)	Figure 8-8
BSATAVT	Average brine saturation in the repository	Figures 8-9 and 8-12
FE_KG	Mass of ferrous metal remaining in the repository (kg)	Figure 8-10
CELL_KG	Mass of cellulose remaining in the repository (kg)	Figure 8-11
BM39LC	Cumulative brine flow southward into Marker Bed 139 (m^3)	Figure 8-13
BM39RC	Cumulative brine flow northward into Marker Bed 139 (m^3)	Figure 8-14
BM38LC	Cumulative brine flow southward into Marker Bed 138 (m^3)	Discussed in Section 8.4.1.2
BM38RC	Cumulative brine flow northward into Marker Bed 138 (m^3)	Discussed in Section 8.4.1.2
MXSG	Maximum gas saturation in the halite above Marker Bed 138 over 10,000 years	Figure 8-15
MXSGABL	Maximum gas saturation in anhydrite layers a and b (south) over 10,000 years	Figure 8-16
MXSGABR	Maximum gas saturation in anhydrite layers a and b (north) over 10,000 years	Figure 8-17
MXSG38L	Maximum gas saturation in anhydrite layers a and b (south) over 10,000 years	Figure 8-18

Values of variables that are shown graphically in Figures 8-5, 8-6, 8-8, 8-9, and 8-12

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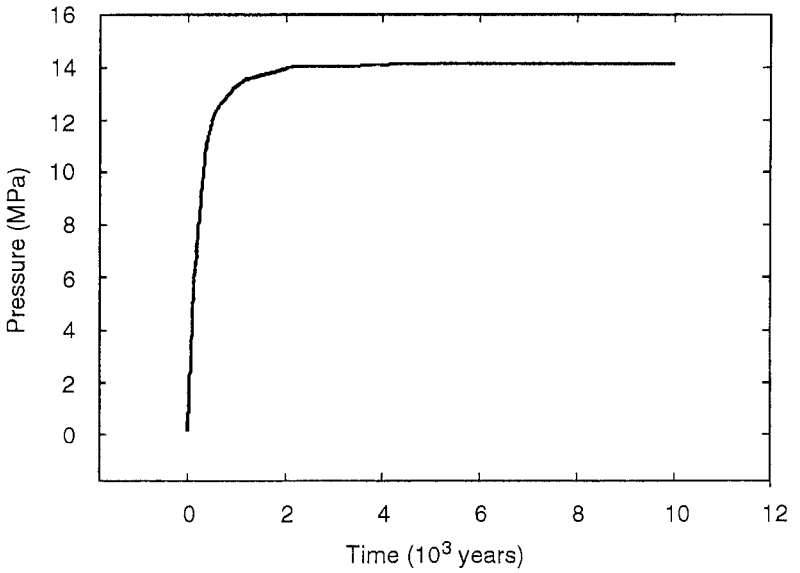

Figure 8-5. Average Pressure in the Repository

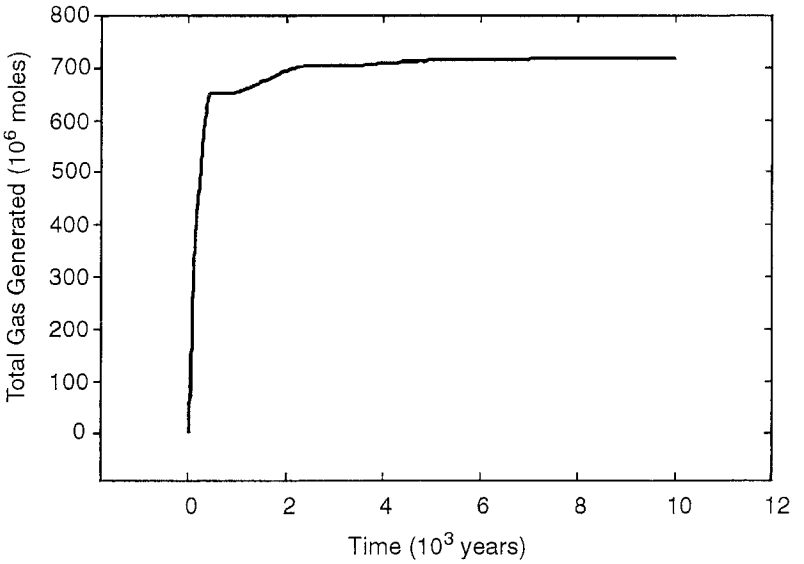

Figure 8-6. Cumulative Amount of Gas Generated by Corrosion and Biodegradation

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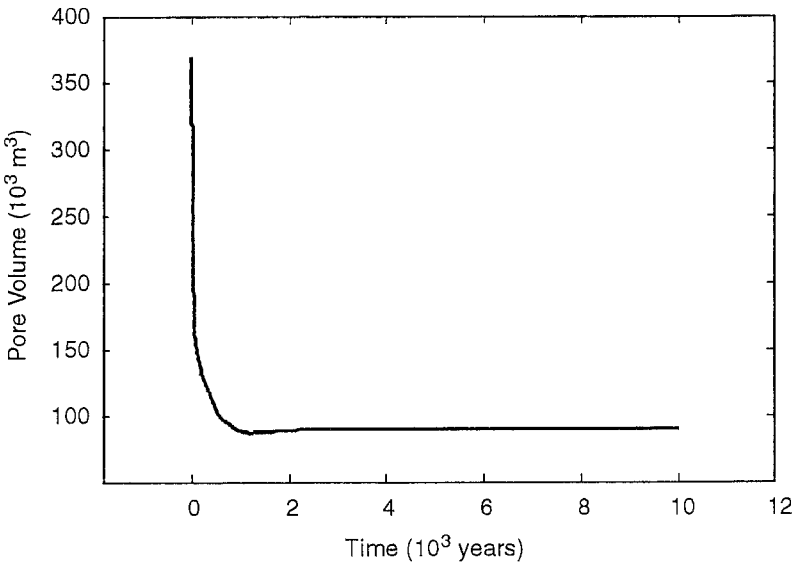

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Figure 8-8. Total Pore Volume in the Repository

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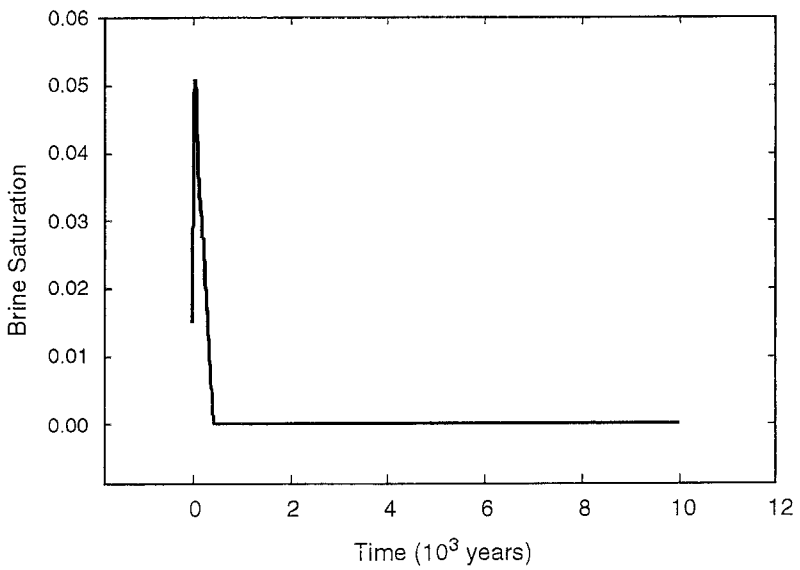

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Figure 8-9. Average Brine Saturation in the Repository

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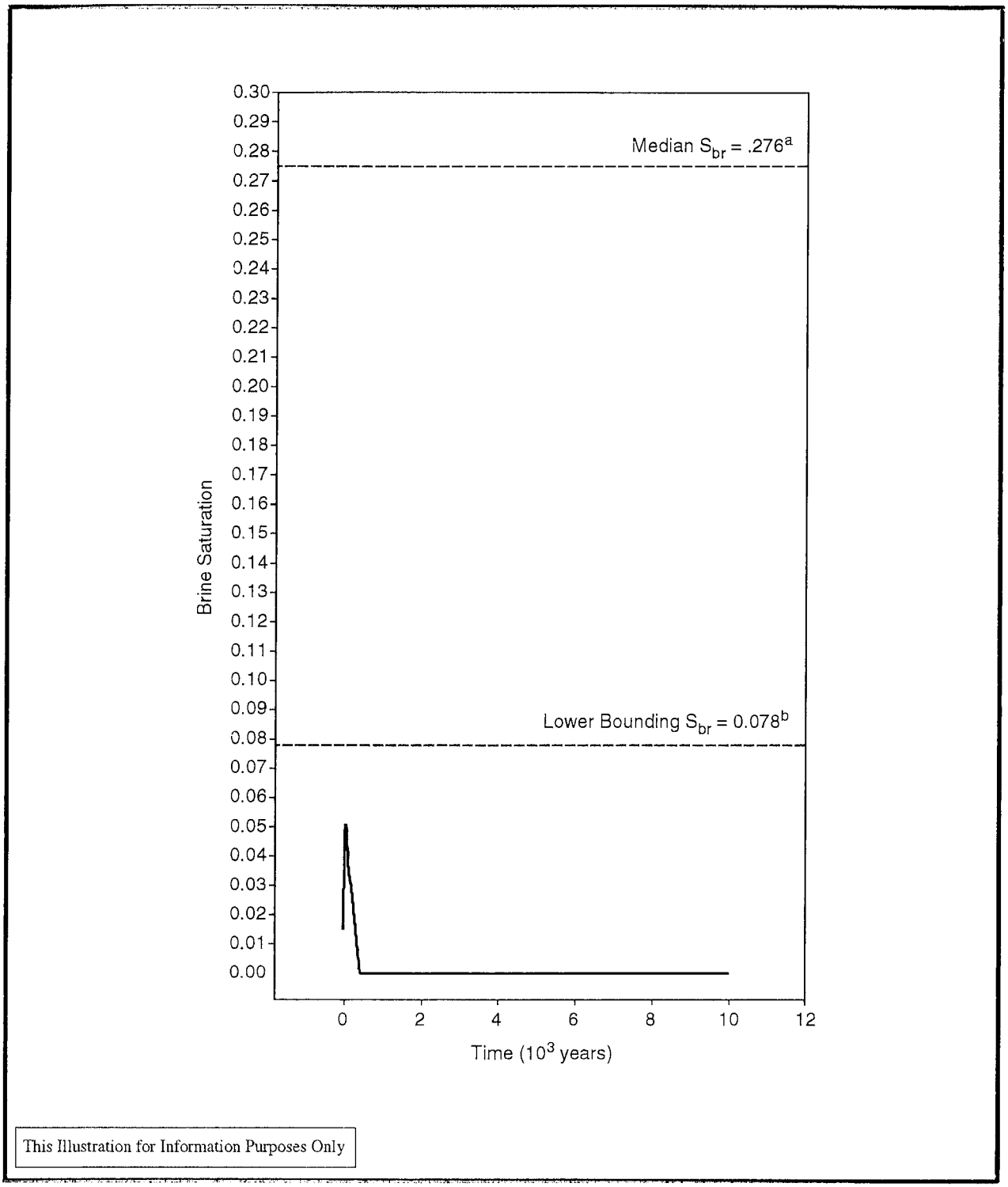

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Figure 8-12. Comparison of Repository Brine Saturation with Estimated Residual Brine Saturation (S_{br}) of the Waste Region

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time	brnpravt	gas_mole	bsatavt	porevolt
0.0000	1.0133e+5	0.0000	0.0150	3.7000e+5
1.7112e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
3.6344e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
4.8852e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
5.8280e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
6.6229e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
7.3364e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
8.0006e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
8.6333e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
9.2452e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
9.8430e-6	1.0133e+5	0.0000	0.0150	3.7000e+5
1.0431e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.1014e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.1594e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.2173e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.2753e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.3336e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.3923e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.4515e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.5115e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.5723e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.6340e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.6968e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.7609e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.8263e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.8933e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
1.9619e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.0324e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.1049e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.1796e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.2568e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.3367e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.4195e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.5055e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.5951e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.6886e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.7864e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.8891e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
2.9971e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.1112e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.2320e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.3603e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.4973e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.6442e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.8024e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
3.9737e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
4.1604e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
4.3653e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
4.5920e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
4.8452e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
5.1311e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
5.4582e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
5.8383e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
6.2885e-5	1.0133e+5	0.0000	0.0150	3.7000e+5
6.8347e-5	1.0133e+5	0.0000	0.0150	3.7000e+5

time	brnpravt	gas_mole	bsatavt	porevolt
7.5172e-5	1.0133e+5	193.5145	0.0150	3.7000e+5
8.3703e-5	1.0133e+5	193.5145	0.0150	3.7000e+5
9.4367e-5	1.0133e+5	193.5145	0.0150	3.7000e+5
1.0770e-4	1.0133e+5	193.5145	0.0150	3.7000e+5
1.2436e-4	1.0133e+5	294.0464	0.0150	3.6999e+5
1.4519e-4	1.0133e+5	294.0464	0.0150	3.6999e+5
1.7122e-4	1.0133e+5	294.0464	0.0150	3.6999e+5
2.0376e-4	1.0133e+5	294.0464	0.0150	3.6999e+5
2.4444e-4	1.0134e+5	344.3124	0.0150	3.6999e+5
2.9529e-4	1.0134e+5	789.1567	0.0150	3.6998e+5
3.4826e-4	1.0134e+5	839.4227	0.0150	3.6998e+5
3.9743e-4	1.0134e+5	1083.2030	0.0150	3.6998e+5
4.4238e-4	1.0134e+5	1083.2030	0.0150	3.6997e+5
4.8423e-4	1.0135e+5	1133.4690	0.0150	3.6997e+5
5.2405e-4	1.0135e+5	1435.0650	0.0150	3.6997e+5
5.6266e-4	1.0135e+5	1435.0650	0.0150	3.6996e+5
6.0063e-4	1.0135e+5	1915.0770	0.0150	3.6996e+5
6.3835e-4	1.0135e+5	1915.0770	0.0150	3.6996e+5
6.7612e-4	1.0135e+5	1965.3430	0.0150	3.6996e+5
7.1420e-4	1.0136e+5	2015.6090	0.0150	3.6995e+5
7.5275e-4	1.0136e+5	2065.8740	0.0150	3.6995e+5
7.9194e-4	1.0136e+5	2367.4700	0.0150	3.6995e+5
8.3192e-4	1.0136e+5	2367.4700	0.0150	3.6994e+5
8.7281e-4	1.0136e+5	2417.7360	0.0150	3.6994e+5
9.1473e-4	1.0136e+5	2661.5170	0.0150	3.6994e+5
9.5780e-4	1.0137e+5	2661.5170	0.0150	3.6994e+5
1.0021e-3	1.0137e+5	2905.2970	0.0150	3.6993e+5
1.0479e-3	1.0137e+5	3156.6270	0.0150	3.6993e+5
1.0951e-3	1.0137e+5	3156.6270	0.0150	3.6993e+5
1.1440e-3	1.0137e+5	3257.1590	0.0150	3.6992e+5
1.1946e-3	1.0138e+5	3257.1590	0.0150	3.6992e+5
1.2471e-3	1.0138e+5	3737.1700	0.0150	3.6992e+5
1.3017e-3	1.0138e+5	3837.7020	0.0150	3.6991e+5
1.3585e-3	1.0138e+5	4089.0320	0.0150	3.6991e+5
1.4176e-3	1.0139e+5	4189.5640	0.0151	3.6990e+5
1.4793e-3	1.0139e+5	4239.8300	0.0151	3.6990e+5
1.5438e-3	1.0139e+5	4483.6100	0.0151	3.6990e+5
1.6112e-3	1.0139e+5	4734.9400	0.0151	3.6989e+5
1.6818e-3	1.0140e+5	4928.4550	0.0151	3.6989e+5
1.7560e-3	1.0140e+5	5028.9870	0.0151	3.6988e+5
1.8339e-3	1.0140e+5	5559.2640	0.0151	3.6987e+5
1.9159e-3	1.0141e+5	5911.1260	0.0151	3.6987e+5
2.0024e-3	1.0141e+5	5961.3920	0.0151	3.6986e+5
2.0938e-3	1.0141e+5	6061.9240	0.0151	3.6986e+5
2.1906e-3	1.0142e+5	6557.0350	0.0151	3.6985e+5
2.2933e-3	1.0142e+5	6607.3010	0.0151	3.6984e+5
2.4026e-3	1.0143e+5	7102.4110	0.0151	3.6984e+5
2.5191e-3	1.0143e+5	7682.9540	0.0151	3.6983e+5
2.6437e-3	1.0144e+5	8034.8150	0.0151	3.6982e+5
2.7775e-3	1.0144e+5	8328.8620	0.0151	3.6981e+5
2.9215e-3	1.0145e+5	8823.9730	0.0151	3.6980e+5
3.0774e-3	1.0145e+5	9505.0480	0.0151	3.6979e+5
3.2468e-3	1.0146e+5	9856.9100	0.0151	3.6978e+5
3.4319e-3	1.0147e+5	1.0596e+4	0.0151	3.6976e+5

time	brnpravt	gas_mole	bsatavt	porevolt
3.6358e-3	1.0148e+5	1.0797e+4	0.0151	3.6975e+5
3.8622e-3	1.0149e+5	1.1679e+4	0.0151	3.6973e+5
4.1165e-3	1.0150e+5	1.2418e+4	0.0151	3.6972e+5
4.4066e-3	1.0151e+5	1.3401e+4	0.0152	3.6970e+5
4.7443e-3	1.0152e+5	1.4542e+4	0.0152	3.6967e+5
5.1098e-3	1.0154e+5	1.5575e+4	0.0152	3.6965e+5
5.4630e-3	1.0155e+5	1.6414e+4	0.0152	3.6962e+5
5.7938e-3	1.0157e+5	1.7841e+4	0.0152	3.6960e+5
6.1057e-3	1.0158e+5	1.8487e+4	0.0152	3.6958e+5
6.4046e-3	1.0159e+5	1.9664e+4	0.0152	3.6956e+5
6.6957e-3	1.0161e+5	2.0309e+4	0.0152	3.6954e+5
6.9832e-3	1.0162e+5	2.1385e+4	0.0152	3.6952e+5
7.2702e-3	1.0163e+5	2.2081e+4	0.0153	3.6950e+5
7.5591e-3	1.0164e+5	2.3064e+4	0.0153	3.6948e+5
7.8520e-3	1.0165e+5	2.3903e+4	0.0153	3.6945e+5
8.1505e-3	1.0167e+5	2.4836e+4	0.0153	3.6943e+5
8.4562e-3	1.0168e+5	2.5927e+4	0.0153	3.6941e+5
8.7705e-3	1.0169e+5	2.6909e+4	0.0153	3.6939e+5
9.0945e-3	1.0170e+5	2.7799e+4	0.0153	3.6937e+5
9.4297e-3	1.0172e+5	2.8731e+4	0.0153	3.6934e+5
9.7772e-3	1.0173e+5	2.9872e+4	0.0153	3.6932e+5
0.0101	1.0175e+5	3.1099e+4	0.0153	3.6930e+5
0.0105	1.0176e+5	3.2139e+4	0.0154	3.6927e+5
0.0109	1.0178e+5	3.3416e+4	0.0154	3.6924e+5
0.0113	1.0180e+5	3.4894e+4	0.0154	3.6921e+5
0.0117	1.0181e+5	3.5884e+4	0.0154	3.6918e+5
0.0122	1.0183e+5	3.7362e+4	0.0154	3.6915e+5
0.0127	1.0185e+5	3.8890e+4	0.0154	3.6912e+5
0.0132	1.0187e+5	4.0217e+4	0.0154	3.6908e+5
0.0137	1.0189e+5	4.1795e+4	0.0155	3.6905e+5
0.0142	1.0192e+5	4.3625e+4	0.0155	3.6901e+5
0.0148	1.0194e+5	4.5253e+4	0.0155	3.6897e+5
0.0154	1.0196e+5	4.7075e+4	0.0155	3.6893e+5
0.0160	1.0199e+5	4.9048e+4	0.0155	3.6888e+5
0.0167	1.0202e+5	5.1215e+4	0.0156	3.6884e+5
0.0174	1.0205e+5	5.3575e+4	0.0156	3.6879e+5
0.0182	1.0208e+5	5.5942e+4	0.0156	3.6873e+5
0.0190	1.0211e+5	5.8310e+4	0.0156	3.6868e+5
0.0199	1.0215e+5	6.0971e+4	0.0157	3.6862e+5
0.0208	1.0218e+5	6.3783e+4	0.0157	3.6855e+5
0.0218	1.0222e+5	6.6545e+4	0.0157	3.6848e+5
0.0228	1.0227e+5	7.0039e+4	0.0157	3.6841e+5
0.0239	1.0231e+5	7.3540e+4	0.0158	3.6833e+5
0.0252	1.0236e+5	7.7285e+4	0.0158	3.6825e+5
0.0265	1.0242e+5	8.1374e+4	0.0159	3.6815e+5
0.0280	1.0248e+5	8.6008e+4	0.0159	3.6805e+5
0.0296	1.0254e+5	9.0843e+4	0.0160	3.6794e+5
0.0313	1.0262e+5	9.6410e+4	0.0160	3.6781e+5
0.0333	1.0270e+5	1.0242e+5	0.0161	3.6768e+5
0.0356	1.0279e+5	1.0957e+5	0.0161	3.6752e+5
0.0382	1.0290e+5	1.1736e+5	0.0162	3.6734e+5
0.0412	1.0302e+5	1.2672e+5	0.0163	3.6713e+5
0.0448	1.0317e+5	1.3772e+5	0.0164	3.6688e+5
0.0493	1.0335e+5	1.5161e+5	0.0165	3.6656e+5

time	brnpravt	gas_mole	bsatavt	porevolt
0.0547	1.0357e+5	1.6823e+5	0.0167	3.6619e+5
0.0607	1.0382e+5	1.8686e+5	0.0168	3.6577e+5
0.0673	1.0410e+5	2.0712e+5	0.0170	3.6530e+5
0.0744	1.0439e+5	2.2939e+5	0.0172	3.6481e+5
0.0820	1.0470e+5	2.5271e+5	0.0174	3.6428e+5
0.0901	1.0504e+5	2.7765e+5	0.0176	3.6372e+5
0.0987	1.0540e+5	3.0437e+5	0.0178	3.6311e+5
0.1080	1.0579e+5	3.3306e+5	0.0180	3.6246e+5
0.1180	1.0621e+5	3.6405e+5	0.0183	3.6177e+5
0.1287	1.0666e+5	3.9708e+5	0.0185	3.6102e+5
0.1402	1.0715e+5	4.3257e+5	0.0188	3.6022e+5
0.1526	1.0768e+5	4.7102e+5	0.0190	3.5935e+5
0.1659	1.0826e+5	5.1237e+5	0.0193	3.5842e+5
0.1803	1.0888e+5	5.5717e+5	0.0196	3.5742e+5
0.1958	1.0955e+5	6.0484e+5	0.0199	3.5634e+5
0.2125	1.1029e+5	6.5659e+5	0.0202	3.5517e+5
0.2305	1.1108e+5	7.1283e+5	0.0205	3.5391e+5
0.2500	1.1195e+5	7.7306e+5	0.0208	3.5255e+5
0.2711	1.1290e+5	8.3867e+5	0.0211	3.5108e+5
0.2939	1.1393e+5	9.0964e+5	0.0215	3.4949e+5
0.3183	1.1506e+5	9.8589e+5	0.0218	3.4778e+5
0.3449	1.1629e+5	1.0685e+6	0.0222	3.4593e+5
0.3739	1.1764e+5	1.1588e+6	0.0226	3.4391e+5
0.4055	1.1915e+5	1.2574e+6	0.0230	3.4170e+5
0.4400	1.2081e+5	1.3653e+6	0.0234	3.3929e+5
0.4778	1.2266e+5	1.4831e+6	0.0238	3.3665e+5
0.5192	1.2430e+5	1.6122e+6	0.0242	3.3486e+5
0.5643	1.2556e+5	1.7534e+6	0.0244	3.3436e+5
0.6136	1.2694e+5	1.9075e+6	0.0247	3.3381e+5
0.6645	1.2837e+5	2.0666e+6	0.0250	3.3325e+5
0.7149	1.2979e+5	2.2245e+6	0.0253	3.3268e+5
0.7643	1.3118e+5	2.3789e+6	0.0255	3.3214e+5
0.8122	1.3254e+5	2.5292e+6	0.0257	3.3160e+5
0.8588	1.3387e+5	2.6752e+6	0.0259	3.3109e+5
0.9043	1.3517e+5	2.8178e+6	0.0261	3.3058e+5
0.9489	1.3645e+5	2.9574e+6	0.0262	3.3008e+5
0.9929	1.3772e+5	3.0953e+6	0.0264	3.2960e+5
1.0363	1.3892e+5	3.2314e+6	0.0265	3.2922e+5
1.0794	1.4012e+5	3.3669e+6	0.0267	3.2887e+5
1.1225	1.4131e+5	3.5017e+6	0.0268	3.2852e+5
1.1655	1.4251e+5	3.6371e+6	0.0269	3.2817e+5
1.2088	1.4371e+5	3.7728e+6	0.0271	3.2781e+5
1.2525	1.4493e+5	3.9101e+6	0.0272	3.2746e+5
1.2968	1.4617e+5	4.0491e+6	0.0273	3.2710e+5
1.3418	1.4743e+5	4.1903e+6	0.0274	3.2673e+5
1.3877	1.4872e+5	4.3345e+6	0.0275	3.2636e+5
1.4348	1.5005e+5	4.4823e+6	0.0276	3.2598e+5
1.4832	1.5142e+5	4.6345e+6	0.0278	3.2558e+5
1.5331	1.5283e+5	4.7917e+6	0.0279	3.2518e+5
1.5850	1.5431e+5	4.9545e+6	0.0280	3.2475e+5
1.6391	1.5585e+5	5.1248e+6	0.0281	3.2431e+5
1.6958	1.5747e+5	5.3029e+6	0.0282	3.2385e+5
1.7555	1.5918e+5	5.4907e+6	0.0284	3.2337e+5
1.8188	1.6100e+5	5.6901e+6	0.0285	3.2285e+5

time	brnpravt	gas_mole	bsatavt	porevolt
1.8865	1.6295e+5	5.9028e+6	0.0286	3.2230e+5
1.9593	1.6506e+5	6.1320e+6	0.0287	3.2171e+5
2.0383	1.6736e+5	6.3808e+6	0.0289	3.2107e+5
2.1251	1.6990e+5	6.6539e+6	0.0290	3.2036e+5
2.2214	1.7273e+5	6.9575e+6	0.0292	3.1958e+5
2.3300	1.7593e+5	7.2996e+6	0.0294	3.1869e+5
2.4547	1.7964e+5	7.6927e+6	0.0296	3.1768e+5
2.6012	1.8402e+5	8.1546e+6	0.0298	3.1649e+5
2.7782	1.8936e+5	8.7129e+6	0.0301	3.1505e+5
2.9996	1.9612e+5	9.4114e+6	0.0304	3.1325e+5
3.2727	2.0456e+5	1.0274e+7	0.0308	3.1102e+5
3.5924	2.1461e+5	1.1284e+7	0.0312	3.0842e+5
3.9572	2.2629e+5	1.2438e+7	0.0317	3.0545e+5
4.1639	2.3301e+5	1.3092e+7	0.0319	3.0377e+5
4.4224	2.4152e+5	1.3910e+7	0.0322	3.0167e+5
4.7454	2.5233e+5	1.4933e+7	0.0326	2.9904e+5
5.1337	2.6559e+5	1.6164e+7	0.0331	2.9588e+5
5.6099	2.8224e+5	1.7674e+7	0.0336	2.9201e+5
6.1533	3.0138e+5	1.9400e+7	0.0342	2.8799e+5
6.7551	3.2183e+5	2.1313e+7	0.0347	2.8473e+5
7.4188	3.4494e+5	2.3424e+7	0.0352	2.8113e+5
8.1589	3.7141e+5	2.5780e+7	0.0358	2.7712e+5
8.1655	3.7165e+5	2.5801e+7	0.0358	2.7708e+5
8.1737	3.7195e+5	2.5827e+7	0.0358	2.7704e+5
8.1840	3.7232e+5	2.5860e+7	0.0358	2.7698e+5
8.1968	3.7279e+5	2.5900e+7	0.0358	2.7691e+5
8.2129	3.7337e+5	2.5951e+7	0.0358	2.7682e+5
8.2329	3.7410e+5	2.6016e+7	0.0358	2.7672e+5
8.2580	3.7501e+5	2.6095e+7	0.0359	2.7658e+5
8.2894	3.7616e+5	2.6195e+7	0.0359	2.7641e+5
8.3286	3.7759e+5	2.6320e+7	0.0359	2.7620e+5
8.3776	3.7938e+5	2.6476e+7	0.0360	2.7593e+5
8.4389	3.8162e+5	2.6671e+7	0.0360	2.7560e+5
8.5154	3.8443e+5	2.6915e+7	0.0361	2.7518e+5
8.6111	3.8796e+5	2.7220e+7	0.0361	2.7467e+5
8.7308	3.9239e+5	2.7601e+7	0.0362	2.7402e+5
8.8803	3.9795e+5	2.8078e+7	0.0363	2.7321e+5
9.0672	4.0496e+5	2.8673e+7	0.0365	2.7219e+5
9.3009	4.1378e+5	2.9418e+7	0.0367	2.7093e+5
9.5930	4.2493e+5	3.0350e+7	0.0369	2.6934e+5
9.9581	4.3904e+5	3.1515e+7	0.0372	2.6736e+5
10.0000	4.4068e+5	3.1649e+7	0.0372	2.6714e+5
10.0001	4.4068e+5	3.1649e+7	0.0372	2.6714e+5
10.0001	4.4068e+5	3.1649e+7	0.0372	2.6714e+5
10.0001	4.4068e+5	3.1649e+7	0.0372	2.6714e+5
10.0002	4.4068e+5	3.1649e+7	0.0372	2.6714e+5
10.0002	4.4069e+5	3.1649e+7	0.0372	2.6714e+5
10.0003	4.4069e+5	3.1649e+7	0.0372	2.6713e+5
10.0004	4.4069e+5	3.1650e+7	0.0372	2.6713e+5
10.0006	4.4070e+5	3.1650e+7	0.0372	2.6713e+5
10.0007	4.4071e+5	3.1651e+7	0.0372	2.6713e+5
10.0009	4.4071e+5	3.1651e+7	0.0372	2.6713e+5
10.0012	4.4072e+5	3.1652e+7	0.0372	2.6713e+5
10.0015	4.4074e+5	3.1653e+7	0.0372	2.6713e+5

time	brnpravt	gas_mole	bsatavt	porevolt
10.0019	4.4075e+5	3.1655e+7	0.0372	2.6713e+5
10.0024	4.4077e+5	3.1656e+7	0.0372	2.6712e+5
10.0030	4.4079e+5	3.1658e+7	0.0372	2.6712e+5
10.0038	4.4083e+5	3.1661e+7	0.0372	2.6712e+5
10.0048	4.4086e+5	3.1664e+7	0.0372	2.6711e+5
10.0060	4.4091e+5	3.1668e+7	0.0372	2.6710e+5
10.0075	4.4097e+5	3.1672e+7	0.0372	2.6710e+5
10.0094	4.4104e+5	3.1679e+7	0.0372	2.6709e+5
10.0118	4.4114e+5	3.1686e+7	0.0372	2.6707e+5
10.0148	4.4125e+5	3.1695e+7	0.0372	2.6706e+5
10.0185	4.4140e+5	3.1707e+7	0.0372	2.6704e+5
10.0231	4.4158e+5	3.1722e+7	0.0372	2.6701e+5
10.0289	4.4181e+5	3.1741e+7	0.0372	2.6698e+5
10.0361	4.4209e+5	3.1764e+7	0.0372	2.6694e+5
10.0452	4.4244e+5	3.1793e+7	0.0372	2.6689e+5
10.0565	4.4289e+5	3.1829e+7	0.0373	2.6683e+5
10.0707	4.4344e+5	3.1874e+7	0.0373	2.6675e+5
10.0884	4.4413e+5	3.1931e+7	0.0373	2.6666e+5
10.1105	4.4500e+5	3.2001e+7	0.0373	2.6654e+5
10.1381	4.4608e+5	3.2089e+7	0.0373	2.6639e+5
10.1727	4.4744e+5	3.2200e+7	0.0373	2.6620e+5
10.2159	4.4914e+5	3.2337e+7	0.0374	2.6597e+5
10.2699	4.5126e+5	3.2510e+7	0.0374	2.6567e+5
10.3374	4.5393e+5	3.2725e+7	0.0375	2.6531e+5
10.4218	4.5727e+5	3.2995e+7	0.0375	2.6485e+5
10.5272	4.6147e+5	3.3331e+7	0.0376	2.6428e+5
10.6590	4.6673e+5	3.3752e+7	0.0377	2.6356e+5
10.8238	4.7336e+5	3.4279e+7	0.0378	2.6267e+5
11.0298	4.8167e+5	3.4937e+7	0.0380	2.6157e+5
11.2873	4.9187e+5	3.5760e+7	0.0382	2.6034e+5
11.6091	5.0474e+5	3.6789e+7	0.0384	2.5881e+5
12.0114	5.2105e+5	3.8075e+7	0.0387	2.5690e+5
12.5143	5.4176e+5	3.9685e+7	0.0390	2.5451e+5
13.1429	5.6818e+5	4.1698e+7	0.0395	2.5152e+5
13.9286	6.0206e+5	4.4216e+7	0.0400	2.4778e+5
14.9108	6.4580e+5	4.7368e+7	0.0407	2.4311e+5
16.1385	7.0236e+5	5.1313e+7	0.0416	2.3741e+5
17.6732	7.7173e+5	5.6251e+7	0.0424	2.3173e+5
19.5915	8.6275e+5	6.2434e+7	0.0435	2.2463e+5
21.9894	9.8088e+5	7.0180e+7	0.0448	2.1635e+5
24.9867	1.1329e+6	7.9884e+7	0.0463	2.0710e+5
24.9999	1.1336e+6	7.9926e+7	0.0463	2.0706e+5
24.9999	1.1336e+6	7.9927e+7	0.0463	2.0706e+5
25.0000	1.1336e+6	7.9927e+7	0.0463	2.0706e+5
25.0000	1.1336e+6	7.9927e+7	0.0463	2.0706e+5
25.0001	1.1336e+6	7.9927e+7	0.0463	2.0706e+5
25.0001	1.1337e+6	7.9927e+7	0.0463	2.0706e+5
25.0002	1.1337e+6	7.9928e+7	0.0463	2.0706e+5
25.0003	1.1337e+6	7.9928e+7	0.0463	2.0706e+5
25.0004	1.1337e+6	7.9928e+7	0.0463	2.0705e+5
25.0006	1.1337e+6	7.9929e+7	0.0463	2.0705e+5
25.0008	1.1337e+6	7.9929e+7	0.0463	2.0705e+5
25.0011	1.1337e+6	7.9930e+7	0.0463	2.0705e+5
25.0014	1.1337e+6	7.9931e+7	0.0463	2.0705e+5

time	brnpravt	gas_mole	bsatavt	porevolt
25.0018	1.1337e+6	7.9933e+7	0.0463	2.0705e+5
25.0023	1.1338e+6	7.9934e+7	0.0463	2.0705e+5
25.0029	1.1338e+6	7.9936e+7	0.0463	2.0705e+5
25.0037	1.1338e+6	7.9939e+7	0.0463	2.0704e+5
25.0047	1.1339e+6	7.9942e+7	0.0463	2.0704e+5
25.0059	1.1340e+6	7.9946e+7	0.0463	2.0704e+5
25.0074	1.1340e+6	7.9951e+7	0.0463	2.0703e+5
25.0093	1.1341e+6	7.9957e+7	0.0463	2.0703e+5
25.0117	1.1343e+6	7.9965e+7	0.0463	2.0702e+5
25.0146	1.1344e+6	7.9974e+7	0.0463	2.0701e+5
25.0183	1.1346e+6	7.9986e+7	0.0463	2.0700e+5
25.0230	1.1349e+6	8.0001e+7	0.0463	2.0699e+5
25.0288	1.1352e+6	8.0020e+7	0.0463	2.0697e+5
25.0360	1.1356e+6	8.0043e+7	0.0463	2.0694e+5
25.0451	1.1360e+6	8.0073e+7	0.0463	2.0692e+5
25.0564	1.1366e+6	8.0109e+7	0.0463	2.0688e+5
25.0706	1.1374e+6	8.0155e+7	0.0464	2.0684e+5
25.0883	1.1383e+6	8.0213e+7	0.0464	2.0678e+5
25.1104	1.1395e+6	8.0284e+7	0.0464	2.0672e+5
25.1380	1.1410e+6	8.0374e+7	0.0464	2.0663e+5
25.1726	1.1428e+6	8.0486e+7	0.0464	2.0652e+5
25.2158	1.1451e+6	8.0626e+7	0.0464	2.0639e+5
25.2698	1.1480e+6	8.0800e+7	0.0465	2.0622e+5
25.3373	1.1516e+6	8.1019e+7	0.0465	2.0601e+5
25.4216	1.1561e+6	8.1292e+7	0.0465	2.0575e+5
25.5271	1.1618e+6	8.1634e+7	0.0466	2.0543e+5
25.6589	1.1688e+6	8.2061e+7	0.0467	2.0502e+5
25.8237	1.1777e+6	8.2595e+7	0.0467	2.0451e+5
26.0297	1.1889e+6	8.3262e+7	0.0469	2.0388e+5
26.2872	1.2023e+6	8.4097e+7	0.0470	2.0318e+5
26.6090	1.2191e+6	8.5140e+7	0.0471	2.0231e+5
27.0113	1.2403e+6	8.6445e+7	0.0473	2.0122e+5
27.5142	1.2670e+6	8.8076e+7	0.0475	1.9986e+5
28.1428	1.3007e+6	9.0116e+7	0.0478	1.9816e+5
28.9285	1.3433e+6	9.2667e+7	0.0482	1.9603e+5
29.9107	1.3972e+6	9.5859e+7	0.0486	1.9337e+5
31.1384	1.4649e+6	9.9852e+7	0.0492	1.9016e+5
32.6731	1.5393e+6	1.0485e+8	0.0495	1.8759e+5
34.5914	1.6344e+6	1.1109e+8	0.0500	1.8427e+5
36.9893	1.7547e+6	1.1891e+8	0.0505	1.8028e+5
39.9866	1.9064e+6	1.2868e+8	0.0510	1.7578e+5
43.6998	2.0899e+6	1.4080e+8	0.0513	1.7153e+5
47.9516	2.3009e+6	1.5468e+8	0.0513	1.6767e+5
49.9985	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9986	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9986	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9986	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9987	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9988	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9988	2.4031e+6	1.6135e+8	0.0512	1.6606e+5
49.9990	2.4032e+6	1.6135e+8	0.0512	1.6606e+5
49.9991	2.4032e+6	1.6136e+8	0.0512	1.6606e+5
49.9992	2.4032e+6	1.6136e+8	0.0512	1.6606e+5
49.9994	2.4032e+6	1.6136e+8	0.0512	1.6606e+5

time	brnpravt	gas_mole	bsatavt	porevolt
49.9997	2.4032e+6	1.6136e+8	0.0512	1.6606e+5
50.0000	2.4032e+6	1.6136e+8	0.0512	1.6606e+5
50.0004	2.4032e+6	1.6136e+8	0.0512	1.6606e+5
50.0009	2.4033e+6	1.6136e+8	0.0512	1.6606e+5
50.0015	2.4033e+6	1.6136e+8	0.0512	1.6606e+5
50.0023	2.4033e+6	1.6137e+8	0.0512	1.6606e+5
50.0033	2.4034e+6	1.6137e+8	0.0512	1.6606e+5
50.0045	2.4034e+6	1.6137e+8	0.0512	1.6606e+5
50.0060	2.4035e+6	1.6138e+8	0.0512	1.6606e+5
50.0079	2.4036e+6	1.6138e+8	0.0512	1.6605e+5
50.0103	2.4037e+6	1.6139e+8	0.0512	1.6605e+5
50.0133	2.4039e+6	1.6140e+8	0.0512	1.6605e+5
50.0170	2.4041e+6	1.6141e+8	0.0512	1.6605e+5
50.0216	2.4043e+6	1.6143e+8	0.0512	1.6604e+5
50.0274	2.4046e+6	1.6145e+8	0.0512	1.6604e+5
50.0347	2.4049e+6	1.6147e+8	0.0512	1.6603e+5
50.0437	2.4054e+6	1.6150e+8	0.0512	1.6603e+5
50.0550	2.4060e+6	1.6154e+8	0.0512	1.6602e+5
50.0692	2.4067e+6	1.6158e+8	0.0512	1.6601e+5
50.0869	2.4076e+6	1.6164e+8	0.0512	1.6599e+5
50.1090	2.4087e+6	1.6171e+8	0.0512	1.6598e+5
50.1367	2.4101e+6	1.6180e+8	0.0512	1.6595e+5
50.1712	2.4118e+6	1.6192e+8	0.0512	1.6593e+5
50.2144	2.4140e+6	1.6206e+8	0.0512	1.6589e+5
50.2684	2.4167e+6	1.6223e+8	0.0512	1.6585e+5
50.3359	2.4201e+6	1.6245e+8	0.0511	1.6580e+5
50.4203	2.4244e+6	1.6273e+8	0.0511	1.6573e+5
50.5257	2.4298e+6	1.6307e+8	0.0511	1.6565e+5
50.6576	2.4364e+6	1.6350e+8	0.0511	1.6555e+5
50.8223	2.4448e+6	1.6404e+8	0.0511	1.6542e+5
51.0283	2.4553e+6	1.6471e+8	0.0511	1.6526e+5
51.2858	2.4681e+6	1.6555e+8	0.0511	1.6508e+5
51.6076	2.4841e+6	1.6660e+8	0.0511	1.6487e+5
52.0099	2.5042e+6	1.6792e+8	0.0510	1.6460e+5
52.5128	2.5294e+6	1.6956e+8	0.0510	1.6426e+5
53.1414	2.5612e+6	1.7161e+8	0.0509	1.6384e+5
53.9271	2.6012e+6	1.7417e+8	0.0509	1.6331e+5
54.9093	2.6516e+6	1.7737e+8	0.0508	1.6266e+5
56.1370	2.7150e+6	1.8137e+8	0.0507	1.6186e+5
57.6717	2.7915e+6	1.8637e+8	0.0504	1.6110e+5
59.5900	2.8883e+6	1.9262e+8	0.0501	1.6015e+5
61.9879	3.0101e+6	2.0043e+8	0.0498	1.5901e+5
64.9852	3.1627e+6	2.1018e+8	0.0492	1.5771e+5
68.7320	3.3521e+6	2.2235e+8	0.0485	1.5630e+5
73.3691	3.5852e+6	2.3739e+8	0.0474	1.5480e+5
78.9483	3.8637e+6	2.5545e+8	0.0461	1.5329e+5
85.9222	4.2074e+6	2.7795e+8	0.0442	1.5178e+5
94.0324	4.5992e+6	3.0396e+8	0.0418	1.5048e+5
100.0002	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0003	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0003	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0004	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0004	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0005	4.8808e+6	3.2282e+8	0.0400	1.4971e+5

time	brnpravt	gas_mole	bsatavt	porevolt
100.0005	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0006	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0008	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0009	4.8808e+6	3.2282e+8	0.0400	1.4971e+5
100.0011	4.8809e+6	3.2282e+8	0.0400	1.4971e+5
100.0014	4.8809e+6	3.2282e+8	0.0400	1.4971e+5
100.0017	4.8809e+6	3.2282e+8	0.0400	1.4971e+5
100.0021	4.8809e+6	3.2282e+8	0.0400	1.4971e+5
100.0026	4.8809e+6	3.2283e+8	0.0400	1.4971e+5
100.0032	4.8809e+6	3.2283e+8	0.0400	1.4971e+5
100.0040	4.8810e+6	3.2283e+8	0.0400	1.4971e+5
100.0050	4.8810e+6	3.2283e+8	0.0400	1.4971e+5
100.0062	4.8811e+6	3.2284e+8	0.0400	1.4971e+5
100.0077	4.8812e+6	3.2284e+8	0.0400	1.4971e+5
100.0096	4.8813e+6	3.2285e+8	0.0400	1.4971e+5
100.0120	4.8814e+6	3.2286e+8	0.0400	1.4971e+5
100.0150	4.8815e+6	3.2286e+8	0.0400	1.4971e+5
100.0187	4.8817e+6	3.2288e+8	0.0400	1.4971e+5
100.0233	4.8819e+6	3.2289e+8	0.0400	1.4971e+5
100.0291	4.8822e+6	3.2291e+8	0.0400	1.4971e+5
100.0364	4.8825e+6	3.2293e+8	0.0400	1.4970e+5
100.0454	4.8829e+6	3.2296e+8	0.0400	1.4970e+5
100.0567	4.8835e+6	3.2300e+8	0.0400	1.4970e+5
100.0709	4.8841e+6	3.2304e+8	0.0400	1.4970e+5
100.0886	4.8850e+6	3.2310e+8	0.0400	1.4970e+5
100.1107	4.8860e+6	3.2317e+8	0.0400	1.4969e+5
100.1384	4.8873e+6	3.2325e+8	0.0400	1.4969e+5
100.1729	4.8890e+6	3.2336e+8	0.0400	1.4969e+5
100.2161	4.8910e+6	3.2350e+8	0.0400	1.4968e+5
100.2701	4.8936e+6	3.2367e+8	0.0400	1.4967e+5
100.3376	4.8967e+6	3.2388e+8	0.0399	1.4967e+5
100.4198	4.9006e+6	3.2414e+8	0.0399	1.4966e+5
100.5153	4.9051e+6	3.2444e+8	0.0399	1.4964e+5
100.6234	4.9102e+6	3.2478e+8	0.0398	1.4963e+5
100.7439	4.9159e+6	3.2516e+8	0.0398	1.4961e+5
100.8777	4.9222e+6	3.2558e+8	0.0398	1.4960e+5
101.0259	4.9292e+6	3.2605e+8	0.0397	1.4958e+5
101.1901	4.9368e+6	3.2656e+8	0.0397	1.4956e+5
101.3725	4.9452e+6	3.2714e+8	0.0396	1.4954e+5
101.5755	4.9545e+6	3.2777e+8	0.0396	1.4952e+5
101.8014	4.9649e+6	3.2848e+8	0.0395	1.4950e+5
102.0510	4.9763e+6	3.2925e+8	0.0394	1.4948e+5
102.3266	4.9889e+6	3.3011e+8	0.0393	1.4945e+5
102.6311	5.0028e+6	3.3105e+8	0.0392	1.4942e+5
102.9690	5.0181e+6	3.3210e+8	0.0391	1.4939e+5
103.3457	5.0352e+6	3.3325e+8	0.0390	1.4935e+5
103.7682	5.0543e+6	3.3454e+8	0.0389	1.4931e+5
104.2457	5.0757e+6	3.3599e+8	0.0388	1.4926e+5
104.7899	5.1000e+6	3.3762e+8	0.0386	1.4920e+5
105.4169	5.1277e+6	3.3948e+8	0.0384	1.4913e+5
106.1484	5.1597e+6	3.4161e+8	0.0382	1.4904e+5
107.0155	5.1970e+6	3.4407e+8	0.0380	1.4893e+5
108.0629	5.2414e+6	3.4694e+8	0.0377	1.4876e+5
109.3591	5.2948e+6	3.5031e+8	0.0374	1.4853e+5

time	brnpravt	gas_mole	bsatavt	porevolt
110.9793	5.3585e+6	3.5420e+8	0.0371	1.4820e+5
113.0045	5.4298e+6	3.5861e+8	0.0368	1.4785e+5
115.5361	5.5130e+6	3.6352e+8	0.0364	1.4735e+5
118.7006	5.6115e+6	3.6906e+8	0.0361	1.4667e+5
122.6562	5.7308e+6	3.7547e+8	0.0357	1.4576e+5
127.6007	5.8733e+6	3.8316e+8	0.0353	1.4473e+5
133.7813	6.0493e+6	3.9254e+8	0.0348	1.4348e+5
141.5071	6.2606e+6	4.0349e+8	0.0341	1.4192e+5
151.1644	6.5084e+6	4.1594e+8	0.0332	1.4003e+5
157.2001	6.6550e+6	4.2342e+8	0.0326	1.3901e+5
164.7448	6.8374e+6	4.3250e+8	0.0319	1.3770e+5
174.1757	7.0615e+6	4.4362e+8	0.0309	1.3616e+5
185.9644	7.3345e+6	4.5735e+8	0.0297	1.3444e+5
200.0005	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0005	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0005	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0006	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0006	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0007	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0008	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0009	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0010	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0012	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0014	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0016	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0020	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0024	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0029	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0035	7.6538e+6	4.7357e+8	0.0282	1.3261e+5
200.0043	7.6539e+6	4.7357e+8	0.0282	1.3261e+5
200.0052	7.6539e+6	4.7357e+8	0.0282	1.3261e+5
200.0064	7.6539e+6	4.7357e+8	0.0282	1.3260e+5
200.0080	7.6540e+6	4.7358e+8	0.0282	1.3260e+5
200.0099	7.6540e+6	4.7358e+8	0.0282	1.3260e+5
200.0122	7.6540e+6	4.7358e+8	0.0282	1.3260e+5
200.0152	7.6541e+6	4.7358e+8	0.0282	1.3260e+5
200.0189	7.6542e+6	4.7359e+8	0.0282	1.3260e+5
200.0236	7.6543e+6	4.7359e+8	0.0282	1.3260e+5
200.0294	7.6544e+6	4.7360e+8	0.0282	1.3260e+5
200.0366	7.6546e+6	4.7361e+8	0.0282	1.3260e+5
200.0456	7.6548e+6	4.7362e+8	0.0282	1.3260e+5
200.0570	7.6551e+6	4.7363e+8	0.0282	1.3260e+5
200.0711	7.6554e+6	4.7365e+8	0.0282	1.3260e+5
200.0888	7.6558e+6	4.7367e+8	0.0282	1.3259e+5
200.1110	7.6563e+6	4.7369e+8	0.0281	1.3259e+5
200.1386	7.6569e+6	4.7373e+8	0.0281	1.3259e+5
200.1731	7.6577e+6	4.7377e+8	0.0281	1.3258e+5
200.2163	7.6586e+6	4.7382e+8	0.0281	1.3258e+5
200.2703	7.6599e+6	4.7388e+8	0.0281	1.3257e+5
200.3378	7.6614e+6	4.7396e+8	0.0281	1.3256e+5
200.4222	7.6633e+6	4.7405e+8	0.0281	1.3255e+5
200.5276	7.6658e+6	4.7418e+8	0.0281	1.3254e+5
200.6595	7.6690e+6	4.7433e+8	0.0281	1.3252e+5
200.8243	7.6731e+6	4.7452e+8	0.0281	1.3249e+5

time	brnpravt	gas_mole	bsatavt	porevolt
201.0303	7.6781e+6	4.7476e+8	0.0280	1.3246e+5
201.2877	7.6842e+6	4.7505e+8	0.0280	1.3242e+5
201.6096	7.6914e+6	4.7542e+8	0.0280	1.3238e+5
202.0119	7.7003e+6	4.7589e+8	0.0279	1.3234e+5
202.5147	7.7115e+6	4.7647e+8	0.0279	1.3228e+5
203.1433	7.7255e+6	4.7719e+8	0.0278	1.3220e+5
203.9291	7.7430e+6	4.7809e+8	0.0277	1.3211e+5
204.9113	7.7649e+6	4.7922e+8	0.0276	1.3200e+5
206.0556	7.7905e+6	4.8054e+8	0.0275	1.3186e+5
207.3313	7.8190e+6	4.8200e+8	0.0273	1.3171e+5
208.7195	7.8502e+6	4.8359e+8	0.0272	1.3155e+5
210.2122	7.8839e+6	4.8530e+8	0.0270	1.3137e+5
211.8092	7.9193e+6	4.8713e+8	0.0268	1.3119e+5
213.5156	7.9575e+6	4.8908e+8	0.0266	1.3099e+5
215.3398	7.9984e+6	4.9116e+8	0.0264	1.3077e+5
217.2932	8.0423e+6	4.9339e+8	0.0262	1.3055e+5
219.3899	8.0893e+6	4.9578e+8	0.0259	1.3030e+5
221.6468	8.1395e+6	4.9834e+8	0.0257	1.3005e+5
224.0840	8.1919e+6	5.0111e+8	0.0254	1.2981e+5
226.7257	8.2509e+6	5.0411e+8	0.0250	1.2952e+5
229.6007	8.3152e+6	5.0736e+8	0.0247	1.2920e+5
232.7440	8.3836e+6	5.1092e+8	0.0243	1.2888e+5
236.1982	8.4579e+6	5.1481e+8	0.0239	1.2855e+5
240.0160	8.5427e+6	5.1911e+8	0.0234	1.2814e+5
244.2634	8.6336e+6	5.2388e+8	0.0229	1.2775e+5
249.0238	8.7365e+6	5.2921e+8	0.0223	1.2730e+5
254.4052	8.8518e+6	5.3521e+8	0.0216	1.2681e+5
260.5495	8.9832e+6	5.4204e+8	0.0208	1.2625e+5
267.6500	9.1319e+6	5.4990e+8	0.0199	1.2567e+5
275.9334	9.3058e+6	5.5902e+8	0.0188	1.2499e+5
284.4510	9.4825e+6	5.6834e+8	0.0177	1.2432e+5
292.6846	9.6532e+6	5.7731e+8	0.0167	1.2368e+5
300.5310	9.8163e+6	5.8581e+8	0.0156	1.2306e+5
308.0685	9.9707e+6	5.9393e+8	0.0146	1.2250e+5
315.4208	1.0120e+7	6.0182e+8	0.0136	1.2199e+5
322.7079	1.0268e+7	6.0959e+8	0.0126	1.2147e+5
330.0356	1.0415e+7	6.1737e+8	0.0117	1.2096e+5
337.4974	1.0558e+7	6.2485e+8	0.0106	1.2046e+5
345.1823	1.0650e+7	6.2790e+8	9.6268e-3	1.1963e+5
353.2043	1.0747e+7	6.3107e+8	8.5530e-3	1.1877e+5
361.6744	1.0847e+7	6.3438e+8	7.4073e-3	1.1791e+5
370.7061	1.0952e+7	6.3790e+8	6.1731e-3	1.1703e+5
380.4201	1.1062e+7	6.4164e+8	4.8339e-3	1.1613e+5
390.9475	1.1180e+7	6.4566e+8	3.3710e-3	1.1517e+5
400.0073	1.1284e+7	6.4907e+8	2.1094e-3	1.1433e+5
400.0073	1.1284e+7	6.4907e+8	2.1094e-3	1.1433e+5
400.0074	1.1284e+7	6.4907e+8	2.1094e-3	1.1433e+5
400.0074	1.1284e+7	6.4907e+8	2.1094e-3	1.1433e+5
400.0074	1.1284e+7	6.4907e+8	2.1094e-3	1.1433e+5
400.0075	1.1284e+7	6.4907e+8	2.1094e-3	1.1433e+5
400.0075	1.1284e+7	6.4907e+8	2.1093e-3	1.1433e+5
400.0076	1.1284e+7	6.4907e+8	2.1093e-3	1.1433e+5
400.0078	1.1284e+7	6.4907e+8	2.1093e-3	1.1433e+5
400.0079	1.1284e+7	6.4907e+8	2.1093e-3	1.1433e+5

time	brnpravt	gas_mole	bsatavt	porevolt
400.0080	1.1284e+7	6.4907e+8	2.1093e-3	1.1433e+5
400.0082	1.1284e+7	6.4907e+8	2.1093e-3	1.1433e+5
400.0085	1.1284e+7	6.4907e+8	2.1092e-3	1.1433e+5
400.0088	1.1284e+7	6.4907e+8	2.1092e-3	1.1433e+5
400.0092	1.1284e+7	6.4907e+8	2.1091e-3	1.1433e+5
400.0097	1.1284e+7	6.4907e+8	2.1090e-3	1.1432e+5
400.0103	1.1284e+7	6.4908e+8	2.1090e-3	1.1432e+5
400.0111	1.1284e+7	6.4908e+8	2.1089e-3	1.1432e+5
400.0121	1.1284e+7	6.4908e+8	2.1087e-3	1.1432e+5
400.0133	1.1284e+7	6.4908e+8	2.1085e-3	1.1432e+5
400.0148	1.1284e+7	6.4908e+8	2.1083e-3	1.1432e+5
400.0167	1.1284e+7	6.4908e+8	2.1081e-3	1.1432e+5
400.0191	1.1284e+7	6.4908e+8	2.1077e-3	1.1432e+5
400.0220	1.1284e+7	6.4908e+8	2.1073e-3	1.1432e+5
400.0257	1.1284e+7	6.4908e+8	2.1068e-3	1.1432e+5
400.0303	1.1284e+7	6.4908e+8	2.1062e-3	1.1432e+5
400.0361	1.1284e+7	6.4908e+8	2.1053e-3	1.1432e+5
400.0434	1.1284e+7	6.4909e+8	2.1043e-3	1.1432e+5
400.0524	1.1284e+7	6.4909e+8	2.1031e-3	1.1432e+5
400.0637	1.1285e+7	6.4910e+8	2.1015e-3	1.1432e+5
400.0778	1.1285e+7	6.4910e+8	2.0995e-3	1.1432e+5
400.0954	1.1285e+7	6.4911e+8	2.0970e-3	1.1432e+5
400.1175	1.1285e+7	6.4912e+8	2.0939e-3	1.1431e+5
400.1451	1.1285e+7	6.4913e+8	2.0901e-3	1.1431e+5
400.1795	1.1286e+7	6.4914e+8	2.0852e-3	1.1431e+5
400.2226	1.1286e+7	6.4916e+8	2.0792e-3	1.1431e+5
400.2765	1.1287e+7	6.4918e+8	2.0716e-3	1.1430e+5
400.3438	1.1288e+7	6.4920e+8	2.0622e-3	1.1429e+5
400.4280	1.1289e+7	6.4923e+8	2.0504e-3	1.1429e+5
400.5332	1.1290e+7	6.4927e+8	2.0357e-3	1.1428e+5
400.6647	1.1291e+7	6.4932e+8	2.0172e-3	1.1426e+5
400.8291	1.1293e+7	6.4938e+8	1.9942e-3	1.1425e+5
401.0345	1.1296e+7	6.4946e+8	1.9655e-3	1.1423e+5
401.2914	1.1299e+7	6.4956e+8	1.9295e-3	1.1421e+5
401.6124	1.1302e+7	6.4968e+8	1.8846e-3	1.1418e+5
402.0136	1.1306e+7	6.4983e+8	1.8286e-3	1.1415e+5
402.5153	1.1311e+7	6.5001e+8	1.7588e-3	1.1411e+5
403.1423	1.1318e+7	6.5025e+8	1.6720e-3	1.1405e+5
403.9261	1.1327e+7	6.5053e+8	1.5643e-3	1.1398e+5
404.9058	1.1338e+7	6.5089e+8	1.4315e-3	1.1389e+5
406.1305	1.1352e+7	6.5132e+8	1.2697e-3	1.1378e+5
407.6613	1.1368e+7	6.5183e+8	1.0781e-3	1.1363e+5
409.5749	1.1389e+7	6.5240e+8	8.6477e-4	1.1345e+5
411.9668	1.1412e+7	6.5295e+8	6.5503e-4	1.1323e+5
414.9567	1.1437e+7	6.5341e+8	4.8474e-4	1.1294e+5
418.6941	1.1469e+7	6.5372e+8	3.7050e-4	1.1255e+5
423.3658	1.1504e+7	6.5393e+8	2.9735e-4	1.1209e+5
429.2054	1.1549e+7	6.5410e+8	2.4128e-4	1.1149e+5
436.5050	1.1601e+7	6.5427e+8	1.8479e-4	1.1079e+5
445.6295	1.1667e+7	6.5447e+8	1.1826e-4	1.0992e+5
456.8080	1.1745e+7	6.5469e+8	4.3943e-5	1.0889e+5
469.7710	1.1834e+7	6.5481e+8	9.8919e-6	1.0772e+5
484.3387	1.1929e+7	6.5486e+8	3.3868e-6	1.0646e+5
500.3398	1.2029e+7	6.5491e+8	2.3804e-6	1.0515e+5

time	brnpravt	gas_mole	bsatavt	porevolt
516.4556	1.2128e+7	6.5495e+8	2.1718e-6	1.0387e+5
532.1435	1.2224e+7	6.5498e+8	2.0644e-6	1.0266e+5
547.3224	1.2305e+7	6.5502e+8	1.9859e-6	1.0163e+5
562.0833	1.2358e+7	6.5505e+8	1.9312e-6	1.0097e+5
576.5588	1.2397e+7	6.5508e+8	1.8933e-6	1.0048e+5
590.8784	1.2438e+7	6.5511e+8	1.8486e-6	9.9987e+4
605.1581	1.2477e+7	6.5514e+8	1.8127e-6	9.9511e+4
619.5016	1.2515e+7	6.5517e+8	1.7760e-6	9.9041e+4
634.0042	1.2554e+7	6.5519e+8	1.7421e-6	9.8569e+4
648.7565	1.2593e+7	6.5522e+8	1.7073e-6	9.8100e+4
663.8491	1.2632e+7	6.5525e+8	1.6725e-6	9.7631e+4
679.3762	1.2672e+7	6.5528e+8	1.6387e-6	9.7156e+4
695.4394	1.2713e+7	6.5531e+8	1.6059e-6	9.6678e+4
712.1512	1.2754e+7	6.5534e+8	1.5780e-6	9.6185e+4
729.6407	1.2797e+7	6.5537e+8	1.5393e-6	9.5686e+4
748.0586	1.2841e+7	6.5540e+8	1.5075e-6	9.5171e+4
767.5851	1.2887e+7	6.5543e+8	1.4737e-6	9.4637e+4
788.4396	1.2936e+7	6.5546e+8	1.4359e-6	9.4077e+4
810.8959	1.2987e+7	6.5550e+8	1.4081e-6	9.3484e+4
835.3019	1.3042e+7	6.5554e+8	1.3644e-6	9.2863e+4
862.1106	1.3102e+7	6.5558e+8	1.3315e-6	9.2184e+4
891.9291	1.3167e+7	6.5562e+8	1.2928e-6	9.1455e+4
925.5939	1.3240e+7	6.5567e+8	1.2471e-6	9.0638e+4
964.3009	1.3325e+7	6.5572e+8	1.2013e-6	8.9697e+4
1009.8390	1.3443e+7	6.5741e+8	1.4793e-6	8.8724e+4
1059.3990	1.3548e+7	6.5939e+8	1.5104e-6	8.7966e+4
1086.7780	1.3560e+7	6.6055e+8	1.6308e-6	8.8052e+4
1103.8900	1.3568e+7	6.6129e+8	1.6475e-6	8.8107e+4
1125.2800	1.3578e+7	6.6222e+8	1.6573e-6	8.8173e+4
1152.0170	1.3591e+7	6.6337e+8	1.6543e-6	8.8254e+4
1185.4390	1.3608e+7	6.6482e+8	1.6453e-6	8.8349e+4
1227.2160	1.3629e+7	6.6663e+8	1.6235e-6	8.8465e+4
1279.4380	1.3656e+7	6.6889e+8	1.6017e-6	8.8606e+4
1334.1960	1.3684e+7	6.7125e+8	1.5788e-6	8.8754e+4
1388.9540	1.3713e+7	6.7362e+8	1.5628e-6	8.8900e+4
1443.7120	1.3741e+7	6.7597e+8	1.5420e-6	8.9043e+4
1498.4700	1.3769e+7	6.7833e+8	1.5142e-6	8.9185e+4
1553.2290	1.3796e+7	6.8067e+8	1.4875e-6	8.9342e+4
1607.9870	1.3824e+7	6.8301e+8	1.4657e-6	8.9478e+4
1662.7450	1.3852e+7	6.8535e+8	1.4458e-6	8.9613e+4
1717.5030	1.3880e+7	6.8767e+8	1.4191e-6	8.9745e+4
1772.2610	1.3907e+7	6.8999e+8	1.3923e-6	8.9876e+4
1827.0190	1.3935e+7	6.9230e+8	1.3833e-6	9.0005e+4
1881.7780	1.3963e+7	6.9461e+8	1.3576e-6	9.0132e+4
1936.5360	1.3991e+7	6.9691e+8	1.3367e-6	9.0258e+4
1991.2940	1.4018e+7	6.9921e+8	1.3298e-6	9.0382e+4
2046.0520	1.4047e+7	7.0150e+8	1.2971e-6	9.0497e+4
2100.8100	1.4075e+7	7.0378e+8	1.2772e-6	9.0609e+4
2155.5680	1.4103e+7	7.0605e+8	1.2574e-6	9.0721e+4
2210.3270	1.4103e+7	7.0616e+8	1.2860e-6	9.0720e+4
2265.0850	1.4102e+7	7.0624e+8	1.2731e-6	9.0718e+4
2319.8430	1.4102e+7	7.0632e+8	1.2603e-6	9.0717e+4
2326.6880	1.4102e+7	7.0633e+8	1.2603e-6	9.0716e+4
2330.9660	1.4102e+7	7.0633e+8	1.2603e-6	9.0716e+4

time	brnpravt	gas_mole	bsatavt	porevolt
2336.3130	1.4102e+7	7.0634e+8	1.2603e-6	9.0716e+4
2342.9980	1.4102e+7	7.0635e+8	1.2543e-6	9.0716e+4
2351.3530	1.4102e+7	7.0636e+8	1.2543e-6	9.0716e+4
2361.7980	1.4102e+7	7.0638e+8	1.2533e-6	9.0716e+4
2374.8530	1.4102e+7	7.0640e+8	1.2474e-6	9.0716e+4
2391.1720	1.4101e+7	7.0642e+8	1.2415e-6	9.0716e+4
2411.5710	1.4101e+7	7.0645e+8	1.2356e-6	9.0717e+4
2437.0700	1.4101e+7	7.0648e+8	1.2286e-6	9.0717e+4
2468.9430	1.4101e+7	7.0652e+8	1.2098e-6	9.0718e+4
2508.7850	1.4100e+7	7.0658e+8	1.1802e-6	9.0718e+4
2558.5870	1.4100e+7	7.0664e+8	1.1555e-6	9.0719e+4
2613.3450	1.4100e+7	7.0671e+8	1.1308e-6	9.0720e+4
2668.1040	1.4099e+7	7.0678e+8	1.1071e-6	9.0722e+4
2722.8620	1.4099e+7	7.0685e+8	1.0813e-6	9.0723e+4
2777.6200	1.4098e+7	7.0691e+8	1.0458e-6	9.0724e+4
2832.3780	1.4098e+7	7.0697e+8	1.0270e-6	9.0725e+4
2887.1360	1.4098e+7	7.0704e+8	1.0093e-6	9.0726e+4
2941.8950	1.4097e+7	7.0710e+8	9.9050e-7	9.0728e+4
2996.6530	1.4097e+7	7.0716e+8	9.5979e-7	9.0729e+4
3051.4110	1.4096e+7	7.0721e+8	9.3510e-7	9.0730e+4
3106.1690	1.4096e+7	7.0727e+8	9.1734e-7	9.0732e+4
3160.9270	1.4096e+7	7.0732e+8	9.0450e-7	9.0733e+4
3215.6860	1.4095e+7	7.0738e+8	8.8673e-7	9.0734e+4
3270.4440	1.4095e+7	7.0743e+8	8.6099e-7	9.0736e+4
3325.2020	1.4095e+7	7.0748e+8	8.4318e-7	9.0737e+4
3379.9600	1.4094e+7	7.0754e+8	8.2441e-7	9.0738e+4
3434.7180	1.4094e+7	7.0759e+8	8.1257e-7	9.0740e+4
3489.4770	1.4094e+7	7.0763e+8	8.0072e-7	9.0741e+4
3544.2350	1.4093e+7	7.0768e+8	7.8091e-7	9.0742e+4
3598.9930	1.4093e+7	7.0773e+8	7.6309e-7	9.0744e+4
3653.7510	1.4092e+7	7.0778e+8	7.5125e-7	9.0745e+4
3708.5090	1.4092e+7	7.0782e+8	7.3841e-7	9.0746e+4
3763.2680	1.4092e+7	7.0787e+8	7.3249e-7	9.0747e+4
3818.0260	1.4091e+7	7.0791e+8	7.1959e-7	9.0749e+4
3872.7840	1.4091e+7	7.0795e+8	7.0675e-7	9.0750e+4
3927.5420	1.4091e+7	7.0800e+8	6.8893e-7	9.0751e+4
3982.3000	1.4090e+7	7.0804e+8	6.8201e-7	9.0753e+4
4037.0590	1.4090e+7	7.0808e+8	6.7609e-7	9.0754e+4
4091.8170	1.4089e+7	7.0812e+8	6.7017e-7	9.0755e+4
4146.5750	1.4089e+7	7.0816e+8	6.6419e-7	9.0756e+4
4201.3330	1.4089e+7	7.0820e+8	6.5035e-7	9.0758e+4
4256.0910	1.4088e+7	7.0824e+8	6.3253e-7	9.0759e+4
4310.8490	1.4088e+7	7.0828e+8	6.2661e-7	9.0760e+4
4338.2290	1.4088e+7	7.0830e+8	6.2661e-7	9.0761e+4
4355.3400	1.4088e+7	7.0831e+8	6.2561e-7	9.0761e+4
4376.7300	1.4087e+7	7.0833e+8	6.2561e-7	9.0762e+4
4403.4680	1.4087e+7	7.0834e+8	6.1969e-7	9.0762e+4
4436.8890	1.4087e+7	7.0837e+8	6.1969e-7	9.0763e+4
4478.6670	1.4089e+7	7.0856e+8	6.4066e-7	9.0772e+4
4530.8880	1.4091e+7	7.0881e+8	6.2582e-7	9.0784e+4
4585.6460	1.4093e+7	7.0905e+8	6.1298e-7	9.0796e+4
4640.4040	1.4095e+7	7.0929e+8	6.0601e-7	9.0808e+4
4695.1630	1.4097e+7	7.0953e+8	6.0501e-7	9.0819e+4
4749.9200	1.4099e+7	7.0975e+8	6.0301e-7	9.0830e+4

time	brnpravt	gas_mole	bsatavt	porevolt
4804.6790	1.4101e+7	7.0998e+8	6.0196e-7	9.0841e+4
4859.4370	1.4103e+7	7.1020e+8	5.8912e-7	9.0852e+4
4914.1950	1.4105e+7	7.1041e+8	5.7628e-7	9.0863e+4
4968.9530	1.4107e+7	7.1062e+8	5.7423e-7	9.0873e+4
5023.7110	1.4109e+7	7.1083e+8	5.7423e-7	9.0883e+4
5078.4700	1.4110e+7	7.1103e+8	5.7323e-7	9.0893e+4
5133.2290	1.4112e+7	7.1123e+8	5.7318e-7	9.0903e+4
5187.9860	1.4114e+7	7.1143e+8	5.7018e-7	9.0912e+4
5242.7450	1.4115e+7	7.1162e+8	5.5834e-7	9.0921e+4
5297.5030	1.4117e+7	7.1181e+8	5.5142e-7	9.0931e+4
5352.2610	1.4118e+7	7.1199e+8	5.5137e-7	9.0939e+4
5407.0190	1.4120e+7	7.1217e+8	5.4937e-7	9.0948e+4
5461.7770	1.4121e+7	7.1234e+8	5.4345e-7	9.0957e+4
5516.5360	1.4122e+7	7.1251e+8	5.4240e-7	9.0965e+4
5571.2940	1.4123e+7	7.1267e+8	5.4040e-7	9.0973e+4
5626.0520	1.4125e+7	7.1283e+8	5.2856e-7	9.0980e+4
5680.8100	1.4126e+7	7.1298e+8	5.2064e-7	9.0988e+4
5735.5680	1.4127e+7	7.1313e+8	5.1959e-7	9.0995e+4
5790.3270	1.4128e+7	7.1327e+8	5.1959e-7	9.1002e+4
5845.0840	1.4129e+7	7.1340e+8	5.1859e-7	9.1008e+4
5899.8430	1.4129e+7	7.1353e+8	5.1754e-7	9.1014e+4
5954.6010	1.4130e+7	7.1365e+8	5.1555e-7	9.1020e+4
6009.3590	1.4131e+7	7.1376e+8	5.0863e-7	9.1025e+4
6064.1170	1.4131e+7	7.1386e+8	4.9578e-7	9.1030e+4
6118.8750	1.4131e+7	7.1396e+8	4.9479e-7	9.1034e+4
6173.6340	1.4132e+7	7.1404e+8	4.9374e-7	9.1038e+4
6228.3920	1.4132e+7	7.1412e+8	4.9174e-7	9.1042e+4
6283.1490	1.4132e+7	7.1419e+8	4.9666e-7	9.1045e+4
6337.9080	1.4132e+7	7.1425e+8	4.9561e-7	9.1047e+4
6392.6670	1.4132e+7	7.1429e+8	4.9561e-7	9.1050e+4
6447.4250	1.4131e+7	7.1433e+8	4.9462e-7	9.1051e+4
6502.1830	1.4131e+7	7.1436e+8	4.8670e-7	9.1052e+4
6556.9400	1.4131e+7	7.1439e+8	4.7386e-7	9.1053e+4
6611.6990	1.4130e+7	7.1442e+8	4.7386e-7	9.1055e+4
6666.4580	1.4130e+7	7.1445e+8	4.7386e-7	9.1056e+4
6721.2150	1.4129e+7	7.1448e+8	4.7380e-7	9.1057e+4
6775.9740	1.4129e+7	7.1451e+8	4.7380e-7	9.1058e+4
6830.7310	1.4129e+7	7.1454e+8	4.7380e-7	9.1060e+4
6885.4910	1.4128e+7	7.1457e+8	4.7375e-7	9.1061e+4
6940.2490	1.4128e+7	7.1459e+8	4.6683e-7	9.1062e+4
6995.0070	1.4128e+7	7.1462e+8	4.6583e-7	9.1063e+4
7049.7650	1.4127e+7	7.1465e+8	4.5399e-7	9.1065e+4
7104.5230	1.4127e+7	7.1468e+8	4.4807e-7	9.1066e+4
7159.2810	1.4126e+7	7.1471e+8	4.4807e-7	9.1067e+4
7214.0400	1.4126e+7	7.1473e+8	4.4807e-7	9.1069e+4
7268.7980	1.4126e+7	7.1476e+8	4.4801e-7	9.1070e+4
7323.5560	1.4125e+7	7.1479e+8	4.4701e-7	9.1071e+4
7378.3130	1.4125e+7	7.1482e+8	4.4701e-7	9.1073e+4
7433.0720	1.4125e+7	7.1485e+8	4.4696e-7	9.1074e+4
7487.8310	1.4124e+7	7.1487e+8	4.4696e-7	9.1075e+4
7542.5890	1.4124e+7	7.1490e+8	4.4696e-7	9.1077e+4
7597.3470	1.4123e+7	7.1493e+8	4.4004e-7	9.1078e+4
7652.1040	1.4123e+7	7.1495e+8	4.3412e-7	9.1079e+4
7706.8630	1.4123e+7	7.1498e+8	4.2820e-7	9.1081e+4

time	brnpravt	gas_mole	bsatavt	porevolt
7761.6220	1.4122e+7	7.1501e+8	4.2720e-7	9.1082e+4
7816.3790	1.4122e+7	7.1503e+8	4.2720e-7	9.1084e+4
7871.1380	1.4122e+7	7.1506e+8	4.2720e-7	9.1085e+4
7925.8960	1.4121e+7	7.1509e+8	4.2715e-7	9.1086e+4
7980.6540	1.4121e+7	7.1511e+8	4.2709e-7	9.1088e+4
8035.4120	1.4121e+7	7.1514e+8	4.2709e-7	9.1089e+4
8090.1700	1.4120e+7	7.1517e+8	4.2709e-7	9.1090e+4
8144.9290	1.4120e+7	7.1519e+8	4.2709e-7	9.1092e+4
8199.6870	1.4120e+7	7.1522e+8	4.2510e-7	9.1093e+4
8254.4440	1.4119e+7	7.1524e+8	4.1918e-7	9.1094e+4
8309.2030	1.4119e+7	7.1527e+8	4.0733e-7	9.1096e+4
8363.9620	1.4118e+7	7.1529e+8	4.0733e-7	9.1097e+4
8418.7200	1.4118e+7	7.1532e+8	4.0733e-7	9.1099e+4
8473.4780	1.4118e+7	7.1534e+8	4.0733e-7	9.1100e+4
8528.2350	1.4117e+7	7.1537e+8	4.0733e-7	9.1101e+4
8582.9940	1.4117e+7	7.1540e+8	4.0728e-7	9.1103e+4
8637.7530	1.4117e+7	7.1542e+8	4.0723e-7	9.1104e+4
8692.5110	1.4116e+7	7.1545e+8	4.0723e-7	9.1106e+4
8747.2690	1.4116e+7	7.1547e+8	4.0623e-7	9.1107e+4
8802.0260	1.4116e+7	7.1549e+8	4.0623e-7	9.1108e+4
8856.7840	1.4115e+7	7.1552e+8	4.0623e-7	9.1110e+4
8911.5440	1.4115e+7	7.1554e+8	4.0523e-7	9.1111e+4
8925.2320	1.4115e+7	7.1555e+8	3.9931e-7	9.1112e+4
8933.7890	1.4115e+7	7.1555e+8	3.9931e-7	9.1112e+4
8935.1250	1.4115e+7	7.1555e+8	3.9931e-7	9.1112e+4
8936.7970	1.4115e+7	7.1556e+8	3.9931e-7	9.1112e+4
8938.8850	1.4115e+7	7.1556e+8	3.9931e-7	9.1112e+4
8941.4960	1.4115e+7	7.1556e+8	3.9931e-7	9.1112e+4
8944.7600	1.4115e+7	7.1556e+8	3.9931e-7	9.1112e+4
8948.8400	1.4115e+7	7.1556e+8	3.9931e-7	9.1112e+4
8953.9390	1.4115e+7	7.1556e+8	3.9338e-7	9.1112e+4
8960.3150	1.4115e+7	7.1557e+8	3.9338e-7	9.1112e+4
8968.2820	1.4115e+7	7.1557e+8	3.9338e-7	9.1113e+4
8978.2440	1.4115e+7	7.1557e+8	3.9338e-7	9.1113e+4
8990.6940	1.4114e+7	7.1558e+8	3.8746e-7	9.1113e+4
9006.2570	1.4114e+7	7.1559e+8	3.8746e-7	9.1114e+4
9025.7110	1.4114e+7	7.1559e+8	3.8746e-7	9.1114e+4
9050.0290	1.4114e+7	7.1561e+8	3.8746e-7	9.1115e+4
9080.4250	1.4114e+7	7.1562e+8	3.8746e-7	9.1116e+4
9118.4220	1.4114e+7	7.1564e+8	3.8746e-7	9.1117e+4
9165.9170	1.4113e+7	7.1566e+8	3.8746e-7	9.1118e+4
9220.6750	1.4113e+7	7.1568e+8	3.8746e-7	9.1119e+4
9275.4340	1.4113e+7	7.1570e+8	3.8646e-7	9.1121e+4
9330.1910	1.4112e+7	7.1573e+8	3.8641e-7	9.1122e+4
9384.9500	1.4112e+7	7.1575e+8	3.8636e-7	9.1123e+4
9439.7080	1.4112e+7	7.1578e+8	3.8636e-7	9.1125e+4
9494.4660	1.4111e+7	7.1580e+8	3.8636e-7	9.1126e+4
9549.2250	1.4111e+7	7.1582e+8	3.8636e-7	9.1128e+4
9603.9820	1.4111e+7	7.1585e+8	3.8636e-7	9.1129e+4
9658.7400	1.4110e+7	7.1587e+8	3.8536e-7	9.1131e+4
9713.4990	1.4110e+7	7.1589e+8	3.7352e-7	9.1132e+4
9768.2570	1.4110e+7	7.1592e+8	3.6759e-7	9.1134e+4
9823.0160	1.4109e+7	7.1594e+8	3.6660e-7	9.1135e+4
9877.7730	1.4109e+7	7.1596e+8	3.6660e-7	9.1136e+4

time	brnpravt	gas_mole	bsatavt	porevolt
9932.5310	1.4109e+7	7.1598e+8	3.6660e-7	9.1138e+4
9987.2900	1.4108e+7	7.1601e+8	3.6660e-7	9.1139e+4
1.0000e+4	1.4108e+7	7.1601e+8	3.6660e-7	9.1140e+4

Values of variables that are shown graphically in Figures 8-7, 8-13, and 8-14

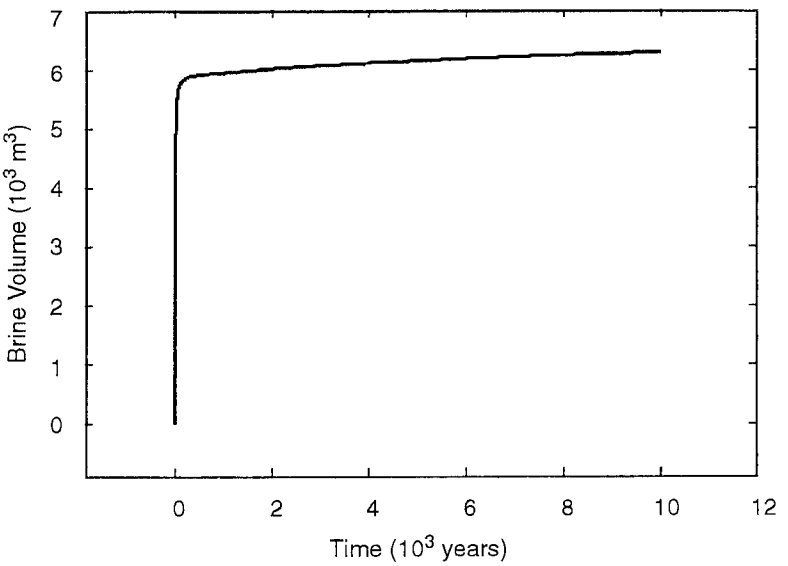

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Figure 8-7. Cumulative Brine Flow into the Repository

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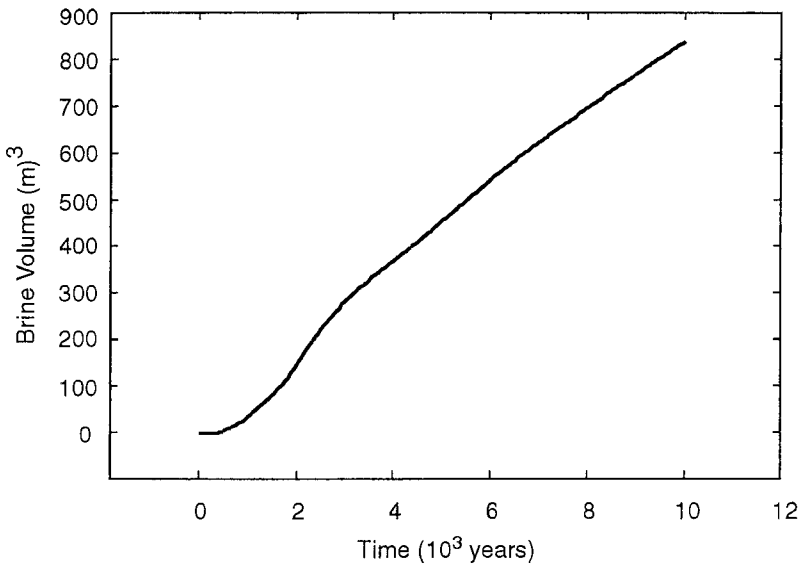

Figure 8-13. Cumulative Brine Flow into Marker Bed 139 at Southern Edge of Repository

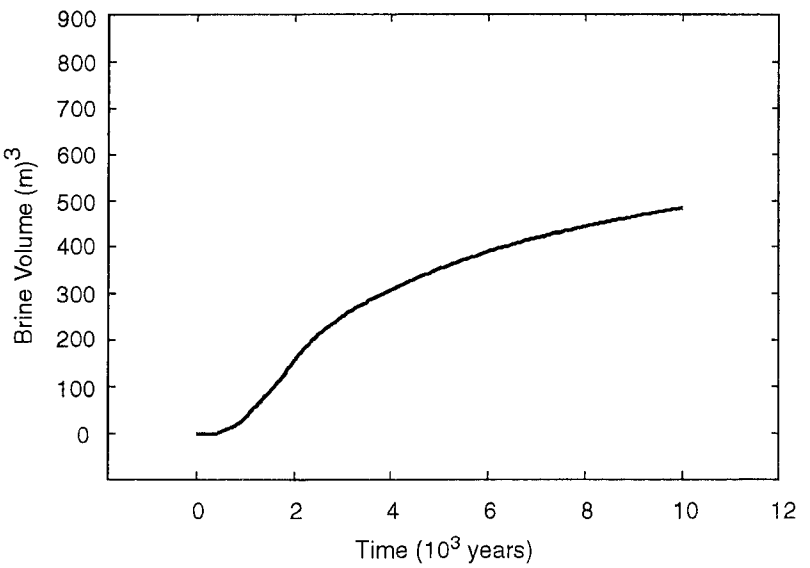

Figure 8-14. Cumulative Brine Flow into Marker Bed 139 at Northern Edge of Repository

This Illustration for Information Purposes Only

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time	brnintc	bm39rc	bm391c	bm38rc	bm381c
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7112e-6	0.0236	0.0000	0.0000	0.0000	0.0000
3.6344e-6	0.0499	0.0000	0.0000	0.0000	0.0000
4.8852e-6	0.0670	0.0000	0.0000	0.0000	0.0000
5.8280e-6	0.0798	0.0000	0.0000	0.0000	0.0000
6.6229e-6	0.0906	0.0000	0.0000	0.0000	0.0000
7.3364e-6	0.1002	0.0000	0.0000	0.0000	0.0000
8.0006e-6	0.1092	0.0000	0.0000	0.0000	0.0000
8.6333e-6	0.1177	0.0000	0.0000	0.0000	0.0000
9.2452e-6	0.1260	0.0000	0.0000	0.0000	0.0000
9.8430e-6	0.1340	0.0000	0.0000	0.0000	0.0000
1.0431e-5	0.1419	0.0000	0.0000	0.0000	0.0000
1.1014e-5	0.1497	0.0000	0.0000	0.0000	0.0000
1.1594e-5	0.1575	0.0000	0.0000	0.0000	0.0000
1.2173e-5	0.1652	0.0000	0.0000	0.0000	0.0000
1.2753e-5	0.1729	0.0000	0.0000	0.0000	0.0000
1.3336e-5	0.1807	0.0000	0.0000	0.0000	0.0000
1.3923e-5	0.1885	0.0000	0.0000	0.0000	0.0000
1.4515e-5	0.1964	0.0000	0.0000	0.0000	0.0000
1.5115e-5	0.2043	0.0000	0.0000	0.0000	0.0000
1.5723e-5	0.2124	0.0000	0.0000	0.0000	0.0000
1.6340e-5	0.2206	0.0000	0.0000	0.0000	0.0000
1.6968e-5	0.2289	0.0000	0.0000	0.0000	0.0000
1.7609e-5	0.2373	0.0000	0.0000	0.0000	0.0000
1.8263e-5	0.2460	0.0000	0.0000	0.0000	0.0000
1.8933e-5	0.2548	0.0000	0.0000	0.0000	0.0000
1.9619e-5	0.2638	0.0000	0.0000	0.0000	0.0000
2.0324e-5	0.2731	0.0000	0.0000	0.0000	0.0000
2.1049e-5	0.2826	0.0000	0.0000	0.0000	0.0000
2.1796e-5	0.2924	0.0000	0.0000	0.0000	0.0000
2.2568e-5	0.3025	0.0000	0.0000	0.0000	0.0000
2.3367e-5	0.3129	0.0000	0.0000	0.0000	0.0000
2.4195e-5	0.3237	0.0000	0.0000	0.0000	0.0000
2.5055e-5	0.3349	0.0000	0.0000	0.0000	0.0000
2.5951e-5	0.3466	0.0000	0.0000	0.0000	0.0000
2.6886e-5	0.3588	0.0000	0.0000	0.0000	0.0000
2.7864e-5	0.3715	0.0000	0.0000	0.0000	0.0000
2.8891e-5	0.3848	0.0000	0.0000	0.0000	0.0000
2.9971e-5	0.3988	0.0000	0.0000	0.0000	0.0000
3.1112e-5	0.4135	0.0000	0.0000	0.0000	0.0000
3.2320e-5	0.4291	0.0000	0.0000	0.0000	0.0000
3.3603e-5	0.4457	0.0000	0.0000	0.0000	0.0000
3.4973e-5	0.4633	0.0000	0.0000	0.0000	0.0000
3.6442e-5	0.4822	0.0000	0.0000	0.0000	0.0000
3.8024e-5	0.5025	0.0000	0.0000	0.0000	0.0000
3.9737e-5	0.5244	0.0000	0.0000	0.0000	0.0000
4.1604e-5	0.5483	0.0000	0.0000	0.0000	0.0000
4.3653e-5	0.5745	0.0000	0.0000	0.0000	0.0000
4.5920e-5	0.6033	0.0000	0.0000	0.0000	0.0000
4.8452e-5	0.6355	0.0000	0.0000	0.0000	0.0000
5.1311e-5	0.6717	0.0000	0.0000	0.0000	0.0000
5.4582e-5	0.7131	0.0000	0.0000	0.0000	0.0000
5.8383e-5	0.7610	0.0000	0.0000	0.0000	0.0000
6.2885e-5	0.8176	0.0000	0.0000	0.0000	0.0000
6.8347e-5	0.8861	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm39lc	bm38rc	bm38lc
7.5172e-5	0.9713	0.0000	0.0000	0.0000	0.0000
8.3703e-5	1.0773	0.0000	0.0000	0.0000	0.0000
9.4367e-5	1.2093	0.0000	0.0000	0.0000	0.0000
1.0770e-4	1.3735	0.0000	0.0000	0.0000	0.0000
1.2436e-4	1.5778	0.0000	0.0000	0.0000	0.0000
1.4519e-4	1.8319	0.0000	0.0000	0.0000	0.0000
1.7122e-4	2.1480	0.0000	0.0000	0.0000	0.0000
2.0376e-4	2.5412	0.0000	0.0000	0.0000	0.0000
2.4444e-4	3.0304	0.0000	0.0000	0.0000	0.0000
2.9529e-4	3.6420	0.0000	0.0000	0.0000	0.0000
3.4826e-4	4.2788	0.0000	0.0000	0.0000	0.0000
3.9743e-4	4.8699	0.0000	0.0000	0.0000	0.0000
4.4238e-4	5.4099	0.0000	0.0000	0.0000	0.0000
4.8423e-4	5.9125	0.0000	0.0000	0.0000	0.0000
5.2405e-4	6.3907	0.0000	0.0000	0.0000	0.0000
5.6266e-4	6.8543	0.0000	0.0000	0.0000	0.0000
6.0063e-4	7.3099	0.0000	0.0000	0.0000	0.0000
6.3835e-4	7.7625	0.0000	0.0000	0.0000	0.0000
6.7612e-4	8.2157	0.0000	0.0000	0.0000	0.0000
7.1420e-4	8.6723	0.0000	0.0000	0.0000	0.0000
7.5275e-4	9.1345	0.0000	0.0000	0.0000	0.0000
7.9194e-4	9.6043	0.0000	0.0000	0.0000	0.0000
8.3192e-4	10.0834	0.0000	0.0000	0.0000	0.0000
8.7281e-4	10.5733	0.0000	0.0000	0.0000	0.0000
9.1473e-4	11.0754	0.0000	0.0000	0.0000	0.0000
9.5780e-4	11.5912	0.0000	0.0000	0.0000	0.0000
1.0021e-3	12.1220	0.0000	0.0000	0.0000	0.0000
1.0479e-3	12.6692	0.0000	0.0000	0.0000	0.0000
1.0951e-3	13.2342	0.0000	0.0000	0.0000	0.0000
1.1440e-3	13.8186	0.0000	0.0000	0.0000	0.0000
1.1946e-3	14.4238	0.0000	0.0000	0.0000	0.0000
1.2471e-3	15.0514	0.0000	0.0000	0.0000	0.0000
1.3017e-3	15.7033	0.0000	0.0000	0.0000	0.0000
1.3585e-3	16.3812	0.0000	0.0000	0.0000	0.0000
1.4176e-3	17.0872	0.0000	0.0000	0.0000	0.0000
1.4793e-3	17.8233	0.0000	0.0000	0.0000	0.0000
1.5438e-3	18.5920	0.0000	0.0000	0.0000	0.0000
1.6112e-3	19.3958	0.0000	0.0000	0.0000	0.0000
1.6818e-3	20.2375	0.0000	0.0000	0.0000	0.0000
1.7560e-3	21.1203	0.0000	0.0000	0.0000	0.0000
1.8339e-3	22.0477	0.0000	0.0000	0.0000	0.0000
1.9159e-3	23.0234	0.0000	0.0000	0.0000	0.0000
2.0024e-3	24.0518	0.0000	0.0000	0.0000	0.0000
2.0938e-3	25.1378	0.0000	0.0000	0.0000	0.0000
2.1906e-3	26.2869	0.0000	0.0000	0.0000	0.0000
2.2933e-3	27.5054	0.0000	0.0000	0.0000	0.0000
2.4026e-3	28.8005	0.0000	0.0000	0.0000	0.0000
2.5191e-3	30.1807	0.0000	0.0000	0.0000	0.0000
2.6437e-3	31.6557	0.0000	0.0000	0.0000	0.0000
2.7775e-3	33.2370	0.0000	0.0000	0.0000	0.0000
2.9215e-3	34.9385	0.0000	0.0000	0.0000	0.0000
3.0774e-3	36.7768	0.0000	0.0000	0.0000	0.0000
3.2468e-3	38.7724	0.0000	0.0000	0.0000	0.0000
3.4319e-3	40.9510	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm39lc	bm38rc	bm38lc
3.6358e-3	43.3459	0.0000	0.0000	0.0000	0.0000
3.8622e-3	46.0013	0.0000	0.0000	0.0000	0.0000
4.1165e-3	48.9782	0.0000	0.0000	0.0000	0.0000
4.4066e-3	52.3655	0.0000	0.0000	0.0000	0.0000
4.7443e-3	56.3004	0.0000	0.0000	0.0000	0.0000
5.1098e-3	60.5456	0.0000	0.0000	0.0000	0.0000
5.4630e-3	64.6374	0.0000	0.0000	0.0000	0.0000
5.7938e-3	68.4595	0.0000	0.0000	0.0000	0.0000
6.1057e-3	72.0541	0.0000	0.0000	0.0000	0.0000
6.4046e-3	75.4911	0.0000	0.0000	0.0000	0.0000
6.6957e-3	78.8316	0.0000	0.0000	0.0000	0.0000
6.9832e-3	82.1229	0.0000	0.0000	0.0000	0.0000
7.2702e-3	85.4008	0.0000	0.0000	0.0000	0.0000
7.5591e-3	88.6934	0.0000	0.0000	0.0000	0.0000
7.8520e-3	92.0235	0.0000	0.0000	0.0000	0.0000
8.1505e-3	95.4099	0.0000	0.0000	0.0000	0.0000
8.4562e-3	98.8693	0.0000	0.0000	0.0000	0.0000
8.7705e-3	102.4167	0.0000	0.0000	0.0000	0.0000
9.0945e-3	106.0660	0.0000	0.0000	0.0000	0.0000
9.4297e-3	109.8304	0.0000	0.0000	0.0000	0.0000
9.7772e-3	113.7226	0.0000	0.0000	0.0000	0.0000
0.0101	117.7555	0.0000	0.0000	0.0000	0.0000
0.0105	121.9415	0.0000	0.0000	0.0000	0.0000
0.0109	126.2934	0.0000	0.0000	0.0000	0.0000
0.0113	130.8244	0.0000	0.0000	0.0000	0.0000
0.0117	135.5479	0.0000	0.0000	0.0000	0.0000
0.0122	140.4777	0.0000	0.0000	0.0000	0.0000
0.0127	145.6286	0.0000	0.0000	0.0000	0.0000
0.0132	151.0158	0.0000	0.0000	0.0000	0.0000
0.0137	156.6559	0.0000	0.0000	0.0000	0.0000
0.0142	162.5664	0.0000	0.0000	0.0000	0.0000
0.0148	168.7665	0.0000	0.0000	0.0000	0.0000
0.0154	175.2770	0.0000	0.0000	0.0000	0.0000
0.0160	182.1209	0.0000	0.0000	0.0000	0.0000
0.0167	189.3239	0.0000	0.0000	0.0000	0.0000
0.0174	196.9145	0.0000	0.0000	0.0000	0.0000
0.0182	204.9253	0.0000	0.0000	0.0000	0.0000
0.0190	213.3931	0.0000	0.0000	0.0000	0.0000
0.0199	222.3606	0.0000	0.0000	0.0000	0.0000
0.0208	231.8769	0.0000	0.0000	0.0000	0.0000
0.0218	241.9997	0.0000	0.0000	0.0000	0.0000
0.0228	252.7971	0.0000	0.0000	0.0000	0.0000
0.0239	264.3505	0.0000	0.0000	0.0000	0.0000
0.0252	276.7579	0.0000	0.0000	0.0000	0.0000
0.0265	290.1395	0.0000	0.0000	0.0000	0.0000
0.0280	304.6443	0.0000	0.0000	0.0000	0.0000
0.0296	320.4604	0.0000	0.0000	0.0000	0.0000
0.0313	337.8298	0.0000	0.0000	0.0000	0.0000
0.0333	357.0715	0.0000	0.0000	0.0000	0.0000
0.0356	378.6168	0.0000	0.0000	0.0000	0.0000
0.0382	403.0692	0.0000	0.0000	0.0000	0.0000
0.0412	431.3077	0.0000	0.0000	0.0000	0.0000
0.0448	464.6806	0.0000	0.0000	0.0000	0.0000
0.0493	505.3998	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
0.0547	553.3283	0.0000	0.0000	0.0000	0.0000
0.0607	606.2150	0.0000	0.0000	0.0000	0.0000
0.0673	662.6604	0.0000	0.0000	0.0000	0.0000
0.0744	722.0184	0.0000	0.0000	0.0000	0.0000
0.0820	784.0752	0.0000	0.0000	0.0000	0.0000
0.0901	848.8102	0.0000	0.0000	0.0000	0.0000
0.0987	916.2589	0.0000	0.0000	0.0000	0.0000
0.1080	986.4382	0.0000	0.0000	0.0000	0.0000
0.1180	1059.3080	0.0000	0.0000	0.0000	0.0000
0.1287	1134.7520	0.0000	0.0000	0.0000	0.0000
0.1402	1212.5800	0.0000	0.0000	0.0000	0.0000
0.1526	1292.5340	0.0000	0.0000	0.0000	0.0000
0.1659	1374.3110	0.0000	0.0000	0.0000	0.0000
0.1803	1457.5860	0.0000	0.0000	0.0000	0.0000
0.1958	1542.0360	0.0000	0.0000	0.0000	0.0000
0.2125	1627.3590	0.0000	0.0000	0.0000	0.0000
0.2305	1713.2800	0.0000	0.0000	0.0000	0.0000
0.2500	1799.5660	0.0000	0.0000	0.0000	0.0000
0.2711	1886.0190	0.0000	0.0000	0.0000	0.0000
0.2939	1972.3300	0.0000	0.0000	0.0000	0.0000
0.3183	2057.9020	0.0000	0.0000	0.0000	0.0000
0.3449	2143.1800	0.0000	0.0000	0.0000	0.0000
0.3739	2228.6760	0.0000	0.0000	0.0000	0.0000
0.4055	2314.1360	0.0000	0.0000	0.0000	0.0000
0.4400	2399.4560	0.0000	0.0000	0.0000	0.0000
0.4778	2484.6200	0.0000	0.0000	0.0000	0.0000
0.5192	2569.5020	0.0000	0.0000	0.0000	0.0000
0.5643	2653.8680	0.0000	0.0000	0.0000	0.0000
0.6136	2737.6340	0.0000	0.0000	0.0000	0.0000
0.6645	2816.4440	0.0000	0.0000	0.0000	0.0000
0.7149	2888.3450	0.0000	0.0000	0.0000	0.0000
0.7643	2953.3230	0.0000	0.0000	0.0000	0.0000
0.8122	3012.1310	0.0000	0.0000	0.0000	0.0000
0.8588	3065.6880	0.0000	0.0000	0.0000	0.0000
0.9043	3114.8520	0.0000	0.0000	0.0000	0.0000
0.9489	3160.3550	0.0000	0.0000	0.0000	0.0000
0.9929	3202.7990	0.0000	0.0000	0.0000	0.0000
1.0363	3242.6830	0.0000	0.0000	0.0000	0.0000
1.0794	3280.4100	0.0000	0.0000	0.0000	0.0000
1.1225	3316.3130	0.0000	0.0000	0.0000	0.0000
1.1655	3350.6750	0.0000	0.0000	0.0000	0.0000
1.2088	3383.7320	0.0000	0.0000	0.0000	0.0000
1.2525	3415.6910	0.0000	0.0000	0.0000	0.0000
1.2968	3446.7380	0.0000	0.0000	0.0000	0.0000
1.3418	3477.0370	0.0000	0.0000	0.0000	0.0000
1.3877	3506.7320	0.0000	0.0000	0.0000	0.0000
1.4348	3535.9540	0.0000	0.0000	0.0000	0.0000
1.4832	3564.8290	0.0000	0.0000	0.0000	0.0000
1.5331	3593.4780	0.0000	0.0000	0.0000	0.0000
1.5850	3622.0220	0.0000	0.0000	0.0000	0.0000
1.6391	3650.6080	0.0000	0.0000	0.0000	0.0000
1.6958	3679.3680	0.0000	0.0000	0.0000	0.0000
1.7555	3708.4440	0.0000	0.0000	0.0000	0.0000
1.8188	3737.9950	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
1.8865	3768.2010	0.0000	0.0000	0.0000	0.0000
1.9593	3799.2710	0.0000	0.0000	0.0000	0.0000
2.0383	3831.4530	0.0000	0.0000	0.0000	0.0000
2.1251	3865.0530	0.0000	0.0000	0.0000	0.0000
2.2214	3900.4580	0.0000	0.0000	0.0000	0.0000
2.3300	3938.1710	0.0000	0.0000	0.0000	0.0000
2.4547	3978.8650	0.0000	0.0000	0.0000	0.0000
2.6012	4023.4810	0.0000	0.0000	0.0000	0.0000
2.7782	4073.3870	0.0000	0.0000	0.0000	0.0000
2.9996	4130.3670	0.0000	0.0000	0.0000	0.0000
3.2727	4193.7880	0.0000	0.0000	0.0000	0.0000
3.5924	4260.2260	0.0000	0.0000	0.0000	0.0000
3.9572	4327.7420	0.0000	0.0000	0.0000	0.0000
4.1639	4363.6650	0.0000	0.0000	0.0000	0.0000
4.4224	4405.3930	0.0000	0.0000	0.0000	0.0000
4.7454	4453.2250	0.0000	0.0000	0.0000	0.0000
5.1337	4505.4500	0.0000	0.0000	0.0000	0.0000
5.6099	4562.9620	0.0000	0.0000	0.0000	0.0000
6.1533	4621.6300	0.0000	0.0000	0.0000	0.0000
6.7551	4679.5200	0.0000	0.0000	0.0000	0.0000
7.4188	4736.1390	0.0000	0.0000	0.0000	0.0000
8.1589	4792.2150	0.0000	0.0000	0.0000	0.0000
8.1655	4792.7130	0.0000	0.0000	0.0000	0.0000
8.1737	4793.3340	0.0000	0.0000	0.0000	0.0000
8.1840	4794.1100	0.0000	0.0000	0.0000	0.0000
8.1968	4795.0780	0.0000	0.0000	0.0000	0.0000
8.2129	4796.2840	0.0000	0.0000	0.0000	0.0000
8.2329	4797.7870	0.0000	0.0000	0.0000	0.0000
8.2580	4799.6590	0.0000	0.0000	0.0000	0.0000
8.2894	4801.9860	0.0000	0.0000	0.0000	0.0000
8.3286	4804.8790	0.0000	0.0000	0.0000	0.0000
8.3776	4808.4680	0.0000	0.0000	0.0000	0.0000
8.4389	4812.9120	0.0000	0.0000	0.0000	0.0000
8.5154	4818.4030	0.0000	0.0000	0.0000	0.0000
8.6111	4825.1690	0.0000	0.0000	0.0000	0.0000
8.7308	4833.4790	0.0000	0.0000	0.0000	0.0000
8.8803	4843.6450	0.0000	0.0000	0.0000	0.0000
9.0672	4856.0200	0.0000	0.0000	0.0000	0.0000
9.3009	4870.9950	0.0000	0.0000	0.0000	0.0000
9.5930	4888.9970	0.0000	0.0000	0.0000	0.0000
9.9581	4910.4600	0.0000	0.0000	0.0000	0.0000
10.0000	4912.9140	0.0000	0.0000	0.0000	0.0000
10.0001	4912.9160	0.0000	0.0000	0.0000	0.0000
10.0001	4912.9170	0.0000	0.0000	0.0000	0.0000
10.0001	4912.9190	0.0000	0.0000	0.0000	0.0000
10.0002	4912.9230	0.0000	0.0000	0.0000	0.0000
10.0002	4912.9270	0.0000	0.0000	0.0000	0.0000
10.0003	4912.9320	0.0000	0.0000	0.0000	0.0000
10.0004	4912.9380	0.0000	0.0000	0.0000	0.0000
10.0006	4912.9460	0.0000	0.0000	0.0000	0.0000
10.0007	4912.9550	0.0000	0.0000	0.0000	0.0000
10.0009	4912.9670	0.0000	0.0000	0.0000	0.0000
10.0012	4912.9820	0.0000	0.0000	0.0000	0.0000
10.0015	4913.0000	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
10.0019	4913.0240	0.0000	0.0000	0.0000	0.0000
10.0024	4913.0530	0.0000	0.0000	0.0000	0.0000
10.0030	4913.0890	0.0000	0.0000	0.0000	0.0000
10.0038	4913.1350	0.0000	0.0000	0.0000	0.0000
10.0048	4913.1920	0.0000	0.0000	0.0000	0.0000
10.0060	4913.2630	0.0000	0.0000	0.0000	0.0000
10.0075	4913.3520	0.0000	0.0000	0.0000	0.0000
10.0094	4913.4630	0.0000	0.0000	0.0000	0.0000
10.0118	4913.6020	0.0000	0.0000	0.0000	0.0000
10.0148	4913.7740	0.0000	0.0000	0.0000	0.0000
10.0185	4913.9910	0.0000	0.0000	0.0000	0.0000
10.0231	4914.2610	0.0000	0.0000	0.0000	0.0000
10.0289	4914.5990	0.0000	0.0000	0.0000	0.0000
10.0361	4915.0210	0.0000	0.0000	0.0000	0.0000
10.0452	4915.5470	0.0000	0.0000	0.0000	0.0000
10.0565	4916.2050	0.0000	0.0000	0.0000	0.0000
10.0707	4917.0250	0.0000	0.0000	0.0000	0.0000
10.0884	4918.0470	0.0000	0.0000	0.0000	0.0000
10.1105	4919.3230	0.0000	0.0000	0.0000	0.0000
10.1381	4920.9110	0.0000	0.0000	0.0000	0.0000
10.1727	4922.8870	0.0000	0.0000	0.0000	0.0000
10.2159	4925.3440	0.0000	0.0000	0.0000	0.0000
10.2699	4928.3950	0.0000	0.0000	0.0000	0.0000
10.3374	4932.1750	0.0000	0.0000	0.0000	0.0000
10.4218	4936.8520	0.0000	0.0000	0.0000	0.0000
10.5272	4942.6230	0.0000	0.0000	0.0000	0.0000
10.6590	4949.7220	0.0000	0.0000	0.0000	0.0000
10.8238	4958.4220	0.0000	0.0000	0.0000	0.0000
11.0298	4969.0390	0.0000	0.0000	0.0000	0.0000
11.2873	4981.9250	0.0000	0.0000	0.0000	0.0000
11.6091	4997.4660	0.0000	0.0000	0.0000	0.0000
12.0114	5016.0680	0.0000	0.0000	0.0000	0.0000
12.5143	5038.1380	0.0000	0.0000	0.0000	0.0000
13.1429	5064.0570	0.0000	0.0000	0.0000	0.0000
13.9286	5094.1430	0.0000	0.0000	0.0000	0.0000
14.9108	5128.6080	0.0000	0.0000	0.0000	0.0000
16.1385	5167.5200	0.0000	0.0000	0.0000	0.0000
17.6732	5210.8370	0.0000	0.0000	0.0000	0.0000
19.5915	5258.2070	0.0000	0.0000	0.0000	0.0000
21.9894	5309.0570	0.0000	0.0000	0.0000	0.0000
24.9867	5362.7180	0.0000	0.0000	0.0000	0.0000
24.9999	5362.9540	0.0000	0.0000	0.0000	0.0000
24.9999	5362.9540	0.0000	0.0000	0.0000	0.0000
25.0000	5362.9550	0.0000	0.0000	0.0000	0.0000
25.0000	5362.9550	0.0000	0.0000	0.0000	0.0000
25.0001	5362.9560	0.0000	0.0000	0.0000	0.0000
25.0001	5362.9580	0.0000	0.0000	0.0000	0.0000
25.0002	5362.9590	0.0000	0.0000	0.0000	0.0000
25.0003	5362.9610	0.0000	0.0000	0.0000	0.0000
25.0004	5362.9630	0.0000	0.0000	0.0000	0.0000
25.0006	5362.9660	0.0000	0.0000	0.0000	0.0000
25.0008	5362.9700	0.0000	0.0000	0.0000	0.0000
25.0011	5362.9740	0.0000	0.0000	0.0000	0.0000
25.0014	5362.9800	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
25.0018	5362.9870	0.0000	0.0000	0.0000	0.0000
25.0023	5362.9960	0.0000	0.0000	0.0000	0.0000
25.0029	5363.0070	0.0000	0.0000	0.0000	0.0000
25.0037	5363.0210	0.0000	0.0000	0.0000	0.0000
25.0047	5363.0380	0.0000	0.0000	0.0000	0.0000
25.0059	5363.0600	0.0000	0.0000	0.0000	0.0000
25.0074	5363.0860	0.0000	0.0000	0.0000	0.0000
25.0093	5363.1210	0.0000	0.0000	0.0000	0.0000
25.0117	5363.1630	0.0000	0.0000	0.0000	0.0000
25.0146	5363.2160	0.0000	0.0000	0.0000	0.0000
25.0183	5363.2820	0.0000	0.0000	0.0000	0.0000
25.0230	5363.3650	0.0000	0.0000	0.0000	0.0000
25.0288	5363.4680	0.0000	0.0000	0.0000	0.0000
25.0360	5363.5970	0.0000	0.0000	0.0000	0.0000
25.0451	5363.7590	0.0000	0.0000	0.0000	0.0000
25.0564	5363.9610	0.0000	0.0000	0.0000	0.0000
25.0706	5364.2130	0.0000	0.0000	0.0000	0.0000
25.0883	5364.5270	0.0000	0.0000	0.0000	0.0000
25.1104	5364.9200	0.0000	0.0000	0.0000	0.0000
25.1380	5365.4110	0.0000	0.0000	0.0000	0.0000
25.1726	5366.0220	0.0000	0.0000	0.0000	0.0000
25.2158	5366.7850	0.0000	0.0000	0.0000	0.0000
25.2698	5367.7350	0.0000	0.0000	0.0000	0.0000
25.3373	5368.9180	0.0000	0.0000	0.0000	0.0000
25.4216	5370.3910	0.0000	0.0000	0.0000	0.0000
25.5271	5372.2190	0.0000	0.0000	0.0000	0.0000
25.6589	5374.4880	0.0000	0.0000	0.0000	0.0000
25.8237	5377.2980	0.0000	0.0000	0.0000	0.0000
26.0297	5380.7710	0.0000	0.0000	0.0000	0.0000
26.2872	5385.0520	0.0000	0.0000	0.0000	0.0000
26.6090	5390.3110	0.0000	0.0000	0.0000	0.0000
27.0113	5396.7440	0.0000	0.0000	0.0000	0.0000
27.5142	5404.5720	0.0000	0.0000	0.0000	0.0000
28.1428	5414.0420	0.0000	0.0000	0.0000	0.0000
28.9285	5425.4110	0.0000	0.0000	0.0000	0.0000
29.9107	5438.9420	0.0000	0.0000	0.0000	0.0000
31.1384	5454.8850	0.0000	0.0000	0.0000	0.0000
32.6731	5473.5700	0.0000	0.0000	0.0000	0.0000
34.5914	5495.1080	0.0000	0.0000	0.0000	0.0000
36.9893	5519.5620	0.0000	0.0000	0.0000	0.0000
39.9866	5546.8480	0.0000	0.0000	0.0000	0.0000
43.6998	5576.5720	0.0000	0.0000	0.0000	0.0000
47.9516	5606.1990	0.0000	0.0000	0.0000	0.0000
49.9985	5619.5560	0.0000	0.0000	0.0000	0.0000
49.9986	5619.5560	0.0000	0.0000	0.0000	0.0000
49.9986	5619.5560	0.0000	0.0000	0.0000	0.0000
49.9986	5619.5560	0.0000	0.0000	0.0000	0.0000
49.9987	5619.5570	0.0000	0.0000	0.0000	0.0000
49.9988	5619.5570	0.0000	0.0000	0.0000	0.0000
49.9988	5619.5580	0.0000	0.0000	0.0000	0.0000
49.9990	5619.5590	0.0000	0.0000	0.0000	0.0000
49.9991	5619.5590	0.0000	0.0000	0.0000	0.0000
49.9992	5619.5610	0.0000	0.0000	0.0000	0.0000
49.9994	5619.5620	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
49.9997	5619.5630	0.0000	0.0000	0.0000	0.0000
50.0000	5619.5650	0.0000	0.0000	0.0000	0.0000
50.0004	5619.5670	0.0000	0.0000	0.0000	0.0000
50.0009	5619.5710	0.0000	0.0000	0.0000	0.0000
50.0015	5619.5750	0.0000	0.0000	0.0000	0.0000
50.0023	5619.5800	0.0000	0.0000	0.0000	0.0000
50.0033	5619.5860	0.0000	0.0000	0.0000	0.0000
50.0045	5619.5940	0.0000	0.0000	0.0000	0.0000
50.0060	5619.6040	0.0000	0.0000	0.0000	0.0000
50.0079	5619.6170	0.0000	0.0000	0.0000	0.0000
50.0103	5619.6330	0.0000	0.0000	0.0000	0.0000
50.0133	5619.6520	0.0000	0.0000	0.0000	0.0000
50.0170	5619.6760	0.0000	0.0000	0.0000	0.0000
50.0216	5619.7070	0.0000	0.0000	0.0000	0.0000
50.0274	5619.7440	0.0000	0.0000	0.0000	0.0000
50.0347	5619.7920	0.0000	0.0000	0.0000	0.0000
50.0437	5619.8500	0.0000	0.0000	0.0000	0.0000
50.0550	5619.9240	0.0000	0.0000	0.0000	0.0000
50.0692	5620.0160	0.0000	0.0000	0.0000	0.0000
50.0869	5620.1310	0.0000	0.0000	0.0000	0.0000
50.1090	5620.2750	0.0000	0.0000	0.0000	0.0000
50.1367	5620.4550	0.0000	0.0000	0.0000	0.0000
50.1712	5620.6790	0.0000	0.0000	0.0000	0.0000
50.2144	5620.9590	0.0000	0.0000	0.0000	0.0000
50.2684	5621.3080	0.0000	0.0000	0.0000	0.0000
50.3359	5621.7440	0.0000	0.0000	0.0000	0.0000
50.4203	5622.2870	0.0000	0.0000	0.0000	0.0000
50.5257	5622.9630	0.0000	0.0000	0.0000	0.0000
50.6576	5623.8040	0.0000	0.0000	0.0000	0.0000
50.8223	5624.8510	0.0000	0.0000	0.0000	0.0000
51.0283	5626.1500	0.0000	0.0000	0.0000	0.0000
51.2858	5627.7630	0.0000	0.0000	0.0000	0.0000
51.6076	5629.7590	0.0000	0.0000	0.0000	0.0000
52.0099	5632.2220	0.0000	0.0000	0.0000	0.0000
52.5128	5635.2530	0.0000	0.0000	0.0000	0.0000
53.1414	5638.9680	0.0000	0.0000	0.0000	0.0000
53.9271	5643.5000	0.0000	0.0000	0.0000	0.0000
54.9093	5648.9950	0.0000	0.0000	0.0000	0.0000
56.1370	5655.6110	0.0000	0.0000	0.0000	0.0000
57.6717	5663.5390	0.0000	0.0000	0.0000	0.0000
59.5900	5672.9140	0.0000	0.0000	0.0000	0.0000
61.9879	5683.8680	0.0000	0.0000	0.0000	0.0000
64.9852	5696.4820	0.0000	0.0000	0.0000	0.0000
68.7320	5710.7770	0.0000	0.0000	0.0000	0.0000
73.3691	5726.5120	0.0000	0.0000	0.0000	0.0000
78.9483	5743.0410	0.0000	0.0000	0.0000	0.0000
85.9222	5760.6070	0.0000	0.0000	0.0000	0.0000
94.0324	5777.6650	0.0000	0.0000	0.0000	0.0000
100.0002	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0003	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0003	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0004	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0004	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0005	5788.7060	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
100.0005	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0006	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0008	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0009	5788.7060	0.0000	0.0000	0.0000	0.0000
100.0011	5788.7070	0.0000	0.0000	0.0000	0.0000
100.0014	5788.7070	0.0000	0.0000	0.0000	0.0000
100.0017	5788.7080	0.0000	0.0000	0.0000	0.0000
100.0021	5788.7080	0.0000	0.0000	0.0000	0.0000
100.0026	5788.7090	0.0000	0.0000	0.0000	0.0000
100.0032	5788.7100	0.0000	0.0000	0.0000	0.0000
100.0040	5788.7120	0.0000	0.0000	0.0000	0.0000
100.0050	5788.7130	0.0000	0.0000	0.0000	0.0000
100.0062	5788.7160	0.0000	0.0000	0.0000	0.0000
100.0077	5788.7190	0.0000	0.0000	0.0000	0.0000
100.0096	5788.7230	0.0000	0.0000	0.0000	0.0000
100.0120	5788.7270	0.0000	0.0000	0.0000	0.0000
100.0150	5788.7320	0.0000	0.0000	0.0000	0.0000
100.0187	5788.7390	0.0000	0.0000	0.0000	0.0000
100.0233	5788.7470	0.0000	0.0000	0.0000	0.0000
100.0291	5788.7580	0.0000	0.0000	0.0000	0.0000
100.0364	5788.7710	0.0000	0.0000	0.0000	0.0000
100.0454	5788.7880	0.0000	0.0000	0.0000	0.0000
100.0567	5788.8090	0.0000	0.0000	0.0000	0.0000
100.0709	5788.8350	0.0000	0.0000	0.0000	0.0000
100.0886	5788.8680	0.0000	0.0000	0.0000	0.0000
100.1107	5788.9090	0.0000	0.0000	0.0000	0.0000
100.1384	5788.9600	0.0000	0.0000	0.0000	0.0000
100.1729	5789.0230	0.0000	0.0000	0.0000	0.0000
100.2161	5789.1030	0.0000	0.0000	0.0000	0.0000
100.2701	5789.2020	0.0000	0.0000	0.0000	0.0000
100.3376	5789.3260	0.0000	0.0000	0.0000	0.0000
100.4198	5789.4770	0.0000	0.0000	0.0000	0.0000
100.5153	5789.6510	0.0000	0.0000	0.0000	0.0000
100.6234	5789.8480	0.0000	0.0000	0.0000	0.0000
100.7439	5790.0670	0.0000	0.0000	0.0000	0.0000
100.8777	5790.3100	0.0000	0.0000	0.0000	0.0000
101.0259	5790.5770	0.0000	0.0000	0.0000	0.0000
101.1901	5790.8730	0.0000	0.0000	0.0000	0.0000
101.3725	5791.2020	0.0000	0.0000	0.0000	0.0000
101.5755	5791.5650	0.0000	0.0000	0.0000	0.0000
101.8014	5791.9690	0.0000	0.0000	0.0000	0.0000
102.0510	5792.4120	0.0000	0.0000	0.0000	0.0000
102.3266	5792.8980	0.0000	0.0000	0.0000	0.0000
102.6311	5793.4330	0.0000	0.0000	0.0000	0.0000
102.9690	5794.0210	0.0000	0.0000	0.0000	0.0000
103.3457	5794.6730	0.0000	0.0000	0.0000	0.0000
103.7682	5795.3970	0.0000	0.0000	0.0000	0.0000
104.2457	5796.2080	0.0000	0.0000	0.0000	0.0000
104.7899	5797.1240	0.0000	0.0000	0.0000	0.0000
105.4169	5798.1660	0.0000	0.0000	0.0000	0.0000
106.1484	5799.3670	0.0000	0.0000	0.0000	0.0000
107.0155	5800.7690	0.0000	0.0000	0.0000	0.0000
108.0629	5802.4310	0.0000	0.0000	0.0000	0.0000
109.3591	5804.4480	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
110.9793	5806.9170	0.0000	0.0000	0.0000	0.0000
113.0045	5809.9580	0.0000	0.0000	0.0000	0.0000
115.5361	5813.6620	0.0000	0.0000	0.0000	0.0000
118.7006	5818.1310	0.0000	0.0000	0.0000	0.0000
122.6562	5823.4500	0.0000	0.0000	0.0000	0.0000
127.6007	5829.7290	0.0000	0.0000	0.0000	0.0000
133.7813	5836.9900	0.0000	0.0000	0.0000	0.0000
141.5071	5845.2890	0.0000	0.0000	0.0000	0.0000
151.1644	5854.6630	0.0000	0.0000	0.0000	0.0000
157.2001	5860.1990	0.0000	0.0000	0.0000	0.0000
164.7448	5866.5680	0.0000	0.0000	0.0000	0.0000
174.1757	5873.7550	0.0000	0.0000	0.0000	0.0000
185.9644	5881.8000	0.0000	0.0000	0.0000	0.0000
200.0005	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0005	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0005	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0006	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0006	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0007	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0008	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0009	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0010	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0012	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0014	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0016	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0020	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0024	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0029	5890.2950	0.0000	0.0000	0.0000	0.0000
200.0035	5890.2960	0.0000	0.0000	0.0000	0.0000
200.0043	5890.2960	0.0000	0.0000	0.0000	0.0000
200.0052	5890.2970	0.0000	0.0000	0.0000	0.0000
200.0064	5890.2970	0.0000	0.0000	0.0000	0.0000
200.0080	5890.2980	0.0000	0.0000	0.0000	0.0000
200.0099	5890.3000	0.0000	0.0000	0.0000	0.0000
200.0122	5890.3010	0.0000	0.0000	0.0000	0.0000
200.0152	5890.3030	0.0000	0.0000	0.0000	0.0000
200.0189	5890.3050	0.0000	0.0000	0.0000	0.0000
200.0236	5890.3080	0.0000	0.0000	0.0000	0.0000
200.0294	5890.3110	0.0000	0.0000	0.0000	0.0000
200.0366	5890.3150	0.0000	0.0000	0.0000	0.0000
200.0456	5890.3210	0.0000	0.0000	0.0000	0.0000
200.0570	5890.3270	0.0000	0.0000	0.0000	0.0000
200.0711	5890.3360	0.0000	0.0000	0.0000	0.0000
200.0888	5890.3470	0.0000	0.0000	0.0000	0.0000
200.1110	5890.3600	0.0000	0.0000	0.0000	0.0000
200.1386	5890.3760	0.0000	0.0000	0.0000	0.0000
200.1731	5890.3970	0.0000	0.0000	0.0000	0.0000
200.2163	5890.4240	0.0000	0.0000	0.0000	0.0000
200.2703	5890.4570	0.0000	0.0000	0.0000	0.0000
200.3378	5890.4970	0.0000	0.0000	0.0000	0.0000
200.4222	5890.5480	0.0000	0.0000	0.0000	0.0000
200.5276	5890.6120	0.0000	0.0000	0.0000	0.0000
200.6595	5890.6910	0.0000	0.0000	0.0000	0.0000
200.8243	5890.7900	0.0000	0.0000	0.0000	0.0000

time	brnintc	bm39rc	bm39lc	bm38rc	bm38lc
201.0303	5890.9140	0.0000	0.0000	0.0000	0.0000
201.2877	5891.0680	0.0000	0.0000	0.0000	0.0000
201.6096	5891.2600	0.0000	0.0000	0.0000	0.0000
202.0119	5891.4990	0.0000	0.0000	0.0000	0.0000
202.5147	5891.7970	0.0000	0.0000	0.0000	0.0000
203.1433	5892.1670	0.0000	0.0000	0.0000	0.0000
203.9291	5892.6260	0.0000	0.0000	0.0000	0.0000
204.9113	5893.1970	0.0000	0.0000	0.0000	0.0000
206.0556	5893.8550	0.0000	0.0000	0.0000	0.0000
207.3313	5894.5810	0.0000	0.0000	0.0000	0.0000
208.7195	5895.3610	0.0000	0.0000	0.0000	0.0000
210.2122	5896.1890	0.0000	0.0000	0.0000	0.0000
211.8092	5897.0640	0.0000	0.0000	0.0000	0.0000
213.5156	5897.9860	0.0000	0.0000	0.0000	0.0000
215.3398	5898.9570	0.0000	0.0000	0.0000	0.0000
217.2932	5899.9790	0.0000	0.0000	0.0000	0.0000
219.3899	5901.0570	0.0000	0.0000	0.0000	0.0000
221.6468	5902.1970	0.0000	0.0000	0.0000	0.0000
224.0840	5903.4030	0.0000	0.0000	0.0000	0.0000
226.7257	5904.6830	0.0000	0.0000	0.0000	0.0000
229.6007	5906.0430	0.0000	0.0000	0.0000	0.0000
232.7440	5907.4930	0.0000	0.0000	0.0000	0.0000
236.1982	5909.0420	0.0000	0.0000	0.0000	0.0000
240.0160	5910.7030	0.0000	0.0000	0.0000	0.0000
244.2634	5912.4890	0.0000	0.0000	0.0000	0.0000
249.0238	5914.4170	0.0000	0.0000	0.0000	0.0000
254.4052	5916.5050	0.0000	0.0000	0.0000	0.0000
260.5495	5918.7770	0.0000	0.0000	0.0000	0.0000
267.6500	5921.2630	0.0000	0.0000	0.0000	0.0000
275.9334	5923.9810	0.0000	0.0000	0.0000	0.0000
284.4510	5926.6010	0.0000	0.0000	0.0000	0.0000
292.6846	5928.9770	0.0000	0.0000	0.0000	0.0000
300.5310	5931.1080	0.0000	0.0000	0.0000	0.0000
308.0685	5933.0400	0.0000	0.0000	0.0000	0.0000
315.4208	5934.8230	0.0000	0.0000	0.0000	0.0000
322.7079	5936.4940	0.0000	0.0000	0.0000	0.0000
330.0356	5938.0830	0.0405	0.0496	0.0000	0.0000
337.4974	5939.6150	0.1219	0.1472	0.0000	0.0000
345.1823	5941.1350	0.2032	0.2271	0.0000	0.0000
353.2043	5942.6610	0.2985	0.3253	0.0000	0.0000
361.6744	5944.2070	0.4175	0.4524	0.0000	0.0000
370.7061	5945.7870	0.5674	0.6161	0.0000	0.0000
380.4201	5947.4100	0.7574	0.8278	0.0000	0.0000
390.9475	5949.0860	0.9996	1.1027	0.0000	0.0000
400.0073	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0073	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0074	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0074	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0074	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0075	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0075	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0076	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0078	5950.4680	1.2379	1.3775	0.0000	0.0000
400.0079	5950.4680	1.2379	1.3775	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
400.0080	5950.4680	1.2380	1.3775	0.0000	0.0000
400.0082	5950.4680	1.2380	1.3775	0.0000	0.0000
400.0085	5950.4680	1.2380	1.3775	0.0000	0.0000
400.0088	5950.4680	1.2380	1.3775	0.0000	0.0000
400.0092	5950.4680	1.2380	1.3776	0.0000	0.0000
400.0097	5950.4680	1.2380	1.3776	0.0000	0.0000
400.0103	5950.4680	1.2380	1.3776	0.0000	0.0000
400.0111	5950.4680	1.2380	1.3776	0.0000	0.0000
400.0121	5950.4680	1.2381	1.3776	0.0000	0.0000
400.0133	5950.4680	1.2381	1.3777	0.0000	0.0000
400.0148	5950.4680	1.2381	1.3777	0.0000	0.0000
400.0167	5950.4680	1.2382	1.3778	0.0000	0.0000
400.0191	5950.4690	1.2382	1.3779	0.0000	0.0000
400.0220	5950.4690	1.2383	1.3779	0.0000	0.0000
400.0257	5950.4700	1.2384	1.3781	0.0000	0.0000
400.0303	5950.4710	1.2385	1.3782	0.0000	0.0000
400.0361	5950.4720	1.2387	1.3784	0.0000	0.0000
400.0434	5950.4730	1.2389	1.3786	0.0000	0.0000
400.0524	5950.4740	1.2391	1.3789	0.0000	0.0000
400.0637	5950.4760	1.2394	1.3792	0.0000	0.0000
400.0778	5950.4780	1.2398	1.3796	0.0000	0.0000
400.0954	5950.4800	1.2403	1.3802	0.0000	0.0000
400.1175	5950.4840	1.2408	1.3808	0.0000	0.0000
400.1451	5950.4880	1.2416	1.3817	0.0000	0.0000
400.1795	5950.4930	1.2425	1.3827	0.0000	0.0000
400.2226	5950.5000	1.2436	1.3840	0.0000	0.0000
400.2765	5950.5080	1.2450	1.3857	0.0000	0.0000
400.3438	5950.5180	1.2468	1.3877	0.0000	0.0000
400.4280	5950.5310	1.2490	1.3903	0.0000	0.0000
400.5332	5950.5470	1.2518	1.3935	0.0000	0.0000
400.6647	5950.5670	1.2553	1.3976	0.0000	0.0000
400.8291	5950.5920	1.2597	1.4026	0.0000	0.0000
401.0345	5950.6230	1.2652	1.4089	0.0000	0.0000
401.2914	5950.6620	1.2720	1.4169	0.0000	0.0000
401.6124	5950.7100	1.2807	1.4268	0.0000	0.0000
402.0136	5950.7710	1.2915	1.4392	0.0000	0.0000
402.5153	5950.8460	1.3051	1.4547	0.0000	0.0000
403.1423	5950.9400	1.3222	1.4744	0.0000	0.0000
403.9261	5951.0580	1.3438	1.4992	0.0000	0.0000
404.9058	5951.2040	1.3711	1.5308	0.0000	0.0000
406.1305	5951.3850	1.4057	1.5708	0.0000	0.0000
407.6613	5951.6100	1.4498	1.6218	0.0000	0.0000
409.5749	5951.8900	1.5059	1.6866	0.0000	0.0000
411.9668	5952.2350	1.5770	1.7679	0.0000	0.0000
414.9567	5952.6630	1.6663	1.8689	0.0000	0.0000
418.6941	5953.1890	1.7790	1.9962	0.0000	0.0000
423.3658	5953.8380	1.9206	2.1548	0.0000	0.0000
429.2054	5954.6320	2.1008	2.3575	0.0000	0.0000
436.5050	5955.6020	2.3308	2.6152	0.0000	0.0000
445.6295	5956.7780	2.6289	2.9502	0.0000	0.0000
456.8080	5958.1670	3.0112	3.3809	0.0000	0.0000
469.7710	5959.7150	3.4778	3.9086	0.0000	0.0000
484.3387	5961.3810	4.0299	4.5353	0.0000	0.0000
500.3398	5963.1290	4.6698	5.2635	0.0000	0.0000

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
516.4556	5964.8130	5.3512	6.0415	0.0000	0.0000
532.1435	5966.3860	6.0504	6.8424	0.0000	0.0000
547.3224	5967.8520	6.7487	7.6393	0.0000	0.0000
562.0833	5969.2410	7.4161	8.3872	0.0000	0.0000
576.5588	5970.5750	8.0548	9.0948	0.0000	0.0000
590.8784	5971.8660	8.6813	9.7874	0.0000	0.0000
605.1581	5973.1280	9.3043	10.4742	0.0000	0.0000
619.5016	5974.3710	9.9309	11.1635	0.0000	0.0000
634.0042	5975.6020	10.5676	11.8631	0.0000	0.0000
648.7565	5976.8310	11.2192	12.5792	0.0000	0.0000
663.8491	5978.0620	11.8909	13.3178	0.0000	0.0000
679.3762	5979.3040	12.5883	14.0848	0.0000	0.0000
695.4394	5980.5640	13.3168	14.8856	0.0000	0.0000
712.1512	5981.8480	14.0900	15.7287	0.0000	9.0000e-5
729.6407	5983.1640	14.9352	16.6213	0.0000	4.2510e-4
748.0586	5984.5190	15.8697	17.5738	0.0000	1.0220e-3
767.5851	5985.9250	16.9128	18.5985	0.0000	1.9062e-3
788.4396	5987.3920	18.0897	19.7110	0.0000	3.1139e-3
810.8959	5988.9330	19.4342	20.9319	0.0000	4.6951e-3
835.3019	5990.5650	20.9869	22.2999	8.0603e-5	6.7171e-3
862.1106	5992.3080	22.8151	23.9174	2.7687e-4	9.2742e-3
891.9291	5994.1890	25.0037	25.8672	6.3027e-4	0.0125
925.5939	5996.2420	27.7019	28.2820	1.1997e-3	0.0166
964.3009	5998.5130	31.1910	31.3792	2.0865e-3	0.0218
1009.8390	6001.8480	36.2049	35.7666	3.5321e-3	0.0302
1059.3990	6005.5100	42.4174	41.0819	5.5415e-3	0.0562
1086.7780	6007.7120	45.5543	43.6963	6.6942e-3	0.0708
1103.8900	6009.0990	47.4171	45.2519	7.4277e-3	0.0801
1125.2800	6010.8350	49.6579	47.1486	8.3653e-3	0.0919
1152.0170	6012.9990	52.3988	49.4866	9.5706e-3	0.1071
1185.4390	6015.6850	55.8075	52.4073	0.0111	0.1268
1227.2160	6019.0090	60.1022	56.0924	0.0132	0.1524
1279.4380	6023.1120	65.5745	60.7876	0.0159	0.1859
1334.1960	6027.3520	71.4481	65.8288	0.0188	0.2227
1388.9540	6031.5330	77.5035	71.0094	0.0220	0.2609
1443.7120	6035.6530	83.7022	76.3508	0.0253	0.3005
1498.4700	6039.7120	90.0582	81.8643	0.0288	0.3414
1553.2290	6043.7160	96.5407	87.5567	0.0325	0.3833
1607.9870	6047.6510	103.2040	93.4990	0.0364	0.4263
1662.7450	6051.5210	110.0330	99.6926	0.0405	0.4704
1717.5030	6055.3230	117.0102	106.1545	0.0448	0.5154
1772.2610	6059.0660	124.1231	112.9065	0.0494	0.5613
1827.0190	6062.7610	131.3551	119.9738	0.0542	0.6079
1881.7780	6066.4070	138.6809	127.3848	0.0592	0.6553
1936.5360	6070.0060	146.0695	135.1719	0.0645	0.7034
1991.2940	6073.5550	153.4907	143.3652	0.0701	0.7520
2046.0520	6077.0420	160.9098	152.0569	0.0759	0.8012
2100.8100	6080.4700	168.2946	161.2662	0.0821	0.8509
2155.5680	6083.8420	175.6089	171.0419	0.0886	0.9011
2210.3270	6087.2960	182.4121	179.7251	0.0951	0.9492
2265.0850	6090.7270	188.8006	188.1255	0.1016	0.9955
2319.8430	6094.1180	194.8391	196.3638	0.1081	1.0400
2326.6880	6094.5420	195.5887	197.3911	0.1090	1.0456
2330.9660	6094.8060	196.0551	198.0322	0.1095	1.0490

time	brnintc	bm39rc	bm39lc	bm38rc	bm38lc
2336.3130	6095.1360	196.6350	198.8319	0.1101	1.0533
2342.9980	6095.5480	197.3551	199.8292	0.1109	1.0586
2351.3530	6096.0620	198.2477	201.0715	0.1119	1.0653
2361.7980	6096.7020	199.3521	202.6172	0.1131	1.0735
2374.8530	6097.4990	200.7153	204.5387	0.1147	1.0838
2391.1720	6098.4910	202.3933	206.9237	0.1166	1.0964
2411.5710	6099.7210	204.4520	209.8779	0.1191	1.1120
2437.0700	6101.2460	206.9681	213.5273	0.1221	1.1311
2468.9430	6103.1270	210.0300	218.0185	0.1259	1.1545
2508.7850	6105.4400	213.7378	223.5184	0.1307	1.1830
2558.5870	6108.2680	218.2044	230.2103	0.1367	1.2175
2613.3450	6111.3010	222.9334	237.3440	0.1432	1.2542
2668.1040	6114.2600	227.4989	244.2538	0.1498	1.2897
2722.8620	6117.1480	231.9165	250.9441	0.1564	1.3241
2777.6200	6119.9670	236.2000	257.4223	0.1630	1.3573
2832.3780	6122.7220	240.3609	263.6984	0.1695	1.3896
2887.1360	6125.4150	244.4094	269.7841	0.1761	1.4208
2941.8950	6128.0480	248.3540	275.6921	0.1827	1.4511
2996.6530	6130.6260	252.2022	281.4356	0.1893	1.4805
3051.4110	6133.1490	255.9605	287.0280	0.1959	1.5090
3106.1690	6135.6200	259.6343	292.4820	0.2024	1.5367
3160.9270	6138.0400	263.2286	297.8099	0.2090	1.5636
3215.6860	6140.4100	266.7471	303.0233	0.2156	1.5898
3270.4440	6142.7300	270.1930	308.1327	0.2221	1.6153
3325.2020	6145.0020	273.5693	313.1480	0.2287	1.6400
3379.9600	6147.2270	276.8798	318.0780	0.2353	1.6641
3434.7180	6149.4080	280.1278	322.9307	0.2418	1.6876
3489.4770	6151.5460	283.3166	327.7132	0.2483	1.7104
3544.2350	6153.6440	286.4485	332.4320	0.2549	1.7327
3598.9930	6155.7030	289.5263	337.0927	0.2614	1.7544
3653.7510	6157.7250	292.5520	341.7004	0.2679	1.7756
3708.5090	6159.7120	295.5276	346.2596	0.2744	1.7962
3763.2680	6161.6650	298.4550	350.7742	0.2809	1.8163
3818.0260	6163.5870	301.3360	355.2476	0.2874	1.8360
3872.7840	6165.4790	304.1719	359.6831	0.2939	1.8552
3927.5420	6167.3410	306.9644	364.0834	0.3003	1.8739
3982.3000	6169.1770	309.7147	368.4508	0.3068	1.8922
4037.0590	6170.9860	312.4240	372.7876	0.3132	1.9100
4091.8170	6172.7710	315.0937	377.0956	0.3196	1.9275
4146.5750	6174.5330	317.7247	381.3766	0.3261	1.9446
4201.3330	6176.2720	320.3182	385.6329	0.3324	1.9613
4256.0910	6177.9910	322.8750	389.9103	0.3388	1.9776
4310.8490	6179.6890	325.3962	394.3333	0.3452	1.9936
4338.2290	6180.5340	326.6479	396.5404	0.3484	2.0015
4355.3400	6181.0600	327.4269	397.9349	0.3503	2.0064
4376.7300	6181.7150	328.3953	399.8906	0.3528	2.0125
4403.4680	6182.5290	329.5975	402.3262	0.3559	2.0200
4436.8890	6183.5410	331.0877	405.3023	0.3598	2.0293
4478.6670	6184.8390	332.9382	408.9996	0.3646	2.0407
4530.8880	6186.4400	335.2321	413.6374	0.3706	2.0548
4585.6460	6188.1010	337.6154	418.5123	0.3769	2.0694
4640.4040	6189.7430	339.9758	423.3950	0.3831	2.0837
4695.1630	6191.3690	342.3128	428.2822	0.3893	2.0978
4749.9200	6192.9790	344.6262	433.1718	0.3956	2.1117

time	brnintc	bm39rc	bm39lc	bm38rc	bm38lc
4804.6790	6194.5750	346.9156	438.0624	0.4018	2.1254
4859.4370	6196.1580	349.1809	442.9527	0.4080	2.1388
4914.1950	6197.7270	351.4221	447.8418	0.4142	2.1520
4968.9530	6199.2830	353.6393	452.7289	0.4204	2.1651
5023.7110	6200.8270	355.8324	457.6135	0.4267	2.1779
5078.4700	6202.3600	358.0016	462.4949	0.4329	2.1905
5133.2290	6203.8810	360.1471	467.3726	0.4392	2.2029
5187.9860	6205.3920	362.2689	472.2460	0.4454	2.2151
5242.7450	6206.8910	364.3673	477.1146	0.4517	2.2271
5297.5030	6208.3800	366.4425	481.9779	0.4579	2.2390
5352.2610	6209.8590	368.4948	486.8352	0.4642	2.2506
5407.0190	6211.3280	370.5243	491.6857	0.4705	2.2621
5461.7770	6212.7860	372.5312	496.5287	0.4767	2.2734
5516.5360	6214.2350	374.5159	501.3634	0.4830	2.2845
5571.2940	6215.6740	376.4785	506.1886	0.4892	2.2955
5626.0520	6217.1040	378.4193	511.0033	0.4955	2.3063
5680.8100	6218.5240	380.3386	515.8064	0.5018	2.3169
5735.5680	6219.9360	382.2365	520.5964	0.5080	2.3274
5790.3270	6221.3380	384.1133	525.3721	0.5143	2.3377
5845.0840	6222.7310	385.9693	530.1320	0.5205	2.3479
5899.8430	6224.1150	387.8046	534.8744	0.5267	2.3580
5954.6010	6225.4900	389.6196	539.5978	0.5330	2.3679
6009.3590	6226.8560	391.4143	544.3004	0.5392	2.3777
6064.1170	6228.2140	393.1891	548.9803	0.5454	2.3875
6118.8750	6229.5630	394.9442	553.6359	0.5516	2.3971
6173.6340	6230.9050	396.6797	558.2651	0.5578	2.4067
6228.3920	6232.2380	398.3958	562.8663	0.5639	2.4161
6283.1490	6233.5620	400.0929	567.4373	0.5701	2.4256
6337.9080	6234.8790	401.7711	571.9763	0.5762	2.4349
6392.6670	6236.1880	403.4306	576.4815	0.5823	2.4442
6447.4250	6237.4890	405.0716	580.9510	0.5884	2.4535
6502.1830	6238.7830	406.6943	585.3831	0.5945	2.4627
6556.9400	6240.0710	408.2992	589.7806	0.6005	2.4719
6611.6990	6241.3540	409.8868	594.1464	0.6065	2.4810
6666.4580	6242.6300	411.4575	598.4821	0.6125	2.4901
6721.2150	6243.9000	413.0117	602.7891	0.6185	2.4992
6775.9740	6245.1650	414.5498	607.0687	0.6245	2.5082
6830.7310	6246.4230	416.0721	611.3214	0.6304	2.5172
6885.4910	6247.6770	417.5791	615.5480	0.6363	2.5261
6940.2490	6248.9240	419.0709	619.7487	0.6422	2.5350
6995.0070	6250.1660	420.5481	623.9238	0.6480	2.5438
7049.7650	6251.4020	422.0108	628.0734	0.6539	2.5526
7104.5230	6252.6330	423.4594	632.1974	0.6597	2.5613
7159.2810	6253.8580	424.8941	636.2958	0.6655	2.5700
7214.0400	6255.0780	426.3152	640.3685	0.6713	2.5786
7268.7980	6256.2920	427.7231	644.4574	0.6770	2.5871
7323.5560	6257.5020	429.1179	648.5228	0.6827	2.5956
7378.3130	6258.7060	430.4998	652.5600	0.6884	2.6040
7433.0720	6259.9040	431.8693	656.5656	0.6941	2.6124
7487.8310	6261.0980	433.2264	660.5482	0.6997	2.6207
7542.5890	6262.2860	434.5714	664.5115	0.7054	2.6289
7597.3470	6263.4690	435.9045	668.5028	0.7110	2.6370
7652.1040	6264.6470	437.2260	672.5040	0.7166	2.6451
7706.8630	6265.8200	438.5359	676.5096	0.7221	2.6530

time	brnintc	bm39rc	bm39lc	bm38rc	bm38lc
7761.6220	6266.9890	439.8346	680.5168	0.7277	2.6609
7816.3790	6268.1520	441.1222	684.5234	0.7332	2.6688
7871.1380	6269.3100	442.3989	688.5278	0.7387	2.6765
7925.8960	6270.4630	443.6649	692.5288	0.7441	2.6842
7980.6540	6271.6120	444.9203	696.5253	0.7496	2.6918
8035.4120	6272.7550	446.1654	700.5163	0.7550	2.6993
8090.1700	6273.8950	447.4002	704.5012	0.7604	2.7067
8144.9290	6275.0290	448.6251	708.4795	0.7657	2.7141
8199.6870	6276.1580	449.8400	712.4506	0.7711	2.7214
8254.4440	6277.2830	451.0453	716.4142	0.7764	2.7286
8309.2030	6278.4040	452.2409	720.3699	0.7817	2.7357
8363.9620	6279.5200	453.4272	724.3175	0.7870	2.7428
8418.7200	6280.6300	454.6042	728.2568	0.7923	2.7497
8473.4780	6281.7370	455.7720	732.1874	0.7975	2.7566
8528.2350	6282.8400	456.9308	736.1094	0.8027	2.7635
8582.9940	6283.9380	458.0808	740.0226	0.8079	2.7702
8637.7530	6285.0310	459.2220	743.9268	0.8131	2.7769
8692.5110	6286.1200	460.3546	747.8219	0.8182	2.7835
8747.2690	6287.2050	461.4788	751.7079	0.8233	2.7900
8802.0260	6288.2850	462.5946	755.5847	0.8284	2.7965
8856.7840	6289.3610	463.7022	759.4523	0.8335	2.8029
8911.5440	6290.4330	464.8017	763.3105	0.8386	2.8092
8925.2320	6290.7000	465.0760	764.2745	0.8398	2.8107
8933.7890	6290.8680	465.2473	764.8768	0.8406	2.8117
8935.1250	6290.8940	465.2741	764.9708	0.8408	2.8119
8936.7970	6290.9260	465.3075	765.0885	0.8409	2.8121
8938.8850	6290.9670	465.3493	765.2355	0.8411	2.8123
8941.4960	6291.0180	465.4015	765.4193	0.8413	2.8126
8944.7600	6291.0820	465.4668	765.6489	0.8416	2.8130
8948.8400	6291.1620	465.5483	765.9359	0.8420	2.8134
8953.9390	6291.2610	465.6501	766.2945	0.8425	2.8140
8960.3150	6291.3850	465.7773	766.7427	0.8431	2.8147
8968.2820	6291.5410	465.9360	767.3027	0.8438	2.8156
8978.2440	6291.7350	466.1342	768.0025	0.8447	2.8168
8990.6940	6291.9770	466.3816	768.8766	0.8459	2.8182
9006.2570	6292.2800	466.6902	769.9686	0.8473	2.8199
9025.7110	6292.6580	467.0749	771.3325	0.8491	2.8221
9050.0290	6293.1290	467.5542	773.0354	0.8513	2.8248
9080.4250	6293.7170	468.1510	775.1611	0.8541	2.8282
9118.4220	6294.4500	468.8932	777.8138	0.8575	2.8324
9165.9170	6295.3620	469.8154	781.1225	0.8618	2.8376
9220.6750	6296.4110	470.8710	784.9277	0.8668	2.8435
9275.4340	6297.4550	471.9193	788.7234	0.8717	2.8493
9330.1910	6298.4960	472.9602	792.5097	0.8766	2.8551
9384.9500	6299.5320	473.9940	796.2866	0.8814	2.8608
9439.7080	6300.5640	475.0206	800.0539	0.8863	2.8665
9494.4660	6301.5930	476.0402	803.8118	0.8911	2.8720
9549.2250	6302.6180	477.0529	807.5602	0.8959	2.8776
9603.9820	6303.6390	478.0588	811.2991	0.9007	2.8830
9658.7400	6304.6560	479.0580	815.0286	0.9055	2.8884
9713.4990	6305.6690	480.0505	818.7486	0.9102	2.8937
9768.2570	6306.6780	481.0364	822.4591	0.9149	2.8990
9823.0160	6307.6840	482.0158	826.1602	0.9196	2.9042
9877.7730	6308.6850	482.9888	829.8519	0.9243	2.9094

time	brnintc	bm39rc	bm391c	bm38rc	bm381c
9932.5310	6309.6830	483.9555	833.5341	0.9290	2.9145
9987.2900	6310.6770	484.9160	837.2070	0.9336	2.9195
1.0000e+4	6310.9080	485.1390	838.0607	0.9347	2.9207

Values of variables that are shown graphically in Figures 8-10 and 8-11

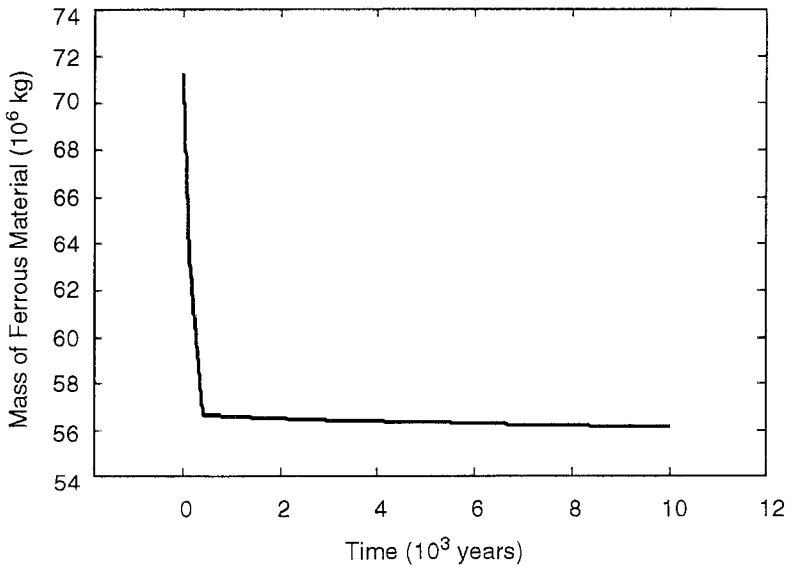

Figure 8-10. Mass of Ferrous Metal Remaining in the Repository

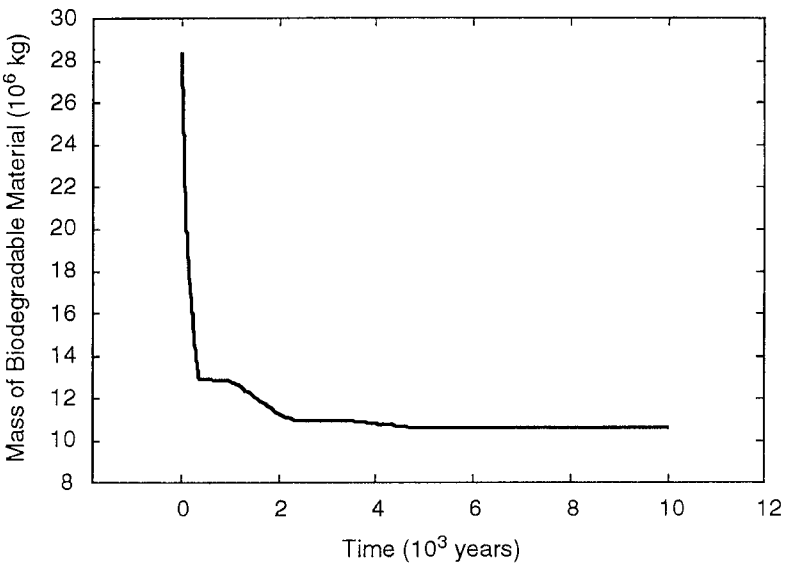

Figure 8-11. Mass of Biodegradable Material Remaining in the Repository

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time	fe_kg	cell_kg
0.0000	7.1293e+7	2.8423e+7
1.7112e-6	7.1293e+7	2.8423e+7
3.6344e-6	7.1293e+7	2.8423e+7
4.8852e-6	7.1293e+7	2.8423e+7
5.8280e-6	7.1293e+7	2.8423e+7
6.6229e-6	7.1293e+7	2.8423e+7
7.3364e-6	7.1293e+7	2.8423e+7
8.0006e-6	7.1293e+7	2.8423e+7
8.6333e-6	7.1293e+7	2.8423e+7
9.2452e-6	7.1293e+7	2.8423e+7
9.8430e-6	7.1293e+7	2.8423e+7
1.0431e-5	7.1293e+7	2.8423e+7
1.1014e-5	7.1293e+7	2.8423e+7
1.1594e-5	7.1293e+7	2.8423e+7
1.2173e-5	7.1293e+7	2.8423e+7
1.2753e-5	7.1293e+7	2.8423e+7
1.3336e-5	7.1293e+7	2.8423e+7
1.3923e-5	7.1293e+7	2.8423e+7
1.4515e-5	7.1293e+7	2.8423e+7
1.5115e-5	7.1293e+7	2.8423e+7
1.5723e-5	7.1293e+7	2.8423e+7
1.6340e-5	7.1293e+7	2.8423e+7
1.6968e-5	7.1293e+7	2.8423e+7
1.7609e-5	7.1293e+7	2.8423e+7
1.8263e-5	7.1293e+7	2.8423e+7
1.8933e-5	7.1293e+7	2.8423e+7
1.9619e-5	7.1293e+7	2.8423e+7
2.0324e-5	7.1293e+7	2.8423e+7
2.1049e-5	7.1293e+7	2.8423e+7
2.1796e-5	7.1293e+7	2.8423e+7
2.2568e-5	7.1293e+7	2.8423e+7
2.3367e-5	7.1293e+7	2.8423e+7
2.4195e-5	7.1293e+7	2.8423e+7
2.5055e-5	7.1293e+7	2.8423e+7
2.5951e-5	7.1293e+7	2.8423e+7
2.6886e-5	7.1293e+7	2.8423e+7
2.7864e-5	7.1293e+7	2.8423e+7
2.8891e-5	7.1293e+7	2.8423e+7
2.9971e-5	7.1293e+7	2.8423e+7
3.1112e-5	7.1293e+7	2.8423e+7
3.2320e-5	7.1293e+7	2.8423e+7
3.3603e-5	7.1293e+7	2.8423e+7
3.4973e-5	7.1293e+7	2.8423e+7
3.6442e-5	7.1293e+7	2.8423e+7
3.8024e-5	7.1293e+7	2.8423e+7
3.9737e-5	7.1293e+7	2.8423e+7
4.1604e-5	7.1293e+7	2.8423e+7
4.3653e-5	7.1293e+7	2.8423e+7
4.5920e-5	7.1293e+7	2.8423e+7
4.8452e-5	7.1293e+7	2.8423e+7
5.1311e-5	7.1293e+7	2.8423e+7
5.4582e-5	7.1293e+7	2.8423e+7
5.8383e-5	7.1293e+7	2.8423e+7
6.2885e-5	7.1293e+7	2.8423e+7
6.8347e-5	7.1293e+7	2.8423e+7

time	fe_kg	cell_kg
7.5172e-5	7.1293e+7	2.8423e+7
8.3703e-5	7.1293e+7	2.8423e+7
9.4367e-5	7.1293e+7	2.8423e+7
1.0770e-4	7.1293e+7	2.8423e+7
1.2436e-4	7.1293e+7	2.8423e+7
1.4519e-4	7.1293e+7	2.8423e+7
1.7122e-4	7.1293e+7	2.8423e+7
2.0376e-4	7.1293e+7	2.8423e+7
2.4444e-4	7.1293e+7	2.8423e+7
2.9529e-4	7.1293e+7	2.8423e+7
3.4826e-4	7.1293e+7	2.8423e+7
3.9743e-4	7.1293e+7	2.8423e+7
4.4238e-4	7.1293e+7	2.8423e+7
4.8423e-4	7.1293e+7	2.8423e+7
5.2405e-4	7.1293e+7	2.8423e+7
5.6266e-4	7.1293e+7	2.8423e+7
6.0063e-4	7.1293e+7	2.8423e+7
6.3835e-4	7.1293e+7	2.8423e+7
6.7612e-4	7.1293e+7	2.8423e+7
7.1420e-4	7.1293e+7	2.8423e+7
7.5275e-4	7.1293e+7	2.8423e+7
7.9194e-4	7.1293e+7	2.8423e+7
8.3192e-4	7.1293e+7	2.8423e+7
8.7281e-4	7.1293e+7	2.8423e+7
9.1473e-4	7.1293e+7	2.8423e+7
9.5780e-4	7.1293e+7	2.8423e+7
1.0021e-3	7.1293e+7	2.8423e+7
1.0479e-3	7.1293e+7	2.8423e+7
1.0951e-3	7.1293e+7	2.8423e+7
1.1440e-3	7.1293e+7	2.8423e+7
1.1946e-3	7.1293e+7	2.8423e+7
1.2471e-3	7.1293e+7	2.8423e+7
1.3017e-3	7.1293e+7	2.8423e+7
1.3585e-3	7.1293e+7	2.8423e+7
1.4176e-3	7.1293e+7	2.8423e+7
1.4793e-3	7.1293e+7	2.8423e+7
1.5438e-3	7.1293e+7	2.8423e+7
1.6112e-3	7.1293e+7	2.8423e+7
1.6818e-3	7.1293e+7	2.8423e+7
1.7560e-3	7.1293e+7	2.8423e+7
1.8339e-3	7.1293e+7	2.8423e+7
1.9159e-3	7.1293e+7	2.8423e+7
2.0024e-3	7.1293e+7	2.8423e+7
2.0938e-3	7.1293e+7	2.8423e+7
2.1906e-3	7.1293e+7	2.8423e+7
2.2933e-3	7.1293e+7	2.8423e+7
2.4026e-3	7.1293e+7	2.8423e+7
2.5191e-3	7.1293e+7	2.8423e+7
2.6437e-3	7.1293e+7	2.8423e+7
2.7775e-3	7.1293e+7	2.8423e+7
2.9215e-3	7.1293e+7	2.8423e+7
3.0774e-3	7.1293e+7	2.8423e+7
3.2468e-3	7.1293e+7	2.8423e+7
3.4319e-3	7.1293e+7	2.8423e+7

time	fe_kg	cell_kg
3.6358e-3	7.1293e+7	2.8423e+7
3.8622e-3	7.1293e+7	2.8423e+7
4.1165e-3	7.1293e+7	2.8423e+7
4.4066e-3	7.1293e+7	2.8423e+7
4.7443e-3	7.1293e+7	2.8423e+7
5.1098e-3	7.1293e+7	2.8423e+7
5.4630e-3	7.1293e+7	2.8423e+7
5.7938e-3	7.1293e+7	2.8423e+7
6.1057e-3	7.1293e+7	2.8423e+7
6.4046e-3	7.1293e+7	2.8423e+7
6.6957e-3	7.1293e+7	2.8423e+7
6.9832e-3	7.1293e+7	2.8423e+7
7.2702e-3	7.1293e+7	2.8423e+7
7.5591e-3	7.1293e+7	2.8423e+7
7.8520e-3	7.1293e+7	2.8423e+7
8.1505e-3	7.1293e+7	2.8423e+7
8.4562e-3	7.1293e+7	2.8423e+7
8.7705e-3	7.1293e+7	2.8423e+7
9.0945e-3	7.1292e+7	2.8423e+7
9.4297e-3	7.1292e+7	2.8423e+7
9.7772e-3	7.1292e+7	2.8423e+7
0.0101	7.1292e+7	2.8423e+7
0.0105	7.1292e+7	2.8423e+7
0.0109	7.1292e+7	2.8423e+7
0.0113	7.1292e+7	2.8423e+7
0.0117	7.1292e+7	2.8423e+7
0.0122	7.1292e+7	2.8423e+7
0.0127	7.1292e+7	2.8423e+7
0.0132	7.1292e+7	2.8422e+7
0.0137	7.1292e+7	2.8422e+7
0.0142	7.1292e+7	2.8422e+7
0.0148	7.1292e+7	2.8422e+7
0.0154	7.1292e+7	2.8422e+7
0.0160	7.1292e+7	2.8422e+7
0.0167	7.1292e+7	2.8422e+7
0.0174	7.1292e+7	2.8422e+7
0.0182	7.1292e+7	2.8422e+7
0.0190	7.1292e+7	2.8422e+7
0.0199	7.1292e+7	2.8422e+7
0.0208	7.1292e+7	2.8422e+7
0.0218	7.1292e+7	2.8422e+7
0.0228	7.1292e+7	2.8422e+7
0.0239	7.1292e+7	2.8422e+7
0.0252	7.1291e+7	2.8422e+7
0.0265	7.1291e+7	2.8421e+7
0.0280	7.1291e+7	2.8421e+7
0.0296	7.1291e+7	2.8421e+7
0.0313	7.1291e+7	2.8421e+7
0.0333	7.1291e+7	2.8421e+7
0.0356	7.1291e+7	2.8421e+7
0.0382	7.1291e+7	2.8421e+7
0.0412	7.1290e+7	2.8420e+7
0.0448	7.1290e+7	2.8420e+7
0.0493	7.1290e+7	2.8420e+7

time	fe_kg	cell_kg
0.0547	7.1290e+7	2.8419e+7
0.0607	7.1289e+7	2.8419e+7
0.0673	7.1289e+7	2.8418e+7
0.0744	7.1288e+7	2.8418e+7
0.0820	7.1288e+7	2.8417e+7
0.0901	7.1287e+7	2.8417e+7
0.0987	7.1287e+7	2.8416e+7
0.1080	7.1286e+7	2.8415e+7
0.1180	7.1285e+7	2.8414e+7
0.1287	7.1285e+7	2.8414e+7
0.1402	7.1284e+7	2.8413e+7
0.1526	7.1283e+7	2.8412e+7
0.1659	7.1282e+7	2.8411e+7
0.1803	7.1281e+7	2.8410e+7
0.1958	7.1280e+7	2.8408e+7
0.2125	7.1279e+7	2.8407e+7
0.2305	7.1278e+7	2.8406e+7
0.2500	7.1277e+7	2.8404e+7
0.2711	7.1275e+7	2.8403e+7
0.2939	7.1274e+7	2.8401e+7
0.3183	7.1272e+7	2.8399e+7
0.3449	7.1271e+7	2.8397e+7
0.3739	7.1269e+7	2.8395e+7
0.4055	7.1267e+7	2.8392e+7
0.4400	7.1264e+7	2.8390e+7
0.4778	7.1262e+7	2.8387e+7
0.5192	7.1259e+7	2.8383e+7
0.5643	7.1256e+7	2.8380e+7
0.6136	7.1253e+7	2.8376e+7
0.6645	7.1250e+7	2.8372e+7
0.7149	7.1246e+7	2.8368e+7
0.7643	7.1243e+7	2.8364e+7
0.8122	7.1240e+7	2.8361e+7
0.8588	7.1237e+7	2.8357e+7
0.9043	7.1234e+7	2.8354e+7
0.9489	7.1231e+7	2.8350e+7
0.9929	7.1228e+7	2.8347e+7
1.0363	7.1225e+7	2.8343e+7
1.0794	7.1222e+7	2.8340e+7
1.1225	7.1219e+7	2.8337e+7
1.1655	7.1217e+7	2.8333e+7
1.2088	7.1214e+7	2.8330e+7
1.2525	7.1211e+7	2.8326e+7
1.2968	7.1208e+7	2.8323e+7
1.3418	7.1205e+7	2.8319e+7
1.3877	7.1202e+7	2.8316e+7
1.4348	7.1199e+7	2.8312e+7
1.4832	7.1196e+7	2.8308e+7
1.5331	7.1192e+7	2.8305e+7
1.5850	7.1189e+7	2.8301e+7
1.6391	7.1185e+7	2.8296e+7
1.6958	7.1182e+7	2.8292e+7
1.7555	7.1178e+7	2.8287e+7
1.8188	7.1173e+7	2.8282e+7

time	fe_kg	cell_kg
1.8865	7.1169e+7	2.8277e+7
1.9593	7.1164e+7	2.8271e+7
2.0383	7.1159e+7	2.8265e+7
2.1251	7.1153e+7	2.8258e+7
2.2214	7.1147e+7	2.8251e+7
2.3300	7.1140e+7	2.8242e+7
2.4547	7.1131e+7	2.8233e+7
2.6012	7.1122e+7	2.8221e+7
2.7782	7.1110e+7	2.8207e+7
2.9996	7.1095e+7	2.8190e+7
3.2727	7.1077e+7	2.8169e+7
3.5924	7.1056e+7	2.8144e+7
3.9572	7.1031e+7	2.8115e+7
4.1639	7.1018e+7	2.8099e+7
4.4224	7.1000e+7	2.8079e+7
4.7454	7.0979e+7	2.8053e+7
5.1337	7.0953e+7	2.8023e+7
5.6099	7.0921e+7	2.7985e+7
6.1533	7.0885e+7	2.7943e+7
6.7551	7.0844e+7	2.7895e+7
7.4188	7.0800e+7	2.7843e+7
8.1589	7.0750e+7	2.7784e+7
8.1655	7.0750e+7	2.7784e+7
8.1737	7.0749e+7	2.7783e+7
8.1840	7.0749e+7	2.7783e+7
8.1968	7.0748e+7	2.7782e+7
8.2129	7.0747e+7	2.7780e+7
8.2329	7.0745e+7	2.7779e+7
8.2580	7.0744e+7	2.7777e+7
8.2894	7.0741e+7	2.7774e+7
8.3286	7.0739e+7	2.7771e+7
8.3776	7.0736e+7	2.7767e+7
8.4389	7.0731e+7	2.7762e+7
8.5154	7.0726e+7	2.7756e+7
8.6111	7.0720e+7	2.7749e+7
8.7308	7.0712e+7	2.7739e+7
8.8803	7.0702e+7	2.7728e+7
9.0672	7.0689e+7	2.7713e+7
9.3009	7.0674e+7	2.7694e+7
9.5930	7.0654e+7	2.7671e+7
9.9581	7.0629e+7	2.7642e+7
10.0000	7.0626e+7	2.7639e+7
10.0001	7.0626e+7	2.7639e+7
10.0001	7.0626e+7	2.7639e+7
10.0001	7.0626e+7	2.7639e+7
10.0002	7.0626e+7	2.7639e+7
10.0002	7.0626e+7	2.7639e+7
10.0003	7.0626e+7	2.7639e+7
10.0004	7.0626e+7	2.7639e+7
10.0006	7.0626e+7	2.7639e+7
10.0007	7.0626e+7	2.7639e+7
10.0009	7.0626e+7	2.7639e+7
10.0012	7.0626e+7	2.7639e+7
10.0015	7.0626e+7	2.7639e+7

time	fe_kg	cell_kg
10.0019	7.0626e+7	2.7639e+7
10.0024	7.0626e+7	2.7639e+7
10.0030	7.0626e+7	2.7639e+7
10.0038	7.0626e+7	2.7639e+7
10.0048	7.0626e+7	2.7639e+7
10.0060	7.0626e+7	2.7639e+7
10.0075	7.0626e+7	2.7639e+7
10.0094	7.0626e+7	2.7638e+7
10.0118	7.0626e+7	2.7638e+7
10.0148	7.0625e+7	2.7638e+7
10.0185	7.0625e+7	2.7638e+7
10.0231	7.0625e+7	2.7637e+7
10.0289	7.0625e+7	2.7637e+7
10.0361	7.0624e+7	2.7636e+7
10.0452	7.0623e+7	2.7636e+7
10.0565	7.0623e+7	2.7635e+7
10.0707	7.0622e+7	2.7634e+7
10.0884	7.0621e+7	2.7632e+7
10.1105	7.0619e+7	2.7630e+7
10.1381	7.0617e+7	2.7628e+7
10.1727	7.0615e+7	2.7626e+7
10.2159	7.0612e+7	2.7622e+7
10.2699	7.0608e+7	2.7618e+7
10.3374	7.0604e+7	2.7612e+7
10.4218	7.0598e+7	2.7606e+7
10.5272	7.0591e+7	2.7597e+7
10.6590	7.0582e+7	2.7587e+7
10.8238	7.0571e+7	2.7574e+7
11.0298	7.0557e+7	2.7558e+7
11.2873	7.0540e+7	2.7537e+7
11.6091	7.0518e+7	2.7512e+7
12.0114	7.0491e+7	2.7480e+7
12.5143	7.0457e+7	2.7440e+7
13.1429	7.0414e+7	2.7390e+7
13.9286	7.0361e+7	2.7328e+7
14.9108	7.0295e+7	2.7250e+7
16.1385	7.0212e+7	2.7152e+7
17.6732	7.0107e+7	2.7030e+7
19.5915	6.9977e+7	2.6877e+7
21.9894	6.9813e+7	2.6686e+7
24.9867	6.9608e+7	2.6446e+7
24.9999	6.9607e+7	2.6445e+7
24.9999	6.9607e+7	2.6445e+7
25.0000	6.9607e+7	2.6445e+7
25.0000	6.9607e+7	2.6445e+7
25.0001	6.9607e+7	2.6445e+7
25.0001	6.9607e+7	2.6445e+7
25.0002	6.9607e+7	2.6445e+7
25.0003	6.9607e+7	2.6445e+7
25.0004	6.9607e+7	2.6445e+7
25.0006	6.9607e+7	2.6445e+7
25.0008	6.9607e+7	2.6445e+7
25.0011	6.9607e+7	2.6445e+7
25.0014	6.9607e+7	2.6444e+7

time	fe_kg	cell_kg
25.0018	6.9607e+7	2.6444e+7
25.0023	6.9607e+7	2.6444e+7
25.0029	6.9607e+7	2.6444e+7
25.0037	6.9607e+7	2.6444e+7
25.0047	6.9607e+7	2.6444e+7
25.0059	6.9607e+7	2.6444e+7
25.0074	6.9606e+7	2.6444e+7
25.0093	6.9606e+7	2.6444e+7
25.0117	6.9606e+7	2.6444e+7
25.0146	6.9606e+7	2.6443e+7
25.0183	6.9606e+7	2.6443e+7
25.0230	6.9605e+7	2.6443e+7
25.0288	6.9605e+7	2.6442e+7
25.0360	6.9604e+7	2.6442e+7
25.0451	6.9604e+7	2.6441e+7
25.0564	6.9603e+7	2.6440e+7
25.0706	6.9602e+7	2.6439e+7
25.0883	6.9601e+7	2.6438e+7
25.1104	6.9599e+7	2.6436e+7
25.1380	6.9598e+7	2.6434e+7
25.1726	6.9595e+7	2.6431e+7
25.2158	6.9592e+7	2.6427e+7
25.2698	6.9588e+7	2.6423e+7
25.3373	6.9584e+7	2.6418e+7
25.4216	6.9578e+7	2.6411e+7
25.5271	6.9571e+7	2.6402e+7
25.6589	6.9562e+7	2.6392e+7
25.8237	6.9551e+7	2.6379e+7
26.0297	6.9536e+7	2.6362e+7
26.2872	6.9519e+7	2.6341e+7
26.6090	6.9497e+7	2.6316e+7
27.0113	6.9469e+7	2.6283e+7
27.5142	6.9435e+7	2.6243e+7
28.1428	6.9392e+7	2.6193e+7
28.9285	6.9338e+7	2.6130e+7
29.9107	6.9270e+7	2.6051e+7
31.1384	6.9186e+7	2.5952e+7
32.6731	6.9080e+7	2.5829e+7
34.5914	6.8948e+7	2.5674e+7
36.9893	6.8782e+7	2.5481e+7
39.9866	6.8576e+7	2.5239e+7
43.6998	6.8319e+7	2.4940e+7
47.9516	6.8026e+7	2.4597e+7
49.9985	6.7884e+7	2.4432e+7
49.9986	6.7884e+7	2.4432e+7
49.9986	6.7884e+7	2.4432e+7
49.9986	6.7884e+7	2.4432e+7
49.9987	6.7884e+7	2.4432e+7
49.9988	6.7884e+7	2.4432e+7
49.9988	6.7884e+7	2.4432e+7
49.9990	6.7884e+7	2.4432e+7
49.9991	6.7884e+7	2.4432e+7
49.9992	6.7884e+7	2.4432e+7
49.9994	6.7884e+7	2.4432e+7

time	fe_kg	cell_kg
49.9997	6.7884e+7	2.4432e+7
50.0000	6.7884e+7	2.4432e+7
50.0004	6.7884e+7	2.4432e+7
50.0009	6.7884e+7	2.4432e+7
50.0015	6.7884e+7	2.4432e+7
50.0023	6.7884e+7	2.4432e+7
50.0033	6.7884e+7	2.4432e+7
50.0045	6.7884e+7	2.4432e+7
50.0060	6.7884e+7	2.4431e+7
50.0079	6.7884e+7	2.4431e+7
50.0103	6.7883e+7	2.4431e+7
50.0133	6.7883e+7	2.4431e+7
50.0170	6.7883e+7	2.4431e+7
50.0216	6.7883e+7	2.4430e+7
50.0274	6.7882e+7	2.4430e+7
50.0347	6.7882e+7	2.4429e+7
50.0437	6.7881e+7	2.4428e+7
50.0550	6.7880e+7	2.4428e+7
50.0692	6.7879e+7	2.4426e+7
50.0869	6.7878e+7	2.4425e+7
50.1090	6.7877e+7	2.4423e+7
50.1367	6.7875e+7	2.4421e+7
50.1712	6.7872e+7	2.4418e+7
50.2144	6.7869e+7	2.4415e+7
50.2684	6.7866e+7	2.4410e+7
50.3359	6.7861e+7	2.4405e+7
50.4203	6.7855e+7	2.4398e+7
50.5257	6.7848e+7	2.4390e+7
50.6576	6.7839e+7	2.4379e+7
50.8223	6.7827e+7	2.4366e+7
51.0283	6.7813e+7	2.4349e+7
51.2858	6.7795e+7	2.4328e+7
51.6076	6.7773e+7	2.4302e+7
52.0099	6.7745e+7	2.4270e+7
52.5128	6.7711e+7	2.4229e+7
53.1414	6.7667e+7	2.4179e+7
53.9271	6.7613e+7	2.4115e+7
54.9093	6.7545e+7	2.4036e+7
56.1370	6.7461e+7	2.3937e+7
57.6717	6.7355e+7	2.3814e+7
59.5900	6.7223e+7	2.3659e+7
61.9879	6.7058e+7	2.3466e+7
64.9852	6.6851e+7	2.3225e+7
68.7320	6.6594e+7	2.2924e+7
73.3691	6.6276e+7	2.2553e+7
78.9483	6.5894e+7	2.2106e+7
85.9222	6.5419e+7	2.1549e+7
94.0324	6.4870e+7	2.0906e+7
100.0002	6.4473e+7	2.0438e+7
100.0003	6.4473e+7	2.0438e+7
100.0003	6.4473e+7	2.0438e+7
100.0004	6.4473e+7	2.0438e+7
100.0004	6.4473e+7	2.0438e+7
100.0005	6.4473e+7	2.0438e+7

time	fe_kg	cell_kg
100.0005	6.4473e+7	2.0438e+7
100.0006	6.4473e+7	2.0438e+7
100.0008	6.4473e+7	2.0438e+7
100.0009	6.4473e+7	2.0438e+7
100.0011	6.4473e+7	2.0438e+7
100.0014	6.4473e+7	2.0438e+7
100.0017	6.4473e+7	2.0438e+7
100.0021	6.4473e+7	2.0438e+7
100.0026	6.4473e+7	2.0438e+7
100.0032	6.4473e+7	2.0438e+7
100.0040	6.4473e+7	2.0438e+7
100.0050	6.4472e+7	2.0438e+7
100.0062	6.4472e+7	2.0438e+7
100.0077	6.4472e+7	2.0438e+7
100.0096	6.4472e+7	2.0437e+7
100.0120	6.4472e+7	2.0437e+7
100.0150	6.4472e+7	2.0437e+7
100.0187	6.4472e+7	2.0437e+7
100.0233	6.4471e+7	2.0436e+7
100.0291	6.4471e+7	2.0436e+7
100.0364	6.4470e+7	2.0435e+7
100.0454	6.4470e+7	2.0435e+7
100.0567	6.4469e+7	2.0434e+7
100.0709	6.4468e+7	2.0433e+7
100.0886	6.4467e+7	2.0431e+7
100.1107	6.4465e+7	2.0430e+7
100.1384	6.4464e+7	2.0427e+7
100.1729	6.4461e+7	2.0425e+7
100.2161	6.4458e+7	2.0421e+7
100.2701	6.4455e+7	2.0417e+7
100.3376	6.4450e+7	2.0412e+7
100.4198	6.4445e+7	2.0405e+7
100.5153	6.4439e+7	2.0398e+7
100.6234	6.4431e+7	2.0389e+7
100.7439	6.4423e+7	2.0380e+7
100.8777	6.4415e+7	2.0370e+7
101.0259	6.4405e+7	2.0358e+7
101.1901	6.4394e+7	2.0345e+7
101.3725	6.4382e+7	2.0331e+7
101.5755	6.4369e+7	2.0315e+7
101.8014	6.4354e+7	2.0298e+7
102.0510	6.4337e+7	2.0279e+7
102.3266	6.4319e+7	2.0257e+7
102.6311	6.4300e+7	2.0234e+7
102.9690	6.4278e+7	2.0208e+7
103.3457	6.4254e+7	2.0179e+7
103.7682	6.4226e+7	2.0147e+7
104.2457	6.4196e+7	2.0111e+7
104.7899	6.4162e+7	2.0070e+7
105.4169	6.4123e+7	2.0024e+7
106.1484	6.4079e+7	1.9971e+7
107.0155	6.4028e+7	1.9909e+7
108.0629	6.3969e+7	1.9837e+7
109.3591	6.3901e+7	1.9752e+7

time	fe_kg	cell_kg
110.9793	6.3823e+7	1.9652e+7
113.0045	6.3737e+7	1.9539e+7
115.5361	6.3643e+7	1.9410e+7
118.7006	6.3542e+7	1.9262e+7
122.6562	6.3427e+7	1.9088e+7
127.6007	6.3291e+7	1.8879e+7
133.7813	6.3126e+7	1.8623e+7
141.5071	6.2923e+7	1.8333e+7
151.1644	6.2670e+7	1.8017e+7
157.2001	6.2514e+7	1.7831e+7
164.7448	6.2322e+7	1.7606e+7
174.1757	6.2087e+7	1.7331e+7
185.9644	6.1797e+7	1.6992e+7
200.0005	6.1454e+7	1.6591e+7
200.0005	6.1454e+7	1.6591e+7
200.0005	6.1454e+7	1.6591e+7
200.0006	6.1454e+7	1.6591e+7
200.0006	6.1454e+7	1.6591e+7
200.0007	6.1454e+7	1.6591e+7
200.0008	6.1454e+7	1.6591e+7
200.0009	6.1454e+7	1.6591e+7
200.0010	6.1454e+7	1.6591e+7
200.0012	6.1454e+7	1.6591e+7
200.0014	6.1454e+7	1.6591e+7
200.0016	6.1454e+7	1.6591e+7
200.0020	6.1454e+7	1.6591e+7
200.0024	6.1454e+7	1.6591e+7
200.0029	6.1454e+7	1.6591e+7
200.0035	6.1454e+7	1.6591e+7
200.0043	6.1454e+7	1.6591e+7
200.0052	6.1454e+7	1.6591e+7
200.0064	6.1454e+7	1.6591e+7
200.0080	6.1454e+7	1.6590e+7
200.0099	6.1454e+7	1.6590e+7
200.0122	6.1454e+7	1.6590e+7
200.0152	6.1454e+7	1.6590e+7
200.0189	6.1454e+7	1.6590e+7
200.0236	6.1454e+7	1.6590e+7
200.0294	6.1454e+7	1.6590e+7
200.0366	6.1453e+7	1.6590e+7
200.0456	6.1453e+7	1.6589e+7
200.0570	6.1453e+7	1.6589e+7
200.0711	6.1453e+7	1.6589e+7
200.0888	6.1452e+7	1.6588e+7
200.1110	6.1452e+7	1.6588e+7
200.1386	6.1451e+7	1.6587e+7
200.1731	6.1450e+7	1.6586e+7
200.2163	6.1449e+7	1.6585e+7
200.2703	6.1448e+7	1.6583e+7
200.3378	6.1446e+7	1.6581e+7
200.4222	6.1444e+7	1.6579e+7
200.5276	6.1441e+7	1.6576e+7
200.6595	6.1438e+7	1.6572e+7
200.8243	6.1434e+7	1.6567e+7

time	fe_kg	cell_kg
201.0303	6.1429e+7	1.6561e+7
201.2877	6.1423e+7	1.6554e+7
201.6096	6.1415e+7	1.6545e+7
202.0119	6.1405e+7	1.6533e+7
202.5147	6.1393e+7	1.6519e+7
203.1433	6.1378e+7	1.6501e+7
203.9291	6.1359e+7	1.6479e+7
204.9113	6.1335e+7	1.6451e+7
206.0556	6.1307e+7	1.6418e+7
207.3313	6.1276e+7	1.6382e+7
208.7195	6.1242e+7	1.6343e+7
210.2122	6.1206e+7	1.6301e+7
211.8092	6.1167e+7	1.6256e+7
213.5156	6.1126e+7	1.6208e+7
215.3398	6.1082e+7	1.6156e+7
217.2932	6.1035e+7	1.6101e+7
219.3899	6.0984e+7	1.6042e+7
221.6468	6.0930e+7	1.5979e+7
224.0840	6.0871e+7	1.5910e+7
226.7257	6.0807e+7	1.5836e+7
229.6007	6.0739e+7	1.5756e+7
232.7440	6.0663e+7	1.5668e+7
236.1982	6.0581e+7	1.5572e+7
240.0160	6.0490e+7	1.5466e+7
244.2634	6.0389e+7	1.5348e+7
249.0238	6.0276e+7	1.5216e+7
254.4052	6.0150e+7	1.5068e+7
260.5495	6.0005e+7	1.4899e+7
267.6500	5.9839e+7	1.4704e+7
275.9334	5.9647e+7	1.4479e+7
284.4510	5.9450e+7	1.4248e+7
292.6846	5.9261e+7	1.4026e+7
300.5310	5.9082e+7	1.3815e+7
308.0685	5.8911e+7	1.3614e+7
315.4208	5.8744e+7	1.3418e+7
322.7079	5.8581e+7	1.3226e+7
330.0356	5.8417e+7	1.3033e+7
337.4974	5.8251e+7	1.2853e+7
345.1823	5.8082e+7	1.2853e+7
353.2043	5.7906e+7	1.2852e+7
361.6744	5.7721e+7	1.2852e+7
370.7061	5.7525e+7	1.2852e+7
380.4201	5.7317e+7	1.2851e+7
390.9475	5.7092e+7	1.2851e+7
400.0073	5.6902e+7	1.2851e+7
400.0073	5.6902e+7	1.2851e+7
400.0074	5.6902e+7	1.2851e+7
400.0074	5.6902e+7	1.2851e+7
400.0074	5.6902e+7	1.2851e+7
400.0075	5.6902e+7	1.2851e+7
400.0075	5.6902e+7	1.2851e+7
400.0076	5.6902e+7	1.2851e+7
400.0078	5.6902e+7	1.2851e+7
400.0079	5.6902e+7	1.2851e+7

time	fe_kg	cell_kg
400.0080	5.6902e+7	1.2851e+7
400.0082	5.6902e+7	1.2851e+7
400.0085	5.6902e+7	1.2851e+7
400.0088	5.6902e+7	1.2851e+7
400.0092	5.6902e+7	1.2851e+7
400.0097	5.6902e+7	1.2851e+7
400.0103	5.6902e+7	1.2851e+7
400.0111	5.6902e+7	1.2851e+7
400.0121	5.6902e+7	1.2851e+7
400.0133	5.6902e+7	1.2851e+7
400.0148	5.6902e+7	1.2851e+7
400.0167	5.6902e+7	1.2851e+7
400.0191	5.6902e+7	1.2851e+7
400.0220	5.6902e+7	1.2851e+7
400.0257	5.6902e+7	1.2851e+7
400.0303	5.6902e+7	1.2851e+7
400.0361	5.6901e+7	1.2851e+7
400.0434	5.6901e+7	1.2851e+7
400.0524	5.6901e+7	1.2851e+7
400.0637	5.6901e+7	1.2851e+7
400.0778	5.6901e+7	1.2851e+7
400.0954	5.6900e+7	1.2851e+7
400.1175	5.6900e+7	1.2851e+7
400.1451	5.6899e+7	1.2851e+7
400.1795	5.6898e+7	1.2851e+7
400.2226	5.6898e+7	1.2851e+7
400.2765	5.6896e+7	1.2851e+7
400.3438	5.6895e+7	1.2851e+7
400.4280	5.6893e+7	1.2851e+7
400.5332	5.6891e+7	1.2851e+7
400.6647	5.6888e+7	1.2851e+7
400.8291	5.6885e+7	1.2851e+7
401.0345	5.6881e+7	1.2851e+7
401.2914	5.6875e+7	1.2851e+7
401.6124	5.6868e+7	1.2851e+7
402.0136	5.6860e+7	1.2851e+7
402.5153	5.6850e+7	1.2851e+7
403.1423	5.6837e+7	1.2851e+7
403.9261	5.6821e+7	1.2851e+7
404.9058	5.6801e+7	1.2851e+7
406.1305	5.6777e+7	1.2851e+7
407.6613	5.6748e+7	1.2851e+7
409.5749	5.6717e+7	1.2851e+7
411.9668	5.6686e+7	1.2851e+7
414.9567	5.6660e+7	1.2851e+7
418.6941	5.6643e+7	1.2851e+7
423.3658	5.6631e+7	1.2850e+7
429.2054	5.6622e+7	1.2850e+7
436.5050	5.6612e+7	1.2850e+7
445.6295	5.6601e+7	1.2850e+7
456.8080	5.6589e+7	1.2850e+7
469.7710	5.6582e+7	1.2850e+7
484.3387	5.6579e+7	1.2850e+7
500.3398	5.6577e+7	1.2850e+7

time	fe_kg	cell_kg
516.4556	5.6575e+7	1.2850e+7
532.1435	5.6573e+7	1.2850e+7
547.3224	5.6571e+7	1.2850e+7
562.0833	5.6569e+7	1.2850e+7
576.5588	5.6567e+7	1.2850e+7
590.8784	5.6566e+7	1.2850e+7
605.1581	5.6564e+7	1.2850e+7
619.5016	5.6562e+7	1.2850e+7
634.0042	5.6561e+7	1.2850e+7
648.7565	5.6559e+7	1.2850e+7
663.8491	5.6558e+7	1.2850e+7
679.3762	5.6556e+7	1.2850e+7
695.4394	5.6555e+7	1.2850e+7
712.1512	5.6553e+7	1.2850e+7
729.6407	5.6551e+7	1.2850e+7
748.0586	5.6549e+7	1.2850e+7
767.5851	5.6548e+7	1.2850e+7
788.4396	5.6546e+7	1.2850e+7
810.8959	5.6544e+7	1.2850e+7
835.3019	5.6542e+7	1.2850e+7
862.1106	5.6539e+7	1.2850e+7
891.9291	5.6537e+7	1.2850e+7
925.5939	5.6534e+7	1.2850e+7
964.3009	5.6532e+7	1.2850e+7
1009.8390	5.6527e+7	1.2786e+7
1059.3990	5.6523e+7	1.2711e+7
1086.7780	5.6520e+7	1.2666e+7
1103.8900	5.6518e+7	1.2638e+7
1125.2800	5.6516e+7	1.2603e+7
1152.0170	5.6513e+7	1.2559e+7
1185.4390	5.6510e+7	1.2504e+7
1227.2160	5.6505e+7	1.2435e+7
1279.4380	5.6500e+7	1.2349e+7
1334.1960	5.6495e+7	1.2259e+7
1388.9540	5.6489e+7	1.2168e+7
1443.7120	5.6484e+7	1.2078e+7
1498.4700	5.6479e+7	1.1988e+7
1553.2290	5.6474e+7	1.1899e+7
1607.9870	5.6469e+7	1.1809e+7
1662.7450	5.6464e+7	1.1720e+7
1717.5030	5.6459e+7	1.1631e+7
1772.2610	5.6454e+7	1.1542e+7
1827.0190	5.6449e+7	1.1453e+7
1881.7780	5.6445e+7	1.1365e+7
1936.5360	5.6440e+7	1.1276e+7
1991.2940	5.6436e+7	1.1188e+7
2046.0520	5.6431e+7	1.1100e+7
2100.8100	5.6427e+7	1.1013e+7
2155.5680	5.6422e+7	1.0926e+7
2210.3270	5.6418e+7	1.0924e+7
2265.0850	5.6414e+7	1.0924e+7
2319.8430	5.6409e+7	1.0924e+7
2326.6880	5.6409e+7	1.0924e+7
2330.9660	5.6408e+7	1.0924e+7

time	fe_kg	cell_kg
2336.3130	5.6408e+7	1.0924e+7
2342.9980	5.6407e+7	1.0924e+7
2351.3530	5.6407e+7	1.0924e+7
2361.7980	5.6406e+7	1.0924e+7
2374.8530	5.6405e+7	1.0924e+7
2391.1720	5.6404e+7	1.0924e+7
2411.5710	5.6402e+7	1.0924e+7
2437.0700	5.6400e+7	1.0924e+7
2468.9430	5.6398e+7	1.0924e+7
2508.7850	5.6395e+7	1.0924e+7
2558.5870	5.6391e+7	1.0924e+7
2613.3450	5.6387e+7	1.0924e+7
2668.1040	5.6384e+7	1.0924e+7
2722.8620	5.6380e+7	1.0924e+7
2777.6200	5.6376e+7	1.0924e+7
2832.3780	5.6373e+7	1.0924e+7
2887.1360	5.6369e+7	1.0924e+7
2941.8950	5.6366e+7	1.0924e+7
2996.6530	5.6363e+7	1.0924e+7
3051.4110	5.6359e+7	1.0924e+7
3106.1690	5.6356e+7	1.0924e+7
3160.9270	5.6353e+7	1.0924e+7
3215.6860	5.6350e+7	1.0924e+7
3270.4440	5.6347e+7	1.0924e+7
3325.2020	5.6344e+7	1.0924e+7
3379.9600	5.6341e+7	1.0924e+7
3434.7180	5.6339e+7	1.0924e+7
3489.4770	5.6336e+7	1.0924e+7
3544.2350	5.6333e+7	1.0924e+7
3598.9930	5.6331e+7	1.0924e+7
3653.7510	5.6328e+7	1.0924e+7
3708.5090	5.6325e+7	1.0924e+7
3763.2680	5.6323e+7	1.0924e+7
3818.0260	5.6320e+7	1.0924e+7
3872.7840	5.6318e+7	1.0924e+7
3927.5420	5.6316e+7	1.0924e+7
3982.3000	5.6313e+7	1.0924e+7
4037.0590	5.6311e+7	1.0924e+7
4091.8170	5.6309e+7	1.0924e+7
4146.5750	5.6306e+7	1.0924e+7
4201.3330	5.6304e+7	1.0924e+7
4256.0910	5.6302e+7	1.0924e+7
4310.8490	5.6300e+7	1.0924e+7
4338.2290	5.6299e+7	1.0924e+7
4355.3400	5.6298e+7	1.0924e+7
4376.7300	5.6297e+7	1.0924e+7
4403.4680	5.6296e+7	1.0924e+7
4436.8890	5.6295e+7	1.0924e+7
4478.6670	5.6293e+7	1.0918e+7
4530.8880	5.6291e+7	1.0909e+7
4585.6460	5.6289e+7	1.0901e+7
4640.4040	5.6287e+7	1.0893e+7
4695.1630	5.6285e+7	1.0885e+7
4749.9200	5.6283e+7	1.0878e+7

time	fe_kg	cell_kg
4804.6790	5.6281e+7	1.0870e+7
4859.4370	5.6279e+7	1.0863e+7
4914.1950	5.6277e+7	1.0856e+7
4968.9530	5.6275e+7	1.0849e+7
5023.7110	5.6273e+7	1.0842e+7
5078.4700	5.6271e+7	1.0835e+7
5133.2290	5.6269e+7	1.0829e+7
5187.9860	5.6267e+7	1.0822e+7
5242.7450	5.6265e+7	1.0816e+7
5297.5030	5.6263e+7	1.0810e+7
5352.2610	5.6261e+7	1.0804e+7
5407.0190	5.6259e+7	1.0798e+7
5461.7770	5.6258e+7	1.0793e+7
5516.5360	5.6256e+7	1.0787e+7
5571.2940	5.6254e+7	1.0782e+7
5626.0520	5.6252e+7	1.0777e+7
5680.8100	5.6250e+7	1.0772e+7
5735.5680	5.6248e+7	1.0768e+7
5790.3270	5.6247e+7	1.0763e+7
5845.0840	5.6245e+7	1.0759e+7
5899.8430	5.6243e+7	1.0756e+7
5954.6010	5.6241e+7	1.0752e+7
6009.3590	5.6240e+7	1.0749e+7
6064.1170	5.6238e+7	1.0746e+7
6118.8750	5.6236e+7	1.0744e+7
6173.6340	5.6234e+7	1.0741e+7
6228.3920	5.6233e+7	1.0740e+7
6283.1490	5.6231e+7	1.0738e+7
6337.9080	5.6229e+7	1.0737e+7
6392.6670	5.6228e+7	1.0736e+7
6447.4250	5.6226e+7	1.0736e+7
6502.1830	5.6224e+7	1.0736e+7
6556.9400	5.6223e+7	1.0736e+7
6611.6990	5.6221e+7	1.0736e+7
6666.4580	5.6219e+7	1.0736e+7
6721.2150	5.6218e+7	1.0736e+7
6775.9740	5.6216e+7	1.0736e+7
6830.7310	5.6215e+7	1.0736e+7
6885.4910	5.6213e+7	1.0736e+7
6940.2490	5.6211e+7	1.0736e+7
6995.0070	5.6210e+7	1.0736e+7
7049.7650	5.6208e+7	1.0736e+7
7104.5230	5.6207e+7	1.0736e+7
7159.2810	5.6205e+7	1.0736e+7
7214.0400	5.6203e+7	1.0736e+7
7268.7980	5.6202e+7	1.0736e+7
7323.5560	5.6200e+7	1.0736e+7
7378.3130	5.6199e+7	1.0736e+7
7433.0720	5.6197e+7	1.0736e+7
7487.8310	5.6196e+7	1.0736e+7
7542.5890	5.6194e+7	1.0736e+7
7597.3470	5.6193e+7	1.0736e+7
7652.1040	5.6191e+7	1.0736e+7
7706.8630	5.6190e+7	1.0736e+7

time	fe_kg	cell_kg
7761.6220	5.6188e+7	1.0736e+7
7816.3790	5.6187e+7	1.0736e+7
7871.1380	5.6185e+7	1.0736e+7
7925.8960	5.6184e+7	1.0736e+7
7980.6540	5.6182e+7	1.0736e+7
8035.4120	5.6181e+7	1.0736e+7
8090.1700	5.6179e+7	1.0736e+7
8144.9290	5.6178e+7	1.0736e+7
8199.6870	5.6177e+7	1.0736e+7
8254.4440	5.6175e+7	1.0736e+7
8309.2030	5.6174e+7	1.0736e+7
8363.9620	5.6172e+7	1.0736e+7
8418.7200	5.6171e+7	1.0736e+7
8473.4780	5.6169e+7	1.0736e+7
8528.2350	5.6168e+7	1.0736e+7
8582.9940	5.6167e+7	1.0736e+7
8637.7530	5.6165e+7	1.0736e+7
8692.5110	5.6164e+7	1.0736e+7
8747.2690	5.6162e+7	1.0736e+7
8802.0260	5.6161e+7	1.0736e+7
8856.7840	5.6160e+7	1.0736e+7
8911.5440	5.6158e+7	1.0736e+7
8925.2320	5.6158e+7	1.0736e+7
8933.7890	5.6158e+7	1.0736e+7
8935.1250	5.6158e+7	1.0736e+7
8936.7970	5.6158e+7	1.0736e+7
8938.8850	5.6158e+7	1.0736e+7
8941.4960	5.6158e+7	1.0736e+7
8944.7600	5.6157e+7	1.0736e+7
8948.8400	5.6157e+7	1.0736e+7
8953.9390	5.6157e+7	1.0736e+7
8960.3150	5.6157e+7	1.0736e+7
8968.2820	5.6157e+7	1.0736e+7
8978.2440	5.6157e+7	1.0736e+7
8990.6940	5.6156e+7	1.0736e+7
9006.2570	5.6156e+7	1.0736e+7
9025.7110	5.6155e+7	1.0736e+7
9050.0290	5.6155e+7	1.0736e+7
9080.4250	5.6154e+7	1.0736e+7
9118.4220	5.6153e+7	1.0736e+7
9165.9170	5.6152e+7	1.0736e+7
9220.6750	5.6151e+7	1.0736e+7
9275.4340	5.6149e+7	1.0736e+7
9330.1910	5.6148e+7	1.0736e+7
9384.9500	5.6147e+7	1.0736e+7
9439.7080	5.6145e+7	1.0736e+7
9494.4660	5.6144e+7	1.0736e+7
9549.2250	5.6143e+7	1.0736e+7
9603.9820	5.6141e+7	1.0736e+7
9658.7400	5.6140e+7	1.0736e+7
9713.4990	5.6139e+7	1.0736e+7
9768.2570	5.6137e+7	1.0736e+7
9823.0160	5.6136e+7	1.0736e+7
9877.7730	5.6135e+7	1.0736e+7

time	fe_kg	cell_kg
9932.5310	5.6134e+7	1.0736e+7
9987.2900	5.6132e+7	1.0736e+7
1.0000e+4	5.6132e+7	1.0736e+7

Values of variables that are shown graphically in Figure 8-15

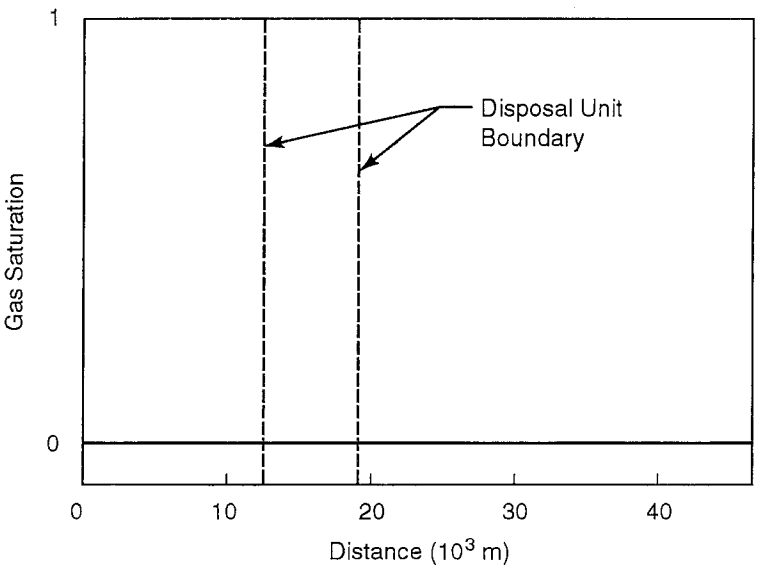

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Figure 8-15. Gas Saturation at 10,000 Years in Halite Layer Immediately Above Marker Bed 138 Across the Model Domain.

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DISTANCE	MXSG
0.0000	0.0000
7500.0000	0.0000
1.7500e+4	0.0000
2.0500e+4	0.0000
2.1375e+4	0.0000
2.2000e+4	0.0000
2.2300e+4	0.0000
2.2370e+4	0.0000
2.2395e+4	0.0000
2.2422e+4	0.0000
2.2449e+4	0.0000
2.2455e+4	0.0000
2.2456e+4	0.0000
2.2457e+4	0.0000
2.2463e+4	0.0000
2.2490e+4	0.0000
2.2532e+4	0.0000
2.2668e+4	0.0000
2.2899e+4	0.0000
2.3131e+4	0.0000
2.3287e+4	0.0000
2.3468e+4	0.0000
2.3635e+4	0.0000
2.3665e+4	0.0000
2.3700e+4	0.0000
2.3980e+4	0.0000
2.4235e+4	0.0000
2.4260e+4	0.0000
2.4330e+4	0.0000
2.4630e+4	0.0000
2.5255e+4	0.0000
2.6130e+4	0.0000
2.9130e+4	0.0000
3.9130e+4	0.0000
4.6630e+4	0.0000

Values of variables that are shown graphically in Figures 8-16, 8-17, and 8-18

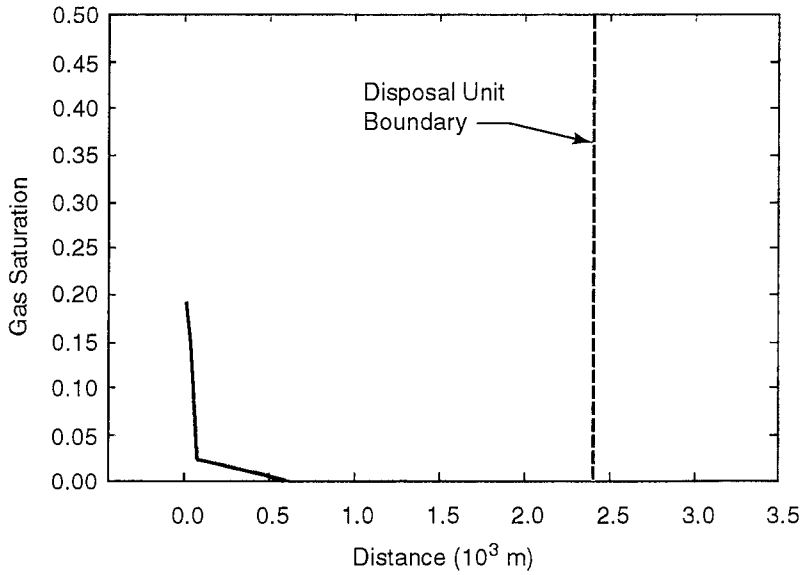

Figure 8-16. Maximum Gas Saturation in Anhydrites a & b South of the Repository

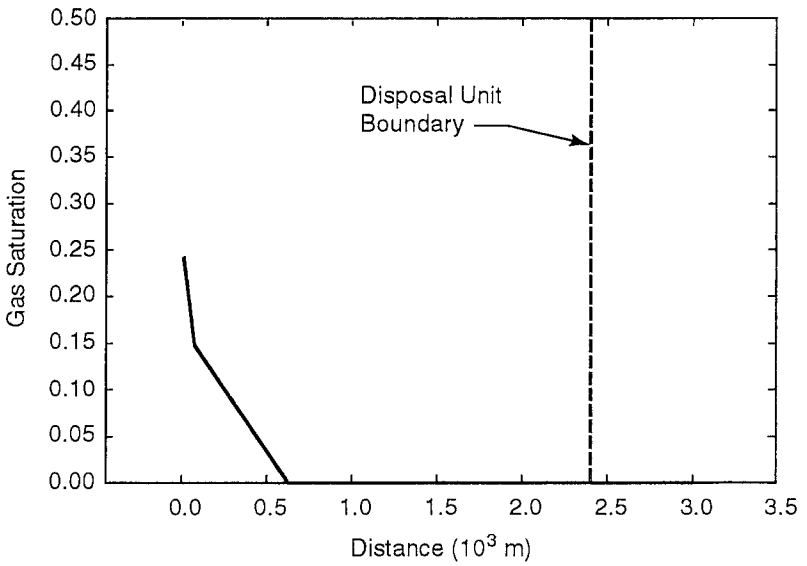

Figure 8-17. Maximum Gas Saturation in Anhydrites a & b North of the Repository

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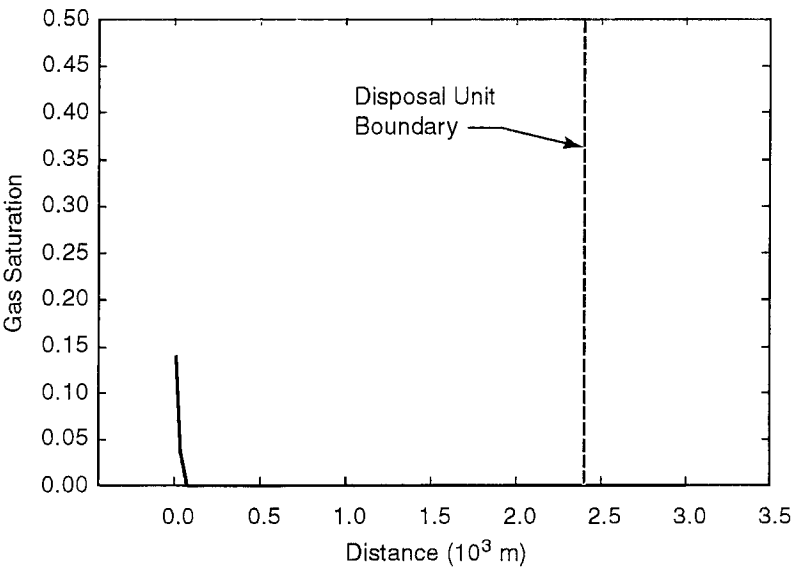

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Figure 8-18. Maximum Gas Saturation in Marker Bed 138 South of the Repository

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DISTANCE	MXSGABR	mxsgabl	MXSG38L
5.0000	0.2432	0.1920	0.1400
25.0000	0.2093	0.1506	0.0371
70.0000	0.1477	0.0249	0.0000
625.0000	7.0696e-4	0.0000	0.0000
875.0000	0.0000	0.0000	0.0000
3000.0000	0.0000	0.0000	0.0000

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APPENDIX PAR: PARAMETER VALUES

Appendix PAR documents the basis for selected parameters used in the No-Migration Variance Petition (NMVP) BRAGFLO simulation. Configuration management of model parameters is maintained through the Performance Assessment (PA) Parameter Database, supported by Parameter Records Packages (PRPs) located in the Sandia Waste Isolation Pilot Plant (WIPP) Central File (SWCF). Appendix PAR augments the Performance Assessment (PA) Database and PRPs by providing parameter and data traceability within the petition, as well as additional information suitable for interpreting the reasonable or reasonably conservative foundation of the NMVP simulation. Readers are referred to Tables PAR-11 and PAR-12, derived from the PA Parameter Database and PRPs for a complete list of parameters and supporting information used in the NMVP analysis.

As with the parameter tables in Chapter 8, the parameter sheets are grouped into the following features of the disposal system:

- Repository and Panel Closures
- Average Stochiometry Gas Generation
- Shaft Materials
- Salado Formation Halite
- Salado Formation Anhydrite
- Salado Formation Fracture
- Disturbed Rock Zone
- Culebra Member of the Rustler Formation
- Magenta Member of the Rustler Formation
- Dewey Lake Formation
- Santa Rosa Formation

As explained in Chapter 8, model parameters are not necessarily analogous to data obtained through experimental means. In most cases, model parameters based strictly on experimental data do not capture uncertainty associated with experimental design, completeness of the data set, or extrapolation of the experimental results to spatial and/or temporal scales required for the no-migration demonstration. For model parameters characterized by such uncertainty, Appendix PAR notes the type of distribution function that characterizes the weights to be given to possible parameter values. For model parameters that are known with high precision, or whose range of uncertainty is unimportant to the analysis, Appendix PAR parameter sheets document the constant values used in the analysis.

PAR.1 Parameter Development Process

The development of parameter values is covered in Quality Assurance Procedure (QAP) *Quality Assurance Requirements for the Selection and Documentation of*

Parameter Values used in WIPP Performance Assessment (QAP 9-2). The process includes documentation of parameter development by those responsible for completion of a particular experimental investigation, development of a system design, or by staff involved in the PA modeling process. All of the references pertaining to parameter selection are contained within the three levels of parameter/data documentation: 1) WIPP Data Entry Form 464, 2) Parameter Records Packages, and 3) supporting data records packages.

The WIPP Data Entry Form 464 is the highest level record documenting parameter development including application of statistics and interpretations. The WIPP Data Entry Form 464s include a "source" section that is a pointer to supporting information, including, where applicable, the Parameter Records Package(s).

The Parameter Records Packages include a data and distribution summary; identify the QA status of the data and related interpretive numerical codes; include references to related references such as SAND reports, test plans, and related SWCF file codes; and, where applicable, include a summary on the experimental data collection (i.e.,method used, assumptions made in testing, and interpretation). The Parameter Records packages point to the supporting data records packages.

The data records packages contain such information as the raw data, analysis, data interpretation, and QA records.

Copies of the Form 464s, Parameter Records Packages, and supporting data records packages are maintained in the Sandia WIPP Central Files (SWCF).

In the WIPP PA parameter database, parameters are classified as follows:

Category 1) parameters based on data derived from experimental sources (e.g., laboratory and field experiments) or deduced from available information;

Category 2) parameters based on data taken from the Department of Energy (DOE) Baseline Inventory report for characteristics of the transuranic (TRU) waste;

Category 3) parameters based on data taken from handbooks, archive journals and standard reference information; and

Category 4a) parameter values that are assigned based on an analogy with an existing disposal system material parameter or through analyst judgment based upon information derived from peer-reviewed literature or knowledge of the disposal system and engineering principles.

Category 4b) parameters used in model configuration: geometric descriptions of geologic, hydrologic and engineered features and switches used in configuring the computer model.

PAR.2 Parameter Distributions

Probability distributions are used to characterize the uncertainty concerning the value of a parameter. Numbers that characterize a particular distribution include the range, the mean, median and mode.

- ***Range.*** The range of a distribution can be denoted by (a,b), the pair of numbers in which a and b are minimum and maximum values of the parameter, respectively.

- ***Mean.*** Analogous to the arithmetic average of a series of numbers, the mean value of a probability distribution is one measure of the central tendency of a distribution. For non-symmetrical distributions that are considerably skewed, the mean value may not lie near the median or mode (see below).

- ***Median.*** The median value of a probability distribution is denoted by x_{50} (50th percentile or 0.5 quantile), the value in the distribution range at which 50 percent of all values lie above and below.

- ***Mode.*** The mode is the "most probable value" of the uncertain parameter; i.e., the maximum value of the associated probability density function.

PAR.2.1 Choice of Parameters in the NMVP

The DOE has chosen to use a single vector of parameters as input to the NMVP simulation. The elements of this vector (i.e., each distinct parameter needed by the computational models) have been assigned values that are deemed to be "best values." In most cases, "best value" means either the single number assigned to a "constant" parameter in the PA Parameter Data Base or — if the parameter is uncertain and has been assigned a probability distribution — the median or mode of the assigned distribution.

Five types of parameter distributions are used to characterize parameters used in the NMVP BRAGFLO simulation: uniform, cumulative, triangular, student-t and constant.

Uniform Distribution

Density Function: $$f(x) = \frac{1}{B-A} \qquad A \le x \le B$$

Distribution Function: $$F(x) = \frac{x-A}{B-A} \qquad A \le x \le B$$

Expected value and variance: $$E(X) = \frac{A+B}{2}$$

$$V(X) = \frac{(B-A)^2}{12}$$

Median: $$X_{0.5} = \text{mean}$$

The program requires the endpoints A and B.

When use of the uniform distribution is appropriate:

Use of the uniform distribution is appropriate when all that is known about a parameter is its range (a,b); the uniform distribution is the *Maximum Entropy* distribution under these circumstances.

Cumulative Distribution

A Cumulative Distribution (also called a *Constructed Distribution)* is described by a set of N ordered pairs:

$$(x_1,0),(x_2,P_2),(x_3,P_3),\cdots,(x_N,1) \quad \{i.e. \quad P_1 = 0 \quad and \quad P_N = 1 \quad always\}$$

where $$x_1 < x_2 < x_3 < \cdots < x_N \quad and \quad 0 < P_2 < P_3 < \cdots < P_{N-1} < 1$$

Due to the nature of the data, the probability density function (pdf) for this distribution takes the form:

$$P(\xi) = \begin{cases} 0 & if\ \xi < x_1 \\ \dfrac{P_n - P_{n-1}}{x_n - x_{n-1}} & if\ x_{n-1} \le \xi \le x_n, \quad n = 2,3,\cdots,N \\ 0 & if\ \xi \ge x_N \end{cases}$$

and so the cumulative distribution function (CDF) takes the form:

$$P_n\{X \le \xi\} \approx \Pi(\xi) = \begin{cases} 0 & \text{if } \xi < x_1 \\ P_{n-1} + \dfrac{(P_n - P_{n-1})(\xi - x_{n-1})}{(x_n - x_{n-1})} & \text{if } \dfrac{x_{n-1} \le \xi \le x_x}{n = 2,3,\cdots,N} \\ 1 & \text{if } \xi > x_N \end{cases}$$

Expected Value: $$E(X) = \sum_{n=2}^{N} (P_n - P_{n-1}) \frac{(x_n + x_{n-1})}{2}$$

Variance: $$V(X) = \sum_{n=2}^{N} (P_n - P_{n-1}) \frac{(x_n^2 + x_n x_{n-1} + x_{n-1}^2)}{3} - \{E(X)\}^2$$

Median: $$X_{0.50} = x_{m-1} + (x_m - x_{m-1}) \frac{(0.50 - P_{m-1})}{(P_m - P_{m-1})} \quad \text{where} \quad P_{m-1} \le 0.50 < P_m .$$

When use of the cumulative distribution is appropriate:

The cumulative distribution takes its name from the fact that it closely resembles the empirical cumulative distribution function obtained by plotting the empirical percentiles of the data set (x_1,x_2,x_3,…,x_N) (Blom 1989, 216). The cumulative distribution in the sense used here is the result of plotting the *subjectively determined* percentile points (x_1,P_1), (x_2,P_2), (x_3,P_3) … , that arise in a formal elicitation of expert opinion concerning the form of the distribution of the parameter in question. A simple form of the cumulative distribution is used when the range [a,c] of the parameter is known and the analyst believes that his or her "best estimate" value, b, is also the median (or 50th percentile) of the unknown distribution. In this case, the subjectively determined percentile points take the form: (a, 0.0), (b, 0.5), (c, 1.0).

The cumulative distribution is the *Maximum Entropy* distribution associated with a set of percentile points (x_1,P_1), (x_2,P_2), …, (x_N, P_N), no matter how that set of percentile points is obtained (i.e. independent of whether the points are empirically or subjectively derived).

Triangular Distribution

Density Function: $$f(x) = \frac{2(x-a)}{(c-a)(b-a)} \qquad a \le x \le b$$

$$= \frac{2(c-x)}{(c-a)(c-b)} \qquad b \le x \le c$$

Distribution Function: $$F(x) = \frac{(x-a)^2}{(c-a)(b-a)} \qquad a \le x \le b$$

$$= \frac{b-a}{c-a} - \frac{(x+b-2c)(x-b)}{(c-a)(c-b)} \qquad b \le x \le c$$

Expected Value: $$E(X) = \frac{a+b+c}{3}$$

Variance: $$V(X) = \frac{a(a-b)+b(b-c)+c(c-a)}{18}$$

Median: $$X_{0.5} = a + \sqrt{\frac{(c-a)(b-a)}{2}} \qquad \text{if} \quad b \ge \frac{a+c}{2}$$

$$= c - \sqrt{\frac{(c-b)(c-a)}{2}} \qquad \text{if} \quad b \le \frac{a+c}{2}$$

The Triangular Distribution is defined on the range $[a,c]$ and has mode b. The mode can equal either of the two boundary values, which may simplify the computations above.

When use of the triangular distribution is appropriate:

Use of the triangular distribution is appropriate when the range, [a,c], of the parameter is known and the analyst believes that his or her "best estimate" value, b, is also the mode (or *most probable value*) of the unknown distribution.

Student-t Distribution

A student-t distribution is the Bayesian distribution for the unknown mean value of a parameter used in cases where N measurements are small (i.e., $3 < N < 10$). For N > 10-20, there is little difference in the shape of a student-t distribution and a normal distribution.

Constants

Parameters may also be assigned a constant value in the PA Parameter Database. The justification of the single-value is discussed in this appendix.

PAR.3 Key to Parameter Sheets

The parameter sheets included in this appendix contain a variety of information, some of which is extracted from the WIPP PA Parameters Database. Only a subset of parameters used in the NMVP simulation are included in Appendix PAR. Information presented in the parameter sheets is grouped into boxes labeled as follows:

Parameter(s): The Parameters box lists the name of the parameter and the disposal system feature with which it is associated (e.g., Residual Brine Saturation for Marker Beds 138 &139). In most cases, there is a one-to-one correspondence between the parameter sheet title and the parameter listed in the relevant table in Section 8.2 of the main body of the report. (Note: One exception is maximum capillary pressure (PC_MAX), which is assigned the same value for all material regions. The PC_MAX parameter sheet for all regions is appended to the Repository and Panel Closures section).

Parameter Description: The Parameter Description box defines the parameter and, where appropriate, explains the role of the parameter in the modeling.

Material and Parameter Name(s): This box provides a link to the PA parameter database. The parameter label listed first is taken from the PA Model Parameter database field IDMTRL, which identifies the type of material in the disposal system being modeled (e.g., S_ANH_AB means Salado Anhydrite Beds a & b). The second label describes the PA Model Parameter name for the physical or operational meaning for the parameter (e.g., SAT_RBRN means residual brine saturation). The number associated with a parameter is the unique identification number (ID) established in the WIPP Model Parameter Database.

Parameter Value: The parameter value selected for the NMVP simulation is identified in this section. These values are based on median or mode of parameter distributions or other constant values specified in the simulation database.

Units/Parameter Statistics: If the parameter is a constant, the units of the parameter are identified in this box. For parameters represented by a distribution, this box is replaced by a parameter statistics box identifying the units, and the mean, median, maximum and minimum values of the parameter distribution.

Distribution Type: This box identifies the type of parameter distribution.

Data: The basis for the parameter values or parameter distribution is provided in this section. For the no-migration variance petition, parameters are derived from the following kinds of data and information:

- *Site-specific or waste-specific experimental data.* This data includes information obtained from in-situ experiments and from research conducted at off-site laboratories (e.g., permeability data, microbial gas generation). This category also

includes simulated waste experiments and may indicate correlations made with other material regions based on professional judgment.

- *Waste-specific observational data*. This category includes data obtained through observation or empirical analysis, such as semi-quantitative and qualitative visual characterization or process knowledge of TRU waste (e.g., waste components).

- *Professional judgment*. Parameter distributions or parameter values may be deduced from available information. This category of information may involve correlating experimental or observational data to other regions, interpreting information obtained from the general literature, or may be based on general engineering knowledge (see below). In many cases, the parameter must be assigned in the course of model configuration and is often assigned by qualified staff involved in the PA modeling process.

  Professional judgment is synonymous with PA category 4 parameters; in some cases, professional judgment is used in category 1 parameters, if the parameter is not explicitly derived from experimental data.

- *General Literature Data*. This category of information includes that obtained from reports, journal articles or handbooks relevant to systems or processes being modeled for the WIPP no-migration demonstration. It is often employed in conjunction with professional judgment.

- *General Engineering Knowledge*. This category of information identifies parameter values obtained from knowledge of standard engineering principles.

Readers are referred to parameter records packages and associated data packages maintained in the SWCF for additional information.

Discussion: This section identifies the source(s) of parameter value(s) and the rationale for selecting the value used in the no-migration simulation. Other relevant background information is also included in this section, where clarification is appropriate.

References: All of the references pertaining to parameter selection are contained within the three levels of parameter/data documentation: 1) WIPP Data Entry Form 464, 2) Parameter Records Packages, and 3) supporting data records packages. For the NMVP, selected references cited in the parameter records packages are included in the parameter sheet to establish data quality.

REFERENCES

Blom, G. 1989. *Probability and Statistics: Theory and Applications*. New York, NY: Springer-Verlag.

Iman, R.L., and M.J. Shortencarier. 1984. *A FORTRAN 77 Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use With Computer Models*. SAND83-2365. Albuquerque, NM: Sandia National Laboratories.

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Repository[a] and Panel Closures Parameter Values[b] (as summarized in Table 8-2, Chapter 8)

[a]Repository refers to operations, experimental, and waste regions, unless otherwise noted.

[b] Appended: Maximum Capillary Pressures - All Material Regions

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Parameter(s): Log of Intrinsic Permeability - Waste and Repository Regions

Parameter Description:

Intrinsic permeability of the Waste Region and Repository region refers to the effective hydraulic conductivity of a collapsed drum-filled waste-disposal room or panel. The Waste Region corresponds to a single excavated panel. The Repository Region refers to the waste disposal area outside the single panel and is important only in instances of disturbed performance. Consequently, for the NMVP, both regions are assigned the same intrinsic permeability.

Material and Parameter Name(s):

WAS_AREA	PRMX_LOG (#663)	REPOSIT PRMX_LOG (#2131)
WAS_AREA	PRMY_LOG (#664)	REPOSIT PRMY_LOG (#2132)
WAS_AREA	PRMZ_LOG (#665)	REPOSIT PRMZ_LOG (#2133)

Parameter Value: -12.769

Units: log (m^2)

Distribution Type: Constant

Data: Simulated Waste Specific Data and Professional Judgment

The recommended overall waste region permeability is unchanged from the value of 1.7×10^{-13} m^2 derived in the 1991 Preliminary Comparison with 40 CFR 191B (SAND91-0893/3, Volume 3, Section 3.4.7, 3-130 to 3-134). The data supporting the analysis in SAND91-0893/3 is published in Luker et al. (1991), Table 4.1, 700. Luker et al. (1991) supersedes Butcher et al. (1991) cited in SAND91-0893/3.

Discussion:

The data supporting the permeability value of 1.7×10^{-13} m^2 is based on laboratory brine permeability tests involving simulated waste compacted to lithostatic conditions. Luker et al. (1991) reports compacted permeabilities for simulated waste ranging on the order of 10^{-12} to 10^{-16} m^2. Assuming that the volume fractions of waste components are 40 percent combustibles, 40 percent metals/glass and 20 percent sludge, a weighting scheme is used to derive the expected permeability of an average drum. SAND91-0893/3 documents scaling of drum-scale permeability to the effective permeability of a collapsed waste-filled

Parameter(s): Log of Intrinsic Permeability - Waste and Repository Regions

Discussion: (continued)

room. The relatively high permeability value of 1.7×10^{-13} m^2 and low coefficient of variation (1.48×10^{-2} m^2) suggest it is appropriate to assign a constant value to waste region permeability (Butcher 1996).

References:

Butcher, B.M. 1996. QAP 9-2 "Documentation of the Overall Waste Permeability and Flow and Flow Property Values for the CCA." Sandia National Laboratories Memorandum of Record, January, 29, SCWF-A1.1.0.1.2.3; DRM.

Butcher, B.M., T.W. Thompson, R.G. Van Buskiek, and N.C. Patti. 1991. *Mechanical Compaction of Waste Isolation Pilot Plant Simulated Waste.* SAND90-1206. Albuquerque, NM: Sandia National Laboratories.

Luker, R.S., T.W. Thompson, and B.M. Butcher. 1991. "Compaction and Permeability of Simulated Waste," *Rock Mechanics as a Multidisciplinary Science: Proceedings of the 32nd U.S. Symposium, University of Oklahoma, Norman, OK, July 10-12, 1991.* Ed. J-C. Roegiers. SAND90-2368C. Brookfield, VT. 693-702. A.A. Balkema.

WIPP Performance Assessment. 1991. *Preliminary Comparison with 40 CFR 191, Subpart B for the Waste Isolation Pilot Plant, December 1991, Vol. 3: Reference Data.* Eds. R.P. Rechard, A.C. Peterson, J.D. Schreiber, H.J. Iuzzolino, M.S. Tierney, and J.S. Sandia. SAND91-0893/3. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability
Operations and Experimental Regions

Parameter Description:

Intrinsic permeability refers to the hydraulic conductivity of the operations and the experimental regions. These regions correspond to the excavated area between the panel closures and the base of the shaft, and to the excavated drifts and decommissioned experimental area situated north of the shaft, respectively.

Material and Parameter Name(s):

OPS_AREA	PRMX_LOG (#14)	EXP_AREA	PRMX_LOG (#214)
OPS_AREA	PRMY_LOG (#15)	EXP_AREA	PRMX_LOG (#215)
OPS_AREA	PRMZ_LOG (#16)	EXP_AREA	PRMX_LOG (#216)

Parameter Value: -11.0

Units: log (m^2)

Distribution Type: Constant

Data: Professional Judgment

The assignment of permeability to the operational and experimental regions is required for model configuration and is a modeling assumption.

Discussion:

The Operational and Experimental regions are assigned a permeability value of $1.0 \times 10^{-11}\ m^2$ to assure that fluid flow is not impeded from the waste and repository regions to these areas. The value assigned is the highest permeability in the model and is believed to overestimate the expected permeability of a closed excavation containing no waste or backfill.

References:

N/A

Parameter(s): Log of Intrinsic Permeability - Panel Closures

Parameter Description:

Intrinsic permeability of the panel closures refers to the effective hydraulic conductivity of the panel closures designed to control occupational exposure to various waste constituents during the operational period, and to withstand potential flammable conditions resulting from gas generation prior to final facility closure.

Material and Parameter Name(s):

PAN_SEAL	PRMX_LOG (#259)
PAN_SEAL	PRMY_LOG (#260)
PAN_SEAL	PRMZ_LOG (#261)

Parameter Value: -15.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

There has been no direct measurement of the permeability of panel closures as proposed in the conceptual design. However, the materials proposed for the panels possess established properties with predictable performance.

Discussion:

The main component of the panel closure system is a rigid concrete plug, either keyed into the disturbed rock zone (DRZ) through Clay G and MB 139, or emplaced before a DRZ develops around a newly created excavation. Panel closures in the air-intake and air-exhaust drifts will be keyed into the DRZ. The enlarged concrete barrier will consist of four cells emplaced with construction joints perpendicular to the axis of the drifts. Other details of the panel closure design, including grouting at the concrete plug-salt interface, are discussed in DOE (1996).

The 10^{-15} m^2 permeability specified for the panel closure system is assigned a value equal to the permeability of the DRZ. The permeability value is constant, and is consistent with a degraded concrete permeability specified in a time-dependent permeability range used to characterize concrete materials in the shaft (e.g., 10^{-19} $m^2 < k < 10^{-14}$ m^2).

Parameter(s): Log of Intrinsic Permeability - Panel Closures

References:

Department of Energy (DOE). 1996. *Detailed Design Report for an Operational Phase Panel-Closure System*. DOE/WIPP-096-2150. Carlsbad, New Mexico.

Parameter(s): Effective Porosity - Waste and Repository Regions

Parameter Description:

The initial effective porosity of the Waste and Repository regions is used in the BRAGFLO analyses. Porosity is adjusted during the simulation based on the porosity surface calculated by SANTOS to account for pressure-dependent consolidation of the waste by creep closure.

Material and Parameter Name(s):

WAS_AREA	POROSITY (#660)
REPOSIT	POROSITY (#2130)

Parameter Value: 8.48×10^{-1}

Units: None

Distribution Type: Constant

Data: Waste-Specific Observational Data and Professional Judgment

There has been no direct measurement of the effective porosity of a collapsed drum-filled waste disposal room or panel. However, this parameter can be estimated given knowledge of the disposal room configuration and the representative porosity of TRU waste published in the Transuranic Waste Baseline Inventory Report (DOE/CAO 1995).

Discussion:

The initial porosity of the waste panel is derived from assumptions of the disposal room configuration and information about the relative abundance of waste forms and their estimated initial void volumes. The current analyses consider a disposal room containing 6804 drums of uniformly distributed unprocessed waste and no backfill. The disposal room model consists of rectangular room 13 ft (3.96 m) high by 33 ft (10.06 m) wide by 300 ft (91.44 m) long resulting in an initial room volume of 3642.75 m^3.

Stone (1995) reports a waste material porosity of 0.681 calculated from densities of 12 waste material parameters identified in the Transuranic Waste Baseline Inventory Report (DOE/CAO 1995).

Parameter(s): Effective Porosity - Waste and Repository Regions

Discussion: (continued)

Given waste material porosity and disposal room volume, the solid volume of a typical disposal room is calculated to be 551.2 m^3. The initial void volume of the waste room is 3642.75 m^3 - 551.2 m^3 = 3091.55 m^3. The initial disposal region porosity of .848 is calculated as follows:

$$\frac{\text{initial void volume of waste room}}{3091.55\ m^3 + 551.2\ m^3}$$

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO 95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Stone, C.M. 1995. "Proposed Model for the Final Porosity Surface Calculations," Sandia National Laboratories Memorandum of Record to B.M. Butcher, October 27, 1995.

Parameter(s): Effective Porosity - Operations and Experimental Regions

Parameter Description:

The initial effective porosity of the operations and experimental regions must be assigned in the BRAGFLO analyses.

Material and Parameter Name(s):

OPS_AREA	POROSITY (#11)
EXP_AREA	POROSITY (#211)

Parameter Value: 1.8×10^{-1}

Units: None

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

The porosity value for both the Operations and Experimental regions is based on a backfill sensitivity study that modeled the closure behavior of an "equivalent" empty room in the experimental area (Arguello 1994).

Discussion:

The attached figure shows the results of the backfill sensitivity study as a series of curves plotting the ratio of time-dependent void volume to excavated volume against gas pressure for various conditions of gas generation. The results of the backfill study indicate closure is virtually complete at 1,000 years after the room is isolated. The assumption of constant porosity is based on a study that shows that time-dependent closure for the north end of the repository is an unimportant process (FEP DR3, Closure of Unfilled North End). The single value of 0.18 is based on the void volume/excavated volume ratio corresponding to a repository pressure of 7.8 MPa after 10,000 years (Butcher 1996).

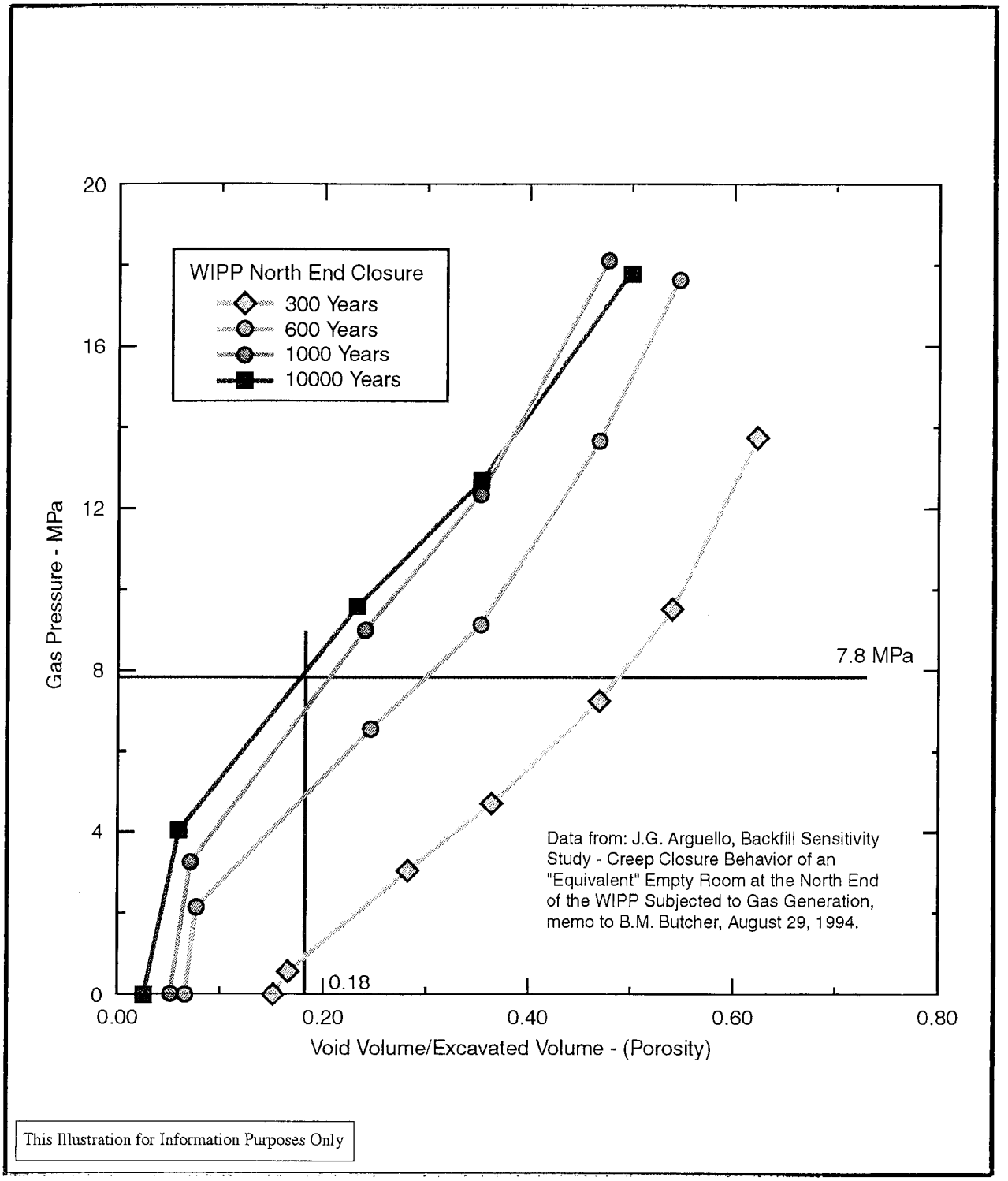

Figure PAR-1. Operations/Experiment Regions n_OPEX.DOC

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Parameter(s): Effective Porosity - Operations and Experimental Regions

References:

Arguello, J.G. 1994. "Backfill Sensitivity Study - Creep Closure Behavior of an Equivalent Empty Room at the North End of the WIPP Subjected to Gas Generation," Sandia National Laboratories Memorandum of Record to B.M. Butcher, August 29, 1994.

Butcher, B.M. 1996. "Porosity of the WIPP North End Excavations," Sandia National Laboratories Memorandum of Record to M.S. Tierney, February 6, 1996.

Parameter(s): Effective Porosity - Panel Closures

Parameter Description:

Effective porosity of the panel closures.

Material and Parameter Name(s):

PAN_SEAL POROSITY (#256)

Parameter Value: 7.5×10^{-2}

Units: None

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

The effective porosity of the panel closures is a modeling assumption.

Discussion:

The conceptual design for the panel closures proposes several component features, including crushed salt backfill, a concrete bulkhead and concrete block retaining walls. The assigned 7.5 percent constant value for panel closure porosity is slightly higher than the 5.0 percent porosity assigned to Salado Mass Concrete proposed for use in the shaft. The value is lower than the constant 18 percent porosity assigned to the Operations and Experimental regions. In general, lower porosity materials provide less potential for gas storage.

References:

N/A

Parameter(s): PCT_A Threshold Pressure Parameter - Repository

Parameter Description:

PCT_A is used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media.

Material and Parameter Name(s):

WAS_AREA	PCT_A (#2805)	OPS_AREA	PCT_A (#2605)
REPOSIT	PCT_A (#2737)	EXP_AREA	PCT_A (#2712)

Parameter Value: 0

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

PCT_A is a modeling assumption.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the correlation established by Davies (1991):

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where PCT_A and PCT_EXP are constants and k is the permeability. Given the relatively unconsolidated and high permeability environment of the waste region, capillary pressure should be zero. Therefore, the threshold pressure linear parameter (PCT_A) is set to zero. The simulation assumes no pressure threshold for flow of gas through any material region in the repository.

Parameter(s): PCT_A Threshold Pressure Parameter - Repository

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter - Panel Closures

Parameter Description:

PCT_A is used to calculate threshold pressure (P_t) as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media

Material and Parameter Name(s):

PAN_SEAL PCT_A (#2732)

Parameter Value: 0.56

Units: Pa/m^2

Distribution Type: Constant

Data: General Literature and Professional Judgment

There are no PCT_A data for panel closures. The linear threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies 1991, 25-26).

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media. P_t is determined from the correlation established by Davies (1991):

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where PCT_A and PCT_EXP are constants and k is the permeability. Use of the Davies correlation is appropriate based on assumed gross similarities between compacted salt backfill and engineered concrete and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter.

Parameter(s): PCT_A Threshold Pressure Parameter - Panel Closures

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Repository

Parameter Description:

PCT_EXP is used to calculate threshold pressure (P_t), a parameter required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media.

Material and Parameter Name(s):

WAS_AREA	PCT_EXP (#2806)	OPS_AREA	PCT_EXP (#2606)
REPOSIT	PCT_EXP (#2737)	EXP_AREA	PCT_EXP (#2713)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

PCT_EXP is a modeling assumption.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the correlation established by Davies (1991):

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where PCT_A and PCT_EXP are constants and k is the permeability. Given the relatively unconsolidated and high permeability environment of the waste region, capillary pressure should be zero. Consequently, as assumed for the threshold pressure linear parameter (PCT_A), PCT_EXP is set to zero. The simulation assumes no pressure threshold for flow of gas through any material region in the repository.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Repository

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Panel Closures

Parameter Description:

PCT_EXP is used to calculate threshold pressure (P_t), a parameter required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media.

Material and Parameter Name(s):

PAN_SEAL PCT_EXP (#2733)

Parameter Value: -0.346

Units: None

Distribution Type: Constant

Data: General Literature and Professional Judgment

PCT_EXP has not been directly measured for panel closures. The exponential threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies 1991, 25-26).

Discussion:

Threshold pressure (P_t) is calculated by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. Use of the Davies correlation is appropriate based on assumed gross similarities between panel closure materials and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter (i.e., relatively tight crystalline textures with interconnected pore space occurring along grain boundaries). Panel closures and halite are assigned the same values for PCT_A and PCT-EXP.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Panel Closures

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Gas Saturation - Repository

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

WAS_AREA	SAT_RGAS (#671)
REPOSIT	SAT_RGAS (#2137)

Parameter Value: 0.075

mean	median	minimum	maximum	units
0.075	0.075	0	0.15	None

Distribution Type: Uniform

Data: General Literature and Professional Judgment

The parameter values are based on a November 15, 1995 Solutions Engineering letter report to D.M. Stoelzel of Sandia National Laboratories entitled "Critical (residual) Gas Saturation Recommendations for WIPP"(Solutions Engineering 1993).

Discussion:

Under conditions of chemical and biochemical gas generation and repository closure, gas saturation may increase to a level where the pore network in repository material regions becomes connected and gas permeability begins to increase. The lowest gas saturation at which continuous gas flow will occur is the residual (critical) gas saturation (S_{gr}). In a review of studies involving S_{gr}, Solutions Engineering (1995) reports values ranging from 0 to 27 percent. The assigned range for S_{gr} between 0 to 15 percent is consistent with recommendations in the Solutions Engineering report. Assigning a constant and relatively low 7.5 percent residual gas saturation facilitates migration of gas through the waste region.

Parameter(s): Residual Gas Saturation - Repository

References:

Solutions Engineering. 1995. "Critical Gas Saturation Recommendations for WIPP." Letter Report to D.M. Stoelzel, Sandia National Laboratories, November 15, 1995, Albuquerque, New Mexico.

Parameter(s): Residual Gas Saturation - Operational and Experimental Regions

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

OPS_AREA	SAT_RGAS (#22)
EXP_AREA	SAT_RGAS (#222)

Parameter Value: 0.0

Units: None

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

SAT_RGAS is a modeling assumption that overestimates migration of the gas phase in the operational and experimental regions.

Discussion:

Residual gas saturation is the gas saturation corresponding to the point on the relative permeability curve above which gas permeability becomes nonzero and gas begins to flow through the porous media. Assigning a zero residual gas saturation assumes no constraint for gas to flow through the operational and experimental regions.

References:

N/A

Parameter(s): Residual Gas Saturation - Panel Closures

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

PAN_SEAL SAT_RGAS (#266)

Parameter Value: 0.2

Units: None

Distribution Type: Constant

Data: General Literature and Professional Judgment

The parameter value is substantiated in a November 15, 1995 Solutions Engineering letter report to D.M. Stoelzel of Sandia National Laboratories entitled "Critical (residual) Gas Saturation Recommendations for WIPP."

Discussion:

S_{gr} is the minimum gas saturation required to create an incipient interconnected system of gas-filled pores, a condition required for initiating nonzero gas phase relative permeability in the material. Solutions Engineering (1995) reports laboratory residual measurements of S_{gr} ranging from 0 to 27 percent. The assigned S_{gr} value of .20 is consistent with the recommendations reported by Solutions Engineering.

References:

Solutions Engineering. 1995. "Critical Gas Saturation Recommendations for WIPP" Letter Report to D.M. Stoelzel, Sandia National Laboratories, November 15, 1995, Albuquerque, New Mexico.

Parameter(s): Residual Brine Saturation - Repository

Parameter Description:

The residual brine saturation (S_{br}) is a parameter of the Brooks-Corey two-phase flow model defining the relative permeability for brine. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation in the waste region corresponds to the brine saturation required to create an incipient interconnected brine-filled pore network in the waste (See Appendix BRAGFLO). Below the S_{br}, brine contained in the effective porosity of the waste is immobile.

Material and Parameter Name(s):

WAS_AREA SAT_RBRN (#670) REPOSIT SAT_RBRN (#2741)

Parameter Value: 0.276

mean	median	minimum	maximum	units
0.276	0.276	0	0.552	None

Distribution Type: Uniform

Data: General Literature and Professional Judgment

Two-phase flow parameters have not been measured for materials representative of a collapsed empty, back-filled, or waste-filled room. A number of literature sources exist for S_{br}; however, the original Brooks and Corey (1964) experimental data are used as the basis for assigning an analog value to the unconsolidated waste region.

To characterize uncertainty, the Brooks and Corey-derived S_{br} is assigned a range from 0 to 0.552. In fact, a nonzero lower bounding S_{br} is believed to be necessary for a material to display relative permeability to the brine phase on a macroscopic scale.

Discussion:

Brooks and Corey evaluated their two-phase characteristic equations against capillary pressure and relative permeability data obtained in laboratory experiments (Brooks and Corey 1964). Mualem (1976) proposed a modified procedure to that of Brooks and Corey for determining the wetting phase permeability curve by adding the constraint that the extrapolated curve should pass through the highest capillary pressure data point.

Parameter(s): Residual Brine Saturation - Repository

Discussion: (continued)

Although their wetting phase relative permeability predictions are similar to each other and to the data, the Mualem procedure, in some cases, results in S_{wr} values less than those predicted by the Brooks and Corey model. Consequently, Table 1 lists the Mualem (1976) residual wetting phase saturations (Swr) to ensure that the potential for brine mobility is not underestimated.

As indicated in Table 1, single-phase liquid permeabilities of the Brooks and Corey materials are similar to those assigned to waste disposal regions (10^{-13} m^2). The selected S_{br} value for the BRAGFLO simulation of .276 is consistent with the fragmented mixture of clay, sandstone and volcanic sand evaluated in the Brooks and Corey study. The lowest S_{br} value of 0.0783 for glass bead materials is considered a reasonable lower bound for assessing brine mobility in the waste region.

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Mualem, Y. 1976. A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media. *Water Resources Research.* Vol. 12, no. 3, 513-522.

Table PAR-1. Brooks and Corey Materials Parameters - Unconsolidated Media[a]

Material	Permeability (m^2)[b]	Porosity	S_{wr}[c]
Volcanic Sand	1.1×10^{-11}	.365	0.137
Fine Sand	2.85×10^{-12}	.360	0.140
Glass Beads	1.05×10^{-11}	.383	0.0783[d]
Fragmented Mixture	1.50×10^{-11}	.441	0.275
Fragmented Fox Hill Sandstone	1.61×10^{-11}	.503	0.318
Touchet Silt Loam	5.00×10^{-13}	.469	0.277
Poudre River Sand	2.26×10^{-11}	.364	0.0824
Amarillo Silty Clay Loam	2.34×10^{-12}	.455	0.242
Consolidated Berea Sandstone	4.81×10^{-13}	.206	0.243
Consolidated Hygiene Sandstone	1.78×10^{-13}	.250	0.560

a - Consolidated materials are identified in the material column
b - Single-phase liquid permeability
c - Mualem S_{wr} corrected for comparison to Brooks and Corey (1964)
d - Considered conservative lower bound; however, for Monte Carlo sampling purposes, zero is assumed.

Swr - Wetting phase residual saturation

Parameter(s): Residual Brine Saturation - Operational and Experimental Regions

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation is used in the second modification of the Brooks and Corey two-phase flow model to calculate the effective saturation (S_e) for the gas and brine phases.

Material and Parameter Name(s):

EXP_AREA SAT_RBRN (#221) OPS_AREA SAT_RBRN (#21)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment and General Engineering Knowledge

SAT_RBRN is a modeling assumption that overestimates migration of the liquid phase in the operational and experimental regions.

Discussion:

Residual brine saturation is the brine saturation corresponding to the point on the relative permeability curve where liquid permeability becomes zero within increasing gas saturation or becomes nonzero with increasing brine saturation. Assigning a zero residual brine saturation assumes no constraint on the flow of the liquid phase through the operational and experimental regions.

References:

N/A

Parameter(s): Residual Brine Saturation - Panel Closures

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{br} is sometimes denoted as S_{wr} (wetting phase) or S_{lr} (liquid phase). (See RBRN_REP.DOC and Appendix BRAGFLO). For brine saturations above S_{br}, brine phase relative permeabiliyt (k_{rw}) increase from a value of zero at the S_{br} to $k_{rw} = 1.0$ for fully saturated conditions.

Material and Parameter Name(s):

PAN_SEAL SAT_RBRN (#265)

Parameter Value: 0.2

Units: None

Distribution Type: Constant

Data: General Literature and Professional Judgment

Two-phase flow parameters have not been measured for panel closure materials.

Discussion:

The conceptual design for the panel closures suggests panel closure materials may include concrete blocks for retaining walls, crushed salt backfill and a concrete bulkhead. The assigned value of 0.2 is at the lower end of the range of 0.08 to 0.56 reported by Brooks and Corey (1964) for several types of porous materials. The value is the same as that used for shaft region materials, and permits incipient brine flow through the panel closures at reasonably low brine saturations.

References:

Brooks, R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Parameter(s): Pore Distribution - Repository

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

WAS_AREA	PORE_DIS (#659)	REPOSIT	PORE_DIS (#2129)

Parameter Value: 2.89

mean	median	minimum	maximum	units
3.25	2.89	1.44	5.78	None

Distribution Type: Cumulative

Data: General Literature and Professional Judgment

Two-phase flow parameters have not been measured for materials representative of a collapsed empty, back-filled or waste-filled room. Consequently, two-phase flow parameters are selected from the literature and assigned as a modeling assumption. Brooks and Corey (1964) is used as the literature reference.

Discussion:

Brooks and Corey (1964) fit capillary pressure data to predict pore size distribution for several types of unconsolidated and consolidated material mixtures. Corey (1990) suggests a common value of about 2.0 for typical porous media. The selected pore size distribution parameter of 2.89 is representative of a fragmented mixture of clay, sandstone and volcanic sand tested in the Brooks and Corey study.

The value of lambda for the repository is larger than values selected for the shaft, panels, operations region, and the Salado. Qualitatively, a larger pore-size distribution parameter reflects a material with uniformly-sized, unclogged interaggregate pores. Materials with a wide range of pore sizes, and/or finer-grained materials, generally exhibit relatively smaller λ values.

Parameter(s): Pore Distribution - Repository

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Corey, A.T. 1990. Mechanics of Immiscible Fluids in Porous Media: Water Resources Publications. Littleton, Colorado.

Parameter(s): Pore Distribution - Operational and Experimental Regions

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

EXP_AREA	PORE_DIS (#210)	OPS_AREA	PORE_DIS (#10)

Parameter Value: 0.70

Units: None

Distribution Type: Constant

Data: General Literature and Professional Judgment

Two-phase flow parameters have not been measured for materials representative of a collapsed empty, back-filled or waste-filled room. Consequently, two-phase flow parameters are selected from the literature.

Discussion:

The pore size distribution parameter value of 0.7 used in the NMVP analysis is based on a study by Morrow et al. (1986) on the Multiwell Tight Gas Sands Project. The parameter value selected for the closed experimental and operational regions falls within the same range of pore size distribution determined experimentally for anhydrites (0.491 to 0.842). See also discussion of PORE_DIS for the repository.

References:

Morrow, N.R., J.S. Ward, and K.R. Brower. 1986. *Rock Matrix and Fracture Analysis of Flow in Western Tight Gas Sands - 1985 Annual Report.* DOE/MC/21179-2032. Socorro, NM: New Mexico Institute of Mining and Technology, New Mexico Petroleum Recovery Research Center.

Parameter(s): Pore Distribution - Panel Closures

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

PAN_SEAL PORE_DIS (#255)

Parameter Value: 0.94

Units: None

Distribution Type: Constant

Data: Professional Judgment

Two-phase flow parameters have not been measured for panel closure materials. The parameter is assigned as a modeling assumption.

Discussion:

The conceptual design for the panel closures suggests panel closure materials may include concrete blocks for retaining walls, crushed salt backfill and a concrete bulkhead. The pore-size distribution parameter is assigned the same value as assigned to all shaft materials. See also discussion in the repository and shaft sections concerning pore-size distribution.

References:

N/A

Parameter(s): Rock Compressibility - Repository

Parameter Description:

Rock compressibility is used in BRAGFLO to calculate pore compressibility to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media.

Material and Parameter Name(s):

WAS_AREA	COMP_RCK (#653)	EXP_AREA	COMP_RCK (#208)
REPOSIT	COMP_RCK (#2112)	OPS_AREA	COMP_RCK (#8)

Parameter Value: 0

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

COMP_RCK is a modeling assumption.

Discussion:

Except for the shaft material regions, COMP_RCK in the parameter database must be divided by material porosity to calculate pore compressibility. Pore compressibility is used in BRAGFLO to evaluate material porosity and mass storage as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

As described in Section 8.2.3.1, repository porosity is evaluated using the SANTOS porosity surface. Consequently, porosity is not adjusted in the repository by the BRAGFLO relation above.

Parameter(s): Rock Compressibility - Repository

References:
N/A

Parameter(s): Pore-Volume Compressibility - Panel Closures

Parameter Description:

Pore compressibility is used in BRAGFLO to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media.

Material and Parameter Name(s):

PAN_SEAL COMP_RCK (#253)

Parameter Value: 2.64×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

COMP_RCK for panel closures is a modeling assumption.

Discussion:

The COMP_RCK value in the parameter data base is usually divided by material porosity to calculate pore compressibility. However, as done for shaft materials, COMP_RCK for panel closures is listed as pore compressibility. Pore compressibility is used in BRAGFLO to evaluate material porosity and mass storage as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where.

- ϕ porosity of solid matrix (dimensionless)
- ϕ_o = porosity at reference pressure p_o
- c_r = pore compressibility of solid matrix (Pa^{-1})

Pore compressibility for the panel closures is assigned on the assumption that the concrete component of the panel closures will have the same pore compressibility as concrete material in the shaft.

References:

N/A

Parameter(s): Maximum Capillary Pressure - All Material Regions

Parameter Description:

Designation of maximum capillary pressure is required in BRAGFLO for two-phase flow modeling. Maximum capillary pressure is assigned the same value for all material regions. See Appendix BRAGFLO for an explanation of the capillary pressure curve defined by the Second Modified Brooks-Corey Model.

Material and Parameter Name(s):

PARAMETER NAME: PC_MAX

MATERIAL NAMES:

WAS_AREA (#658)	REPOSIT (#2242)
EXP_AREA (#209)	OPS_AREA (#9)
PAN_SEAL (#254)	EARTH (#2498)
CLAY_RUS (#3003)	CL_L_T1 (#2329)
CL_L_T2 (#2346)	CL_L_T3 (#2363)
CL_L_T4 (#3073)	CL_M_T1 (#2380)
CL_M_T2 (#2397)	CL_M_T3 (#2414)
CL_M_T4 (#2431)	CL_M_T5 (#2448)
CLAY_BOT (#2312)	CONC_T1 (#2465)
CONC_T2 (#2482)	CONC_MON (#3054)
ASPHALT (#2278)	SALT_T1 (#2515)
SALT_T2 (#2532)	SALT_T3 (#2549)
SALT_T4 (#2566)	SALT_T5 (#2583)
SALT_T6 (#2986)	S_HALITE (#542)
S_ANH_AB (#522)	S_MB138 (#561)
S_MB139 (#582)	DRZ_0 (#176)
DRZ_1 (#193)	CULEBRA (#137)
MAGENTA (#2098)	DEWYLAKE (#156)
SANTAROS (#339)	

Parameter Value: 10^8

Units: Pa

Distribution Type: Constant

Parameter(s): Maximum Capillary Pressure - All Material Regions

Data: Professional Judgment and General Engineering Knowledge

The anhydrite two-phase flow parameter data package retained in Sandia National Laboratories WIPP Central Files shows similar data values for maximum capillary pressure in anhydrite, specifically at conditions reached when the liquid expelled during centrifuge tests became constant. However, the basis of the assigned value is general engineering knowledge. Essentially, the upper bound value selected for all material regions provides an infinite capillary pressure relative to the threshold pressure.

SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters.

Discussion:

For all material regions, the maximum capillary pressure is merely a model configuration assumption required to implement the capillary pressure function defined in the Second Modified Brooks-Corey Model.

References:

N/A

Parameter(s): Relative Permeability Model Number

Parameter Description:

The relative permeability model number parameter is the flag used to select a two-phase flow model for use in BRAGFLO. For the NMVP simulation, the Brooks-Corey model (Choice "4") was used.

Material and Parameter Name(s):

PARAMETER NAME: RELP_MOD

MATERIAL NAMES:

WAS_AREA (# 668)	REPOSIT (#2135)
EXP_AREA (#219)	OPS_AREA (#19)
PAN_SEAL (#264)	EARTH (#2509)
CLAY_RUS (#3012)	CL_L_T1 (#2340)
CL_L_T2 (#2357)	CL_L_T3 (#2374)
CL_L_T4 (#3081)	CL_M_T1 (#2391)
CL_M_T2 (#2408)	CL_M_T3 (#2425)
CL_M_T4 (#2442)	CL_M_T5 (#2459)
CLAY_BOT (#2323)	CONC_T1 (#2476)
CONC_T2 (#2492)	CONC_MON (#3062)
ASPHALT (#2289)	SALT_T1 (#2526)
SALT_T2 (#2543)	SALT_T3 (#2560)
SALT_T4 (#2577)	SALT_T5 (#2594)
SALT_T6 (#2991)	S-HALITE (#553)
S_ANH_AB (#536)	S_MB138 (#575)
S_MB139 (#596)	DRZ_0 (#186)
DRZ_1 (#203)	CULEBRA (#148)
MAGENTA (#2106)	DEWYLAKE (#166)
SANTAROS (#349)	

Parameter Value: 4

mean	median	minimum	maximum	units
4	4	1	4	None

Distribution Type: Delta

Parameter(s): Relative Permeability Model Number

Data: Site-Specific Experimental Data

Site-specific experimental data was collected from whole core taken from six underground boreholes at the WIPP. The specimens first underwent permeability and porosity testing, then subsequent capillary pressure tests. Test data was from Marker Bed 139, and was applied to the other material regions.

Assumptions made during testing were:

(1) Cores were 100 percent saturated at initiation of capillary pressure tests.
(2) Use of a 140° contact angle was appropriate for correcting mercury-air data to brine-air repository conditions.
(3) Although tests were conducted at ambient conditions (no stress), the data is adequate to describe two-phase conditions at stress.

The following data package is associated with the tests:

SWCF-A:1.2.07.1:PDD:QA:SALADO:PKG 10:Salado Anhydrite Two-Phase Parameters

Discussion:

There are several two-phase relative permeability models described in Appendix BRAGFLO, including van Genuchten-Parker and the second modified Brooks-Corey.

Interpretation of the experimental test results showed that either the second modified Brooks-Corey or the van Genuchten-Parker two-phase flow models could be used to describe the data. Because the available evidence supports either model, the DOE selected the second modified Brooks-Corey capillary pressure and relative permeability curves for use in this demonstration.

References:

N/A

Average Stochiometry Gas Generation Model Parameter Values (as summarized in Table 8-3, Chapter 8)

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Parameter(s): Inundated Corrosion Rate for Steel Without CO_2 Present

Parameter Description:

This parameter is used to describe the rate of anoxic steel corrosion under brine inundated conditions and with no CO_2 present (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

STEEL CORRMCO2 (#2907)

Parameter Value: 7.937×10^{-15}

mean	median	minimum	maximum	units
7.937×10^{-15}	7.937×10^{-15}	0	1.587×10^{-14}	m/s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

Without CO_2 present, anoxic steel corrosion will proceed via the reaction: $Fe^{\circ} + 2H_2O = Fe(OH)_2 + H_2$. The upper limit of the parameter is determined from long-term anoxic steel corrosion experiments. The minimum rate is set to zero because of the possibility that salt crystallization on the steel surface could potentially prevent steel corrosion.

References:

Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Humid Corrosion Rate for Steel

Parameter Description:

This parameter is used to describe the rate of anoxic steel corrosion under humid conditions (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

STEEL HUMCORR (#2910)

Parameter Value: 0

Units: m/s

Distribution Type: Constant

Data: Site-Specific Experimental Data

See: Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996. The memo refers to reports by Telander and Westerman (1993) and Telander and Westerman (in review).

Discussion:

The humid corrosion rate for steel is set to zero because the corrosion observed on test specimens exposed to humid conditions was negligible.

References:

Telander, M. R. and Westerman. 1993. *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Progress Report for the Period November 1989 through December 1992*. SAND92-7347. Sandia National Laboratories, Albuquerque, NM.

Telander, M.R. and Westerman, (in review). *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Final Report*.

Parameter(s): Anoxic Corrosion Stoichiometric Factor X

Parameter Description:

X is the stoichiometric factor in the steel corrosion reaction used in the Average-Stoichiometry model: Fe + 4/3 H_2O → 4/3 H_2 + 1/3 Fe_3O_4 (see Section 1.13 of Appendix BRAGFLO.

Material and Parameter Name(s):

STEEL STOIFX (#2898)

Parameter Value: 1.0

Units: None

Distribution Type: Constant

Data: Site-Specific Experimental Data

See: Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

If Fe_3O_4 were to form, it would be expected that H_2 would be produced (on a molar basis) in excess of Fe consumed. But, the anoxic corrosion experiments under expected WIPP conditions did not show the production of H_2 in excess of Fe reacted. Therefore, the stoichiometric factor x is set to 1.0.

References:

Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Biodegradation Rate of Cellulosics Under Humid Conditions

Parameter Description:

This parameter is used to describe the rate of cellulosics biodegradation under anaerobic, humid conditions (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	GRATMICH (#656)
REPOSIT	GRATMICH (#2127)

Parameter Value: 6.342×10^{-10}

mean	median	minimum	maximum	units
6.342×10^{-10}	6.342×10^{-10}	0.0	1.2684×10^{-9}	mol/kg*s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

The maximum rate was estimated from cellulosics-biodegradation experiments under anaerobic, humid conditions. The minimum rate is set to zero, corresponding to the cases where microbes become inactive due to water or nutrient stress.

References:

Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Biodegradation Rate of Cellulosics Under Brine-Inundated Conditions

Parameter Description:

This parameter is used to describe the rate of cellulosics biodegradation under anaerobic, brine-inundated condtions (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	GRATMICI (#657)
REPOSIT	GRATMICI (#2128)

Parameter Value: 4.915×10^{-9}

mean	median	minimum	maximum	units
4.915×10^{-9}	4.915×10^{-9}	3.171×10^{-10}	9.5129×10^{-9}	mol/kg*s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

The maximum rate is estimated from the data obtained from both NO_3^- - and nutrients-amended experiments, whereas the minimum rate is derived from the data obtained from the inoculated-only experiments without any nutrient and NO_3^- amendment. The rates were calculated from the initial linear part of the experimental curve of CO_2 vs. time, by assuming that cellulosics biodegradation in those experiments were nitrate- or nutrient-limited.

References:

Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Factor β for Microbial Reaction Rates

Parameter Description:

Factor β characterizes the extent of microbially-generated gas reacting with steel and steel corrosion products (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

CELLULS FBETA (#2994)

Parameter Value: 0.5

mean	median	minimum	maximum	units
0.5	0.5	0	1.0	None

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

CO_2 and H_2S generated by microbial reactions can be consumed by reaction with steel or steel corrosion product. Factor β is used to characterize the extent of this consumption reaction. $\beta = 0$, if no CO_2 and H_2S are consumed, or $\beta = 1$, if all CO_2 and H_2S are consumed. The median value 0.5 is selected as a reasonable value that represents this chemical process.

References:

Wang, Y., and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Probability of Microbial Degradation of Plastics and Rubbers in the Waste in the Event of Significant Gas Generation

Parameter Description:

This parameter is used to describe the probability of microbial degradation of plastics and rubbers in the waste in the repository in the event of significant gas generation.

Material and Parameter Name(s):

WAS_AREA	PROBDEG (#2823)
REPOSIT	PROBDEG (#2824)

Parameter Value: 2

mean	median	minimum	maximum	units
2	2	0	2	None

Distribution Type: Delta

Data: General Engineering Knowledge-Professional Judgment

Discussion:

Cellulosics, plastics, and rubbers have been identified as the major organic materials to be emplaced in the WIPP repository (DOE/CAO 1996) and could be degraded by microbes in 10,000 years. The occurrence of significant microbial gas generation in the repository will depend on: (1) whether microbes capable of consuming the emplaced organic materials will be present and active; (2) whether sufficient electron acceptors will be present and available; (3) whether enough nutrients will be present and available. The NMVP demonstration conservatively assumes that all cellulosic, plastics, and rubbers are available to degrade and participate in the gas generation process. Biodegradation is considered to have a 50 percent chance of occurring, primarily due to uncertainties in the long-term survival of microbes (Wang and Bush 1996). "Branch 2" (or simply 2) in Figure 2 is chosen as the default (median) value, because it is the case of highest gas generation (Tierney 1996).

Parameter(s): Probability of Microbial Degradation of Plastics and Rubbers in the Waste in the Event of Significant Gas Generation

References:

Alexander, M., 1994. *Biodegradation and Bioremediation.* Academic Press, N.Y.

DOE/CAO, 1996. *Transuranic Waste Baseline Inventory Report* (Rev. 2).

Tierney, M., 1996. Memorandum to File, Re: Reasons for choice of the PROBDEG parameter (id nos. 2824 and 2823) on February 22, 1996, March 29, 1996.

Wang, Y. And L. Brush, 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Probability of Microbial Degradation of Plastics and Rubbers in the Waste in the Event of Significant Gas Generation

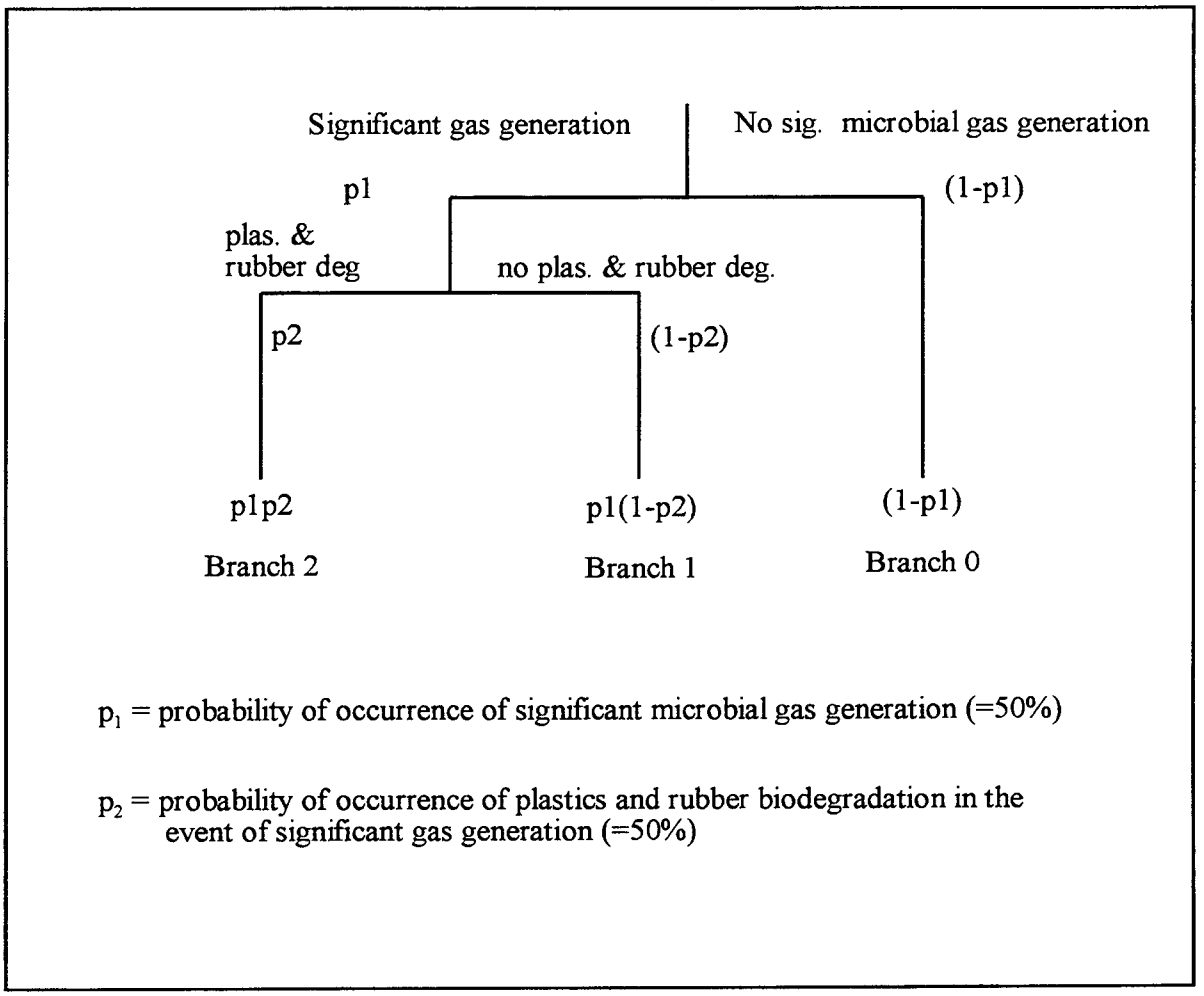

Figure PAR-2. Logic Diagram for Possible Outcomes and Probabilities for the Parameter PROBDEG.

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Parameter(s): Average Density of Cellulosics in Contact-Handled Waste

Parameter Description:

The average density of cellulosics in CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DCELLCHW (#2041)
REPOSIT	DCELLCHW (#2113)

Parameter Value: 54.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of cellulosics in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Cellulosics in Remote-Handled Waste

Parameter Description:

The average density of cellulosics in RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DCELLRHW (#2274)
REPOSIT	DCELLRHW (#2114)

Parameter Value: 17.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of cellulosics in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Iron-Based Materials in Contact-Handled Waste

Parameter Description:

The average density of iron-based materials in CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRONCHW (#2040)
REPOSIT	DIRONCHW (#2117)

Parameter Value: 170.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of iron-based materials in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Iron-Based Material in Remote-Handled Waste

Parameter Description:

The average density of iron-based materials in RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRONRHW (#2044)
REPOSIT	DIRONRHW (#2118)

Parameter Value: 100.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of iron-based materials in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Plastics in Contact-Handled Waste

Parameter Description:

The average density of plastics in CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DPLASCHW (#2043)
REPOSIT	DPLASCHW (#2119)

Parameter Value: 34.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of plastics in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Plastics in Remote-Handled Waste

Parameter Description:

The average density of plastics in RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DPLASRHW (#2275)
REPOSIT	DPLASRHW (#2120)

Parameter Value: 15.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of plastics in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Rubber in Contact-Handled Waste

Parameter Description:

The average density of rubber materials in CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DRUBBCHW (#2042)
REPOSIT	DRUBBCHW (#2122)

Parameter Value: 10.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of rubber materials in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Average Density of Rubber in Remote-Handled Waste

Parameter Description:

The average density of rubber materials in RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DRUBBRHW (#2046)
REPOSIT	DRUBBRHW (#2123)

Parameter Value: 3.3

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the average density of rubber materials in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Bulk Density of Steel Containers in Contact-Handled Waste

Parameter Description:

The bulk density of steel containers in CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRNCCHW (#1992)
REPOSIT	DIRNCCHW (#2115)

Parameter Value: 139.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the bulk density of steel containers in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Bulk Density of Steel Canisters Plus Steel Plugs in Remote-Handled Waste

Parameter Description:

The bulk density of steel canisters plus the steel plug in RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRNCRHW (#1993)
REPOSIT	DIRNCRHW (#2116)

Parameter Value: 2,591.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the bulk density of steel canisters in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams. This average density of steel is equal to that of the remote-handled canisters (446 kg/m^3) plus that of the steel plugs (2,145 kg/m^3).

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Bulk Density of Plastic Liners in Contact-Handled Waste

Parameter Description:

The bulk density of plastic liners in CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DPLSCCHW (#1995)
REPOSIT	DPLSCCHW (#2121)

Parameter Value: 26.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the bulk density of plastic liners in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Bulk Density of Plastic Liners in Remote-Handled Waste

Parameter Description:

The bulk density of plastic liners in RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA DPLSCRHW (#2228)

Parameter Value: 3.1

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Discussion:

The value provided in DOE/CAO (1995) for the bulk density of plastic liners in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report, Revision 2.* DOE/CAO-95-1121. Carlsbad, NM: Carlsbad Area Office Technical Assistance Contractor for U.S. Department of Energy.

Parameter(s): Total Volume of Remote-Handled Waste

Parameter Description:

The total volume of RH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	VOLRHW (#2233)
REPOSIT	VOLRHW (#2142)

Parameter Value: 7,080.0

Units: m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE (U.S. Department of Energy) and State of New Mexico (1981, originally). Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Discussion:

The value for the total volume of remote-handled waste was identified in the Agreement for Consultation and Cooperation between DOE and the State of New Mexico on the WIPP.

References:

DOE (U.S. Department of Energy) and State of New Mexico (1981, originally). Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Parameter(s): Total Volume of Contact-Handled Waste

Parameter Description:

The total volume of CH-TRU waste; this value is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	VOLCHW (#2232)
REPOSIT	VOLCHW (#2141)

Parameter Value: 1.69×10^5

Units: m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: Public Law 102-579, 102d Congress, October 30, 1992, Waste Isolation Pilot Plant Land Withdrawal Act; Section 7, subpart (a)(3) and DOE (U.S. Department of Energy) and State of New Mexico (1981 originally), Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Discussion:

The value for the total volume of contact-handled waste is the total volume identified in the Land Withdrawal Act (1992) minus the volume of remote-handled waste identified in the Agreement for Consultation and Cooperation between DOE and the State of New Mexico on the WIPP.

References:

Public Law 102-579, 102d Congress. October 30, 1992. Waste Isolation Pilot Plant Land Withdrawal Act; Section 7, subpart (a)(3).

Parameter(s): Total Volume of Contact-Handled Waste

References: (continued)

DOE (U.S. Department of Energy) and State of New Mexico (1981, originally). Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Parameter(s): Wicking Saturation

Parameter Description:

The wicking saturation in the waste is used in the gas generation model (see Section 1.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	SATWICK (#2231)
REPOSIT	SATWICK (#2138)

Parameter Value: 0.5

mean	median	minimum	maximum	units
0.5	0.5	0	1.0	None

Distribution Type: Uniform

Data: Professional Judgment

Discussion:

Wicking is the ability of a material to carry a fluid by capillary action above the level it would normally seek in response to gravity. The use of a two-phase Darcy flow model in BRAGFLO includes possible effects of capillary action, but uncertainty remains about the extent to which the assumed homogeneous properties of the waste adequately characterize wicking. Because estimated rates of gas generation are higher for waste that is in direct contact with brine, brine saturation in the repository is adjusted in BRAGFLO to account for the possibility of wicking in the waste. This adjusted brine saturation is used only for calculating gas generation.

The adjustment is done as follows:

$S_{b,}eff = S_b + S_{w,}$

and

$S_{b,}eff \quad 1.0,$

where S_b is the brine saturation in the waste calculated by BRAGFLO, S_w is the wicking saturation that describes the additional amount of brine that may be present and in contact

Parameter(s): Wicking Saturation

Discussion: (continued)

with the waste because of wicking, and $S_{b,eff}$ is the effective brine saturation used to determine the gas generation rates used in the analysis. The wicking saturation is assigned a constant value of 0.5 for this analysis.

References:

N/A

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Shaft Material Parameter Values (as summarized in Table 8-4, Chapter 8)

All Shaft Materials

Clay Shaft Material

Salt Shaft Materials

Concrete and Concrete Monolith Shaft Materials

Asphalt Shaft Material

Earthen Fill Shaft Material

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Residual Brine Saturation - All Shaft Materials

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. For brine saturations above the S_{br}, brine phase relative permeability (k_{rw}) slowly increases from a value of zero at the S_{br} to $k_{rw} = 1.0$ for fully brine-saturated conditions.

Material and Parameter Name(s):

EARTH	SAT_RBRN (#2511)
CLAY_RUS	SAT_RBRN (#3014)
CL_L_T1	SAT_RBRN (#2342)
CL_L_T2	SAT_RBRN (#2359)
CL_L_T3	SAT_RBRN (#2376)
CL_L_T4	SAT_RBRN (#3082)
CL_M_T1	SAT_RBRN (#2393)
CL_M_T2	SAT_RBRN (#2427)
CL_M_T4	SAT_RBRN (#2444)
CL_M_T5	SAT_RBRN (#2461)
CLAY_BOT	SAT_RBRN (#2325)
CONC_T1	SAT_RBRN (#2478)
CONC_T2	SAT_RBRN (#2494)
CONC_MON	SAT_RBRN (#3063)
ASPHALT	SAT_RBRN (#2291)
SALT_T1	SAT_RBRN (#2528)
SALT_T2	SAT_RBRN (#2545)
SALT_T3	SAT_RBRN (#2562)
SALT_T4	SAT_RBRN (#2579)
SALT_T5	SAT_RBRN (#2596)
SALT_T6	SAT_RBRN (#2992)

Parameter Value: 0.20

Parameter(s): Residual Brine Saturation - All Shaft Materials

mean	median	minimum	maximum	units
0.25	0.20	0	0.60	None

Distribution Type: Cumulative

Data: General Literature-Professional Judgment

A literature review is documented in the shaft material parameter records package.

Discussion:

The shaft materials group conducted an extensive literature search to obtain residual liquid saturation values for consolidated geologic materials, concrete, and asphalt. Residual liquid saturations for geologic materials were found in four references (Brooks and Corey 1964; Lappala et al. 1987; Parker et al. 1987; and Rawls et al. 1982). Brooks and Corey (1964) determined residual saturations for five unconsolidated samples based on measured values of liquid saturation as a function of capillary pressure. Lappala et al. (1987) determined residual moisture content for 11 soils by obtaining best fits to measured moisture content versus pressure head data using three models. The residual moisture contents determined for each soil using the three models were averaged and divided by the reported porosity to obtain a residual liquid saturation for each soil. Parker et al. (1987) fit their saturation-pressure relationship to observed data to obtain residual saturations for a sandy and clayey porous media. Residual water contents reported by Rawls et al. (1982) for 11 soil texture classes were divided by the reported porosity to obtain residual saturations.

Mayer et al. (1992) reported a residual liquid saturation for normal concrete of 0.30 based on gas permeability testing. Data regarding residual liquid saturations in asphalt materials were not found in the literature.

Based on the above literature review, the residual brine saturation (S_{br}) is assigned a parameter range from 0 to 0.60. Because residual brine saturation is not an especially sensitive parameter (i.e., S_{br} does not affect BRAGFLO calculations unless the S_{br} is reached in the shaft), the median value from the distribution is used to characterize all shaft materials.

References:

Brooks, R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

References: (continued)

Lappala, E.G., R.W. Healy, and E.P. Weeks. 1987. *Documentation of Computer Program VS2D to Solve the Equations of Fluid Flow in Variably Saturated Porous Media.* Water-Resources Investigations Report 83-4099. Denver, CO: U.S. Geological Survey.

Mayer, G., F. Jacobs, and F.H. Wittmann. 1992. "Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," *Nuclear Engineering and Design.* Vol. 138, no. 2, 171-177.

Parker, J.C., R.J. Lenhard, and T. Kuppusamy. 1987. "A Parametric Model for Constitutive Properties Governing Multiphase Flow in Porous Media," *Water Resources Research.* Vol. 23, no. 4, 618-624.

Rawls, W.J., D.L. Brakensiek, and K.E. Saxton. 1982. "Estimation of Soil Water Properties," *Transactions of the ASAE.* St. Joseph, MI: American Society of Agricultural Engineers. 1316-1328.

Parameter(s): Residual Gas Saturation - All Shaft Materials

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{gr} is the minimum gas saturation above which relative permeability (k_{rg}) to the gas phase becomes nonzero and begins to increase to $k_{rg} = 1.0$ at 100 percent gas saturation.

Material and Parameter Name(s):

EARTH	SAT_RGAS (#2512)
CLAY_RUS	SAT_RGAS (#3015)
CL_L_T1	SAT_RGAS (#2343)
CL_L_T2	SAT_RGAS (#2360)
CL_L_T3	SAT_RGAS (#2377)
CL_L_T4	SAT_RGAS (#3083)
CL_M_T1	SAT_RGAS (#2394)
CL_M_T2	SAT_RGAS (#2411)
CL_M_T3	SAT_RGAS (#2428)
CL_M_T4	SAT_RGAS (#2445)
CL_M_T5	SAT_RGAS (#2462)
CLAY_BOT	SAT_RGAS (#2326)
CONC_T1	SAT_RGAS (#2479)
CONC_T2	SAT_RGAS (#2495)
CONC_MON	SAT_RGAS (#3064)
ASPHALT	SAT_RGAS (#2292)
SALT_T1	SAT_RGAS (#2529)
SALT_T2	SAT_RGAS (#2546)
SALT_T3	SAT_RGAS (#2563)
SALT_T4	SAT_RGAS (#2580)
SALT_T5	SAT_RGAS (#2597)
SALT_T6	SAT_RGAS (#2993)

Parameter Value: 0.20

Parameter(s): Residual Gas Saturation - All Shaft Materials

mean	median	minimum	maximum	units
0.20	0.20	0	0.40	None

Distribution Type: Uniform

Data: General Literature-Professional Judgment

A literature review is documented in the shaft material parameter records package (WP030640).

Discussion:

The shaft materials group conducted a literature search to obtain residual gas saturation (S_{gr}) values for consolidated geologic materials, concrete, and asphalt. Mayer et al. (1992) reported a residual gas saturation for normal concrete of 0.18 based on gas permeability testing. Literature values for residual gas saturation of asphalt were not found. Based on a review of the literature, Solutions Engineering (1995) reports S_{gr} values ranging from 0-27 percent obtained by field and laboratory studies on geologic and man-made materials. An expected value and range are assumed for all seal components. The expected value of 0.2 is consistent with the value used for the panel closures.

References:

Mayer, G., F. Jacobs, and F.H. Wittmann. 1992. "Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," *Nuclear Engineering and Design*. Vol. 138, no. 20, 171-177.

Solutions Engineering. 1995. "Critical Gas Saturation Recommendations for WIPP" Letter Report to D.M. Stoelzel, Sandia National Laboratories, November 15, 1995. Albuquerque, NM.

Parameter(s): Pore Distribution - All Shaft Materials

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

EARTH	PORE_DIS (#2499)
CLAY_RUS	PORE_DIS (#3006)
CL_L_T1	PORE_DIS (#2330)
CL_L_T2	PORE_DIS (#2347)
CL_L_T3	PORE_DIS (#2364)
CL_L_T4	PORE_DIS (#3076)
CL_M_T1	PORE_DIS (#2381)
CL_M_T2	PORE_DIS (#2398)
CL_M_T3	PORE_DIS (#2415)
CL_M_T4	PORE_DIS (#2432)
CL_M_T5	PORE_DIS (#2449)
CLAY_BOT	PORE_DIS (#2313)
CONC_T1	PORE_DIS (#2466)
CONC_T2	PORE_DIS (#2483)
CONC_MON	PORE_DIS (#3057)
ASPHALT	PORE_DIS (#2279)
SALT_T1	PORE_DIS (#2516)
SALT_T2	PORE_DIS (#2533)
SALT_T3	PORE_DIS (#2550)
SALT_T4	PORE_DIS (#2567)
SALT_T5	PORE_DIS (#2809)
SALT_T6	PORE_DIS (#2989)

Parameter Value: 0.94

Parameter(s): Pore Distribution - All Shaft Materials

mean	median	minimum	maximum	units
2.52	0.94	0.11	8.1	None

Distribution Type: Cumulative

Data: General Literature-Professional Judgment

Data is based on a review of the available literature.

Discussion:

A literature search was conducted to find pore distribution (i.e., lambda) values for geologic materials and concrete. For geologic materials, 81 lambda values were found in five references (Brooks and Corey 1964; Mualem 1976; Rawls et al. 1982; Haverkamp and Parlange 1986; and Lappala et al. 1987). In addition, 38 lambda values were calculated from values of the van Genuchten parameter n found in six references (van Genuchten 1980; van Genuchten and Nielsen 1985; Hopmans and Overmars 1986; Parker et al. 1987; Stephens et al. 1988; and Wosten and van Genuchten 1988).

The total number of lambda values found in the literature or calculated from n values found in the literature was 119. In a few cases, different literature sources reported different values of lambda and/or n for the same materials. For this situation, the different lambda values were arithmetically averaged to obtain a single value for the material. This procedure yielded lambda values for a total of 85 different geologic materials.

Brooks and Corey (1964) report lambda values for five unconsolidated samples and two consolidated samples determined by fitting to observed capillary pressure curves. Lambda values for 42 soils determined by fitting to observed drainage data are presented in Mualem (1976). Rawls et al. (1982) give lambda values for the 11 USDA soil texture classes. They fit the measured water retention-matrix potential data reported in 26 sources and averaged within texture classes. Haverkamp and Parlange (1986) report lambda values for ten sandy soils. They estimated the value of lambda using the cumulative particle-size distribution function. Lambda values determined by fitting to experimental data for 11 soils are given in Lappala et al. (1987).

van Genuchten (1980) reports n values for five soils. These values were determined by fitting his model to measured conductivity curves. Values of n for four soils determined by fitting to observed data are given in van Genuchten and Nielsen (1985). Hopmans and Overmars (1986) determined n values for a Norfolk sandy loam at two soil temperatures by fitting to experimental data. Parker et al. (1987) report n values for a sandy porous

Discussion: (continued)

media and a clayey porous media which they determined by fitting to observed data. Stephens et al. (1988) determined five n values for three stratigraphic units underlying the IT Corporation's Imperial Valley Facility located in southern California. The n values were determined by fitting to the data obtained from in-situ field testing. A single n value was determined for two units and three n values were determined for a third stratified unit. The latter were for individual clay and silt layers and for the composite unit. Observed hydraulic conductivity and water retention data from soils in the Netherlands were used by Wosten and van Genuchten (1988) to obtained n values. They report 20 average n values for 105 coarse-textured samples, 43 medium-textured samples, and 49 fine-textured samples.

For concrete, a literature search yielded only one reference (Mayer et al. 1992). This reference indicates that the Corey (1954) relationships are appropriate for describing the two-phase characteristic curves for the normal concretes they tested. For asphalt materials, data regarding lambda values were not found in the literature.

Based on the above background research, the shaft materials parameter records package reports a range for lambda between 0.11 and 11.67 and interprets the data as lognormally distributed. The record package median value of 0.94 is preserved in the cumulative distribution defined for the simulation and is used for all shaft materials.

References:

Brooks, R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Corey, A.T. 1954. "The Interrelation Between Gas and Oil Relative Permeabilities," *Producer's Monthly.* Vol. XIX, no. 1, 38-41

Haverkamp, R., and J.Y. Parlange. 1986. "Predicting the Water-Retention Curve From Particle-Size Distribution: 1. Sandy Soils Without Organic Matter," *Soil Science.* Vol. 142, no. 6, 325-339.

References: (continued)

Hopmans, J.W., and B. Overmars. 1986. "Presentation and Application of an Analytical Model to Describe Soil Hydraulic Properties," *Journal of Hydrology.* Vol. 87, no. 1-2, 135-143.

Lappala, E.G., R.W. Healy, and E.P. Weeks. 1987. *Documentation of Computer Program VS2D to Solve the Equations of Fluid Flow in Variably Saturated Porous Media.* Water-Resources Investigations Report 83-4099. Denver, CO: U.S. Geological Survey.

Mayer, G., F. Jacobs, and F.H. Wittmann. 1992. "Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," *Nuclear Engineering and Design.* Vol. 138, no. 2, 171-177.

Mualem, Y. 1976. "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research.* Vol.12, no. 3, 513-522.

Parker, J.C., R.J. Lenhard, and T. Kuppusamy. 1987. "A Parametric Model for Constitutive Properties Governing Multiphase Flow in Porous Media," *Water Resources Research.* Vol. 23, no. 4, 618-624.

Rawls, W.J., D.L. Brakensiek, and K.E. Saxton. 1982. "Estimation of Soil Water Properties," *Transactions of the ASAE.* 1316-1328. St. Joseph, MI: American Society of Agricultural Engineers.

Stephens, D.B., M. Unruh, J. Havlena, R.G. Knowlton, Jr., E. Mattson, and W. Cox. 1988. "Vadose Zone Characterization of Low-Permeability Sediments Using Field Permeameters," *Ground Water Monitoring Review.* Vol. 8, no. 2, 59-66.

van Genuchten, M. Th. 1980. "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," *Soil Science Society of America Journal.* Vol. 44, no. 5, 892-898.

van Genuchten, M. Th., and D.R. Nielsen. 1985. "On Describing and Predicting the Hydraulic Properties of Unsaturated Soils," *Annales Geophysicae.* Vol. 3, no. 5, 615-628.

Wosten, J.H.M., and M. Th. van Genuchten. 1988. "Using Texture and Other Soil Properties to Predict the Unsaturated Soil Hydraulic Functions," *Soil Science Society of America Journal.* Vol. 52, no. 6, 1762-1770.

Parameter(s): PCT_A Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

EARTH	PCT_A (#2707)
CLAY_RUS	PCT_A (#3004)
CL_L_T1	PCT_A (#2642)
CL_L_T2	PCT_A (#2647)
CL_L_T3	PCT_A (#2652)
CL_L_T4	PCT_A (#3074)
CL_M_T1	PCT_A (#2657)
CL_M_T2	PCT_A (#2662)
CL_M_T3	PCT_A (#2667)
CL_M_T4	PCT_A (#2672)
CL_M_T5	PCT_A (#2677)
CLAY_BOT	PCT_A (#2637)
CONC_T1	PCT_A (#2682)
CONC_T2	PCT_A (#2687)
CONC_MON	PCT_A (#3055)
SALT_T1	PCT_A (#2745)
SALT_T2	PCT_A (#2750)
SALT_T3	PCT_A (#2755)
SALT_T4	PCT_A (#2760)
SALT_T5	PCT_A (#2765)
SALT_T6	PCT_A (#2987)

Parameter Value: 0.56

Units: Pa/m^2

Parameter(s): PCT_A Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Distribution Type: Constant

Data: General Literature - Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Shaft Materials.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

For consolidated material, literature values for the coefficient range from 3×10^{-7} to 9×10^{-7} and literature values for the exponent range from -0.34 to -0.37 (Davies 1991). The literature correlations separately considered carbonate, anhydrite, shale, and sandstone materials. Davies (1991) constructed a best-fit power curve to the combined data for all lithologies to obtain:

$$P_t = 5.6 \times 10^7 k^{0.346}$$

where P_t is the threshold pressure in MPa and k is the intrinsic permeability in m^2.

For intrinsic permeabilities less than 10^{-17} m^2, Davies (1991) found the threshold pressures estimated using the capillary tube model to be less accurate than those estimated using the intrinsic permeability correlations.

Pihlajavaara (1991) conducted gas permeability tests on normal concretes under wet conditions. Based on the results of 23 tests, he developed a relationship between threshold pressure and permeability. His results cover a threshold pressure range of about 10 to 0.3 MPa and a permeability range of about 10^{-21} to 10^{-18} m^2. The results of Pihlajavaara (1991) were compared to the threshold pressure-permeability correlation given in Davies (1991) above. Using, the calculated threshold pressures for permeabilities of 10^{-21}, 10^{-20}, 10^{-19}, and 10^{-18} m^2 are 10.3, 4.7, 2.1, and 0.9 MPa, respectively. These calculated values fall within the experimental data from Pihlajavaara (1991) for

Parameter(s): PCT_A Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Discussion: (continued)

permeabilities between 10^{-20} and 10^{-18} m^2. It appears, however, that the experimental threshold pressure data of Pihlajavaara (1991) is limited for low permeability. This suggests that the correlation between threshold pressure and permeability given in the Davies equation is appropriate to use for the concrete seal materials as well as for seal components based on geologic materials.

Based on Davies (1991) work, the correlation between the threshold pressure and the intrinsic permeability given in the above equation is recommended for determination of the threshold pressure for all seal materials in future performance assessment calculations. The expected value and distribution for the threshold pressure will, therefore, be controlled by the expected value and distribution for the intrinsic permeability for each seal material.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Pihlajavaara, S.E. 1991. "Long-Term Gas Permeability Properties of Concrete in Wet Repository Conditions," *Nuclear Engineering and Design.* Vol. 129, no. 1, 41-48.

Parameter(s): PCT_EXP Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

EARTH	PCT_EXP (#2708)
CLAY_RUS	PCT_EXP (#3005)
CL_L_T1	PCT_EXP (#2643)
CL_L_T2	PCT_EXP (#2648)
CL_L_T3	PCT_EXP (#2653)
CL_L_T4	PCT_EXP (#3075)
CL_M_T1	PCT_EXP (#2658)
CL_M_T2	PCT_EXP (#2663)
CL_M_T3	PCT_EXP (#2668)
CL_M_T4	PCT_EXP (#2673)
CL_M_T5	PCT_EXP (#2678)
CLAY_BOT	PCT_EXP (#2638)
CONC_T1	PCT_EXP (#2683)
CONC_T2	PCT_EXP (#2688)
CONC_MON	PCT_EXP (#3056)
SALT_T1	PCT_EXP (#2746)
SALT_T2	PCT_EXP (#2751)
SALT_T3	PCT_EXP (#2756)
SALT_T4	PCT_EXP (#2761)
SALT_T5	PCT_EXP (#2766)
SALT_T6	PCT_EXP (#2988)

Parameter Value: -0.346

Units: None

Parameter(s): PCT_EXP Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Distribution Type: Constant

Data: General Literature - Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Shaft Materials.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

For consolidated material, literature values for the coefficient range from 3×10^{-7} to 9×10^{-7} and literature values for the exponent range from -0.34 to -0.37 (Davies 1991). The literature correlations separately considered carbonate, anhydrite, shale, and sandstone materials. Davies (1991) constructed a best-fit power curve to the combined data for all lithologies to obtain:

$$P_t = 5.6 \quad 10^7 k^{0.346}$$

where P_t is the threshold pressure in MPa and k is the intrinsic permeability in m^2.

For intrinsic permeabilities less than 10^{-17} m^2, Davies (1991) found the threshold pressures estimated using the capillary tube model to be less accurate than those estimated using the intrinsic permeability correlations.

Pihlajavaara (1991) conducted gas permeability tests on normal concretes under wet conditions. Based on the results of 23 tests, he developed a relationship between threshold pressure and permeability. His results cover a threshold pressure range of about 10 to 0.3 MPa and a permeability range of about 10^{-21} to 10^{-18} m^2. The results of Pihlajavaara (1991) were compared to the threshold pressure-permeability correlation given in Davies (1991) above. The calculated threshold pressures for permeabilities of 10^{-21}, 10^{-20}, 10^{-19}, and 10^{-18} m^2 are 10.3, 4.7, 2.1, and 0.9 MPa, respectively. These calculated

Parameter(s): PCT_EXP Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Discussion: (continued)

values fall within the experimental data from Pihlajavaara (1991) for permeabilities between 10^{-20} and 10^{-18} m^2. It appears, however, that the experimental threshold pressure data of Pihlajavaara (1991) is limited for low permeability. This suggests that the correlation between threshold pressure and permeability given in the Davies equation is appropriate to use for the concrete seal materials as well as for seal components based on geologic materials.

Based on Davies (1991) work, the correlation between the threshold pressure and the intrinsic permeability given in the above equation is recommended for determination of the threshold pressure for all seal materials in future performance assessment calculations. The expected value and distribution for the threshold pressure will, therefore, be controlled by the expected value and distribution for the intrinsic permeability for each seal material.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Pihlajavaara, S.E. 1991. "Long-Term Gas Permeability Properties of Concrete in Wet Repository Conditions," *Nuclear Engineering and Design.* Vol. 129, 41-48.

Parameter(s): Log of Intrinsic Permeability - All Clay Shaft Materials

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the Rustler compacted clay, the lower Salado compacted clay, and the upper Salado compacted clay, and the bottom clay column from 0 to 10,000 yrs.

Material and Parameter Name(s):

CLAY_RUS	PRMX_LOG (#3009)
CLAY_RUS	PRMY_LOG (#3010)
CLAY_RUS	PRMZ_LOG (#3011)
CL_L_T1	PRMX_LOG (#2334)
CL_L_T1	PRMY_LOG (#2335)
CL_L_T1	PRMZ_LOG (#2336)
CL_L_T2	PRMX_LOG (#2351)
CL_L_T2	PRMY_LOG (#2352)
CL_L_T2	PRMZ_LOG (#2353)
CL_L_T3	PRMX_LOG (#2368)
CL_L_T3	PRMY_LOG (#2369)
CL_L_T3	PRMZ_LOG (#2370)
CL_L_T4	PRMX_LOG (#3078)
CL_L_T4	PRMY_LOG (#3079)
CL_L_T4	PRMZ_LOG (#3080)
CL_M_T1	PRMX_LOG (#2385)
CL_M_T1	PRMY_LOG (#2386)
CL_M_T1	PRMZ_LOG (#2387)
CL_M_T2	PRMX_LOG (#2402)
CL_M_T2	PRMY_LOG (#2403)
CL_M_T2	PRMZ_LOG (#2404)
CL_M_T3	PRMX_LOG (#2419)
CL_M_T3	PRMY_LOG (#2420)
CL_M_T3	PRMZ_LOG (#2421)
CL_M_T4	PRMX_LOG (#2436)
CL_M_T4	PRMY_LOG (#2437)
CL_M_T4	PRMZ_LOG (#2438)

Parameter(s): Log of Intrinsic Permeability - All Clay Shaft Materials

Material and Parameter Name(s): (continued)

CL_M_T5	PRMX_LOG (#2453)
CL_M_T5	PRMY_LOG (#2454)
CL_M_T5	PRMZ_LOG (#2455)
CLAY_BOT	PRMX_LOG (#2317)
CLAY_BOT	PRMY_LOG (#2318)
CLAY_BOT	PRMZ_LOG (#2319)

Parameter Value: -18.3010

mean	median	minimum	maximum	units
-18.8670	-18.3010	-21.0000	-17.3010	$\log(m^2)$

Distribution Type: Triangular

Data: General Literature - Professional Judgment and Site-Specific Experimental Data

Data is based on a review of the available literature and a series of small-scale in-situ tests.

Discussion:

A significant body of literature regarding compacted bentonite permeability was reviewed. Most literature sources report hydraulic conductivity rather than intrinsic permeability. Hydraulic conductivity can be related to intrinsic permeability through the fluid density and viscosity and the acceleration of gravity. The permeability of reported bentonites ranges from 1×10^{-21} m^2 to 1×10^{-15} m^2.

A series of in-situ tests were conducted to evaluate the feasibility of various candidate materials to be used for sealing materials at the WIPP Site. These tests are referred to as the Small Scale Seal Performance Tests (SSSPT). Results from these tests support the use of compacted bentonite as a sealing material at the WIPP Site and in the Salado Formation. Test Series D tested two 100 percent bentonite vertical seals emplaced in vertical boreholes within the Salado Formation at the repository horizon. The diameter of each seal was 2.9 ft (0.91 m) and the length of each seal was 2.9 ft (0.91 m). Cores of the two bentonite seals had initial dry densities of 1.8 and 2.0 g/cm^3. Pressure differentials of 0.72 and 0.32 MPa were maintained across the bentonite seals with a brine

Discussion: (continued)

reservoir on the upstream (bottom) of the seals for several years. Over the course of the seal test, no visible brine was observed at the downstream end of the seals. Because the saturation state of the bentonite seals is unknown, determination of the absolute permeability of the bentonite seals cannot be estimated precisely. However, a bounding calculation of permeability was reported by Knowles and Howard (1996) for the bentonite seals of 1×10^{-19} m^2.

The compacted bentonite material specification in the Compliance Submittal Design Report (in review) specifies that the clay seals will be emplaced at a dry density of 1.8 to 2.0 g/cm^3. Based upon this information, a distribution function for clay permeability was developed. The basis for the proposed distribution is the following:

(1) A practical minimum for the distribution can be specified at 1×10^{-21} m^2.

(2) Assuming that the effective dry density of the bentonite emplaced in the seals only varies from 1.8 to 2.0 g/cm^3, then a maximum expected permeability can be extrapolated as 1×10^{-19} m^2.

(3) The material specification does require that the bentonite be emplaced at a high density, between 1.8 and 2.0 g/cm^3. However, the effective dry density of emplacement is somewhat uncertain. Uncertainty exists in being able to emplace mass columns of bentonite at such high densities. To address this uncertainty, it is assumed that the compacted clay may be emplaced at a dry density as low as 1.6 g/cm^3. This actuality is not considered to be a high probability, but cannot be completely ruled out. At 1.6 g/cm^3, the maximum permeability for the clay would be approximately 5×10^{-19} m^2. Therefore, assuming no salinity effects, a range of permeability from 1×10^{-21} to 5×10^{-19} m^2 with a best estimate of less than 1×10^{-19} m^2 is defined (assuming a best estimate emplacement density of 1.8 g/cm^3). It could be argued that the best estimate could be as low as 2×10^{-20} m^2.

(4) The literature reports that salinity increases permeability. However, these effects are greatly reduced at the emplacement densities specified for the shaft seal. At seawater salinities, Pusch et al. (1987) report the effects on permeability could be as much as a factor of 5 (one-half of an order of magnitude). Salinity effects are currently uncertain at the WIPP.

(5) To account for salinity effects, the maximum permeability is increased from 5×10^{-19} to 5×10^{-18} m^2. The best estimate permeability is increased by one-half order of magnitude to 5×10^{-19} m^2. The lower limit is held at 1×10^{-21} m^2. Because salinity effects are greatest at higher densities, the maximum is adjusted one full order of magnitude while the best estimate (assumed to reside at a density of 1.8 g/cm^3) is adjusted one-half of an order.

Discussion: (continued)

The effective seal/DRZ permeabilities for the clay shaft materials are calculated from the equation

$$k_{model} = \frac{k_s A_s + k_d A_d}{A_{model}}$$

where: k_{model} = effective seal/DRZ permeability used in BRAGFLO
A_{model} = effective shaft area modeled in BRAGFLO (equal to the shaft area, A_s)
k_s = average shaft seal permeability (given in this parameter sheet)
A_s = average shaft area
k_d = average DRZ permeability (SHFT_DRZ PRMX_LOG in PA database)
A_d = average DRZ area

Assuming that the change in permeability within the DRZ is log linear, the effective DRZ permeability, k_d, is calculated from:

$$k_d = \frac{2}{r_o + r_i}\left[\left(\frac{r_o(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_o - \left(\frac{r_i(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_i\right]$$

where: r_i = inner radius (shaft excavation radius)
r_o = outer DRZ radius
Δr = outer DRZ radius minus the inner DRZ radius
k_i = inner skin permeability (DRZ permeability at the shaft/DRZ interface)
k_o = intact halite permeability

The average DRZ permeability is calculated from:

$$k_d A_d = k_{d1} A_{d1} + k_{d2} A_{d2} + k_{d3} A_{d3} + k_{d4} A_{d4}$$

where: d1 = air-supply shaft
d2 = salt-handling shaft
d3 = waste-handling shaft
d4 = air-exhaust shaft

and the average seal permeability is calculated from

$$k_s A_s = k_{s1} A_{s1} + k_{s2} A_{s2} + k_{s3} A_{s3} + k_{s4} A_{s4}$$

Parameter(s): Log of Intrinsic Permeability - All Clay Shaft Materials

Discussion: (continued)

The resulting effective seal/DRZ permeabilities for the clay shaft materials are given below:

Clay Layer	Time Period (yrs)	Intrinsic Permeability (m^2)
Rustler	0 - 10,000	5.00×10^{-19}
Upper Salado	0 - 10	7.65×10^{-17}
Upper Salado	10 - 25	5.02×10^{-17}
Upper Salado	25 - 50	3.02×10^{-17}
Upper Salado	50 - 100	1.16×10^{-17}
Upper Salado	> 100	5.00×10^{-17}
Lower Salado	0 - 10	9.32×10^{-17}
Lower Salado	10 - 25	1.74×10^{-17}
Lower Salado	25 - 50	7.07×10^{-19}
Lower Salado	> 50	5.00×10^{-19}
Bottom Clay	0 - 10,000	5.00×10^{-19}

References:

Compliance Submittal Design Report, in review. Appendix A: Material Specifications. Albuquerque, NM: Sandia National Laboratories.

Knowles, M.K., and C.L. Howard. 1996. "Field and Laboratory Testing of Seal Materials Proposed for the Waste Isolation Pilot Plant," *Proceedings of the Waste Management 1996-Symposium,* Tucson, AZ, February 25-29, 1996. SAND95-2082. Albuquerque, NM: Sandia National Laboratories.

Pusch, R., L. Borgesson, and G. Ramqvist. 1987. *Final Report of the Borehole, Shaft, and Tunnel Sealing Test -- Volume I: Borehole Plugging.* SKB 87-01. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management Co.

Parameter(s): Effective Porosity - All Clay Shaft Materials

Parameter Description:

Effective porosity of the Rustler compacted clay, the lower Salado compacted clay, and the upper Salado compacted clay, and the bottom clay column from 0 to 10,000 yrs.

Material and Parameter Name(s):

CLAY_RUS	POROSITY (#3007)
CL_L_T1	POROSITY (#2331)
CL_L_T2	POROSITY (#2348)
CL_L_T3	POROSITY (#2365)
CL_L_T4	POROSITY (#3077)
CL_M_T1	POROSITY (#2382)
CL_M_T2	POROSITY (#2399)
CL_M_T3	POROSITY (#2416)
CL_M_T4	POROSITY (#2433)
CL_M_T5	POROSITY (#2450)
CLAY_BOT	POROSITY (#2314)

Parameter Value: 0.24

Units: m^3/m^3

Distribution Type: Constant

Data: Professional Judgment

The effective porosity was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The porosity of natural unconsolidated clays can vary from 0.4 to 0.8 (Freeze and Cherry 1979). Consolidated clay formations such as shales have much smaller porosities ranging from 0.01 to 0.4 (Touloukian et al. 1981). The compacted clay seal will be composed of sodium bentonite.

Discussion: (continued)

The specific gravity of a commercial bentonite (Volclay GPG-30) is 2.5 (Ran and Daemen 1995). The expected water content of the compacted clay may vary from 0.1 to 0.12 (Hansen 1995). The dry density of the compacted clay is specified to be from 1.8 to 2.0 g/cm^3 (Compliance Submittal Design Report, in review). Based upon estimates of the compacted clay water content, dry density, and specific gravity, the porosity of the compacted clay can be calculated. The calculated void ratio of the compacted clay varies from 0.25 to 0.39 and the corresponding porosity varies from 0.2 to 0.28. An average value of 0.24 is chosen as the compacted clay total porosity. Diamond (1970) found that the effective porosity of montmorillonites was approximately 35 percent less than the calculated porosity. Therefore, a constant value of 0.24 for effective porosity is very conservative.

References:

Diamond, S. 1970. "Pore Size Distributions in Clays," *Clays & Clay Minerals*. Vol. 18, no. 1, 7-23.

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Compliance Submittal Design Report, in review. Appendix A: Material Specifications. Albuquerque, NM: Sandia National Laboratories.

Hansen, F.D. 1995. Memorandum to T. Jones, INTERA Inc., November 30, 1995.

Ran, C., and J. Daemen. 1995. "Bentonite Properties with Corrections." Memorandum to F. Hansen, Sandia National Laboratories, December 4, 1995.

Touloukian, Y.S., W.R. Judd, and R.F. Roy. 1981. *Physical Properties of Rocks and Minerals*. Volume II-2 of McGraw-Hill/Cindas Data Series on Material Properties, Eds. Y.S. Touloukian and C.Y. Ho. New York, NY: McGraw-Hill Book Company.

Parameter(s): Pore-Volume Compressibility - Rustler Clay

Parameter Description:

Pore-volume compressibility of the Rustler compacted clay column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CLAY_RUS COMP_RCK (#3001)

Parameter Value: 1.96×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

The bulk modulus of the Rustler clay column will not change as a function of time because the Rustler will not creep in towards the shaft after closure. Therefore, the initial (emplaced) bulk modulus of 2.129×10^{9} Pa (RE/SPEC 1995) was used to calculate the Rustler clay column compressibility. Assuming a compacted clay porosity of 0.24, the pore-volume compressibility is 1.96×10^{-9} Pa^{-1} for the Rustler compacted clay column.

References:

RE/SPEC. 1995. "Transmittal of Bulk Modulus Values for Various Sealing Materials." Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Pore-Volume Compressibility - Upper Salado Clay

Parameter Description:

Pore-volume compressibility of the upper Salado compacted clay column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CL_M_T1	COMP_RCK (#2379)
CL_M_T2	COMP_RCK (#2396)
CL_M_T3	COMP_RCK (#2413)
CL_M_T4	COMP_RCK (#2430)
CL_M_T5	COMP_RCK (#2447)

Parameter Value: 1.81×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

The bulk modulus is reported to be 2.297×10^{9} Pa for the Upper Salado compacted clay component at 150 years (RE/SPEC 1995). The pore-volume compressibility will be treated as a constant in the BRAGFLO simulations. Therefore, the bulk modulus value at 150 years has been used to calculate the seal compressibility. Assuming a compacted clay porosity of 0.24, the pore-volume compressibility is 1.81×10^{-9} Pa^{-1} for the Upper Salado compacted clay.

Parameter(s): Pore-Volume Compressibility - Upper Salado Clay

References:

RE/SPEC. 1995. "Transmittal of Bulk Modulus Values for Various Sealing Materials." Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Pore-Volume Compressibility - Lower Salado and Bottom Clays

Parameter Description:

Pore-volume compressibility of the lower Salado compacted clay and the bottom clay column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CL_L_T1	COMP_RCK (#2328)
CL_L_T2	COMP_RCK (#2345)
CL_L_T3	COMP_RCK (#2362)
CL_L_T4	COMP_RCK (#3071)
CLAY_BOT	COMP_RCK (#2311)

Parameter Value: 1.59×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

The bulk modulus is reported to be 2.627×10^{9} Pa for the Lower Salado compacted clay column at 150 years (RE/SPEC 1995). The pore-volume compressibility will be treated as a constant in the BRAGFLO simulations. Therefore, the bulk modulus value at 150 years has been used to calculate the seal compressibility. Assuming a compacted clay porosity of 0.24, the pore-volume compressibility is 1.59×10^{-9} Pa^{-1} for the Lower Salado compacted clay column.

Parameter(s): Pore-Volume Compressibility - Lower Salado and Bottom Clays

References:

RE/SPEC. 1995. "Transmittal of Bulk Modulus Values for Various Sealing Materials." Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column during the first 50 yrs.

Material and Parameter Name(s):

SALT_T1	PMLT_MD (#2940)
SALT_T2	PMLT_MD (#2948)
SALT_T3	PMLT_MD (#2956)

Parameter Value: -14.7825

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

Brodsky (1994) measured permeability as part of a comprehensive study to characterize both the consolidation characteristics and permeability of WIPP crushed salt. A total of 16 brine permeability tests were performed in the study including 15 tests performed on crushed salt specimens consolidated by Brodsky (1994) and one test performed on a crushed salt specimen. All tests were performed using brine as the permeant and specimens having nominal dimensions of 3.9 in. (100 mm) in diameter by 7.8 in. (200 mm) in length. The brine was manufactured by saturating distilled water with WIPP crushed salt ground to a fine powder. Saturation of the brine was assumed when salt precipitated out of solution. The permeability tests were performed using a brine-filled accumulator located on the upstream side of the specimen to induce brine pressure gradients that ranged from 0.05 MPa to 2.01 MPa and a buret located on the downstream side of the specimen to measure flow. In all tests, the flow-versus-time curves were nonlinear with higher flow rates measured early in the test and lower rates measured later in the test. The permeabilities reported by Brodsky (1994) represent values calculated from the high flow rates measured during the early portion of each test. These data show that permeability decreases as the fractional density increases.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Discussion: (continued)

Hansen and Ahrens (1996) have reported gas permeability measurements from testing performed as part of a large-scale dynamic compaction demonstration using WIPP crushed salt. In this test, about 1,412 ft^3 (40 m^3) of WIPP crushed salt was placed in a steel cylindrical chamber and compacted in three lifts by dropping a 19,845-lb (9,000-kg) weight 49 ft (15 m) in a systematic pattern to achieve an input energy of three times Modified Proctor Energy. The chamber had a diameter of 12 ft (3.65 m) and a height of 12 ft (3.65 m). Each lift was 3.9 ft (1.2 m) in original thickness and sufficient water was added to the lifts to bring the moisture content of the crushed salt up to about 1.0 percent (by weight). After the mass was compacted, seven vertical test holes were drilled into the compacted crushed salt to recover cores for density determinations and also to provide access for in situ gas permeability equipment. The fractional density of the compacted mass was determined to be about 0.88. A total of 14 permeability measurements were made in the test holes with a reported average permeability of 9.0×10^{-14} m^2.

RE/SPEC (1996) performed permeability tests on specimens prepared from cores recovered from the large-scale dynamic compaction test (described above) and from two small-scale dynamic compaction tests performed earlier (Hansen et al. 1995). The specimens tested were nominally 3.9 in. (100 mm) in diameter with lengths that varied from 3.9 in. to 7.8 in. (100 mm to 200 mm). The tests were performed with nitrogen gas using a steady-state flow technique. Pressure gradients of 0.345 MPa or smaller were used in each test and rotameter flowmeters were used to measure gas flow rates. The specimens were confined with a pressure of 1 MPa during the permeability measurements. A total of 13 tests were performed including seven tests on specimens recovered from the large-scale dynamic compaction test, two tests on specimens from the first small-scale dynamic compaction test, and four tests on specimens from the second small-scale dynamic compaction test. The density of each specimen was determined before the permeability test was conducted. The data from these test are included in the attached table.

The effective seal/DRZ permeabilities for the salt shaft materials are calculated from the equation

$$k_{model} = \frac{k_s A_s + k_d A_d}{A_{model}}$$

where: k_{model} = effective seal/DRZ permeability used in BRAGFLO
A_{model} = effective shaft area modeled in BRAGFLO (equal to the shaft area, A_s)
k_s = average shaft seal permeability (given in this parameter sheet)
A_s = average shaft area
k_d = average DRZ permeability (SHFT_DRZ PRMX_LOG in PA database)
A_d = average DRZ area

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Discussion: (continued)

Assuming that the change in permeability within the DRZ is log linear, the effective DRZ permeability, k_d, is calculated from:

$$k_d = \frac{2}{r_o + r_i}\left[\left(\frac{r_o(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_o - \left(\frac{r_i(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_i\right]$$

where:
- r_i = inner radius (shaft excavation radius)
- r_o = outer DRZ radius
- Δr = outer DRZ radius minus the inner DRZ radius
- k_i = inner skin permeability (DRZ permeability at the shaft/DRZ interface)
- k_o = intact halite permeability

The average DRZ permeability is calculated from:

$$k_d A_d = k_{d1} A_{d1} + k_{d2} A_{d2} + k_{d3} A_{d3} + k_{d4} A_{d4}$$

where:
- d1 = air-supply shaft
- d2 = salt-handling shaft
- d3 = waste-handling shaft
- d4 = air-exhaust shaft

and the average seal permeability is calculated from

$$k_s A_s = k_{s1} A_{s1} + k_{s2} A_{s2} + k_{s3} A_{s3} + k_{s4} A_{s4}$$

The permeability data summarized above were transformed into logarithmic space (base 10) and plotted as a function of fractional density by RE/SPEC (1996). In this transformed (semi-log) space, the permeability-versus-fractional density data exhibited a linear trend over the range of densities investigated. Therefore, an empirical linear model was fitted to the semi-log data to relate permeability to fractional density (RE/SPEC 1996). Because of the scatter associated with the laboratory data, three predictor intervals were determined; i.e., (1) the 80 percent interval bounded by the 10 and 90 percent predictor limits, (2) the 90 percent interval bounded by the 5 and 95 percent predictor limits, and (3) the 98 percent interval bounded by the 1 and 99 percent predictor limits. The predictor interval incorporates both the error from the fitted model and the error associated with future observations. It was shown that the 90 percent interval contained nearly all of the laboratory data.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Discussion: (continued)

Chieslar (1996) performed structural calculations using the finite element analysis code, **SPECTROM-32**, to calculate the density of the crushed salt placed in the WIPP Air Intake Shaft as a function of time. These predictions and the correlation between permeability and fractional density developed by RE/SPEC (1996) were used to predict permeability as a function of time. Upper and lower bound permeabilities were established at each time using the 90 percent predictor interval and assuming the upper bound corresponded to the 95 percent prediction limit and the lower bound corresponded to the five percent prediction limit. The assumed distribution function for intrinsic permeability (i.e., log triangular) used the upper and lower bounds and the most probable value as the distribution parameters.

The resulting effective seal/DRZ permeabilites for the salt shaft materials are:

TIME PERIOD (yrs)	INTRINSIC PERMEABILITY (m^2)
0-50	10^{-14}
50-100	7×10^{-17}
100-200	10^{-18}
200-400	3.3×10^{-21}
> 400	10^{-21}

References:

Brodsky, N.S. 1994. *Hydrostatic and Shear Consolidation Tests With Permeability Measurements on Waste Isolation Pilot Plant Crushed Salt.* SAND93–7058. Albuquerque, NM: Sandia National Laboratories.

Hansen, F.D. and E.H. Ahrens. 1996. "Large-Scale Dynamic Compaction Demonstration Using WIPP Salt: Fielding and Preliminary Results," *Proceedings of the 4th Conference on the Mechanical Behavior of Salt, Montreal, Quebec, Canada, June.*

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

References: (continued)

Hansen, F.D., E.H. Ahrens, V.C. Tidwell, J.R. Tillerson, and N.S. Brodsky. 1995. "Dynamic Compaction of Salt: Initial Demonstration and Performance Testing," *Rock Mechanics, Proceedings of the 35th U.S. Symposium on Rock Mechanics, University of Nevada, Reno, NV, June 5–7, 1995*. Eds. J.J.K. Taemer and R.A. Schultz. SAND94-2131C. Brookfield, VT: A.A. Balkema. 755-760.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment*. Calculation No. 325/13/02. February 1996. Rapid City, SD: RE/SPEC Inc.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Table PAR-2. Summary of Permeability Measurements for WIPP Crushed Salt

Specimen Identification No.	Fractional Density[a]	Permeability (m^2)	Reference
HC1A	0.8953	6.34 E-18	
HC2A	0.9377	4.88 E-18	
HC3A	0.9333	2.14 E-19	
HC4A	0.9272	1.37 E-19	
HC5A	0.9907	3.42 E-22	
HC6A	0.9907	1.00 E-20	
SC1B	0.9546	3.54 E-19	
SC2A	0.9788	1.23 E-18	
SC3A	0.9607	3.22E-19	Brodsky 1994
SC4A	0.9428	5.18 E-19	
SC5A	1.0051	6.90 E-19	
SC6A	0.9678	2.56 E-20	
SC7A	0.9691	9.24 E-20	
SC8A	0.9629	1.29 E-19	
SC9A	0.9804	3.31 E-20	
19JUN90	0.9709	5.77 E-20	
In Situ	0.8800	9.00 E-14	Hansen and Ahrens 1996
CS/DC1-4-1/3/1	0.9026	2.50 E-15	
CS/DC1-8-3	0.8644	2.43 E-13	
CS/DC2/MM-1/1	0.8782	1.71 E-13	
CS/DC2/MM-2/1	0.8220	4.11 E-13	
CS/DC2/T2S-1/1	0.8626	5.71 E-13	
CS/DC2/T2S-3/2	0.8349	1.10 E-12	
DCCS3/3/3-1	0.8892	7.88 E-14	RE/SPEC 1996
DCCS3/2/1-1	0.9012	4.99 E-14	
DCCS3/1/1-4	0.8886	5.51 E-14	
	0.9007	4.99 E-14	
DCCS3/3/1-4	0.9160	2.63 E-14	
	0.9289	4.58 E-15	
	0.9339	4.95 E-15	

(a) Fractional density is based on an intact salt density of 2,160 kg m^{-3}.

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column during the first 50 yrs.

Material and Parameter Name(s):

SALT_T1	PMLT_LO (#2941)
SALT_T2	PMLT_LO (#2949)
SALT_T3	PMLT_LO (#2957)

Parameter Value: -17.301

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column during the first 50 yrs.

Material and Parameter Name(s):

SALT_T1	PMLT_HI (#2942)
SALT_T2	PMLT_HI (#2950)
SALT_T3	PMLT_HI (#2958)

Parameter Value: -12.2652

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 50-100 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column from 50 to 100 yrs.

Material and Parameter Name(s):

SALT_T4 PMLT_MD (#2964)

Parameter Value: -17.1656

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T = 50-100 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column from 50-100 yrs.

Material and Parameter Name(s):

SALT_T4 PMLT_LO (#2965)

Parameter Value: -22.8761

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T = 50-100 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column from 50 to 100 yrs.

Material and Parameter Name(s):

SALT_T4 PMLT_HI (#2966)

Parameter Value: -13.9508

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 100-200 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column from 100 to 200 yrs.

Material and Parameter Name(s):

SALT_T5 PMLT_MD (#2973)

Parameter Value: -19.2782

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T= 100 -200 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column from 100-200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_LO (#2981)

Parameter Value: -22.8761

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T=100-200 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column from 100-200 yrs.

Material and Parameter Name(s):

SALT_T5 PMLT_HI (#2974)

Parameter Value: -15.4260

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T > 200 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column after 200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_MD (#2980)

Parameter Value: -20.2716

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T > 200 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column after 200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_LO (#2981)

Parameter Value: -22.8761

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T > 200 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column after 200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_HI (#2982)

Parameter Value: -17.6676

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Effective Porosity - Salt Shaft Material

Parameter Description:

Effective porosity of the compacted salt column.

Material and Parameter Name(s):

SALT_T1	POROSITY (#2517)
SALT_T2	POROSITY (#2534)
SALT_T3	POROSITY (#2551)
SALT_T4	POROSITY (#2568)
SALT_T5	POROSITY (#2990)
SALT_T6	POROSITY (#2990)

Parameter Value: 0.05

Units: m^3/m^3

Distribution Type: Constant

Data: Professional Judgment

The effective porosity was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

Data used in the development of transient best estimators for effective porosity are based on predictions of crushed salt density with time and subsequent calculation of porosity. Density predictions of the crushed salt column midheight have been made by Chieslar (1996). Porosity values determined from these density predictions are given in the attached table.

The porosity of the emplaced crushed-salt column is initially about 0.10 and is reduced to about 0.01 after the crushed salt reconsolidates because of the creep deformation of the salt surrounding the shaft. Therefore, a mean porosity over this consolidation time is about 0.05, which is the value selected as the best estimator.

Parameter(s): Effective Porosity - Salt Shaft Material

References:

Chieslar, J.D. 1996. *Material Property (Permeability, Bulk Moduli) Determination for Material WIPP Shaft Seals/Components, Calculation File 325/13/01*. Albuquerque, NM: Sandia National Laboratories. Rapid City, SD: RE/SPEC Inc.

Table PAR-3. Best Estimators for Porosity of Compacted Crushed Salt

Time After Seal Emplacement (years)	Density[a] ($kg\ m^{-3}$)	Porosity (percent)
0	1,944	10.0
50	2,038	5.6
100	2,121	1.8
200	2,160	1.0[b]
400	2,160	1.0[b]

(a) After Chieslar (1996).
(b) Equal to the porosity of Salado salt.

Parameter(s): Pore-Volume Compressibility - Salt Shaft Material

Parameter Description:

Pore-volume compressibility of the compacted salt column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

SALT_T1	COMP_RCK (#2514)
SALT_T2	COMP_RCK (#2531)
SALT_T3	COMP_RCK (#2548)
SALT_T4	COMP_RCK (#2565)
SALT_T5	COMP_RCK (#2582)
SALT_T6	COMP_RCK (#2984)

Parameter Value: 1.60×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

The bulk modulus of crushed salt has been measured in the laboratory at different levels of density by Holcomb and Hannum (1982); however, these measurements were performed on crushed salt obtained from the Mississippi Chemical Co. mine rather than from the WIPP. Although Holcomb and Hannum (1982) did not compare the bulk moduli of Mississippi Chemical Co. crushed salt and WIPP crushed salt directly, they did perform paired quasi-static compression tests on both materials and concluded that their respective quasi-static behaviors was similar.

Parameter(s): Pore-Volume Compressibility - Salt Shaft Material

Discussion: (continued)

RE/SPEC (1996) performed limited testing on specimens prepared from cores recovered from a large-scale dynamic compaction test (Hansen and Ahrens, 1996). The objectives of the testing were to (1) evaluate the elastic behavior of the dynamically compacted salt, and (2) to obtain bulk modulus at fractional densities ranging from 0.9 to 1.0. Bulk modulus values were obtained as a function of density from a single test specimen by subjecting the specimen to repeated stages of hydrostatic consolidation followed by hydrostatic unload/reload cycles. The stages of hydrostatic consolidation were performed at hydrostatic stresses that ranged from 10 to 15 MPa and were conducted to induce changes in density. The hydrostatic unload/reload cycles were performed to obtain data appropriate for calculating bulk modulus. The data from these tests are summarized in Table 4 along with the values of bulk modulus reported by Holcomb and Hannum (1982). The data indicate that the nonlinear elastic model for bulk modulus proposed by Sjaardema and Krieg (1987) is a reasonably good approximation both for Mississippi Chemical Co. crushed salt and for dynamically-compacted WIPP crushed salt.

References:

Hansen, F.D., and E.H. Ahrens. 1996. "Large-Scale Dynamic Compaction Demonstration Using WIPP Salt: Fielding and Preliminary Results," *Proceedings of the 4th Conference on the Mechanical Behavior of Salt, Montreal, Quebec, Canada, June.*

Holcomb, D.J., and D.W. Hannum. 1982. *Consolidation of Crushed Salt Backfill Under Conditions Appropriate to the WIPP Facility.* SAND82-0630. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment. Calculation No. 325/13/02.* February 1996. Rapid City, SD: RE/SPEC Inc.

Sjaardema, G.D., and R.D. Krieg. 1987. *A Constitutive Model for the Consolidation of WIPP Crushed Salt and Its Use in Analyses of Backfilled Shaft and Drift Configurations.* SAND87-1977. Albuquerque, NM: Sandia National Laboratories.

Table PAR-4. Summary of Crushed Salt Bulk Modulus Values

Specimen Identification No.	Dry Density (kg m^{-3})	Bulk Modulus (GPa)
24MAY82[a]	1,540	0.562
	1,620	0.855
	1,670	1.269
	1,720	1.381
	1,760	1.823
	1,790	1.557
	1,830	1.938
	1,870	2.290
	1,900	2.700
DCCS3/3/1-4[b]	1,978	9.640
	2,006	11.300
	2,017	12.180

(a) Mississippi Chemical Co. Crushed salt [Holcomb and Hannum 1982].
(b) Dynamically compacted WIPP crushed salt (test performed by RE/SPEC Inc. 1996)

Parameter(s): Log of Intrinsic Permeability - Concrete (T = 0-400 yrs)

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the concrete column during the first 400 yrs.

Material and Parameter Name(s):

CONC_T1	PRMX_LOG (#2470)
CONC_T1	PRMY_LOG (#2471)
CONC_T1	PRMZ_LOG (#2472)

Parameter Value: -18.7496

mean	median	minimum	maximum	units
-18.8160	-18.7496	-20.699	-17.000	$\log(m^2)$

Distribution Type: Triangular

Data: Site-Specific Experimental Data

The intrinsic permeability of the concrete column is based on laboratory and *in situ* data.

Discussion:

As reported in the Compliance Submittal Design Report (in review), traditional fresh-water concrete has been widely used for hydraulic applications such as water storage tanks, water and sewer systems, and massive dams because it has exceptionally low permeability (less than 10^{-20} m^2 upon hydration). Salado Mass Concrete (SMC) is a specially-designed salt-saturated concrete mix that has been developed recently (Wakeley et al. 1994; Wakeley et al. 1995).

RE/SPEC (1996) performed two permeability tests on concrete specimens prepared from cores recovered from the WIPP SSSPT field experiments and one test on an SMC specimen prepared from a sample batched by the Waterways Experiment Station (WES). The specimens were tested as received with no attempts made to dry the specimens or to determine their moisture contents. Each test was performed using nitrogen gas as the permeant, flowmeters to measure gas flow, and fluid pressure gradients of either 0.3, 0.6,

Discussion: (continued)

or 0.75 MPa. Attempts were made to apply Klinkenberg corrections to measured values of permeability, but the range in pressure gradients used in the testing was not large enough to establish any particular trend when the permeability data were plotted as a function of reciprocal mean fluid pressure.

A total of 18 permeability measurements were made on the three specimens. Permeability of the SMC and SSPT specimens are all very low with a range from 2.1×10^{-21} m^2 to 7.51×10^{-21} m^2 with an average of 4.71×10^{-21} m^2. Permeability of the SSSPT specimens ranged from 3.00×10^{-20} m^2 to 5.04×10^{-19} m^2 with and average of 2.18×10^{-19} m^2. Knowles and Howard (1996) presented results of field permeability tests performed in the WIPP SSSPT boreholes during 1985–1987 and 1993–1995. Although individual seal system component material permeabilities for concrete, DRZ salt, and salt were not determined, overall seal system permeabilities were determined and ranged from 1.0×10^{-20} m^2 to 1.0×10^{-17} m^2 and from 1.0×10^{-23} m^2 to 1.0×10^{-19} m^2 for the 1985–1987 tests and the 1993–1995 tests, respectively. These ranges encompass the laboratory values measured by RE/SPEC (1996).

References:

Compliance Submittal Design Report, in review. Appendix A: Material Specifications. Albuquerque, NM: Sandia National Laboratories.

Knowles, M.K., and C.L. Howard. 1996. "Field and Laboratory Testing of Seal Materials Proposed for the Waste Isolation Pilot Plant." *Proceedings of the Waste Management 1996 Symposium, Tucson, AZ, February 25-29, 1996.* SAND95-2082C. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment.* Calculation No. 325/13/02. February 1996. Rapid City, SD: RE/SPEC Inc.

Wakeley, L.D., T.S. Poole, and J.P. Burkes. 1994. *Durability of Concrete Materials in High-Magnesium Brine.* SAND93-7073. Albuquerque, NM: Sandia National Laboratories.

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete.* SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Concrete (T > 400 yrs) and Concrete Monolith (T = 0 - 10,000 yrs)

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the concrete column after 400 yrs. and the concrete monolith at the base of the shaft from 0 to 10,000 yrs.

Material and Parameter Name(s):

CONC_T2	PRMX_LOG (#2486)
CONC_T2	PRMY_LOG (#2487)
CONC_T2	PRMZ_LOG (#2488)
CONC_MON	PRMX_LOG (#3059)
CONC_MON	PRMY_LOG (#3060)
CONC_MON	PRMZ_LOG (#3061)

Parameter Value: -14.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

The long-term intrinsic permeability value for concrete materials is not explicitly based on laboratory data. The parameter value is conservatively assigned; no credit is taken for the expected performance of concrete materials in the shaft over the long-term.

Discussion:

Traditional fresh-water concrete has been widely used for hydraulic applications such as water storage tanks, water and sewer systems, and massive dams because it has exceptionally low permeability (less than 10^{-20} m^2 upon hydration). RE/SPEC (1996) performed two permeability tests on concrete specimens prepared from cores recovered from the WIPP SSSPT field experiments and one test on a Salado Mass Concrete (SMC) specimen prepared from a sample batched by the Waterways Experiment Station (WES).

Permeability of the SMC specimens ranges from 2.1×10^{-21} m^2 to 7.51×10^{-21} m^2 with an average of 4.71×10^{-21} m^2. Permeability of the SSSPT specimens ranged from 3.00×10^{-20} m^2 to 5.04×10^{-19} m^2 with an average of 2.18×10^{-19} m^2. Knowles and Howard

Parameter(s): Log of Intrinsic Permeability - Concrete (T > 400 yrs) and Concrete Monolith (T = 0 - 10,000 yrs)

Discussion: (continued)

(1996) have also determined overall seal system permeabilities ranging from 1.0×10^{-20} m^2 to 1.0×10^{-17} m^2 and from 1.0×10^{-23} m^2 to 1.0×10^{-19} m^2 for 1985-1987 tests and the 1993-1995 tests, respectively.

Attachment IA of Appendix CLP discusses the expected long-term performance of shaft concrete materials.

References:

Knowles, M.K., and C.L. Howard. 1996. "Field and Laboratory Testing of Seal Materials Proposed for the Waste Isolation Pilot Plant." *Proceedings of the Waste Management 1996 Symposium, Tucson, AZ, February 25-29, 1996.* SAND95-2082C. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment.* Calculation No. 325/13/02. February 1996. Rapid City, SD: RE/SPEC Inc.

Wakeley, L.D., T.S. Poole, and J.P. Burkes. 1994. *Durability of Concrete Materials in High-Magnesium Brine*. SAND93-7073. Albuquerque, NM: Sandia National Laboratories.

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete*. SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Effective Porosity - Concrete and Concrete Monolith

Parameter Description:

Effective porosity of the concrete column and the concrete monolith at the base of the shaft.

Material and Parameter Name(s):

CONC_T1	POROSITY (#2467)
CONC_T2	POROSITY (#2484)
CONC_MON	POROSITY (#3058)

Parameter Value: 0.05

Units: m^3/m^3

Distribution Type: Constant

Data: Site-Specific Experimental Data

The effective porosity of the concrete is based on air entrainment measurements made both on "green" concrete and on cured concrete cores.

Discussion:

Data used in the development of the best estimator of porosity for Salado Mass Concrete (SMC) were derived exclusively from a single literature source. Wakeley et al. (1995) measured air entrainment in both "green" SMC and cured SMC concrete cores. Measurements of air entrainment were made for 19 batches of "green" SMC. For each batch, air entrainment was determined at two distinct times, once at the beginning of the mixing process and once near the end of the mixing process (~2 hours). Air entrainment values of "green" SMC ranged from 1.1 to 3.3 percent with an average of 2.0 percent. Wakeley et al. (1995) also determined air entrainment from concrete cores recovered from two SMC cast monoliths identified as 161SM3 and 231SM3. These monoliths were prepared by discharging the portions of the SMC into oval galvanized metal tanks with approximate dimensions of 4 ft × 8 ft × 3 ft (1.2 m × 2.4 m × 0.9 m). The SMC was allowed to flow freely from one end of the tank to the opposite end of the tank. After the monoliths had cured (six months), cores were recovered from six locations within the monolith to obtain samples for determining air entrainment (and other

Parameter(s): Effective Porosity - Concrete and Concrete Monolith

Discussion: (continued)

characteristics). The locations included three horizontal sampling positions; i.e., at discharge, near middle, and at far end, and two vertical sampling depths; i.e., top and bottom. Air voids were determined by sectioning the samples and using petrographic techniques. Air entrainment values of the cast SMC ranged from 1.5 to 4.5 percent with an average of 3.2 percent.

A porosity value of 0.05 was used because field emplaced concrete is expected to be similar to cast SMC concrete. It has the same batch design and will be transported over moderate distances, thus increasing its entrained air content.

References:

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete*. SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Pore-Volume Compressibility - Concrete and Concrete Monolith

Parameter Description:

Pore-volume compressibility of the concrete column and the concrete monolith at the base of the shaft is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CONC_T1	COMP_RCK (#2464)
CONC_T2	COMP_RCK (#2481)
CONC_MON	COMP_RCK (#3052)

Parameter Value: 2.64×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: General Literature - Professional Judgment and Site-Specific Experimental Data

Data used in the development of the best estimator of bulk modulus for SMC were derived from two sources: (1) literature reviews; and (2) testing of both SMC cores and concrete cores recovered from the WIPP Small Scale Seal Performance Test (SSSPT).

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

Chen and Loken (1994) performed a literature review to develop material properties for use in rock mechanics analyses of SMC sealing materials. Their review revealed relatively few references, primarily because the SMC is a specially-designed mix that has been developed only recently (Wakeley et al. 1994; Wakeley et al.1995), and, thus, has been subjected to very little mechanical testing. Citing Wakeley et al. (1994) and Van Sambeek (1987), Chen and Loken (1994) selected values for Young's modulus and Poisson's ratio for use in their analyses. The values selected for Young's modulus and Poisson's ratio were 30 GPa and 0.2, respectively. The bulk modulus for SMC was calculated to be 16.667 GPa. Wakeley et al. (1995) have reported values for Young's modulus as

Discussion: (continued)

determined from unconfined compression tests of SMC; however, no lateral strain measurements were made during the testing so Poisson's ratio could not be determined. Furthermore, bulk modulus could not be determined because only values of Young's modulus were determined from the testing.

A total of three compression tests were performed to measure Young's modulus and Poisson's ratio (RE/SPEC 1996). These values were then used to compute bulk modulus. One test was performed on SMC batched and cast at the Waterways Experiment Station (WES); while two tests were performed on concrete recovered from the WIPP SSSPT. The results of the testing show that the value of bulk modulus determined for SMC concrete is 19.2 GPa which is approximately 15 percent higher than that used in rock mechanics analyses (Chen and Loken 1994); while the average of the two values determined for SSSPT concrete is 30.1 GPa which is approximately 80 percent higher than that used in rock mechanics analyses. The concrete components emplaced in the Salado Formation are expected to comprise materials nearly identical to the SMC tested in the laboratory by RE/SPEC (1996). In view of the fact that only one test was performed on the SMC, the difference between the laboratory determined value and the rock mechanics analysis value is relatively small.

References:

Chen, R.U., and M.C. Loken. 1994. *Concrete/Steel Panel Seal Structural Response, Calculation File 325/03/01.* Rapid City, SD: RE/SPEC Inc.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment. Calculation No. 325/13/02.* February 1996. Rapid City, SD: RE/SPEC Inc.

Van Sambeek, L.L., D.D. Luo, M.S. Lin, W. Ostrowski, and D. Oyenuga. 1993. *Seal Design Alternatives Study.* SAND92-7340. Albuquerque, NM: Sandia National Laboratories.

Wakeley, L.D., T.S. Poole, and J.P. Burkes. 1994. *Durability of Concrete Materials in High-Magnesium Brine.* SAND93-7073. Albuquerque, NM: Sandia National Laboratories.

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete.* SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Asphalt Shaft Material

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the asphalt shaft material.

Material and Parameter Name(s):

ASPHALT	PRMX_LOG (#2283)
ASPHALT	PRMY_LOG (#2284)
ASPHALT	PRMZ_LOG (#2285)

Parameter Value: -20.000

mean	median	minimum	maximum	units
-19.667	-20.000	-21.000	-18.000	$\log(m^2)$

Distribution Type: Triangular

Data: Professional Judgment

Discussion:

The WIPP asphalt will consist of an asphalt mastic mix (AMM) with a mineral filler. It will be approximately 10-20 percent asphalt by weight and air voids (porosity) will be 1 percent or less. The material specifications for the WIPP asphalt component (i.e., low void volume) are such that the permeability will be very low.

Several sources were reviewed in an attempt to find relevant information on the permeability of asphalt and asphaltic based construction materials. A large body of literature exists on applications of using asphalt as a barrier to water flow such as in the case of dams. Asphalt is routinely referred to in the literature as being impermeable, waterproof, etc. However, very little quantitative information exists regarding the permeability of asphalt. No permeability values were found for an AMM which shares the expected low void volume and high asphalt content that will exist in the shaft seal.

Robert Romine, a Research Scientist in the Environmental Technology Division of Pacific Northwest National Laboratories (PNNL) and technical expert to Sandia in the design and development of the specifications for the shaft seal AMM, expects the permeability for the WIPP AMM seal to be less than 1×10^{-20} m^2 (Romine 1995).

Discussion: (continued)

The effective seal/DRZ permeability for the asphalt shaft material is calculated from the equation

$$k_{model} = \frac{k_s A_s + k_d A_d}{A_{model}}$$

where: k_{model} = effective seal/DRZ permeability used in BRAGFLO
A_{model} = effective shaft area modeled in BRAGFLO (equal to the shaft area, A_s)
k_s = average shaft seal permeability (given in this parameter sheet)
A_s = average shaft area
k_d = average DRZ permeability (SHFT_DRZ PRMX_LOG in PA database)
A_d = average DRZ area

Assuming that the change in permeability within the DRZ is log linear, the effective DRZ permeability, k_d is calculated from:

$$k_d = \frac{2}{r_o + r_i}\left[\left(\frac{r_o(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_o - \left(\frac{r_i(\ln(k_o) - \ln(k_i)) - \Delta r}{(\ln(k_o) - \ln(k_i))^2}\right) k_i\right]$$

where: r_i = inner radius (shaft excavatin radius)
r_o = outer DRZ radius
Δr = outer DRZ radius minus the inner DRZ radius
k_i = inner skin permeability (DRZ permeability at the shaft/DRZ interface)
k_o = intact halite permeability

The average DRZ permeability is calculated from:

$$k_d A_d = k_{d1} A_{d1} + k_{d2} A_{d2} + k_{d3} A_{d3} + k_{d4} A_{d4}$$

where: d1 = air-supply shaft
d2 = salt-handling shaft
d3 = waste-handling shaft
d4 = air-exhaust shaft

and the average seal permeability is calculated from

$$k_s A_s = k_{s1} A_{s1} + k_{s2} A_{s2} + k_{s3} A_{s3} + k_{s4} A_{s4}$$

The resulting effective seal/DRZ permeability for the asphalt shaft material is 6.76×10^{-17} m^2.

Parameter(s): Log of Intrinsic Permeability - Asphalt Shaft Material

References:

Kelley, V., T. Jones, and J. Ogintz. 1996. Memorandum to Diane Hurtado, Re: WIPP Seal System Parameters for Performance Assessment BRAGFLO Compliance Calculations, January 15, 1996 (with updates).

Romine, R. 1995. E-mail communication to V. Kelley, INTERA Inc., November 29, 1995.

Parameter(s): Effective Porosity - Asphalt Shaft Material

Parameter Description:

Effective porosity of the asphalt shaft material.

Material and Parameter Name(s):

ASPHALT POROSITY (#2280)

Parameter Value: 0.01

Units: m^3/m^3

Distribution Type: Constant

Data: Professional Judgment

The effective porosity of the asphalt shaft material is specified in the material specifications.

Discussion:

The WIPP asphalt will consist of an asphalt mastic mix (AMM) with a mineral filler. It will be approximately 10-20 percent asphalt by weight. The Compliance Submittal Design Report (in review) reports that the asphalt column composed of an AMM will have an extremely low air void content (porosity), between 1 and 2 percent. It is assumed that the asphalt column has a porosity of 0.01.

References:

Compliance Submittal Design Report, in review. Appendix A: Material Specifications. Albuquerque, NM: Sandia National Laboratories.

Kelly, V., T. Jones, and J. Ogintz. 1996. Memorandum to Diane Hurtado, Re: WIPP Seal System Parameters for Performance Assessment BRAGFLO Compliance Calculations, January 15, 1996 (with updates).

Parameter(s): PCT_A Threshold Pressure Parameter - Asphalt Shaft Material

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

ASPHALT	PCT_A (#2600)

Parameter Value: 0

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Asphalt Shaft Material.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Data regarding threshold pressures in asphalt materials were not found in the literature. Therefore, the Davies (1991) relationship is assumed to be applicable for the asphalt seal material.

Parameter(s): PCT_A Threshold Pressure Parameter - Asphalt Shaft Material

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Asphalt Shaft Material

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

ASPHALT PCT_EXP (#2601)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_EXP and PCT_EXP) have not been measured for the Asphalt Shaft Material.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Data regarding threshold pressures in asphalt materials were not found in the literature. Therefore, the Davies (1991) relationship is assumed to be applicable for the asphalt seal material.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Asphalt Shaft Material

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Pore-Volume Compressibility - Asphalt Shaft Material

Parameter Description:

Pore-volume compressibility of the asphalt shaft material is required for specification in BRAGFLO and makes up part of the hydraulic diffusivity term for a porous medium.

Material and Parameter Name(s):

ASPHALT COMP_RCK (#2277)

Parameter Value: 2.97×10^{-8}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

The bulk modulus reported for asphalt is 3.371×10^{9} Pa (RE/SPEC 1995). Assuming an asphalt porosity of 0.01, the pore-volume compressibility for the asphalt column is 2.97×10^{-8} Pa^{-1}.

References:

RE/SPEC. 1995. "Transmittal of Bulk Modulus Values for Various Sealing Materials." Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Log of Intrinsic Permeability - Earthen Fill Shaft Material

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the earthen fill material.

Material and Parameter Name(s):

EARTH	PRMX_LOG (#2503)
EARTH	PRMY_LOG (#2504)
EARTH	PRMZ_LOG (#2505)

Parameter Value: -14.0

mean	median	minimum	maximum	units
-14.333	-14.000	-17.000	-12.000	$\log(m^2)$

Distribution Type: Triangular

Data: General Literature-Professional Judgment

Data is based on a review of the available literature.

Discussion:

The intrinsic permeability values for the earthen fill material are based upon literature values of permeability for soils which are classified as SC or SM (clayey sand or silty sand) according to the Unified Soil Classification System. These references include Freeze and Cherry (1979), Davis and DeWiest (1966), and de Marsily (1986). All of the literature sources, with the exception of one, report a maximum permeability for these types of soils of 1×10^{-12} m^2. Freeze and Cherry (1979) report a maximum hydraulic conductivity for unconsolidated silty sand of 0.002 m/s which converts to a permeability of 2.04×10^{-10} m^2. This value is not considered for a maximum value because the earthen fill in the shaft will be consolidated through compaction. Because the earthen fill will be consolidated and because the permeability of the earthen fill column will be controlled by low permeability lifts (layers), the maximum permeability assumed for earthen fill is 1×10^{-12} m^2. The best estimate permeability is assumed to be 1×10^{-14} m^2 and the minimum permeability is assumed to be 1×10^{-17} m^2. The minimum value is based upon actual measurements of hydraulic conductivity of compacted SM and SC soils (U.S. Department of Interior 1977; 1987). The permeability distribution is therefore log triangular with the preceding maximum, best estimate, and minimum values.

Parameter(s): Log of Intrinsic Permeability - Earthen Fill Shaft Material

References:

Davis, S.N., and R.J.M. DeWiest. 1966. *Hydrogeology*. New York, NY: John Wiley & Sons.

de Marsily, G. 1986. *Quantitative Hydrogeology*. Orlando, FL: Academic Press, Inc.

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

U.S. Department of the Interior. 1977. *Design of Small Dams*. Revised Reprint. A Water Resources Technical Publication.

U.S. Department of the Interior. 1987. *Design of Small Dams*. Third Edition. A Water Resources Technical Publication.

Parameter(s): Effective Porosity - Earthen Fill Shaft Material

Parameter Description:

Effective porosity of the earthen fill material.

Material and Parameter Name(s):

EARTH POROSITY (#2500)

Parameter Value: 0.32

Units: m^3/m^3

Distribution Type: Constant

Data: Professional Judgment

The effective porosity was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The effective porosity of the earthen fill can be calculated from knowing the void ratio of the earthen fill. The void ratio for SM and SC (clayey sand or silty sand) soils is reported to be 0.48 (U.S. Department of Interior 1977). Therefore, the calculated effective porosity of the earthen fill is 0.32.

References:

Kelley, V., T. Jones, and J. Ogintz. 1996. Memorandum to Diane Hurtado, Re: WIPP Seal System Parameters for Performance Assessment BRAGFLO Compliance Calculations, January 15, 1996 (with updates).

U.S. Department of the Interior. 1977. *Design of Small Dams*. Revised Reprint. A Water Resources Technical Publication.

Parameter(s): Pore-Volume Compressibility - Earthen Fill Shaft Material

Parameter Description:

Pore-volume compressibility of the earthen fill material is required for specification in BRAGFLO and makes up part of the hydraulic diffusivity term for a porous medium.

Material and Parameter Name(s):

EARTH COMP_RCK (#2497)

Parameter Value: 3.1×10^{-8}

Units: Pa^{-1}

Distribution Type: Constant

CDF Graph: Not applicable

Data: Professional Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The pore compressibility is equal to the rock compressibility divided by the effective porosity and the rock compressibility is the inverse of the bulk modulus. Therefore, the pore compressibility is equal to the inverse of the product of the bulk modulus and the effective porosity.

The range of compressibility reported by Freeze and Cherry (1979) for clays is from 1×10^{-8} to 1×10^{-6} Pa^{-1}. The range of compressibility for sands reported by Freeze and Cherry (1979) is from 1×10^{-9} to 1×10^{-7} Pa^{-1}. The earthen fill represents a mixture of clay, silt and sand. Assuming a mixture and the ranges listed above, a representative compressibility is 1×10^{-8} Pa^{-1}. Dividing this compressibility by a porosity of 0.32 yields a pore-volume compressibility of 3.1×10^{-8} Pa^{-1}.

Parameter(s): Pore-Volume Compressibility - Earthen Fill Shaft Material

References:

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

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Salado Formation Halite Parameter Values (as summarized in Table 8-5, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of Intrinsic Permeability - Halite

Parameter Description:

The Salado Formation halite is assigned an intrinsic permeability intended to reflect the stratigraphic variability of Salado halite and far-field hydraulic conditions. The permeability parameters in the x and y direction are assigned the same value as S_HALITE PRMX_LOG.

Material and Parameter Name(s):

S_HALITE	PRMX_LOG (#547)
S_HALITE	PRMY_LOG (#548)
S_HALITE	PRMZ_LOG (#549)

Parameter Value: -22.5

mean	median	low	high	units
- 22.5	-22.5	-24.0	-21.0	$\log(m^2)$

Distribution Type: Uniform

Data: Site-Specific Experimental Data

The reported permeability range of undisturbed impure halite is based on four selected in-situ hydraulic tests: three flow tests believed representative of far-field permeability and one flow test that measured permeability in a zone that included a range of halite lithologies. Computer-derived permeabilities based upon brine inflow data from Room Q fall within the range derived from flow tests. The reader is referred to the relevant parameter record package for more detail; the following data packages are included in the records package:

SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 7:Halite Permeability (x,y,z)
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 7:Salado Halite Permeability

Discussion:

Impure halite denotes a broad range of lithologic types ranging from "pure" halite to lithologies with various degrees of impurities, including polyhalite, argillaceous and anhydritic halite. Three hydraulic tests believed representative of far-field permeability were conducted in the present location of Room Q in map units with relatively low

Parameter(s): Log of Intrinsic Permeability - Halite

Discussion: (continued)

impurities: a halite with less than 0.5 percent impurity, a halite containing approximately 1 percent impurity and a halite/polyhalite zone with a 1-2 percent impurity. These units were tested before the large-scale brine inflow excavation was mined and at stratigraphic intervals located over 20 m from the excavation. These tests are believed to represent the lower end of the permeability range for Salado halite (see Table 5).

Far-field hydraulic tests data do not exist for relatively impure halites, which tend to show higher permeabilities in the near-field. Although located within the influence of the DRZ, one flow test (C2H01-BGZ) measured within map units 0-4 is used to bound the maximum permeability of Salado halite containing relatively high impurities. The median $\log_{10}$ value of -22.5 is believed to be the best value.

A summary of selected interpretative results of these four flow and pressure tests is compiled in the attached table. A schematic representation of Salado map units near the disposal area horizon, adapted from Deal et. al. (1989), is attached for information purposes.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report.* SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Deal, D.E., R.J. Abitz, D.S. Belski, and J.B. Case. 1989. Brine Sampling and Evaluation Program. 1988 Report. DOE-WIPP-89-015. Carlsbad, NM: Westinghouse Electric Corporation.

Jensen, A.L., C.L., Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991.* SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, G.J. Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen. 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

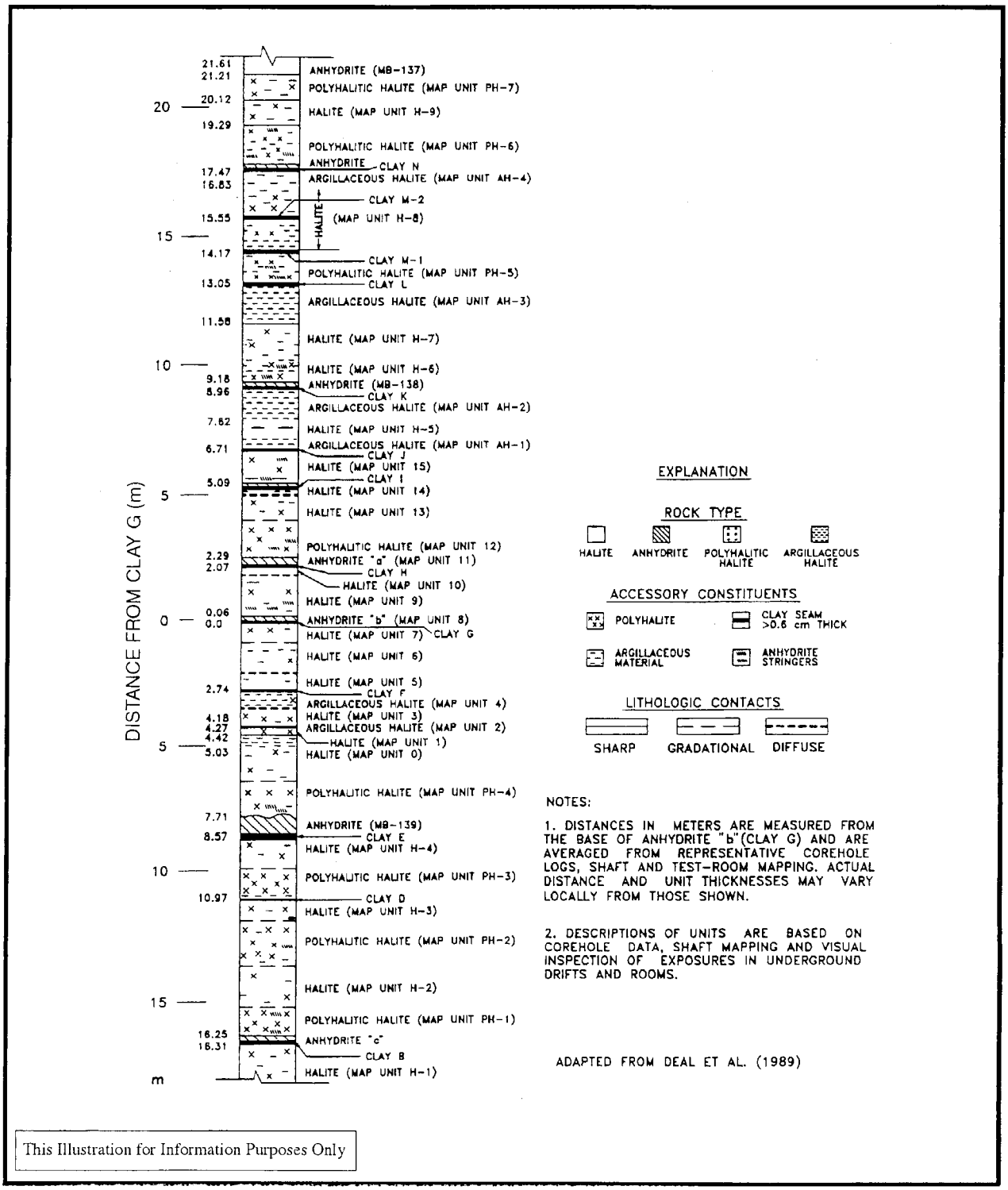

Figure PAR-2. Detailed Stratigraphy Near the WIPP Site (after Deal et al., 1989)

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Parameter(s): Log of Intrinsic Permeability - Halite

References: (continued)

Stensrud, W.A., T.P. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, G.J. Saulnier, Jr., and A.L. Jensen. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2*. SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Table PAR-5. Summary of Permeability Test-Interpretations Results from In Situ Permeability Tests Representing Undisturbed Impure Halite

TEST INTERVAL (meters from excavation)	HOLE	MAP UNIT(s)	ANALYSIS METHOD	PERMEABILITY K (m^2)
20.13-21.03	QPPO5	MU 6	GTFM6.0	1.12×10^{-24}
23.35-24-20	QPP12	H3	GTFM6.0	2.69×10^{-22}
20.19-21.09	QPP15	MU O - MU PH-4	GTFM6.0	5.5×10^{-24}
4.50-5.58	C2H01-BGZ	MU O - MU 4	GTFM6.0	1.38×10^{-21}

Note: See Record Parameter Package for additional detail.

Parameter(s): Effective Porosity - Halite

Parameter Description:

The effective porosity of Salado Formation halite and polyhalite refers to the ratio of the interconnected pore volume to bulk volume; total porosity, is defined as the ratio of interconnected plus non-connected pore space to bulk volume.

Material and Parameter Name(s):

S_HALITE POROSITY (#544)

Parameter Value: 0.01

mean	median	minimum	maximum	units
0.0128	0.01	0.001	0.03	None

Distribution Type: Cumulative

Data: Site-Specific Experimental Data

The effective porosity of Salado halite used in the NMVP analysis is supported by three separate porosity calculations: 1) Skokan et al., (1989, 15) determined from electromagnetic and DC resistivity experiments, 2) drying experiments described in Powers et al., (1978, 7-30), and 3) drying experiments reported in Deal et al., (1993). The data package associated with this parameter is as follows:

SCWF-A:WBS 1.2.07.1:PDD:QA:SALADO:PKG8:POROSITY effective porosity/hal

Discussion:

The high value (0.03) for the range of porosity is suggested in Skokan et al. (1989, 13), based on the low end (10 ohm) of the DC resistivity measurements registered in the underground. The low value (0.001) is suggested in Powers et al. (1978) based on drying experiments. The median value of 0.01 is suggested in Skokan et al.(1989, 15). Deal et al. (1993) found an average value of 0.016 for total porosity from a different series of drying experiments, providing support for selecting a reasonable constant value of 0.01 used in the NMVP simulation.

Parameter(s): Effective Porosity - Halite

References:

Deal, D.E., R.J. Abitz, J. Myers, M.L. Martin, D.J. Millgan, R.W. Sobocinski, P.P.J. Lipponer, and D.S. Belski. 1993. *Brine Sampling and Evaluation Program, 1991 Report*. DOE-WIPP-93-026. Carlsbad, NM: Westinghouse Electric Corporation, Waste Isolation Division.

Powers, D.W., S.J. Lambert, S.E. Shaffer, L.R. Hill, and W.D. Weart, eds. 1978. *Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico*. SAND78-1596. Albuquerque, NM: Sandia National Laboratories. Vols. 1-2.

Skokan, C.K., M.C. Pfeifer, G.V. Keller, and H.T. Andersen. 1989. *Studies of Electrical and Electromagnetic Methods for Characterizing Salt Properties at the WIPP Site, New Mexico*. SAND87-7174. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter - Halite

Parameter Description:

PCT_A is linear factor used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media. The sum of the existing pore pressure in the rock and the threshold pressure is the gas-pressure level that must be reached to overcome capillary resistance and drive gas into brine-filled rock pores.

Material and Parameter Name(s):

S_HALITE PCT_A (#2779)

Parameter Values: 0.56

Units: Pa/m^2

Distribution Type: Constant

Data: General Literature and Professional Judgment

There is no site-specific PCT_A parameter measurement for halite. The linear threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies 1991, 25-26).

Discussion:

Threshold pressure (P_t) is calculated by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. Use of the Davies correlation is appropriate based on gross similarities between halite rock and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter. Halite possesses a relatively tight crystalline textures with interconnected pore space occurring along grain boundaries.

Parameter(s): PCT_A Threshold Pressure Parameter - Halite

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Halite

Parameter Description:

PCT_EXP is an exponential factor used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media. The sum of the existing pore pressure in the rock and the threshold pressure is the gas-pressure level that must be reached to overcome capillary resistance and drive gas into brine-filled rock pores.

Material and Parameter Name(s):

S_HALITE PCT_EXP (#2780)

Parameter Values: -0.346

Units: None

Distribution Type: Constant

Data: General Literature and Professional Judgment

There is no site-specific PCT_EXP parameter measurement for halite. The exponential threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies 1991, 25-26).

Discussion:

Threshold pressure (P_t) is calculated by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. Use of the Davies correlation is appropriate based on gross similarities between halite rock and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter (e.g. relatively tight crystalline textures with interconnected pore space occurring along grain boundaries).

Parameter(s): PCT_EXP Threshold Pressure Parameter - Halite

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant*. SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Halite

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{br} is also referred to as S_{wr} (wetting phase) or S_{lr} (liquid phase). For brine saturations above S_{br}, brine phase relative permeability (K_{rw}) increases as dictated by the shape of K_{rw} curve to a valve K_{rw} = 1.0 for fully brine-saturated conditions. For modeling purposes, halite is specified as 100 percent brine-saturated.

Material and Parameter Name(s):

S_HALITE SAT_RBRN (#555)

Parameter Value: 0.3

mean	median	minimum	maximum	units
0.3	0.3	0.0	0.6	None

Distribution Type: Uniform

Data: General Literature and Professional Judgment

There have been no measurements of residual brine saturation in halite rock materials for the WIPP project. Consequently, natural analog data are used to justify the range and best value for halite (Brooks and Corey 1964).

Discussion:

Brooks and Corey (1964) report a residual wetting phase saturation (S_{wr}) range of 0.08 to 0.56 based on curve fitting capillary pressure data for several types of porous unconsolidated and consolidated analog materials. The selected S_{br} value of 0.30 is the median of the uniform distribution and is consistent with the Berea Sandstone tested in the Brooks and Corey study. Due to the high threshold pressure assigned to halite, this material maintains brine saturation above the residual for the duration of the simulation (i.e., gas does not displace brine).

Parameter(s): Residual Brine Saturation - Halite

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Parameter(s): Residual Gas Saturation - Halite

Parameter Description:

The residual (critical) gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{gr} corresponds to the degree of waste-generated gas saturation necessary to create an incipient interconnected pathway in porous material, a condition required for porous rock to be permeable to gas.

Material and Parameter Name(s):

S_HALITE SAT_RGAS (#556)

Parameter Value: 0.2

mean	median	minimum	maximum	units
0.2	0.2	0.0	0.4	None

Distribution Type: Uniform

Data: General Literature and Professional Judgment

Two-phase flow parameters have not been measured for halite rock material. In past brine and gas flow simulations, this range was also applied to anhydrite marker beds. Two-phase flow measurements have since shown a smaller range for anhydrite (1.4 - 19.7 percent). At this time, such experimental data do not exist for halite, suggesting the larger range of S_{gr} remains appropriate.

Discussion:

The range, mean and median values developed for this analysis are the same as those used in previous performance assessment analyses, when the range was defined simply by doubling the median value. In a review of studies in the general literature, Solutions Engineering (1995) documents a natural analog S_{gr} range from 0-27 percent. In developing empirical equations for two-phase flow in consolidated rock, of sandstone, dolomite, limestone and conglomerate lithologies, Honarpour et al. (1982) reports a range of 0-40 percent for residual gas saturation based on several hundred data points. The value of 20 percent used in the NMVP is considered the best value.

Parameter(s): Residual Gas Saturation - Halite

References:

Honarpour M, Koederitz, L.F., and Harvey, H.A. 1982. "Empirical Equations for Estimating Two-Phase Relative Permeability in Consolidated Rock," *Journal of Petroleum Technology*, December 1982, p. 2905-2908.

Solutions Engineering. 1995. "Critical Gas Saturation Recommendations for WIPP," Letter Report to D.M. Stoelzel, November 15, 1995, Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Pore Distribution - Halite

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

S_HALITE PORE_DIS (#543)

Parameter Value: 0.7

mean	median	minimum	maximum	units
2.9	0.7	0.2	10.0	None

Distribution Type: Cumulative

Data: General Literature, Site-Specific Experimental Data and Professional Judgment

Pore size distribution has not been measured in halite. The range and distribution of parameter values is derived from natural-analog data, but is supported by site-specific experimental data measured in the laboratory for marker bed anhydrites.

Discussion:

The range limits for the pore-size distribution parameter λ for halite is based on Mualem (1976) who fit the Brooks and Corey model to data for 45 soils. The median value of 0.7 used in the NMVP analysis was originally based on a study by Morrow et al. (1986) on the Multiwell Tight Gas Sands Project. The justification was that the permeabilities in the the tight sands, ranging from 2.3×10^{-17} to $4.3 \times 10^{-17} m^2$, were the lowest permeability materials for which pore size information was available.

The WIPP project now has site-specific experimental data for low permeability anhydrite marker beds. The parameter range specified for the anhydrites (0.491 to 0.842) supports the median value calculated at the lower end of the parameter range.

Parameter(s): Pore Distribution - Halite

References:

Morrow, N.R., J.S. Ward, and K.R. Brower. 1986. *Rock Matrix and Fracture Analysis of Flow in Western Tight Gas Sands - 1985 Annual Report.* DOE/MC/21179-2032. Socorro, NM: New Mexico Institute of Mining and Technology, New Mexico Petroleum Recovery Research Center.

Mualem, Y. 1976. "A New Model of Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research*. Vol. 12, no. 3, 513-522.

Parameter(s): Rock Compressibility - Halite

Parameter Description:

Rock compressibility of Salado Formation halite is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

S_HALITE COMP_RCK (#541)

Parameter Value: 9.75×10^{-11}

mean	median	minimum	maximum	units
9.75×10^{-11}	9.75×10^{-11}	2.94×10^{-12}	1.92×10^{-10}	Pa^{-1}

Distribution Type: Uniform

Data: Site-Specific Experimental Data

The parameter distribution for halite rock compressibility is based upon data from two hydraulic tests in Room Q: QPP05 and QPP15. Another data point calculated from sensitivity studies using brine inflow data from Room Q is within the range derived from the hydraulic tests.

Data packages associated with this parameter are located at:
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 4: Halite Rock Compressibility
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 5: Salado Halite Rock Compressibility

Parameter(s): Rock Compressibility - Halite

Discussion:

The two *in situ* hydraulic tests were conducted in the location of Room Q before the large-scale brine inflow excavation was mined. Test intervals were located over 65 ft (20 m) from the excavation. Map units (MU) represented included MU 6 (halite) and MU 0 (halite)/MU PH-4 (polyhalite) within a radius of about 3.2808 ft (one m) of each borehole. Raw data included pressure, fluid volume, temperature, axial test-tool movement, and radial borehole closure.

Interpretation of all flow tests in the WIPP facility is based on the assumption that Darcy flow and borehole closure are the only forms of pressure/flow transmission during hydraulic tests. References related to data collection and interpretation are listed in the references section.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report*. SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report*. SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.L., Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991*. SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, G.J. Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen. 1991. *WIPP Salado Hydrology Program Data Report #1*. SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.P. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, G.J. Saulnier, Jr., and A.L. Jensen. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2*. SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Table PAR-6. Summary of Rock Compressibility Test-Interpretations Results from In Situ Permeability Tests for Undisturbed Halite and Polyhalite Map Units

TEST INTERVAL (meters from excavation)	HOLE AND LOCATION	ZONE	MAP UNIT(s)	ANALYSIS METHOD	ROCK COMPRESSIBILITY K (1/Pa)	FORMATION PORE PRESSURE (Mpa)*
20.13-21.03 down	QPPO5 Room Q	undisturbed	MU 6	GTFM6.0	2.94×10^{-12}	13.89
20.19-21.09 down	QPP15 Room Q	undisturbed	MU 0 MU PH-4	GTFM6.0	1.92×10^{-10}	11.04

* - Mean

Note: See Parameter Record Package for additional detail.

Parameter(s): Initial Pressure - Salado Halite

Parameter Description:

Initial brine far-field pore pressure in the Salado Halite.

Material and Parameter Name(s):

S_HALITE PRESSURE (#546)

Parameter Value: 1.247×10^7

mean	median	minimum	maximum	units
1.247×10^7	1.247×10^7	1.104×10^7	1.389×10^7	Pa

Distribution Type: Uniform

Data: Site-Specific Experimental Data

Two hydraulic tests were performed in boreholes in undisturbed halite in the underground WIPP. Both tests were performed in the area where Room Q would later be mined. The tests were undertaken in April-July, 1989. Pressure, fluid volume, temperature, axial test-tool movement, and radial borehole closure were measured during the hydraulic tests in undisturbed rock. The following data package is associated with the tests:

SWCF-A:WBS 1.2.07.1:PDD:QA:SALADO:PKG4:Halite Pressure

Discussion:

It was assumed that Darcy flow and borehole closure were the only forms of pressure/flow transmission during the hydraulic tests in undisturbed halite. The uncertainty associated with the estimated parameter values is high. The distribution is based on the two data points provided in the data package and the calculated median is 1.247×10^7 Pa.

Parameter(s): Initial Pressure - Salado Halite

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis, 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report.* SAND99-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.P. Dale, M.D. Port, and W.A. Stensrud, 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.L. Howard, R.L. Jones, and T.P. Peterson, 1993. *Room Q Data Report: Test Borehole data from April 1989 through November 1991.* SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, G.J., Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen, 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.P. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Port, and G.J. Saulnier, Jr., 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2.* SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

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Salado Formation Anhydrite Layers a and b and Marker Beds 138 and 139 Parameter Values (as summarized in Table 8-6, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

Intrinsic undisturbed permeabilities along the three principal axes of the BRAGFLO grid for Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139 are set equal to the value for S_MB139 PRMX_LOG.

Material and Parameter Name(s):

S_ANH_AB	PRMX_LOG	(#531)	S_MB138	PRMX_LOG	(#570)
S_ANH_AB	PRMY_LOG	(#532)	S_MB138	PRMY_LOG	(#571)
S_ANH_AB	PRMZ_LOG	(#533)	S_MB138	PRMZ_LOG	(#572)
S_MB139	PRMX_LOG	(#591)			
S_MB139	PRMY_LOG	(#592)			
S_MB139	PRMZ_LOG	(#593)			

Parameter Value: -18.89

mean	median	minimum	maximum	units
-18.89	-18.89	-21.00	-17.10	$\log(m^2)$

Distribution Type: Student-t

Data: Site-Specific Experimental Data and Laboratory-Measured Data

The reported parameter range of undisturbed Salado anhydrite permeabilities is based upon selected data collected from *in situ* hydraulic tests and measurements conducted in the laboratory: 1) five hydraulic tests conducted in the underground experimental area; and 2) 31 Klinkenberg-corrected gas permeabilities measured in the laboratory on specimens collected from MB 139 core samples. Summary data tables are attached for both in-situ and laboratory tests.

Data packages associated with this parameter are located at: SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 13:Anhydrite Permeability (x,y,z) A:WBS1.2.07.1:PDD:QA: SALADO:PKG 13:PRMX_LOG Log of Permeability in x direction/anh

Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Discussion:

Out of 15 borehole and field permeability tests conducted in MB 140, MB 139, MB 138 and anhydrites a and b, five *in situ* hydraulic tests are considered representative of undisturbed anhydrite permeability. Located from about 33 to 79 ft (10 to 24 m) from the excavation, the test intervals for these five boreholes were outside of the disturbed rock zone; the radius of visibility ranged from 13 to 82 ft (4 to 25 m). The five successful tests are summarized as follows:

Borehole	Location	Map Unit	Testing Period	
QPP03	Room Q	Anhydrite b	4/89	11/91
QPP13	Room Q	MB 139	4/89	11/91
C2H02	Room C2	MB 139	4/89	12/89
L4P51-C1	Room L4	MB 140	4/92	6/94
SCP01-A	Core Storage	MB 139	4/90	10/90

Klinkenberg-corrected gas permeabilities measured in the laboratory can be used as an equivalent measure of liquid permeabilities. Gas-corrected test specimen data exist from six whole cores taken from MB 139 in the northern experimental area: E1X07, E1X08, E1X10, E1X11 (E140 Drift) P3X10 and P3X11 (Room L3).

For purposes of parameterization, *in situ* test data are treated differently than laboratory-derived data. Uncertainty exists in regards to the spatial representativeness of the core samples, as well as the consideration of *in situ* stress conditions in laboratory measurements. In general, *in situ* hydraulic tests are considered representative of expected permeability conditions on the scale of the grid system used in the BRAGFLO mesh. Consequently, for the parameter distribution above, laboratory data are averaged as one data point, whereas each of the five hydraulic tests is considered an individual data point. The parameter value used in the NMVP simulation is considered appropriate: it is higher than the mean/median value as determined from *in situ* data.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report*. SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

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Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Reference(s): (continued)

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

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Saulnier, G.J., Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen. 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.F. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, G.J. Saulnier, Jr., and A.L. Jensen. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2.* SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Table PAR-7. Summary of Test-Interpretations Results from In Situ Permeability Tests for Undisturbed Anhydrite Map Units

TEST INTERVAL (meters from excavation)	HOLE	ZONE	MAP UNIT	ANALYSIS METHOD	PERMEABILITY K (m^2)	FORMATION PORE PRESSURE (Mpa)*
10.68-14.78 down	SCP01-A	undisturbed	MB139	GTFM6.0	1.4×10^{-19}	12.27
9.47-10.86 down	C2H02	undisturbed	MB139	GTFM6.0	1.0×10^{-21}	11.11
20.50-21.40 up	QPPO3	undisturbed	anhydrite "b"	GTFM6.0	7.6×10^{-20}	12.9
20.62-21.52 down	QPP13	undisturbed	MB139	GTFM6.0	6.0×10^{-20}	12.43
17.44-22.20 down	L4P51-C1	undisturbed	MB140	GTFM6.0	8.7×10^{-18}	9.38

* - Mean

Note: See Record Parameter Package for additional detail.

Table PAR-8. Marker Bed 139 Data

Lab	Bore Hole	Sample No.	Zone	Depth	Flow Dir.	Bulk Vol	*Grain Den.	Porosity					Permeability (pressure values are net effective stress)					
								Total	Effective				Gas (Klinkenberg Corrected)			Log of Permeability		
									0 MPa	3.4 MPa	6 MPa	10 MPa	3.4 MPa	6 MPa	10 MPa	2 MPa	6 MPa	10 MPa
	No.			(ft)		(cc)	(g/cc)	(%)	(%)	(%)	(%)	(%)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)
CL	E1X10	1	2	4.50	H	11.88	2.64			0.6								
CL	E1X10	2	2	4.50	H	10.70	2.59			0.8	0.7		6.5E-19	4.6E-19	2.3E-19	-18.19	-18.33	-18.64
CL	E1X10	3	2	5.00	H													
CL	E1X10	4	2	5.00	H	12.69	2.62			0.9	0.9		1.3E-18	8.8E-19	6.5E-19	-17.89	-18.06	-18.19
CL	E1X10	5	3	5.25	H	12.45	2.62			0.7	0.6		5.1E-19	3.8E-19	1.8E-19	-18.29	-18.42	-18.75
CL	E1X10	6	3	5.25	H	12.43	2.62			0.7			5.8E-19	3.0E-19	5.0E-20	-18.24	-18.53	-19.30
CL	E1X10	7	3	5.25	V	12.65	2.95			1.1	1.0		9.5E-19	5.5E-19		-18.02	-18.26	
CL	E1X10	8	3	5.25	V	12.98	2.95			1.1	1.0		8.2E-19	4.9E-19	1.4E-19	-18.08	-18.31	-18.86
CL	E1X10	9	3	5.50	H	12.65	2.85			0.9			4.7E-19			-18.33		
CL	E1X10	10	3	5.50	H	12.65	2.94			1.0			1.1E-18	1.8E-19	1.1E-18	-17.97	-18.75	
CL	E1X10	11	3	5.75	H	12.53	2.89			1.7	1.7	1.6	1.8E-18	1.6E-18	7.3E-19	-17.74	-17.81	-17.94
CL	E1X10	12	3	5.75	H	12.93	2.92			1.4	1.3		1.4E-18	1.0E-18		-17.87	-17.99	-18.13
CL	E1X10	13	3	5.75	V	12.70	2.96			1.6	1.5	1.5	1.6E-18	3.1E-19	1.7E-19	-17.79	-18.51	
CL	E1X10	14	3	5.75	V	10.78	2.95			1.2	1.1		6.1E-19	3.1E-19	6.4E-20	-18.21	-18.51	-18.76
CL	E1X10	15	4	6.25	V	12.60	2.96			1.0	0.9		5.9E-19	1.3E-19		-18.23	-18.89	-19.19
CL	E1X10	16	4	6.25	V	12.37	2.96			0.6								
CL	E1X11	17	2	4.50	H	11.38	2.63			0.8			4.0E-19	3.4E-19	1.0E-19	-18.40	-18.47	-19.00
CL	E1X11	18	2	4.50	H	11.88	2.63			1.8								
CL	E1X11	19	3	4.75	H	12.91	2.72			0.9			4.7E-19	3.2E-19	1.0E-19	-18.32	-18.49	-19.00
CL	E1X11	20	3	4.75	H	12.83	2.79			0.9	0.8		3.9E-19			-18.41		
CL	E1X11	21	3	5.00	H	12.04	2.82			1.1	1.0		7.7E-19	5.7E-19	2.6E-19	-18.12	-18.25	-18.58
CL	E1X11	22	3	5.00	H	12.29	2.69			1.4	1.3		1.5E-18	8.4E-19		-17.83	-18.07	
CL	E1X11	23	3	5.25	H	12.62	2.65			2.1			1.3E-18	5.9E-19		-17.88	-18.23	
CL	E1X11	24	3	5.25	H	12.20	2.67			1.4	1.4		1.5E-18	5.7E-19		-17.82	-18.24	
CL	E1X11	25	3	5.25	V	13.00	2.61			0.9	0.8		2.0E-18	5.6E-19	2.9E-19	-17.70	-18.25	-18.53
CL	E1X11	26	3	5.25	V	12.93	2.74			1.6			2.2E-18	7.5E-19	3.3E-19	-17.66	-18.13	-18.48
CL	E1X11	27	4	5.75	H	12.72	2.75			1.6	1.4	1.2						
CL	E1X11	28	4	5.75	H	13.67	2.91											
CL	E1X11	29	4	5.75	V	12.69	2.96			0.8								
CL	E1X11	30	4	5.75	V	12.72	2.96			1.0			1.5E-18	5.9E-19		-17.84	-18.23	
RS	P3X11	5-2-SP1	2	5.50	H	823.5							3.2E-18	1.7E-18	1.4E-18	-17.49	-17.77	-17.87
RS	P3X11	5-2-SP1	2	5.50	H	12.62	2.73											
RS	P3X11	5-2-SP1	2	5.50	H	13.97	2.73											
RS	P3X10	6-SP2	3	5.70	H	820.5												
RS	P3X10	6-SP2T	3	5.70	H	14.59	2.69											
RS	P3X10	6-SP2B	3	5.70	H	13.19	2.57											
RS	P3X11	5-3-SP3	4	7.05	H	813.0							1.6E-17	8.9E-18	5.1E-18	-16.79	-17.05	-17.29
RS	P3X11	5-3-SP3	4	7.05	H	14.97	2.53											
RS	P3X11	5-3-SP3	4	7.05	H	17.88	2.70											
RS	P3X11	5-3-2-TS	3	5.93	H													
RS	P3X11	5-3-2-TS	3	5.93	V													
RS	P3X11	5-3-2-TS	3	5.93	V													
RS	P3X11	5-3-2-TS	3	5.93	V													
RS	P3X10	5-3-2-TS	2	5.28	H													
RS	P3X10	5-3-2-TS	2	5.28	V													
RS	P3X10	5-3-2-TS	2	5.28	V													
RS	P3X10	5-3-2-TS	2	5.28	V													
RS	P3X11	6-TS3-1	4	7.60	H													
RS	P3X11	6-TS3-2	4	7.60	V													
RS	P3X11	6-TS3-3	4	7.60	V													
RS	P3X11	6-TS3-4	4	7.60	V													
TT	E1X08	A	2	3.82	H	822.8	2.65		1.9				8.2E-18	5.7E-18	5.0E-18	-17.08	-17.24	-17.30
TT	E1X08	B	3	4.66	H	776.8	2.60		0.5				1.3E-17	7.4E-18	4.6E-18	-16.90	-17.13	-17.34
TT	E1X08	C	4	5.53	H	819.6	2.72		1.0				4.6E-18	2.6E-18	2.0E-18	-17.34	-17.58	-17.70
TT	E1X08	EP1	2	3.57	H	83.47	2.56	1.4	1.3									
TT	E1X08	EP2	3	4.40	H	84.39	2.66		0.8									
TT	E1X08	EP3	3	5.12	H	83.54	2.58	0.4	0.4									
TT	E1X08	EP4	4	5.93	H	83.35	2.88	1.6	1.6									
TT	E1X08	PX1	2	4.07														
TT	E1X08	PX2	3	4.93														
TT	E1X08	PX3	4	5.78														
TT	E1X07	D	2	4.32	H	803.8	2.71		0.7				1.5E-19	5.9E-20	5.5E-20	-18.84	-19.23	-19.26
TT	E1X07	E	3	4.82	H	843.1	2.71		1.5				8.3E-16	3.0E-16	1.5E-16	-15.08	-15.52	-15.82
TT	E1X07	F	4	5.38	H	815.3	2.88		1.0				1.1E-18	6.9E-19	5.7E-19	-17.95	-18.16	-18.25
TT	E1X07	EP5	2	4.07	H	84.85	2.64		1.9									
TT	E1X07	EP6	2	4.57	H	84.04	2.70		2.7									
TT	E1X07	EP7	3	5.07	H	83.73	2.80		0.6									
TT	E1X07	EP8	4	5.66	H	84.52	2.75		1.6									
TT	E1X07	PX4	2	4.07														
TT	E1X07	PX5	3	5.07														
TT	E1X07	PX6	4	5.80														

* Grain densities from effective grain volume measurements

Minimum	2.53	0.4	0.4	0.6	0.6	1.2	1.5E-19	5.9E-20	5.0E-20	-18.84	-19.23	-19.30
Maximum	2.96	1.6	2.7	2.1	1.7	1.6	8.3E-16	3.0E-16	1.5E-16	-15.08	-15.52	-15.82
Sum	134.8	3.4	17.4	31.4	17.3	4.4	9.0E-16	3.4E-16	1.8E-16	-552.29	-524.43	-402.17
Points	49	3	14	28	16	3	31	29	22	31	29	22
Mean	2.75	1.1	1.2	1.1	1.1	1.5	29E-17	1.2E-17	8.0E-18	-17.82	-18.08	-18.28
Median	2.72	1.4	1.2	1.0	1.0	1.5	1.3E-18	5.7E-19	3.1E-19	-17.89	-18.24	-18.51
Std Deviation	0.14	0.63	0.66	0.40	0.32	0.20	1.5E-16	5.6E-17	3.2E-17	0.67	0.69	0.83
Variance	0.02	0.40	0.44	0.16	0.10	0.04	2.2E-32	3.2E-33	1.1E-33	0.45	0.48	0.69

Parameter(s): Effective Porosity - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

The effective porosity of Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139 refers to the ratio of the interconnected pore volume to bulk volume, as opposed to total porosity, defined as ratio of interconnected plus non-connected pore space to bulk volume.

Material and Parameter Name(s):

S_ANH_AB	POROSITY (#528)
S_MB138	POROSITY (#567)
S_MB139	POROSITY (#588)

Parameter Value: 0.011

mean	median	minimum	maximum	units
0.011	0.011	0.006, 0.009	0.017	None

Distribution Type: Student-t

Data: Site-Specific Laboratory-Measured Data

As part of the Two-Phase Flow Laboratory Program for the Waste Isolation Pilot Plant, effective porosity was successfully measured on forty-two specimens under various conditions of net effective stress (e.g., lithostatic minus hydrostatic pressure). See the attached table (k_ANH) for a summary of porosity and permeability data measured as part of the two-phase flow program.

The data package associated with this parameter is located at: SCWF-A:WBS1.2.07.1: PDD:QA: SALADO:PKG11:POROSITY:effective porosity/anh.

Discussion:

Data exist from 42 specimens ranging in size from 10 to 825 cc cut from MB 139 core samples measured at the following conditions of net effective stress: 0 MPa (14), 3.4 MPa (28), 6 MPa (16), and 10 MPa (3). The median value of 0.011 used in the NMVP calculation is the same for all units and is consistent with mean and median data values ranging from 0.010 to 0.015 representing all net effective stress levels. Note that anhydrites a and b and MB 138 are assigned a lower minimum parameter value (0.006). The reader is referred to the anhydrite porosity parameter record package for more detail.

Parameter(s): Effective Porosity - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

PCT_A is used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media. The sum of the existing pore pressure in the rock and the threshold pressure is the gas-pressure level that must be reached to overcome capillary resistance and drive gas into brine-filled rock pores.

Material and Parameter Name(s):

S_ANH_AB	PCT_A (#2774)
S_MB138	PCT_A (#2784)
S_MB139	PCT_A (#2789)

Parameter Value: 0.26

Units: Pa/m^2

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

PCT_A is based on an empirical correlation for computing threshold pressure, as reported in Davies (1991, 19) for anhydrite rocks. Supporting use of this threshold pressure equation in BRAGFLO, P_t values derived from measurements of capillary pressure on six anhydrite specimens from the repository are found to be well-bounded by the Davies correlation (Howarth and Christian-Frear in review).

Discussion:

Defined in the experiment as the first gas bubble to enter a 100 percent liquid saturated rock, threshold pressure (P_t) is equal to the entry pressure. P_t values derived by curve fitting are the threshold pressures at critical (residual) gas saturation and are consistent with the Brooks and Corey definition of threshold pressure. Experimental data supporting this threshold pressure parameter value is published in Howarth and Christian-Frear (in review).

PCT_A and PCT_EXP are constants used in BRAGFLO modeling to calculate P_t by the following relationship:

Parameter(s): PCT_A Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Discussion: (continued)

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. These constants can be used to derive threshold pressures for similar or analog materials in the disposal system.

References:

Davies, P.B. 1991. *Evauation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

The exponential pressure threshold parameter (PCT_EXP) is used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model. See the discussion of the linear threshold pressure parameter PCT_A.

Material and Parameter Name(s):

S_ANH_AB	PCT_EXP (#2775)
S_MB138	PCT_EXP (#2785)
S_MB139	PCT_EXP (#2790)

Parameter Value: -0.348

Units: None

Distribution Type: Constant

Data: Site-Specific Experimental Data and Professional Judgment

PCT_EXP is based on an empirical correlation for computing threshold pressure, as reported in Davies (1991, 19) for anhydrite rocks. Supporting use of this threshold pressure equation in BRAGFLO, P_t values derived from measurements of capillary pressure on six anhydrite specimens from the repository are found to be well-bounded by the Davies correlation (Howarth and Christian-Frear in review).

Discussion:

Defined in the experiment as the first gas bubble to enter a 100 percent liquid saturated rock, threshold pressure (P_t) is equal to the entry pressure. P_t values derived by curve fitting are the threshold pressures at the critical (residual) gas saturation and are consistent with the Brooks and Corey definition of threshold pressure. Experimental data supporting this threshold pressure parameter value is published in Howarth and Christian-Frear (in review).

PCT_A and PCT_EXP are constants used in BRAGFLO modeling to calculate P_t by the following relationship:

Parameter(s): PCT_EXP Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Discussion: (continued)

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. These constants can be used to derive threshold pressures for similar or analog materials in the disposal system.

References:

Davies, P.B. 1991. *Evauation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation is the point reached under increasing gas saturation conditions when brine is sufficiently displaced by gas to impede formation of a continuous brine-filled pore network. Relative brine permeability becomes zero at the S_{br}.

Material and Parameter Name(s):

S_MB138	SAT_RBRN (#577)
S_MB139	SAT_RBRN (#598)
S_ANH_AB	SAT_RBRN (#538)

Parameter Value: 0.08363

mean	median	minimum	maximum	units
0.08363	0.08362	0.0078, 0.0688	0.174	None

Distribution Type: Student-t

Data: Site-Specific Experimental Data

Residual brine saturation parameter values for the marker beds are based on curve fit parameter values predicted from laboratory measurements of capillary pressure. The data package associated with this parameter is retained in Sandia National Laboratories WIPP Central Files: SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters.

Discussion:

Parameter values are based on curve fit capillary pressure data measured using a mercury injection technique. The two-phase flow program reports the results of curve-fitted measurements of capillary pressure on six marker bed samples (Howarth and Christian-Frear in review). Specimens were collected from intact MB 139 core samples taken from the experimental area of the repository. Note that anhydrite layers a and b are assigned a slightly higher "minimum" residual brine saturation (0.0688) due to extrapolation from MB 139 data. The median value assigned for all anhydrite units is not affected.

Parameter(s): Residual Brine Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Gas Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

The residual (critical) gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{gr} corresponds to the degree of waste-generated gas saturation necessary to create an incipient interconnected pathway in porous material, a condition required for porous rock to be permeable to gas.

Material and Parameter Name(s):

S_ANH_AB	SAT_RGAS (#539)
S_MB138	SAT_RGAS (#578)
S_MB139	SAT_RGAS (#599)

Parameter Value: 0.07711

mean	median	minimum	maximum	units
0.07711	0.07711	0.01398	0.19719	None

Distribution: Student-t

Data: Site-Specific Experimental Data

Residual gas saturation parameter values for the marker beds are based on curve-fitted laboratory measurements of capillary pressure. The data package is retained in Sandia National Laboratories WIPP Central Files: SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters

Discussion:

The two-phase flow program reports the results of curve-fitted measurements of capillary pressure on six marker bed samples tested using mercury injection (Howarth and Christian-Frear in review). The samples were taken from intact MB 139 core samples collected from the northern experimental area of the repository. The measurements were conducted at ambient conditions (no stress) and were assumed to be 100 percent saturated at the initiation of capillary pressure tests.

Parameter(s): Residual Gas Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, New Mexico: Sandia National Laboratories.

Parameter(s): Pore Distribution - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter(s) Description:

The pore size distribution parameter (λ) is used to calculate capillary pressure and relative permeabilities for gas and brine flow in the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

S_MB138	PORE_DIS (#566)	S_MB139	PORE_DIS (#587)
S_ANH_AB	PORE_DIS (#527)		

Parameter Value: 0.644

mean	median	minimum	maximum	units
0.6436	0.6436	0.4905	0.8418	None

Distribution Type: Student-t

Data: Site-Specific Experimental Data

Pore size distribution parameter values for all anhydrite units are based on curve fit values predicted from laboratory measurements of capillary pressure. The data package associated with this parameter is retained in Sandia National Laboratories WIPP Central Files: SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters.

Discussion:

Curve fit parameter values are derived from six specimens cut from intact MB 139 core samples collected from the northern experimental area of the repository. Reported data and parameters are based on mercury injection capillary pressure tests. As with other two-phase flow parameters, the median value assigned to MB 138 and anhydrite a and b is supported by and based on MB 139 data.

Parameter(s): Pore Distribution - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. In review. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Rock Compressibility - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

Rock compressibility of the Salado Formation Anhydrite Interbeds a and b and Marker Beds 138 and 139 is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

S_ANH_AB	COMP_RCK (#521)
S_MB138	COMP_RCK (#560)
S_MB139	COMP_RCK (#580)

Parameter Value: 8.26×10^{-11}

mean	median	minimum	maximum	units
8.26×10^{-11}	8.26×10^{-11}	1.09×10^{-11}	2.75×10^{-10}	Pa^{-1}

Distribution Type: Student-t

Data: Site-Specific Experimental Data

The parameter distribution for anhydrite rock compressibility is based upon data from four hydraulic tests in the underground WIPP facility. The boreholes and map units tested include: C2H02 (MB 139); QPP03 (Anhydrite b); QPP13 (MB 139); SCP01 (Marker Bed 139).

The data package associated with this parameter is located at:
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 19:Rock Compressibility

Parameter(s): Rock Compressibility - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Discussion:

The four successful tests include:

Borehole	Location	Start Date of Testing	End Date of Testing
QPP03	Room Q	4/89	11/91
QPP13	Room Q	4/89	11/91
C2H02	Room C2	4/89	12/89
SCP01-A	Core Storage	4/90	10/90

Raw data collected during hydraulic tests include pressure, fluid volume, temperature, axial test-tool movement and radial borehole closure. Pressure/flow transmission during hydraulic tests is assumed to be a result of Darcy flow and borehole closure. The reader is referred to the anhydrite porosity parameter record package for more detail.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report*. SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.L. Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991*. SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, G.J., Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen. 1991. *WIPP Salado Hydrology Program Data Report #1*. SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.F. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, G.J. Saulnier, Jr., and A.L. Jensen. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2*. SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Rock Compressibility - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Table PAR-9. Summary of Rock Compressibility Test-Interpretations Results from In Situ Permeability Tests for Undisturbed Anhydrite Marker Beds

TEST INTERVAL (meters from excavation)	HOLE	ZONE	MAP UNIT(s)	ANALYSIS METHOD	ROCK COMPRESSIBILITY K (1/Pa)	FORMATION PORE PRESSURE (Mpa)*
9.47-10.86 down	C2H02	undisturbed	MB 139	GTFM6.0	1.09×10^{-11}	11.11
20.62-21.52 down	QPP13	undisturbed	MB 139	GTFM6.0	3.37×10^{-11}	12.43
10.68-14.78 down	SCP01	undisturbed	MB 139	GTFM6.0	1.09×10^{-11}	12.27
20.50-21.40 up	QPP03	undisturbed	Anhydrite b	GTFM6.0	2.75×10^{-10}	12.94

* - Mean

Note: See Parameter Record Package for additional detail.

Salado Formation Anhydrite Interbeds Fracture Parameter Values (as summarized in Table 8-7, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Increment Above Initial Pressure for Fracture Initiation Pressure - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

The pressure increment above the initial pressure required to initiate fracturing in Marker Beds 138 and 139 and Anhydrite Layers a and b; this value is used in the pressure-induced fracture model (see Section BRAGFLO.10 of Appendix BRAGFLO).

Material and Parameter Name(s):

S_MB139	PI_DELTA (#586)
S_MB138	PI_DELTA (#565)
S_ANH_AB	PI_DELTA (#526)

Parameter Value: 2.0×10^5

Units: Pa

Distribution Type: Constant

Data: Professional Judgment

See: Chu (1996) and Lord (1996).

Discussion:

Lord (1996) recommended using the same PI_DELTA value as was used in the 1995 Features, Events, and Processes (FEPs) calculations. In the FEPs calculations, the fracture initiation pressure was assigned a value of 2.0×10^5 Pa above the grid block initial pressure.

References:

Chu, Margaret. 1996. Memorandum to Palmer Vaughn, Re: Strawman for Altered Anhydrite Model in Support of the CCA, January 22, 1996.

Lord, Michael. 1996. Memorandum to Margaret Chu, Re: Parameters Describing the Variable Porosity and Permeability within Anhydrite Material, January 29, 1996.

Parameter(s): Increment Above Intact Porosity for Full Fracture Porosity - Marker Beds 138 and 139

Parameter Description:

The porosity increment required to produce full fracture porosity in Marker Beds 138 and 139; this value is used in the pressure-induced fracture model (see Section BRAGFLO.10 of Appendix BRAGFLO).

Material and Parameter Name(s):

S_MB139	DPHIMAX (#2177)
S_MB138	DPHIMAX (#2169)

Parameter Value: 0.039

Units: None

Distribution Type: Constant

Data: Professional Judgment

See Chu (1996) and Lord (1996).

Discussion:

At all times after t = 0, porosity in the interbeds (and other rock units in BRAGFLO) is a calculated number dependent on initial porosity, pressure, and rock compressibility. Above the fracture initiation pressure, the local compressibility of the interbed is assumed to increase linearly with pressure and greatly increase the rate at which porosity increases with increasing pore pressure.

The maximum fractured porosity is equal to the initial porosity of the Salado halite plus the "increment," DPHIMAX. The porosity at full fracture condition was adjusted to produce a change in porosity of about 1 percent at 2.5 MPa above fracture initiation pressure or a pressure of 15.2 MPa (Lord 1996). This was obtained with a maximum porosity of 0.05. Therefore, the increment DPHIMAX is equal to 0.039 for Marker Beds 138 and 139.

Parameter(s): Increment Above Intact Porosity for Full Fracture Porosity - Marker Beds 138 and 139

References:

Chu, Margaret. 1996. Memorandum to Palmer Vaughn, Re: Strawman for Altered Anhydrite Model in Support of the CCA, January 22, 1996.

Lord, Michael. 1996. Memorandum to Margaret Chu, Re: Parameters Describing the Variable Porosity and Permeability within Anhydrite Material, January 29, 1996.

Parameter(s): Increment Above Intact Porosity for Full Fracture Porosity - Anhydrite Layers a and b

Parameter Description:

The porosity increment required to produce full fracture porosity in Anhydrite Layers a and b; this value is used in the pressure-induced fracture model (see Section BRAGFLO.10 of Appendix BRAGFLO).

Material and Parameter Name(s):

S_ANH_AB DPHIMAX (#2158)

Parameter Value: 0.239

Units: Pa

Distribution Type: Constant

Data: Professional Judgment

See Chu (1996) and Lord (1996).

Discussion:

The maximum fractured porosity is equal to the initial porosity of the Salado halite plus the "increment," DPHIMAX. The porosity at full fracture condition was adjusted to produce a change in porosity of about 3 percent at 2.5 MPa above fracture initiation pressure or a pressure of 15.2 MPa (Lord 1996). This was obtained with a maximum porosity of 0.25. Therefore, the increment DPHIMAX is equal to 0.239 for Anhydrite Layers a and b.

References:

Chu, Margaret. 1996. Memorandum to Palmer Vaughn, Re: Strawman for Altered Anhydrite Model in Support of the CCA, January 22, 1996.

Lord, Michael. 1996. Memorandum to Margaret Chu, Re: Parameters Describing the Variable Porosity and Permeability within Anhydrite Material, January 29, 1996.

Parameter(s): Log of the Maximum Allowable Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139

Parameter Description:

The log of the maximum allowable intrinsic permeability in Marker Beds 138 and 139 and Anhydrite Layers a and b; this value is used in the pressure-induced fracture model (see Section BRAGFLO.10 of Appendix BRAGFLO).

Material and Parameter Name(s):

S_MB139	KMAXLOG (#2178)
S_MB138	KMAXLOG (#2170)
S_ANH_AB	KMAXLOG (#2159)

Parameter Value: -9.0

Units: Pa

Distribution Type: Constant

Data: Professional Judgment

See Chu (1996) and Lord (1996).

Discussion:

Lord (1996) recommended that the maximum full fracture permeability be a large value such as 10^{-9} m^2. This is the same intrinsic permeability value that was used in the 1995 Features, Events, and Processes (FEPs) calculations.

References:

Chu, Margaret. 1996. Memorandum to Palmer Vaughn, Re: Strawman for Altered Anhydrite Model in Support of the CCA, January 22, 1996.

Lord, Michael. 1996. Memorandum to Margaret Chu, Re: Parameters Describing the Variable Porosity and Permeability within Anhydrite Material, January 29, 1996.

Parameter(s): Increment Above Fracture Initiation Pressure to Obtain Maximum Fracture Pressure - Marker Bed 138, Anhydrite Layers a and and Marker Bed 139

Parameter Description:

The increment of lithostatic pressure required to produce maximum fracture pressure in Marker Beds 138 and 139 and Anhydrite Layers a and b; this value is used in the pressure-induced fracture model (see Section BRAGFLO.10 of Appendix BRAGFLO).

Material and Parameter Name(s):

S_MB139	PF_DELTA (#2180)
S_MB138	PF_DELTA (#563)
S_ANH_AB	PF_DELTA (#524)

Parameter Value: 3.8×10^6

Units: Pa

Distribution Type: Constant

Data: Professional Judgment

See Chu (1996) and Lord (1996).

Discussion:

Lord (1996) recommended that the pressure at full fracture condition be an increment of 3.8×10^6 Pa above the fracture initiation pressure. This would result in a full fracture pressure of approximately 1.65×10^7 Pa which is a desirable value in that it is slightly above lithostatic pressure.

References:

Chu, Margaret. 1996. Memorandum to Palmer Vaughn, Re: Strawman for Altered Anhydrite Model in Support of the CCA, January 22, 1996.

Lord, Michael. 1996. Memorandum to Margaret Chu, Re: Parameters Describing the Variable Porosity and Permeability within Anhydrite Material, January 29, 1996.

Disturbed Rock Zone Parameter Values (as summarized in Table 8-8, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of the Intrinsic Permeability (T = -5 to 0 yrs) - Disturbed Rock Zone

Parameter Description:

The log of the intrinsic permeability of the Disturbed Rock Zone (DRZ) from time -5 to 0 years.

Material and Parameter Name(s):

DRZ_0	PRMX_LOG (#181)
DRZ_0	PRMY_LOG (#182)
DRZ_0	PRMZ_LOG (#183)

Parameter Value: -17.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

Two hydraulic tests were performed in boreholes where the tested interval included DRZ anhydrite and/or halite in the underground WIPP facility. The radius of visibility for the DRZ tests ranged from 0.66 ft to 6.6 ft (0.2 m to 2 m). The test in QPP05 is considered representative of the DRZ not because of the depth of the test interval, but because of the proximity of the test interval to Room Q. A clear distinction is visible between the tests performed in halite (C2H01-A & QPP05) and the test performed in anhydrite (OH-36). The halite tests have much lower values of k and compressibility and higher pore pressure, while the anhydrite test displays high relative k and compressibility and zero pore pressure. The difference being caused by the style of deformation - brittle for anhydrite and ductile for halite.

Table 10 contains a summary of the DRZ permeability test results. Note that only the test in QPP05 is considered representative of the DRZ.

Discussion:

Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. The first time period is intended to

Parameter(s): Log of the Intrinsic Permeability (T = -5 to 0 yrs) - Disturbed Rock Zone

Discussion: (continued)

represent the time from the initial excavation of a new panel (at -5 years) to the sealing of that panel after waste is emplaced (at time 0 years).At the start of this time period (the instant the excavation is made) the surrounding formation is assumed to have the properties of intact rock. During this first five years this initially intact rock becomes depressurized and partially desaturated do to the presence of the excavation. Therefore the initial (at t= -5 years) pressure and brine saturation of this material is assumed to be fully brine saturated and in hydrostatic equilibrium with the rest of the Salado formation. The model will calculated the degree of desaturation and depressurization which occurs over this five year period. Also, during this first five years the formation will alter becoming more permeable and perhaps more porous as a result of the influence of the excavation. Because these hydrologic properties are not dynamically adjusted within the numerical simulation during this five year drainage period, the appropriate values should represent the average values.

For this time period the DRZ because of its proximity to the excavation is characterized by a higher permeability than its intact counterpart. Alteration of this material is not complete at the end of this time period so that further deterioration of its hydrological properties (at least permeability) is expected.

References:

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report*. SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report*. SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of the Intrinsic Permeability (T = -5 to 0 yrs) - Disturbed Rock Zone

Table PAR-10. Summary of Test-Interpretation Results from In Situ Permeability Tests

Test Interval (meters from excavation)	Hole	Map Unit	Analysis Method(s)	Permeability log (m^2)
2.16 - 2.85	C2H01-A	MU-05	GTMF6.0	-17.82
-	OH-36	MB139	BSEP 1989	-19.28
			DOE-WIPP91-009	
20.13 - 21.03	QPP05	MU6	GTFM6.0	-12.53

Parameter(s): Log of the Intrinsic Permeability (T = 0 to 10,000 yrs) - Disturbed Rock Zone

Parameter Description:

The log of the intrinsic permeability of the Disturbed Rock Zone (DRZ) from 0 to 10,000 years.

Material and Parameter Name(s):

DRZ_1	PRMX_LOG (#198)
DRZ_1	PRMY_LOG (#199)
DRZ_1	PRMZ_LOG (#200)

Parameter Value: -15.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

The DRZ permeability for the repository (T = 0 to 1,000 years) is a modeling assumption based on laboratory and field permeability data related to the shaft, and modeling studies of DRZ development over time. In addition to the field data used to support the DRZ permeability for the time period T = -5 to 0 years, a number of studies have focused on charcterizing the development of the DRZ around the excavated underground facility (Stormont and Howard 1987; Stormont 1990; Borns and Stormont 1988; Holcomb 1988; Pfeifer et al. 1989). In laboratory tests of salt cores, Hansen and Mellegard (1979) found that dilatency is favored by conditions of low-confining stress and high deviatoric stress which characterizes the region near an excavation. Laboratory testing has shown that a halite DRZ is self-healing given the proper stress conditions (Brodsky 1990). Brodsky (1990) showed that artificially damaged cores could be healed with certain confining pressures and time.

Although a sizeable body of laboratory and field evidence of DRZ development exists, there have been no definitive studies conducted in vertical excavations at the WIPP until recently. Two hydraulic testing programs have been conducted within WIPP shafts. The earliest hydraulic testing program was conducted in the Waste Handling Shaft (WHS) (Saulnier and Avis 1988). More recently, hydraulic testing was performed to determine the extent of the DRZ in the Air Intake Shaft (AIS). Six boreholes, three at each of two levels, were used to determine gas and brine permeabilities.

Parameter(s): Log of the Intrinsic Permeability (T = 0 to 10,000 yrs) - Disturbed Rock Zone

Discussion:

The intrinsic permeability value for the DRZ for the time period from 0 to 10,000 years is the same as mode of the value for the shaft seal DRZ which is described in the "Data" section above. Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. For t = 0 to 10,000 yrs., the DRZ is assumed to be a well developed region characterized by vertical fractures. Because of gas generation and the resulting pressures in the repository, the DRZ above and below the repository is assumed not to heal. These fractures are a result of both the presence of the excavation and the pressurization of the repository due to gas generation. Consequently, the DRZ is assumed to provide a relatively permeable connection between the repository and the adjacent anhydrite layers. Because this enhanced permeability is associated with vertical fracturing there is little further increase in porosity. Many of the parameter values are selected to reduce the possibility of the numerical model result of over pressurization (pressures in excess of lithostatic for extend periods of time) of the repository due to gas generation. The surrounding formation will respond by providing pathways to relieve this pressure so that pressures of this magnitude are not realistic. The Salado FEP issue S-6 examined modeling of the DRZ and is documented in the FEPs record package. This analysis shows that use of a time invariant elevated permeability is an acceptable alternative to using a time varying permeability.

References:

Borns, D.J., and J.C. Stormont. 1988. *An Interim Report on Excavation Effects Studies at the Waste Isolation Pilot Plant: Delineation of the Disturbed Rock Zone*. SAND87-1375. Albuquerque, NM: Sandia National Laboratories.

Brodsky, N.S. 1990. *Crack Closure and Healing Studies in WIPP Salt Using Compressional Wave Velocity and Attenuation Measurements*. SAND90-7076. Albuquerque, NM: Sandia National Laboratories.

Hansen, F.D., and K.D. Mellegard. 1979. *Creep Behavior of Bedded Salt From Southeastern New Mexico at Elevated Temperature*. SAND79-7030. Albuquerque, NM: Sandia National Laboratories.

Holcomb, D.J. 1988. "Crosshole Measurements of Velocity and Attenuation to Detect a Disturbed Rock Zone in Salt at the Waste Isolation Pilot Plant." *Key Questions in Rock Mechanics, Proceedings of the 29th U.S. Symposium, University of Minnesota, Minneapolis, MN, June 13-15, 1988*. Eds. P.A. Cundall, R.L. Sterling, and A.M Starfield. Brookfield, VT: A.A. Balkema. 633-640.

Parameter(s): Log of the Intrinsic Permeability (T = 0 to 10,000 yrs) - Disturbed Rock Zone

References: (continued)

Pfeifer, M.C., D.J. Borns, C.K. Skokan, H.T. Andersen, and J.M. Starrett. 1989. "Geophysical Methods to Monitor Development of the Disturbed Rock Zone Around Underground Excavations in Bedded Salt," *Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Golden, CO, March 13, 1989.* Vol. 2. 400-411. SAND89-7055A. Albuquerque, NM: S andia National Laboratories.

Saulnier, G.J. Jr., and J.D. Avis. 1988. *Interpretation of Hydraulic Tests Conducted in the Waste-Handling Shaft at the Waste Isolation Pilot Plant (WIPP) Site*. SAND88-7001. Albuquerque, NM: Sandia National Laboratories.

Stormont, J.C. 1990. *Summary of 1988 WIPP Facility Horizon Gas Flow Measurements.* SAND89-2497. Albuquerque, NM: Sandia National Laboratories.

Stormont, J.C., and C.L. Howard. 1987. *Development, Implementation and Early Results: Test Series C of the Small-Scale Seal Performance Tests*. SAND87-2203. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Effective Porosity - Disturbed Rock Zone

Parameter Description:

Effective porosity of the Disturbed Rock Zone (DRZ) from time t = -5 yrs to 10,000 yrs.

Material and Parameter Name(s):

DRZ_0	POROSITY (#178)
DRZ_1	POROSITY (#195)

Parameter Value: 1.29×10^{-2}

mean	median	minimum	maximum	units
1.565×10^{-2}	1.29×10^{-2}	3.90×10^{-3}	3.29×10^{-2}	m^3/m^3

Distribution Type: Cumulative

Data: Professional Judgment

Discussion:

Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. The effective porosity for both time periods is the same and is equal to 0.0029 plus the Salado halite effective porosity.

References:

Vaughn, Palmer. 1996. E-mail from Palmer Vaughn to Margaret Chu, Re: Revision to DRZ and TZ Properties to be used in the BRAGFLO CCA Calculations. January 24, 1996.

Parameter(s): PCT_A Threshold Pressure Parameter - Disturbed Rock Zone

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

DRZ_0	PCT_A (#2702)
DRZ_1	PCT_A (#3128)

Parameter Value: 0

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Disturbed Rock Zone

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

DRZ_0	PCT_EXP (#2703)
DRZ_1	PCT_EXP (#3129)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Disturbed Rock Zone

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. Initially, the DRZ is specified to be 100 percent brine saturated. S_{br} is the point reached under increasing gas saturation when brine in the pore network becomes discontinuous due to displacement by gas, and the relative permeability to the liquid phase becomes zero.

Material and Parameter Name(s):

DRZ_0	SAT_RBRN (#188)
DRZ_1	SAT_RBRN (#205)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment

Discussion:

Assigning a zero residual brine saturation to the DRZ is conservative. The assumption allows relative brine phase permeability to be maintained over the full range of brine saturations (0-100 percent), regardless of the gas saturation level.

References:

Vaughn, Palmer. 1996. E-mail from Palmer Vaughn to Margaret Chu, Re: Revision to DRZ and TZ Properties to be used in the BRAGFLO CCA Calculations. January 24, 1996.

Parameter(s): Residual Gas Saturation - Disturbed Rock Zone

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

DRZ_0	SAT_RGAS (#189)
DRZ_1	SAT_RGAS (#206)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment

Discussion:

Assigning a zero residual gas saturation is conservative. This assumption allows relative gas phase permeability to be maintained over the full range of potential gas saturation conditions (0-100 percent).

References:

Vaughn, Palmer. 1996. E-mail from Palmer Vaughn to Margaret Chu, Re: Revision to DRZ and TZ Properties to be used in the BRAGFLO CCA Calculations. January 24, 1996.

Parameter(s): Pore Distribution - Disturbed Rock Zone

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

DRZ_0	PORE_DIS (#177)
DRZ_1	PORE_DIS (#194)

Parameter Value: 0.7

Units: None

Distribution Type: Constant

Data: Professional Judgment

Using the median value assigned to the Salado halite for the DRZ is a modeling assumption.

See Also: Data section of Parameter Sheet for "Pore Distribution - Halite."

Discussion:

Assigning a relatively low pore-size distribution to the DRZ is reasonable based on observations that porous materials with wide ranges of pore sizes typically display small λ values (Corey 1990).

See Also: Discussion section of Parameter Sheet for "Pore Distribution - Halite."

References:

Corey, A.T. 1990. Mechanics of Immiscible Fluids in Porous Media: Water Resources Publications. Littleton, CO.

Parameter(s): Rock Compressibility - Disturbed Rock Zone

Parameter Description:

The rock compressibility of the DRZ is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

DRZ_0	COMP_RCK (#175)
DRZ_1	COMP_RCK (#191)

Parameter Value: 7.41×10^{-10}

Units: Pa^{-1}

Distribution Type: Constant

Data: Site-Specific Experimental Data

Three hydraulic tests were performed in boreholes where the tested interval included DRZ anhydrite and/or halite in the underground WIPP facility. The test in QPP05 is considered representative of the DRZ not because of the depth of the test interval, but because of the proximity of the test interval to Room Q. A clear distinction is visible between the tests performed in halite (C2H01-A & QPP05) and the test performed in anhydrite (OH-36). The halite tests have much lower values of k and compressibility and higher pore pressure, while the anhydrite test displays high relative k and compressibility and zero pore pressure. The difference being caused by the style of deformation - brittle for anhydrite and ductile for halite.

See: Data Package for DRZ Rock Compressibility (SWCF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG16:DRZ ROCK COMPRESSIBILITY)

Parameter(s): Rock Compressibility - Disturbed Rock Zone

Discussion:

Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. Data for the first time period was used for the entire lifetime of the facility.

References:

SWCF-A:WBS1.2.07.1:PDD:QA:SALADO:PKG16:DRZ ROCK COMPRESSIBILITY

Rustler Formation Culebra Member Parameter Values (as summarized in Table 8-9, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of Intrinsic Permeability - Culebra

Parameter Description:

Log of the intrinsic permeability of the Culebra Member of the Rustler Formation.

Material and Parameter Name(s):

CULEBRA	PRMX_LOG (#143)
CULEBRA	PRMY_LOG (#144)
CULEBRA	PRMZ_LOG (#145)

Parameter Value: -13.678

Units: $\log(m^2)$

Distribution Type: Constant

Data: Professional Judgment

Discussion:

For each of the 70 transmissivity fields used in the 1992 PA analysis, an area weighted hydraulic conductivity was computed. The conductivity was estimated for a circular region 3.1 mi (5 km) in radius centered at the intrusion borehole location. These 70 hydraulic conductivity estimates provide a distribution that exists in the material property database, (PROPERTY. SDB) under material name CULEBRA and property name HYCD5000.

BRAGFLO uses intrinsic permeability rather than hydraulic conductivity. The relationship between these is given by

$$k = \frac{K\mu}{\rho g}$$

where k = intrinsic permeability (m^2)
K = hydraulic conductivity (m/s)
μ = fluid viscosity (Pa-s)
ρ = fluid mass density (kg/m^3)
g = gravitational constant (m/s^2)

Parameter(s): Log of Intrinsic Permeability - Culebra

Discussion: (continued)

The median value of hydraulic conductivity was used and fluid properties for Culebra brine (BRINECUL) were also obtained form the property database. The following were used:

$K = 2.24\ 10^{-7}$ m/s (median value)
$\mu = 0.001$ Pa-s
$\rho = 1090$ Kg/m^3
$g = 9.79$ m/s^2

resulting in an intrinsic permeability, k, of 2.10×10^{-14} m^2.

References:

SWCF-A 1.2.07.1:PDD:QA:NON-SALADO:PKG 21A:CULEBRA PERMEABILITY

Parameter(s): Effective Porosity - Culebra

Parameter Description:

Effective porosity of the Culebra Member of the Rustler Formation.

Material and Parameter Name(s):

CULEBRA POROSITY (#140)

Parameter Value: 0.151

Units: None

Distribution Type: Constant

Data: Site-Specific Experimental Data

Laboratory porosity data for Culebra core samples were provided in a memorandum from Wes Martin, Terra Tek, to Richard Beauheim, Sandia National Laboratories, dated January 8, 1996, RE: Progress Report - Contract AA-2896 and from Table 4.4 of SAND90-7011, *Core Analyses for Selected Samples from the Culebra Dolomite at the Waste Isolation Pilot Plant Site* by V. A. Kelley, G. J. Saulnier, Jr.

Discussion:

A total of 103 core samples from the Culebra were analyzed in the laboratory by Terra Tek, Inc., Salt Lake City, Utah. These included core samples from H-19b4, AIS, H-2a, H-2b, H-2b1, H-3b2, H-3b3, H-4b, H-5b, H-6b, H-7b1, H-7b2, H-7c, H-10b, H-11, WIPP-12, WIPP-13, WIPP-25, WIPP-26, WIPP-28, WIPP-30, and AEC-8.

The distribution of porosity values equals a point and that point is equal to the mean. Therefore, that point is a constant (0.151).

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#22:NON-SALADO EFFECTIVE POROSITY.

References: (continued)

Kelley, V.A., and G.J. Saulnier, Jr. 1990. *Core Analyses for Selected Samples from the Culebra Dolomite at the Waste Isolation Pilot Plant Site*. SAND90-7011. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter - Culebra

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

CULEBRA PCT_A (#2692)

Parameter Value: 0.26

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Culebra. The mean values measured for the anhydrites from the WIPP site are considered reasonable.

See Also: Data section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Given the lack of site-specific data, using the mean values measured for the anhydrites from the WIPP site for PCT_A and PCT_EXP are reasonable.

Parameter(s): PCT_A Threshold Pressure Parameter - Culebra

Discussion: (continued)

See Also: Discussion section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

See Also: References section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Parameter(s): PCT_EXP Threshold Pressure Parameter - Culebra

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

CULEBRA PCT_EXP (#2693)

Parameter Value: -0.348

Units: None

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Culebra. The mean values measured for the anhydrites from the WIPP site are considered reasonable.

See Also: Data section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Given the lack of site-specific data, using the mean values measured for the anhydrites from the WIPP site for PCT_A and PCT_EXP are reasonable.

See Also: Discussion section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Parameter(s): PCT_EXP Threshold Pressure Parameter - Culebra

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

See Also: References section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Parameter(s): Residual Brine Saturation - Culebra

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

CULEBRA SAT_RBRN (#150)

Parameter Value: 0.08363

Units: None

Distribution Type: Constant

Data: Professional Judgment

The mean value measured for Salado anhydrites from the WIPP site is considered reasonable.

See: Data section of Parameter Sheet for "Residual Brine Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

For modeling purposes, the Culebra Dolomite is assigned the value used for Salado anhydrites. The S_{br} value is relatively low, allowing relative permeability to the brine phase to be maintained over a wide range of brine saturations.

References:

See: References section of Parameter Sheet for "Residual Brine Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Parameter(s): Residual Gas Saturation - Culebra

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

CULEBRA SAT_RGAS (#151)

Parameter Value: 0.07711

Units: None

Distribution Type: Constant

Data: Professional Judgment

Using the mean value measured for Salado anhydrites for the Culebra Dolomite site is a modeling assumption.

Discussion:

Using the mean value measured for the anhydrites from the WIPP site for SAT_RGAS is reasonable. The mean values for the anhydrites fall within the range of values reported in the literature.

References:

See: "Residual Gas Saturation - Panel Closures" for discussion of general references.

Parameter(s): Pore Distribution - Culebra

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

CULEBRA PORE_DIS (#139)

Parameter Value: 0.6436

Units: None

Distribution Type: Constant

Data: Professional Judgment

The mean value measured for Salado anhydrites from the WIPP site is considered reasonable.

See: Data section of Parameter Sheet for "Pore Distribution - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

Although literature references are used to support similar PORE_DIS values assigned to other disposal system materials (e.g. Maloney et al. 1990; Mualem 1976; Brooks and Corey 1964), the Culebra Dolomite is assigned the value used for Salado anhydrites.

References:

Maloney, D.R., A.D. Brinkmeyer, and M.M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartlesville, OK: National Institute for Petroleum and Energy Research.

References (continued):

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Brooks, R.H. and A.T. Corey. 1964. Hydraulic Properties of Porous Media. Fort Collins, CO: Colorado State University.

Parameter(s): Rock Compressibility - Culebra

Parameter Description:

The rock compressibility of the Culebra Member of the Rustler Formation is used to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

CULEBRA COMP_RCK (#120)

Parameter Value: 10^{-10}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

See: Freeze, R.A., and R.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall, p. 55.

Discussion:

The value chosen represents an average literature value for this material type. Freeze and Cherry (1979) gave a range of 10^{-9} to 10^{-11} Pa^{-1} for the compressibility of sound rock. Therefore, the average, or 10^{-10} Pa^{-1}, was chosen for the Culebra.

Parameter(s): Rock Compressibility - Culebra

References:

Freeze, R.A., and R.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall, p. 55.

Parameter(s): Initial Pressure - Culebra

Parameter Description:

Initial brine far-field pore pressure in the Culebra Member of the Rustler Formation.

Material and Parameter Name(s):

CULEBRA PRESSURE (#142)

Parameter Value: 8.22×10^5

Units: Pa

Distribution Type: Pa

Data: Site-Specific Experimental Data

Data used in the calculation of initial pressure in the Magenta came from Mercer, J. W., 1983, *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico*," USGS Water Resources Investigations Report 83-4016, Prepared in cooperation with the US DOE.

Discussion:

The initial pressure in the Culebra was calculated from fluid level and fluid density data from H-1, H-2B, H-3, H-4B, H-5B, H-6B, P-14, P-15, and P-17 which are all located within the land-withdrawal area boundary. The constant value used in the NMVP represents the average value calculated from these nine points.

References:

Mercer, J.W. 1983. *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medaños Area, Southeastern New Mexico*. USGS Water Resources Investigations Report 83-4016. Prepared in cooperation with the U.S. DOE. Albuquerque, NM: U.S. Geological Survey.

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#24:NON-SALADO PRESSURE.

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Rustler Formation Magenta Member Parameter Values (as summarized in Table 8-10, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of Intrinsic Permeability - Magenta

Parameter Description:

Log of the intrinsic permeability of the Magenta Member of the Rustler Formation.

Material and Parameter Name(s):

MAGENTA	PRMX_LOG (#2102)
MAGENTA	PRMY_LOG (#2103)
MAGENTA	PRMZ_LOG (#2104)

Parameter Value: -15.2

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

Transmissivity data for the Magenta Member of the Rustler Formation was determined via a field hydrologic test at H-1 which was reported in Mercer, J.W., 1983, *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico*, USGS Water Resources Investigations Report 83-4016, Prepared in cooperation with the U.S. Department of Energy.

Discussion:

The Magenta transmissivity was calculated to be 0.05 ft^2/day (4.6×10^{-3} m^2/day) from the field hydrologic test at H-1. This transmissivity is equivalent to a permeability of 7.0×10^{-16} m^2 or -15.2 $\log(m^2)$ for the Magenta.

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#21:NON-SALADO PERMEABILITY.

Parameter(s): Log of Intrinsic Permeability - Magenta

References: (continued)

Mercer, J.W. 1983. *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medaños Area, Southeastern New Mexico*. USGS Water Resources Investigations Report 83-4016. Prepared in cooperation with the U.S. DOE. Albuquerque, NM: U.S. Geological Survey.

Parameter(s): Effective Porosity - Magenta

Parameter Description:

Effective porosity of the Magenta Member of the Rustler Formation.

Material and Parameter Name(s):

MAGENTA POROSITY (#2100)

Parameter Value: 0.138

mean	median	minimum	maximum	units
0.138	0.138	0.027	0.252	None

Distribution Type: Student-t

Data: Site-Specific Experimental Data

Laboratory porosity data for Magenta core samples was provided in a memorandum from Wes Martin, Terra Tek, to Richard Beauheim, Sandia National Laboratories, dated January 8, 1996, RE: Progress Report - Contract AA-2896.

Discussion:

Four core samples from the Magenta at H-19b1 were analyzed in the laboratory by Terra Tek, Inc., Salt Lake City, Utah. The four data points were used to fit a Student-t distribution for effective porosity.

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#22:NON-SALADO EFFECTIVE POROSITY.

Parameter(s): PCT_A Threshold Pressure Parameter - Magenta

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

MAGENTA PCT_A (#2726)

Parameter Value: 0.26

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Culebra. The mean values measured for the anhydrites from the WIPP site are considered reasonable.

See Also: Data section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Given the lack of site-specific data, using the mean values measured for the anhydrites from the WIPP site for PCT_A and PCT_EXP are reasonable.

Parameter(s): PCT_A Threshold Pressure Parameter - Magenta

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Magenta

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

MAGENTA PCT_EXP (#2727)

Parameter Value: -0.348

Units: None

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Culebra. The mean values measured for the anhydrites from the WIPP site are considered reasonable.

See Also: Data section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Given the lack of site-specific data, using the mean values measured for the anhydrites from the WIPP site for PCT_A and PCT_EXP are reasonable.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Magenta

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Magenta

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

MAGENTA SAT_RBRN (#2241)

Parameter Value: 0.08363

Units: None

Distribution Type: Constant

Data: Professional Judgment

The mean value measured for Salado anhydrites from the WIPP site is considered reasonable.

See Also: Data section of Parameter Sheet for "Residual Brine Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

For modeling purposes, the Magenta Dolomite is assigned the value used for Salado anhydrites. The S_{br} value is relatively low, allowing relative brine phase permeability to be maintained over a wide range of brine saturations.

References:

N/A

Parameter(s): Residual Gas Saturation - Magenta

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

MAGENTA SAT_RGAS (#2107)

Parameter Value: 0.07711

Units: None

Distribution Type: Constant

Data: Professional Judgment

Applying the mean value measured for Salado anhydrites to the Magenta Dolomite site is a modeling assumption.

See Also: Data section of Parameter Sheet for "Residual Gas Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

Using the mean value measured for the anhydrites from the WIPP site for SAT_RGAS is reasonable. The mean values for the anhydrites fall within the range of values reported in the literature (Mualem 1976; Maloney et al. 1990).

See "Residual Gas Saturation - Panel Closures" for discussion of references.

Parameter(s): Residual Gas Saturation - Magenta

References:

Maloney, D. R., A. D. Brinkmeyer, and M. M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone*. DOE Report NIPER-496. Bartlesville, OK: National Institute for Petroleum and Energy Research.

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils*. Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Parameter(s): Pore Distribution - Magenta

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

MAGENTA PORE_DIS (#2099)

Parameter Value: 0.6436

Units: None

Distribution Type: Constant

Data: Professional Judgment

Assigning the mean value for Salado anhydrites to the Magenta Dolomite is a modeling assumption.

See Also: Data section of Parameter Sheet for "Pore Distribution - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

Although literature references are used to support similar PORE_DIS values assigned to other disposal system materials (e.g., Maloney et al. 1990; Mualem 1976; Brooks and Corey 1964), the Magenta Dolomite is assigned the value used for Salado anhydrites.

See Also: Discussion section of Parameter Sheet for "Pore Distribution - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139."

Parameter(s): Pore Distribution - Magenta

References:

Maloney, D. R., A. D. Brinkmeyer, and M. M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartelsville, OK: National Institute for Petroleum and Energy Research.

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Brooks, R.H., and A.T. Corey. 1964. Hydraulic Properties of Porous Media. Fort Collins, CO: Colorado State University.

Parameter(s): Rock Compressibility - Magenta

Parameter Description:

The rock compressibility of the Magenta Member of the Rustler Formation is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)

ϕ_o = porosity at reference pressure p_o

c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

MAGENTA COMP_RCK (#3016)

Parameter Value: 2.644×10^{-10}

mean	median	minimum	maximum	units
2.644×10^{-10}	2.644×10^{-10}	1.162×10^{-10}	4.553×10^{-10}	Pa^{-1}

Distribution Type: Student-t

Data: Site- Specific Experimental Data

Laboratory compressibility data for Magenta core samples was provided in a memorandum from Wes Martin, Terra Tek, to Richard Beauheim, Sandia National Laboratories, dated January 8, 1996, RE: Progress Report - Contract AA-2896.

Discussion:

Three core samples from the Magenta at H-19b1 were analyzed in the laboratory by Terra Tek, Inc., Salt Lake City, Utah. The three data points were used to fit a Student-t distribution.

Parameter(s): Rock Compressibility - Magenta

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#23:NON-SALADO COMPRESSIBILITY.

Parameter(s): Initial Pressure - Magenta

Parameter Description:

Initial brine far-field pore pressure in the mid-point of the Magenta Member of the Rustler Formation.

Material and Parameter Name(s):

MAGENTA PRESSURE (#2101)

Parameter Value: 9.17×10^5

Units: Pa

Distribution Type: Constant

Data: Site-Specific Experimental Data

Data used in the calculation of initial pressure in the Magenta came from Mercer, J.W., 1983, *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico*," USGS Water Resources Investigations Report 83-4016, Prepared in cooperation with the US DOE.

Discussion:

The initial pressure in the Magenta was calculated from fluid level and fluid density data from H-1, H-2A, H-3, H-4A, H-5A, and H-6A which are all located within the LWA boundary. The constant value used in the NMVP represents the average value calculated from these six points.

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#24:NON-SALADO PRESSURE.

Mercer, J.W. 1983. *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medaños Area, Southeastern New Mexico*. USCS Water Resources Investigations Report 83-4016. Prepared in cooperation with the U.S. DOE. Albuquerque, NM: U.S. Geological Survey.

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Dewey Lake Formation Parameter Values (as summarized in Table 8-11, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of Intrinsic Permeability - Dewey Lake

Parameter Description:

Log of the Intrinsic permeability of the Dewey Lake Formation.

Material and Parameter Name(s):

DEWYLAKE	PRMX_LOG (#161)
DEWYLAKE	PRMY_LOG (#162)
DEWYLAKE	PRMZ_LOG (#163)

Parameter Value: -16.30

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

Laboratory permeability data for Dewey Lake core samples was provided in a memorandum from Wes Martin, Terra Tek, to Richard Beauheim, Sandia National Laboratories, dated January 8, 1996, RE: Progress Report - Contract AA-2896.

Discussion:

Intrinsic permeability in the Dewey Lake, as well as all other formations, is considered to be homogeneous and isotropic. Horizontal permeability was measured in the laboratory for five core samples from the Dewey Lake at H-19b1 by Terra Tek, Inc., Salt Lake City, Utah. The constant value [-16.30 $\log(m^2)$] chosen for the intrinsic permeability of the Dewey Lake is the median of the five data points.

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#21:NON-SALADO PERMEABILITY.

Parameter(s): Effective Porosity - Dewey Lake

Parameter Description:

Effective porosity of the Dewey Lake Formation.

Material and Parameter Name(s):

DEWYLAKE POROSITY (#158)

Parameter Value: 0.143

mean	median	minimum	maximum	units
0.143	0.143	0.035	0.248	m^3/m^3

Distribution Type: Student-t

Data: Site-Specific Experimental Data

Laboratory porosity data for Dewey Lake core samples was provided in a memorandum from Wes Martin, Terra Tek, to Richard Beauheim, Sandia National Laboratories, dated January 8, 1996, RE: Progress Report - Contract AA-2896.

Discussion:

Eight core samples from the Dewey Lake at H-19b1 were analyzed in the laboratory by Terra Tek, Inc., Salt Lake City, Utah. The eight data points were used to fit a Student-t distribution for effective porosity.

References:

SWCF-A:WBS1.2.07.1:PDD:QA:NON-SALADO:PKG#22:NON-SALADO EFFECTIVE POROSITY.

Parameter(s): PCT_A Threshold Pressure Parameter - Dewey Lake

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

DEWYLAKE PCT_A (#2697)

Parameter Value: 0.26

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Culebra. The mean values measured for the anhydrites from the WIPP site are considered reasonable.

See Also: Data section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Given the lack of site-specific data, using the mean values measured for the anhydrites from the WIPP site for PCT_A and PCT_EXP are reasonable.

Parameter(s): PCT_A Threshold Pressure Parameter - Dewey Lake

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Dewey Lake

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

DEWYLAKE PCT_EXP (#2698)

Parameter Value: -0.348

Units: None

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Culebra. The mean values measured for the anhydrites from the WIPP site are considered reasonable.

See Also: Data section of Parameter Sheet for "PCT_EXP Threshold Parameter - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Given the lack of site-specific data, using the mean values measured for the anhydrites from the WIPP site for PCT_A and PCT_EXP are reasonable.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Dewey Lake

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Dewey Lake

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{br} is also referred to as S_{wr} (wetting phase) or S_{lr} (liquid phase) and defines the minimum liquid saturation necessary for a material to exhibit relative permeability to that phase.

Material and Parameter Name(s):

DEWYLAKE SAT_RBRN (#169)

Parameter Value: 0.08363

Units: None

Distribution Type: Constant

Data: Professional Judgment

Assigning the mean value for Salado anhydrites to the Dewey Lake Formation is a modeling assumption.

See Also: Data section of Parameter Sheet for "Residual Brine Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

For modeling purposes, the Dewey Lake Formation is assigned the value used for Salado anhydrites. The S_{br} value is at the lower end of the range of values reported in the literature (Maloney et al. 1990; Mualem 1976), allowing relative permeability to the wetting phase to be maintained over a wide range of liquid saturations.

Parameter(s): Residual Brine Saturation - Dewey Lake

References:

Maloney, D.R., A.D. Brinkmeyer, and M.M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartlesville, OK: National Institute for Petroleum and Energy Research.

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Parameter(s): Residual Gas Saturation - Dewey Lake

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

DEWYLAKE SAT_RGAS (#170)

Parameter Value: 0.07711

Units: None

Distribution Type: Constant

Data: Professional Judgment

Using the mean value measured for Salado anhydrites for the Dewey Lake Formation site is a modeling assumption.

See Also: Data section of Parameter Sheet for "Residual Gas Saturation - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

Using the mean value measured for the anhydrites from the WIPP site for SAT_RGAS is reasonable. The mean values for the anhydrites fall at the lower end of the range of values reported in the literature (Mualem 1976; Maloney et al. 1990).

See "Residual Gas Saturation - Panel Closures" for discussion and references.

Parameter(s): Residual Gas Saturation - Dewey Lake

References:

Maloney, D.R., A.D. Brinkmeyer, and M.M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartlesville, OK: National Institute for Petroleum and Energy Research.

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodyamics and Hydraulic Laboratory.

Parameter(s): Pore Distribution - Dewey Lake

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

DEWYLAKE PORE_DIS (#157)

Parameter Value: 0.6436

Units: None

Distribution Type: Constant

Data: Professional Judgment

The mean value measured for Salado anhydrites from the WIPP site is considered reasonable.

See Also: Data section of Parameter Sheet for "Pore Distribution - Marker Bed 138, Anhydrite Layers a and b, and Marker Bed 139."

Discussion:

Literature references could be used to support the PORE_DIS value assigned to the well-sorted, fine-grained sandstone and siltstone of the Dewey Lake Formation (e.g., Morrow et al. 1986; Maloney et al. 1990; Mualem 1976; and Brooks and Corey 1964). For modeling purposes, the Dewey Lake Red Beds are assigned the same value as that used for Salado anhydrites.

Parameter(s): Pore Distribution - Dewey Lake

References:

Brooks, A.H., and A.T. Corey. 1964. Hydraulic Properties of Porous Media. Fort Collins, CO: Colorado State University.

Maloney, D.R., A.D. Brinkmeyer, and M.M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartlesville, OK: National Institue for Petroleum and Energy Research.

Morrow, N.R., J.S. Ward, and K.R. Brower. 1986. Rock Matrix and Fracture Analyses of Flow in Western Tight Gas Sands—1985 Annual Report. DOE/MC/21179-2032.

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Parameter(s): Rock Compressibility - Dewey Lake

Parameter Description:

The rock compressibility of the Dewey Lake Formation is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

DEWYLAKE COMP_RCK (#154)

Parameter Value: 10^{-8}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

See: Freeze, R.A. and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 55.

Discussion:

The value chosen represents an average literature value for this material type. Freeze and Cherry (1979) gave a range of 10^{-7} to 10^{-9} for the compressibility of sand. Therefore, the average, or 10^{-8} Pa^{-1}, was chosen for the Dewey Lake.

Parameter(s): Rock Compressibility - Dewey Lake

References:

Freeze, R.A. and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 55.

Parameter(s): Initial Pressure - Dewey Lake

Parameter Description:

Initial pressure in the Dewey Lake Formation.

Material and Parameter Name(s):

DEWYLAKE PRESSURE (#160)

Parameter Values: 1.01325×10^5

Units: Pa

Distribution Type: Constant

Data: Professional Judgment

The water table is set at 3,215 ft (980 m) above mean sea level based on calculations performed as part of the FEPs (Features, Events, and Processes) screening analyses performed in 1995. The region above 3,215 ft (980 m) (above the water table) is assumed to be at a residual liquid saturation of 20 percent.

Discussion:

The initial pressure above the water table in the Dewey Lake Formation is equal to 1.0 atm or 1.01325×10^5 Pa. The liquid saturation in the unsaturated zone above the water table is assumed to be 20 percent. The initial pressure below the water table in the Dewey Lake Formation is assumed to be hydrostatic. That is, the pressure exerted by the water at any given point in the formation is at rest. The pressure at any given point in the formation is due to the weight of water above it in the zone of saturation. The water table in the Dewey Lake Formation is at 3,215 ft (980 m) above mean sea level, which is 142 ft (43.3 m) below the top of the formation. As stated above, this elevation is based on calculations performed as part of the Features, Events, and Processes (FEPs) screening analyses performed in 1995.

References:

SWCF-A:1.1.6.3:PA:QA:TSK:NS-1 (Dewey Lake Data Collection and Compilation).

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Santa Rosa Formation Parameter Values (as summarized in Table 8-12, Chapter 8)

Note - Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" Section

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Parameter(s): Log of Intrinsic Permeability - Santa Rosa

Parameter Description:

Log of the intrinsic Permeability of the Santa Rosa Formation.

Material and Parameter Name(s):

SANTAROS	PRMX_LOG (#344)
SANTAROS	PRMY_LOG (#345)
SANTAROS	PRMZ_LOG (#346)

Parameter Value: -10.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Professional Judgment

See: Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 29.

Discussion:

The value chosen represents an average literature value for this material type (Freeze and Cherry 1979).

References:

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 29.

Parameter(s): Effective Porosity - Santa Rosa

Parameter Description:

Effective porosity of the Santa Rosa Formation.

Material and Parameter Name(s):

SANTAROS POROSITY (#341)

Parameter Value: 0.175

Units: None

Distribution Type: Constant

Data: Professional Judgment

See: Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 37.

Discussion:

The value chosen represents an average literature value for this material type. Freeze and Cherry (1979) gave a range of values for the porosity of sandstone of 0.05 to 0.30. Therefore, the average value, or 0.175, was chosen for the Santa Rosa.

References:

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 29.

Parameter(s): PCT_A Threshold Pressure Parameter - Santa Rosa

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

SANTAROS PCT_A (#2769)

Parameter Value: 0

Units: Pa/m^2

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Santa Rosa.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Santa Rosa

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

SANTAROS PCT_EXP (#2770)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Professional Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Santa Rosa.

Discussion:

The threshold pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Santa Rosa

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves (constant value). S_{br} is also referred to as S_{wr} (wetting phase) or as S_{lr} (liquid phase) and defines the minimum liquid saturation necessary for a material to exhibit relative permeability to that phase.

Material and Parameter Name(s):

SANTAROS SAT_RBRN (#351)

Parameter Value: 0.08363

Units: None

Distribution Type: Constant

Data: Professional Judgment

Assigning the mean value for Salado anhydrites to the Santa Rosa Formation is a modeling assumption.

Discussion:

For modeling purposes, the Santa Rosa is assigned the value used for Salado anhydrites. The S_{br} value is at the lower end of the range of values reported in the literature (Maloney et. al. 1990; Mualem 1976), allowing relative permeability to the wetting phase to be maintained over a wide range of liquid saturations.

References:

Maloney, D.R., A.D. Brinkmeyer, and M.M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartleville, OK: National Institute for Petroleum and Energy Research.

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Parameter(s): Residual Gas Saturation - Santa Rosa

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

SANTAROS SAT_RGAS (#352)

Parameter Value: 0.07711

Units: None

Distribution Type: Constant

Data: Professional Judgment

Applying the mean value measured for Salado anhydrites to the Santa Rosa Formation is a modeling assumption.

Discussion:

Using the mean value measured for the anhydrites from the WIPP site for SAT_RGAS is reasonable. The mean values for the anhydrites fall at the low end of the range of values reported in the literature.

References:

See: "Residual Gas Saturation - Panel Closures" for discussion and references.

Parameter(s): Pore Distribution - Santa Rosa

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

SANTAROS PORE_DIS (#340)

Parameter Value: 0.6436

Units: None

Distribution Type: Constant

Data: Professional Judgment

The mean value measured for the anhydrites from the WIPP site is considered reasonable.

Discussion:

Literature references could be used to support the PORE_DIS value assigned to the poorly-sorted, angular coarse-grained sandstone of the Santa Rosa Formation (e.g. Morrow et al. 1986; Mualem 1976; Brooks and Corey 1964). For modeling purposes, the Santa Rosa Formation is assigned the same value as that used for Salado anhydrites.

References:

Brooks, A.H. and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Fort Collins, CO: Colorado State University.

Maloney, D.R., A.D. Brinkmeyer, and M.M. Honarpour. 1990. *Relative Permeabilities and Other Characteristics of 700-Millidarcy Fired Berea Sandstone.* DOE Report NIPER-496. Bartleville, OK: National Institute for Petroleum and Energy Research.

Morrow, N.R., J.S. Ward, and K.R. Brower. 1986. Rock Matrix and Fracture Analyses of Flow in Western Tight Gas Sands - 1985 Annual Report. DOE/MC/21179-2032.

Parameter(s): Pore Distribution - Santa Rosa

References: (continued)

Mualem, Y. 1976. *A Catalogue of the Hydraulic Properties of Unsaturated Soils.* Project No. 442, Haifa, Israel: Technion, Israel Institute of Technology. Hydrodynamics and Hydraulic Laboratory.

Parameter(s): Rock Compressibility - Santa Rosa

Parameter Description:

The rock compressibility of the Santa Rosa Formation is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where

ϕ_o = porosity of solid matrix (dimensionless)
ϕ = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

SANTAROS COMP_RCK (#337)

Parameter Value: 10^{-8}

Units: Pa^{-1}

Distribution Type: Constant

Data: Professional Judgment

See: Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 55.

Discussion:

The value chosen represents an average literature value for this material type. Freeze and Cherry (1979) gave a range of values for the compressibility of sand of 10^{-7} to 10^{-9} Pa^{-1}. Therefore, the average value, or 10^{-8} Pa^{-1}, was chosen for the Santa Rosa.

Parameter(s): Rock Compressibility - Santa Rosa

References:

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice Hall. p. 55.

Parameter(s): Initial Pressure - Santa Rosa

Parameter Description:

Initial pressure in the unsaturated Santa Rosa Formation.

Material and Parameter Name(s):

SANTAROS PRESSURE (#343)

Parameter Value: 1.01325×10^5

Units: Pa

Distribution Type: Constant

Data: Professional Judgment

Discussion:

The initial pressure in the Santa Rosa Formation is equal to 1.0 atm or 1.01325×10^5 Pa. The Santa Rosa Formation is assumed to be unsaturated with an assumed liquid saturation of 20 percent.

References:

N/A

Table PAR-11. Key for NMVP Database

idmtrl	mtrldesc
ASPHALT	Asphalt shaft material
BRINESAL	Salado brine
CAVITY_1	Cavity for waste areas
CAVITY_2	Cavity for non-waste areas
CAVITY_3	Cavity for shaft
CAVITY_4	Cavity for borehole
CELLULS	Cellulose in waste material
CLAY_BOT	Bottom clay shaft material
CLAY_RUS	Clay seals in Rustler formation
CL_L_T1	Lower Salado clay shaft material: time period, 0 to 10 years
CL_L_T2	Lower Salado clay shaft material: time period, 10 to 25 years
CL_L_T3	Lower Salado clay shaft material: time period, 25 to 50 years
CL_L_T4	Lower Salado clay shaft material: time period, 50 to 10K years
CL_M_T1	Upper Salado clay shaft material: time period, 0 to 10 years
CL_M_T2	Upper Salado clay shaft material: time period, 10 to 25 years
CL_M_T3	Upper Salado clay shaft material: time period, 25 to 50 years
CL_M_T4	Upper Salado clay shaft material: time period, 50 to 100 years
CL_M_T5	Upper Salado clay shaft material: time period, 100 to 10K years
CONC_MON	Degraded concrete monolith at shaft base
CONC_T1	Concrete shaft material: time period, 0 to 400 years
CONC_T2	Concrete shaft material: time period, 400 to 10K years
CULEBRA	Culebra member of the Rustler formation
DEWYLAKE	Dewey Lake Red Beds
DRZ_0	Disturbed rock zone: time period -5 to 0 years
DRZ_1	Disturbed rock zone: time period 0 to 1000 years
EARTH	Earthen fill shaft material
EXP_AREA	Experimental area
FORTYNIN	Forty-niner member of the Rustler formation
H2	Hydrogen Gas
MAGENTA	Magenta member of the Rustler formation
NITRATE	Nitrate

NOTES:
idmtrl = material name
mtrldesc = material description

Table PAR-11. Key for NMVP Database (continued)

idmtrl	mtrldesc
OPS_AREA	Operations region
PAN_SEAL	Panel seal
REFCON	Reference Constant
REPOSIT	Repository regions outside of Panel region
SALT_T1	Shaft salt material column compacted: time 0 to 10 years
SALT_T2	Shaft salt material column compacted: time 10 to 25 years
SALT_T3	Shaft salt material column compacted: time 25 to 50 years
SALT_T4	Shaft salt material column compacted: time 50 to 100 years
SALT_T5	Shaft salt material column compacted: time 100 to 200 years
SALT_T6	Shaft salt material column compacted: time 200 to 10K years
SANTAROS	Santa Rosa formation
SHFT_DRZ	Permeability of the disturbed rock zone around the shafts
STEEL	Generic steel in waste
SULFATE	Sulfate
S_ANH_AB	Salado anhydrite beds a & b, intact and fractured
S_HALITE	Salado halite, intact
S_MB138	Salado marker bed 138, intact and fractured
S_MB139	Salado marker bed 139, intact and fractured
TAMARISK	Tamarisk member of the Rustler formation
UNNAMED	Unnamed Lower Member of Rustler formation
WAS_AREA	Waste emplacement area and waste

NOTES:
idmtrl = material name
mtrldesc = material description

Table PAR-12. Parameter Key for NMVP Database

idpram	pramdesc	units
ASDRUM	Surface area of corrodable metal per drum	m^2
ATMPA	Conversion from std. atmospheres to Pascals	Pa/atm
BKLINK	Klinkenberg b correction parameters for H_2 gas	Pa/m**2exp
CAP_MOD	Model number, capillary pressure model	NONE
COMP_RCK	Bulk compressibility	Pa^{-1}
COMPRES	Brine compressibility	Pa^{-1}
CORRMCO2	Inundated corrosion rate for steel without CO_2 present	m/s
CUMPROB	Index for selecting shaft material permeabilities	NONE
DCELLCHW	Average density of cellulosics in Contact-Handled (CH) Transuranic (TRU) waste	kg/m^3
DCELLRHW	Average density of cellulosics in Remote-Handled (RH) TRU waste	kg/m^3
DELTA_PF	Fracture initiation pressure	Pa
DIRNCCHW	Bulk density of iron containers, CH-TRU waste	kg/m^3
DIRNCRHW	Bulk density of iron containers, RH-TRU waste	kg/m^3
DIRONCHW	Average density of iron-based material in CH-TRU waste	kg/m^3
DIRONRHW	Average density of iron-based material in RH-TRU waste	kg/m^3
DNSFLUID	Brine density	kg/m^3
DPHIMAX	Incremental increase in porosity relative to intact conditions	NONE
DPLASCHW	Average density of plastics in CH-TRU waste	kg/m^3
DPLASRHW	Average density of plastics in RH-TRU waste	kg/m^3
DPLSCCHW	Bulk density of plastic liners, CH-TRU waste	kg/m^3
DPLSCRHW	Bulk density of plastic liners, RH-TRU waste	kg/m^3
DRROOM	Number of drums, per room, in ideal packing	NONE
DRUBBCHW	Average density of rubber in CH-TRU waste	kg/m^3
DRUBBRHW	Average density of rubber in RH-TRU waste	kg/m^3
EXPKLINK	Klinkenberg b correction parameters for H_2 gas	NONE
FBETA	Factor beta for microbial reaction rates	NONE
FCLAYFLL	Fraction of clay fill	NONE
FRAC_PR	Fraction of plastics and rubbers that are biodegradeable	NONE
GRATCORH	Gas generation rate, corrosion, humid conditions relative to inundated conditions	NONE
GRATCORI	Gas generation rate, corrosion, inundated conditions	mol H_2/m^2Fe
GRATMICH	Gas production rate, microbial, humid conditions relative to inundated rate	NONE
GRATMICI	Gas production rate, microbial, inundated conditions	mol/kg*s
GRAVACC	Standard gravitational acceleration	m/s^2
HUMCORR	Humid corrosion rate for steel	m/s
KMAXLOG	Log of maximum permeability in altered anhydrite flow model anhydrites	log (m**2)

NOTES:
idpram = parameter name
pramdesc = parameter description

Table PAR-12. Parameter Key for NMVP Database (continued)

idpram	pramdesc	units
KPT	Flag for permeability-determined threshold	NONE
OPS_AREA	Operations Area	NONE
PC_MAX	Maximum allowable capillary pressure	Pa
PCT_A	Threshold pressure linear parameter	Pa/(m**2PCT_EXP)
PCT_EXP	Threshold pressure exponential parameter	NONE
PF_DELTA	Incremental pressure for full fracture development	Pa
PI	Mathematical constant: PI	NONE
PMLT_HI	Log triangular distribution high value for permeability	$\log(m^2)$
PMLT_LO	Log triangular distribution low value for permeability	$\log(m^2)$
PMLT_MD	Log triangular distribution mode for permeability	$\log(m^2)$
PO_MIN	Minimum brine pressure for capillary model KPC=3	Pa
PORE_DIS	Brooks-Corey pore distribution parameter	NONE
POROSITY	Effective porosity	NONE
PRESSURE	Brine far-field pore pressure	Pa
PRMX_LOG	Log of intrinsic permeability, X-direction	$\log(m^2)$
PRMY_LOG	Log of intrinsic permeability, Y-direction	$\log(m^2)$
PRMZ_LOG	Log of intrinsic permeability, Z-direction	$\log(m^2)$
RADN_DRZ	DRZ outer radius at each shaft	m/m
RELP_MOD	Model number, relative permeability model	NONE
RSH_AIR	Air-supply shaft radius (3.09 m)	m
RSH_EXH	Air-exhaust shaft radius (2.3 m)	m
RSH_SAL	Salt-handling shaft radius (1.8 m)	m
RSH_WAS	Waste-handling shaft radius (3.5 m)	m
SAL_USAT	Average saturation, unsaturated zones	none
SAT_IBRN	Initial brine saturation	none
SAT_RBRN	Residual brine saturation	NONE
SAT_RGAS	Residual gas saturation	NONE
SAT_WICK	Index for computing wicking	NONE
SECYR	Conversion: Seconds to years	yr/s
STOICOR	Anoxic corrosion stoichiometric factor	none
STOIFX	Stoichiometric factor - X	NONE
STOIMIC	Stoichiometric factor for microbial gas generation	none
VISCO	Viscosity of H_2 Gas at 27 degrees Celsius & 0.101325 MPa	Pa*s
VOLCHW	Baseline Inventory Report (BIR) total volume of CH-TRU waste	m^3

NOTES:
idpram = parameter name
pramdesc = parameter description

Table PAR-12. Parameter Key for NMVP Database (continued)

idpram	pramdesc	units
VOLRHW	BIR total volume of RH-TRU waste	m^3
VPANLEX	Excavated volume of one panel	m^3
VREPOS	Excavated storage volume of the repository	m^3
VROOM	Volume of one room in repository	m^3
YRSEC	Conversion: Years to seconds	s/yr

NOTES:
idpram = parameter name
pramdesc = parameter description

Table PAR-13. Waste Panel Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
652	CAP_MOD	WAS_AREA	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
653	COMP_RCK	WAS_AREA	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2041	DCELLCHW	WAS_AREA	kg/m^3	CONSTANT	5.40000E+01	5.40000E+01	0.00000E+00	5.40000E+01	5.40000E+01
2274	DCELLRHW	WAS_AREA	kg/m^3	CONSTANT	1.70000E+01	1.70000E+01	0.00000E+00	1.70000E+01	1.70000E+01
1992	DIRNCCHW	WAS_AREA	kg/m^3	CONSTANT	1.39000E+02	1.39000E+02	0.00000E+00	1.39000E+02	1.39000E+02
1993	DIRNCRHW	WAS_AREA	kg/m^3	CONSTANT	2.59100E+03	2.59100E+03	0.00000E+00	2.59100E+03	2.59100E+03
2040	DIRONCHW	WAS_AREA	kg/m^3	CONSTANT	1.70000E+02	1.70000E+02	0.00000E+00	1.70000E+02	1.70000E+02
2044	DIRONRHW	WAS_AREA	kg/m^3	CONSTANT	1.00000E+02	1.00000E+02	0.00000E+00	1.00000E+02	1.00000E+02
2043	DPLASCHW	WAS_AREA	kg/m^3	CONSTANT	3.40000E+01	3.40000E+01	0.00000E+00	3.40000E+01	3.40000E+01
2275	DPLASRHW	WAS_AREA	kg/m^3	CONSTANT	1.50000E+01	1.50000E+01	0.00000E+00	1.50000E+01	1.50000E+01
1995	DPLSCCHW	WAS_AREA	kg/m^3	CONSTANT	2.60000E+01	2.60000E+01	0.00000E+00	2.60000E+01	2.60000E+01
2228	DPLSCRHW	WAS_AREA	kg/m^3	CONSTANT	3.10000E+00	3.10000E+00	0.00000E+00	3.10000E+00	3.10000E+00
2042	DRUBBCHW	WAS_AREA	kg/m^3	CONSTANT	1.00000E+01	1.00000E+01	0.00000E+00	1.00000E+01	1.00000E+01
2046	DRUBBRHW	WAS_AREA	kg/m^3	CONSTANT	3.30000E+00	3.30000E+00	0.00000E+00	3.30000E+00	3.30000E+00
656	GRATMICH	WAS_AREA	mol/kg*s	UNIFORM	6.34200E-10	6.34200E-10	3.66160E-10	0.00000E+00	1.26840E-09
657	GRATMICI	WAS_AREA	mol/kg*s	UNIFORM	4.91500E-09	4.91500E-09	2.65460E-09	3.17100E-10	9.51290E-09
2804	KPT	WAS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+01	0.00000E+00	0.00000E+00	0.00000E+00
658	PC_MAX	WAS_AREA	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2805	PCT_A	WAS_AREA	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2806	PCT_EXP	WAS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
661	PO_MIN	WAS_AREA	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
659	PORE_DIS	WAS_AREA	NONE	CUMULATIVE	3.25000E+00	2.89000E+00	1.27000E+00	1.44000E+00	5.78000E+00
660	POROSITY	WAS_AREA	NONE	CONSTANT	8.48000E-01	8.48000E-01	0.00000E+00	8.48000E-01	8.48000E-01
663	PRMX_LOG	WAS_AREA	$log(m^2)$	CONSTANT	-1.27690E+01	-1.27690E+01	0.00000E+00	-1.27690E+01	-1.27690E+01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-13. Waste Panel Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
664	PRMY_LOG	WAS_AREA	log(m^2)	CONSTANT	-1.27690E+01	-1.27690E+01	0.00000E+00	-1.27690E+01	-1.27690E+01
665	PRMZ_LOG	WAS_AREA	log(m^2)	CONSTANT	-1.27690E+01	-1.27690E+01	0.00000E+00	-1.27690E+01	-1.27690E+01
2823	PROBDEG	WAS_AREA	NONE	DELTA	2.00000E+00	2.00000E+00	0.00000E+00	0.00000E+00	2.00000E+00
668	RELP_MOD	WAS_AREA	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
669	SAT_IBRN	WAS_AREA	NONE	CONSTANT	1.50000E-02	1.50000E-02	0.00000E+00	1.50000E-02	1.50000E-02
670	SAT_RBRN	WAS_AREA	NONE	UNIFORM	2.76000E-01	2.76000E-01	1.59300E-01	0.00000E+00	5.52000E-01
671	SAT_RGAS	WAS_AREA	NONE	UNIFORM	7.50000E-02	7.50000E-02	4.33000E-02	0.00000E+00	1.50000E-01
2231	SAT_WICK	WAS_AREA		UNIFORM	5.00000E-01	5.00000E-01	2.89000E-01	0.00000E+00	1.00000E+00
2232	VOLCHW	WAS_AREA	m^3	CONSTANT	1.69000E+05	1.69000E+05	0.00000E+00	1.69000E+05	1.69000E+05
2233	VOLRHW	WAS_AREA	m^3	CONSTANT	7.08000E+03	7.08000E+03	0.00000E+00	7.08000E+03	7.08000E+03

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-14. Rest of Repository Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2110	CAP_MOD	REPOSIT	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2112	COMP_RCK	REPOSIT	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2113	DCELLCHW	REPOSIT	kg/m^3	CONSTANT	5.40000E+01	5.40000E+01	0.00000E+00	5.40000E+01	5.40000E+01
2114	DCELLRHW	REPOSIT	kg/m^3	CONSTANT	1.70000E+01	1.70000E+01	0.00000E+00	1.70000E+01	1.70000E+01
2115	DIRNCCHW	REPOSIT	kg/m^3	CONSTANT	1.39000E+02	1.39000E+02	0.00000E+00	1.39000E+02	1.39000E+02
2116	DIRNCRHW	REPOSIT	kg/m^3	CONSTANT	2.59100E+03	2.59100E+03	0.00000E+00	2.59100E+03	2.59100E+03
2117	DIRONCHW	REPOSIT	kg/m^3	CONSTANT	1.70000E+02	1.70000E+02	0.00000E+00	1.70000E+02	1.70000E+02
2118	DIRONRHW	REPOSIT	kg/m^3	CONSTANT	1.00000E+02	1.00000E+02	0.00000E+00	1.00000E+02	1.00000E+02
2119	DPLASCHW	REPOSIT	kg/m^3	CONSTANT	3.40000E+01	3.40000E+01	0.00000E+00	3.40000E+01	3.40000E+01
2120	DPLASRHW	REPOSIT	kg/m^3	CONSTANT	1.50000E+01	1.50000E+01	0.00000E+00	1.50000E+01	1.50000E+01
2121	DPLSCCHW	REPOSIT	kg/m^3	CONSTANT	2.60000E+01	2.60000E+01	0.00000E+00	2.60000E+01	2.60000E+01
2995	DPLSCRHW	REPOSIT	kg/m^3	CONSTANT	3.10000E+00	3.10000E+00	0.00000E+00	3.10000E+00	3.10000E+00
2122	DRUBBCHW	REPOSIT	kg/m^3	CONSTANT	1.00000E+01	1.00000E+01	0.00000E+00	1.00000E+01	1.00000E+01
2123	DRUBBRHW	REPOSIT	kg/m^3	CONSTANT	3.30000E+00	3.30000E+00	0.00000E+00	3.30000E+00	3.30000E+00
2127	GRATMICH	REPOSIT	mol/kg*s	UNIFORM	6.34200E-10	6.34200E-10	3.66160E-10	0.00000E+00	1.26840E-09
2128	GRATMICI	REPOSIT	mol/kg*s	UNIFORM	4.91500E-09	4.91500E-09	2.65460E-09	3.17100E-10	9.51290E-09
2736	KPT	REPOSIT	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2242	PC_MAX	REPOSIT	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2737	PCT_A	REPOSIT	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2738	PCT_EXP	REPOSIT	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2739	PO_MIN	REPOSIT	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2129	PORE_DIS	REPOSIT	NONE	CUMULATIVE	3.25000E+00	2.89000E+00	1.27000E+00	1.44000E+00	5.78000E+00
2130	POROSITY	REPOSIT	NONE	CONSTANT	8.48000E-01	8.48000E-01	0.00000E+00	8.48000E-01	8.48000E-01
2131	PRMX_LOG	REPOSIT	$log(m^2)$	CONSTANT	-1.27690E+01	-1.27690E+01	0.00000E+00	-1.27690E+01	-1.27690E+01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-14. Rest of Repository Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2132	PRMY_LOG	REPOSIT	log(m^2)	CONSTANT	-1.27690E+01	-1.27690E+01	0.00000E+00	-1.27690E+01	-1.27690E+01
2133	PRMZ_LOG	REPOSIT	log(m^2)	CONSTANT	-1.27690E+01	-1.27690E+01	0.00000E+00	-1.27690E+01	-1.27690E+01
2824	PROBDEG	REPOSIT	NONE	DELTA	2.00000E+00	2.00000E+00	0.00000E+00	0.00000E+00	2.00000E+00
2135	RELP_MOD	REPOSIT	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2740	SAT_IBRN	REPOSIT	NONE	CONSTANT	1.50000E-02	1.50000E-02	0.00000E+02	1.50000E-02	1.50000E-02
2741	SAT_RBRN	REPOSIT	NONE	UNIFORM	2.76000E-01	2.76000E-01	1.59300E-01	0.00000E+00	5.52000E-01
2137	SAT_RGAS	REPOSIT	NONE	UNIFORM	7.50000E-02	7.50000E-02	4.33000E-02	0.00000E+00	1.50000E-01
2138	SAT_WICK	REPOSIT	NONE	UNIFORM	5.00000E-01	5.00000E-01	2.89000E-01	0.00000E+00	1.00000E+00
2141	VOLCHW	REPOSIT	m^3	CONSTANT	1.69000E+05	1.69000E+05	0.00000E+00	1.69000E+05	1.69000E+05
2142	VOLRHW	REPOSIT	m^3	CONSTANT	7.08000E+03	7.08000E+03	0.00000E+00	7.08000E+03	7.08000E+03

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-15. Operations Region Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
7	CAP_MOD	OPS_AREA	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
8	COMP_RCK	OPS_AREA	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2604	KPT	OPS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
9	PC_MAX	OPS_AREA	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2605	PCT_A	OPS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2606	PCT_EXP	OPS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
12	PO_MIN	OPS_AREA	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
10	PORE_DIS	OPS_AREA	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
11	POROSITY	OPS_AREA	NONE	CONSTANT	1.80000E-01	1.80000E-01	0.00000E+00	1.80000E-01	1.80000E-01
14	PRMX_LOG	OPS_AREA	$log(m^2)$	CONSTANT	-1.10000E+01	-1.10000E+01	0.00000E+00	-1.10000E+01	-1.10000E+01
15	PRMY_LOG	OPS_AREA	$log(m^2)$	CONSTANT	-1.10000E+01	-1.10000E+01	0.00000E+00	-1.10000E+01	-1.10000E+01
16	PRMZ_LOG	OPS_AREA	$log(m^2)$	CONSTANT	-1.10000E+01	-1.10000E+01	0.00000E+00	-1.10000E+01	-1.10000E+01
19	RELP_MOD	OPS_AREA	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
21	SAT_RBRN	OPS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
22	SAT_RGAS	OPS_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-16. Experimental Area Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
207	CAP_MOD	EXP_AREA	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
208	COMP_RCK	EXP_AREA	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2711	KPT	EXP_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
209	PC_MAX	EXP_AREA	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2712	PCT_A	EXP_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2713	PCT_EXP	EXP_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
212	PO_MIN	EXP_AREA	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
210	PORE_DIS	EXP_AREA	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
211	POROSITY	EXP_AREA	NONE	CONSTANT	1.80000E-01	1.80000E-01	0.00000E+00	1.80000E-01	1.80000E-01
214	PRMX_LOG	EXP_AREA	$log(m^2)$	CONSTANT	-1.10000E+01	-1.10000E+01	0.00000E+00	-1.10000E+01	-1.10000E+01
215	PRMY_LOG	EXP_AREA	$log(m^2)$	CONSTANT	-1.10000E+01	-1.10000E+01	0.00000E+00	-1.10000E+01	-1.10000E+01
216	PRMZ_LOG	EXP_AREA	$log(m^2)$	CONSTANT	-1.10000E+01	-1.10000E+01	0.00000E+00	-1.10000E+01	-1.10000E+01
219	RELP_MOD	EXP_AREA	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
221	SAT_RBRN	EXP_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
222	SAT_RGAS	EXP_AREA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-17. Panel Closure Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
252	CAP_MOD	PAN_SEAL	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
253	COMP_RCK	PAN_SEAL	Pa^{-1}	CONSTANT	2.64000E-09	2.64000E-09	0.00000E+00	2.64000E-09	2.64000E-09
2731	KPT	PAN_SEAL	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
254	PC_MAX	PAN_SEAL	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2732	PCT_A	PAN_SEAL	NONE	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2733	PCT_EXP	PAN_SEAL	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
257	PO_MIN	PAN_SEAL	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
255	PORE_DIS	PAN_SEAL	NONE	CONSTANT	9.40000E-01	9.40000E-01	0.00000E+00	9.40000E-01	9.40000E-01
256	POROSITY	PAN_SEAL	NONE	CONSTANT	7.50000E-02	7.50000E-02	0.00000E+00	7.50000E-02	7.50000E-02
259	PRMX_LOG	PAN_SEAL	$log(m^2)$	CONSTANT	-1.50000E+01	-1.50000E+01	0.00000E+00	-1.50000E+01	-1.50000E+01
260	PRMY_LOG	PAN_SEAL	$log(m^2)$	CONSTANT	-1.50000E+01	-1.50000E+01	0.00000E+00	-1.50000E+01	-1.50000E+01
261	PRMZ_LOG	PAN_SEAL	$log(m^2)$	CONSTANT	-1.50000E+01	-1.50000E+01	0.00000E+00	-1.50000E+01	-1.50000E+01
264	RELP_MOD	PAN_SEAL	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2734	SAT_IBRN	PAN_SEAL	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
265	SAT_RBRN	PAN_SEAL	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01
266	SAT_RGAS	PAN_SEAL	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-18. Salado Formation Halite Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
540	CAP_MOD	S_HALITE	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
541	COMP_RCK	S_HALITE	Pa^{-1}	UNIFORM	9.75000E-11	9.75000E-11	5.46000E-11	2.94000E-12	1.92000E-10
2778	KPT	S_HALITE	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
542	PC_MAX	S_HALITE	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2779	PCT_A	S_HALITE	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2780	PCT_EXP	S_HALITE	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
545	PO_MIN	S_HALITE	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
543	PORE_DIS	S_HALITE	NONE	CUMULATIVE	2.90000E+00	7.00000E-01	3.10000E+00	2.00000E-01	1.00000E+01
544	POROSITY	S_HALITE	NONE	CUMULATIVE	1.28000E-02	1.00000E-02	8.52000E-03	1.00000E-03	3.00000E-02
546	PRESSURE	S_HALITE	Pa	UNIFORM	1.24700E+07	1.24700E+07	8.23000E+05	1.10400E+07	1.38900E+07
547	PRMX_LOG	S_HALITE	$log(m^2)$	UNIFORM	-2.25000E+01	-2.25000E+01	8.66025E-01	-2.40000E+01	-2.10000E+01
548	PRMY_LOG	S_HALITE	$log(m^2)$	UNIFORM	-2.25000E+01	-2.25000E+01	8.66025E-01	-2.40000E+01	-2.10000E+01
549	PRMZ_LOG	S_HALITE	$log(m^2)$	UNIFORM	-2.25000E+01	-2.25000E+01	8.66025E-01	-2.40000E+01	-2.10000E+01
553	RELP_MOD	S_HALITE	NONE	DELTA	4.00000E+00	4.00000E+00	0.00000E+00	1.00000E+00	4.00000E+00
555	SAT_RBRN	S_HALITE	NONE	UNIFORM	3.00000E-01	3.00000E-01	1.73000E-01	0.00000E+00	6.00000E-01
556	SAT_RGAS	S_HALITE	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15000E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-19. Gas Generation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2994	FBETA	CELLULS	NONE	UNIFORM	5.00000E-01	5.00000E-01	2.88680E-01	0.00000E+00	1.00000E+00
228	VISCO	H2	Pa*s	CONSTANT	8.93389E-06	8.93389E-06	0.00000E+00	8.93389E-06	8.93389E-06
2906	QINIT	NITRATE	moles	CONSTANT	2.61000E+07	2.61000E+07	0.00000E+00	2.61000E+07	2.61000E+07
2907	CORRMCO2	STEEL	m/s	UNIFORM	7.93700E-15	7.93700E-15	4.58100E-15	0.00000E+00	1.58700E-14
2910	HUMCORR	STEEL	m/s	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2898	STOIFX	STEEL	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2909	QINIT	SULFATE	moles	CONSTANT	6.59000E+06	6.59000E+06	0.00000E+00	6.59000E+06	6.59000E+06

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-20. Shaft Disturbed Rock Zone

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
3133	PRMX LOG	SHFT DRZ	log(m^2)	TRIANGULAR	-1.53333E+01	-1.50000E+01	6.23610E-01	-1.70000E+01	-1.40000E+01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-21. Earthen Fill Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2496	CAP_MOD	EARTH	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2497	COMP_RCK	EARTH	Pa^{-1}	CONSTANT	3.10000E-08	3.10000E-08	0.00000E+00	3.10000E-08	3.10000E-08
2706	KPT	EARTH	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2498	PC_MAX	EARTH	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2707	PCT_A	EARTH	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2708	PCT_EXP	EARTH	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2501	PO_MIN	EARTH	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2499	PORE_DIS	EARTH	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2500	POROSITY	EARTH	m^3/m^3	CONSTANT	3.20000E-01	3.20000E-01	0.00000E+00	3.20000E-01	3.20000E-01
2502	PRESSURE	EARTH	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2503	PRMX_LOG	EARTH	$log(m^2)$	TRIANGULAR	-1.43330E+01	-1.40000E+01	1.02700E+00	-1.70000E+01	-1.20000E+01
2504	PRMY_LOG	EARTH	$log(m^2)$	TRIANGULAR	-1.43330E+01	-1.40000E+01	1.02700E+00	-1.70000E+01	-1.20000E+01
2505	PRMZ_LOG	EARTH	$log(m^2)$	TRIANGULAR	-1.43330E+01	-1.40000E+01	1.02700E+00	-1.70000E+01	-1.20000E+01
2509	RELP_MOD	EARTH	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3032	RSH_AIR	EARTH	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3035	RSH_EXH	EARTH	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3033	RSH_SAL	EARTH	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3034	RSH_WAS	EARTH	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2510	SAT_IBRN	EARTH	NONE	CONSTANT	8.00000E-01	8.00000E-01	0.00000E+00	8.00000E-01	8.00000E-01
2511	SAT_RBRN	EARTH	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2512	SAT_RGAS	EARTH	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-22. Rustler Compacted Clay Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
3000	CAP_MOD	CLAY_RUS	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
3001	COMP_RCK	CLAY_RUS	Pa^{-1}	CONSTANT	1.96000E-09	1.96000E-09	0.00000E+00	1.96000E-09	1.96000E-09
3002	KPT	CLAY_RUS	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3003	PC_MAX	CLAY_RUS	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
3004	PCT_A	CLAY_RUS	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
3005	PCT_EXP	CLAY_RUS	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
3131	PO_MIN	CLAY_RUS	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
3006	PORE_DIS	CLAY_RUS	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
3007	POROSITY	CLAY_RUS	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
3008	PRESSURE	CLAY_RUS	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
3009	PRMX_LOG	CLAY_RUS	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3010	PRMY_LOG	CLAY_RUS	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3011	PRMZ_LOG	CLAY_RUS	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3012	RELP_MOD	CLAY_RUS	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2996	RSH_AIR	CLAY_RUS	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2999	RSH_EXH	CLAY_RUS	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2997	RSH_SAL	CLAY_RUS	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2998	RSH_WAS	CLAY_RUS	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
3013	SAT_IBRN	CLAY_RUS	NONE	CONSTANT	7.90000E-01	7.90000E-01	0.00000E+00	7.90000E-01	7.90000E-01
3014	SAT_RBRN	CLAY_RUS	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
3015	SAT_RGAS	CLAY_RUS	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-23. Asphalt Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2276	CAP_MOD	ASPHALT	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2277	COMP_RCK	ASPHALT	Pa^{-1}	CONSTANT	2.97000E-08	2.97000E-08	0.00000E+00	2.97000E-08	2.97000E-08
2599	KPT	ASPHALT	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2278	PC_MAX	ASPHALT	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2600	PCT_A	ASPHALT	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2601	PCT_EXP	ASPHALT	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2281	PO_MIN	ASPHALT	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2279	PORE_DIS	ASPHALT	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2280	POROSITY	ASPHALT	m^3/m^3	CONSTANT	1.00000E-02	1.00000E-02	0.00000E+00	1.00000E-02	1.00000E-02
2283	PRMX_LOG	ASPHALT	$log(m^2)$	TRIANGULAR	-1.96670E+01	-2.00000E+01	6.23600E-01	-2.10000E+01	-1.80000E+01
2284	PRMY_LOG	ASPHALT	$log(m^2)$	TRIANGULAR	-1.96670E+01	-2.00000E+01	6.23600E-01	-2.10000E+01	-1.80000E+01
2285	PRMZ_LOG	ASPHALT	$log(m^2)$	TRIANGULAR	-1.96670E+01	-2.00000E+01	6.23600E-01	-2.10000E+01	-1.80000E+01
2933	RADN_DRZ	ASPHALT	m/m	CONSTANT	1.62900E+00	1.62900E+00	0.00000E+00	1.62900E+00	1.62900E+00
2289	RELP_MOD	ASPHALT	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2929	RSH_AIR	ASPHALT	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2932	RSH_EXH	ASPHALT	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2930	RSH_SAL	ASPHALT	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2931	RSH_WAS	ASPHALT	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2290	SAT_IBRN	ASPHALT	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2291	SAT_RBRN	ASPHALT	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2292	SAT_RGAS	ASPHALT	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-24. Concrete Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2463	CAP_MOD	CONC_T1	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2464	COMP_RCK	CONC_T1	Pa^{-1}	CONSTANT	2.64000E-09	2.64000E-09	0.00000E+00	2.64000E-09	2.64000E-09
2681	KPT	CONC_T1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2465	PC_MAX	CONC_T1	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2682	PCT_A	CONC_T1	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2683	PCT_EXP	CONC_T1	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2468	PO_MIN	CONC_T1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2466	PORE_DIS	CONC_T1	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2467	POROSITY	CONC_T1	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2470	PRMX_LOG	CONC_T1	$log(m^2)$	TRIANGULAR	-1.88160E+01	-1.87496E+01	7.55000E-01	-2.06990E+01	-1.70000E+01
2471	PRMY_LOG	CONC_T1	$log(m^2)$	TRIANGULAR	-1.88160E+01	-1.87496E+01	7.55000E-01	-2.06990E+01	-1.70000E+01
2472	PRMZ_LOG	CONC_T1	$log(m^2)$	TRIANGULAR	-1.88160E+01	-1.87496E+01	7.55000E-01	-2.06990E+01	-1.70000E+01
3040	RADN_DRZ	CONC_T1	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2476	RELP_MOD	CONC_T1	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3036	RSH_AIR	CONC_T1	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3039	RSH_EXH	CONC_T1	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3037	RSH_SAL	CONC_T1	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3038	RSH_WAS	CONC_T1	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2477	SAT_IBRN	CONC_T1	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2478	SAT_RBRN	CONC_T1	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2479	SAT_RGAS	CONC_T1	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2480	CAP_MOD	CONC_T2	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2481	COMP_RCK	CONC_T2	Pa^{-1}	CONSTANT	2.64000E-09	2.64000E-09	0.00000E+00	2.64000E-09	2.64000E-09
2686	KPT	CONC_T2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-24. Concrete Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2482	PC_MAX	CONC_T2	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2687	PCT_A	CONC_T2	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2688	PCT_EXP	CONC_T2	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2808	PO_MIN	CONC_T2	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2483	PORE_DIS	CONC_T2	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2484	POROSITY	CONC_T2	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2486	PRMX_LOG	CONC_T2	$log(m^2)$	CONSTANT	-1.40000E+01	-1.40000E+01	0.00000E+00	-1.40000E+01	-1.40000E+01
2487	PRMY_LOG	CONC_T2	$log(m^2)$	CONSTANT	-1.40000E+01	-1.40000E+01	0.00000E+00	-1.40000E+01	-1.40000E+01
2488	PRMZ_LOG	CONC_T2	$log(m^2)$	CONSTANT	-1.40000E+01	-1.40000E+01	0.00000E+00	-1.40000E+01	-1.40000E+01
3045	RADN_DRZ	CONC_T2	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2492	RELP_MOD	CONC_T2	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3041	RSH_AIR	CONC_T2	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3044	RSH_EXH	CONC_T2	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3042	RSH_SAL	CONC_T2	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3043	RSH_WAS	CONC_T2	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2494	SAT_RBRN	CONC_T2	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2495	SAT_RGAS	CONC_T2	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-25. Crushed Salt Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2513	CAP_MOD	SALT_T1	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2514	COMP_RCK	SALT_T1	Pa^{-1}	CONSTANT	1.60000E-09	1.60000E-09	0.00000E+00	1.60000E-09	1.60000E-09
2939	CUMPROB	SALT_T1	NONE	UNIFORM	5.00000E-01	5.00000E-01	2.88000E-01	0.00000E+00	1.00000E+00
2744	KPT	SALT_T1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2515	PC_MAX	SALT_T1	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2745	PCT_A	SALT_T1	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2746	PCT_EXP	SALT_T1	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2942	PMLT_HI	SALT_T1	$log(m^2)$	CONSTANT	-1.22652E+01	-1.22652E+01	0.00000E+00	-1.22652E+01	-1.22652E+01
2941	PMLT_LO	SALT_T1	$log(m^2)$	CONSTANT	-1.73010E+01	-1.73010E+01	0.00000E+00	-1.73010E+01	-1.73010E+01
2940	PMLT_MD	SALT_T1	$log(m^2)$	CONSTANT	-1.47825E+01	-1.47825E+01	0.00000E+00	-1.47825E+01	-1.47825E+01
2518	PO_MIN	SALT_T1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2516	PORE_DIS	SALT_T1	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2517	POROSITY	SALT_T1	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2938	RADN_DRZ	SALT_T1	m/m	CONSTANT	1.81400E+00	1.81400E+00	0.00000E+00	1.81400E+00	1.81400E+00
2526	RELP_MOD	SALT_T1	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2934	RSH_AIR	SALT_T1	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2937	RSH_EXH	SALT_T1	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2935	RSH_SAL	SALT_T1	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2936	RSH_WAS	SALT_T1	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2527	SAT_IBRN	SALT_T1	NONE	CONSTANT	3.20000E-01	3.20000E-01	0.00000E+00	3.20000E-01	3.20000E-01
2528	SAT_RBRN	SALT_T1	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2529	SAT_RGAS	SALT_T1	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2530	CAP_MOD	SALT_T2	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2531	COMP_RCK	SALT_T2	Pa^{-1}	CONSTANT	1.60000E-09	1.60000E-09	0.00000E+00	1.60000E-09	1.60000E-09

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-25. Crushed Salt Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2749	KPT	SALT_T2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2532	PC_MAX	SALT_T2	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2750	PCT_A	SALT_T2	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2751	PCT_EXP	SALT_T2	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2950	PMLT_HI	SALT_T2	$log(m^2)$	CONSTANT	-1.22652E+01	-1.22652E+01	0.00000E+00	-1.22652E+01	-1.22652E+01
2949	PMLT_LO	SALT_T2	$log(m^2)$	CONSTANT	-1.73010E+01	-1.73010E+01	0.00000E+00	-1.73010E+01	-1.73010E+01
2948	PMLT_MD	SALT_T2	$log(m^2)$	CONSTANT	-1.47825E+01	-1.47825E+01	0.00000E+00	-1.47825E+01	-1.47825E+01
2535	PO_MIN	SALT_T2	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2533	PORE_DIS	SALT_T2	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2534	POROSITY	SALT_T2	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2947	RADN_DRZ	SALT_T2	m/m	CONSTANT	1.11000E+00	1.11000E+00	0.00000E+00	1.11000E+00	1.11000E+00
2543	RELP_MOD	SALT_T2	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2943	RSH_AIR	SALT_T2	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2946	RSH_EXH	SALT_T2	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2944	RSH_SAL	SALT_T2	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2945	RSH_WAS	SALT_T2	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2545	SAT_RBRN	SALT_T2	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2546	SAT_RGAS	SALT_T2	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2547	CAP_MOD	SALT_T3	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2548	COMP_RCK	SALT_T3	Pa^{-1}	CONSTANT	1.60000E-09	1.60000E-09	0.00000E+00	1.60000E-09	1.60000E-09
2754	KPT	SALT_T3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2549	PC_MAX	SALT_T3	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2755	PCT_A	SALT_T3	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2756	PCT_EXP	SALT_T3	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-25. Crushed Salt Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2958	PMLT_HI	SALT_T3	log(m^2)	CONSTANT	-1.22652E+01	-1.22652E+01	0.00000E+00	-1.22652E+01	-1.22652E+01
2957	PMLT_LO	SALT_T3	log(m^2)	CONSTANT	-1.73010E+01	-1.73010E+01	0.00000E+00	-1.73010E+01	-1.73010E+01
2956	PMLT_MD	SALT_T3	log(m^2)	CONSTANT	-1.47825E+01	-1.47825E+01	0.00000E+00	-1.47825E+01	-1.47825E+01
2552	PO_MIN	SALT_T3	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2550	PORE_DIS	SALT_T3	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2551	POROSITY	SALT_T3	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2955	RADN_DRZ	SALT_T3	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2560	RELP_MOD	SALT_T3	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2951	RSH_AIR	SALT_T3	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2954	RSH_EXH	SALT_T3	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2952	RSH_SAL	SALT_T3	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2953	RSH_WAS	SALT_T3	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2562	SAT_RBRN	SALT_T3	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-010
2563	SAT_RGAS	SALT_T3	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2564	CAP_MOD	SALT_T4	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2565	COMP_RCK	SALT_T4	Pa^{-1}	CONSTANT	1.60000E-09	1.60000E-09	0.00000E+00	1.60000E-09	1.60000E-09
2759	KPT	SALT_T4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2566	PC_MAX	SALT_T4	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2760	PCT_A	SALT_T4	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2761	PCT_EXP	SALT_T4	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2966	PMLT_HI	SALT_T4	log(m^2)	CONSTANT	-1.39508E+01	-1.39508E+01	0.00000E+00	-1.39508E+01	-1.39508E+01
2965	PMLT_LO	SALT_T4	log(m^2)	CONSTANT	-2.28761E+01	-2.28761E+01	0.00000E+00	-2.28761E+01	-2.28761E+01
2964	PMLT_MD	SALT_T4	log(m^2)	CONSTANT	-1.71656E+01	-1.71656E+01	0.00000E+00	-1.71656E+01	-1.71656E+01
2569	PO_MIN	SALT_T4	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-25. Crushed Salt Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2567	PORE_DIS	SALT_T4	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2568	POROSITY	SALT_T4	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2963	RADN_DRZ	SALT_T4	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2577	RELP_MOD	SALT_T4	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2959	RSH_AIR	SALT_T4	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2962	RSH_EXH	SALT_T4	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2960	RSH_SAL	SALT_T4	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2961	RSH_WAS	SALT_T4	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2579	SAT_RBRN	SALT_T4	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2580	SAT_RGAS	SALT_T4	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2581	CAP_MOD	SALT_T5	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2582	COMP_RCK	SALT_T5	Pa^{-1}	CONSTANT	1.60000E-09	1.60000E-09	0.00000E+00	1.60000E-09	1.60000E-09
2764	KPT	SALT_T5	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2583	PC_MAX	SALT_T5	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2765	PCT_A	SALT_T5	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2766	PCT_EXP	SALT_T5	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2974	PMLT_HI	SALT_T5	$log(m^2)$	CONSTANT	-1.54260E+01	-1.54260E+01	0.00000E+00	-1.54260E+01	-1.54260E+01
2973	PMLT_LO	SALT_T5	$log(m^2)$	CONSTANT	-2.28761E+01	-2.28761E+01	0.00000E+00	-2.28761E+01	-2.28761E+01
2972	PMLT_MD	SALT_T5	$log(m^2)$	CONSTANT	-1.92782E+01	-1.92782E+01	0.00000E+00	-1.92782E+01	-1.92782E+01
3125	PO_MIN	SALT_T5	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2809	PORE_DIS	SALT_T5	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2585	POROSITY	SALT_T5	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2971	RADN_DRZ	SALT_T5	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2594	RELP_MOD	SALT_T5	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-25. Crushed Salt Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2967	RSH_AIR	SALT_T5	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2970	RSH_EXH	SALT_T5	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2968	RSH_SAL	SALT_T5	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2969	RSH_WAS	SALT_T5	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2596	SAT_RBRN	SALT_T5	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2597	SAT_RGAS	SALT_T5	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2983	CAP_MOD	SALT_T6	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2984	COMP_RCK	SALT_T6	Pa^{-1}	CONSTANT	1.60000E-09	1.60000E-09	0.00000E+00	1.60000E-09	1.60000E-09
2985	KPT	SALT_T6	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2986	PC_MAX	SALT_T6	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2987	PCT_A	SALT_T6	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2988	PCT_EXP	SALT_T6	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2982	PMLT_HI	SALT_T6	$log(m^2)$	CONSTANT	-1.76676E+01	-1.76676E+01	0.00000E+00	-1.76676E+01	-1.76676E+01
2981	PMLT_LO	SALT_T6	$log(m^2)$	CONSTANT	-2.28761E+01	-2.28761E+01	0.00000E+00	-2.28761E+01	-2.28761E+01
2980	PMLT_MD	SALT_T6	$log(m^2)$	CONSTANT	-2.02716E+01	-2.02716E+01	0.00000E+00	-2.02716E+01	-2.02716E+01
3126	PO_MIN	SALT_T6	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2989	PORE_DIS	SALT_T6	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2990	POROSITY	SALT_T6	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
2979	RADN_DRZ	SALT_T6	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2991	RELP_MOD	SALT_T6	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2975	RSH_AIR	SALT_T6	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2978	RSH_EXH	SALT_T6	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2976	RSH_SAL	SALT_T6	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2977	RSH_WAS	SALT_T6	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-25. Crushed Salt Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2992	SAT_RBRN	SALT_T6	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2993	SAT_RGAS	SALT_T6	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-26. Upper Clay Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2378	CAP_MOD	CL_M_T1	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2379	COMP_RCK	CL_M_T1	Pa^{-1}	CONSTANT	1.81000E-09	1.81000E-09	0.00000E+00	1.81000E-09	1.81000E-09
2656	KPT	CL_M_T1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2380	PC_MAX	CL_M_T1	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2657	PCT_A	CL_M_T1	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2658	PCT_EXP	CL_M_T1	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2383	PO_MIN	CL_M_T1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2381	PORE_DIS	CL_M_T1	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2382	POROSITY	CL_M_T1	$m^3/m^{\wedge 3}$	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2385	PRMX_LOG	CL_M_T1	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2386	PRMY_LOG	CL_M_T1	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2387	PRMZ_LOG	CL_M_T1	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3088	RADN_DRZ	CL_M_T1	m/m	CONSTANT	1.70900E+00	1.70900E+00	0.00000E+00	1.70900E+00	1.70900E+00
2391	RELP_MOD	CL_M_T1	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3084	RSH_AIR	CL_M_T1	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3087	RSH_EXH	CL_M_T1	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3085	RSH_SAL	CL_M_T1	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3086	RSH_WAS	CL_M_T1	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2392	SAT_IBRN	CL_M_T1	NONE	CONSTANT	7.90000E-01	7.90000E-01	0.00000E+00	7.90000E-01	7.90000E-01
2393	SAT_RBRN	CL_M_T1	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2394	SAT_RGAS	CL_M_T1	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2395	CAP_MOD	CL_M_T2	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2396	COMP_RCK	CL_M_T2	Pa^{-1}	CONSTANT	1.81000E-09	1.81000E-09	0.00000E+00	1.81000E-09	1.81000E-09
2661	KPT	CL_M_T2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-26. Upper Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2397	PC_MAX	CL_M_T2	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2662	PCT_A	CL_M_T2	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2663	PCT_EXP	CL_M_T2	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2400	PO_MIN	CL_M_T2	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2398	PORE_DIS	CL_M_T2	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2399	POROSITY	CL_M_T2	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2402	PRMX_LOG	CL_M_T2	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2403	PRMY_LOG	CL_M_T2	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2404	PRMZ_LOG	CL_M_T2	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3093	RADN_DRZ	CL_M_T2	m/m	CONSTANT	1.46900E+00	1.46900E+00	0.00000E+00	1.46900E+00	1.46900E+00
2408	RELP_MOD	CL_M_T2	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3089	RSH_AIR	CL_M_T2	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3092	RSH_EXH	CL_M_T2	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3090	RSH_SAL	CL_M_T2	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3091	RSH_WAS	CL_M_T2	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2410	SAT_RBRN	CL_M_T2	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2411	SAT_RGAS	CL_M_T2	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2412	CAP_MOD	CL_M_T3	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2413	COMP_RCK	CL_M_T3	Pa^{-1}	CONSTANT	1.81000E-09	1.81000E-09	0.00000E+00	1.81000E-09	1.81000E-09
2666	KPT	CL_M_T3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2414	PC_MAX	CL_M_T3	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2667	PCT_A	CL_M_T3	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2668	PCT_EXP	CL_M_T3	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2417	PO_MIN	CL_M_T3	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-26. Upper Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2415	PORE_DIS	CL_M_T3	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2416	POROSITY	CL_M_T3	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2419	PRMX_LOG	CL_M_T3	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2420	PRMY_LOG	CL_M_T3	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2421	PRMZ_LOG	CL_M_T3	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3098	RADN_DRZ	CL_M_T3	m/m	CONSTANT	1.28300E+00	1.28300E+00	0.00000E+00	1.28300E+00	1.28300E+00
2425	RELP_MOD	CL_M_T3	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3094	RSH_AIR	CL_M_T3	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3097	RSH_EXH	CL_M_T3	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3095	RSH_SAL	CL_M_T3	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3096	RSH_WAS	CL_M_T3	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2427	SAT_RBRN	CL_M_T3	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2428	SAT_RGAS	CL_M_T3	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2429	CAP_MOD	CL_M_T4	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2430	COMP_RCK	CL_M_T4	Pa^{-1}	CONSTANT	1.81000E-09	1.81000E-09	0.00000E+00	1.81000E-09	1.81000E-09
2671	KPT	CL_M_T4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2431	PC_MAX	CL_M_T4	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2672	PCT_A	CL_M_T4	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2673	PCT_EXP	CL_M_T4	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2434	PO_MIN	CL_M_T4	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2432	PORE_DIS	CL_M_T4	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2433	POROSITY	CL_M_T4	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2436	PRMX_LOG	CL_M_T4	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2437	PRMY_LOG	CL_M_T4	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-26. Upper Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2438	PRMZ_LOG	CL_M_T4	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2923	RADN_DRZ	CL_M_T4	m/m	CONSTANT	1.10700E+00	1.10700E+00	0.00000E+00	1.10700E+00	1.10700E+00
2442	RELP_MOD	CL_M_T4	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2919	RSH_AIR	CL_M_T4	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
2922	RSH_EXH	CL_M_T4	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2920	RSH_SAL	CL_M_T4	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2921	RSH_WAS	CL_M_T4	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2444	SAT_RBRN	CL_M_T4	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2445	SAT_RGAS	CL_M_T4	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2446	CAP_MOD	CL_M_T5	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2447	COMP_RCK	CL_M_T5	Pa^{-1}	CONSTANT	1.81000E-09	1.81000E-09	0.00000E+00	1.81000E-09	1.81000E-09
2676	KPT	CL_M_T5	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2448	PC_MAX	CL_M_T5	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2677	PCT_A	CL_M_T5	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2678	PCT_EXP	CL_M_T5	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2451	PO_MIN	CL_M_T5	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2449	PORE_DIS	CL_M_T5	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2450	POROSITY	CL_M_T5	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2453	PRMX_LOG	CL_M_T5	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2454	PRMY_LOG	CL_M_T5	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2455	PRMZ_LOG	CL_M_T5	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2928	RADN_DRZ	CL_M_T5	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2459	RELP_MOD	CL_M_T5	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2924	RSH_AIR	CL_M_T5	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-26. Upper Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2927	RSH_EXH	CL_M_T5	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
2925	RSH_SAL	CL_M_T5	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
2926	RSH_WAS	CL_M_T5	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2461	SAT_RBRN	CL_M_T5	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2462	SAT_RGAS	CL_M_T5	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-27. Lower Clay Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2327	CAP_MOD	CL_L_T1	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2328	COMP_RCK	CL_L_T1	Pa^{-1}	CONSTANT	1.59000E-09	1.59000E-09	0.00000E+00	1.59000E-09	1.59000E-09
2641	KPT	CL_L_T1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2329	PC_MAX	CL_L_T1	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2642	PCT_A	CL_L_T1	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2643	PCT_EXP	CL_L_T1	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2332	PO_MIN	CL_L_T1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2330	PORE_DIS	CL_L_T1	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2331	POROSITY	CL_L_T1	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2334	PRMX_LOG	CL_L_T1	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2335	PRMY_LOG	CL_L_T1	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2336	PRMZ_LOG	CL_L_T1	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3021	RADN_DRZ	CL_L_T1	m/m	CONSTANT	1.85800E+00	1.85800E+00	0.00000E+00	1.85800E+00	1.85800E+00
2340	RELP_MOD	CL_L_T1	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3017	RSH_AIR	CL_L_T1	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3020	RSH_EXH	CL_L_T1	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3018	RSH_SAL	CL_L_T1	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3019	RSH_WAS	CL_L_T1	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2341	SAT_IBRN	CL_L_T1	NONE	CONSTANT	7.90000E-01	7.90000E-01	0.00000E+00	7.90000E-01	7.90000E-01
2342	SAT_RBRN	CL_L_T1	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.67000E-02	0.00000E+00	6.00000E-01
2343	SAT_RGAS	CL_L_T1	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2344	CAP_MOD	CL_L_T2	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2345	COMP_RCK	CL_L_T2	Pa^{-1}	CONSTANT	1.59000E-09	1.59000E-09	0.00000E+00	1.59000E-09	1.59000E-09
2646	KPT	CL_L_T2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-27. Lower Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2346	PC_MAX	CL_L_T2	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2647	PCT_A	CL_L_T2	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2648	PCT_EXP	CL_L_T2	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2349	PO_MIN	CL_L_T2	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2347	PORE_DIS	CL_L_T2	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2348	POROSITY	CL_L_T2	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2351	PRMX_LOG	CL_L_T2	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2352	PRMY_LOG	CL_L_T2	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2353	PRMZ_LOG	CL_L_T2	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3026	RADN_DRZ	CL_L_T2	m/m	CONSTANT	1.16200E+00	1.16200E+00	0.00000E+00	1.16200E+00	1.16200E+00
2357	RELP_MOD	CL_L_T2	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3022	RSH_AIR	CL_L_T2	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3025	RSH_EXH	CL_L_T2	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3023	RSH_SAL	CL_L_T2	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3024	RSH_WAS	CL_L_T2	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2359	SAT_RBRN	CL_L_T2	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2360	SAT_RGAS	CL_L_T2	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
2361	CAP_MOD	CL_L_T3	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2362	COMP_RCK	CL_L_T3	Pa^{-1}	CONSTANT	1.59000E-09	1.59000E-09	0.00000E+00	1.59000E-09	1.59000E-09
2651	KPT	CL_L_T3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2363	PC_MAX	CL_L_T3	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2652	PCT_A	CL_L_T3	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2653	PCT_EXP	CL_L_T3	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2366	PO_MIN	CL_L_T3	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-27. Lower Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2364	PORE_DIS	CL_L_T3	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2365	POROSITY	CL_L_T3	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2368	PRMX_LOG	CL_L_T3	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2369	PRMY_LOG	CL_L_T3	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2370	PRMZ_LOG	CL_L_T3	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3031	RADN_DRZ	CL_L_T3	m/m	CONSTANT	1.00200E+00	1.00200E+00	0.00000E+00	1.00200E+00	1.00200E+00
2374	RELP_MOD	CL_L_T3	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3027	RSH_AIR	CL_L_T3	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3030	RSH_EXH	CL_L_T3	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3028	RSH_SAL	CL_L_T3	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3029	RSH_WAS	CL_L_T3	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
2376	SAT_RBRN	CL_L_T3	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
2377	SAT_RGAS	CL_L_T3	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01
3070	CAP_MOD	CL_L_T4	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
3071	COMP_RCK	CL_L_T4	Pa^{-1}	CONSTANT	1.59000E-09	1.59000E-09	0.00000E+00	1.59000E-09	1.59000E-09
3072	KPT	CL_L_T4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3073	PC_MAX	CL_L_T4	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
3074	PCT_A	CL_L_T4	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
3075	PCT_EXP	CL_L_T4	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
3123	PO_MIN	CL_L_T4	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
3076	PORE_DIS	CL_L_T4	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
3077	POROSITY	CL_L_T4	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
3078	PRMX_LOG	CL_L_T4	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81110E-01	-2.10000E+01	-1.73010E+01
3079	PRMY_LOG	CL_L_T4	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-27. Lower Clay Shaft Material Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
3080	PRMZ_LOG	CL_L_T4	log(m^2)	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
3069	RADN_DRZ	CL_L_T4	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
3081	RELP_MOD	CL_L_T4	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3065	RSH_AIR	CL_L_T4	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3068	RSH_EXH	CL_L_T4	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3066	RSH_SAL	CL_L_T4	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3067	RSH_WAS	CL_L_T4	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
3082	SAT_RBRN	CL_L_T4	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
3083	SAT_RGAS	CL_L_T4	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-28. Bottom Clay Component Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2310	CAP_MOD	CLAY_BOT	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
2311	COMP_RCK	CLAY_BOT	Pa^{-1}	CONSTANT	1.59000E-09	1.59000E-09	0.00000E+00	1.59000E-09	1.59000E-09
2636	KPT	CLAY_BOT	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2312	PC_MAX	CLAY_BOT	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2637	PCT_A	CLAY_BOT	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
2638	PCT_EXP	CLAY_BOT	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
2315	PO_MIN	CLAY_BOT	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2313	PORE_DIS	CLAY_BOT	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
2314	POROSITY	CLAY_BOT	m^3/m^3	CONSTANT	2.40000E-01	2.40000E-01	0.00000E+00	2.40000E-01	2.40000E-01
2317	PRMX_LOG	CLAY_BOT	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2318	PRMY_LOG	CLAY_BOT	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2319	PRMZ_LOG	CLAY_BOT	$log(m^2)$	TRIANGULAR	-1.88670E+01	-1.83010E+01	7.81100E-01	-2.10000E+01	-1.73010E+01
2323	RELP_MOD	CLAY_BOT	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2324	SAT_IBRN	CLAY_BOT	NONE	CONSTANT	7.90000E-01	7.90000E-01	0.00000E+00	7.90000E-01	7.90000E-01
2325	SAT_RBRN	CLAY_BOT	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.67000E-02	0.00000E+00	6.00000E-01
2326	SAT_RGAS	CLAY_BOT	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-29. Concrete Monolith Shaft Material Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
3051	CAP_MOD	CONC_MON	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
3052	COMP_RCK	CONC_MON	Pa^{-1}	CONSTANT	2.64000E-09	2.64000E-09	0.00000E+00	2.64000E-09	2.64000E-09
3053	KPT	CONC_MON	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3054	PC_MAX	CONC_MON	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
3055	PCT_A	CONC_MON	Pa	CONSTANT	5.60000E-01	5.60000E-01	0.00000E+00	5.60000E-01	5.60000E-01
3056	PCT_EXP	CONC_MON	NONE	CONSTANT	-3.46000E-01	-3.46000E-01	0.00000E+00	-3.46000E-01	-3.46000E-01
3124	PO_MIN	CONC_MON	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
3057	PORE_DIS	CONC_MON	NONE	CUMULATIVE	2.52000E+00	9.40000E-01	2.48000E+00	1.10000E-01	8.10000E+00
3058	POROSITY	CONC_MON	m^3/m^3	CONSTANT	5.00000E-02	5.00000E-02	0.00000E+00	5.00000E-02	5.00000E-02
3059	PRMX_LOG	CONC_MON	$log(m^2)$	CONSTANT	-1.40000E+01	-1.40000E+01	0.00000E+00	-1.40000E+01	-1.40000E+01
3060	PRMY_LOG	CONC_MON	$log(m^2)$	CONSTANT	-1.40000E+01	-1.40000E+01	0.00000E+00	-1.40000E+01	-1.40000E+01
3061	PRMZ_LOG	CONC_MON	$log(m^2)$	CONSTANT	-1.40000E+01	-1.40000E+01	0.00000E+00	-1.40000E+01	-1.40000E+01
3050	RADN_DRZ	CONC_MON	m/m	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
3062	RELP_MOD	CONC_MON	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3046	RSH_AIR	CONC_MON	m	CONSTANT	3.09000E+00	3.09000E+00	0.00000E+00	3.09000E+00	3.09000E+00
3049	RSH_EXH	CONC_MON	m	CONSTANT	2.30000E+00	2.30000E+00	0.00000E+00	2.30000E+00	2.30000E+00
3047	RSH_SAL	CONC_MON	m	CONSTANT	1.80000E+00	1.80000E+00	0.00000E+00	1.80000E+00	1.80000E+00
3048	RSH_WAS	CONC_MON	m	CONSTANT	3.50000E+00	3.50000E+00	0.00000E+00	3.50000E+00	3.50000E+00
3115	SAT_IBRN	CONC_MON	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
3063	SAT_RBRN	CONC_MON	NONE	CUMULATIVE	2.50000E-01	2.00000E-01	1.76000E-01	0.00000E+00	6.00000E-01
3064	SAT_RGAS	CONC_MON	NONE	UNIFORM	2.00000E-01	2.00000E-01	1.15500E-01	0.00000E+00	4.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-30. Salado Marker Bed 139 Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2905	BKLINK	S_MB139	Pa	CONSTANT	3.36000E-01	3.36000E-01	0.00000E+00	3.36000E-01	3.36000E-01
579	CAP_MOD	S_MB139	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
580	COMP_RCK	S_MB139	Pa^{-1}	STUDENT	8.26300E-11	8.26300E-11	1.11500E-10	1.09000E-11	2.75000E-10
2177	DPHIMAX	S_MB139	NONE	CONSTANT	3.90000E-02	3.90000E-02	0.00000E+00	3.90000E-02	3.90000E-02
2903	EXPKLINK	S_MB139	NONE	CONSTANT	-3.36000E-01	-3.36000E-01	0.00000E+00	-3.36000E-01	-3.36000E-01
2811	IFRX	S_MB139	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2814	IFRY	S_MB139	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2817	IFRZ	S_MB139	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2178	KMAXLOG	S_MB139	log (m**2)	CONSTANT	-9.00000E+00	-9.00000E+00	0.00000E+00	-9.00000E+00	-9.00000E+00
2788	KPT	S_MB139	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
582	PC_MAX	S_MB139	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2789	PCT_A	S_MB139	Pa	CONSTANT	2.60000E-01	2.60000E-01	0.00000E+00	2.60000E-01	2.60000E-01
2790	PCT_EXP	S_MB139	NONE	CONSTANT	-3.48000E-01	-3.48000E-01	0.00000E+00	-3.48000E-01	-3.48000E-01
2180	PF_DELTA	S_MB139	Pa	CONSTANT	3.80000E+06	3.80000E+06	0.00000E+00	3.80000E+06	3.80000E+06
586	PI_DELTA	S_MB139	Pa	CONSTANT	2.00000E+05	2.00000E+05	0.00000E+00	2.00000E+05	2.00000E+05
589	PO_MIN	S_MB139	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
587	PORE_DIS	S_MB139	NONE	STUDENT	6.43600E-01	6.43600E-01	1.08600E-01	4.90530E-01	8.41780E-01
588	POROSITY	S_MB139	NONE	STUDENT	1.10000E-02	1.10000E-02	3.04000E-03	9.00000E-03	1.70000E-02
591	PRMX_LOG	S_MB139	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
592	PRMY_LOG	S_MB139	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
593	PRMZ_LOG	S_MB139	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
596	RELP_MOD	S_MB139	NONE	DELTA	4.00000E+00	4.00000E+00	0.00000E+00	1.00000E+00	4.00000E+00
598	SAT_RBRN	S_MB139	NONE	STUDENT	8.36300E-02	8.36300E-02	5.01100E-02	7.84600E-03	1.74000E-01
599	SAT_RGAS	S_MB139	NONE	STUDENT	7.71100E-02	7.71100E-02	6.41100E-02	1.39800E-02	1.97190E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-31. Salado Marker Bed 138 Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2904	BKLINK	S_MB138	Pa	CONSTANT	3.36000E-01	3.36000E-01	0.00000E+00	3.36000E-01	3.36000E-01
559	CAP_MOD	S_MB138	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
560	COMP_RCK	S_MB138	Pa^{-1}	STUDENT	8.26300E-11	8.26300E-11	1.11500E-10	1.09000E-11	2.75000E-10
2169	DPHIMAX	S_MB138	NONE	CONSTANT	3.90000E-02	3.90000E-02	0.00000E+01	3.90000E-02	3.90000E-02
2902	EXPKLINK	S_MB138	NONE	CONSTANT	-3.36000E-01	-3.36000E-01	0.00000E+00	-3.36000E-01	-3.36000E-01
2810	IFRX	S_MB138	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2813	IFRY	S_MB138	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2816	IFRZ	S_MB138	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2170	KMAXLOG	S_MB138	log (m**2)	CONSTANT	-9.00000E+00	-9.00000E+00	0.00000E+00	-9.00000E+00	-9.00000E+00
2783	KPT	S_MB138	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
561	PC_MAX	S_MB138	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2784	PCT_A	S_MB138	Pa	CONSTANT	2.60000E-01	2.60000E-01	0.00000E+00	2.60000E-01	2.60000E-01
2785	PCT_EXP	S_MB138	NONE	CONSTANT	-3.48000E-01	-3.48000E-01	0.00000E+00	-3.48000E-01	-3.48000E-01
563	PF_DELTA	S_MB138	Pa	CONSTANT	3.80000E+06	3.80000E+06	0.00000E+00	3.80000E+06	3.80000E+06
565	PI_DELTA	S_MB138	Pa	CONSTANT	2.00000E+05	2.00000E+05	0.00000E+00	2.00000E+05	2.00000E+05
568	PO_MIN	S_MB138	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
566	PORE_DIS	S_MB138	NONE	STUDENT	6.43600E-01	6.43600E-01	1.08600E-01	4.90530E-01	8.41780E-01
567	POROSITY	S_MB138	NONE	STUDENT	1.10000E-02	1.10000E-02	3.04000E-03	6.00000E-03	1.70000E-02
570	PRMX_LOG	S_MB138	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
571	PRMY_LOG	S_MB138	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
572	PRMZ_LOG	S_MB138	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
575	RELP_MOD	S_MB138	NONE	DELTA	4.00000E+00	4.00000E+00	0.00000E+00	1.00000E+00	4.00000E+00
577	SAT_RBRN	S_MB138	NONE	STUDENT	8.36300E-02	8.36300E-02	5.01100E-02	7.84600E-03	1.74000E-01
578	SAT_RGAS	S_MB138	NONE	STUDENT	7.71100E-02	7.71100E-02	6.41100E-02	1.39800E-02	1.97190E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-32. Salado Anhydrite Layers A and B Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2819	BKLINK	S_ANH_AB	Pa	CONSTANT	3.36000E-01	3.36000E-01	0.00000E+00	3.36000E-01	3.36000E-01
520	CAP_MOD	S_ANH_AB	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
521	COMP_RCK	S_ANH_AB	Pa^{-1}	STUDENT	8.26300E-11	8.26300E-11	1.11500E-10	1.09000E-11	2.75000E-10
2158	DPHIMAX	S_ANH_AB	NONE	CONSTANT	2.39000E-01	2.39000E-01	0.00000E+00	2.39000E-01	2.39000E-01
2820	EXPKLINK	S_ANH_AB	NONE	CONSTANT	-3.36000E-01	-3.36000E-01	0.00000E+00	-3.36000E-01	-3.36000E-01
2812	IFRX	S_ANH_AB	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2815	IFRY	S_ANH_AB	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2818	IFRZ	S_ANH_AB	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2159	KMAXLOG	S_ANH_AB	log (m**2)	CONSTANT	-9.00000E+00	-9.00000E+00	0.00000E+00	-9.00000E+00	-9.00000E+00
2773	KPT	S_ANH_AB	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
522	PC_MAX	S_ANH_AB	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2774	PCT_A	S_ANH_AB	Pa	CONSTANT	2.60000E-01	2.60000E-01	0.00000E+00	2.60000E-01	2.60000E-01
2775	PCT_EXP	S_ANH_AB	NONE	CONSTANT	-3.48000E-01	-3.48000E-01	0.00000E+00	-3.48000E-01	-3.48000E-01
524	PF_DELTA	S_ANH_AB	Pa	CONSTANT	3.80000E+06	3.80000E+06	0.00000E+00	3.80000E+06	3.80000E+06
526	PI_DELTA	S_ANH_AB	Pa	CONSTANT	2.00000E+05	2.00000E+05	0.00000E+00	2.00000E+05	2.00000E+05
529	PO_MIN	S_ANH_AB	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
527	PORE_DIS	S_ANH_AB	NONE	STUDENT	6.43600E-01	6.43600E-01	1.08600E-01	4.90530E-01	8.41780E-01
528	POROSITY	S_ANH_AB	NONE	STUDENT	1.10000E-02	1.10000E-02	3.04000E-03	6.00000E-03	1.70000E-02
531	PRMX_LOG	S_ANH_AB	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
532	PRMY_LOG	S_ANH_AB	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
533	PRMZ_LOG	S_ANH_AB	$log(m^2)$	STUDENT	-1.88900E+01	-1.88900E+01	1.19600E+00	-2.10000E+01	-1.71000E+01
536	RELP_MOD	S_ANH_AB	NONE	DELTA	4.00000E+00	4.00000E+00	0.00000E+00	1.00000E+00	4.00000E+00
538	SAT_RBRN	S_ANH_AB	NONE	STUDENT	8.36300E-02	8.36300E-02	5.01100E-02	6.88400E-02	1.74010E-01
539	SAT_RGAS	S_ANH_AB	NONE	STUDENT	7.71100E-02	7.71100E-02	6.41100E-02	1.39800E-02	1.97190E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-33. Disturbed Rock Zone Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
174	CAP_MOD	DRZ_0	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
175	COMP_RCK	DRZ_0	Pa^{-1}	CONSTANT	7.41000E-10	7.41000E-10	0.00000E+00	7.41000E-10	7.41000E-10
2701	KPT	DRZ_0	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
176	PC_MAX	DRZ_0	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2702	PCT_A	DRZ_0	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2703	PCT_EXP	DRZ_0	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
179	PO_MIN	DRZ_0	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
177	PORE_DIS	DRZ_0	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
178	POROSITY	DRZ_0	NONE	CUMULATIVE	1.56500E-02	1.29000E-02	8.52000E-03	3.90000E-03	3.29000E-02
181	PRMX_LOG	DRZ_0	$log(m^2)$	CONSTANT	-1.70000E+01	-1.70000E+01	0.00000E+00	-1.70000E+01	-1.70000E+01
182	PRMY_LOG	DRZ_0	$log(m^2)$	CONSTANT	-1.70000E+01	-1.70000E+01	0.00000E+00	-1.70000E+01	-1.70000E+01
183	PRMZ_LOG	DRZ_0	$log(m^2)$	CONSTANT	-1.70000E+01	-1.70000E+01	0.00000E+00	-1.70000E+01	-1.70000E+01
186	RELP_MOD	DRZ_0	NONE	DELTA	4.00000E+00	4.00000E+00	0.00000E+00	1.00000E+00	4.00000E+00
188	SAT_RBRN	DRZ_0	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
189	SAT_RGAS	DRZ_0	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
190	CAP_MOD	DRZ_1	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
191	COMP_RCK	DRZ_1	Pa^{-1}	CONSTANT	7.41000E-10	7.41000E-10	0.00000E+00	7.41000E-10	7.41000E-10
3116	KPT	DRZ_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
193	PC_MAX	DRZ_1	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
3128	PCT_A	DRZ_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3129	PCT_EXP	DRZ_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
196	PO_MIN	DRZ_1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
194	PORE_DIS	DRZ_1	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
195	POROSITY	DRZ_1	NONE	CUMULATIVE	1.56500E-02	1.29000E-02	8.52000E-03	3.90000E-03	3.29000E-02

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-33. Disturbed Rock Zone Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
198	PRMX_LOG	DRZ_1	log(m^2)	CONSTANT	-1.50000E+01	-1.50000E+01	0.00000E+00	-1.50000E+01	-1.50000E+01
199	PRMY_LOG	DRZ_1	log(m^2)	CONSTANT	-1.50000E+01	-1.50000E+01	0.00000E+00	-1.50000E+01	-1.50000E+01
200	PRMZ_LOG	DRZ_1	log(m^2)	CONSTANT	-1.50000E+01	-1.50000E+01	0.00000E+00	-1.50000E+01	-1.50000E+01
203	RELP_MOD	DRZ_1	NONE	DELTA	4.00000E+00	4.00000E+00	0.00000E+00	1.00000E+00	4.00000E+00
205	SAT_RBRN	DRZ_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
206	SAT_RGAS	DRZ_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-34. Forty-Niner Member of the Rustler Formation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2085	CAP_MOD	FORTYNIN	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2238	COMP_RCK	FORTYNIN	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2715	KPT	FORTYNIN	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2239	PC_MAX	FORTYNIN	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2716	PCT_A	FORTYNIN	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2717	PCT_EXP	FORTYNIN	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2718	PO_MIN	FORTYNIN	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2087	PORE_DIS	FORTYNIN	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
2088	POROSITY	FORTYNIN	NONE	STUDENT	8.20000E-02	8.20000E-02	1.02900E-01	0.00000E+00	2.40000E-01
2899	PRMX_LOG	FORTYNIN	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2900	PRMY_LOG	FORTYNIN	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2901	PRMZ_LOG	FORTYNIN	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2093	RELP_MOD	FORTYNIN	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2240	SAT_RBRN	FORTYNIN	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01
2094	SAT_RGAS	FORTYNIN	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-35. Culebra Dolomite Member of the Rustler Formation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
119	CAP_MOD	CULEBRA	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
120	COMP_RCK	CULEBRA	Pa^{-1}	CONSTANT	1.00000E-10	1.00000E-10	0.00000E+00	1.00000E-10	1.00000E-10
2691	KPT	CULEBRA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
137	PC_MAX	CULEBRA	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2692	PCT_A	CULEBRA	Pa	CONSTANT	2.60000E-01	2.60000E-01	0.00000E+00	2.60000E-01	2.60000E-01
2693	PCT_EXP	CULEBRA	NONE	CONSTANT	-3.48000E-01	-3.48000E-01	0.00000E+00	-3.48000E-01	-3.48000E-01
141	PO_MIN	CULEBRA	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
139	PORE_DIS	CULEBRA	NONE	CONSTANT	6.43600E-01	6.43600E-01	0.00000E+00	6.43600E-01	6.43600E-01
140	POROSITY	CULEBRA	NONE	CONSTANT	1.51000E-01	1.51000E-01	0.00000E+00	1.51000E-01	1.51000E-01
142	PRESSURE	CULEBRA	Pa	CONSTANT	8.22000E+05	8.22000E+05	0.00000E+00	8.22000E+05	8.22000E+05
143	PRMX_LOG	CULEBRA	$log(m^2)$	CONSTANT	-1.36780E+01	-1.36780E+01	0.00000E+00	-1.36780E+01	-1.36780E+01
144	PRMY_LOG	CULEBRA	$log(m^2)$	CONSTANT	-1.36780E+01	-1.36780E+01	0.00000E+00	-1.36780E+01	-1.36780E+01
145	PRMZ_LOG	CULEBRA	$log(m^2)$	CONSTANT	-1.36780E+01	-1.36780E+01	0.00000E+00	-1.36780E+01	-1.36780E+01
148	RELP_MOD	CULEBRA	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
150	SAT_RBRN	CULEBRA	NONE	CONSTANT	8.36300E-02	8.36300E-02	0.00000E+00	8.36300E-02	8.36300E-02
151	SAT_RGAS	CULEBRA	NONE	CONSTANT	7.71100E-02	7.71100E-02	0.00000E+00	7.71100E-02	7.71100E-02

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-36. Tamarisk Member of the Rustler Formation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2183	CAP_MOD	TAMARISK	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2243	COMP_RCK	TAMARISK	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2793	KPT	TAMARISK	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2244	PC_MAX	TAMARISK	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2794	PCT_A	TAMARISK	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2795	PCT_EXP	TAMARISK	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2796	PO_MIN	TAMARISK	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2185	PORE_DIS	TAMARISK	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
2186	POROSITY	TAMARISK	NONE	STUDENT	6.40000E-02	6.40000E-02	9.56000E-02	0.00000E+00	2.17000E-01
2914	PRMX_LOG	TAMARISK	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2915	PRMY_LOG	TAMARISK	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2916	PRMZ_LOG	TAMARISK	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2191	RELP_MOD	TAMARISK	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2245	SAT_RBRN	TAMARISK	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01
2192	SAT_RGAS	TAMARISK	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-37. Magenta Dolomite Member of the Rustler Formation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2097	CAP_MOD	MAGENTA	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
3016	COMP_RCK	MAGENTA	Pa^{-1}	STUDENT	2.64400E-10	2.64400E-10	1.41700E-10	1.16200E-10	4.55300E-10
2725	KPT	MAGENTA	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2098	PC_MAX	MAGENTA	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2726	PCT_A	MAGENTA	Pa	CONSTANT	2.60000E-01	2.60000E-01	0.00000E+00	2.60000E-01	2.60000E-01
2727	PCT_EXP	MAGENTA	NONE	CONSTANT	-3.48000E-01	-3.48000E-01	0.00000E+00	-3.48000E-01	-3.48000E-01
2728	PO_MIN	MAGENTA	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2099	PORE_DIS	MAGENTA	NONE	CONSTANT	6.43600E-01	6.43600E-01	0.00000E+00	6.43600E-01	6.43600E-01
2100	POROSITY	MAGENTA	NONE	STUDENT	1.38000E-01	1.38000E-01	8.23000E-02	2.70000E-02	2.52000E-01
2101	PRESSURE	MAGENTA	Pa	CONSTANT	9.17000E+05	9.17000E+05	0.00000E+00	9.17000E+05	9.17000E+05
2102	PRMX_LOG	MAGENTA	$log(m^2)$	CONSTANT	-1.52000E+01	-1.52000E+01	0.00000E+00	-1.52000E+01	-1.52000E+01
2103	PRMY_LOG	MAGENTA	$log(m^2)$	CONSTANT	-1.52000E+01	-1.52000E+01	0.00000E+00	-1.52000E+01	-1.52000E+01
2104	PRMZ_LOG	MAGENTA	$log(m^2)$	CONSTANT	-1.52000E+01	-1.52000E+01	0.00000E+00	-1.52000E+01	-1.52000E+01
2106	RELP_MOD	MAGENTA	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2241	SAT_RBRN	MAGENTA	NONE	CONSTANT	8.36300E-02	8.36300E-02	0.00000E+00	8.36300E-02	8.36300E-02
2107	SAT_RGAS	MAGENTA	NONE	CONSTANT	7.71100E-02	7.71100E-02	0.00000E+00	7.71100E-02	7.71100E-02

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-38. Unnamed Lower Member of the Rustler Formation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
2217	CAP_MOD	UNNAMED	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2218	COMP_RCK	UNNAMED	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2799	KPT	UNNAMED	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2247	PC_MAX	UNNAMED	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2800	PCT_A	UNNAMED	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2801	PCT_EXP	UNNAMED	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2802	PO_MIN	UNNAMED	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2219	PORE_DIS	UNNAMED	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
2220	POROSITY	UNNAMED	NONE	STUDENT	1.81000E-01	1.81000E-01	1.26600E-01	2.00000E-03	2.73000E-01
2911	PRMX_LOG	UNNAMED	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2912	PRMY_LOG	UNNAMED	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2913	PRMZ_LOG	UNNAMED	$log(m^2)$	CONSTANT	-3.50000E+01	-3.50000E+01	0.00000E+00	-3.50000E+01	-3.50000E+01
2225	RELP_MOD	UNNAMED	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
2248	SAT_RBRN	UNNAMED	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01
2226	SAT_RGAS	UNNAMED	NONE	CONSTANT	2.00000E-01	2.00000E-01	0.00000E+00	2.00000E-01	2.00000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-39. Dewey Lake Red Beds Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
153	CAP_MOD	DEWYLAKE	NONE	CONSTANT	2.00000E+00	2.00000E+00	0.00000E+00	2.00000E+00	2.00000E+00
154	COMP_RCK	DEWYLAKE	Pa^{-1}	CONSTANT	1.00000E-08	1.00000E-08	0.00000E+00	1.00000E-08	1.00000E-08
2696	KPT	DEWYLAKE	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
156	PC_MAX	DEWYLAKE	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2697	PCT_A	DEWYLAKE	Pa	CONSTANT	2.60000E-01	2.60000E-01	0.00000E+00	2.60000E-01	2.60000E-01
2698	PCT_EXP	DEWYLAKE	NONE	CONSTANT	-3.48000E-01	-3.48000E-01	0.00000E+00	-3.48000E-01	-3.48000E-01
159	PO_MIN	DEWYLAKE	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
157	PORE_DIS	DEWYLAKE	NONE	CONSTANT	6.43600E-01	6.43600E-01	0.00000E+00	6.43600E-01	6.43600E-01
158	POROSITY	DEWYLAKE	NONE	STUDENT	1.43000E-01	1.43000E-01	7.66000E-02	3.50000E-02	2.48000E-01
161	PRMX_LOG	DEWYLAKE	$log(m^2)$	CONSTANT	-1.63000E+01	-1.63000E+01	0.00000E+00	-1.63000E+01	-1.63000E+01
162	PRMY_LOG	DEWYLAKE	$log(m^2)$	CONSTANT	-1.63000E+01	-1.63000E+01	0.00000E+00	-1.63000E+01	-1.63000E+01
163	PRMZ_LOG	DEWYLAKE	$log(m^2)$	CONSTANT	-1.63000E+01	-1.63000E+01	0.00000E+00	-1.63000E+01	-1.63000E+01
166	RELP_MOD	DEWYLAKE	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
167	SAL_USAT	DEWYLAKE	NONE	CONSTANT	8.36000E-02	8.36000E-02	0.00000E+00	8.36000E-02	8.36000E-02
168	SAT_IBRN	DEWYLAKE	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
169	SAT_RBRN	DEWYLAKE	NONE	CONSTANT	8.36300E-02	8.36300E-02	0.00000E+00	8.36300E-02	8.36300E-02
170	SAT_RGAS	DEWYLAKE	NONE	CONSTANT	7.71100E-02	7.71100E-02	0.00000E+00	7.71100E-02	7.71100E-02

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-40. Santa Rosa Formation Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
336	CAP_MOD	SANTAROS	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
337	COMP_RCK	SANTAROS	Pa^{-1}	CONSTANT	1.00000E-08	1.00000E-08	0.00000E+00	1.00000E-08	1.00000E-08
2768	KPT	SANTAROS	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
339	PC_MAX	SANTAROS	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2769	PCT_A	SANTAROS	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2770	PCT_EXP	SANTAROS	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
342	PO_MIN	SANTAROS	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
340	PORE_DIS	SANTAROS	NONE	CONSTANT	6.43600E-01	6.43600E-01	0.00000E+00	6.43600E-01	6.43600E-01
341	POROSITY	SANTAROS	NONE	CONSTANT	1.75000E-01	1.75000E-01	0.00000E+00	1.75000E-01	1.75000E-01
343	PRESSURE	SANTAROS	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
344	PRMX_LOG	SANTAROS	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
345	PRMY_LOG	SANTAROS	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
346	PRMZ_LOG	SANTAROS	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
349	RELP_MOD	SANTAROS	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
350	SAT_IBRN	SANTAROS	NONE	CONSTANT	8.36300E-02	8.36300E-02	0.00000E+00	8.36300E-02	8.36300E-02
351	SAT_RBRN	SANTAROS	NONE	CONSTANT	8.36300E-02	8.36300E-02	0.00000E+00	8.36300E-02	8.36300E-02
352	SAT_RGAS	SANTAROS	NONE	CONSTANT	7.71100E-02	7.71100E-02	0.00000E+00	7.71100E-02	7.71100E-02

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-41. Predisposal Cavities Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
76	CAP_MOD	CAVITY_1	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
77	COMP_RCK	CAVITY_1	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2612	KPT	CAVITY_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
78	PC_MAX	CAVITY_1	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2613	PCT_A	CAVITY_1	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2614	PCT_EXP	CAVITY_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
81	PO_MIN	CAVITY_1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
79	PORE_DIS	CAVITY_1	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
80	POROSITY	CAVITY_1	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
82	PRESSURE	CAVITY_1	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
83	PRMX_LOG	CAVITY_1	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
84	PRMY_LOG	CAVITY_1	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
85	PRMZ_LOG	CAVITY_1	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
88	RELP_MOD	CAVITY_1	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3099	SAT_IBRN	CAVITY_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
89	SAT_RBRN	CAVITY_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
90	SAT_RGAS	CAVITY_1	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
91	CAP_MOD	CAVITY_2	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
92	COMP_RCK	CAVITY_2	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2616	KPT	CAVITY_2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
93	PC_MAX	CAVITY_2	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2617	PCT_A	CAVITY_2	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2618	PCT_EXP	CAVITY_2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
96	PO_MIN	CAVITY_2	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-41. Predisposal Cavities Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
94	PORE_DIS	CAVITY_2	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
95	POROSITY	CAVITY_2	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
97	PRESSURE	CAVITY_2	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
98	PRMX_LOG	CAVITY_2	log(m^2)	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
99	PRMY_LOG	CAVITY_2	log(m^2)	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
100	PRMZ_LOG	CAVITY_2	log(m^2)	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
103	RELP_MOD	CAVITY_2	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3100	SAT_IBRN	CAVITY_2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
104	SAT_RBRN	CAVITY_2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
105	SAT_RGAS	CAVITY_2	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2049	CAP_MOD	CAVITY_3	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2051	COMP_RCK	CAVITY_3	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2620	KPT	CAVITY_3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2234	PC_MAX	CAVITY_3	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2621	PCT_A	CAVITY_3	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2622	PCT_EXP	CAVITY_3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2623	PO_MIN	CAVITY_3	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2052	PORE_DIS	CAVITY_3	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
2053	POROSITY	CAVITY_3	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
3101	PRESSURE	CAVITY_3	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2054	PRMX_LOG	CAVITY_3	log(m^2)	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
2055	PRMY_LOG	CAVITY_3	log(m^2)	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
2056	PRMZ_LOG	CAVITY_3	log(m^2)	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
2058	RELP_MOD	CAVITY_3	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-41. Predisposal Cavities Parameters (continued)

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
3102	SAT_IBRN	CAVITY_3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2235	SAT_RBRN	CAVITY_3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2059	SAT_RGAS	CAVITY_3	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2060	CAP_MOD	CAVITY_4	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
2062	COMP_RCK	CAVITY_4	Pa^{-1}	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2625	KPT	CAVITY_4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2236	PC_MAX	CAVITY_4	Pa	CONSTANT	1.00000E+08	1.00000E+08	0.00000E+00	1.00000E+08	1.00000E+08
2626	PCT_A	CAVITY_4	Pa	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2627	PCT_EXP	CAVITY_4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2628	PO_MIN	CAVITY_4	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2063	PORE_DIS	CAVITY_4	NONE	CONSTANT	7.00000E-01	7.00000E-01	0.00000E+00	7.00000E-01	7.00000E-01
2064	POROSITY	CAVITY_4	NONE	CONSTANT	1.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00
3103	PRESSURE	CAVITY_4	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
2065	PRMX_LOG	CAVITY_4	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
2066	PRMY_LOG	CAVITY_4	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
2067	PRMZ_LOG	CAVITY_4	$log(m^2)$	CONSTANT	-1.00000E+01	-1.00000E+01	0.00000E+00	-1.00000E+01	-1.00000E+01
2069	RELP_MOD	CAVITY_4	NONE	CONSTANT	4.00000E+00	4.00000E+00	0.00000E+00	4.00000E+00	4.00000E+00
3104	SAT_IBRN	CAVITY_4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2237	SAT_RBRN	CAVITY_4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2070	SAT_RGAS	CAVITY_4	NONE	CONSTANT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-42. Salado Brine Parameters

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
48	COMPRES	BRINESAL	Pa^{-1}	CONSTANT	3.10000E-10	3.10000E-10	0.00000E+00	3.10000E-10	3.10000E-10
49	DNSFLUID	BRINESAL	kg/m^3	CONSTANT	1.22000E+03	1.22000E+03	0.00000E+00	1.22000E+03	1.22000E+03
50	REF_PRES	BRINESAL	Pa	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
51	REF_TEMP	BRINESAL	K	CONSTANT	3.00150E+02	3.00150E+02	0.00000E+00	3.00150E+02	3.00150E+02
55	VISCO	BRINESAL	Pa*s	CONSTANT	2.10000E-03	2.10000E-03	0.00000E+00	2.10000E-03	2.10000E-03
57	WTF	BRINESAL	NONE	STUDENT	3.24000E-01	3.24000E-01	9.83000E-03	3.07000E-01	3.32000E-01

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

Table PAR-43. Reference Constants

id	idpram	idmtrl	units	distyp	mean	median	stdev	lowrange	hirange
3106	ASDRUM	REFCON	m^2	CONSTANT	6.00000E+00	6.00000E+00	0.00000E+00	6.00000E+00	6.00000E+00
2890	ATMPA	REFCON	Pa/atm	CONSTANT	1.01325E+05	1.01325E+05	0.00000E+00	1.01325E+05	1.01325E+05
3132	DRROOM	REFCON	NONE	CONSTANT	6.80400E+03	6.80400E+03	0.00000E+00	6.80400E+03	6.80400E+03
2889	GRAVACC	REFCON	m/s^2	CONSTANT	9.80665E+00	9.80665E+00	0.00000E+00	9.80665E+00	9.80665E+00
2896	PI	REFCON	NONE	CONSTANT	3.14159E+00	3.14159E+00	0.00000E+00	3.14159E+00	3.14159E+00
3112	SECYR	REFCON	yr/s	CONSTANT	3.16888E-08	3.16888E-08	0.00000E+00	3.16888E-08	3.16888E-08
3107	VPANLEX	REFCON	m^3	CONSTANT	4.60977E+04	4.60977E+04	0.00000E+00	4.60977E+04	4.60977E+04
3108	VREPOS	REFCON	m^3	CONSTANT	4.36023E+05	4.36023E+05	0.00000E+00	4.36023E+05	4.36023E+05
3105	VROOM	REFCON	m^3	CONSTANT	3.64438E+03	3.64438E+03	0.00000E+00	3.64438E+03	3.64438E+03
2888	YRSEC	REFCON	s/yr	CONSTANT	3.15569E+07	3.15569E+07	0.00000E+00	3.15569E+07	3.15569E+07

NOTES:
id = id number
idpram = parameter name
idmtrl = material name
distyp = distribution type
stdev = standard deviation

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APPENDIX PMR

PMR.1.0 INTRODUCTION

PMR.1.1 Purpose

This conceptual design report describes a concept for permanently marking the Waste Isolation Pilot Plant (WIPP) as required by Title 40 CFR 191.14(c), which states that:

> Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location.

Although erection of the permanent marker system will not be initiated until after closure of the WIPP, design information is necessary to evaluate the efficacy of the marker system, which in turn can be used in the demonstration of compliance. This conceptual design will be used as part of the 40 CFR 191 Compliance Certification Application and the No-Migration Variance Petition (NMVP) for disposal submitted to the Environmental Protection Agency (EPA).

PMR.1.2 Scope

This report describes a design concept for a permanent marker system comprised of various messages, surface monument markers, small subsurface warning markers, on-site rooms for long term storage of messages, archival storage of WIPP information off-site, and large earthen structures marking the WIPP repository footprint on the surface. It should be noted that the illustrations used to support this conceptual design report are not intended to represent the final configurations, or even the most current concepts. Rather, they represent the type of illustrations that are intended to be used in the final design.

Three separate concepts of the configuration of the earthen structures, arrangement of the monument markers, and placement of the archival storage rooms within the perimeter of the repository footprint are described. The first concept consists of a large earthworks configured in the shape of a trefoil centered above the repository surface footprint center. An Information Center is also placed at the center with large monoliths arranged along the footprint's perimeter and outside the trefoil. Two Storage Rooms are located east and west of the trefoil center. Each of these rooms is buried approximately 20 ft (6 m) below the footprint surface.

A second configuration consists of a large earthworks configured as an earthen berm enclosing the footprint's perimeter. The large monoliths are arranged just inside the berm along the footprint perimeter. The locations of the Information Center and the Storage Rooms are geographically similar to the trefoil concept with small warning markers buried throughout the footprint surface.

The third concept includes several large earthen berm-like structures arranged in a pattern intended to convey a "menacing" appearance. The structures "radiate" out from the footprint perimeter as outlined by the monoliths. The four corner sections are significantly larger than the other sections. Within each corner section is buried a Storage Room. The Information Center is located at the footprint center. Again, small warning markers are buried throughout the footprint surface area.

The second configuration is the concept currently recommended for consideration of a preliminary design effort. When initiated, the preliminary design should include detailed planning for the testing of various materials and configurations over a period of several decades of WIPP operation and active control after closure.

All three earthwork configurations are constructed in a similar manner, as described later in this report. The purpose of the testing effort is to better understand the long term chemical stability and weathering resistance characteristics of various materials and message configurations. The resulting information will then be used for the final design of the permanent marker system prior to its construction after closure of the facility.

PMR.1.3 Background

Title 40 of the Code of Federal Regulations (CFR), Part 191 prescribes that disposal systems be designed and built to provide a reasonable expectation that for 10,000 years: 1) the undisturbed performance of the system will not result in an annual committed effective dose to any member of the public in excess of 15 millirem; 2) the levels of radioactivity in groundwater will not exceed limits specified by the standard in 40 CFR §191.24; and 3) the probability of releases from all significant processes and events acting on the disposal system will not exceed the specifications in 40 CFR §191.13(a). Appendix C to Title 40 CFR Part 191 states that inadvertent and intermittent intrusion by exploratory drilling for resources is the most severe intrusion scenario assumed by the Department of Energy (DOE). This represents the greatest potential risk to release of the stored transuranic (TRU) mixed waste into the environment. The primary goal of the permanent marker system is to minimize the likelihood of inadvertent human intrusion.

Sandia National Laboratories (SNL), in its capacity as the scientific advisor to the DOE for the WIPP Project, established two groups of experts to examine the issues involved with selecting, designing, and implementing an effective system of permanent markers. These groups assumed 10,000 years as the applicable time period. 40 CFR §191.13 also specifies 10,000 years as the applicable period of the containment requirements. Hora et al., *Expert Judgment on Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*, SAND90-3063, December 1991 documents the Futures Panel (FP) discussion or the "underlying physical and societal factors that would influence society and the likely modes of human-intrusion at the WIPP."

The FP also developed probabilities of various alternative futures, of inadvertent human intrusion, and, in some cases, of particular modes of intrusion. The report was an important source of information for the follow-on group of experts when developing Trauth et al., *Expert Judgment on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Plant*, SAND92-1382, November 1993. Trauth et al. (1993) reports the results of two teams of experts, the Markers Panel (MP), who considered various concepts of marking the site and conveying to future generations information regarding the presence of dangerous waste material and the potential consequence of intrusion into the waste repository. The conceptual designs described in this report are expansions of the ideas developed by the MP.

The testing described in Section PMR.9.0 will include the development of data regarding the long term durability of construction materials intended to be used in the Permanent Marker System (PMS). It is anticipated that this testing program will initiate during the disposal phase and continue beyond decommissioning into the Active Controls phase. During the Active Controls phase, periodic evaluation of test structures will be conducted. Actual construction of the PMS will be delayed for some decades after decommissioning to provide sufficient time to effectively evaluate the long-term durability of the various construction materials and the effects of weathering on monument markers and a section of berm.

PMR.2.0 SITE DESCRIPTION

The WIPP facility was constructed 26 mi (42 km) east of Carlsbad, New Mexico in southeastern New Mexico's Eddy County. The site, occupying 10,240 acres (40.96 km^2), was withdrawn from the public domain in October 1992 by the Waste Isolation Pilot Plant Land Withdrawal Act (LWA) (Public Law 102-579). This law places jurisdiction of the land in the hands of the Secretary of Energy. The area surrounding the site is sparsely populated, with about 25 people living within 10 mi (16 km). The activities in the general area are primarily devoted to livestock grazing, potash mining, and oil and gas development. Figure PMR-1 shows the general location of the WIPP site.

The surface physiography of the land in the immediate WIPP vicinity is that of sand dunes from which the area gets its name, Los Mendaños. The area within the waste disposal area footprint is punctuated with dunes up to approximately 10 ft (3 m) high. The dunes have been stabilized primarily by Havard Shin Oak, which has an extensive root structure to limit the wind effects on the sand dunes. The sand is underlain by a caliche layer. The caliche represents a fairly impermeable barrier to moisture. Within the 10,240 acres (40.96 km^2), approximately 35 acres (0.14 km^2) are devoted to surface structures and facilities including the four shafts leading to the repository horizon 2150 ft (655 m) below the surface. The surface footprint of the repository occupies an area south of the surface structures. Figure PMR-2 provides a general spatial rendition of the relative locations of the surface facilities, the underground Experimental Area, and the underground Waste Disposal Area.

The surface facilities provide security and safeguards, accommodate routine operations, provide administrative and management facilities, and support ongoing scientific studies. These facilities are designed to service full-scale operations and have undergone extensive testing and operational review. The Waste Handling Building is the principal surface structure dedicated to supporting the handling of TRU waste containers and their transport to the repository. The building shelters the facilities for receiving Contact Handled (CH) TRU waste containers within the Nuclear Regulatory Commission certified Transuranic Package Transporter-II (TRUPACT-II), unloading the TRUPACT-II, inspecting the waste containers, and preparing the containers for transfer to the underground repository. The building also shelters facilities for receiving Remote Handled (RH) TRU waste in canisters and shielded casks. The building is divided into two major areas. One area is for receipt and inspection of CH-TRU waste and the other area is dedicated to the receipt and inspection of RH-TRU waste. A single Waste Shaft is designed integral with the Waste Handling Building to transport either CH- or RH-TRU waste containers to the underground repository. Within the RH-TRU waste area is the Hot Cell. The Hot Cell provides a radiation shielded facility for unloading and manipulating containers of radioactive waste with surface radiation dose rates of up to 1000 Rem/hr. The Hot Cell is constructed of concrete walls 4.5 ft (1.4 m) thick and extending 60 ft (18 m) above grade. The Hot Cell basement extends approximately 20 ft (6.1 m) below the grade level. As part of this conceptual design, the concrete hot cell will remain as an archeological monument after decommissioning the WIPP site.

External to the Waste Handling Building and the Waste Shaft are additional buildings and three shafts. The major buildings are the Support Building, the Safety and Emergency Services Facility, the Engineering Building, the Training Building, the Warehouse/Shops Building, and the Core Storage Building. A number of temporary buildings and trailers are also used to support various operational, maintenance, technical, and administrative functions.

The salt handling shaft, located north of the Support Building, is used for transporting personnel to and from the repository, transporting mined salt from the mine, and as a secondary source of air to the underground. An air intake shaft provides the primary source of air into the underground ventilation system. An Exhaust Shaft with two normal ventilating fans and three emergency fans provides for the forced ventilation of the entire underground area. The three emergency fans exhaust through a bag house containing particulate filters to mitigate the release of radioactive particulate in the unlikely event that such material is released in the underground storage area.

In the repository, to the north of the surface structures, is the Experimental Area. This 12-acre (0.05-km^2) area was dedicated to conducting scientific investigations and experiments, and with completion of programmed investigations and experiments this area is being deactivated. To the south of the surface structures' footprint is the Waste Disposal Area. Approximately 100 acres (4 km^2) are dedicated to the eight panels planned for storage of TRU-mixed waste. Connecting the Experimental and Waste Disposal Areas are four major interconnecting drifts (tunnels) used for ventilation and

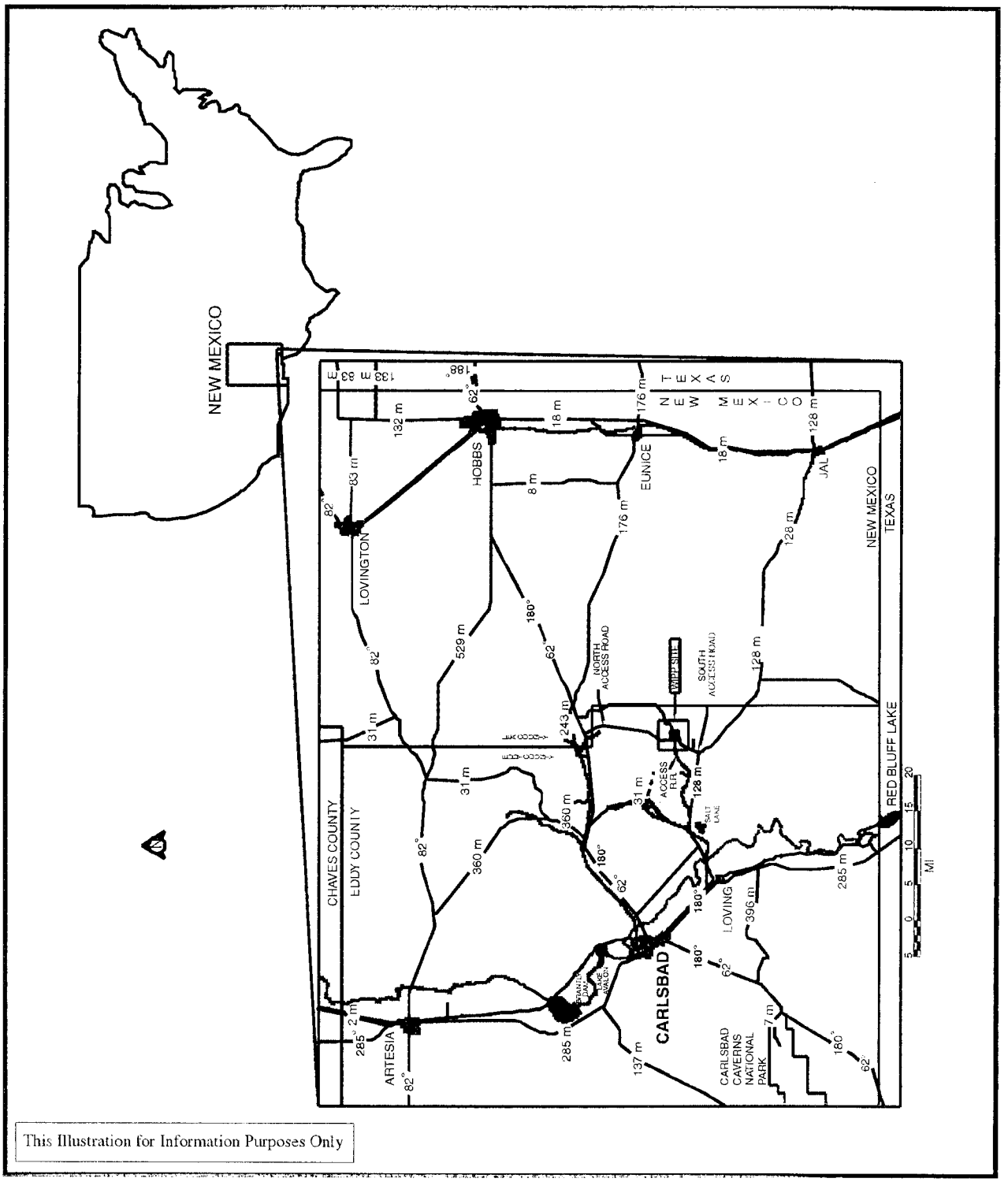

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Figure PMR-1. WIPP Site Location

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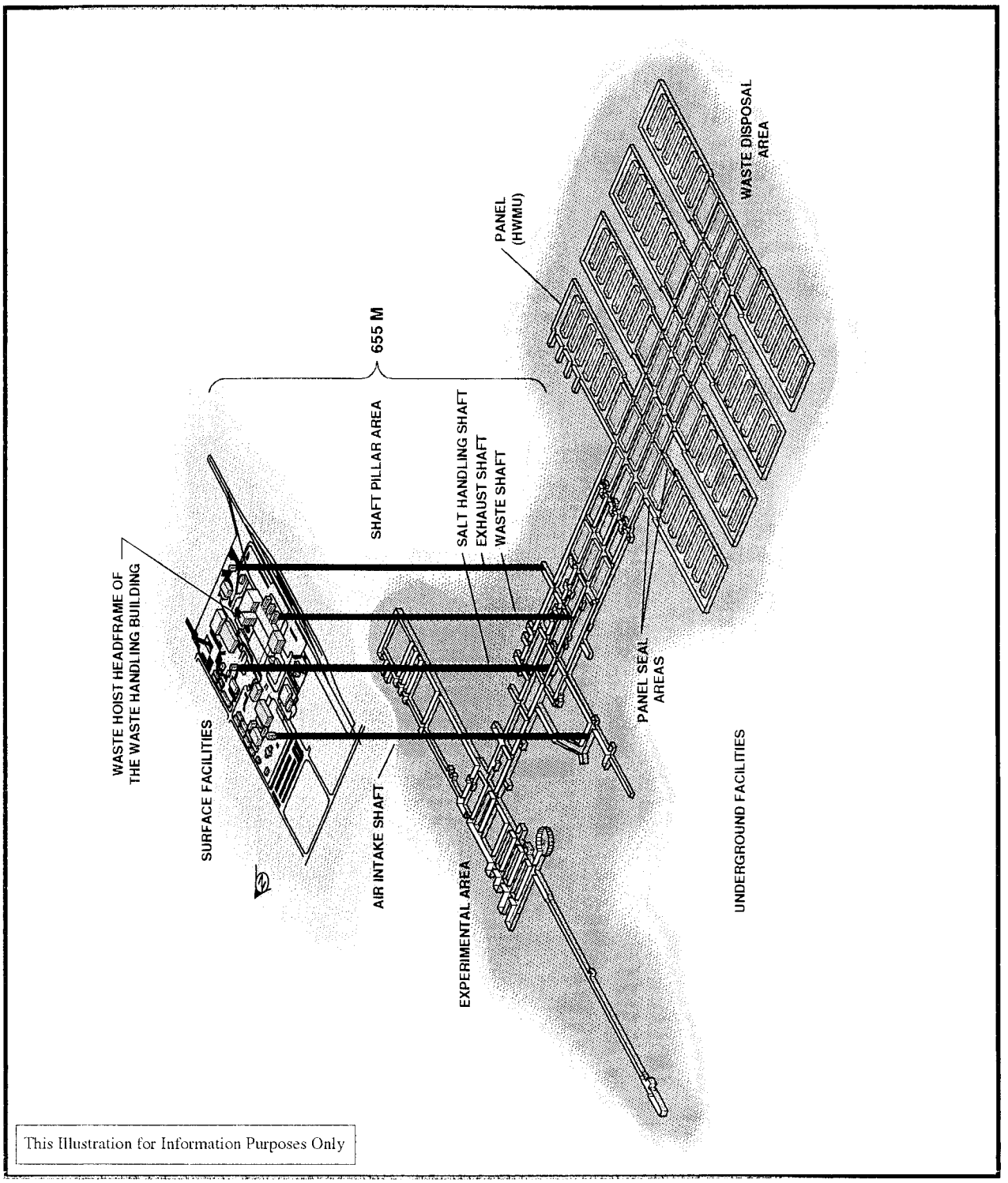

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Figure PMR-2. Spatial View of WIPP Surface & Underground Facilities

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traffic. In addition, equipment and maintenance facilities supporting the underground mining and operational activities are constructed along the drifts.

Each of the eight panels (only Panel 1 is currently mined) will be comprised of seven rooms. The nominal excavated dimensions of the individual rooms are 300 ft by 33 ft by 13 ft (91.4 m by 10 m by 4 m). The designed storage capacity of the repository is 6,200,000 ft^3 (175,000 m^3). CH-TRU waste will be contained in individual Standard Waste Boxes (SWB) or 55-gallon drums arranged in seven-packs. The SWBs and seven-packs will be stacked in the waste disposal rooms. Containers will also be emplaced within the ventilation supply and exhaust drifts in each panel. Individual panels will be closed as they are filled. Upon complete filling of the repository, the shafts will be plugged and sealed along their entire lengths up to the surface. Figure PMR-3 illustrates a shaft plugging and sealing configuration (Nowak 1990).

PMR.3.0 DESIGN REQUIREMENTS/CRITERIA

Trauth et al. (1993) discusses at length the processes used to form the expert panel. The panel was divided into two teams, Team A and Team B. Each team then developed its philosophy for passing messages on to future generations. Attachment 1 is the table from Trauth et al. (1993) comparing the Marker System Components developed by each team. As shown in the table, some differences existed between the teams. Drawing on information found in the table and a review of the individual team reports documented in Trauth et al. (1993), the following principles were applied to guiding the conceptual permanent marker design:

- The site is marked
- Message(s) are truthful and informative
- Multiple components exist within a marker system
- Multiple means of communication (e.g., language, pictographs, scientific diagrams) are provided
- Multiple messages with differing levels of complexity are inscribed on individual marker system elements
- Materials with little recycle value are used to the extent practicable
- Markers will comply with international standards of marking locations and contents of nuclear waste repositories

All but the last of these principles are discussed in this PMR document. The last principle, while laudatory, is not achievable at this time. No international standards exist. If, in the future, standards are developed and adopted by the United States, they will be evaluated for incorporation in preparing the final permanent marker design.

The following design requirements were developed from a review of Trauth et al. (1993) and the applicable regulations. Each of the requirements was addressed in the development of the design criteria.

- The marking system should provide reasonable assurance that the site will be uniquely marked visually and/or electronically and such marking will endure and be recognizable for a period of 10,000 years. Experience gained during the first 100 years may result in marker system modifications to improve the endurance capability of the system.
  BASIS: Title 40 CFR Part 191 and Trauth et al. (1993). The period of regulatory interest is 10,000 years. The period of Active Controls credit is 100 years after disposal.

- The site must be marked in a manner that provides reasonable assurance that the marker's purpose cannot be mistaken or its intended message misinterpreted. The system should include a combination of surface and subsurface markers.
  BASIS: Trauth et al. (1993). Expert panel judgment to account for possible removal of surface markers and effects of erosion for uncovering subsurface markers.

- The marking system must include the concept of "defense in depth," which implies redundancy by way of its physical design and message delivery concepts.
  BASIS: Trauth et al. (1993). Expert panel judgment and a common design philosophy of the nuclear industry.

- Materials comprising the marking system should have as little intrinsic value as is reasonable to minimize the likelihood of future generations salvaging the material for recycling purposes.
  BASIS: Trauth et al. (1993). Expert panel judgment.

- The marking system on the surface should encompass the grade level equivalent of the entire waste storage footprint (waste-filled panels and drifts), but not exceed the footprint by more than 10 percent.
  BASIS: Trauth et al. (1993) and engineering judgment. Expert panel judgment that the marker system extent should be limited to the repository footprint so as not to give false sense of the hazard if deep drilling is conducted outside the footprint with no hazardous material encountered. Engineering judgment to provide a 10 percent margin.

- The message delivery subsystem should provide a means of communicating with reasonable assurance the what, when, who, why, and how essentials of the WIPP program to future generations using an assortment of symbolic, pictographic, linguistic, narrative, diagrammatic, scientific, and astronomic messages.
  BASIS: Trauth et al. (1993). Expert judgment.

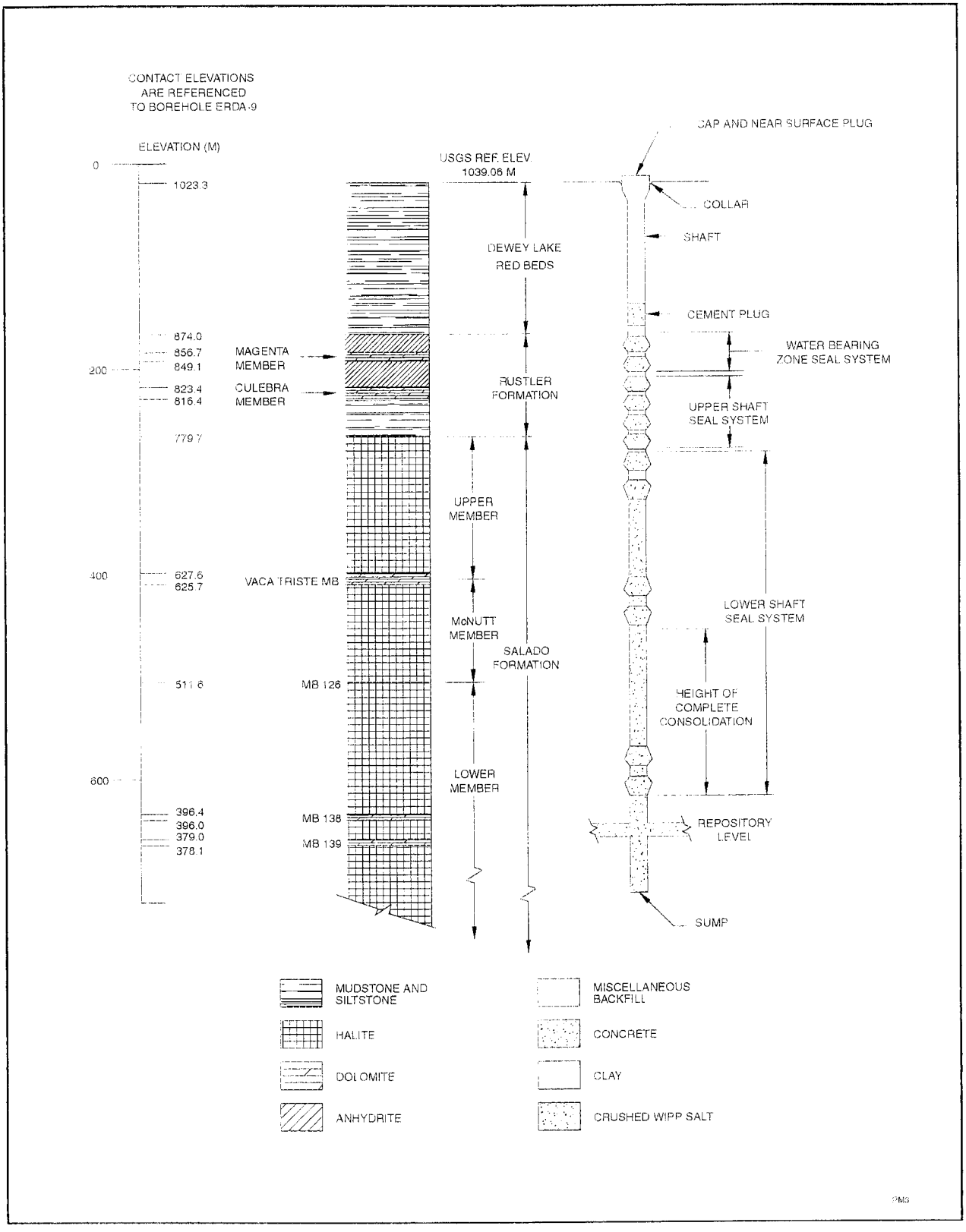

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Figure PMR-3. Details of the Shaft Sealing

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- The marker system should be constructed using available technology and its construction should be cost-effective.
  BASIS: Engineering judgment.

Development of the design criteria applicable to the PMS included adherence to the guidelines and design requirements addressed above. Design criteria were established to:

1. Provide a system for marking the disposal area footprint on the surface through use of berms and monoliths:

   - Berm dimensions should be a minimum of 100 ft (30 m) at the base and a minimum 31 ft (10 m) high.
     BASIS: Trauth et al. (1993). Expert judgment. Berms should be massive to withstand human and natural forces. Slope needs to accommodate a roadway on the surface to facilitate construction.

   - Berm slope should be at least 1.3 horizontal to 1.0 vertical.
     BASIS: Slope of a natural talus is 1.3 to 1.0. A steeper slope may significantly impact effects of erosion.

   - Berm should be mechanically packed.
     BASIS: A mechanically packed berm provides a more stable structure and reduces slumping over time.

   - Berm should provide a dielectric or magnetic anomaly when compared to the local surface characteristics.
     BASIS: Trauth et al., (1993). Expert judgment. Provide a capability for marker detection by electronic means as part of the defense-in-depth concept.

   - Configuration of the berm marker should provide for observation of the entire marked area from any point on top of the berm adjacent to the marked area.
     BASIS: Trauth et al. (1993). Expert judgment.

   - To the extent practical when considering a projected 10,000 year life, local material should be used for the majority of the berm structure.
     BASIS: Trauth et al. (1993). Expert judgment.

   - Monoliths should be at least 25 ft (7.5 m) high.
     BASIS: Trauth et al. (1993). Expert judgment. The monoliths' height should prevent coverage by blowing sand.

   - Monoliths should include a minimum 20 tons (18 metric tons) continuous mass (no bonding materials should be used between components of individual monoliths).

BASIS: Trauth et al. (1993). Expert judgment. Monoliths should be sufficiently massive to minimize the affects of vandalism or removal. Bonding materials of different chemical composition than the monolith material may have long-term detrimental effects on the monolith material.

- The total number of perimeter marking monoliths should be a power of two.
  BASIS: Trauth et al. (1993). Expert judgment. Provide a sufficient number of monoliths to permit future societies to reconstruct monolith orientation if several monoliths are missing.

- Monoliths should be spaced so that an average individual standing adjacent to one monolith will be able to see the monoliths on either side.
  BASIS: Trauth et al. (1993). Expert judgment.

- Monolithic material should be relatively unaffected by anticipated environmental and climatic conditions for 10,000 years.
  BASIS: Trauth et al. (1993). Expert judgment. Minimize the risk of adverse environmental effects.

- The monolith messages shall be engraved to a depth of at least 0.39 in. (1cm).
  BASIS: Engineering judgment when considering 10,000 year environmental effects.

2. Place subsurface warning markers throughout the disposal area footprint:

- Warning markers shall be less than 2 ft (0.6 m) in their longest point.
  BASIS: Engineering judgment. Sufficient size to carry a warning message, but not represent a major emplacement effort.

- Marker material should be inert with respect to the local environmental conditions at their burial depth.
  BASIS: Trauth et al. (1993). Endure a 10,000-year burial period.

- Burial depth should be greater than that expected from deep plowing/tilling or digging by amateur archaeologists.
  BASIS: Trauth et al. (1993). Minimize loss due to inadvertent uncovering or vandalism.

- The message on the warning markers shall be engraved in such a manner that slight erosion or fracture of the marker will not render the message completely unintelligible.
  BASIS: Engineering judgment.

- The warning message shall be written in Spanish, English, Russian, Chinese, French, Arabic, and Navajo. The seven languages should be distributed evenly among all the buried warning markers.
  BASIS: Trauth et al. (1993). Expert and engineering judgment.

- Markers should be spaced so that their discovery is highly probable under conditions currently anticipated to be created by drilling crews and professional archaeologists.
  BASIS: Engineering judgment.

3. Provide for detailed, complex information storage:

- Structures for the permanent storage of detailed and complex information relating to the repository location, contents, and associated hazards shall be constructed.
  BASIS: Trauth et al. (1993). Expert judgment.

- Buried and surface structures shall be provided.
  BASIS: Trauth et al. (1993). Expert judgment. Provide reasonable assurance that complex information is available during the entire period of regulatory concern.

- The structural material shall be inert and sufficiently durable to provide a high degree of protection for the stored information for a period of 10,000 years.
  BASIS: Trauth et al. (1993) and engineering judgment.

- Stored written records, tables, figures, graphs, maps, and diagrams shall be engraved in stone or man-made materials having the durability to retain the engraved information over the 10,000-year period.
  BASIS: Trauth et al. (1993) and engineering judgment.

- Entry to buried structures shall be designed to preclude removal of the stored information by curious individuals. Removal should require a concerted effort by a well-financed and technically competent organization.
  BASIS: Engineering judgment.

- Concrete for construction shall be in accordance with the Building Code requirements for Reinforced Concrete (ACI-318, latest edition) with special emphasis on durability (ACI-201.2, Guide to Durable Concrete).
  BASIS: Engineering judgment.

PMR.4.0 MESSAGES

Five levels of messages will be used in the PMS.

- Level I conveys the message that the site is man-made. The message itself is in the physical form of the marker system and the effort expended in constructing it.

- Level II conveys the message that something dangerous is buried here and that no digging or drilling should be conducted. This message is carried in seven languages uniformly distributed among the subsurface warning markers. Each marker has the message in a single language. The level II message is also engraved on each monolith in seven languages.

- Level III conveys basic information that tells what, why, when, where, who, and how. This message is carried by the monolithic markers.

- Level IV conveys complex information in seven languages and is stored in the permanent structure(s) buried underground and the Information Center on the surface.

- Level V is archival and involves storing a more complete rulemaking record than the messages provided at the WIPP site. This record is not stored at the site, but shall be located in various public access facilities at the local, state, federal, and international levels.

Figure PMR-4 represents the level II and level III messages. Attachment 2 contains the level II, III, and IV message text in English. During the final design phase, the messages will be translated into the other six languages. Testing of the messages' ability to inform the public about the danger of intruding into the repository will be conducted among populations indigenous to the language's locale.

The level I message consists of the surface structures delineating the site boundaries and provides the surfaces upon which to engrave the level II, III, and IV messages. This includes the earthen berm, the granite monoliths, and the information center. The physical size of these structures should clearly convey the notion that the site is a man-made facility that required a significant amount of effort to construct Trauth et al. (1993). This should inspire any organization with sufficient resources to dismantle the surface structures to investigate and attempt to understand the purpose of the site prior to initiating activities which are counter to maintaining the site's integrity. Individuals intent on vandalism or artifact collection may cause some superficial damage, but it is very doubtful that they could reduce the structures sufficiently to destroy the implication that something man-made occupies the site.

LEVEL II MESSAGE

DANGER

POISONOUS RADIOACTIVE ☢ WASTE HERE
DO NOT DIG OR DRILL

LEVEL III MESSAGE

THESE STRUCTURES MARK AN AREA USED TO BURY RADIOACTIVE ☢ WASTES. THE AREA IS 0.66 BY 0.81 KILOMETERS AND THE WASTE IS BURIED 0.66 KILOMETERS DOWN. THIS PLACE WAS CHOSEN TO PUT THIS DANGEROUS MATERIAL FAR AWAY FROM PEOPLE AND OTHER LIVING THINGS. THE ROCK AND WATER IN THIS AREA MAY NOT LOOK, FEEL, OR SMELL UNUSUAL, BUT MAY BE POISONED BY RADIOACTIVE ☢ WASTES. WHEN RADIOACTIVE ☢ MATTER DECAYS, IT GIVES OFF INVISIBLE ENERGY THAT CAN DESTROY OR DAMAGE PEOPLE, ANIMALS, AND PLANTS.

DO NOT DRILL HERE. DO NOT DIG HERE. DO NOT DO ANYTHING WITH THE ROCKS OR WATER IN THE AREA.

DO NOT DESTROY THIS MARKER. THIS MARKING SYSTEM HAS BEEN DESIGNED TO LAST 10,000 YEARS. IF THE MARKER IS DIFFICULT TO READ, ADD NEW MARKERS COMPOSED OF LONGER-LASTING MATERIALS AND COPY THIS MESSAGE IN YOUR LANGUAGE ONTO THEM.

FOR MORE INFORMATION, GO TO THE BUILDING FURTHER INSIDE THIS MARKED AREA. THE SITE WAS KNOWN AS THE WIPP (WASTE ISOLATION PILOT PLANT) SITE WHEN IT WAS CLOSED IN 2020 A.D.

This Illustration for Information Purposes Only

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Figure PMR-4. Level II and III Messages

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The level II and III (Figure PMR-4) messages are engraved on the granite monoliths. The level II message is a warning of danger. The graphic symbols from Trauth et al. (1993) accompanying the "DANGER" warning are meant to convey:

- - Horror and terror
- - Something nauseating or poisonous

The definition describes the waste as both poisonous and radioactive. The trefoil symbol (☢) is used throughout the messages in association with the terms "radioactive" and "radioactivity." Its use in association with these terms should provide the interpretive definition of the symbols' significance. This would seem to be more appropriate than attempting to define the symbol narratively. The biohazard symbol is shown along with the trefoil on the monoliths and the small subsurface warning markers as indicated in Figure PMR-14 and Figure PMR-15. Finally, the level II message admonishes the reader not to dig or drill. Figure PMR-4 illustrates the three-part level II message.

The level III message, also illustrated in Figure PMR-4, provides more definition with respect to what is buried, the size of the area in which digging or drilling should be prohibited, and the depth at which the radioactive waste is located. Readers of this message will also be made aware of when the WIPP closed and that there was an intent to preserve the warning information for 10,000 years. Included in this message is a request that the reader take action to update the message or the marker system to add long lasting materials and/or messages written in languages more current to the times. The design of the monoliths provide sufficient blank surface areas for the addition of messages in other languages. It is anticipated that over time the languages will change sufficiently to become incomprehensible to the general public and only scholars will be able to interpret their meaning.

Jensen (1993) provides an example of how quickly (relative to 10,000 years) the English language has changed by providing the following quote from *Sir Gawain and the Greene Knight* (author unknown, written about 1375 AD—less than 650 years ago):

> The stele of a stif staf the sturne hit bi gripte
> That was wounden with iron to the wandes ende,
> And al bigraven with grene in gravios werkes.

In the modern English, this quote is written as:

> The grim man gripped it by its great strong handle,
> which was wound with iron all the way to the end,
> and graven in green with graceful designs.

For this reason, the messages will be presented in a variety of languages to improve the likelihood that their meaning will be understood by future generations. A monolith with its messages in seven different languages is a modern Rosetta stone. However, unlike the Rosetta stone, the size of each monolith makes it unlikely to be moved to some remote location in order to be studied and interpreted. Rather, the interpreters will need to record the messages for study and even if the study activity does occur elsewhere, not moving the original messages from the site should enhance the probability that the interpreted results will be quickly made known at the site.

Figure PMR-5 shows the spatial perspective of the marking system to the repository and the underground shafts which will support the repository during its construction, operation, and closure. Figures PMR-6 and PMR-7 will support the level III message. Figure PMR-6 shows the spatial perspective of the marking system to the underground repository. As a warning, it depicts a sequence of activities which lead to releasing the waste from the repository and causing death to the individual digging or drilling down to the repository level. Figure PMR-7 (Diagram 3 of the message text in Attachment 1) provides the skilled and technically knowledgeable reader a method to independently determine when the repository was closed after waste emplacement. The constellation formations for Ursa Minor, Draco, Cygnus, Ursa Major, and the brightest star, Vega are shown with respect to the position of the north celestial pole 10,000 years after repository closure. The reader can estimate when the repository was closed by comparing the pole position at closure to its position at the reader's time. The decreasing size of the ☢ (Trefoil) conveys the idea that the amount of radioactivity is decreasing with time. The faces (Trauth et al. 1993) show disgust at the time of closure, neutrality at 10,000 years, and contentment well beyond 10,000 years.

The level IV message is the most comprehensive and complex message located at the WIPP site. Attachment 2 provides the text of the level IV message in the seven languages in which it will be presented. The text portion of the level IV message expands upon the brief level III message. In particular, the level IV message provides the following details:

- It describes the potential leakage path for radioactive material through groundwater, should deep drilling occur
- It specifies the disease cancer as the potential human impact from radiation poisoning and explains that cancer is a long-term result
- It specifies the particular radioactive isotopes, their individual quantities, and the hazardous chemicals which were originally buried
- It identifies that the U.S. Government was responsible for this long-term solution of isolating waste derived from its bomb-making activities
- It describes why the Salado formation was chosen as the repository site

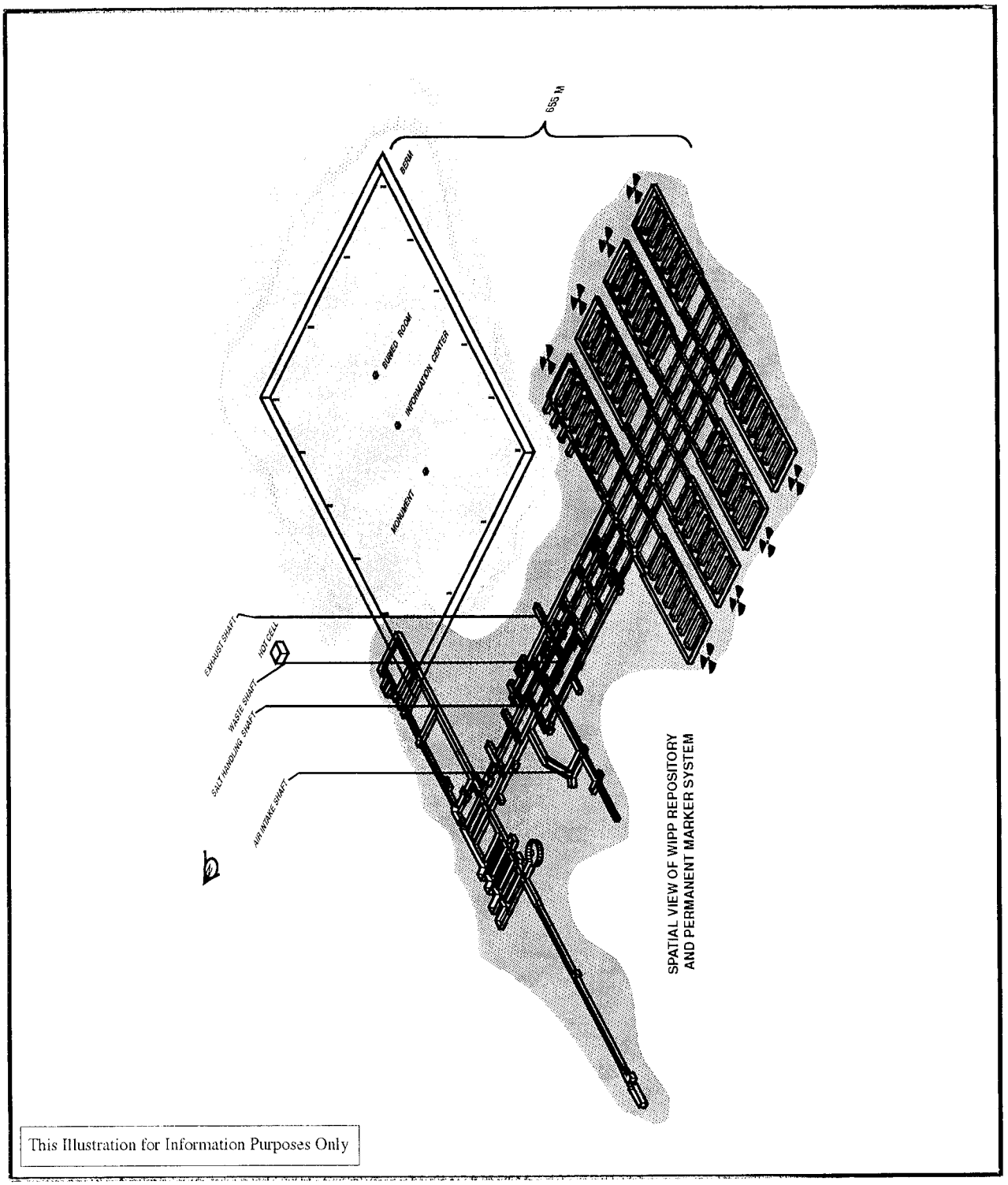

Figure PMR-5. Spatial View of WIPP Repository, Shafts, and Permanent Marker System

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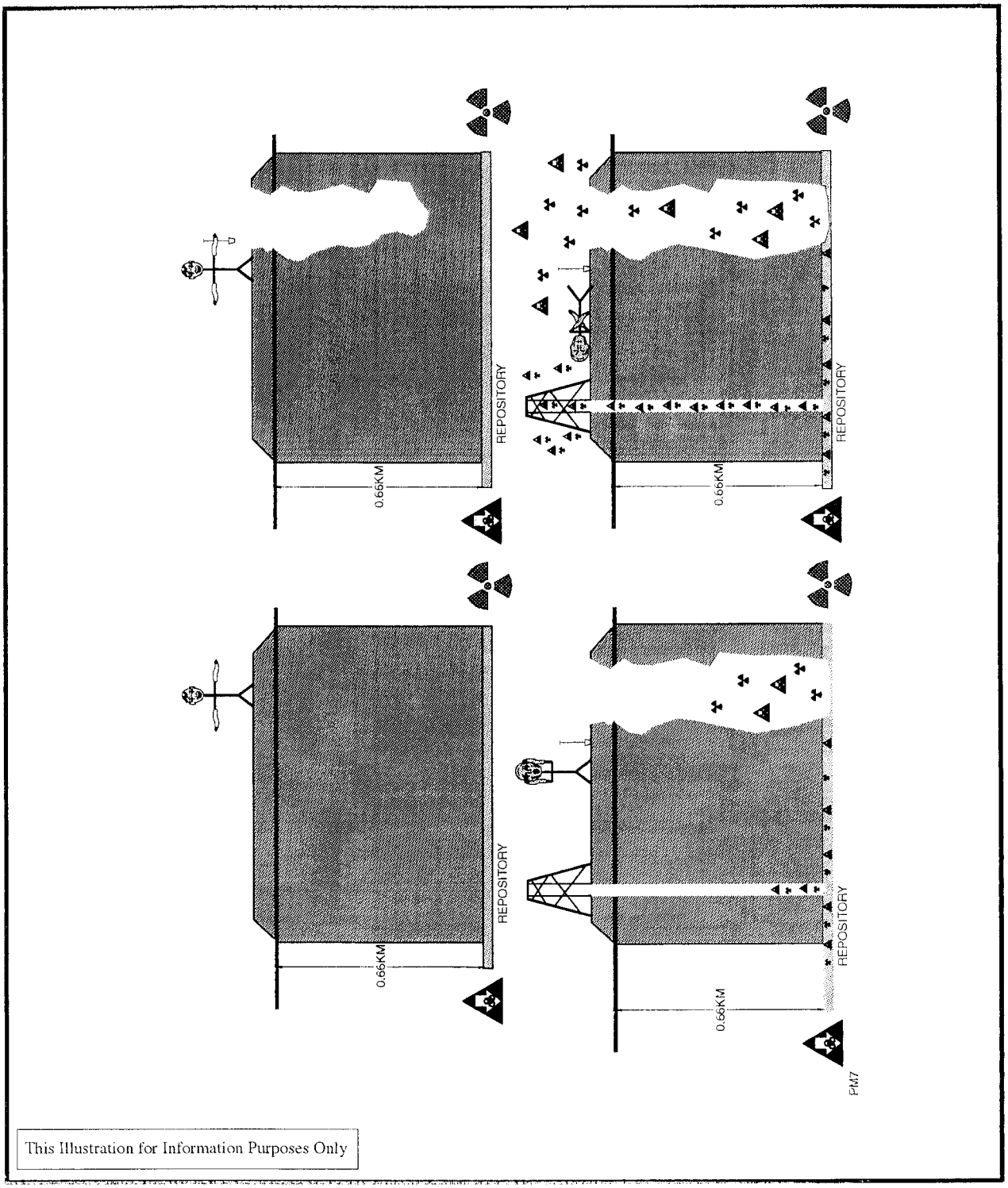

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Figure PMR-6. Monument Hazard Inscription

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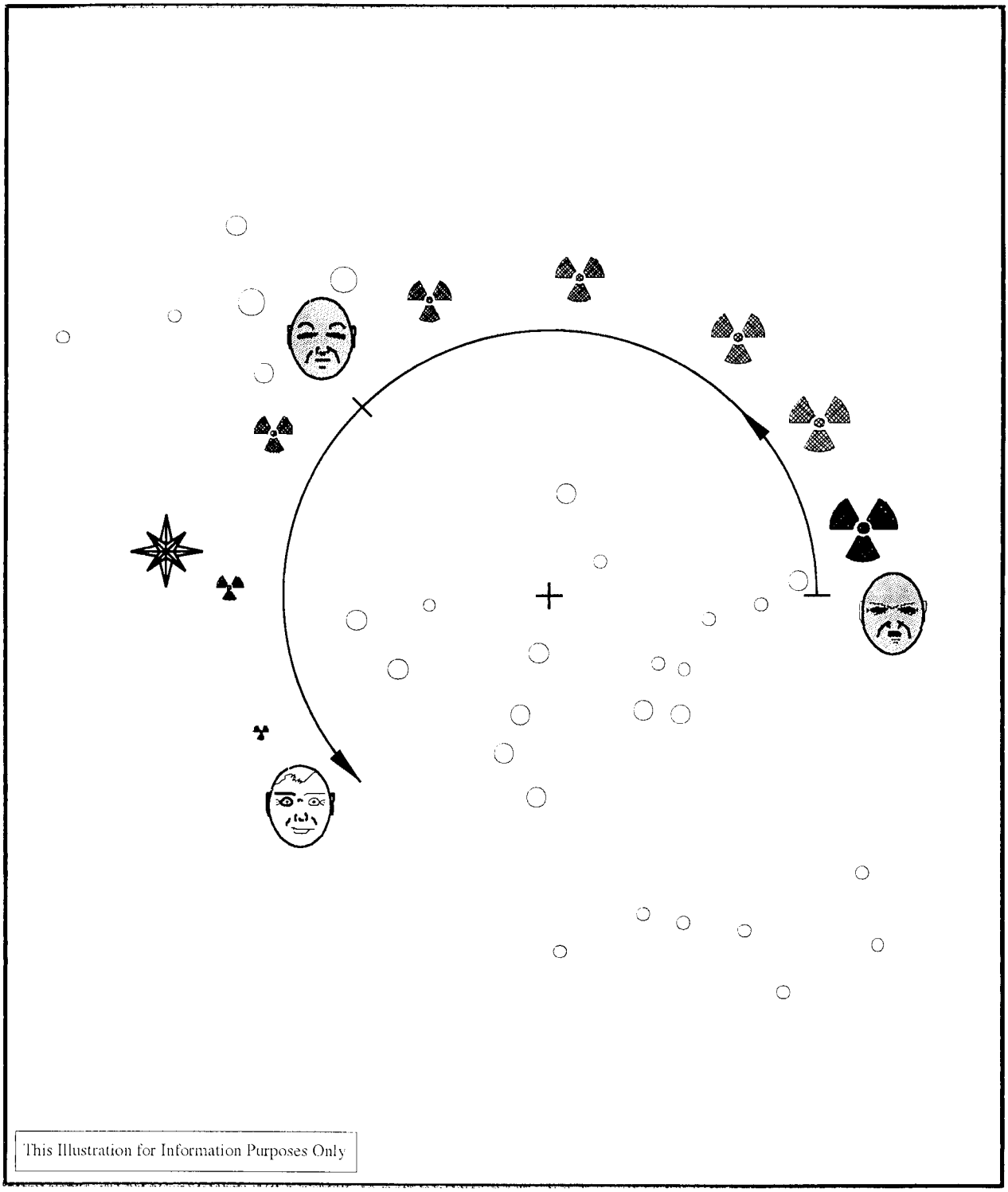

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Figure PMR-7. Celestial Calendar

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- It describes the general layout of the repository and the original configuration of the emplaced waste
- It provides an explanation of the trefoil and Biohazard symbols
- It explains the diagram showing the four brightest stars at the time of waste burial, including their azimuth angles, to provide an independent means for future generations to determine when the waste was buried
- It explains the diagram showing the precession of the north celestial pole through constellations and the diminution of the radioactive waste with time
- It provides an equivalency of the year of WIPP closure with five other calendar dates
- It explains the diagrams associated with the level IV message
- It urges the reader to check other locations around the world where radioactive wastes are buried for consistency with the markings used at the WIPP and the basic criteria used for establishing the character and protection of the message

Figure PMR-8 through Figure PMR-14 are associated with the level IV message. Figure PMR-8 (Diagram 1 of the message text in Attachment 2) provides a more detailed spatial perspective of the repository than that shown with the level III message. Figure PMR-3 (Diagram 2 of the message text) provides information on how the shafts supporting the repository were sealed at closure. Figure PMR-9 (Diagram 4 of the message text in Attachment shows the geologic cross section of the WIPP site and locates the relative position of the repository within the geologic formations shown. Dimensional characteristics are provided in Attachment as are the names of repository components. Figure PMR-10 (Diagram 5 in the message text in Attachment) is the periodic chart. It identifies the radioactive elements with a ☢ and specifically identifies those elements which have significant quantities of their radioactive isotopes buried at the WIPP site with a ■. The nonradioactive toxic elements that are also buried in significant quantities are identified with a circle on the periodic chart. Figure PMR-11 (Diagram 7 in the message text in Attachment) provides the azimuths of the bright stars (Vega, Arcturus, Sirius, and Canopus) as they rise above the horizon at the time of WIPP closure. From this information, future generations can determine the length of time the repository has been closed. Figure PMR-12 (Diagram 6 in the message text) is a world map showing the locations throughout the world where radioactive wastes are buried (the locations shown in Figure PMR-12 are examples, and are not necessarily where the wastes will be buried at the time the WIPP is closed). The ■ symbol is used to convey that "Radioactive Waste Is Buried Here." Figure PMR-13 (Diagram 8 in the message text) is comprised of two circles as described in Trauth et al. (1993). The numbers corresponding to the dots refer to the buried waste storage locations shown on the world map. The outer circle provides the longitudinal position of the storage locations relative to the WIPP. The inner circle

provides the latitude of the storage locations relative to the WIPP. According to Trauth et al. (1993), if circles approximately 9.8 ft (3 m) in diameter are used and the positions are placed with an accuracy of 0.039 in. (1 mm), the locations of the storage sites can be located to within 25 mi (4 km). The design of the buried rooms containing the level IV message accommodate both the map and the 9.8 ft (3 m) diameter latitude/longitude circles.

PMR.5.0 MONUMENT MARKERS

Monument markers are those elements of the marker system consisting of large monoliths (Kaplan 1982) on the surface and small warning markers buried throughout the repository footprint. To facilitate fabrication and shipping of the monoliths, each monolith will consist of two separate stones connected by a tendon joint. The large monoliths will be engraved with level II and III messages. Figure PMR-14 provides the dimensional characteristics of the large monoliths. Each monolith will be inscribed with the level II and III messages in seven languages, the six official United Nations languages (English, French, Spanish, Chinese, Russian, and Arabic) and Navajo. Trauth et al. (1993) discusses in some detail the selection of these languages by the MP. In addition, each monolith will be inscribed with a diagram (Figures PMR-5 and PMR-7) depicting two concepts. The first concept is comprised of four frames illustrating the danger of digging or drilling into the repository and releasing the radioactive and toxic waste. The second concept illustrates the decay of the radioactive material (decreasing size of the trefoil and improving disposition of the icon) over many thousands of years by depicting the position of the north pole through the major constellations (Ursa Minor, Ursa Major, Draco, and Cygnus) and the brightest star, Vega.

One of the MP recommendations with respect to the monolith placement is for both aboveground and belowground inscriptions. Trauth et al. (1993) prescribes that at least one copy of the level II and III messages should be inscribed at a height well above a position "accessible to a standing person, or a person on horseback or standing on top of common farm equipment (wagons, pickup trucks, tractors)." To meet the intent of this restriction, individual monoliths will have the messages inscribed in the top 6 to 8 ft (1.8 to 2.4 m) on all four sides. This places the messages 17 to 19 ft (5.2 to 5.8 m) aboveground. Three translations and one illustration are inscribed aboveground. Four translations are inscribed on the buried portion of the monolith in the area of 5 to 12 ft (1.5 to 3.6 m) above the base. Placement of the messages in these areas also provides ample surface area for future generations to inscribe messages in their respective languages. Individual translations will be varied in their locations among all of the monoliths so that copies of all translations will be located both aboveground and belowground.

The monoliths will be made from granite and shipped by rail to the WIPP site. Monolith locations will be excavated to at least 5 ft (1.5 m) into the caliche. After emplacing the base monolith, the upper monolith will be placed over the base tendon and the excavation

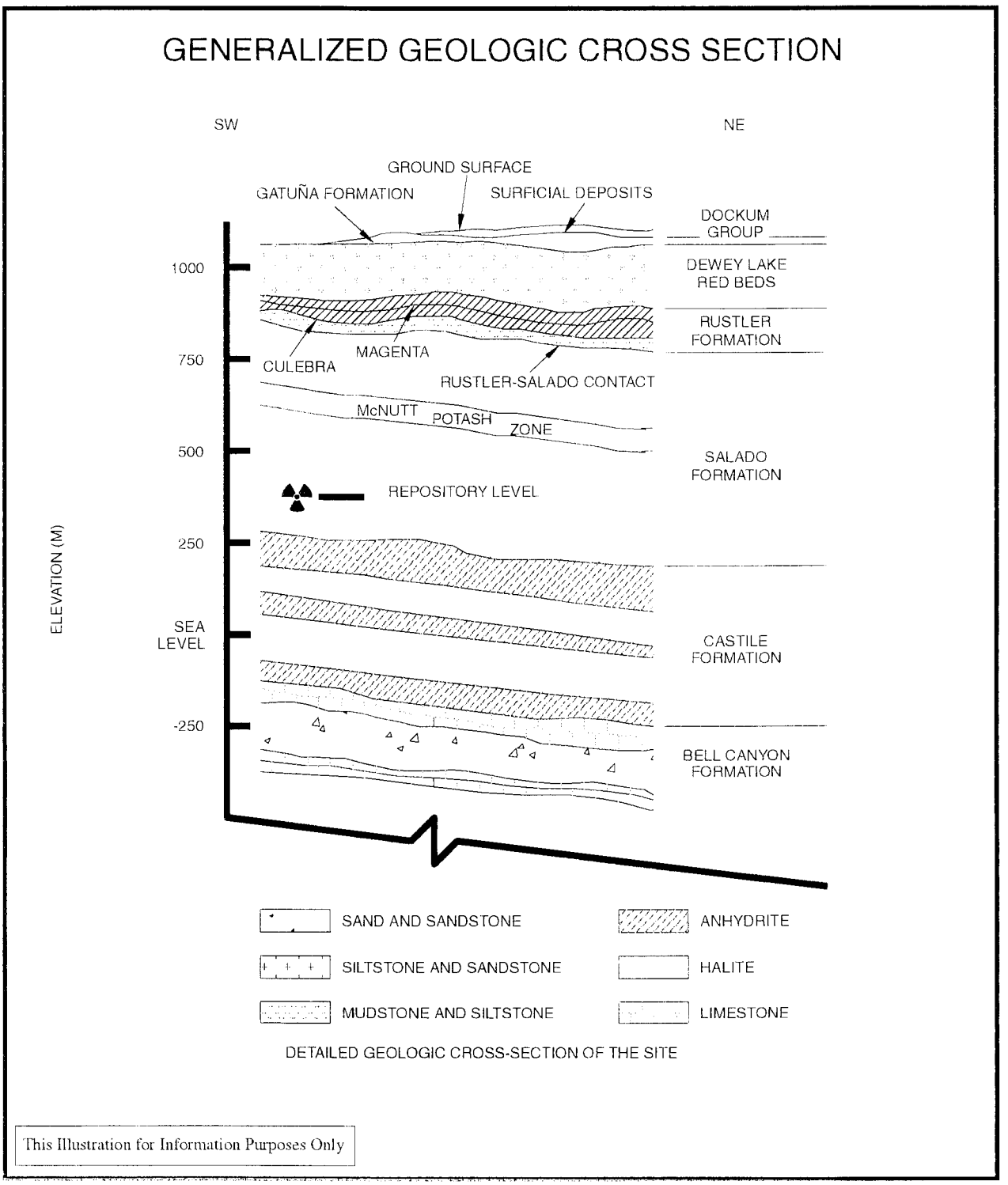

Figure PMR-8. Generalized Geologic Cross Section

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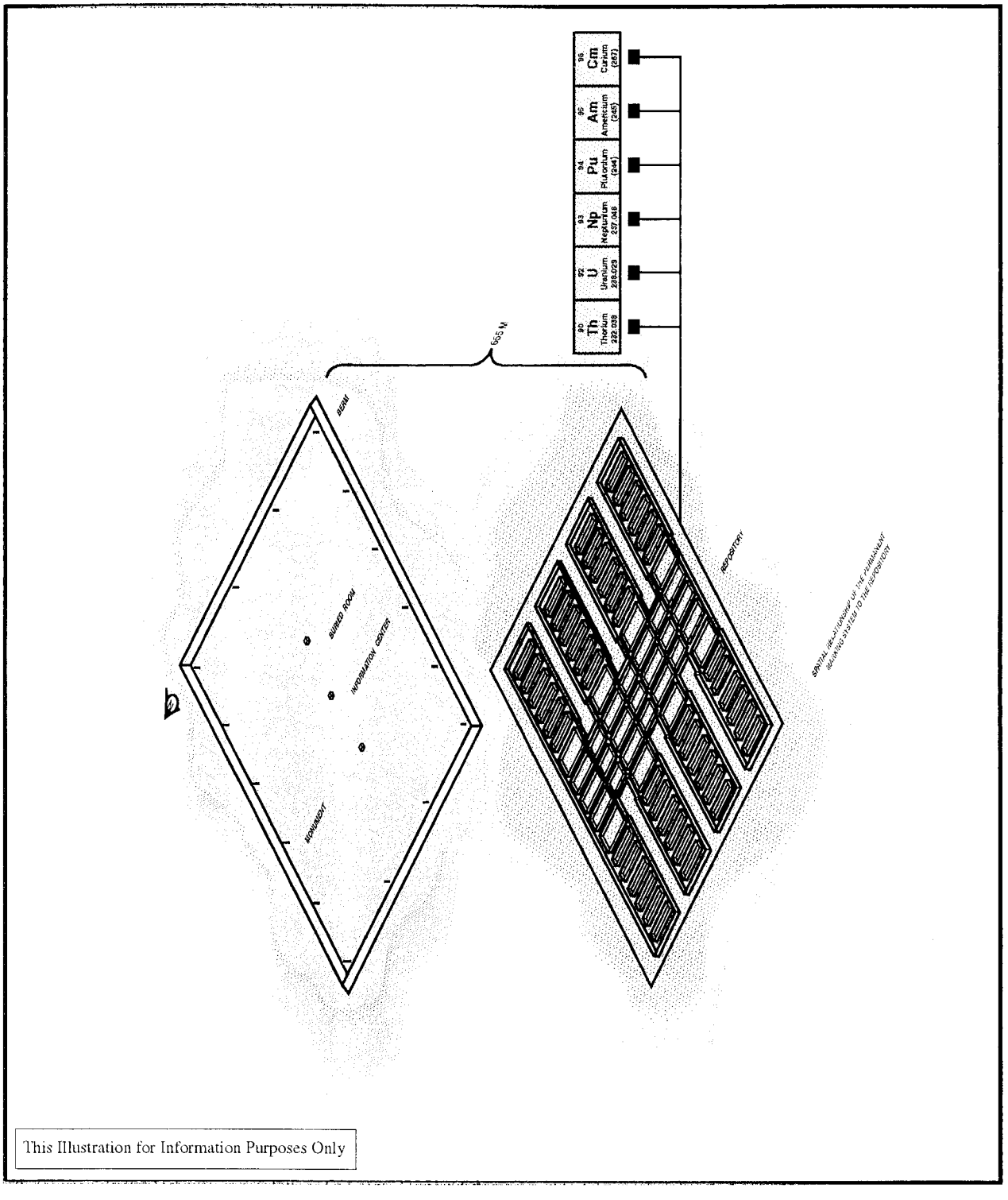

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Figure PMR-9. Spatial View of Sealed Repository and Permanent Marker System

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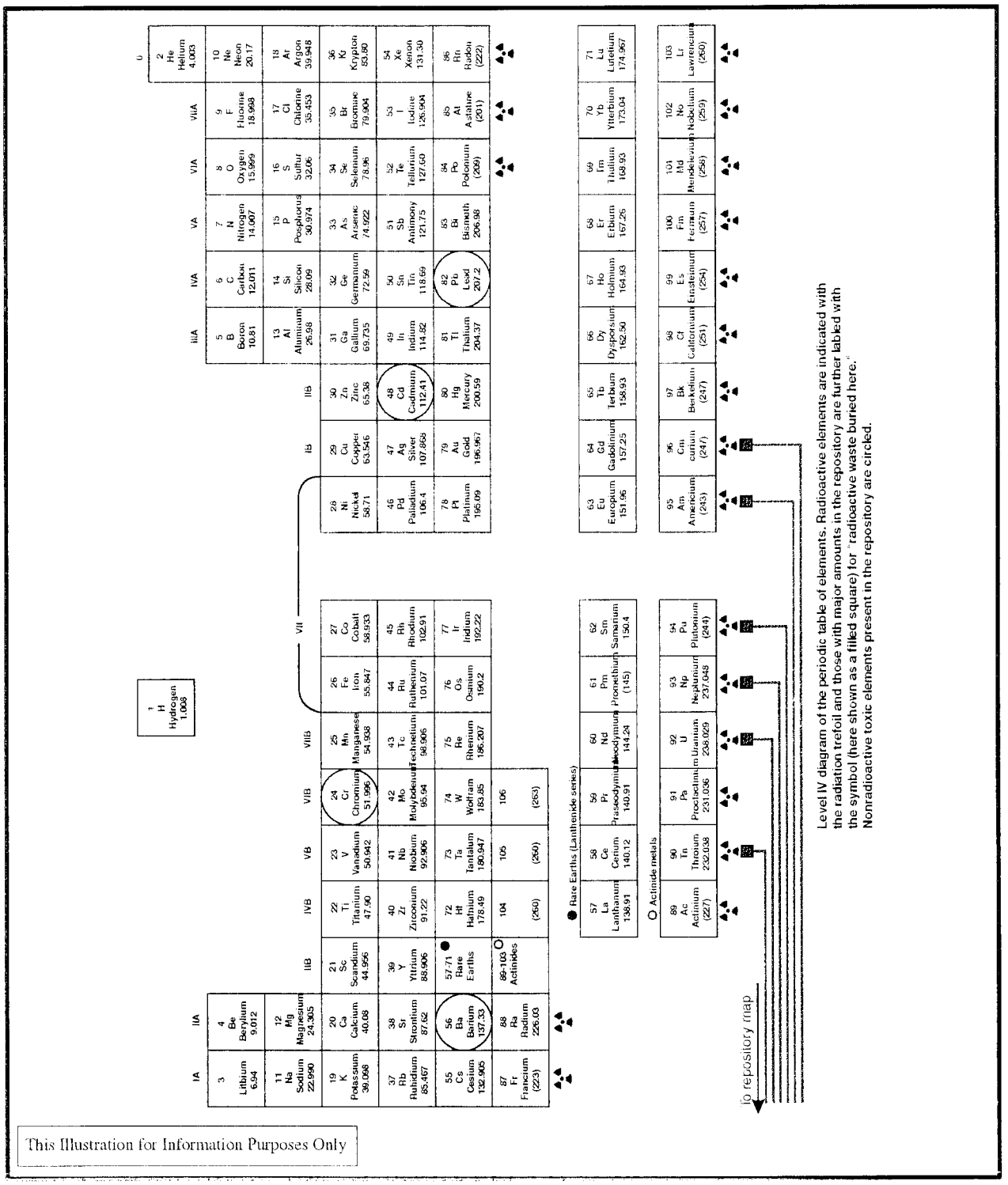

Figure PMR-10. Periodic Table

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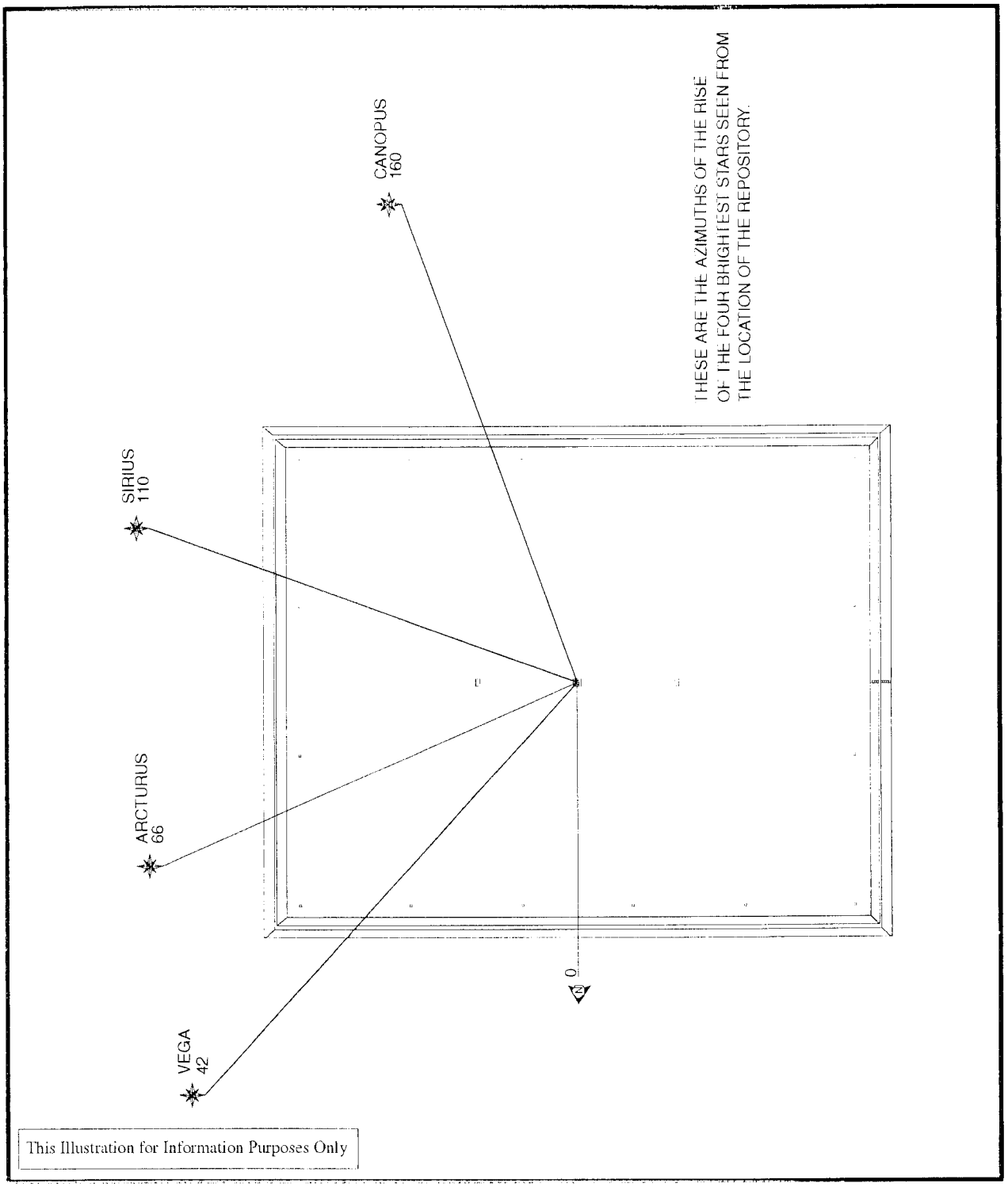

Figure PMR-11. Star Azimuths Relative to WIPP Location

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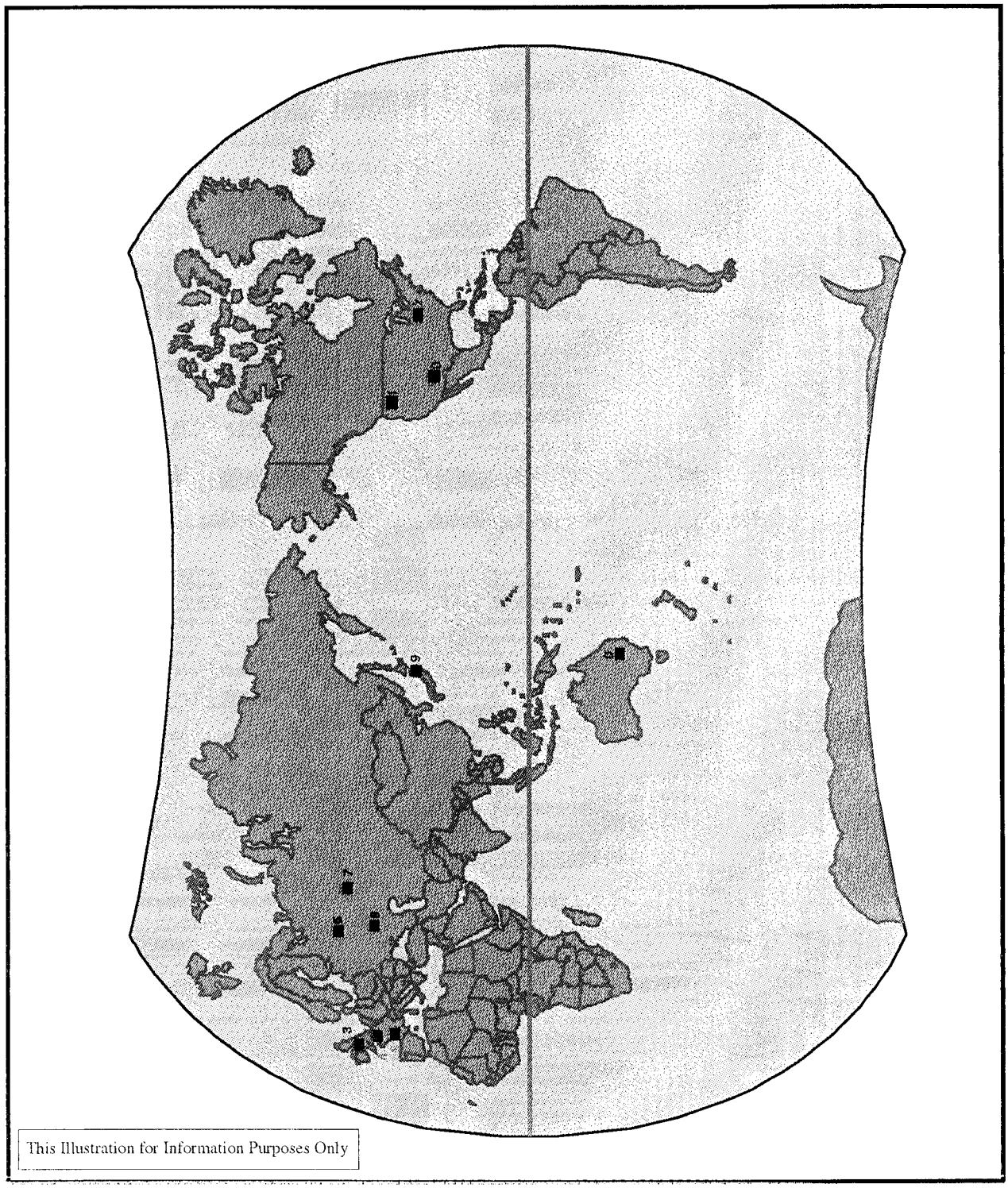

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Figure PMR-12. World Map of Repository Locations

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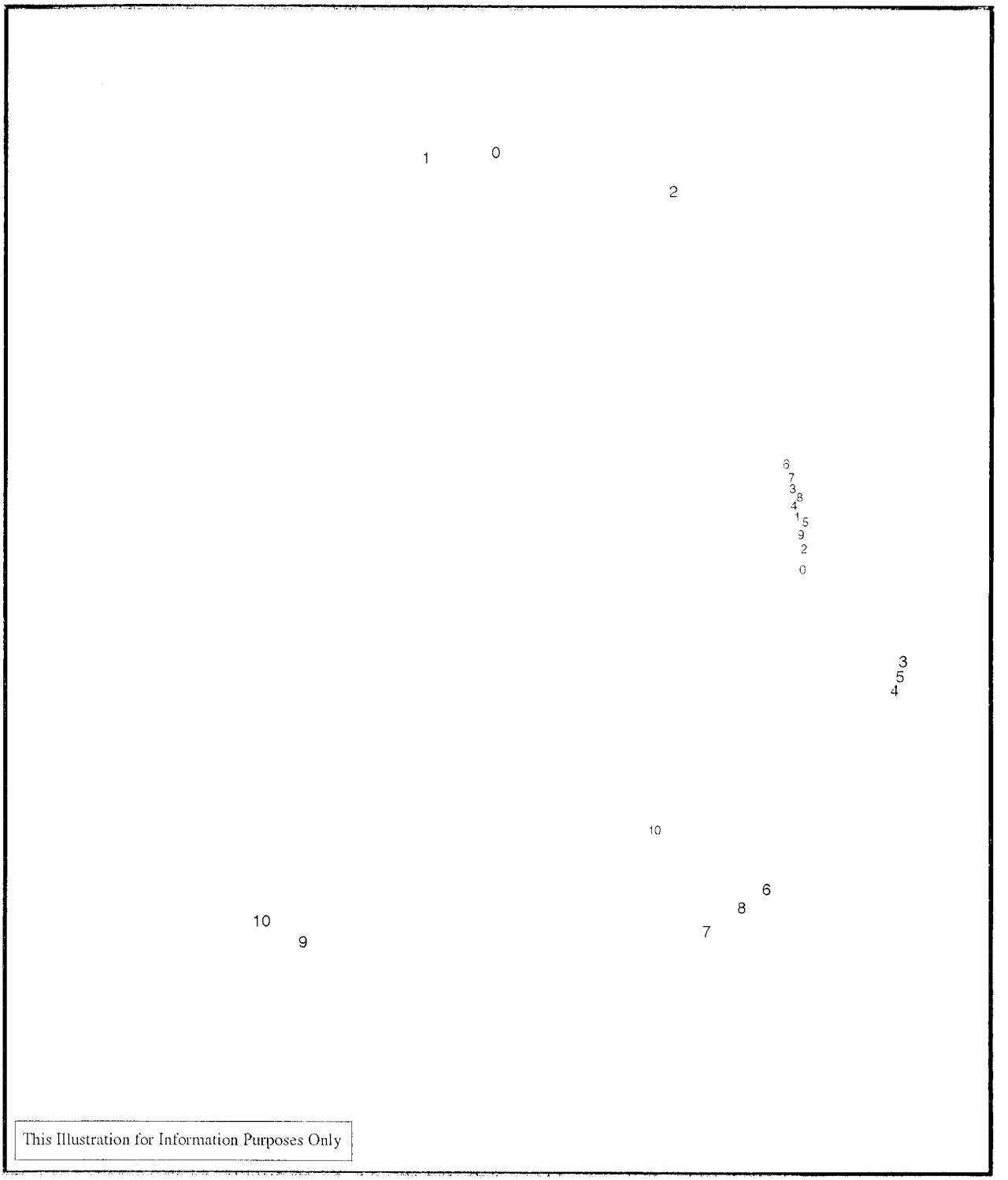

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Figure PMR-13. Repository Latitudes and Longitudes

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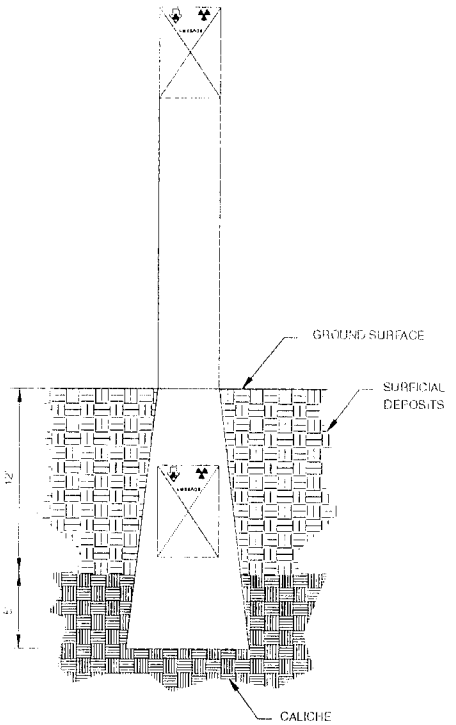


MONUMENT EMPLACEMENT

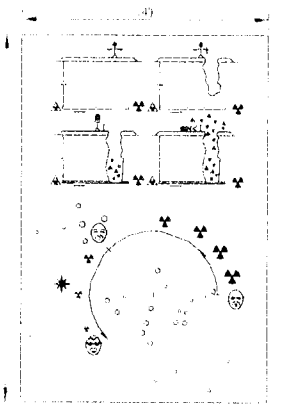
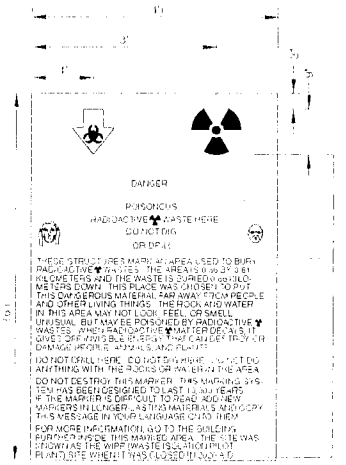


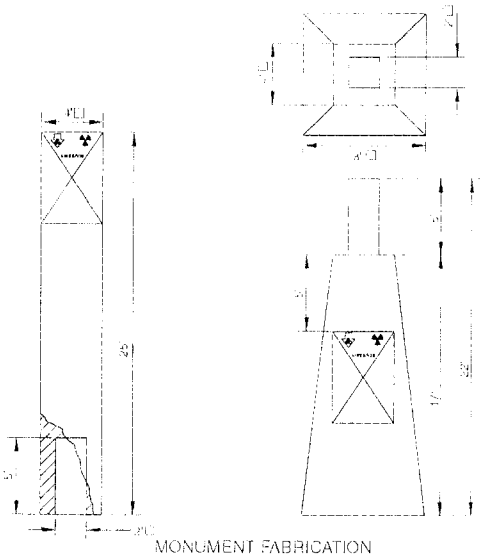
DIAGRAM INSCRIPTION
NOTE 6



MESSAGE INSCRIPTION

NOTES:

1. MONUMENT TO BE HEWN FROM TWO SOLID PIECES OF GRANITE
2. MESSAGE TO BE CARVED INTO STONE FACE AND GENERAL LOCATIONS AS SHOWN ON DRAWING. THE MESSAGE WILL APPEAR SEVEN TIMES ON THE MONUMENT, ONCE IN EACH LANGUAGE LISTED BELOW. THE MESSAGE WILL APPEAR AT THE TOP OF THE MONUMENT ON THREE FACES LEAVING ONE BLANK FACE. IT WILL APPEAR ON FOUR SURFACES AT THE BOTTOM
   A. ENGLISH
   B. SPANISH
   C. RUSSIAN
   D. FRENCH
   E. CHINESE
   F. ARABIC
   G. NAVAJO
3. THE LEVEL I MESSAGE WILL BE IN 3" HIGH LETTERS WITH A 3" SPACE ABOVE AND A 3" SPACE BELOW
4. THE LEVEL II MESSAGE WILL BE IN 1 1/2" HIGH LETTERS WITH A 1" SPACE BETWEEN LINES AND A 2" SPACE BELOW THE BOTTOM LINE OF THE MESSAGE
5. THE LEVEL III MESSAGE WILL BE IN 1" HIGH LETTERS WITH A 3/8" SPACE BETWEEN THE LINES. THERE WILL BE A 1 1/2" SPACE BETWEEN THE PARAGRAPHS OF THE MESSAGE
6. THE DIAGRAM INSCRIPTION WILL APPEAR ON THE BLANK FACE ON THE TOP OF THE MONUMENT. THE DIAGRAM DESCRIBES THE HAZARDS OF DIGGING HERE AND HOW LONG THAT HAZARD WILL EXIST



MONUMENT FABRICATION

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Figure PMR-14. Monument Configuration

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will be backfilled. This will suitably support the base monolith within the caliche deposit or the Gatuna formation even under conditions where the overlaying layer of sand is removed through erosion or other weathering phenomena. The center of gravity of the two monolithic stones is 15.5 ft (4.7 m) from the bottom of the base. The monolithic structure would require sufficient erosion to tip approximately 14.5 degrees from the vertical before the structure would become unstable.

In discussions with a number of quarry operators and a memorial distributor in the local area, it is apparent that granite will come in a variety of grades. Granite is commonly referred to as blue, grey, black, or red. The color is a result of the granite composition and the hardness will vary. As a result of this condition, the testing addressed in Section IX below, provides for subjecting a number of different types of granite to long-term testing prior to actual purchase of the final monoliths. A local memorial distributor with over 40 years of actual experience in the Carlsbad area stated that one of the harder grades, blue granite from Vermont, is not as durable as grey granite from Georgia. Although this is only a single reference point, it does support the proposed testing of various grades of granite over a period of decades prior to the final monolith material decision.

The small warning marker is shown in Figure PMR-15. The level II message placed on the small subsurface warning markers will also be in the seven languages described above. However, each marker will have the message in only one of the seven languages. Warning markers will be placed throughout the repository footprint, within the berm, and in the shaft sealing system. The level II message is shown in Figure PMR-4. The warning markers will be made of granite, aluminum oxide, and fired clay to provide a diversity of materials and thus improve the likelihood that at least some materials will endure for a 10,000-year period.

Warning markers should be spaced approximately 15 ft (4.5 m) apart. The warning markers should be buried 6-8 ft (1.8-2.4 m) below the surface, but above the caliche. This depth is below that which would be encountered from deep plowing or amateur archaeologists. This burying criteria is based upon two conditions. The first condition is that the soil covering the caliche in the local WIPP area ranges to a depth of 10 ft (3 m). The second condition is based upon discussions with local drilling operators regarding their standard practice for drilling preparation. Discussions with local well drilling companies reveal that typically an area 200 ft by 300 ft (61 m by 91.5 m) is cleared down to the caliche in preparation for drilling. Included within this area is the excavation of a "mud pit" that is typically 150 ft (45.7 m) square and 10 ft (3 m) deep. Thus, by placing the small warning markers above the caliche at intervals of approximately 15 ft (4.6 m), over 250 warning markers should be unearthed during the well drilling preparation. This provides a reasonable likelihood that at least some of the warning markers would be discovered by a drilling crew.

Trauth et al. (1993) discusses the use of deep markers. Discussions were held with local drilling company representatives regarding possible techniques for alerting drilling crews.

No practicable scheme was identified to mark the repository in a manner that would alert drill crews to the potential of a drill bit entering radioactive waste. In discussing drilling routines and the degree that the drilling fluid is monitored once a routine drilling operation has commenced, oil field drilling company representatives stated that close observation of the fluid does not occur until the bit is below local salt formations. Unless an extremely hard material (steel or titanium) was emplaced to encounter the drill bit and dull it quickly, the drilling operation would not likely be stopped upon encountering rock that is harder to drill than salt. According to at least one local drilling contractor, most drilling plans identify the depth to which the drilling operation is targeted and after some initial checks of the operation, continuous drilling proceeds to that depth with little or no significant monitoring of the drilling fluid. One drilling company manager stated that if 2 to 3 in. (5 to 8 cm) of steel or titanium were encountered, it would probably impact the drilling operation sufficiently to cause additional investigation. Anything short of this would only be seen as an inconvenience.

A second drilling operations supervisor stated that drilling for oil and gas in the local area required depths of 8,000 and 16,000 ft (2,438 and 4,877 m), respectively. Knowledge of the area is ample enough that no examination of the drilling fluid is normally conducted until after the drill has passed through the salt layers. The same supervisor also stated that the drill cuttings ranged in size from about 3 micron grains to small slivers up to 1 1/2 in. (3.8 cm) in length. Under these conditions, there is no practical way to provide a message. In addition, current drill materials can typically penetrate even granitic rock at 6 to 8 ft (1.8 to 2.4 m) per hour. It was the opinion of at least one drilling supervisor that for a 1/2 in. (1.3 cm) steel plate to dull a bit sufficiently to prevent penetration, the steel would require placement at a shallow depth. Otherwise, the weight of the drill string would sufficiently improve the capability of the drill bit to penetrate the steel plate without alerting the drill crew to any unusual condition. Placing a steel plate near the surface would violate the requirement against using material of intrinsic value. In addition, the corrosion resistance of steel reduces the likelihood of its remaining an effective barrier over a period of 10,000 years.

Emplacement of markers in the panels immediately above the waste would be ineffective, because there would be insufficient lag time to alert the crew even if they were closely monitoring the drilling fluid content. The use of a dye was also discussed as a possible marking option. Discussions with a number of dye manufacturers and suppliers failed to identify a dye material that would affect the drilling fluid at specific concentrations and that could be emplaced with the waste. In addition, some means would be necessary to provide a message telling the drilling crew why the dye was present. Finally, the use of pyrotechnics as deep marker components is not practical since significant quantities of drilling fluid under high pressure are used to flush out the drill cuttings. The fluid would extinguish any flammable materials long before the material could be brought to the surface to alert the drilling crew. If thermite were used in a configuration and quantity that would melt the drill bit, it might stop the operation—but without a message to convey to the drillers what they were about to enter, the drillers have one of three choices:

WARNING MARKER

FIGURE V-2

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Figure PMR-15. Small Marker Configuration

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- They could change out the drill bit and commence drilling again. In this case, they would successfully pass through the waste unless the design included multiple layers of thermite separated sufficiently to prevent sympathetic detonation.

- They could abandon the drill site and set up elsewhere. In this case, they might strike another thermite condition and abandon the attempt, or simply move a third time.

- They could abandon the area altogether.

The material used to "melt" the drill would require a protective cover to remain stable for 10,000 years. In addition, a prodigious quantity of the material would be required and in itself would represent a significant hazard during fabrication and field emplacement.

Tolan (1993) reports that experience with environmental remediation work on old landfills indicates that old tires or steel fencing/baling wire can make effective barriers to truck-mounted rotary drilling. He states that in two cases where the material was layered greater than 33 ft (10 m), the problems presented to the drillers resulted in their abandoning the boreholes.

The installation of a 30 ft (10 m) thick barrier of old tires or steel wire in itself represents a significant construction effort when considering a repository footprint (excluding the area of the pillars between repository rooms and panels) of .05 mi^2 (0.13 km^2). Placing the barrier near the surface requires excavating the entire area to provide reasonable assurance that the repository is protected. Emplacing the barrier only over the room footprints and not the pillars would ignore the risks associated with drilling near the pillar/room boundaries and the inaccuracies that might be associated with the vertical trueness of the drilling process. Emplacing the barrier nearer the location of the repository, over the room footprints plus some small percentage overlap, may require significant additional study to determine what, if any, effects this additional mining above the repository may have on the performance of the repository. This additional study time could significantly affect obtaining the required permits to begin waste emplacement, yet result in a barrier that will not be effective against slant or possible future horizontal drilling techniques.

When discussing what action a drilling crew might take upon encountering a barrier made of old rubber tires, the experienced drilling personnel interviewed responded that they would investigate the problem. Under current operating practices, this would entail a review of the maps provided by state and federal agencies to determine the cause. However, unless some means not yet identified provided a message regarding the presence of the repository, drilling would probably recommence. If a typical 8,000-ft-(2,438-m-) deep oil well in the WIPP locale costs $300,000, abandoning a well after drilling over 1,000 ft (305 m) represents a significant financial loss.

As stated at the beginning of this section, a practical means of warning the drilling crew that they are about to enter a waste repository has not been identified. Therefore, this conceptual design report does not recommend emplacing a deep marker system in the strata above the repository.

PMR.6.0 STORAGE ROOM

The storage room for containing the level IV message and associated diagrams is designed to endure for the 10,000-year period of the PMS. The design characteristics contributing to this longevity are the material and environmental conditions associated with its construction and location. The room is made of granite with a minimum number of joints. As designed, individual walls, the floor, and the roof are comprised of single granite slabs joined only at the perimeter locations. The internal walls are each made of three sections to provide redundancy of information. Figure PMR-16 is an isometric view of the planned buried storage room containing the level IV message. The magnets shown in the figure are to permit locating the rooms magnetically. Figures PMR-17 through PMR-19 show views of the building from the top, side, and end. They include overall dimensional characteristics. The configuration minimizes the risk of failure due to chemical interactions between the construction material, joining materials, and environment.

In each of the conceptual design configurations described later in this report, at least one room is buried. In addition, an Information Center will be located on the surface providing access to the same information contained in the buried rooms. This should limit the incentive to future generations to excavate the buried rooms. The Information Center will house details regarding the location of the buried Storage Rooms containing identical information. Attachment 3 contains the "Storage Room Location" message placed in the Information Center. It is anticipated that distribution of archival information regarding the WIPP site in local, state, federal, and international repositories will also deter future generations from excavating and entering any of the buried rooms for a significant number of years. If societal changes, calamities, or loss of the archival information mean that society cannot determine what the buried room(s) contain, it is assumed that at least one of the rooms will be entered and observed. Entry into any of the buried rooms will be precluded by establishing access control and maintaining active control for at least 100 years after decommissioning of the site. A significant effort would be required to fully excavate the rooms and even occasional surveillance by local law enforcement personnel should thwart any significant damage to the rooms by vandalism or souvenir hunters during the active controls period.

The overall dimensions of each buried storage room are approximately 39 ft by 22 ft by 16 ft (11.9 m long by 6.7 m wide by 4.9 m high). The message texts in Attachment 2 are engraved on the walls in an arrangement similar to that for the Information Center shown in Figure PMR-20. In addition, the diagrams are arranged on the walls of the rooms similar to that shown in Figure PMR-20 for the Information Center and as depicted in

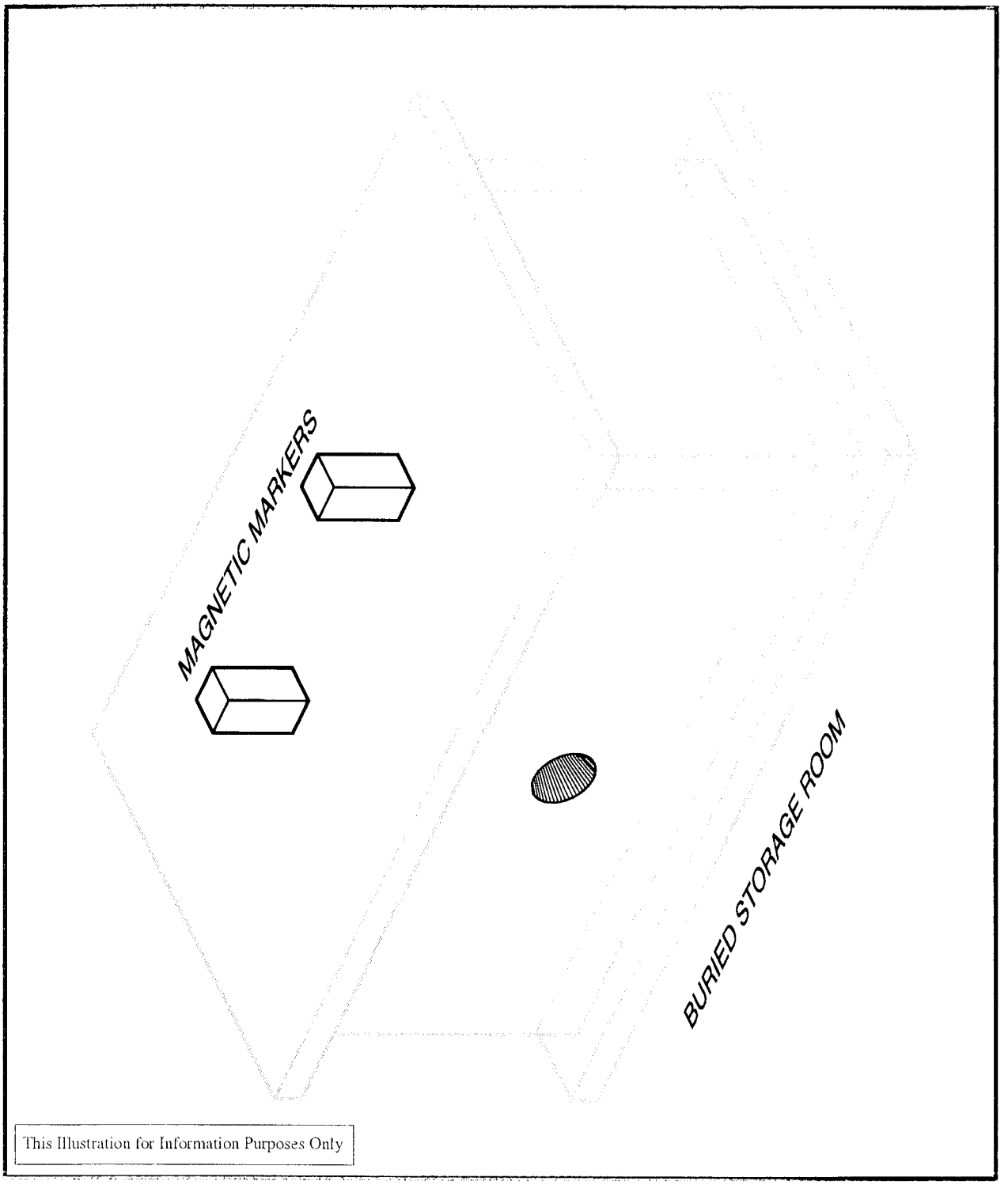

Figure PMR-16. Storage Room Configuration

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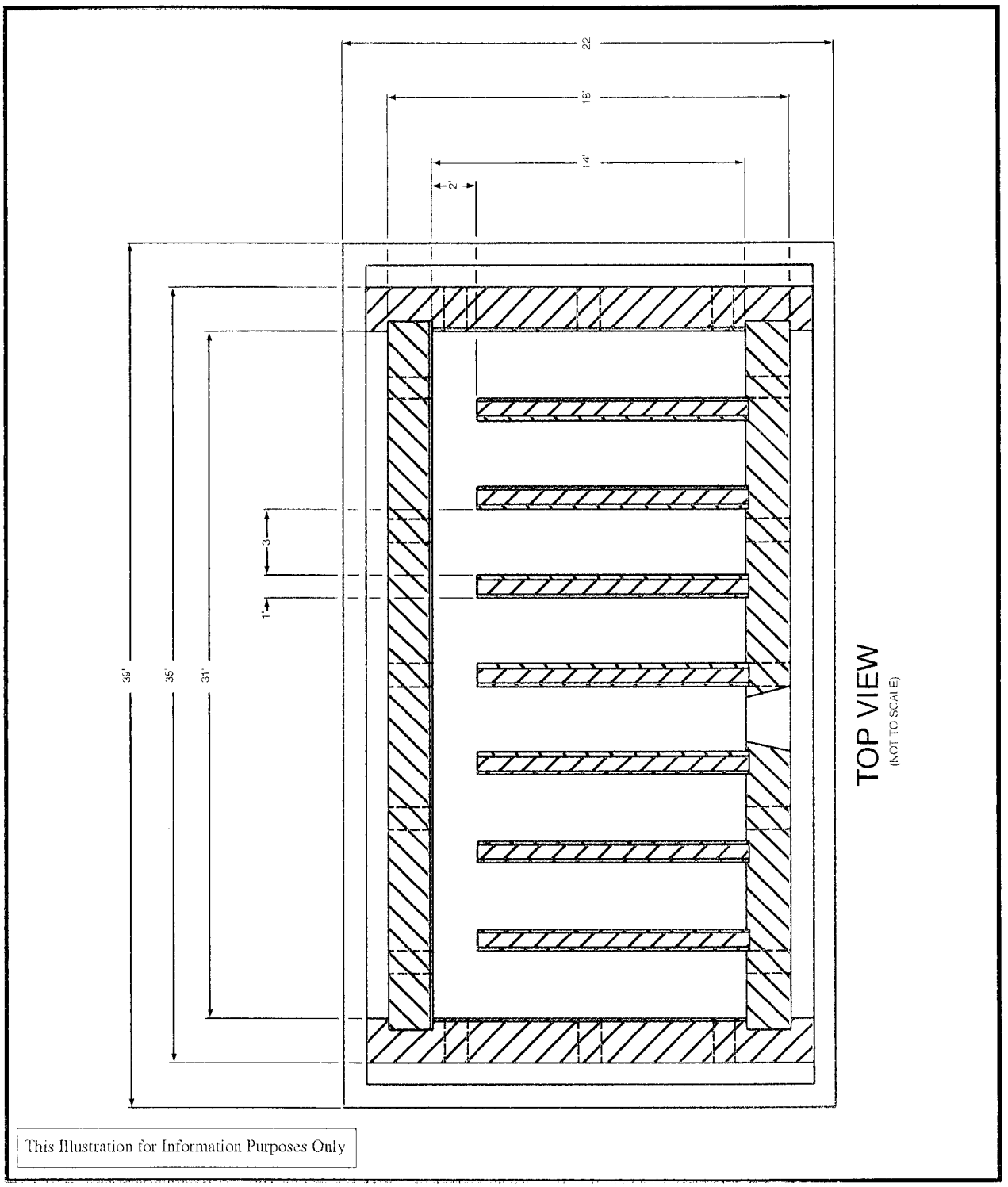

Figure PMR-17. Storage Room Top View

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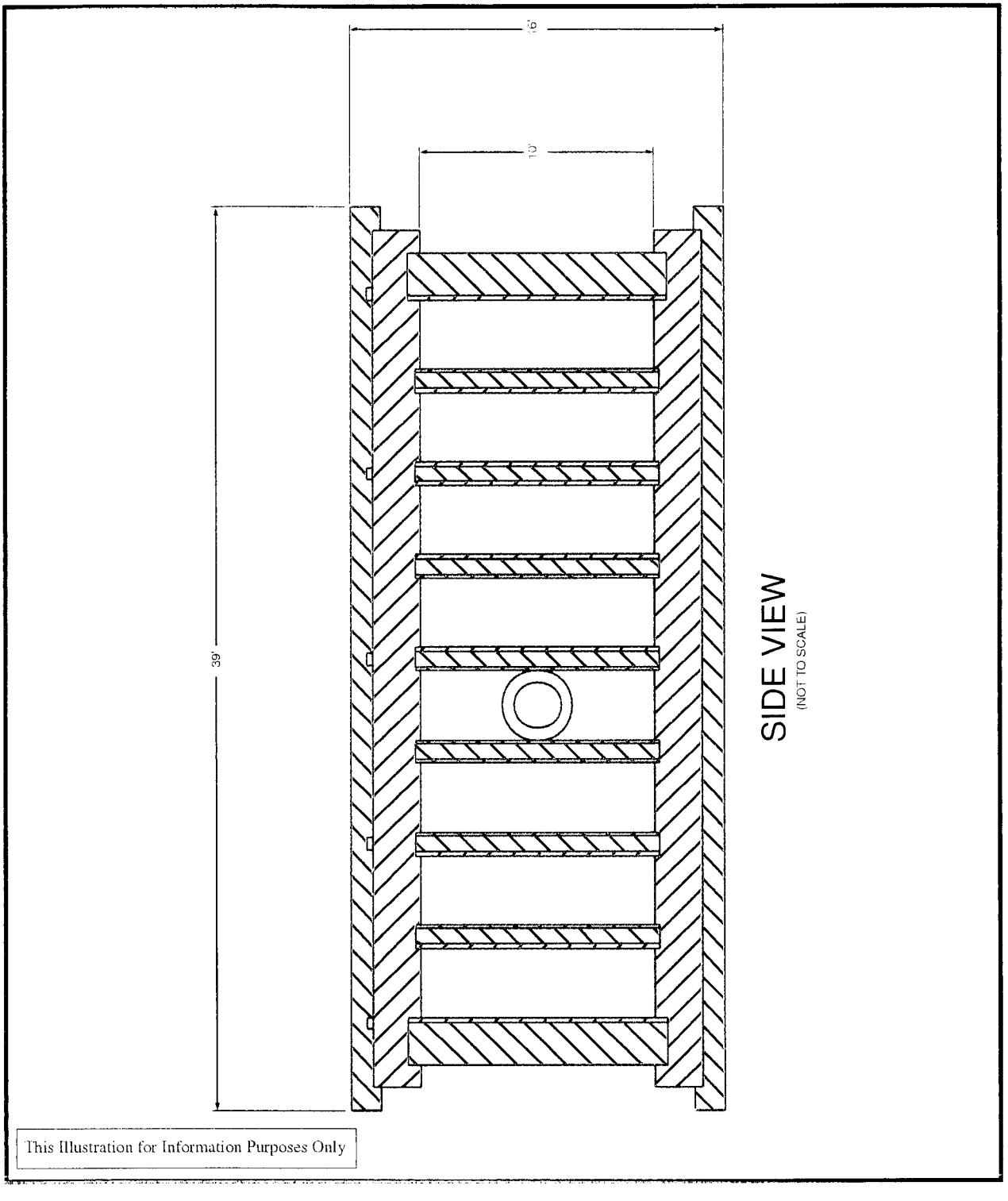

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Figure PMR-18. Storage Room Side View

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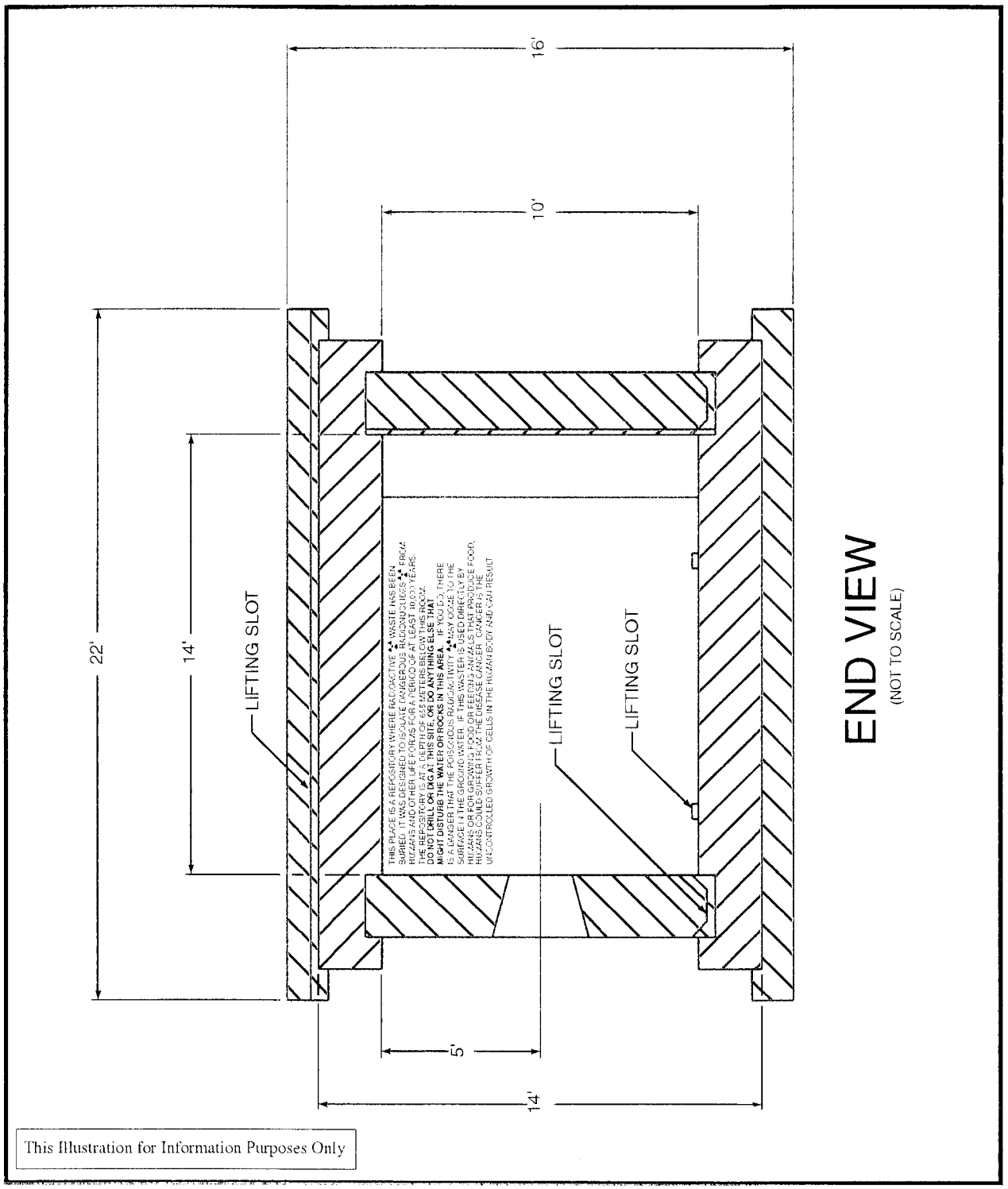

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Figure PMR-19. Storage Room End View

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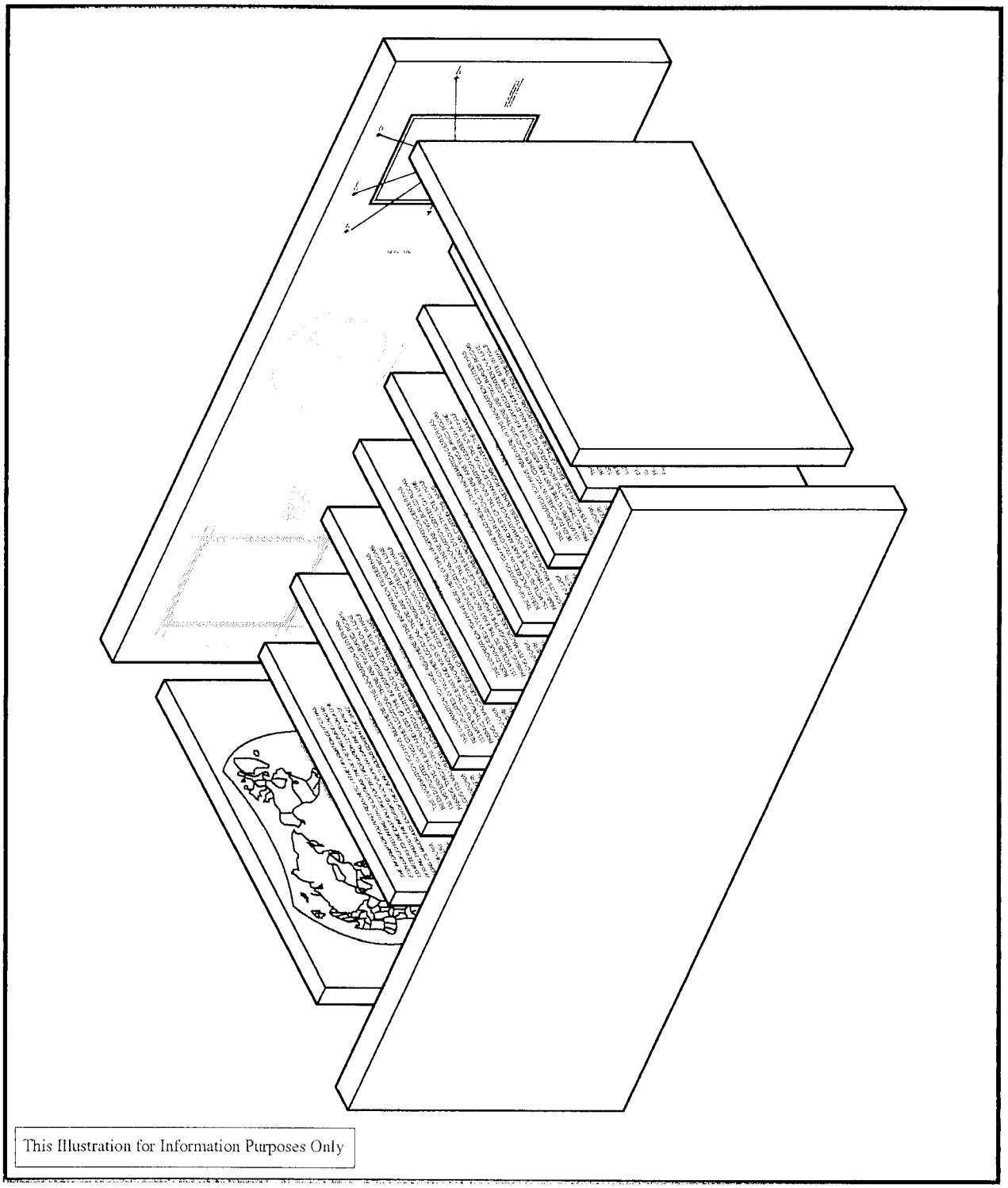

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Figure PMR-20. Information Center

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Figure PMR-19 for the buried rooms. To provide redundancy, additional granite slabs engraved with the message text and the diagrams are held in place against the interior walls. The room entrance is a single plug in one wall measuring 2 ft (0.6 m) at the inner minimum diameter. The tapered plug weighs approximately 1,600 pounds. Its removal will likely require more than a single individual. The opening is small, so that the room contents cannot be removed easily by an unorganized group or individuals intent on vandalism. Although some damage could be inflicted by vandals, the granite composition of the message-carrying materials provides the greatest opportunity for preventing complete destruction of the information contained within the buried room.

The physical size of the Storage Rooms is dictated by the minimum size lettering which can be engraved in granite. Discussions with a number of quarry operators and local memorial vendors indicate that the minimum lettering size is 5/8". This is limited by the sandblasting technique typically used. Engraving smaller size letters causes "blowout" of small enclosed characters, such as "A," "P," "R," etc. No laser engraving capability exists within the granite quarrying industry. Additional discussions with laser manufacturers verified the lack of laser engraving capability on large pieces of granite. One manufacturer stated that he gets called at least once a week by memorial dealers inquiring about laser engraving technology. Two reasons are given for the lack of the technology today. First, high laser power (6-8 kilowatts) would most likely be required. Second, the granite quarry and memorial industry is not willing to fund research to develop the technology. This particular manufacturer suggested that perhaps a national laboratory attempting to convert defense related technology to commercial use might take on such a development effort. In any event, the technology currently does not exist to engrave granite with characters smaller than 5/8".

PMR.7.0 INFORMATION CENTER

An isometric drawing of the Information Center shown in Figure PMR-20 illustrates an aboveground structure which contains the same information provided in the buried storage rooms. Construction of the Information Center is comprised of solid granite walls embedded in compacted caliche for support. Engraved on the walls is the level IV message in seven languages and the graphics information provided in the storage rooms buried underground. In addition, the Information Center contains a diagram (Figure PMR-21) of the PMS locating the buried rooms relative to the Information Center. The Information Center is an open structure allowing natural sunlight to illuminate the engraved information.

In addition to the level IV message, the Information Center will also contain a message regarding the Storage Rooms. Figure PMR-22 illustrates the proposed message. The message provides information for locating the rooms both in relation to the Information Center and by magnetic signature. The magnetic signature is developed by permanent magnets similar to those described in Section PMR.8.0 below. The message also cautions not to excavate the Storage Rooms arbitrarily, but to leave them alone for future generations as a backup in the event that the information presented on the Information

Center walls has been lost. It also requests that the rooms be reburied if conditions have caused them to become exposed.

Figure PMR-23 provides the dimensional characteristics of the Information Center exterior and interior walls. Placement of the walls and the relatively narrow spacing between the walls will minimize the erosion due to wind-driven sand and rain. It is anticipated that, barring vandalism, this structure and its information will endure as long as the monoliths. However, should this not to be the case, the information will also be available in the underground storage rooms.

PMR.8.0 BERM CONFIGURATION

The decision to base a PMS design on the construction of a berm or berm-like structure is based upon the following arguments:

- The structure should identify the extent of the surface footprint of the repository, but need not follow the footprint outline
- The structure should be sufficiently massive to provide reasonable assurance that it will endure for 10,000 years
- The structure's profile should minimize the likelihood that it can become buried by shifting sands or that characteristics of the profile may lead to fabrication stresses affecting the ability of the structure to retain its configuration
- It should be constructable without the need for high-tech equipment or processes
- Its construction materials should be reasonably available to the WIPP site and have as little intrinsic value as is reasonable
- Its cost should be competitive with other alternatives. That is to say, its cost should not be disproportionately high for the advantages it provides
- To the extent practicable, the nature of the structure should lend itself to valid testing over a period of 2 to 5 decades

Trauth et al. (1993) explores a number of different techniques and structures for defining the repository's surface footprint. The resulting recommendation from each of the two teams is to use a berm-like configuration. A berm also meets the arguments listed above to a greater extent than any of the other configurations proposed. Each of the conceptual design configurations described below make use of a berm configuration. Although the individual configurations may have an outwardly different appearance, their construction consists of similar materials and material placement. Figure PMR-24 depicts the general cross-sectional berm construction configuration. The core base material to be used is salt remaining from the excavation of the repository. The design capacity of the repository of

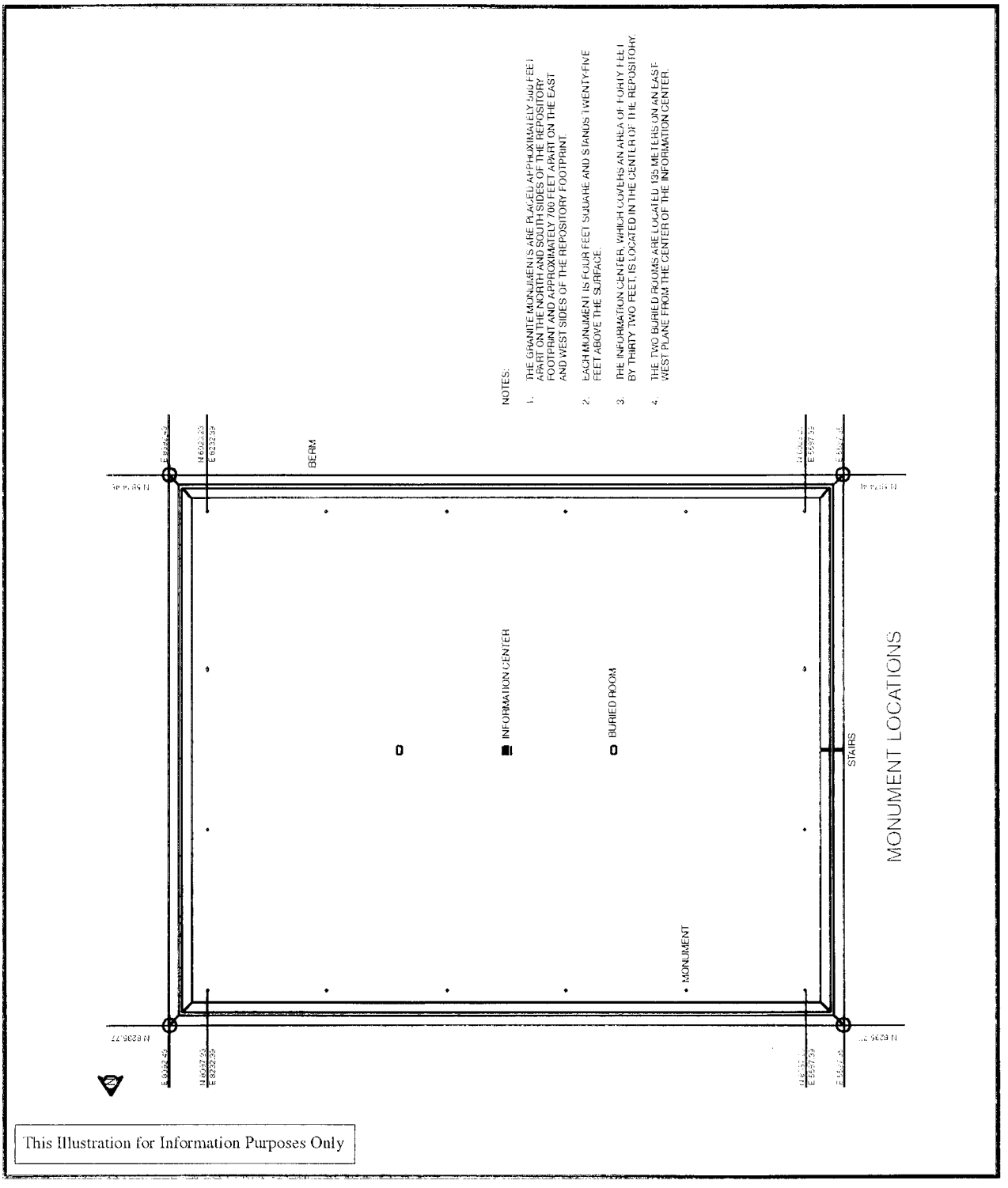

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Figure PMR-21. Relative Permanent Marker Locations

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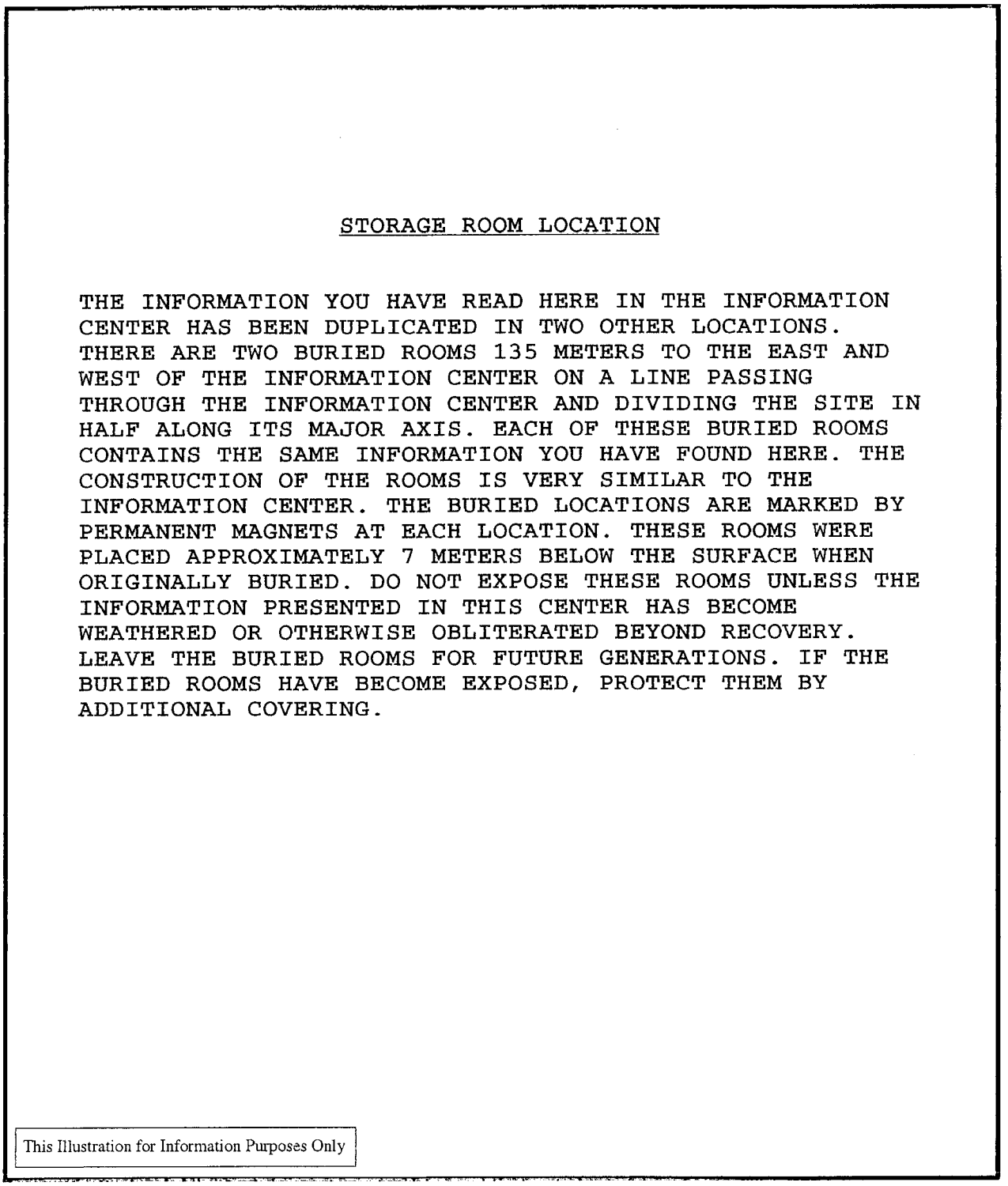

STORAGE ROOM LOCATION

THE INFORMATION YOU HAVE READ HERE IN THE INFORMATION CENTER HAS BEEN DUPLICATED IN TWO OTHER LOCATIONS. THERE ARE TWO BURIED ROOMS 135 METERS TO THE EAST AND WEST OF THE INFORMATION CENTER ON A LINE PASSING THROUGH THE INFORMATION CENTER AND DIVIDING THE SITE IN HALF ALONG ITS MAJOR AXIS. EACH OF THESE BURIED ROOMS CONTAINS THE SAME INFORMATION YOU HAVE FOUND HERE. THE CONSTRUCTION OF THE ROOMS IS VERY SIMILAR TO THE INFORMATION CENTER. THE BURIED LOCATIONS ARE MARKED BY PERMANENT MAGNETS AT EACH LOCATION. THESE ROOMS WERE PLACED APPROXIMATELY 7 METERS BELOW THE SURFACE WHEN ORIGINALLY BURIED. DO NOT EXPOSE THESE ROOMS UNLESS THE INFORMATION PRESENTED IN THIS CENTER HAS BECOME WEATHERED OR OTHERWISE OBLITERATED BEYOND RECOVERY. LEAVE THE BURIED ROOMS FOR FUTURE GENERATIONS. IF THE BURIED ROOMS HAVE BECOME EXPOSED, PROTECT THEM BY ADDITIONAL COVERING.

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Figure PMR-22. Storage Room Message

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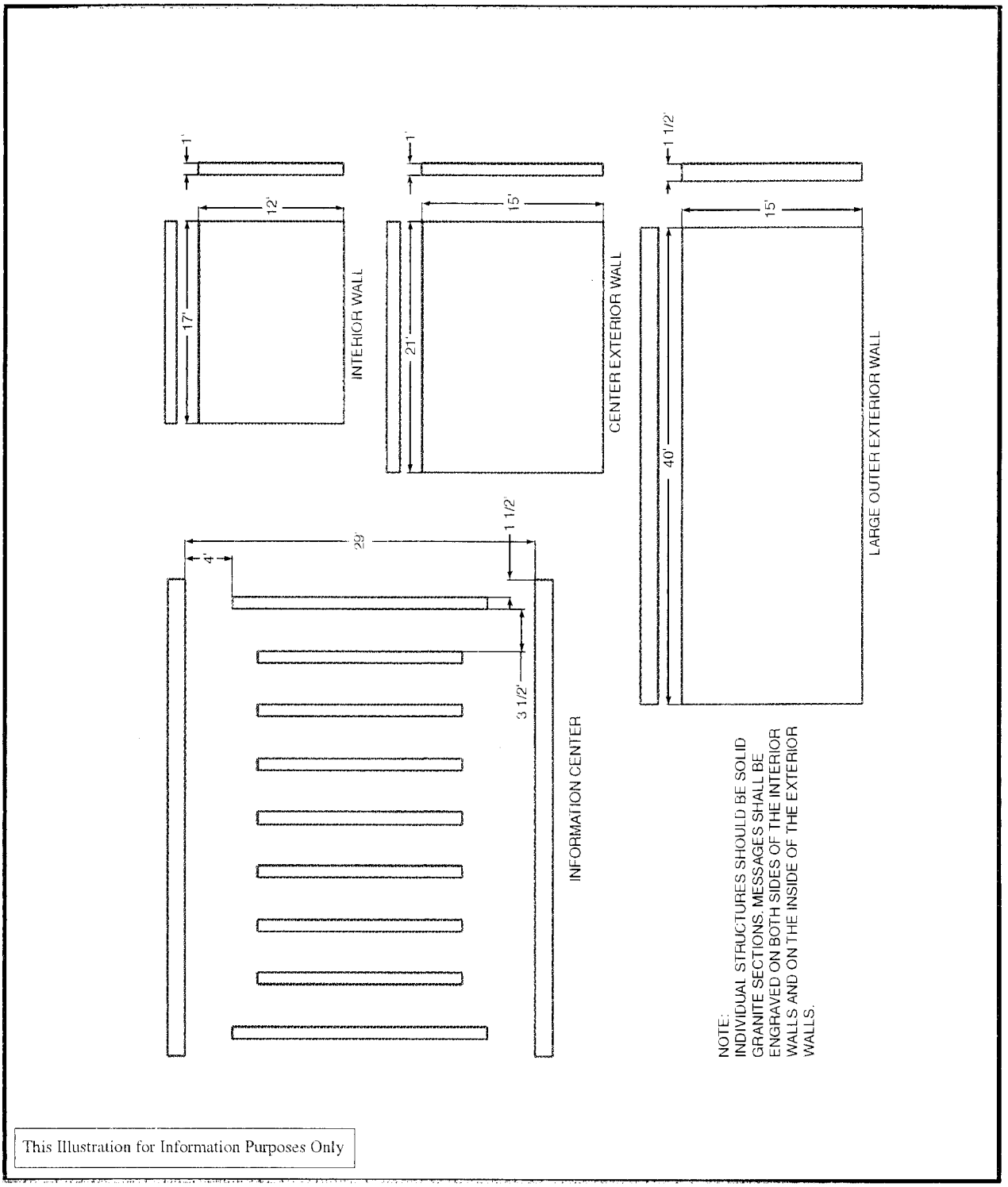

Figure PMR-23. Information Center Structure Details

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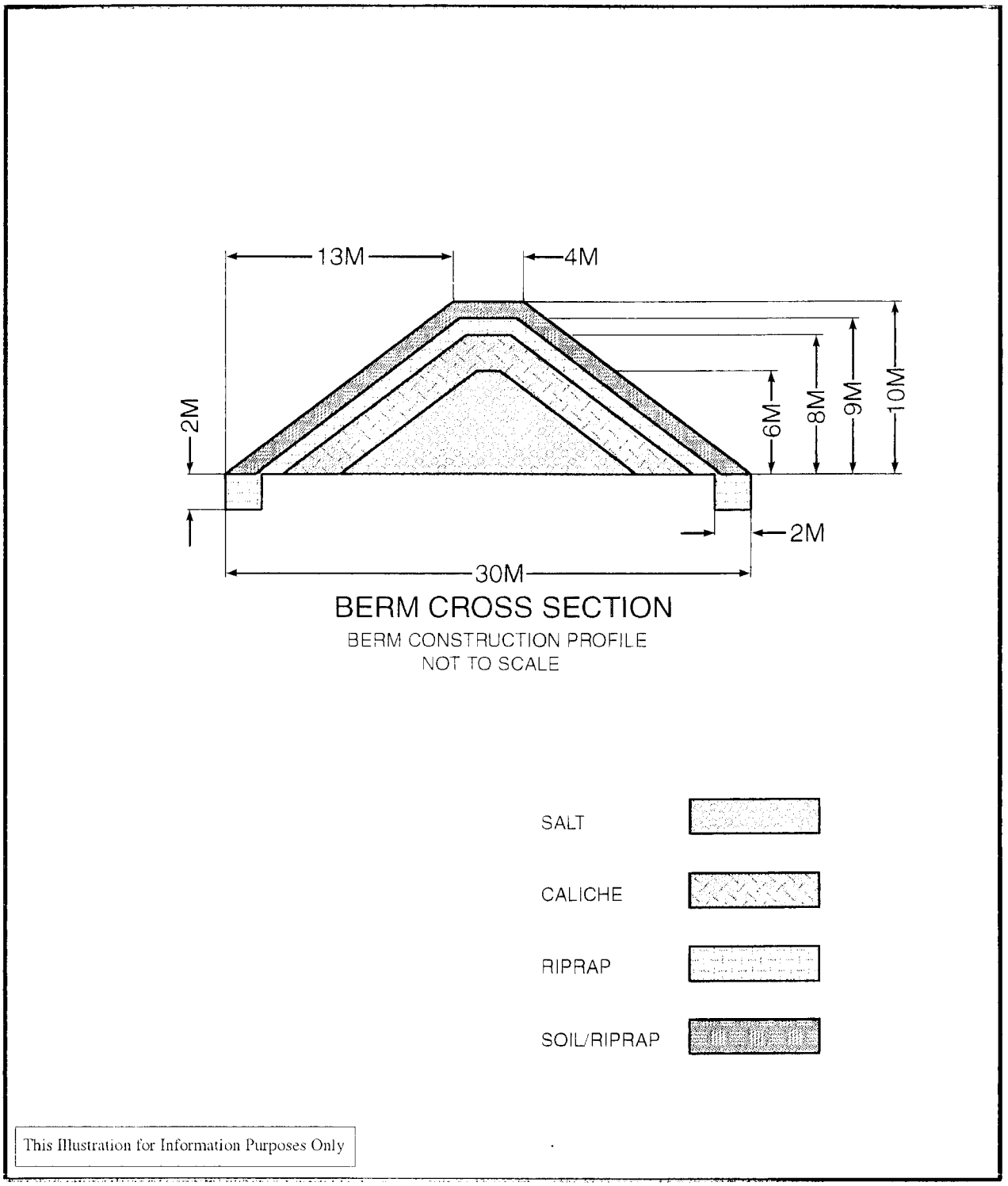

Figure PMR-24. Berm Cross Section

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6,200,000 ft^3 (175,000 m^3) will provide a significant amount of material remaining after closure. This material will be used to form the core of the berm(s). Although the salt would be susceptible to water and wind erosion if left unprotected, using it as a base core material for the berm with other material applied as a protective cover should effectively protect the salt. The WIPP site is in a semi-arid region in which, for the worst case, the rainfall will no more than double in the next 10,000 years (Swift 1992). Therefore, it is reasonable to assume that water erosion will not become a major issue with respect to berm durability.

A practical and locally available protective covering for the salt core is the caliche soil found locally up to 15 ft (4.6 m) below the surface. Large quantities are available. The caliche is reasonably impervious to water penetration in the semi-arid environment of the WIPP. Studies of the locale report that even at the height of an ice age, the annual rainfall is not expected to more than double its current 13 in. (33 cm) per year average. Therefore, 6.6 to 9.8 ft (2 to 3 m) of caliche compacted over the salt core should provide significant protection of the salt from water.

A third layer of berm material will be comprised of riprap quarried near Carlsbad, New Mexico. This will provide protection for the caliche from wind erosion. It will also provide for runoff of rainwater to the surrounding desert with minimum water erosion of the caliche layer. The final layer of berm material will consist of a mixture of riprap and native soil. This should support local vegetation and add another erosion-resistant characteristic to the overall berm configuration. During the disposal phase of the WIPP, testing will be conducted to determine what combination of rock sizes, soil, and vegetation provide the best likelihood of success, at least in the near term (100 years).

To provide a unique magnetic signature for the berm with respect to the local geology, as recommended in Trauth et al. (1993), an investigation into the use of magnetite as a layered material over the salt was conducted. Although magnetite in its natural state often demonstrates a detectable magnetic anomaly, removing large quantities by mining and transporting them to another locale to provide local detectable magnetic anomaly may not be a prudent course of action. In its natural state, the mineral magnetite (Fe_3O_4) develops its magnetic signal through induced magnetism from the earth's own magnetic field over eons of time. When mined, the magnetite material becomes mixed up and the individual dipoles will not all be aligned to reinforce each other as is found in the natural state. After being emplaced, large quantities of the mineral could be magnetized with a large electromagnet. However, successfully completing such a task would require considerable effort to demonstrate and evaluate. Even if successful, the retention of the artificially induced magnetic field over thousands of years is unknown and could not be determined with a high degree of certainty. In view of the shortcomings of magnetite, a unique magnetic signature will be provided by large permanent magnets.

To provide a distinctive magnetic signature for the berm, large permanent magnets buried in the berm can be used (Mallick 1994; Krefta 1994). Large strontium ferrite permanent magnets buried within the berm at intervals of 246 to 328 ft (75 to 100 m) would give a

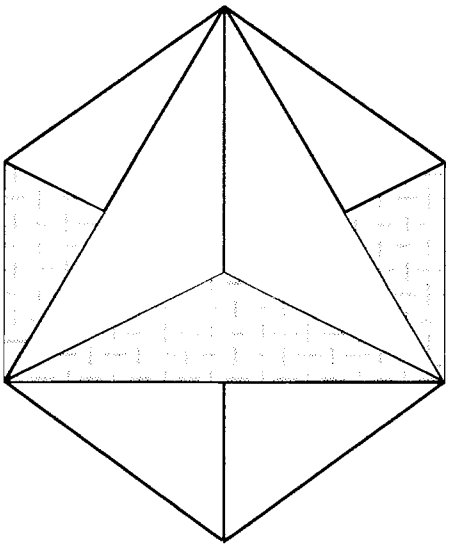
signal detectable with current state-of-the art airborne equipment 328 ft (100 m) above the magnets. The individual magnets would be approximately 3.28 ft (1 m) in length and 1.6 ft by 1.6 ft (1/2 m by 1/2 m) in cross-section. Should unexpected future climatic conditions cause sand shifts so extensive that the berm and monoliths become covered, future generations conducting magnetic surveys of the area should still be able to detect a magnetic anomaly resulting from the permanent magnets. The magnetic signal's geometric form will provide strong indication that it could only have been man-made. This should inspire any organization capable of magnetic surveying to investigate this anomaly further prior to initiating any planned drilling activities in the local area enclosed by the magnetic signature.

Bellus (1994) describes the use of trihedrals fabricated from metal as a means of providing a radar reflective signature unique from the surrounding terrain. Figure PMR-25 illustrates the basic trihedral configuration. Current ground-penetrating radars operate below 100MHz. Much of the communication allocations occupy frequencies below 100MHz; therefore, radars operating below this range must use filters to avoid problems with communications bands. Bellus reports that recent experience in the Middle East with SeaSat operating at 1.2GHz produced excellent images of roads and structures buried under the desert.

The dimensional characteristics of a trihedral facet that will give a peak Radar Cross Section (RCS) is 3X the wavelength of the incident radar signal. Assuming a radar operating at 1 GHz, a trihedral with facets measuring 2.9 ft (0.9 m) on a side will be optimal. This will provide a peak RCS of 17dBsm/sm (decibels m^2 per m^2) (Bellus 1994). The typical peak terrain RCS is -15dBsm/sm. The difference in RCS strength operating at 1 GHz is 32 dBsm/sm. This will give a highly visible signal. The trihedrals will be fabricated from stainless steel and placed within the berm at the surface of the salt core. To provide a unique radar signature, the trihedrals will be grouped in sets of four spaced approximately every 300 ft (91 m) around in the berm, as shown in Figure PMR-26. In addition, four trihedrals will be placed around each of the buried rooms to provide a unique radar signature at the room location. One trihedral will be placed adjacent to each room's exterior wall approximately midway along the wall. During the disposal phase and for some period after decommissioning, buried bare stainless steel trihedrals and trihedrals encased in concrete should be evaluated for performance of their respective RCS. Encasing the trihedral in concrete reduces the likelihood of its being efficiently salvaged and may also add to the effective lifetime of the trihedral by the protective concrete covering.

PMR.9.0 TESTING

Upon closure of the WIPP, at the conclusion of the disposal phase, active controls will be implemented to control the access to the site and long-term monitoring systems will detect significant deviations in repository performance. With active control provided over the site, the schedule for constructing the PMS could be extended out to decades after disposal. Because the design of the PMS has a 10,000-year-lifetime goal, it is



TRIHEDRAL CONFIGURATION

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Figure PMR-25. Trihedral Configuration

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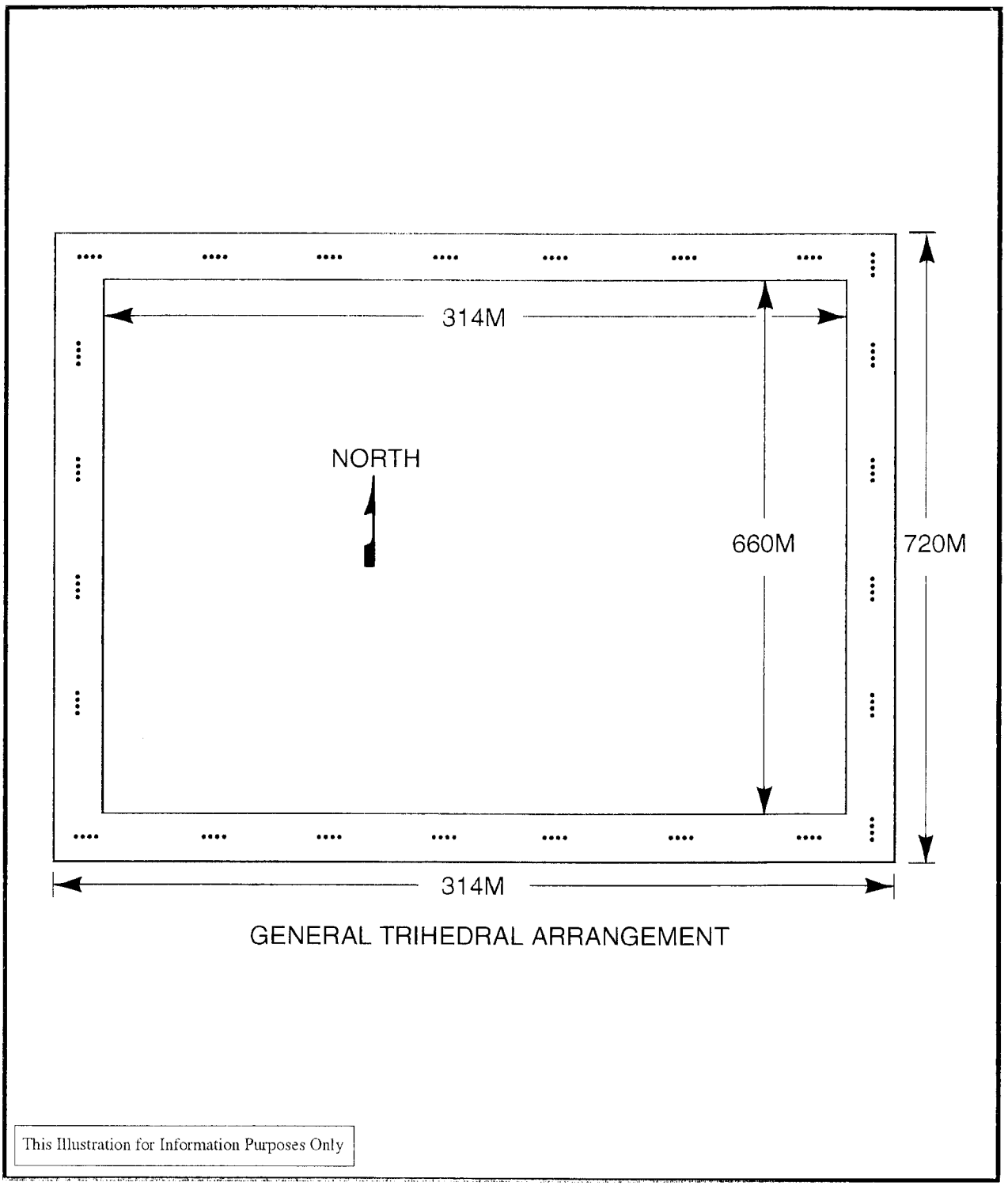

Figure PMR-26. General Trihedral Arrangement

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prudent that the DOE conduct some long-range testing of the construction materials planned for use as PM material.

One aspect of the long-term testing is the construction of a section of the berm. The overall size (height and width) of the test section will match the design of the PM berm. However, the test berm length will be shorter than the full size berm. A section approximately 164 to 328 ft (50 to 100 m) will provide a length sufficient to test a number of different configurations. Included within the test section will be varying thicknesses of the salt core, the caliche layer, and the top layer of riprap and soil material. The DOE will construct a section of the berm to evaluate materials and construction techniques. Actual construction and testing will begin during the disposal phase to provide a maximal time for testing. The major subjects which may be evaluated during this testing program are:

- The system for unloading and moving large quantities of material from the railroad spur to the PM site
- Performance of the railroad spur and maintenance required. This may impact a decision of whether to conduct periodic maintenance of the spur or refurbish it at the time of initiating construction of the PMS
- Evaluation of the climatic environmental affects on granite by surveying representative monuments within a 150-mi (93-km) radius of the WIPP
- Identification of a suitable local source of caliche and establishing the required contractual and regulatory agreements to obtain and move the caliche in the quantities required
- Identification of a suitable local source of riprap and establishing the required contractual and regulatory agreements to obtain and move the riprap in the quantities required
- Identification of construction techniques applicable to a large berm. Determine what, if any, configuration changes may have significant impacts on the cost of construction
- Evaluation of various berm surface materials (e.g., size of rocks, types of soil, types of vegetation) for durability and success in supporting vegetation overgrowth
- Procure, ship, erect, and evaluate various types of monument rock (granites and sandstones) to determine long-term environmental effects of wind, rain, and shifting sand. This will provide experience for meeting of contractual specifications developed for procurement and erection of multiple monuments. In

addition, concrete should be emplaced underground and tested for durability as a substitute for granite in construction of the Storage Rooms

- Evaluation of the magnetic signature provided by sample permanent magnets buried within the berm to determine optimum locations and spacing
- Evaluation of the effects of various soils used as protective backfill for granites and sandstones
- Evaluation of the effects of chemical interaction with the backfill material
- Evaluation of the environmental effects on the berm caused by wind, rain, and shifting sand, including the depth of infiltration under a variety of climatic conditions
- Evaluation of the effects of plant root and burrowing animal intrusion into the berm and potential for salt dissolution and berm slumping
- Evaluation of the effectiveness of sample radar reflectors buried within the berm at various distances. Evaluations should include reflectors directly buried in the berm and buried reflectors encased in concrete
- Development of cost estimates for various configurations and materials tested

Other testing should address the refinement of the messages, diagrams, and the method of presentation. As recommended in Trauth et al. (1993), the translated versions of the message text should be evaluated by presentations to groups indigenous to the countries whose language is represented in the message. This should provide input as to how comprehensible the messages are. When considering that the messages were developed by educated individuals residing in the U.S., it is prudent to thoroughly test the effectiveness of the messages to convey their information to a broader cross-section of individuals. The testing, therefore, should include cross-cultural groups in evaluating the effectiveness of conveying the intended messages through diagrams and pictures as well as script.

Testing should also be conducted on the various materials used for the warning markers buried near the surface. Warning markers made of aluminum oxide, granite, fired clay, glass (specifically lanthanumborate made by Corning, (Trauth et al. (1993)), and polyethylene should be fabricated and buried at depths of 5 to 10 ft (1.5 to 3 m) below the surface. It is anticipated that subsurface warning markers made from some of these materials will be used in the final design. However, by burying these "test" warning markers for 40 to 60 years and then evaluating their condition, it can be established whether some of these materials seem unsuitable for burying in the WIPP soil/caliche environment. Each of the "test" warning markers should also be engraved with the level II message.

During a conversation with the proprietor of a Carlsbad, New Mexico memorial distributor, it was determined that local experience with granite memorials in cemeteries indicate that artificial watering accelerates the weathering of granite. Therefore, any judgments made on the effects of weathering due to local conditions would be biased by the artificial watering phenomenon. To provide for a more accurate assessment of the environmental effects on granite at the WIPP site, granite monuments made from materials from multiple quarries within the U.S. will be engraved and emplaced at the WIPP site during the disposal phase. Over a period of decades, data will be taken to judge the affect of weathering on both the granite material and the lettering. The data will be developed for both the buried and aboveground surfaces. These data will then be used in developing the final design specifications for the monolithic monuments emplaced as permanent markers.

A variety of permanent magnet materials and protective coating for the magnets should be buried at the bottom of the berm. In addition, this permanent magnet test program should evaluate the effectiveness of providing a directional magnetic signal. These signals should be detectable from an appropriately equipped airplane. Testing should also be conducted at ground level to verify detectability. Verifying the capability to fix a particular location within the repository footprint through triangulation of multiple magnetic signals should also be conducted. Subsequent to being buried for a significant number of years, the magnets should be recovered and the condition evaluated against the risk of their failure over a 10,000-year period. At least one manufacturer stated that some permanent magnets lose their strength at the rate of 0.1% per 10,000 hours. If this is a constant rate, a magnet would only have 10% of its strength remaining after about 2,700 years.

PMR.10.0 CONCEPTUAL DESIGN A

Figure PMR-27 represents the surface plan view of design A. The salient features of this PM design consist of the repository footprint delineated by monolithic monuments along the rectangular perimeter with an earthen berm constructed in the shape of a trefoil. At the center of the trefoil is the Information Center described above. The trefoil is built up of halite (salt) originally excavated from the repository, caliche, riprap, and a mixture of riprap and soil used to support vegetation on the surface of the berm. The type of vegetation planted on the berm should be representative of vegetation occurring in the local WIPP region.

Figure PMR-28 provides a cross-sectional view with dimensional characteristics for the trefoil circle and typical trefoil circle sections. Ghosted in the figure is the repository footprint. This illustrates the relative location of the trefoil over the actual repository. As shown in Figure PMR-27, the footprint outline is described by the monuments erected outside of the trefoil dimensions. Approximately 38,841,000 ft^3 (1,100,000 m^3) of material would be required for the trefoil. Buried within the trefoil and the remainder of the site are the small warning markers described above.

PMR.11.0 CONCEPTUAL DESIGN B

Figure PMR-29 represents the surface plan view of design B. The repository footprint and its panels, rooms, and salt pillars are ghosted with dotted lines within the berm area. This design concept features a rectangular berm slightly larger than the footprint dimensions enclosing the repository footprint. Immediately within the berm enclosure and along the dimensional perimeter of the repository footprint, the 16 granite monoliths are emplaced. At the center of the footprint, the Information Center described above is erected. The small warning markers are buried below the surface throughout the footprint area. Within the enclosed footprint the two Storage Rooms containing the level IV message are buried approximately 20 ft (6 m) below the surface. Access across the berm will be provided by a stairway along the berm's western edge.

Outside the berm perimeter, the concrete hot cell structure will remain as an archeological remnant. During the test program, the Hot Cell structure will be periodically monitored to determine the erosion resistance of concrete in the WIPP environment. The stairway will be constructed of concrete or granite stones. The volume of material required to construct the berm is approximately 18,890,850 ft^3 (535,000 m^3). This is considerably less material than required by design concepts A or C.

PMR.12.0 CONCEPTUAL DESIGN C

Figure PMR-30 represents the surface plan view of design C. This design concept incorporates the "Menacing Earthworks" concept recommended in Trauth et al. (1993). Sections of earthen berms radiate outward from the perimeter of the repository footprint. The repository footprint outline is described by the emplacement of 16 granite monoliths as utilized in designs A and B above. At each corner of the earthworks, a large earthwork structure is located. A Storage Room is buried within each of the four corner earthworks. Each Storage Room configuration is as described in Section VI. The Information Center is located at the center of the footprint and the small warning markers are buried within the footprint.

Figures PMR-31 through PMR-34 provide the profile structural details of the various earthwork configurations used to make up the Menacing Earthworks, including the approximate total volume of material for each configuration. The various configurations and their mirror images are used in making up the total earthworks structure. The cross-sectional material composition of the structure is similar to that shown in Figure PMR-29. The total volume of material required to construct the berms is approximately 32,838,300 ft^3 (930,000 m^3). Discussions with at least one construction contractor raised some significant issues with respect to erecting earthworks configured as depicted in concept C or any similar earthwork. Providing a steep slope (a ratio of 1.3:1.0 horizontal to vertical) combined with a zigzag configuration results in a safety issue with respect to turning large construction equipment to create the zigzag. This is especially true during the final stages, when the top of the berm is narrowed. Increasing the width of the berm top or increasing the slope adds additional material either in a higher profile or a broader base.

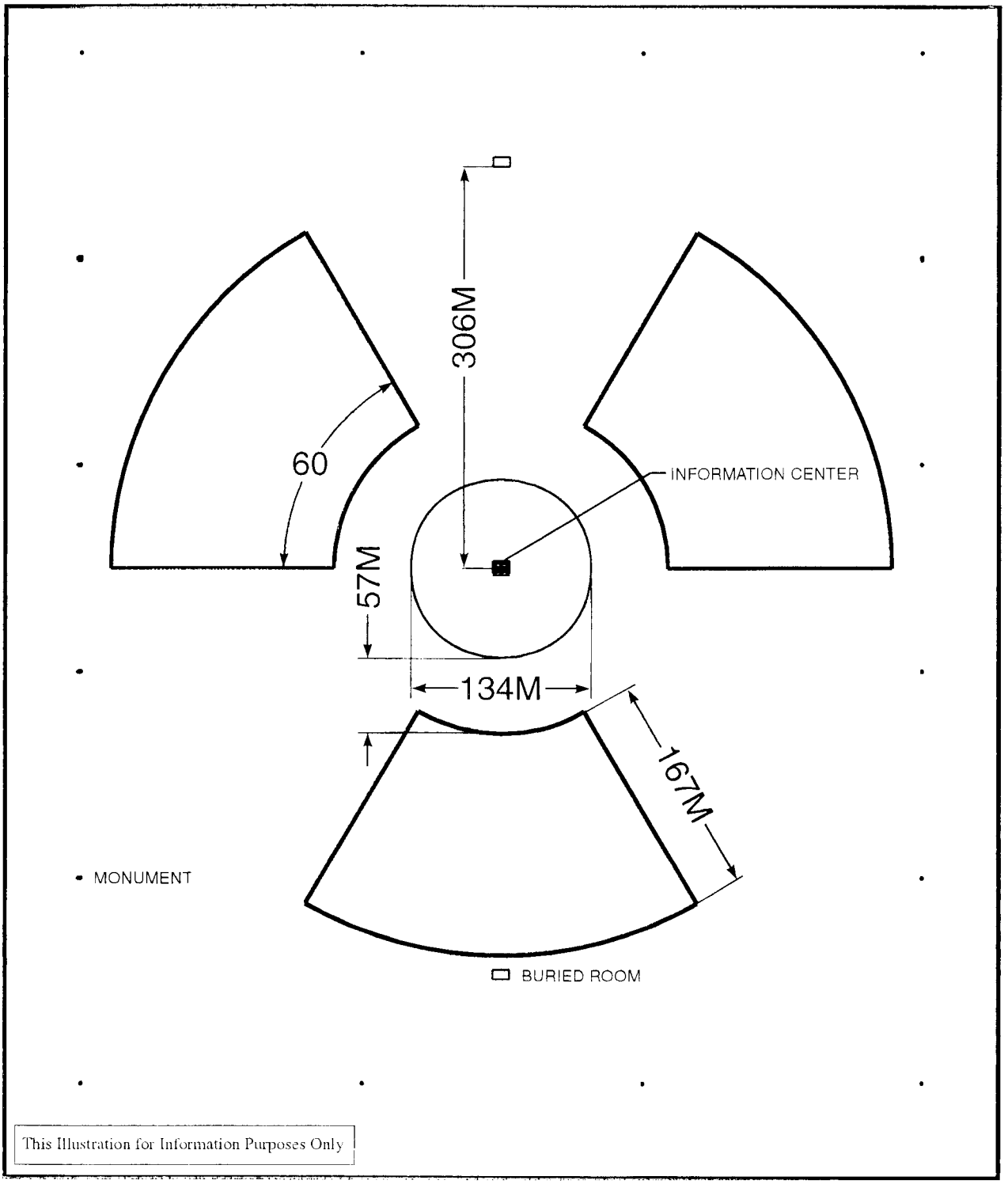

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Figure PMR-27. Trefoil Configuration

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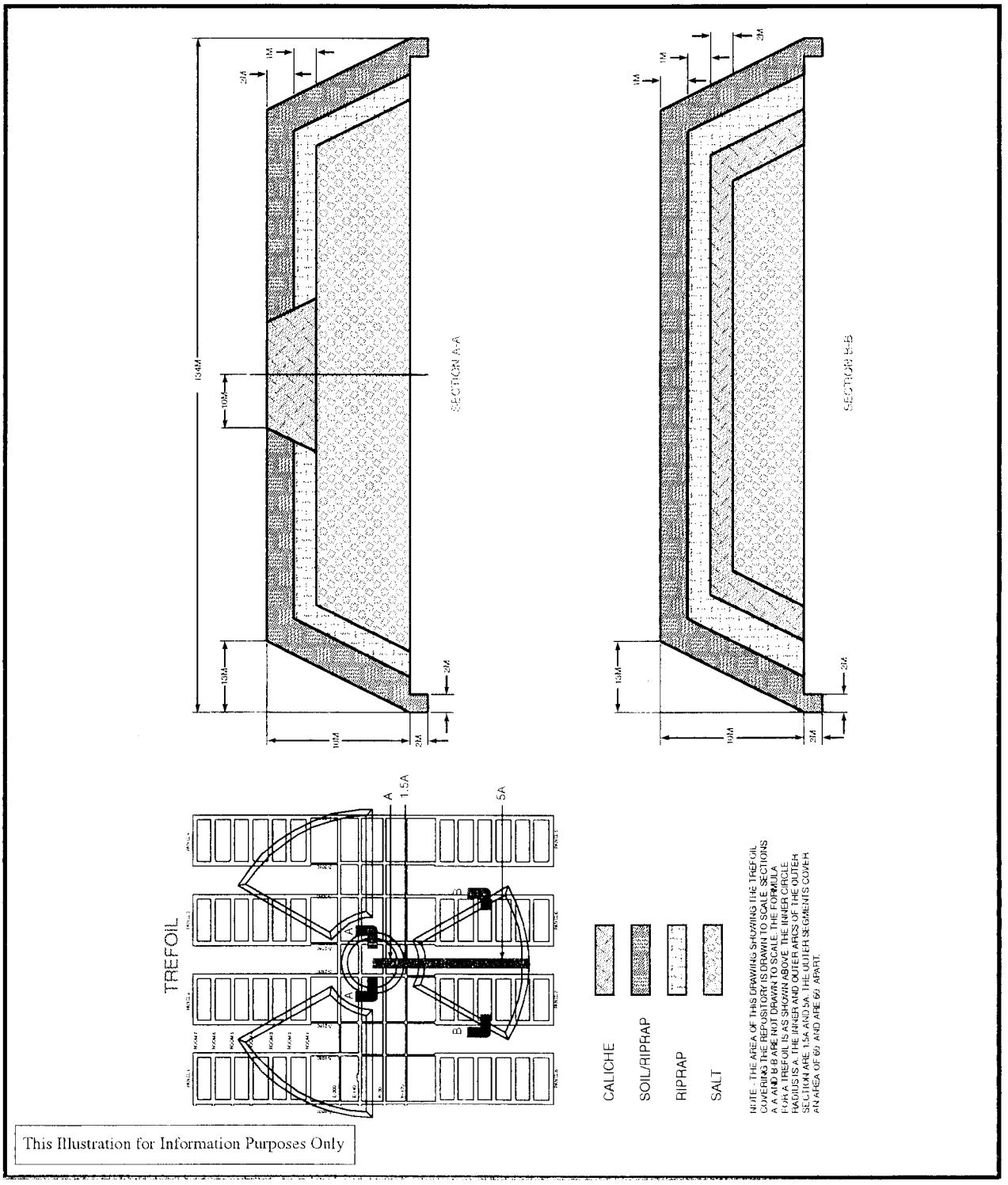

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Figure PMR-28. Trefoil Cross Section

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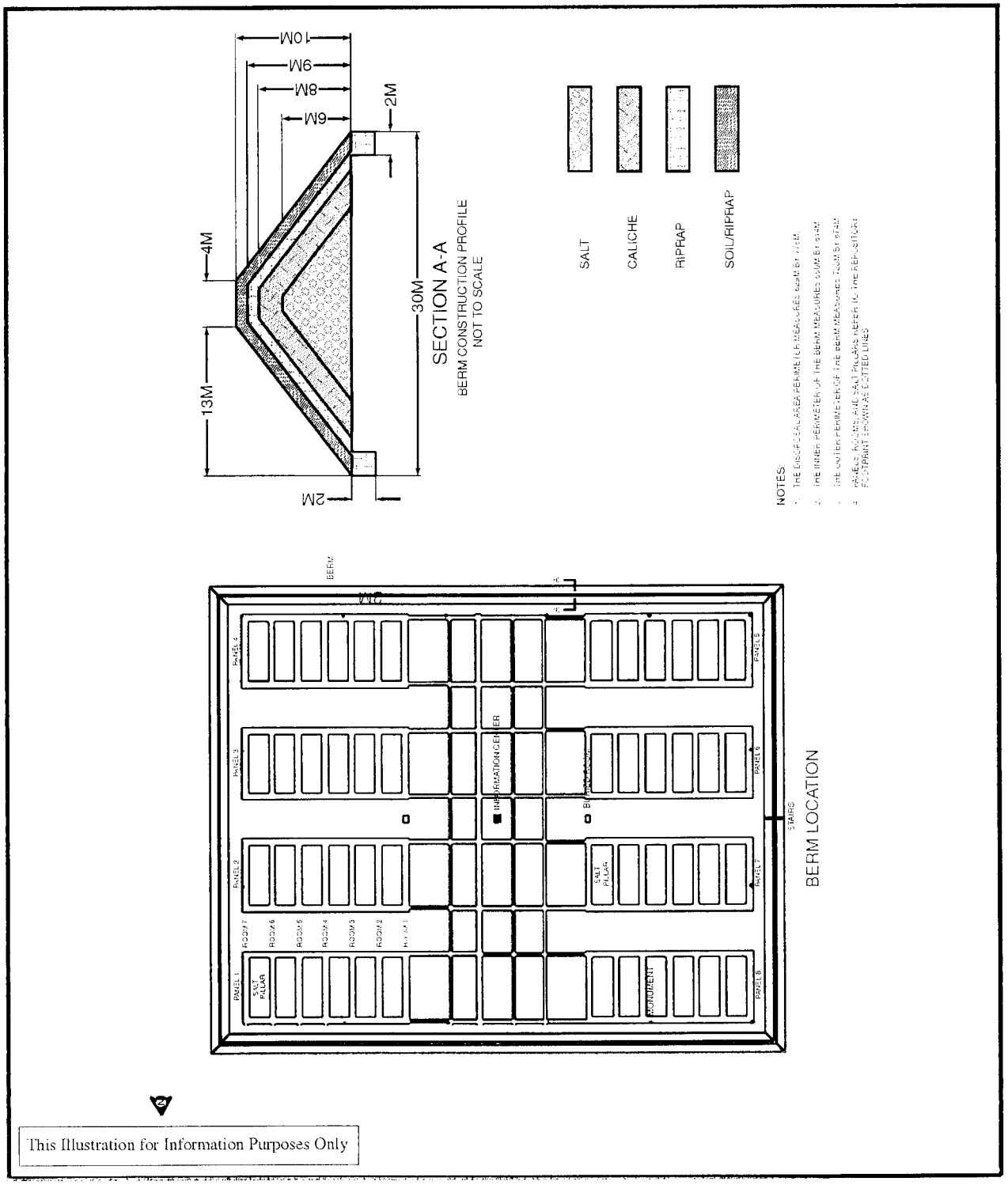

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Figure PMR-29. Perimeter Berm Arrangement

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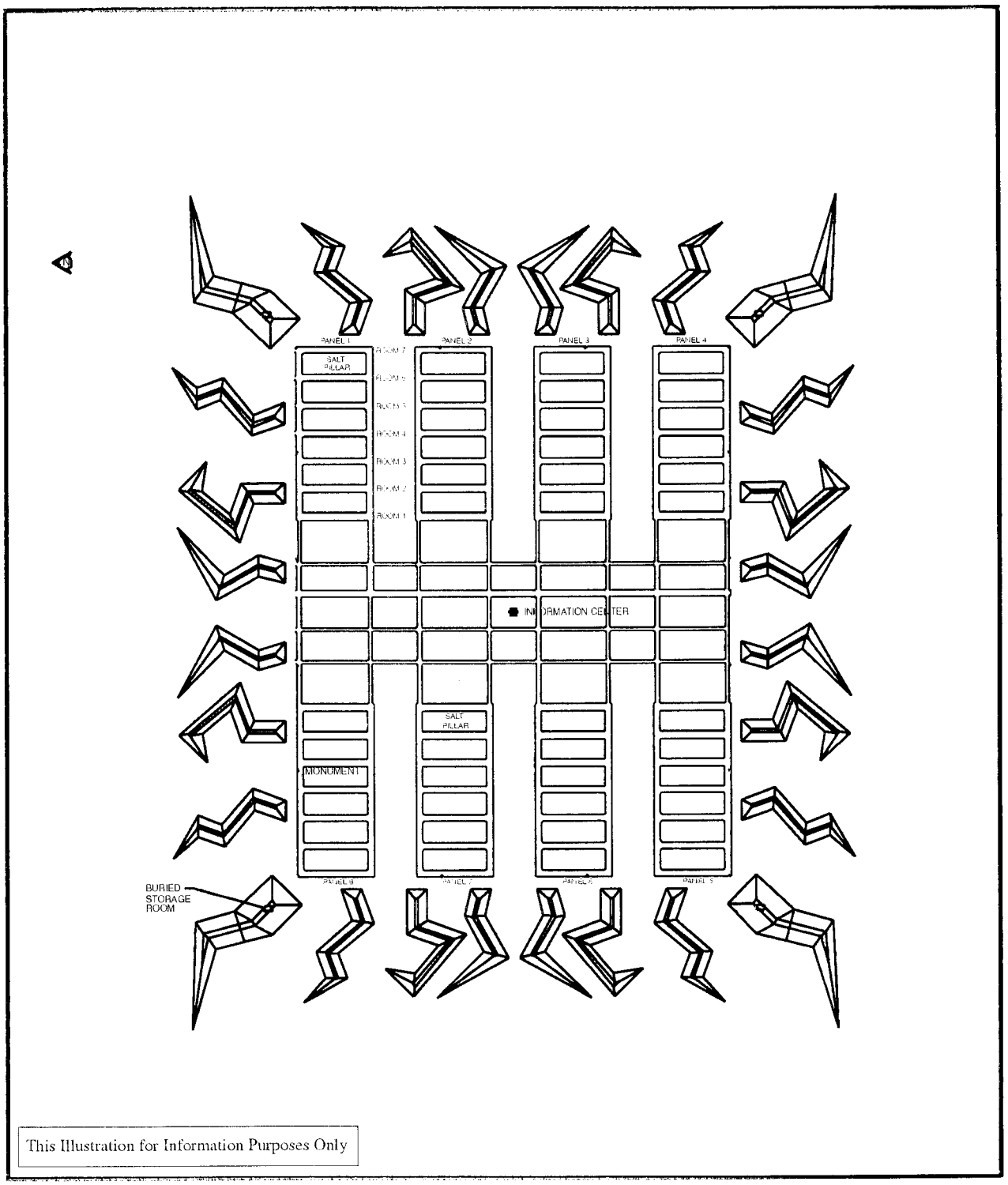

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Figure PMR-30. Menacing Earthworks

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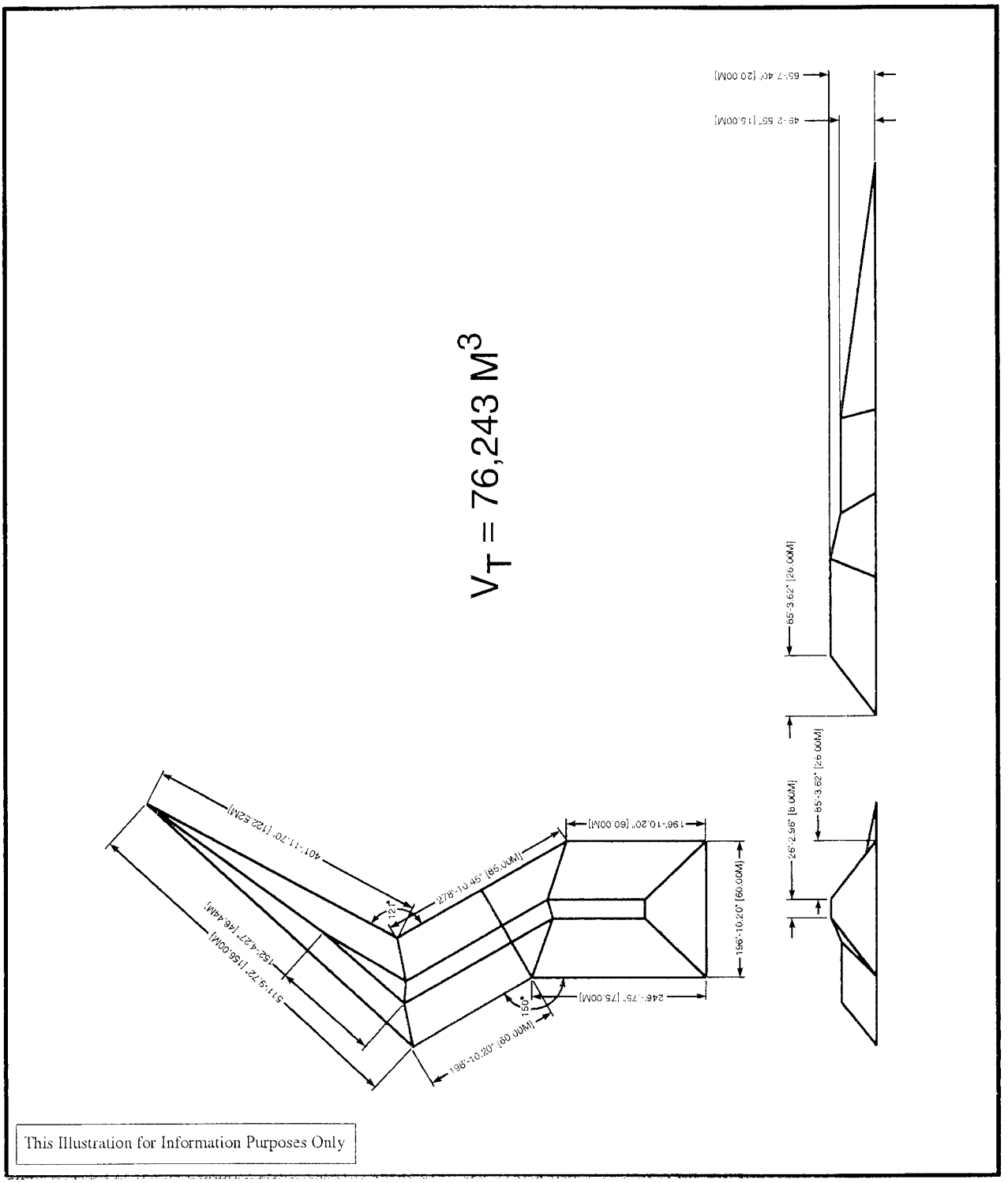

Figure PMR-31. Menacing Earthworks

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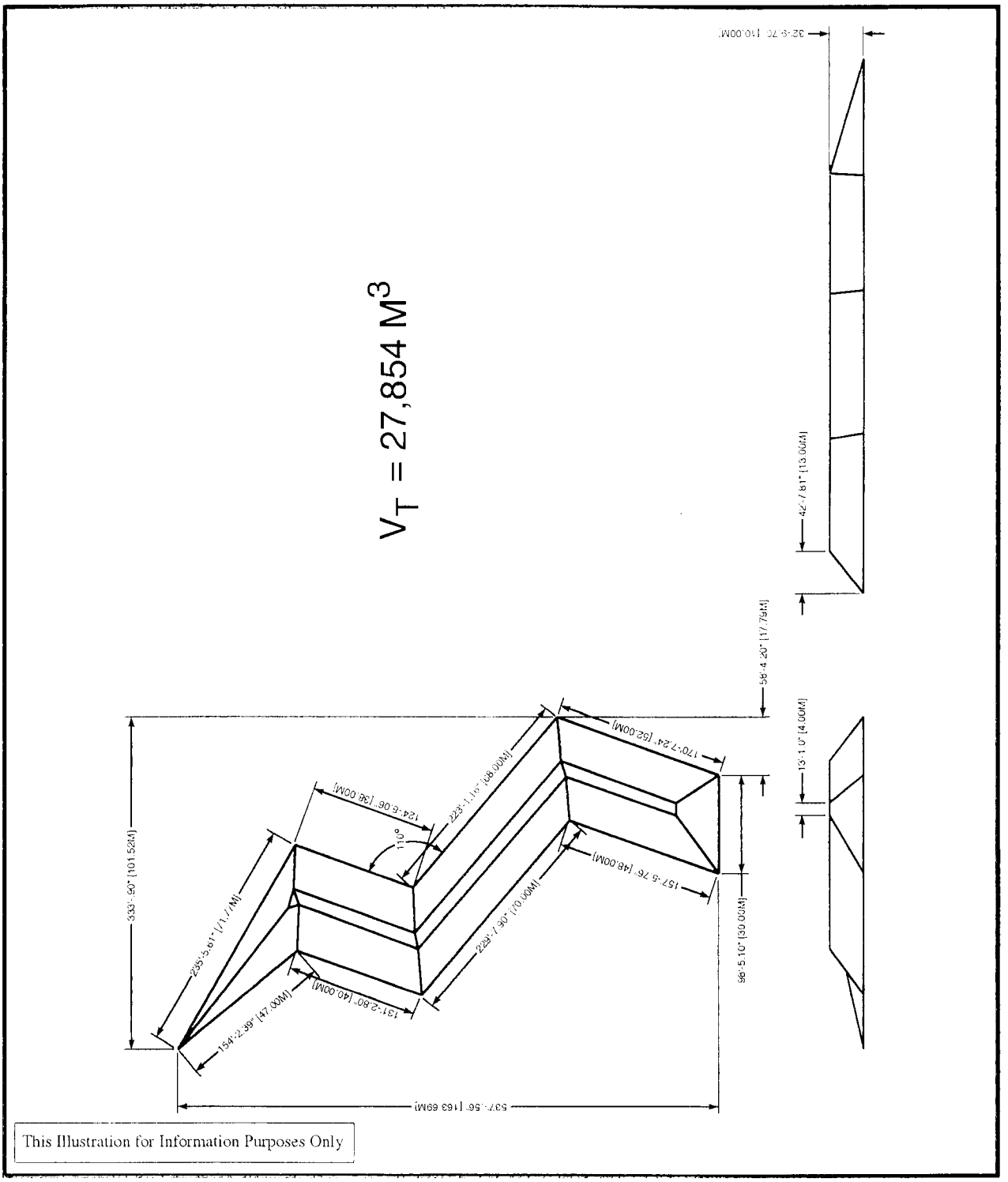

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Figure PMR-32. Menacing Earthworks

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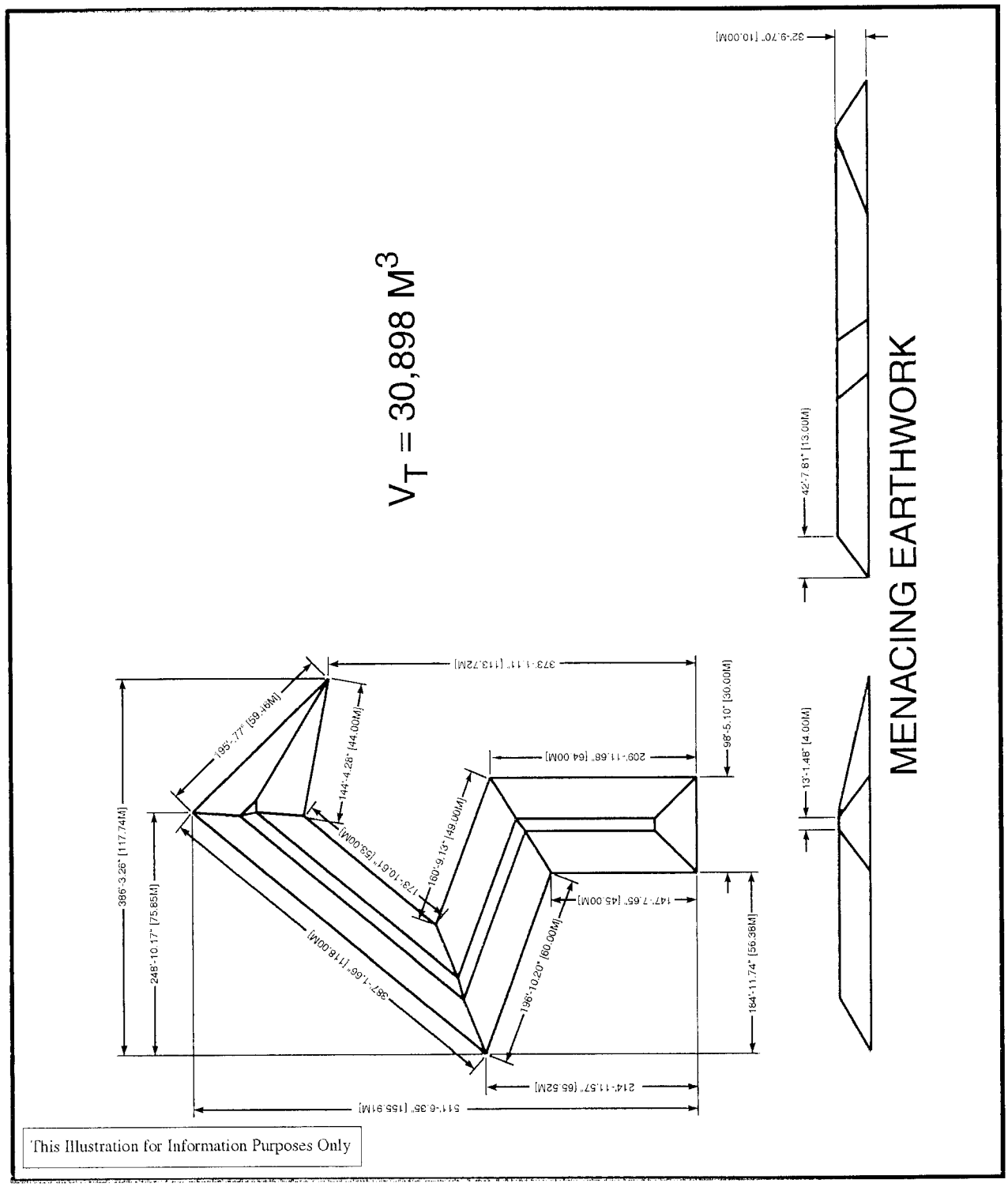

Figure PMR-33. Menacing Earthworks

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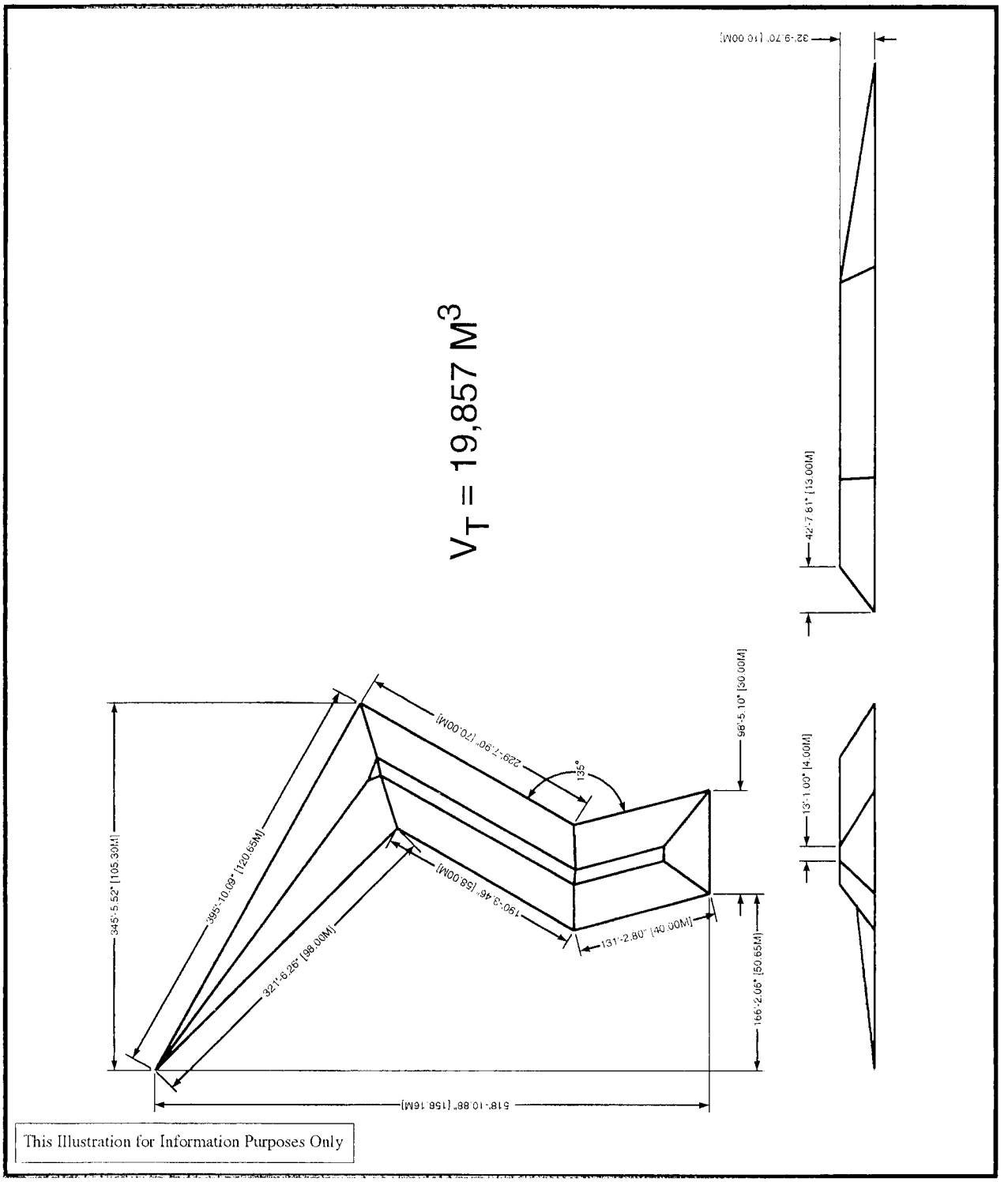

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Figure PMR-34. Menacing Earthworks

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This increases the expense of the construction effort. In addition, those portions of individual earthwork configurations which have a narrow or almost nonexistent upper roadway offer an additional construction difficulty. Conventional berm or earth dam construction activities will not lend themselves to the final stages of construction for those berm portions which have no upper roadway.

PMR.13.0 CONCEPT SELECTION

The following discussion addresses the selection of conceptual design B as the recommended design for permanently marking the site.

The distinguishing features of the individual designs considered are the berm configurations. This arises from the various configurations addressed in Trauth et al. (1993). The quantity of material and general configuration of the berms suggest a significant construction effort in their erection. For total quantity of material required, designs A and C each represent on the order of 35,290,000 ft^3 (1,000,000 m^3). Design B is approximately 21,186,000 ft^3 (600,000 m^3). In addition, the shape of the various berm sections for design C add an additional degree of construction complexity over that of designs A and B. Although design C is more "menacing," the actual warning of danger is conveyed effectively by the inscribed information on the monoliths. The primary purpose of the berm is to convey the level 1 message that something man-made is here. All of the berm configurations will perform this function.

Design A does not provide the degree of "protection" (i.e., enclose the repository footprint) that is conveyed by either design B or C. It is acknowledged that access to much of the footprint is inhibited by an additional 32.8 ft (10 m) of material when design A is considered. However, other than causing some additional effort to set up a drilling platform, it adds little protection when considering that the repository is 2,148 ft (655 m) below the surface. The volume of the trefoil-shaped berm is also considerably more than that required to construct design B. Design A would appear not to provide the same degree of protection from wind-drive erosion of the monoliths that design B does. The proximity of the monuments to the berm in design B may provide more protection to at least one face of a monument than would be available to the more exposed monuments in design A. Although barriers can be erected to improve protection of the inscribed material, there is no apparent advantage of the trefoil over that of the perimeter berm. The location of the Information Center in design A may also be subjected to greater wind-driven erosion than the location provided by design B.

The berm aspect of the three permanent marking concepts considered is the major design variable. The monoliths, the Information Center, the Storage Rooms, and the subsurface warning markers will not significantly vary in cost for any of the three configurations. When all the salient features, including total materials required, ease of construction, design requirements/criteria, and establishing permanence are compared, the conceptual configuration using a rectangular berm to enclose the entire repository footprint is the best. For this reason, design B is the configuration of choice for the PMS.

PMR.14.0 OFFSITE ARCHIVAL STORAGE

This report has described the PMS with emphasis on those portions of the system which are in close proximity to the waste repository location. A significant part of the overall system is the archiving of important information away from the repository. The archived material should include information that is important to defining the location, design, content, and hazards associated with the WIPP. This information will be more extensive in volume than that available within the PMS at the repository footprint location and should be widely distributed in a number of locations, including some locations worldwide. The initial form of the information should be on archival-quality paper and high quality microfilm. Jensen (1993), a Scandinavian paper, describes a specification which prescribes that the archival-quality paper contain fibers from cotton, linen, and/or bleached chemical pulp with any other type pulp making up less than 5 percent of the fiber content. In addition, the pH is specified as 7.5 to 10 with a minimum 2 percent calcium carbonate alkaline reserve.

Specific documents which should be included in the archived information portfolio include:

1. The Final Safety Analysis Report (FSAR) and the addenda, which describes the disposal phase of the WIPP.

2. The Final Environmental Impact Statement (FEIS) for WIPP and the Supplement(s) to the Environmental Impact Statement (EIS).

3. The NMVP and the No-Migration Determination for Disposal.

4. The Resource Conservation and Recovery Act (RCRA) Permit.

5. The Certification of Demonstration of Compliance with Title 40 CFR 191.

6. Environmental and ecological background data collected during the pre-operational phase of WIPP and summaries of data collected during the disposal and decommissioning phases of WIPP.

7. Records of the waste containers contents and disposal locations within the WIPP repository.

8. Drawings defining the construction and configuration of the repository and shafts.

9. Drawings, procedures, and the design report(s) describing how the waste was emplaced; how the rooms, drifts, and panels were closed; and how the shafts were backfilled and sealed.

10. Detailed maps showing the exact location of the repository.

Locations for this information should include public funded organizations, that may be more likely to expend the resources necessary to preserve the documents in well-controlled environments. However, the most likely strategy for long-term protection of the information is through widespread distribution. The information will be submitted to the following facilities/organizations for archiving:

- Library of Congress
- National Archives
- Within the States of New Mexico and Texas
  - The State Archives
  - The State Library
  - The City Libraries of population centers exceeding 15,000 within 150 mi (241 km) of the WIPP site
- The state libraries of the remaining 48 states
- The local office of the Bureau of Land Management
- The local office of the Bureau of Mines
- The local office of the Bureau of Reclamation
- The national library and national archives of the nations worldwide which possess nuclear weapons and/or operate nuclear power generating plants
- The archive of the United Nations
- The national archive/libraries of the signatory nations to the nuclear non-proliferation treaty
- The U.S. Nuclear Regulatory Commission
- The 53 Federal Regional Depository Libraries

Location and hazards information should be submitted to various federal and State of New Mexico mapping agencies to ensure that the WIPP location and drilling or mining restrictions are identified on widely distributed maps used by almost all public and private organizations. These agencies include:

- Bureau of Land Management
- U.S. Geological Survey
- Library of Congress
- National Archives and Records Service
- Defense Mapping Agency
- International Boundary Commission
- Federal Highway Administration
- New Mexico State Highway Department Planning and Research Division, Cartography Section
- One-Call System of notification of underground utilities

To ensure widespread location information of the WIPP site and the hazards associated with the emplaced waste, detailed maps and descriptions of the hazardous material should be sent to national and international professional societies of cartographers and

geographers. Weitzburg (1982) suggests the following organizations and societies receive this location and hazards information:

- The American Congress on Surveying and Mapping
- The American Society of Cartographers
- The Commission for the Geological Map of the World
- The International Cartographic Association
- The American Geographical Society
- The Association of American Geographers
- The International Geographical Union
- The Society of Women Geographers
- The American Geological Institute
- The American Geophysical Union
- The American Society of Professional Geographers
- The National Geographic Society
- The Federal Aviation Administration
- Mining, Oil, and Gas Professional Organizations

Many of the members of these various organizations are employed in secondary and college education, providing an opportunity for this information to become more widely disseminated among students during their formal education.

PMR.15.0 QUALITY ASSURANCE

Quality Assurance (QA) and Quality Control (QC) discipline should be applied to a number of aspects of the PM procurement and construction efforts.

The basic PM building materials are granite and possibly concrete and can be subjected to QC inspection and testing to ensure that the final specifications for the materials and their properties are met. In the case of the granite monoliths and the granite slabs for fabrication of the storage rooms, the final products lend themselves to measurements and evaluation of cutting tolerances and alignment. If the final Storage Room design uses granite instead of poured concrete, it will be prudent to have QC inspection at the quarry for verification of configuration alignment and tolerances prior to shipping the massive granite slabs and monuments. Similarly, the engraving of such a large quantity of letters and characters to provide the messages in different languages will offer a unique challenge to both the supplier and the DOE's QA program. For concrete work, the testing techniques of individual pour characteristics is well established and can be applied where applicable to support the PM construction effort.

Construction of the berms consisting of layers of materials and their compaction also lends itself to QC inspection techniques developed for the construction of earthen dams. Although permeability is not a concern for the PM berms, other testing and measuring techniques can be applied for quantities of specified materials applied, required slopes, degree of compaction, and overall dimensional requirements.

QA/QC will also be applied to the fabrication of the small warning markers. These warning markers will be made of different materials to provide a higher level of confidence that no single adverse material characteristic will render all of the small warning markers ineffective over the prescribed 10,000-year design life required of the PMS. Ceramic, granite, and fired clay warning markers will be utilized in the small marker system.

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ATTACHMENT 1

MARKER SYSTEM COMPONENT COMPARISON FOR TEAM A AND TEAM B OF SANDIA'S EXPERT PANEL

TEAM A	TEAM B
ARCHITECTURAL DESIGN	
Mark area over panels plus possibly buffer to potential radionuclide migration distance	Mark area over panels only
Multiple components to marker system	Multiple components to marker system
• large earthen berms • monoliths (inscribed) • message chambers for complex information • buried message disks (e.g., clay, glass) • world map of other nuclear disposal sites • stone markers in the sealed shafts and in the repository • part of the WIPP surface facilities (e.g., hot cell)	• large earthen berms • monoliths (inscribed) • message chambers for complex • buried message capsules (e.g. clay, ceramics, glass, sintered alumina) • world map of other nuclear disposal sites • stone markers in the sealed shafts • part of the WIPP surface facilities (e.g., the Hot Cell)
No sense of center ("nothing" is there)	Attract to center to inform
Progressively encounter higher levels of information from outside toward (but not at) center	Progressively encounter higher levels of information from outside to center
LINGUISTICS	
Less emphasis on pictographs	Prominent role for pictographs
Use human facial expressions (horror and sickness)	
Use several languages	Use several languages
Greater reliance on sense of place	Purely functional area; not artistic
Reliance on language	Reliance on language
Accurately convey the risk of intrusion (not an attempt to scare)	Accurately convey the risk of intrusion (not an attempt to scare)

TEAM A	TEAM B
MATERIAL PROPERTIES	
Use low-value materials	Use low value materials
• local materials for berms • "common" rock for monoliths (e.g., granite)	• local materials for berms • "common" rocks for monoliths (e.g., granite)
MESSAGE LEVELS	
Five levels of messages	Four levels of messages
Levels based on complexity of messages	Levels based on complexity of messages
OTHER MESSAGE MEDIA	
Star map and celestial marker to indicate time since closure	Star map and celestial marker to indicate time since closure
Placement near the surface of materials with magnetic and electrical conductivity properties anomalous to those of the naturally-occurring materials in the area	Placement near the surface of materials with magnetic and electrical conductivity properties anomalous to those of the naturally occurring materials in the area
Periodic table of the elements	Periodic table of the elements and diagrams of nuclear reactions
Aeolian structures	
Models of the WIPP's surface facilities, stratigraphy, shafts, and waste panels	Models of the WIPP's surface facilities, stratigraphy, shafts, and waste panels
International radiation symbol used with test and other media	International biohazard symbol used with test and other media
OTHER MARKING COMPONENTS	
Public information effort (current)	
International standard for the basic design features for long-term marking	International standard for the basic design features for long-term
Testing for the longevity of markers and the interpretability of messages across cultures	Testing for the longevity of markers and the intepretability of messages across cultures
Off-site archives	Off-site archives

ATTACHMENT 2

MESSAGES

LEVEL II MESSAGE:

1. DANGER

2. POISONOUS RADIOACTIVE ☢ WASTE HERE

3. DO NOT DIG OR DRILL.

LEVEL III MESSAGE:

THESE STRUCTURES MARK AN AREA USED TO BURY RADIOACTIVE ☢ WASTES. THE AREA IS 0.41 BY 0.50 MI (0.66 BY 0.81 KM) AND THE WASTE IS BURIED 0.41 MI (0.66 KM) DOWN. THIS PLACE WAS CHOSEN TO PUT THIS DANGEROUS MATERIAL FAR AWAY FROM PEOPLE AND OTHER LIVING THINGS. THE ROCK AND WATER IN THIS AREA MAY NOT LOOK, FEEL, OR SMELL UNUSUAL, BUT MAY BE POISONED BY RADIOACTIVE ☢ WASTES. WHEN RADIOACTIVE ☢ MATTER DECAYS, IT GIVES OFF INVISIBLE ENERGY THAT CAN DESTROY OR DAMAGE PEOPLE, ANIMALS, AND PLANTS.

DO NOT DRILL HERE. DO NOT DIG HERE. DO NOT DO ANYTHING WITH THE ROCKS OR WATER IN THE AREA.

DO NOT DESTROY THIS MARKER. THIS MARKING SYSTEM HAS BEEN DESIGNED TO LAST 10,000 YEARS. IF THE MARKER IS DIFFICULT TO READ, ADD NEW MARKERS IN LONGER-LASTING MATERIALS AND COPY THIS MESSAGE IN YOUR LANGUAGE ONTO THEM.

FOR MORE INFORMATION, GO TO THE BUILDING FURTHER INSIDE THIS MARKED AREA. THE SITE WAS KNOWN AS THE WIPP (WASTE ISOLATION PILOT PLANT) SITE WHEN IT WAS CLOSED IN 2020 A.D.

LEVEL IV MESSAGE:

THIS PLACE IS A REPOSITORY WHERE RADIOACTIVE ☢ WASTE HAS BEEN BURIED. IT WAS DESIGNED TO ISOLATE DANGEROUS RADIONUCLIDES ☢ FROM HUMANS AND OTHER LIFE FORMS FOR A PERIOD OF AT LEAST 10,000 YEARS. THE REPOSITORY IS AT A DEPTH OF 2,148 FT (655 M) BELOW THIS ROOM.

DO NOT DRILL OR DIG AT THIS SITE, OR DO ANYTHING ELSE THAT MIGHT DISTURB THE WATER OR ROCKS IN THIS AREA. IF YOU DO, THERE IS DANGER THAT THE POISONOUS RADIOACTIVITY ☢ MAY COME TO THE SURFACE IN THE GROUNDWATER. IF THIS WATER IS USED DIRECTLY BY HUMANS OR FOR GROWING FOOD OR FEEDING ANIMALS THAT PRODUCE FOOD, HUMANS COULD SUFFER FROM THE DISEASE CANCER. CANCER IS THE UNCONTROLLED GROWTH OF CELLS IN THE HUMAN BODY AND CAN RESULT FROM THE DAMAGE TO CELLS CAUSED BY THE ENERGY FROM DECAYING RADIOACTIVE ☢ MATERIALS. IT SOMETIMES TAKES MANY YEARS FOR THE SICKNESS AND DEATH DUE TO CANCER TO BECOME EVIDENT. IF YOU SUSPECT THAT RADIOACTIVITY ☢ MAY HAVE REACHED THE SURFACE, CHECK THIS SITE FOR (1) FAILED SEALS IN THE SHAFTS OF THE ORIGINAL REPOSITORY AS SHOWN ON DIAGRAMS 1 AND 2 AND (2) DRILLHOLES OR MINE SHAFTS THAT MAY HAVE PROVIDED A MEANS FOR ESCAPE OF THE RADIOACTIVITY ☢.

THIS REPOSITORY WAS CONSTRUCTED DURING THE PERIOD AD 1985 TO 1998, WAS FILLED WITH WASTE FROM 1998 TO 20.., AND HAS BEEN SEALED IN 20.. THIS IS A MAJOR EFFORT BY HUMANS TO ATTEMPT A LONG-TERM SOLUTION TO THE PROBLEM OF RADIOACTIVE ☢ WASTE DISPOSAL, FOR WE BELIEVE THAT WE HAVE AN OBLIGATION TO PROTECT FUTURE GENERATIONS FROM THE HAZARDS THAT WE HAVE CREATED. THIS REPOSITORY IS KNOWN AS THE WASTE ISOLATION PILOT PLANT AND HAS BEEN BUILT AND OPERATED BY THE GOVERNMENT OF THE UNITED STATES OF AMERICA. THE LONG-TERM RADIOACTIVE ☢ WASTES BURIED HERE CONSIST OF RADIONUCLIDES ☢ WITH ATOMIC NUMBERS GREATER THAN 92, HALF-LIVES EXCEEDING 20 YEARS, AND CONCENTRATIONS EXCEEDING 3700 NUCLEAR DISINTEGRATIONS PER GRAM PER SECOND (A GRAM IS THE MASS OF THREE HUNDRED THOUSANDS OF A FOOT (ONE MILLIONTH OF A CUBIC METER) OF WATER, AND THERE ARE 31,600,000 SECONDS IN A YEAR, THE ORBITAL PERIOD OF THE EARTH).

THE INFORMATION IN THIS ROOM IS THE MOST DETAILED ON THE SITE. OTHER ROOMS IDENTICAL TO THIS ONE ARE LOCATED UNDERGROUND, BUT WE URGE YOU TO KEEP THE ROOMS INTACT AND BURIED AS THEY ARE, SO THAT THEY MAY BE PRESERVED FOR FUTURE GENERATIONS. IF THE LANGUAGES AND DIAGRAMS IN THIS ROOM ARE DIFFICULT FOR YOU TO UNDERSTAND, WE URGE YOU TO ADD NEW TRANSLATIONS OF OUR TEXTS FOR THE BENEFIT OF FUTURE GENERATIONS. THIS SHOULD BE DONE FOR TEXTS IN THIS ROOM AND THROUGHOUT THE SITE; ALSO ADD NEW MARKERS AND OTHER STRUCTURES IF NECESSARY TO MAINTAIN THE MARKING SYSTEM IN GOOD, EFFECTIVE CONDITION. HOWEVER, DO NOT DEFACE OR REMOVE THE ORIGINAL TEXTS, DIAGRAMS, OR MARKERS, FOR THEY WILL REMAIN VALUABLE TO FUTURE PERSONS TRYING TO

UNDERSTAND YOUR OWN TRANSLATIONS AND ADDITIONS. IF YOU WANT MORE INFORMATION THAN IS AVAILABLE IN THIS ROOM, SEARCH IN HISTORICAL AND ARCHAEOLOGICAL LIBRARIES, MUSEUMS, AND ARCHIVES APPROPRIATE TO OUR TIME.

THE SALT BED AT THIS SITE AT A DEPTH OF 2,148 FT (655 M) IS ABOUT 220 MILLION YEARS OLD AND IS CONSIDERED VERY STABLE ON A TIME-SCALE OF 10,000 YEARS AGAINST GEOLOGICAL EVENTS SUCH AS EARTHQUAKES AND VOLCANISM. DIAGRAM 4 SHOWS THE GEOLOGICAL STRATA AT THIS SITE AND THE LOCATION OF THE REPOSITORY. SALT IS CONSIDERED A GOOD MEDIUM FOR THE PERMANENT STORAGE OF THESE WASTES BECAUSE ITS PRESENCE INDICATES A LACK OF CIRCULATING GROUNDWATER, IT IS EASY TO MINE, AND IT IS MOBILE IN THE SENSE THAT IT RELATIVELY QUICKLY SEALS ANY FRACTURES OR VOIDS, SUCH AS THOSE OF A WASTE REPOSITORY. THE SITE IS ALSO CONSIDERED ACCEPTABLE IN THAT FEW RESOURCES ATTRACTIVE FOR EXTRACTION ARE KNOWN IN THE VICINITY. THE MAIN SUCH RESOURCES KNOWN IN THIS REGION ARE POTASH, OIL, AND SOME NATURAL GAS. THE SITE ALSO IS NOT ASSOCIATED WITH ANY POTABLE AQUIFER AND HAS A VERY DRY CLIMATE (1 FT [0.3 M] OF RAIN PER YEAR); MOREOVER, WE EXPECT THE CLIMATE TO REMAIN DRY OVER THE NEXT 10,000 YEARS.

THE REPOSITORY AS CONSTRUCTED CONSISTED OF A SERIES OF ROOMS CARVED OUT OF THE SALT, EACH ABOUT 33-FT BY 13-FT (10-M WIDE BY 4-M) HIGH BY 330-FT (100-M) LONG. THE ROOMS COVERED A TOTAL AREA OF APPROXIMATELY 2,050 BY 2,624 FT (625 BY 800 M) AND WERE ACCESSED BY A WASTE SHAFT APPROXIMATELY 23 FT (7 M) IN DIAMETER AND ACCESS DRIFTS WITH CROSS SECTIONS OF APPROXIMATELY 26-FT BY 13-FT (8-M BY 4-M), DIAGRAM 1. OTHER SHAFTS WERE PROVIDED FOR REMOVAL OF SALT, AND FOR AIR INTAKE AND EXHAUST. ALTOGETHER OVER 800,000 BARRELS, EACH OF VOLUME OF 7.1 FT^3 (0.2 M^3), WERE BROUGHT TO THIS SITE IN ABOUT 20,000 TRUCK SHIPMENTS. THE AVERAGE MASS OF A BARREL IS .... GRAMS. THE BARRELS CONTAIN MOSTLY ORDINARY ITEMS THAT BECAME RADIOACTIVE ☢ AT SOME STAGE IN THE DEVELOPING, TESTING, CONSTRUCTING, AND RENEWING OF NUCLEAR WEAPONS. BURIED ITEMS INCLUDE RAGS, CLOTHING, BAGS, AND CONTAINERS; THESE ARE MADE OF FABRICS, PLASTIC, GLASS, AND METAL. THERE ARE ALSO COMPLEX MACHINES SUCH AS MOTORS, HAND TOOLS, AND MACHINE TOOLS. ABOUT 60 PERCENT OF THE RADIOACTIVE ☢ WASTE ALSO CONTAINS HAZARDOUS CHEMICAL WASTES SUCH AS LEAD, CADMIUM, CHROMIUM, BARIUM, METHYLENE CHLORIDE (CH_2Cl_2), AND TOLUENE ($C_6H_5CH_3$). MOST OF THE RADIOACTIVE ☢ WASTE HAS MINIMAL EMISSIONS OF GAMMA RAYS, BUT ABOUT 3 PERCENT HAS ENOUGH GAMMA-RAY EMISSION THAT IT HAD TO BE REMOTELY HANDLED AT ALL STAGES, WITH HUMANS WELL REMOVED FROM THE BARRELS. THE ESTIMATED AMOUNT AT THE TIME OF BURIAL OF THE

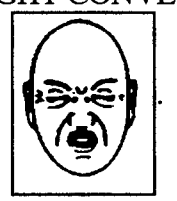
MAJOR RADIONUCLIDES ☢ BURIED HERE IS: NEPTUNIUM-237 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 2,100,000 YEARS); PLUTONIUM-238 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 88 YEARS); PLUTONIUM-239 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 24,000 YEARS) ; PLUTONIUM-240 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 6,500 YEARS); AMERICIUM-241 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 432 YEARS); AMERICIUM-243 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 7,380 YEARS); CURIUM-244 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 18); AND URANIUM-233 (... GRAMS, EACH WITH ... NUCLEAR DISINTEGRATIONS PER SECOND, HALF-LIFE OF 158,000 YEARS). WE ESTIMATE THAT AFTER 10,000 YEARS THE TOTAL NUMBER OF DISINTEGRATIONS IN THE BURIED WASTE HERE WILL BE REDUCED TO ... PER SECOND, WHICH MEANS THAT SOMEONE STANDING NEXT TO THIS WASTE WOULD ENCOUNTER A LEVEL OF RADIOACTIVITY ☢ CORRESPONDING TO .. PERCENT OF THE NATURAL BACKGROUND AT THE SURFACE, OR ABOUT THE AMOUNT CORRESPONDING TO TYPICAL URANIUM ORE. DIAGRAM 5 IS A PERIODIC TABLE OF THE ELEMENTS, WITH THE RADIOACTIVE ☢ ELEMENTS INDICATED BY THE INTERNATIONAL "RADIOACTIVITY HAZARD" SYMBOL "☢" THAT HAS BEEN USED IN OUR TIME SINCE 1950. ELEMENTS WITH A LARGE AMOUNT OF RADIONUCLIDES ☢ BURIED HERE ARE ALSO MARKED WITH A "■" THAT MEANS "RADIOACTIVE ☢ WASTE BURIED HERE"; THESE SYMBOLS ARE THEN CONNECTED BY LINES TO THE REPOSITORY, SEE DIAGRAM 1. THESE TWO SYMBOLS HAVE ALSO BEEN USED WIDELY ELSEWHERE IN OUR MARKING SYSTEM. NONRADIOACTIVE, CHEMICALLY TOXIC ELEMENTS BURIED HERE ARE INDICATED WITH A CIRCLE ON DIAGRAM 5. A DOWNWARD-POINTING

IN A TRIANGLE IS USED IN THE MARKING SYSTEM TO INDICATE THAT "BIOHAZARD MATERIAL IS BURIED HERE".

AFTER EACH ROOM WAS FILLED WITH BARRELS OF WASTE, THE REMAINING SPACE WAS THEN COMPLETELY FILLED WITH SALT. GROUPS OF SEVEN ROOMS WERE EACH SEALED WITH CEMENT PLUGS AND RECONSOLIDATED SALT. UPON COMPLETE FILLING OF THE REPOSITORY IN AD 2020 EACH OF THE FOUR SHAFTS TO THE SURFACE WAS SEALED WITH A SERIES OF MATERIALS, DIAGRAM 2, TOPPED BY A CONCRETE CAP ..M THICK. THE WASTE ROOMS ARE EXPECTED TO COLLAPSE FROM THE WEIGHT OF ROCK ABOVE THEM WITHIN 100 YEARS AND THE STEEL BARRELS WILL BREAK. THE SALT IS EXPECTED TO PREVENT THE RADIONUCLIDES ☢ FROM ESCAPING TO THE SURFACE; THE EXPECTED OUTWARD DIFFUSION INTO THE SALT IS ONLY .. METERS PER YEAR. WE BELIEVE THAT THE GREATEST POSSIBILITY FOR RADIONUCLIDES ☢ TO MAKE THEIR WAY TO THE SURFACE IS THROUGH

HUMAN INTRUSION, AND HENCE WE HAVE DESIGNED AND BUILT THIS ELABORATE MARKING SYSTEM TO WARN YOU OF THE DANGERS. **DO NOT DRILL OR DIG AT THIS SITE, DO NOT DO ANYTHING ELSE THAT MIGHT DISTURB THE WATER OR ROCKS IN THIS AREA.** WE BELIEVE THAT THE MOST LIKELY TYPE OF ACCIDENTAL INTRUSION IS DRILLING A HOLE THAT PENETRATES BOTH THE SITE AND THE SALTY WATER FOUND AT SOME LEVELS ABOVE AND BELOW THE REPOSITORY. THIS WATER MAY THEN BECOME CONTAMINATED AND REACH THE SURFACE THROUGH THE DRILLHOLE.

A DETAILED MAP OF THE MARKER SYSTEM IS GIVEN IN DIAGRAM 6. THE ALIGNMENTS SHOWN ON THE MAP TOWARD THE AZIMUTH ANGLES OF 110 DEGREES, 160 DEGREES, 66 DEGREES, AND 42 DEGREES CORRESPOND TO THE LOCATIONS WHERE THE FOUR BRIGHTEST STARS NOW VISIBLE FROM THIS SITE RISE: SIRIUS, CANOPUS, ARCTURUS, AND VEGA. BECAUSE OF PRECESSION OF THE POLES, THESE STAR-RISE LOCATIONS CONSTANTLY CHANGE AND THUS A MEASUREMENT OF THESE ALIGNMENTS ALLOWS AN ACCURATE DATING OF THIS SITE.

IN ORDER TO INCREASE THE CHANCES OF SUCCESSFUL TRANSMISSION, THE DETAILS OF THE MESSAGE HAVE BEEN GIVEN MANY DIFFERENT, REDUNDANT FORMS, IN MATERIALS, LOCATIONS, LANGUAGES, GRAPHICS, AND AMOUNT OF DETAIL. MOST COMMON IS THE APPROXIMATELY 10-WORD BASIC MESSAGE FLANKED BY TWO HUMAN FACES, WHICH WE BELIEVE WILL CARRY FOR DISTANT FUTURE GENERATIONS THE SAME EFFECT AS FOR US. THE ONE ON THE LEFT CONVEYS HORROR AND TERROR AND THE ONE ON THE RIGHT CONVEYS THE PRESENCE OF SOMETHING NAUSEOUS OR POISONOUS  . IN THIS MESSAGE THE INTERNATIONAL "RADIOACTIVITY HAZARD" SYMBOL ☢ IS ALSO INTRODUCED BY PLACING IT NEXT TO THE WORD "RADIOACTIVE" ☢ WITH AN ARROW BELOW IT POINTING DOWNWARDS, TO INDICATE THAT THE RADIOACTIVITY ☢ IS BELOW THE GROUND, NOT ON THE SURFACE. THIS AND ALL OTHER MESSAGES ARE GIVEN IN THE FOLLOWING SIX LANGUAGES, WHICH ARE THE OFFICIAL LANGUAGES OF THE UNITED NATIONS ORGANIZATION: CHINESE, RUSSIAN, ENGLISH, SPANISH, ARABIC, AND FRENCH. WE ALSO GIVE THESE MESSAGES IN NAVAJO.

THE NEXT TYPE OF MESSAGE IS ENGRAVED LESS FREQUENTLY ON THE SITE AND IS MORE DETAILED THAN THE BASIC MESSAGE DESCRIBED ABOVE, BUT STILL DOES NOT ASSUME ANY SCIENTIFIC KNOWLEDGE ABOUT RADIOACTIVITY ☢. IT IS FLANKED BY TWO DIAGRAMS. THE ONE ON THE LEFT IS A PERSPECTIVE, SCALE VIEW OF THE REPOSITORY IN RELATION TO THE SURFACE AND ITS MARKING SYSTEM; THIS IS A SIMPLER VERSION OF DIAGRAM 1. IT ALSO SHOWS WITH AN ARROW WHERE THE READER IS LOCATED. THE RIGHT DIAGRAM 3 SHOWS THE PATH OF THE NORTH CELESTIAL POLE THROUGH THE SKY DUE TO THE PRECESSION OF THE EARTH'S AXIS OF ROTATION. BRIGHT STARS ARE INDICATED BY CIRCLES (THE BRIGHTEST STAR, ON THE LEFT, IS VEGA) AND PORTIONS OF OUR CONSTELLATIONS URSA MINOR, DRACO, AND CYGNUS ARE SHOWN BY DASHED LINES CONNECTING STARS. THE ILLUSTRATED SECTION OF ARC CORRESPONDS TO THE PERIOD FROM AD 2020, WHEN THE POLE WAS CLOSE TO THE STAR POLARIS AND REPOSITORY WAS SEALED, TO AD 12,000, WHEN THE POLE WILL BE IN CYGNUS. THE FACES AT THE TWO EPOCHS EXPRESS DIFFERING EMOTIONS ABOUT THE SAFETY OF INTRUDING INTO THE REPOSITORY, AND THE SEQUENCE OF "RADIOACTIVE WASTE BURIED HERE" SYMBOLS ☢ OF DIMINISHING SIZE EXPRESSES THE DIMINISHING AMOUNT OF RADIOACTIVITY ☢ PRESENT IN THE REPOSITORY AS 10,000 YEARS PASS. THE LEVEL OF RADIOACTIVITY ☢ IN THE WASTE DECREASES OVER TIME, BUT IT WILL NOT ALL BE GONE AFTER 10,000 YEARS. IF YOU HAVE ACCURATELY OBSERVED THE CHANGING POSITION OF THE POLE IN YOUR OWN TIME, THIS DIAGRAM SHOWS YOU HOW TO DETERMINE THE DATE OF THE SEALING OF THIS REPOSITORY REASONABLY ACCURATELY EVEN IF YOU DO NOT UNDERSTAND THE "AD" (ANNO DOMINI) NOTATION USED FOR GREGORIAN CALENDAR DATES IN THIS MESSAGE. IN OTHER CALENDARS OF OUR TIME, THE END OF THE YEAR AD 2020 OCCURS DURING THE FOLLOWING YEARS: 7529 IN THE BYZANTINE CALENDAR, 5781 IN THE JEWISH CALENDAR, 1441 IN THE ISLAMIC CALENDAR, AND 4718 IN THE CHINESE CALENDAR. IT ALSO OCCURS ON JULIAN DATE 2459275. THIS RADIOACTIVE WASTE REPOSITORY AND MARKER SYSTEM IS IN FACT ONLY ONE OF MANY CONSTRUCTED ALL OVER THE EARTH; DIAGRAM 7 SHOWS A MAP OF THE WORLD WITH THE WASTE SITES INDICATED BY THE "RADIOACTIVE WASTE BURIED HERE" SYMBOL ☢. IN ORDER TO LOCATE THESE SITES MORE ACCURATELY, EACH SYMBOL ON THE MAP HAS BEEN LOCATED WITH A NUMBER THAT CAN ALSO BE FOUND LABELING TWO DOTS FOUND IN DIAGRAM 8. EACH DOT ON THE CIRCUMFERENCE OF THE OUTER CIRCLE GIVES THE LONGITUDE OF ANOTHER WASTE SITE RELATIVE TO THE LONGITUDE OF THIS SITE; THIS RELATIVE LONGITUDE IS EQUAL TO THE ARC TRAVERSED FROM THE DOT LABELED 0 AT THE TOP (WHICH CORRESPONDS TO THIS SITE), DOTS TO THE RIGHT REPRESENT SITES TO THE EAST. IN A SIMILAR MANNER, THE INNER PARTIAL CIRCLE GIVES THE RELATIVE LATITUDE OF A SITE, WHICH IS EQUAL TO THE ARC TRAVERSED FROM THE DOT LABELED 0. DOTS ON THE UPPER SIDE ARE SITES TO THE NORTH. THE FABRICATION OF THESE PANELS (ACCURACY OF

0.039 IN. [1 MM]) HAS BEEN SUCH THAT WE BELIEVE THAT YOU CAN DETERMINE THE LOCATION OF ALL OTHER RADIOACTIVE ☢ WASTE SITES FROM OUR TIME TO AN ACCURACY OF ABOUT 2.5 MI (4 KM). WE URGE YOU TO CHECK THESE LOCATIONS AROUND THE WORLD AND MAKE CERTAIN THAT THE MARKINGS SYSTEMS FOR THESE OTHER MARKING SYSTEMS ARE IDENTICAL TO THOSE HERE. THE INTERNATIONAL STANDARD FOR THESE MARKING SYSTEMS CAN BE SUMMARIZED THUS:

> **"EACH SITE MUST (1) DISPLAY ITS BASIC WARNING MESSAGES IN AT LEAST THE FOLLOWING LANGUAGES: CHINESE, RUSSIAN, ENGLISH, SPANISH, FRENCH AND ARABIC; (2) PROMINENTLY DISPLAY THE SYMBOL FOR INTERNATIONAL RADIOACTIVE WASTE BURIAL ☢; (3) DISPLAY IN A PROTECTED CHAMBER A WORLD MAP OF ALL DISPOSAL SITES, TOGETHER WITH A STANDARD DIAGRAM THAT GEOMETRICALLY ALLOWS THEIR LOCATION TO AN ACCURACY OF AT LEAST 3 MI (5 KM); AND (4) INCLUDE EARTHEN BERMS TO DELINEATE THE DISPOSAL AREA WITH HEIGHTS OF AT LEAST 5 MI (10 M)."**

ATTACHMENT 3

STORAGE ROOM LOCATION

THE INFORMATION YOU HAVE READ HERE IN THE INFORMATION CENTER HAS BEEN DUPLICATED IN TWO OTHER LOCATIONS. THERE ARE TWO BURIED ROOMS 443 FT (135 M) TO THE EAST AND WEST OF THE INFORMATION CENTER ON A LINE PASSING THROUGH THE INFORMATION CENTER AND DIVIDING THE SITE IN HALF ALONG ITS MAJOR AXIS. EACH OF THESE BURIED ROOMS CONTAINS THE SAME INFORMATION YOU HAVE FOUND HERE. THE CONSTRUCTION OF THE ROOMS IS VERY SIMILAR TO THE INFORMATION CENTER. THE BURIED LOCATIONS ARE MARKED BY PERMANENT MAGNETS AT EACH LOCATION. THESE ROOMS WERE PLACED APPROXIMATELY 23 FT (7 M) BELOW THE SURFACE WHEN ORIGINALLY BURIED. DO NOT EXPOSE THESE ROOMS UNLESS THE INFORMATION PRESENTED IN THIS CENTER HAS BECOME WEATHERED OR OTHERWISE OBLITERATED BEYOND RECOVERY. LEAVE THE BURIED ROOMS FOR FUTURE GENERATIONS. IF THE BURIED ROOMS HAVE BECOME EXPOSED, PROTECT THEM BY ADDITIONAL COVERING.

TRANSLATION OF THE ENGLISH VERSION OF THE LEVEL II, III, AND IV MESSAGES INTO ARABIC, CHINESE, FRENCH, SPANISH, RUSSIAN, AND NAVAJO WILL BE COMPLETED DURING THE FINAL DESIGN PHASE AND SUBJECTED TO TESTING AMONG INDIGENOUS PEOPLE PRIOR TO FINALIZATION.

APPENDIX QAPD

U.S. DEPARTMENT OF ENERGY
CARLSBAD AREA OFFICE

QUALITY ASSURANCE PROGRAM DOCUMENT

CAO-94-1012

REVISION 1

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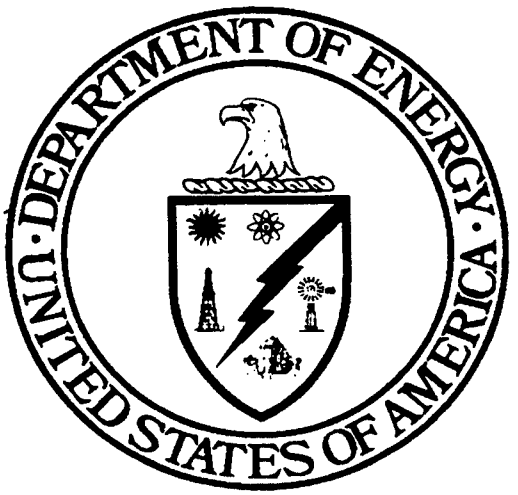

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APRIL 1996

U.S. DEPARTMENT OF ENERGY
CARLSBAD AREA OFFICE

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CARLSBAD AREA OFFICE

QUALITY ASSURANCE PROGRAM DOCUMENT

CAO-94-1012

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U.S. DEPARTMENT OF ENERGY
CARLSBAD AREA OFFICE

POLICY STATEMENT

The mission of the Carlsbad Area Office (CAO) is to protect human health and the environment by opening and operating the Waste Isolation Pilot Plant (WIPP) for safe disposal of transuranic (TRU) waste, and establishing an effective system for management of TRU waste from generation to disposal.

To help in fulfilling this mission and to ensure that the risks and environmental impacts are identified and minimized, and that safety, reliability, and performance are optimized, it is the policy of the CAO to establish, implement, and maintain an effective quality assurance (QA) program that supports compliance with applicable Federal, State, and local regulations, and U.S. Department of Energy (DOE) Orders and requirements.

Further, it is the intent of the CAO to establish a culture and work environment that encourages setting and maintaining effective standards, identifying and resolving problems, emphasizing a continual pursuit of improvement, and fostering mutual respect and effective communication within the CAO, and among its participants, their suppliers, the public, and other stakeholders.

The *CAO Quality Assurance Program Document* (QAPD) establishes QA program requirements for all programs, projects, and activities sponsored by the CAO. The CAO and organizations supporting the CAO shall implement the applicable requirements of this QAPD within their systems for management and control of these activities.

It is the responsibility of all personnel assigned to CAO sponsored activities to achieve quality, identify problems, and recommend improvements. Line organizations define, achieve, and verify quality; recommend and promote improvements in the quality of items and process; and identify, document, and resolve problems. CAO management establishes and cultivates principles and practices that integrate QA program requirements and performance standards into their management approach and control systems. CAO management additionally, provides personnel performing work with the proper qualifications, training, resources, oversight, and support to achieve the CAO organizational and mission objectives.

The CAO QA Program requirements, as described in this QAPD, have my full endorsement and complete support. Implementation of the applicable QAPD requirements, responsibilities, and authorities is mandatory for all CAO personnel.

In support of this Policy Statement, all CAO personnel are expected to demonstrate their personal commitment to the achievement of quality through their active involvement in the implementation of the CAO QA Program.

George E. Dials
Manager, CAO

April 22, 1996
Date

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CHANGE HISTORY

Revision:	Changes to the QAPD
1	The QAPD has been substantially rewritten, the structure has been reorganized and the content supplemented to transition from a CAO internal requirements and participant guidance document to a CAO "program-wide" requirements document. The document elements that defined the extent of applicability regarding specific QA program requirements have been clarified through the identification of "general" and "additional" requirements. Requirements for the grading of management controls have been clarified and more fully developed. The requirement for SNL and WID QAPDs was deleted. A requirement was added for each organization to prepare, submit for review, and maintain a QA implementing procedures matrix. Revisions were made to incorporate all the requirements of 40 CFR Part 194; ANSI/NCSL Z540-1; and stakeholder comments. The use of the terms "will" and "shall" are interchangeable and denote requirements. Editorial changes were made throughout.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
ASTM	American Society for Testing and Materials
CAO	Carlsbad Area Office
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE-AL	U.S. Department of Energy-Albuquerque
DOE-HQ	U.S. Department of Energy-Headquarters
EEG	Environmental Evaluation Group
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
M&TE	Measuring and Test Equipment
M&O	Management and Operating Contractor
NAS	National Academy of Sciences
NARA	National Archives and Records Administration
NDE	Nondestructive Examination
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NMED	New Mexico Environment Department
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Report Designation
QA	Quality Assurance
QAPD	Quality Assurance Program Document
QAPjP	Quality Assurance Project Plan
QAPP	Quality Assurance Program Plan
QARD	Quality Assurance Requirements and Description

QC	Quality Control
SNL	Sandia National Laboratories
SQA	Software Quality Assurance
TRU	Transuranic
TRUPACT	Transuranic Package Transporter
WID	Westinghouse Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

I – INTRODUCTION

The CAO QAPD is the document that describes and establishes the CAO QA Program. The provisions of this QAPD apply to all programs and projects managed by the CAO. This document serves to identify the sources of all applicable QA program requirements. The subject requirements are based on criteria contained, or incorporated by reference, in documents such as 10 CFR Part 830, *Nuclear Safety Management*; 40 CFR Part 194, *Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations*; DOE Order 5700.6C, *Quality Assurance*; and the DOE-EM *Quality Assurance Requirements and Description Document* (QARD). Table I-1 lists applicable QA program source documents. These documents have been placed into one of three categories:

A. Regulatory documents, including those incorporated by reference, that define the requirements necessary for the Waste Isolation Pilot Plant (WIPP) to be granted a certificate of compliance by the federal government and permit(s) by state governmental agencies to dispose of TRU and mixed-TRU wastes in the WIPP repository, or that define requirements applicable to the management of the WIPP as a DOE non-reactor nuclear facility.

B. Commitment documents that are imposed by DOE management.

C. Guidance documents that provide additional information, useful in the development and implementation of the CAO QA Program.

The purpose of the QAPD is to describe the applicability and requirements of the CAO QA Program as applied within the CAO management infrastructure. In this context, the management infrastructure includes all CAO Program participants (e.g. Sandia National Laboratories (SNL), as Science Advisor; Westinghouse Waste Isolation Division (WID), as the Management and Operating (M&O) Contractor of the WIPP; and various DOE organizations and contractors performing work under the cognizance of the CAO). This program is developed and maintained through an ongoing process that selectively applies the varied QA program criteria. This process provides due consideration to: the extent of source requirement applicability; a graded-approach; available guidance; and the current foreseeable activities expected to be performed under the cognizance of CAO.

The requirements in this QAPD are based on the principle that work shall be planned, documented, performed under controlled conditions, and periodically assessed to establish work item quality and process effectiveness and to promote improvement. Management and line personnel are responsible for planning, achieving, verifying, and assessing quality and promoting continuous improvement. This QAPD further delineates the quality contributions expected of all personnel and encourages their active participation in implementing the CAO QA Program.

Table I-1 QA PROGRAM SOURCE DOCUMENTS

REGULATORY REQUIREMENTS DOCUMENTS	TITLE
10 CFR Part 71, Subpart H	Packaging and Transportation of Radioactive Material, Quality Assurance
10 CFR Part 830	Nuclear Safety Management
40 CFR Part 194	Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations
40 CFR Part 261	Identification and Listing of Hazardous Waste
40 CFR Part 268.6	Land Disposal Restrictions
ASME NQA-1-1989 (incorporated by reference in 40 CFR Part 194)	Quality Assurance Program Requirements for Nuclear Facilities
ASME NQA-2a-1990 addenda, Part 2.7 (incorporated by reference in 40 CFR Part 194)	Quality Assurance Requirements of Computer Software for Nuclear Facility Applications
ASME NQA-3-1989 excluding Section 2.1 (b) and © and Section 17.1 (incorporated by reference in 40 CFR Part 194)	Quality Assurance Program Requirements for the Collection of Scientific and Technical Information for Site Characterization of High-Level Nuclear Waste Repositories
NUREG-1297(1988) (incorporated by reference in 40 CFR Part 194)	Peer Review for High-Level Nuclear Waste Repositories
COMMITMENT DOCUMENTS	**TITLE**
DOE Order 5700.6C	Quality Assurance
DOE-EM QARD	U. S. Department of Energy - Office of Environmental Management (EM) Quality Assurance Requirements and Description Document
ANSI/NCSL Z540-1	General Requirements for Calibration Laboratories and Measuring and Test Equipment
GUIDANCE DOCUMENTS	**TITLE**
DOE Order 5700.6C, Attachment 1	Quality Assurance Program Implementation Guide
DOE, Division of Nuclear Safety, G-830.120	Implementation Guide for use with 10 CFR Part 830.120 Quality Assurance
NUREG/BR-0167 (1993)	Software Quality Assurance Program and Guidelines

SECTION 1 – MANAGEMENT REQUIREMENTS

This section describes the fundamental elements related to the organization and management of the CAO QA Program, as well as the fundamentals to be applied in managing the work of the CAO.

1.1 ORGANIZATION AND QUALITY ASSURANCE PROGRAM

This section describes the CAO organizational structure, primary interfaces, functional responsibilities, and levels of authority established to develop and implement the CAO QA Program. In addition, this section describes the basic elements of the QA Program and their applicability.

1.1.1 Organization

Effective implementation of the CAO QA Program is dependent on the efforts at all levels of the CAO and participant organizations. The CAO organization is structured such that the individual performing the work is responsible for achieving and maintaining quality. Management is responsible for defining quality, developing appropriate plans to attain quality, providing support of the workers in pursuit of quality, and verifying quality achievement. The QA Manager is responsible for defining, integrating, and ensuring effective implementation of the CAO QA Program.

The CAO Organization Chart is shown in Figure 1-1.

1.1.1.1 CAO Manager

The CAO Manager reports to the Assistant Secretary, Environmental Management, (EM-1) and has overall responsibility for the CAO QA Program. The CAO Manager is responsible for approving this QAPD and for maintaining an organizational environment conducive to the effective implementation of the CAO QA Program. Authority for execution of the CAO QA function, including the verification of effective implementation, is delegated to the CAO QA Manager.

1.1.1.2 CAO Management

A. CAO management has overall responsibility for the successful accomplishment of the CAO objectives. CAO management provides the necessary planning, organization, direction, control, resources, and support to achieve the CAO mission objectives. Management is responsible for planning, performing, assessing, and improving the work. For a description of the CAO Management system, see CAO operational plan, WIPP/CAO-95-1127.

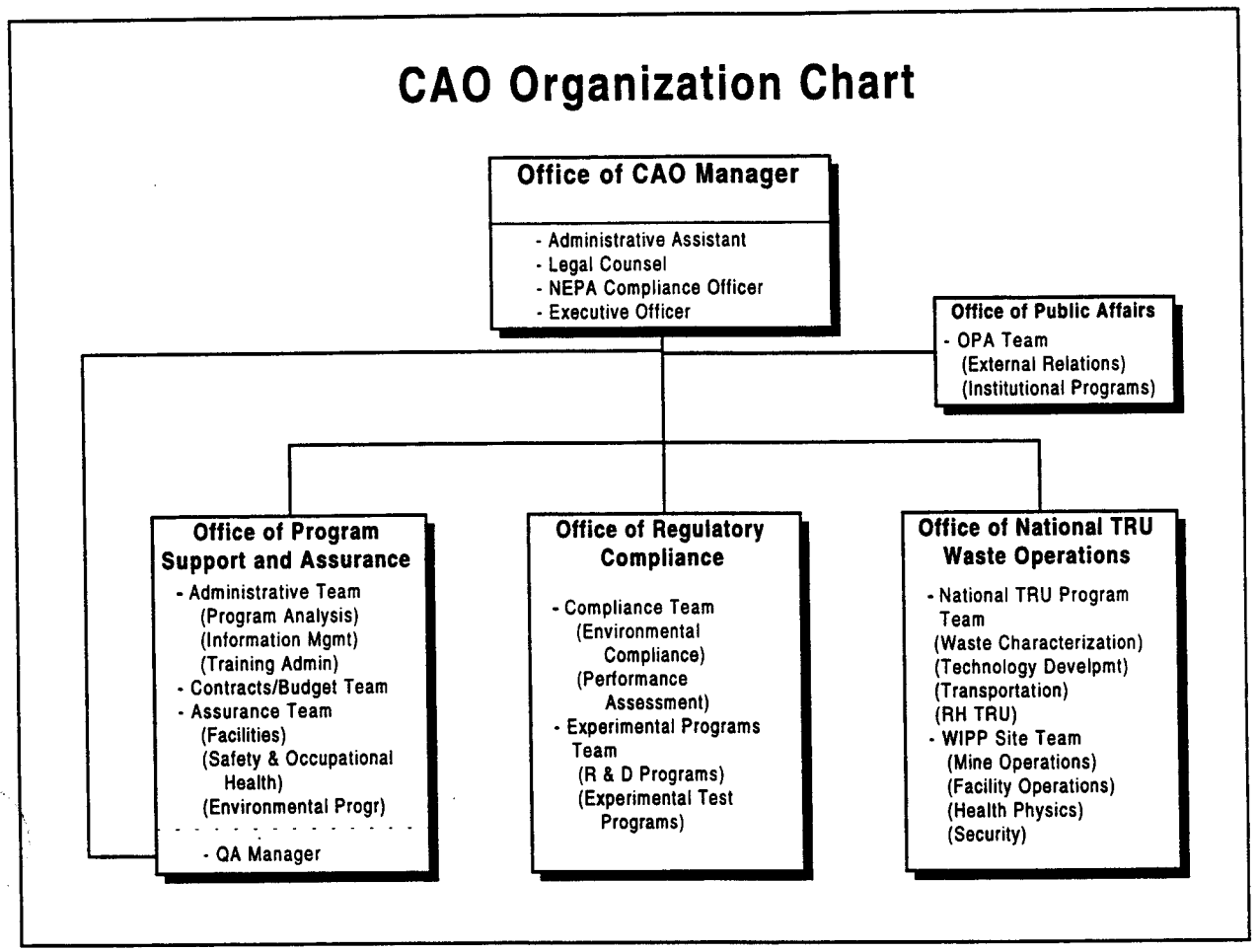

Figure 1-1

B. CAO management is responsible for establishing and implementing policies, plans, and procedures that control the quality of work, consistent with the provisions of this QAPD.

C. CAO management has various QA responsibilities that include:

1. ensuring that adequate technical and QA training is provided for personnel performing activities important to the satisfaction of CAO objectives;

2. ensuring compliance with all applicable regulations, DOE orders and requirements applicable to CAO programs, and applicable state and local laws;

3. ensuring that personnel adhere to procedures for the generation, identification, control, and protection of QA records;

4. exercising the authority and responsibility to stop unsatisfactory work such that cost and schedule do not override environmental, safety, or health considerations;

5. developing, implementing, and maintaining plans, policies, and procedures that implement this QAPD; and

6. identifying, investigating, reporting, and correcting quality problems.

D. Quality achievement is the responsibility of those performing the work. Members of CAO management are responsible for the achievement and verification of quality in their area. CAO management shall identify the responsibilities and authorities of those organizational line management positions responsible for achieving and verifying quality.

E. CAO management empowers employees by delegating authority and decision making to the lowest appropriate level in the organization.

1.1.1.3 CAO Employees

Each CAO employee, including contractor personnel working to CAO procedures, is responsible for the quality of his or her work and for promptly reporting all existing, developing, or potential conditions adverse to quality to the responsible management for evaluation and action.

1.1.1.4 CAO QA Manager

The CAO QA Manager has the authority and overall responsibility to independently assess the effective implementation of the CAO QA Program, both within the CAO organization, and participant organizations.

A. Additional authorities and responsibilities of the QA Manager include the following:

1. scheduling and conducting QA assessments;

2. maintaining liaison with participant QA organizations and other affected organizations;

3. preparing, as appropriate, and reviewing internal procedures that implement the provisions of this QAPD;

4. reviewing and approving, with line management concurrence, supplier and sub-tier participant QA plans;

5. tracking, performing trend analysis, and reporting quality problem areas; and

6. providing for the administrative processing of documentation concerning conditions adverse to quality.

B. The CAO QA Manager shall:

1. have direct access to responsible management at a level where appropriate action can be effected;

2. be sufficiently independent from cost and schedule considerations;

3. have the organizational freedom to communicate with management; and

4. have no other assigned responsibilities unrelated to the quality assurance program that would prevent full attention to quality assurance matters.

C. CAO management policy grants the QA organization sufficient authority, access to work areas, and organizational freedom to:

1. identify quality problems;

2. recommend solutions;

3. verify implementation of solutions; and

4. assure that unsatisfactory conditions are controlled until proper disposition has occurred.

D. In addition to the above responsibilities and authorities, the CAO QA Manager shall:

1. develop, establish, interpret, CAO QA policy and ensure effective implementation.

2. prepare, issue, and maintain the CAO QAPD and review CAO implementing procedures;

3. interface with the CAO staff, participants, and other stakeholders, on quality assurance matters;

4. review and jointly approve, with CAO line management, subordinate QA plans including the Quality Assurance Program Plan (QAPP) and participant Quality Assurance Project Plans (QAPjPs);

5. assist other CAO organizations with quality planning, documentation, quality measurement, and problem identification and resolution; and

6. provide guidance to all CAO organizations concerning identification, control, and protection of QA records.

1.1.1.5 Participant Organization

A. Participant Management

1. Management within each participant organization shall provide the necessary planning, organization, direction, control, resources, and support to achieve their defined objectives. Management is responsible for planning, performing, assessing, and improving work.

2. Participant management is responsible for establishing and implementing policies, plans, and procedures that control the quality of work, consistent with the provisions of this QAPD.

3. Participant management has various QA responsibilities that include:

   a. ensuring that adequate technical and QA training is provided for personnel performing activities subject to this QAPD;

   b. ensuring compliance with all applicable regulations, DOE orders and requirements applicable to activities subject to this QAPD;

   c. ensuring that personnel adhere to procedures for the generation, identification, control, and protection of QA records;

   d. exercising the authority and responsibility to stop unsatisfactory work such that cost and schedule do not override environmental, safety, or health considerations;

   e. developing, implementing, and maintaining plans, policies, and procedures that implement this QAPD; and

   f. identifying, investigating, reporting, and correcting quality problems.

4. Quality achievement is the responsibility of those performing the work. Members of participant management are responsible for the achievement and verification of quality in their area. Participant management shall identify the responsibilities and authorities of those organizational line management positions responsible for achieving and verifying quality.

5. Participant management shall ensure that each participant employee is responsible for the quality of his or her work and for promptly reporting all existing, developing, or potential conditions adverse to quality to the responsible management for evaluation and action.

B. Participant QA Management

1. Participant QA management shall have the authority and responsibility to independently assess the effective implementation of the CAO QA Program, both within the participant organization, and their sub-tier organizations. Additional authorities and responsibilities of the participant QA managers include the following:

   a. scheduling and conducting QA assessments;

   b. maintaining liaison with the CAO QA organization and sub-tier organizations;

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c. preparing and reviewing internal procedures that implement the provisions of their QA plans;

d. reviewing and approving lower-tier organizational QA plans;

e. tracking, performing trend analysis, and reporting quality problem areas; and

f. providing for the administrative processing of documentation concerning conditions adverse to quality.

2. Participant QA Management shall:

a. have direct access to responsible management at a level where appropriate action can be effected;

b. be sufficiently independent from cost and schedule considerations;

c. have the organizational freedom to communicate with management; and

d. have no other assigned responsibilities unrelated to the quality assurance program that would prevent full attention to quality assurance matters.

3. The participant QA organization shall have sufficient authority, access to work areas, and organizational freedom to:

a. identify quality problems;

b. recommend solutions;

c. verify implementation of solutions; and

d. assure that unsatisfactory conditions are controlled until proper disposition has occurred.

1.1.1.6 Communication and Interface Responsibilities

A. Communication Responsibilities

Participating organizations at all management levels shall establish communication channels that provide timely, routine, and wide dissemination of information pertinent to quality performance such as:

1. the status of development and implementation of the QA program;

2. the status and resolution of significant quality problems;

3. the lessons learned from significant quality problems and adverse conditions;

4. quality management practices and improvements; and

5. trend analysis results.

B. Interface Responsibilities

The primary CAO interfaces are shown in Figure 1-2.

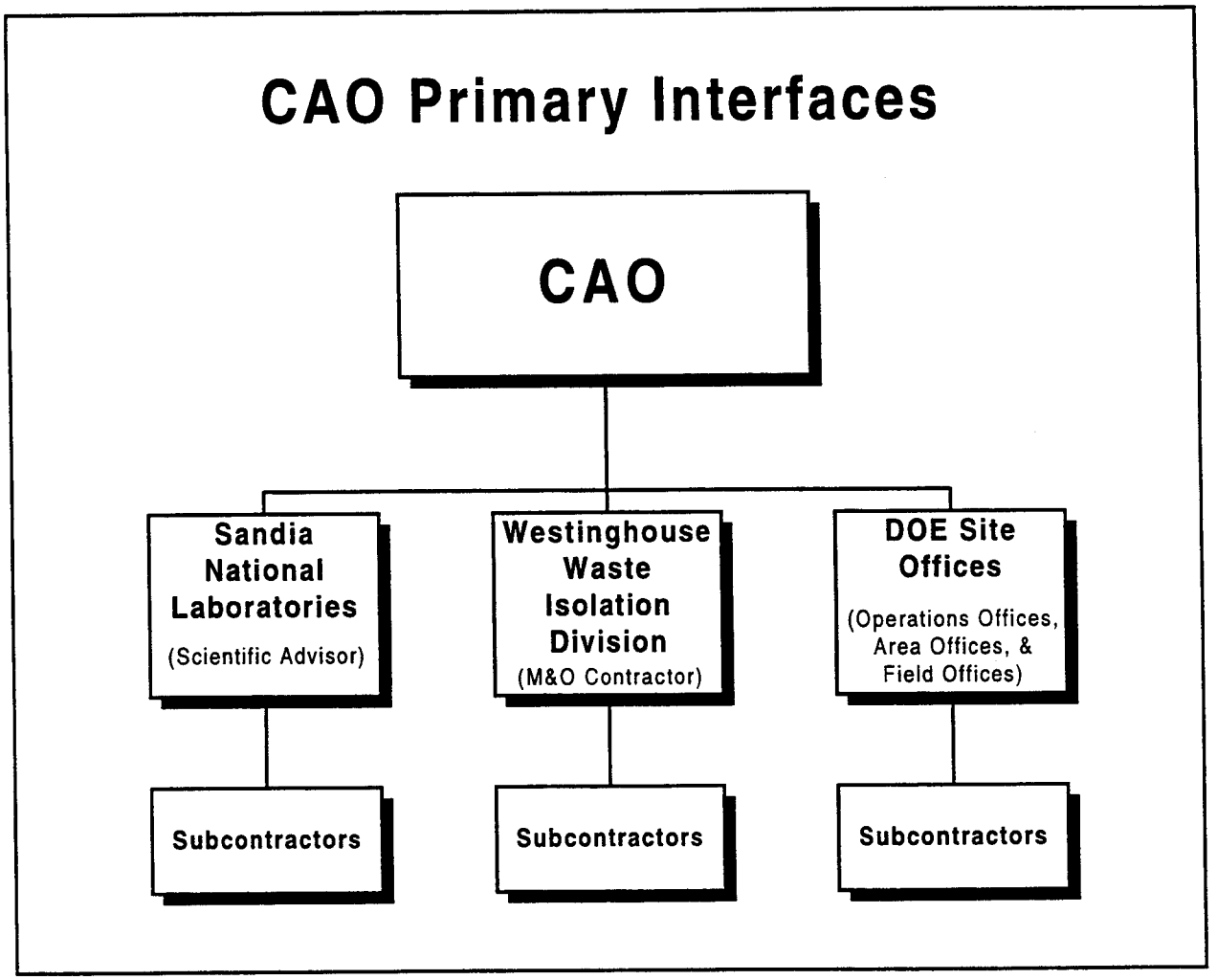

Figure 1-2

1. Where more than one organization is involved in the execution of activities covered by this QAPD, the responsibility and authority of each organization shall be clearly established and documented. The external interfaces between organizations and the internal interfaces between organizational units, and interface changes, shall be documented. Interface responsibilities shall be defined, documented, and shall include the responsibilities for management, performance, and assessment.

2. CAO external interfaces include other DOE elements, CAO program participants, suppliers, the Environmental Protection Agency (EPA), the Environmental Evaluation Group (EEG), and the New Mexico Environment Department (NMED).

3. The management of CAO organizations that interface with other DOE elements, program participants, and regulatory agencies, shall be responsible to notify the CAO QA Manager of all issues related to quality assurance, including new or proposed quality assurance requirements and questions regarding the CAO QA policies or program.

4. CAO sponsored activities, performed by organizations external to the CAO, include, but are not limited to, waste characterization, repository performance assessment, and management and operation of the WIPP facility. Responsible CAO organizations cognizant of such activities shall be responsible to ensure the effective implementation of the CAO QA Program.

1.1.1.7 Delegation of Work

Individuals or organizations responsible for establishing, planning, accomplishing, and assessing the work may delegate work to other individuals or organizations; however, the individuals or organizations making the delegation shall retain overall responsibility for the delegated work.

1.1.1.8 Resolution of Disputes

Differences of opinion involving the definition and implementation of QA program requirements will be brought to the attention of the cognizant QA Manager and the responsible manager and, if not resolved, will be elevated progressively to successively higher levels of management as necessary.

1.1.2 Implementation of the CAO QA Program

1.1.2.1 Quality Assurance Program Documents

A. The CAO and each program participant shall develop and follow procedures that effectively implement the requirements described herein, as applicable to the activities they perform in support of the CAO. The principal participants (i.e. the WIPP M&O Contractor, and Science Advisor) may implement the requirements of the QAPD directly through internal implementing plans and procedures prepared and maintained by their respective organization. The principal participants may choose to maintain their own QAPDs to support their implementation of the CAO QA Program.

B. The Transuranic Waste Characterization QAPP is prepared, issued, and maintained by CAO, in order to prescribe program-specific QA and quality control (QC) provisions that apply to multiple participants. The QAPP shall indicate that the requirements described supplement those of this QAPD.

C. QAPjPs are prepared, issued, and maintained by CAO participants, as appropriate, to identify project QA and QC provisions, and implementing procedures.

D. The following requirements apply to the development and implementation of QAPPs, QAPjPs, and the associated implementing procedures.

1. Participants are expected to develop QA implementing procedures, that provide for top-down implementation of the QAPD, QAPP and QAPjPs, as applicable.

2. CAO and participant QA plans and implementing procedures shall provide control over internal and external interfaces. An interface exists when one participant prescribes an activity or requirement to, or shares an activity or requirement with, another participant. Interfaces shall be defined, documented, and controlled.

The CAO Document Hierarchy is shown in Figure 1-3.

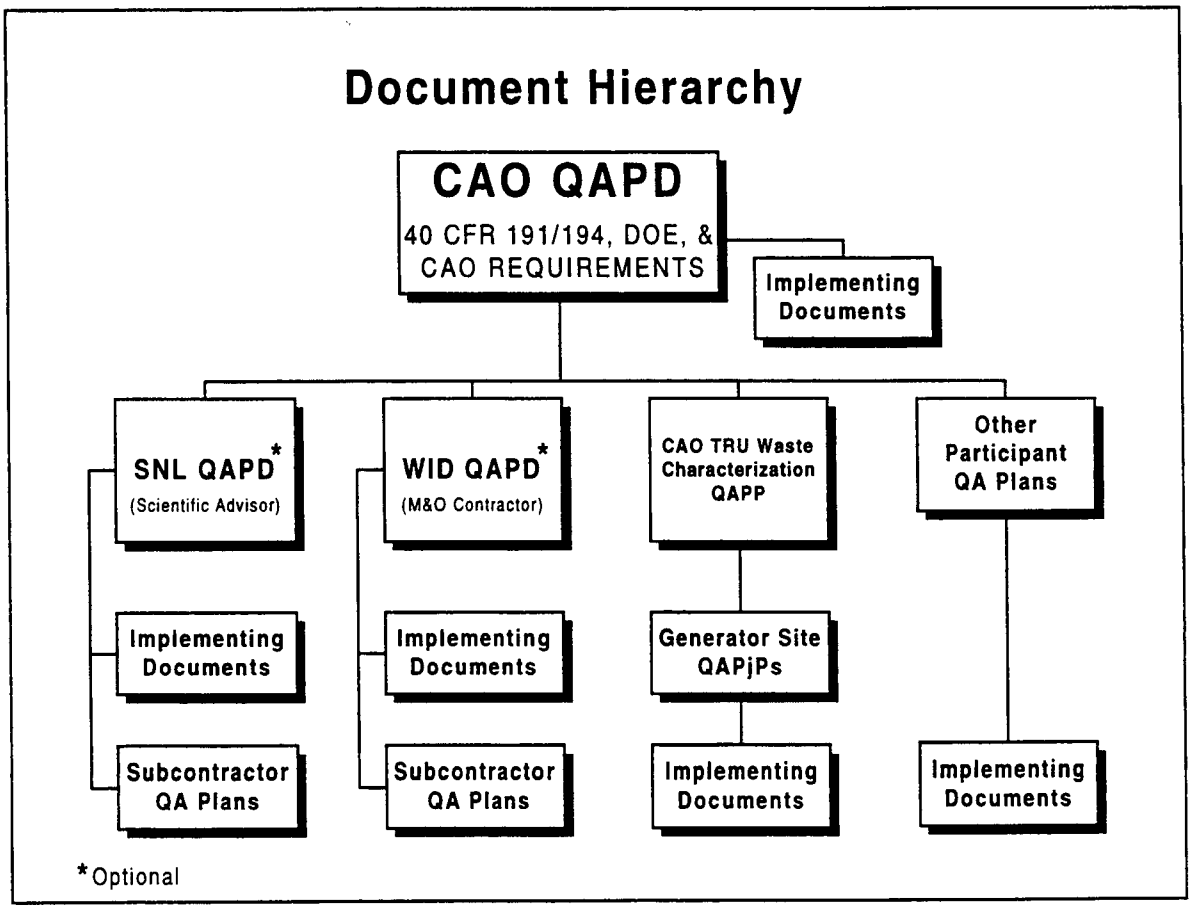

Figure 1-3

1.1.2.2 Procedures Matrix

Each organization that directly supports CAO activities shall prepare and maintain a procedures matrix, identifying all current and applicable documents of each organization or project that serve to implement each applicable requirement of this QAPD. The procedure matrix shall be submitted to the CAO QA Manager for review. The matrix shall be updated as implementation procedures are revised.

When this QAPD is revised, all QAPP, QAPjPs, and implementing procedures are to be evaluated and revised as necessary to ensure that the QA program of each organization continues to satisfy the applicable requirements of the CAO QA Program.

1.1.2.3 Applicability of QAPD Requirements

The CAO QA Program, as described in this QAPD, is driven by a variety of source requirements, as identified in Table I-1. The objective of this QAPD is to effectively and efficiently satisfy the QA program requirements through the application of management controls appropriate to the varied activities of the CAO and participants. In pursuit of this objective, the QAPD establishes two primary categories of requirements, identified as "general requirements" and "additional requirements".

The requirements of QAPD sections that do not identify specific applications, are "general requirements", that shall apply to all items, activities, and processes under the cognizance of the CAO. In most cases the "general requirements" form the introductory portion of a given section, followed by any "additional requirements". Several sections of the QAPD have a more limited application, as specifically identified within the given section. The requirements of QAPD sections identified as "additional requirements" shall apply to all items and activities listed below, unless otherwise specified in this QAPD.

The terminology "items or activities important to compliance application, nuclear safety, waste characterization, or waste isolation" is used generically throughout this QAPD to refer to the following:

A. WIPP Site activities or operations that produce, process, or store radioactive liquid or solid waste; perform waste management activities involving radioactive materials; or design, manufacture, or assemble items for use with radioactive materials and or fissionable materials in such a form and quantity that a nuclear hazard exists;

B. waste characterization activities and assumptions;

C. environmental monitoring, monitoring the performance of the disposal system, sampling, and analysis activities;

D. field measurements of geological factors, ground water, meteorology, and topography;

E. computations, codes, models, and methods used to demonstrate compliance with disposal regulations;

F. expert judgement elicitation to support applications for certification or determination of compliance;

G. design of the disposal system and actions taken to ensure compliance with design specifications;

H. the collection of data and information used to support compliance application(s);

I. other systems, structures, components, and activities important to the isolation of waste in the disposal system; or

J. those items and activities related to NRC licensed packaging (e.g., Transuranic Package Transporter (TRUPACT)-II): design, purchase, fabrication, handling, shipping, storage, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification or components of packaging which are important to safety.

1.1.2.4 Grading Items and Activities and Applying Management Controls

A. The graded approach is the process by which the level of analysis, documentation, verification, and other controls necessary to comply with QA program requirements are developed commensurate with the following factors:

1. the relative importance of an item or activity with respect to safety, safeguards, security, waste isolation, and other mission objectives (e.g., cost and schedule);

2. the importance of the data to be generated;

3. the need to demonstrate compliance with specific regulatory design and QA requirements;

4. the impact on the results of performance assessments and engineering analyses;

5. the magnitude of any hazard or the consequences of failure;

6. the life-cycle stage of a facility or item;

7. the programmatic mission of a facility;

8. the particular characteristics of a facility, item or activity (e.g. complexity, uniqueness, history, or the necessity for special controls or processes); and

9. any other relevant factor.

B. The extent of management and QA controls applied to an item or activity will vary as a function of the degree of confidence needed to achieve the desired quality of the item or activity. The grading process provides the flexibility to design and implement controls that best suit the facility or activity. The graded approach process is not intended to reduce or in any way degrade the full implementation of requirements specified in this QAPD. The use of the graded approach shall determine the appropriate controls necessary to manage the items, systems, and activities under the cognizance of the CAO.

C. Implementing procedures for each organization shall provide for:

1. the assignment of management and QA control levels;

2. the definitive criteria used in the selecting those levels; and

3. detailed descriptions of the management and QA control provisions corresponding to those levels, based on the above requirements.

D. It is not the intent of this QAPD to require a CAO-specific process for participant organizations that have already implemented a site- or company-wide grading process, as long as the provisions of such control systems satisfy the requirements of this QAPD. Participant procedures that establish and implement a graded approach for items and activities under the cognizance of the CAO shall submit those procedures to the next higher-tier participant QA organization and the CAO QA Manager for approval for use in CAO programs.

1.1.2.5 Planning Work

A. General Requirements

Planning shall be performed and documented to ensure that work is accomplished under suitably controlled conditions. Programmatic planning documentation shall include a description of the applicable management systems and processes, including those that govern planning, scheduling, and resource considerations.

Appropriate, nationally recognized standards shall be used, where applicable, to develop and implement methods and processes to control items, processes, and activities, as appropriate. Standards used to develop the implementing procedures shall be identified and documented in work activity planning. When no recognized standard exists, the procedures shall be reviewed to assure the technical adequacy and validity of the methods and processes to be implemented.

B. Additional Requirements

For programs, projects, items, activities, and processes related to compliance application, nuclear safety, waste characterization, or waste isolation, planning shall be coordinated among the responsible organizations and shall include the following elements, as applicable:

1. the definition of the program, project, or task work scope, objectives, applicable QA controls, and a listing of the primary activities involved;

2. the identification of the specific scientific and technical information to be collected and analyzed;

3. the identification of methods or procedures for field, laboratory, and engineering sampling, testing, and analysis activities;

4. the identification of applicable technical and quality assurance standards and criteria, including provisions for quality verification;

5. provisions for determining the resources and numbers of personnel required;

6. a description of any management reviews, technical reviews, QA reviews, peer reviews, and readiness reviews, as appropriate;

7. the identification of applicable implementation documents;

8. the identification of field and laboratory testing equipment or other equipment;

9. the identification of required QA records, including provisions and documentation for providing objective evidence of the work performed;

10. the identification of prerequisites, special controls, specific environmental conditions, processes, or skills; and

11. the identification of applicable computer software.

1.1.2.6 Compliance Application Peer Reviews

Peer reviews performed in support of WIPP Compliance activities shall be documented, as shall all peer review processes.

Peer reviews of the following activities shall be conducted in a manner consistent with NUREG-1297, *Generic Technical Position on Peer Review for High-Level Nuclear Waste Repositories:*

A. conceptual models selected and developed by the DOE;

B. waste characterization analysis as required in 40 CFR § 194.24(b); and

C. engineered barrier evaluation as required in 40 CFR § 194.44.

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1.2 PERSONNEL QUALIFICATION AND TRAINING

Personnel shall be trained and qualified to ensure they are capable of performing their assigned tasks. Personnel shall be provided training to ensure that job proficiency is maintained.

1.2.1 Additional Qualification Requirements

Qualification requirements for CAO and participant positions or job functions shall be established for activities important to compliance application, nuclear safety, waste characterization or waste isolation. The evaluation shall be documented. These positions include but are not limited to managers, designers, scientists, independent assessment personnel, operators, maintenance personnel, technicians, and inspectors. The responsible organization shall:

A. Analyze each job position to determine the task responsibilities of the position, that are subject to the QAPD . The analysis shall identify minimum education, experience, and training prerequisites for each position involved in the planning, performance, or verification of activities that are subject to the QAPD, commensurate with the scope, complexity, and nature of the work.

B. Personnel selected to perform or verify activities, that are subject to the QAPD, shall have education, experience, and training commensurate with the minimum requirements specified. The qualification of an individual shall be based upon an evaluation of education and experience and shall be compared to those established for the position.

1.2.2 Additional Training Requirements

CAO and participant personnel performing activities important to compliance application, nuclear safety, waste characterization or waste isolation shall receive related training in accordance with the following requirements. Training shall emphasize the correct performance of work, provide a description of why the applicable quality and nuclear safety requirements exist, and describe the fundamentals of the work and the context. Training shall be subject to ongoing review to determine instruction and training program effectiveness, and shall be upgraded whenever needed improvements or enhancements are identified. Management is expected to:

A. Ensure personnel receive indoctrination and training, including on-the-job and hands-on training, as needed to achieve initial proficiency; maintain proficiency; and adapt to changes in technology, methods, job responsibilities, and quality assurance implementing procedures, prior to performing any tasks, that are subject to the QAPD.

B. Ensure personnel receive indoctrination in the following:

1. general criteria, including, applicable QA Plans, codes, regulations, and standards; and

2. specific criteria, including applicable QAPjPs and implementing procedures.

C. Records generated during qualification, general indoctrination and training, or specific skill training activities shall be collected and maintained as QA records.

1.3 QUALITY IMPROVEMENT

1.3.1 General Requirements

A. This section defines CAO management responsibility for building a culture in which continuous improvement is a fundamental and integral part of the organization's mission. The CAO and participants shall establish and implement processes to detect and prevent conditions adverse to quality and to ensure continuous improvement. Items and processes that do not meet established requirements shall be identified, controlled, and corrected.

B. Corrective action for significant condition adverse to quality shall include identification of the causes of adverse conditions and provisions to preclude recurrence. Item reliability, process implementation, and other relevant information shall be reviewed and the data analyzed to identify items and processes needing improvement.

C. All personnel shall be responsible for identifying nonconforming items, activities, and processes and shall be encouraged by management to suggest improvements. Management at all levels should foster a "no-fault" attitude to encourage the identification of nonconforming items and processes. Nonconformances shall be documented, evaluated, and dispositioned.

1.3.2 Additional Requirements

The requirements of this section shall apply, in addition to the above requirements, for items, activities, and processes related to compliance application, nuclear safety, waste characterization or waste isolation.

1.3.2.1 Identifying and Classifying Conditions Adverse To Quality

A condition adverse to quality is an all-inclusive term used in reference to failures, malfunctions, deficiencies, and nonconforming items and processes. Conditions adverse to quality shall be identified and documented. Documentation shall clearly identify and describe the characteristics that do not conform to specified criteria.

A. Conditions adverse to quality shall be classified in regard to their significance. Corrective actions shall be developed accordingly.

B. Two categories of classification shall be established:

1. conditions adverse to quality; and

2. significant conditions adverse to quality.

Significant conditions adverse to quality are conditions that if not corrected, could have a serious effect on safety, operability, waste isolation, compliance, or the reliability of the QA program.

1.3.2.2 Control of Conditions Adverse to Quality

A. Conditions adverse to quality shall be investigated, including the extent of the condition and the impact on completed work, and documented. Corrective action plans, as appropriate and as discussed in Section 1.3.2.4, shall be developed, documented, and implemented as soon as practical.

B. Significant conditions adverse to quality shall be reported to and evaluated by the cognizant quality assurance organization, other relevant compliance functions (e.g. environmental and safety) and the responsible management to determine if a work suspension order is necessary. Corrective action plans for significant conditions adverse to quality shall address all provisions of Section 1.3.2.4. Management of the cognizant organization shall be notified and provided with the results of the subject evaluations.

1. The cognizant organization shall issue work suspension order to the responsible management after a work suspension condition has been identified.

2. The cognizant organization shall take appropriate action to lift and close (in part or total) the work suspension order based on the resolution of the related significant condition adverse to quality. The quality assurance organization shall verify and document the completion of applicable corrective actions prior to any management action releasing the work suspension order.

1.3.2.3 Control and Disposition of Nonconforming Items

Nonconforming items are adverse conditions, or the result of adverse conditions requiring the following additional controls.

A. Nonconforming items shall be identified by marking, tagging, or other methods that do not adversely affect their end use. The identification shall provide traceability to the related adverse condition documentation, and shall be legible and easily recognizable. If marking or tagging of a nonconforming item is not practical then the item, container, package, or segregated storage area shall be clearly identified.

B. Nonconforming items shall be segregated, when practical, by placing them in a clearly identified and designated hold area until properly dispositioned. If segregation is impractical or impossible due to physical conditions, then other administrative controls and precautions shall be employed to preclude inadvertent use of a nonconforming item. Nonconforming items shall be controlled to prevent

any adverse impact on test, installation, or use. Organizations affected by the nonconformance shall be notified.

C. Responsibility for the control of further processing, delivery, installation, or operation of nonconforming items, systems or equipment shall be designated in writing.

D. The nonconforming characteristics shall be reviewed and recommended. Dispositions of nonconforming items shall be proposed and approved in accordance with documented procedures. The responsibility and authority for the evaluation and disposition of nonconforming items shall be defined in applicable QA plans or implementing procedures. Personnel performing evaluations to determine a disposition shall have demonstrated competence in the specific area they are evaluating, have an adequate understanding of the requirements, and have access to pertinent background information.

E. The disposition of nonconforming items shall be identified and documented, and have the concurrence of the cognizant quality assurance organization.

1. The disposition, such as "use-as-is," "reject," "repair," "rework," or "scrap" for nonconforming items shall be identified and documented. Further processing, delivery, installation, or use of a nonconforming item shall be controlled, in accordance with approved procedures, pending the evaluation and approval of the disposition.

2. Items that do not meet original design requirements that are dispositioned "use as is" or "repair" shall be subject to design control measures commensurate with those applied to the original design. The as-built records, if such records are required, shall reflect the accepted deviation. The technical justification for the acceptability of a nonconforming item that has been dispositioned "repair" or "use as is" shall be documented.

3. The disposition of an item to be reworked or repaired shall contain a requirement to re-examine (inspect, test, or conduct nondestructive examination) the item to verify acceptability. Repaired or reworked items shall be re-examined using the original process and acceptance criteria unless alternative acceptance criteria or methods have been established and approved as part of the nonconforming item disposition.

1.3.2.4 Corrective Action Planning and Follow-up

Corrective action plans are required for all significant conditions adverse to quality and shall address the following points, as appropriate:

A. the actions to resolve the initial problem (remedial actions);

B. the assessment of the extent and impact of the significant condition adverse to quality (investigative actions);

C. the determination of the root cause of the problem;

D. the actions be taken to preclude recurrence of the problem; and

E. the expected completion dates and responsibilities for the required actions.

A follow-up system shall be established to verify the effective implementation of scheduled corrective actions and to complete the corrective action in a timely manner. The cognizant organization (the organization that documented the condition adverse to quality) shall evaluate the adequacy of corrective actions planned, assign responsibility for follow-up verification, and perform and document the corrective action verification.

1.3.2.5 Improvement Analysis

Quality performance data shall be identified, collected, and routinely analyzed to identify opportunities to improve items, activities, and processes. This analysis shall consider information from external sources and not be limited to one type of work or to one organization.

The analyses shall be performed by the organization, in a manner and at a frequency that provides for prompt identification of trends adverse to quality. CAO and participants will report trending information to responsible management and to the quality assurance organization of the next higher level participant. Reports of conditions adverse to quality shall be evaluated to identify adverse quality trends, and identify root causes, with results reported to the organization responsible for corrective action.

1.3.2.6 Recurring Conditions Adverse to Quality

For recurring conditions adverse to quality, management shall, as appropriate:

A. determine the events leading to the occurrences;

B. develop an understanding of the technical and work activities associated with the conditions adverse to quality;

C. ascertain any generic implications;

D. determine the extent to which similar quality problems, or precursors to the problem, have been recognized by the responsible organization; determine the effectiveness of any corrective actions that were taken, and identify any generic implications and impacts on completed work;

E. consider suspending work associated with the applicable activity; and

F. suggest actions that can be taken by the responsible organization to preclude recurrence.

1.4 DOCUMENTS

1.4.1 General Requirements

Documents shall be prepared, reviewed, approved, issued, used, and revised to prescribe processes, specify requirements, or establish design.

1.4.2 Additional Requirements

Documents that specify requirements, prescribe processes, or establish design important to compliance application, nuclear safety, waste characterization, or waste isolation, such as instructions, procedures, drawings, test plans, management plans, technical reports, performance reports, and test reports, shall be controlled according to the requirements listed below, to assure that correct documents are being employed.

1.4.2.1 Document Preparation, Review, Approval, and Issuance

Documents shall be reviewed for adequacy, correctness, and completeness prior to approval and issuance. The CAO and participants shall identify the individuals or organizations responsible for the preparation, review, approval, and issuance of controlled documents.

A. Documents shall be controlled during the review and approval phase in accordance with approved procedures.

B. The requesting organization shall identify the applicable criteria for the review. These criteria shall consider technical adequacy, accuracy, completeness, and compliance with established requirements.

C. Pertinent background information or data shall be made available by the organization requesting the review, if the information is not readily available to the reviewer.

D. The review will be performed by individuals other than the originator.

E. Reviewers will be technically competent in the subject area being reviewed.

F. The organization or technical discipline affected by the document shall review the document according to the established review criteria.

G. The cognizant quality assurance organization shall review documents that translate CAO QAPD or QAPP requirements.

H. Review comment documentation shall be resolved in accordance with approved procedures. Dispositioned review comment documentation shall be maintained by the originating organization.

I. Documents shall be approved for release by authorities designated in accordance with approved procedures.

J. Documents shall be issued by designated individuals or organizations in accordance with approved procedures.

1.4.2.2 Document Distribution and Use

The distribution and use of controlled documents and forms that document or prescribe work, including changes and editorial corrections to documents, shall be controlled to meet the following requirements:

A. Documents shall be distributed to affected personnel and used at the work location.

B. Effective dates shall be established and identified on the approved documents.

C. The disposition of obsolete or superseded documents and forms shall be controlled to avoid their inadvertent use.

D. Controls shall be established and maintained to identify the current status or revision of controlled documents and forms.

E. Controls shall provide for identification of documents to be controlled and their distribution.

1.4.2.3 Document Changes

Changes to documents, other than those defined below as editorial changes, shall be reviewed and approved by the same organizations that performed the original review and approval, unless other organizations are specifically designated in accordance with approved procedures.

A. Document changes shall be:

1. reviewed by the organizations or technical disciplines affected; and

2. clearly indicated in the changed document.

B. Editorial changes may be made without the same level of review and approval as the original or otherwise changed document. The following items are considered editorial changes:

1. correcting grammar or spelling (the meaning has not changed);

2. renumbering sections or attachments; or

3. updating organizational titles

C. A change in an organizational title accompanied by a change in responsibilities is not considered to be an editorial change.

D. The organization responsible for preparing the document shall identify and approve editorial changes.

1.5 RECORDS

1.5.1 General Requirements

Records shall be specified, prepared, reviewed, approved, and maintained.

1.5.2 Additional Requirements

A "QA record" is an authenticated record that provides objective evidence of the quality of items or activities. QA records shall be controlled in accordance with the following requirements.

1.5.2.1 Records System

A QA records system(s) shall be established by the organization responsible at the earliest practicable time consistent with the schedule for accomplishing work activities. The QA records system(s) shall be defined, implemented, and enforced in accordance with written procedures, instructions, or other documentation.

This does not prohibit the management of QA records within a general records system, nor does this require a separate records system for QA records, as long as the applicable provisions of Section 1.5.2 are satisfied for the control of QA records.

1.5.2.2 Generating QA Records

A. Prior to conducting a work activity, the cognizant organization shall:

1. identify those documents that shall become QA records; and

2. identify the organization responsible for submitting the QA records to the records system.

B. QA records shall be legible, accurate, and completed appropriate to the work accomplished.

C. Individuals handling documents that are intended to become QA records, shall provide reasonable protection for the records from damage or loss until the records are submitted to the records system (this includes documents generated during field operations).

D. Documents shall be considered valid QA records only if stamped, initialed, or signed and dated by authorized personnel or otherwise authenticated. If the nature of the record (such as magnetic or optical media) precludes stamping or signing, then other means of authentication by authorized personnel are required. This authentication represents a certification as to the content of the record by those

individuals with knowledge of the related facts, whether by direct personal knowledge or through the direct reports of others. The authentication should not be confused with any subsequent reviews of the content.

E. Once authenticated, QA records shall be submitted to the records system, as described above, for either permanent or temporary storage. Upon completion of a project or other discrete task or activity, responsible management shall verify that the contents of the applicable QA records package are stored in the records system.

F. QA records may be originals or reproducible copies; unless, otherwise required.

G. Documents referenced by final reports, except readily available references such as encyclopedias, dictionaries, engineering handbooks, national codes and standards, etc. shall be retrievable from records files. Preparers of such records shall ensure that the documents are entered into the records system.

1.5.2.3 Indexing QA Records

The records system shall provide for the indexing of QA records according to the following requirements:

A. An individual or organization shall be assigned the responsibility of indexing and maintaining QA records.

B. The indexing system shall include, as a minimum, record retention times and the location of the record within the records system. These and other features of the record system shall facilitate the disposition of scheduled QA records and ensure the retrievability of any and all QA records entered.

1.5.2.4 Classifying QA Records

QA records shall be initially classified as either "post closure", "lifetime" or "nonpermanent."

A. Records that fall into one or more of the following categories shall be classified as "post closure" QA records:

1. records that assist in preventing actions that could impair the long-term isolation of the waste;

2. records preserving information that would prevent inadvertent human intrusion, such as the nature and hazard of the waste and the locations of the geologic repository operations area, the underground facility, boreholes, and shafts, and boundaries of the controlled area;

3. records providing information relevant to post-closure monitoring and assessment of performance of the repository system;

4. records preserving for future generations information regarding the geologic setting relevant to mitigation of releases of radioactive materials; and

5. records that would be of significant value after decommissioning and closure of the repository.

B. Records that do not fall into the above listed categories but do fall into one or more of the following categories shall be classified as "lifetime" QA records:

1. records that may be used for repository permitting or certification;

2. records that may be used to identify and assess the performance capabilities of those engineered and natural barriers important to waste isolation;

3. records of computer programs and mathematical models needed to perform ongoing correlations between performance assessment predictions and actual tests and data analyses;

4. records that would be of significant value in demonstrating the capability for safe operation or in determining the cause of an accident or a malfunction of an item in the WIPP repository;

5. records that would be of significant value in maintaining, reworking, repairing, replacing, or modifying WIPP repository systems, components, or structures;

6. records that would be needed during decommissioning and closure of the repository;

7 records that relate to site characterization samples and data;

8 records that relate to data used in performance assessment of the WIPP facility;

9. records that relate to the mixed transuranic waste form characterization and acceptance of the mixed transuranic waste form; and

10. records that document regulatory compliance.

C. Records that provide objective evidence that the QA program has been properly implemented but do not meet the above criteria shall be classified as "nonpermanent" QA records.

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1.5.2.5 Receiving QA Records

Each organization responsible for the receipt of QA records shall designate the person or organization responsible for receiving QA records. The designee shall be responsible for organizing and implementing a system of controls for the receipt of QA

records for permanent and temporary storage. As a minimum, the receipt control system shall include the following:

A. provisions to permit a current and accurate assessment of the status of QA records;

B. a method for identifying the records required to be included in the records system;

C. a method for identifying the records that have been received;

D. procedures for the receipt and inspection of incoming records, including verification that the QA records received are in agreement with the transmittal document and that the records are legible;

E. provisions to control and protect the records from damage or loss during the receiving processes; and

F. a method for submittal of completed records to the storage facility without unnecessary delay.

1.5.2.6 Storage, Preservation, Safekeeping, and Disposition of QA Records

A. QA records shall be stored and preserved in predetermined storage facilities in accordance with approved QA implementing procedures that provide a:

1. a description of the storage facility;

2. a description of the filing and indexing systems that are used;

3. a method for ensuring that a receipt acknowledgment is returned to the sender;

4. a description of controls governing QA record access, retrieval, and removal; and

5. a method for filing supplemental information and documenting the authorization for corrections.

B. The records storage arrangements shall provide adequate protection of records, including special processed records (such as radiographs, photographs, negatives, microfilm, and magnetic media) to preclude damage from moisture, temperature, rodent infestation, excessive light, electromagnetic fields, or stacking, as appropriate for the type of record being stored.

C. Records that require special processing and control, such as software and related documentation or information on high density media or optical disks, hardware and software required to maintain and access records, shall be controlled to ensure that the records are useable.

D. Lifetime QA records are required to be retained and preserved in an acceptable condition for the operating life of the WIPP repository (i.e., until termination of the operating permits), or the particular item while it is installed in the repository or is being stored for future use. Lifetime records shall be evaluated for the need to be upgraded to post closure records prior to their destruction.

E. Design and construction of a single record storage facility shall meet the following criteria:

1. reinforced concrete, concrete block, masonry, or equal construction;

2. floor and roof with drainage control (if a floor drain is provided, a check valve, or equal, shall be included);

3. doors, structure and frames, and hardware shall be designed to comply with the requirements of a minimum 2-hour fire rating;

4. sealant applied over walls as a moisture or condensation barrier;

5. surface sealant on floor providing a hard wear surface to minimize concrete dusting;

6. foundation sealant and provisions for drainage;

7. forced air circulation with filter system;

8. fire protection system; and

9. only those penetrations used exclusively for fire protection, communication, lighting, or temperature/humidity control are allowed; all such penetrations shall be sealed or dampened to comply with the minimum 2-hour fire protection rating.

The construction details shall be reviewed to determine the adequacy of protection of contents by a person who is competent in the technical field of fire protection and fire extinguishing. If the facility is located within a building or structure, the environments and construction of that building can provide a portion or all of these criteria.

F. The following are acceptable alternatives to the criteria of Section F. above, for a single storage facility:

1. 2-hour fire rated vault meeting the National Fire Protection Association (NFPA) 232-1986, *Standards for the Protection of Records* or NFPA 232AM-1986 or both;

2. 2-hour fire rated Class B file containers meeting the requirements of NFPA 232-1986 or NFPA 232AM-1986 or both; or

3. 2-hr fire rated file room meeting the requirements of NFPA 232-1986 or NFPA 232AM-1986 or both, with the following additional provisions:

   a. Early warning fire detection and automatic fire suppression capability with electronic supervision at a constantly attended central station;

   b. Records storage in fully enclosed metal cabinets;

   c. Adequate access and aisle ways;

   d. Prohibition in the room of work not directly associated with record storage or retrieval;

   e. Prohibition in the room of smoking, eating, or drinking;

   f. 2-hour fire rated dampers or doors in all boundary penetrations.

G. If storage at dual facilities for each record is provided, the facilities shall be at locations sufficiently remote from each other to eliminate the chance of exposure to a simultaneous hazard. Each facility is not required to satisfy the requirements of either Sections F or G above, but shall meet all other records storage requirements prescribed in this QAPD.

H. When temporary storage of records (such as for processing, review, or use) is required by an organization's procedures, prior to establishing storage at dual facilities, the records shall be stored in a one-hour fire-rated container. The procedures shall specify the maximum allowable time limit for temporary storage. The container shall bear a UL label (or equivalent) certifying one-hour fire protection or be certified by a person competent in fire protection.

I. Access to storage facilities shall be controlled. A list designating personnel who are permitted access to the QA records shall be maintained and posted. Measures shall be established to preclude the entry of unauthorized personnel into the storage area. These measures shall guard against larceny and vandalism.

J. Measures shall be taken to provide for replacement, restoration, or substitution of lost or damaged records.

K. QA records shall not be destroyed until the following conditions are met:

   1. the appropriately assigned National Archives and Records Administration (NARA) authorized disposition specifies destruction;

   2. regulatory requirements are satisfied;

   3. operational status permits the disposal of such records; and

   4. the related contractual requirements have been satisfied.

1.5.2.7. Correcting Information in QA Records

A. Corrections to records will include the initials or signature of the authorized person making the correction and the date the correction was made.

B. Corrections to QA records shall be authorized by the originating organization.

C. Corrections to QA records should be made with a single line-through, and shall not obliterate the prior entry. QA records shall not be corrected through the use of correction fluids or tapes.

SECTION 2 – PERFORMANCE REQUIREMENTS

2.1 WORK PROCESSES

A. Work shall be performed in accordance with established technical standards and administrative controls. Work shall be performed under controlled conditions using approved instructions, procedures, or other appropriate means. Items shall be identified and controlled to ensure their proper use. Items shall be maintained to prevent their damage, loss, or deterioration. Equipment used for process monitoring or data collection shall be calibrated and maintained.

B. The intent of this section is to establish the policy that each person, who performs work, is responsible for the quality of his or her work, and he or she will have the goal of doing work correctly the first time. To ensure that the person doing the work achieves that goal, management is responsible for establishing processes and procedures to ensure that all work is planned and performed under controlled conditions by personnel who are knowledgeable of the work requirements, and that these individuals are capable of accomplishing the work in accordance with the requirements of this QAPD.

C. This section further establishes management involvement in the work processes through their interactions with personnel performing the work and through their review and verification of ongoing and completed work. This will help ensure that the definition of "acceptable work performance" is clearly communicated and that personnel are provided the necessary training, resources, and administrative controls to properly accomplish their tasks.

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2.1.1 Work

A. Personnel performing work are responsible for the quality of their work. Because the individual worker is the first line in ensuring quality, personnel will be knowledgeable of requirements for work they perform and the capability of the tools and processes they use.

B. Line managers will ensure that personnel working under their supervision are qualified and are provided the necessary training, resources, and administrative controls to accomplish assigned tasks. Criteria describing acceptable work performance shall be defined for the worker.

C. Line managers will review work and related information to assure that the desired quality is being achieved and to identify areas needing improvement.

D. Work shall be planned, authorized, and accomplished under controlled conditions using technical and QA standards and implementing procedures commensurate with applicable control levels.

2.1.2 Implementing Procedures

For activities and processes supporting compliance application, or related to nuclear safety, waste characterization or waste isolation, appropriate procedures, shall be developed and followed in accordance with the requirements of this section.

A. Implementing procedures shall be developed, reviewed, and approved by technically competent personnel.

B. Implementing procedures shall include the following information as appropriate to the work to be performed:

1. responsibilities of the organizations affected by the document;

2. technical, regulatory, quality assurance, or other program requirements;

3. sequential description of the work to be performed, including any allowance for out-of-sequence processing;

4. quantitative or qualitative acceptance criteria sufficient for determining that activities were satisfactorily accomplished;

5. prerequisites, limits, precautions, process parameters, and environmental conditions;

6. special qualification and training requirements;

7. verification points and hold points;

8. methods for demonstrating that the work was performed as required (such as provisions for recording inspection and test results, check-off lists, or sign-off blocks); and

9. identification and classification of QA records to be generated by the implementing procedure.

C. Individuals performing work shall comply with implementing procedures; however, when work cannot be accomplished as described in the implementing procedure or accomplishment of such work would result in an undesirable situation, a condition adverse to quality, or an unacceptable safety risk, the work shall be suspended until the appropriate procedure change provisions are implemented.

2.1.3 Item Identification and Control

A. Items and systems supporting compliance application, or related to nuclear safety, waste characterization or waste isolation, shall be identified and controlled in accordance with the requirements of this section.

B. Processes shall be established and maintained to identify, control, and maintain items. The identification of items shall be maintained to ensure appropriate traceability. Traceability requirements shall be specified in design documents or implementing procedures. Processes shall be established and implemented to control consumables and items with limited operating or shelf life and to prevent the use of incorrect or defective items.

C. The following additional controls shall be established to ensure that only correct and accepted items are used or installed:

1. Items shall be identified and traced from the time of receipt, up to and including, installation or end use. Records shall be maintained to ensure that the item can be traced at all times from its source through installation or end use.

2. Item identification methods shall include physical markings. If physical markings are either impractical or insufficient, other appropriate means shall be employed (such as physical separation, labels or tags attached to containers, or procedural control). When used, physical markings shall:

   a. be applied using materials and methods that provide a clear, permanent, and legible identification;

   b. not be detrimental to the function or service life of the item;

   c. be transferred to each part of an identified item when the item is subdivided; and

   d. not be obliterated or hidden by surface treatments, or coatings, or installation unless other means of identification are substituted.

3. If codes, standards, or specifications include specific identification or traceability requirements (such as identification or traceability of the item to applicable specification or grade of material; heat, batch, lot, part, or serial number; or specified inspection, test, or other records), then identification and traceability methods shall be implemented to ensure meeting the special requirements.

4. Item identification control system records shall provide the inspection, test, and operating status of items. Items that have satisfactorily passed the required inspections and tests shall be identified. The identification methods shall preclude the inadvertent installation, use, or operation of items that have not passed required inspections and tests.

5. The status of inspections and tests shall be identified either on the items or in documents traceable to the items. Status shall be maintained through the use of status indicators (such as tags, markings, labels, and stamps) or other means (such as travelers, inspection or test records) and the authority for applying and removing status indicators shall be specified.

2.1.4 Special Processes

Special processes supporting compliance application or related to nuclear safety, waste characterization or waste isolation, shall be controlled in accordance with the requirements of this section.

A. Processes shall be considered as special processes if they meet any one or combination of the following criteria:

1. the results are highly dependent on the control of the process;

2. the results are highly dependent on the skill of the operator; or

3. the quality of the results cannot be readily determined by inspection or test of the product.

B. Implementing procedures shall be established to ensure special process parameters are controlled and specified environmental conditions are maintained. In addition to the requirements provided in Section 2.1.2, special process implementing procedures shall include or reference:

1. the requirements for qualification of personnel, processes, and equipment; and

2. the conditions necessary for completion of the special process, including equipment, statistical process control, controlled parameters of the process, and calibration requirements.

2.1.5 Handling, Storage, and Shipping

Items supporting compliance application or related to nuclear safety, waste characterization or waste isolation, shall be controlled in accordance with the requirements of this section.

A. Handling, storage, cleaning, shipping, and other means of preserving, transporting, and packaging of items shall be conducted in accordance with established work and inspection procedures, shipping instructions, or other specified documents.

B. If required for critical, sensitive, perishable, or high-value articles, specific implementing procedures for handling, storage, cleaning, packaging, shipping, and other preservation shall be prepared and used.

C. Measures shall be established and implemented for the marking and labeling of items for packaging, shipping, handling, and storage as necessary to adequately identify, maintain, and preserve the item. Markings and labels shall indicate the presence of special environments or the need for special controls, as necessary, and be applied and removed by authorized personnel.

D. If required for protection or maintenance of particular items, special equipment (such as containers, shock absorbers, and accelerometers) and special protective environments (such as inert gas and specific moisture and temperature levels) shall be specified, planned for, and provided.

1. If special protective equipment and environments are used, provisions shall be made for verifying their adequacy.

2. Special handling tools and equipment shall be used and controlled, as necessary, to ensure safe and adequate handling.

3. Special handling tools and equipment shall be inspected and tested at specified intervals and in accordance with implementing procedures to verify that the tools and equipment are adequately maintained.

4. Operators of special handling and lifting equipment shall be sufficiently experienced and trained to use the equipment.

E. If storage of items is required, then methods shall be established for the control of item identification records that are commensurate with the planned duration and conditions of storage. These methods shall provide for, as applicable:

1. maintenance or replacement of markings and identification tags damaged during handling or aging;

2. protection of identification markings that are subject to excessive deterioration resulting from environmental exposure; and

3. update of related identification records and documentation.

F. Status indicators, such as tagging valves and switches to prevent inadvertent operation, shall be used to indicate the operating status of items. Status indicators, such as lockout tagging, shall also be used where appropriate, and be applied and removed by authorized personnel.

2.2 DESIGN CONTROL

2.2.1 General Requirements

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Items and processes shall be designed using sound engineering and scientific principles and appropriate standards. Design work, including changes, shall incorporate appropriate requirements such as general design criteria and design bases. Design interfaces shall be identified and controlled.

The adequacy of design products shall be verified by individuals or groups other than those who performed the work. Required verification and validation work shall be completed before approval and implementation of the design.

2.2.2 Additional Requirements

The design of items and processes supporting compliance application or related to nuclear safety, waste characterization, or waste isolation, shall be controlled in accordance with the requirements of this and following sections.

This section provides requirements to ensure that designs (from conceptual through final) are defined, controlled, and verified. In establishing design controls, management is responsible to ensure that design inputs are technically correct; that design interfaces are identified; that authorities, responsibilities, and lines of communication are clearly defined; and that the design processes clearly define the acceptance criteria for the product.

2.2.2.1 Design Input

Applicable design inputs, such as design bases, conceptual design reports, performance requirements, regulatory requirements, codes, and standards, shall be controlled by those responsible for the design in accordance with the following requirements:

A. design inputs shall be identified and documented, and their selection reviewed and approved by those responsible for the design;

B. design inputs shall be specified and approved on a timely basis and to the level of detail necessary to permit the design work to be carried out correctly in a manner that provides a consistent basis for making design decisions, accomplishing design verification, and evaluating design changes; and

C. changes from approved design inputs and reasons for the changes shall be identified, approved, documented, and controlled.

2.2.2.2 Design Process

The design process shall be controlled according to the following requirements:

A. Appropriate standards shall be identified and documented, and their selection reviewed and approved. Changes from specified standards, including the reasons for the change, shall be identified, approved, documented, and controlled;

B. Design work shall be prescribed and documented on a timely basis and to the level of detail necessary to permit the design process to be carried out correctly;

C. Design documents shall be adequate to support design, fabrication, construction, and operation;

D. Design documents shall be sufficiently detailed as to purpose, method, assumptions, design input, references, and units such that a person technically qualified in the subject can understand the documents and verify their adequacy without recourse to the originator;

E. Controls for identifying assemblies or components that are part of the item being designed shall be established. If a commercial grade assembly or component is modified or selected by special inspection or testing to meet requirements that are more restrictive than the supplier's published product description, then the assembly or component shall be represented as different from the commercial grade item in a manner traceable to a documented definition of the difference;

F. Controls for selecting and reviewing design methods, materials, parts, equipment, and processes essential to the function of an item shall be established; and

G. Drawings, specifications, and other design output documents shall contain appropriate inspection and testing acceptance criteria.

2.2.2.3 Design Analyses

A. Design analyses shall be planned, controlled, and documented.

B. Documentation of design analyses shall include:

1. definition of the objective of the analyses;

2. definition of design inputs and their sources;

3. results of literature searches or other applicable background data;

4. identification of assumptions and designation of those assumptions that shall be verified as the design proceeds;

5. identification of any computer calculations, including computer type, computer software name, revision identification, inputs, outputs, and the bases (or reference thereto) supporting application of the software to the specific physical problem; and

6. identification of the reviewer and the approver.

C. Calculations shall be identifiable by subject (including structure, system, or component to which the calculation applies), originator, reviewer, and date, or by other designator such that the calculations are traceable.

D. Computer software used to perform design analyses shall be developed, qualified, and used according to the requirements of Section 6.

2.2.2.4 Design Interface

Design interfaces shall be identified and controlled so that efforts are coordinated among participating organizations.

A. Design interface controls shall include the assignment of responsibility and the establishment of implementing procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.

B. Design information transmitted across interfaces shall be documented and controlled.

C. The status of the design information or issued design documents shall be identified in transmittals. Where necessary, incomplete designs that require further evaluation, review, or approval shall be identified.

2.2.2.5 Design Verification

The acceptability of design work and documents, including design inputs, processes, outputs, and changes, shall be verified. The following design control requirements shall be applied to verify the adequacy of design:

A. Design verification shall be performed using one or a combination of the following methods:

   1. design review;

   2. alternate calculations; or

   3. qualification testing.

B. The particular design verification method shall be identified.

C. The results of design verification shall be documented, including the identification of the verifier.

D. Design verification shall be performed by competent individuals or groups other than those who performed the original design (but they may be from the same organization). If necessary, this design verification may be performed by the originator's supervisor provided that:

   I. the supervisor did not specify a singular design approach or rule out certain design considerations and did not establish the design inputs used in the design, or

   2. the supervisor is the only individual in the organization competent to perform the verification, and

3. the determination to use the supervisor is documented and approved in advance.

E. Design verification shall be performed at appropriate times during the design process.

1. Verification shall be performed before release for procurement, manufacture, construction, or release to another organization for use in other design work.

2. Design verification shall be completed before relying on the item to perform its function.

F. The extent of the design verification required shall be based on the complexity, risk, uniqueness of the design, complexity of design, degree of standardization, state of the art, and similarity with previously proven designs.

G. Use of previously proven designs shall be controlled according to the following requirements:

1. the applicability of standardized or previously proven designs shall be verified with respect to meeting pertinent design inputs for each application;

2. known problems affecting standard or previously proven designs and their effects on other features shall be considered;

3. the original design and associated verification measures shall be adequately documented and referenced in the files of subsequent application of the design; and

4. changes in previously verified designs shall require reverification. Such reverifications shall include the evaluation of the effects of those changes on the overall previously verified design and on any design analyses upon which the design is based.

2.2.2.6. Design Reviews

A. Design reviews shall be controlled, documented, and performed. Design reviews shall consider the following:

1. design inputs were correctly selected and incorporated;

2. assumptions necessary to perform the design work were adequately described, reasonable, and reverified as necessary;

3. appropriate design methods were used;

4. design output is reasonable compared to design inputs; and

5. the necessary design input and verification requirements for interfacing organizations were specified in the design documents or in supporting implementing procedures.

B. Disposition of design review comments shall be documented.

2.2.2.7. Alternative Calculations

These are calculations or analyses that are made using alternate methods to verify correctness of the original calculations or analyses. The appropriateness of any assumptions, the input data used, any computer programs, or other calculation methods used shall be evaluated.

2.2.2.8. Qualification Testing

When qualification testing is used, the following requirements shall apply:

A. the test configuration shall be defined and documented;

B. testing shall demonstrate the adequacy of performance under conditions that simulate the most adverse design conditions. Operating modes and environmental conditions in which the item shall perform satisfactorily shall be considered in determining the most adverse conditions;

C. if the tests verify only specific design features, then the other features of the design shall be verified by other means;

D. test results shall be documented and evaluated by the responsible design organization to ensure that test requirements have been met;

E. if qualification testing indicates that a modification to an item is necessary to obtain acceptable performance, then the modification shall be documented and the modified item retested or otherwise verified to ensure satisfactory performance;

F. scaling laws shall be established and verified when tests are being performed on models or mockups; and

G. the results of model test work shall be subject to error analysis, where applicable, before using the results in final design work.

2.2.2.9 Design Change

Design changes shall be controlled in accordance with the following requirements:

A. changes to final designs, field changes, and nonconforming items dispositioned "use as is" or "repair" shall be justified and shall be subject to design control measures commensurate with those applied to the original design;

B. design control measures for changes shall include provisions to ensure that the design analyses for the item are still valid;

C. changes shall be approved by the same groups or organizations that reviewed and approved the original design documents;

   1. If an organization that originally was responsible for approving a particular design document is no longer responsible, then a new responsible organization shall be designated.

   2. The cognizant design organization shall have demonstrated competence in the specific design area of interest and have an adequate understanding of the requirements and intent of the original design.

D. if a significant design change becomes necessary because of an incorrect original design, the design process and design verification methods and implementing procedures shall be reviewed and modified as appropriate. These design deficiencies shall be documented according to the requirements provided in Section 1.3.2;

E. field changes shall be incorporated into the applicable design documents; and

F. design changes that impact related implementing procedures or training programs shall be communicated to the appropriate organizations.

2.3 PROCUREMENT

2.3.1 General Requirements

CAO and participant organizations shall ensure that procured items and services meet established technical and QA requirements and that they perform as specified. Prospective suppliers shall be evaluated and selected on the basis of documented criteria. The responsible organization shall verify that approved suppliers continue to provide acceptable items and services.

2.3.2 Additional Requirements

The procurement of items and services important to compliance application, nuclear safety, waste characterization, or waste isolation, shall be controlled in accordance with the requirements of this and following sections.

2.3.2.1 Procurement Planning Requirements

Procurement activities shall be planned as early as possible and documented to assure a systematic approach to the procurement process. Procurement planning shall:

A. Identify procurement methods and organizational responsibilities, including the appropriate QA organization.

B. Identify and document the sequence of actions and milestones needed to effectively complete the procurement. Provide for the integration of the following activities:

1. procurement document preparation, review, and change control;

2. selection of procurement sources;

3. proposal or bid evaluation and award;

4. purchaser evaluation of supplier performance;

5. purchaser verifications including any hold-point and witness-point notifications;

6. control of nonconformances;

7. corrective action;

8. acceptance of the item or service; and

9. identification of QA records.

2.3.2.2 Supplier Selection

Supplier selection shall be based on an evaluation of the supplier's capability to provide items or services in accordance with procurement document requirements.

A. Organizations responsible for supplier source selection shall be identified and shall include the appropriate QA organization.

B. Measures for selecting procurement sources shall include:

1. an evaluation of the supplier's history for providing an identical or similar product that performs satisfactorily in actual use;

2. an evaluation of the supplier's current QA documentation supported by any qualitative and quantitative information; and

3. an evaluation of the supplier's technical and QA capability based on an evaluation of the supplier's facilities, personnel, and quality program implementation.

C. The results of procurement source selection shall be documented.

2.3.2.3 Proposal/Bid Evaluation

A. The proposal or bid evaluation process shall include a determination of the extent of conformance to the procurement document requirements. This evaluation shall be performed by designated, technically qualified personnel and shall include, at a minimum, the following:

1. technical considerations;

2. QA program applicability;

3. supplier personnel skills;

4. supplier production capabilities;

5. supplier past performance;

6. alternatives proposed by the supplier; and

7. exceptions taken by the supplier.

B. Before the contract is awarded, the purchaser shall resolve, or obtain commitments to resolve deficiencies identified during the proposal or bid evaluation.

C. Supplier QA provisions shall be accepted by the purchaser QA management before authorizing the supplier to start work.

2.3.2.4 Procurement Document Requirements

Procurement documents shall include the following, as applicable to the item or service being procured:

A. the scope of work;

B. technical requirements, including:

1. design bases shall be identified or referenced;

2. specific documents (such as drawings, codes, standards, regulations, procedures, or instructions) that describe the technical requirements of the items or services to be furnished shall be identified. The revision level or change status of these documents shall also be identified; and

3. tests, inspections, hold points or acceptance criteria that the purchaser shall use to monitor and evaluate the performance of the supplier shall be specified;

C. QA provisions specified by the purchaser QA organization, including:

1. the requisite QA and documentation requirements, depending on the control level of the item or service being procured;

2. the pass-down requirements that the supplier shall incorporate into any sub-tier procurement document; and

3. when deemed appropriate, the purchaser may permit some or all supplier work to be performed under the purchaser QA program, provided that the requirements are adequately implemented. In these cases, procurement documents shall specify that the purchaser's QA implementing procedures are applicable to the supplier and that the purchaser shall provide these applicable documents to the supplier.

D. right of access to supplier facilities and records for inspection or audit by the purchaser, CAO, or other designee authorized by the purchaser;

E. the requirements of Section 1.5 and provisions for disposition, if the supplier is required to maintain QA records;

F. requirements for the supplier to report nonconformances and obtain purchaser approval of supplier recommended dispositions;

G. spare and replacement parts or assemblies and the appropriate technical and QA requirements for ordering; and

H. requirements for the use, control, and calibration of measuring and test equipment in conformance to the requirements of ANSI/NCSL Z540-1, *Calibration Laboratories and Measuring and Testing Equipment - General Requirements.*

2.3.2.5 Procurement Document Review and Approval

A. A review of the procurement documents and any changes thereto shall be made to verify that documents include appropriate provisions to ensure that items or services shall meet the prescribed requirements.

B. Procurement document reviews shall be performed and documented prior to the document being issued to the supplier.

C. Reviews shall be performed by personnel who have access to pertinent information and who have an adequate understanding of the requirements and scope of the procurement.

D. Procurement document reviews shall include representatives from the technical and QA organizations and shall be approved by appropriate management.

2.3.2.6 Supplier Performance Evaluation Requirements

The purchaser of items and services shall establish measures to interface with the supplier and to verify supplier performance, as deemed necessary by the purchaser. The measures shall include:

A. establishing an understanding between the purchaser and supplier of the requirements and specifications identified in the procurement documents;

B. requiring the supplier to identify planning techniques and processes to be used in fulfilling procurement document requirements;

C. reviewing supplier documents that are prepared or processed during work performed to fulfill procurement requirements;

D. identifying and processing necessary change information;

E. establishing the method to be used to document information exchanges between purchaser and supplier; and

F. establishing the extent of assessment activities and inspection.

2.3.2.7 Acceptance of Items or Services

A. Source Verification

The purchaser may accept an item or service by monitoring, auditing, surveillance, witnessing, or observing activities performed by the supplier. This method of acceptance is called source verification.

The extent of source verifications shall be a function of the relative importance, complexity, and quantity of items or services being procured, as well as the supplier's quality of performance. Source verifications shall be accomplished as early as possible, but in any case, prior to the start of those activities that are required to be controlled and shall include the active involvement of the purchaser's QA organization. In addition:

1. Source verification shall be accomplished consistent with the supplier's planned inspections, examinations, or tests, and performed at intervals consistent with the importance and complexity of the item.

2. Documented evidence of acceptance of source verified items or services shall be furnished to the party receiving the item, to the purchaser, and to the supplier.

3. Source verification shall be performed by qualified personnel.

B. Receiving Inspection

When a receiving inspection is used to accept an item:

1. The inspection shall include consideration of source assessments, verifications, and audits, and the demonstrated performance quality of the supplier.

2. The inspection shall be performed in accordance with established inspection procedures or instructions.

3. The inspection shall verify, as applicable, proper configuration; identification; dimensional, physical, and other characteristics; freedom from shipping damage; and cleanliness.

4. The inspection shall be planned and executed in accordance with the applicable requirements of Section 2.4.

5. Receiving inspection shall include a review of the adequacy and completeness of any required supplier documentation.

C. Post-Installation Testing

When post-installation testing is used as a method of acceptance, then post-installation test requirements and acceptance documentation shall be mutually established and agreed upon by the purchaser and supplier.

D. Supplier Certificate of Conformance

When a certificate of conformance is used, the following, as a minimum, shall be met:

1. The certificate shall identify the purchased material or equipment, including the purchase order and item number, or other identification that is traceable to the requirements of the procurement document.

2. The certificate shall identify the specific procurement requirements met by the purchased material or equipment, such as codes, standards, and other specifications. The procurement requirements identified shall include any approved changes, waivers, or deviations applicable to the subject material or equipment.

3. The certificate shall identify any procurement requirements that have not been met, together with an explanation and the means for resolving the nonconformances.

4. The certificate shall be signed or otherwise authenticated by an official of the supplier organization.

5. The certification system, including the procedures to be followed in filling out a certificate and the administrative procedures for review and approval of the certificates, shall be described in the purchaser or supplier QA program.

6. Means shall be provided to verify the validity of supplier certificates and the effectiveness of the certification system, such as during the performance of audits of the supplier or independent inspection or test of the items. Such verification shall be conducted by the purchaser at intervals commensurate with supplier quality performance.

2.3.2.8. Control of Supplier Nonconformances

The purchaser and supplier shall establish and document the process for dispositioning items that do not meet procurement document requirements in accordance with the following:

A. The supplier shall submit a report of nonconformance to the purchaser that includes supplier-recommended disposition (for example, "use as is" or "repair") and provide technical justification for such disposition.

B. Reports of nonconformances to procurement document requirements or documents approved by the purchaser shall be submitted to the purchaser for approval. Examples of conditions requiring a report of nonconformance include:

1. Failure to meet technical or material requirements.

2. Failure to meet a requirement in supplier documents that have been approved by the purchaser.

3. The nonconformance cannot be corrected by continuation of the original manufacturing process or by rework.

4. The item does not conform to the requirement even though the function of the item is apparently unimpaired.

C. The purchaser shall evaluate the supplier-recommended disposition.

D. The purchaser shall verify implementation of the disposition.

2.3.2.9 Commercial Grade Items

Where the design specifies the use of commercial grade items, the following requirements are an acceptable alternative to other requirements of this section.

A. The commercial grade item shall be identified in an approved design output document, such as drawing, specification or other document translated from a design input document. An alternative commercial grade item may be applied, as long as the responsible design organization provides verification that the alternative commercial grade item performs the intended function and meets design requirements that are applicable to both the replaced item and its application.

B. Supplier selection shall be in accordance with source selection requirements.

C. Commercial grade items shall be identified in the procurement document by the manufacturer's published product description.

D. After receipt of a commercial grade item, the purchaser shall ensure that:

1. Damage was not sustained during shipment.

2. The item received was the item ordered.

3. Inspection or testing is accomplished, to the extent determined by the purchaser, to assure conformance with the manufacturer's published requirements.

4. Documentation, as applicable to the item, was received and is acceptable.

2.4 INSPECTION AND TESTING

2.4.1 General Requirements

Inspections and testing shall be performed in accordance with approved implementing procedures. An essential part of the work planning process is to identify the items and processes to be inspected or tested, the parameters or characteristics to be evaluated, the techniques to be used, the acceptance criteria, any hold points, and the organizations responsible for performing the tests and inspections. Inspection for acceptance shall be performed by personnel other than those who performed or directly supervised the work being inspected. Inspection and testing of specified items and processes shall be conducted using established acceptance and performance criteria. The acceptance of items and processes shall be made by and documented by qualified and authorized personnel. Equipment used for inspections and tests shall be calibrated and maintained.

2.4.2 Additional Requirements

Inspection and testing activities supporting compliance application or related to nuclear safety, waste characterization, or waste isolation, shall be conducted in accordance with the requirements of this section, as applicable.

2.4.2.1 Qualification of Inspection and Test Personnel

This section provides amplified requirements for the qualification of personnel who perform inspection and testing to verify conformance to specified requirements for the purpose of acceptability.

The requirements of this section do not apply to the qualification of personnel for performance of nondestructive examination. Qualification of personnel for nondestructive examination is addressed in Section 2.4.2.2.

A. The responsible organization shall designate those activities that require qualified inspection and test personnel and the minimum requirements for such personnel. Further, the responsible organization shall establish written procedures for the qualification of inspection and test personnel and for the assurance that only those personnel who meet the requirements of this section are permitted to perform applicable inspection and test activities.

B. When a single inspection or test requires implementation by a team or a group, personnel not meeting the requirements of this section may be used in data-taking assignments or in plant or equipment operation, provided they are supervised or overseen by a qualified individual.

C. Personnel selected for performing inspection and test activities shall have the experience or training commensurate with the scope, complexity, or special nature of the activities.

D. Provisions shall be made for the indoctrination of personnel to the technical objectives and requirements of the applicable codes and standards and the QA program controls that are to be employed.

E. The need for a formal training program shall be determined, and such training activities shall be conducted as required to qualify personnel that perform such inspections and tests. On-the-job training shall also be included in the program, as appropriate, with emphasis on first-hand experience gained through actual performance of inspections and tests.

F. The capabilities of a candidate for certification shall be initially determined by a suitable evaluation of the candidate's previous education, experience, training, and either test results or capability demonstration.

G. The job performance of inspection and test personnel shall be reevaluated for capability at periodic intervals not to exceed three years. Reevaluation shall be by evidence of continued satisfactory performance or redetermination of capability in accordance with the above requirements. If during this evaluation, or at any other time, it is determined by the responsible organization that the capabilities of an individual are not in accordance with the qualification requirements specified for the job, that person shall be removed from that activity until such time as the required capability has been demonstrated. Any person who has not performed inspection or

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testing activities in their qualified area for a period of one year shall be reevaluated for the required capability in accordance with the above requirements.

H. The qualification of personnel shall be certified in writing in an appropriate form, and shall include the following information:

1. employer's name;

2. identification of person being certified;

3. activities certified to perform;

4. basis used for certification, including such factors as: (1) education, experience, indoctrination, and training; (2) test results, where applicable; and (3) results of capability demonstration;

5. results of periodic evaluation;

6. results of physical examinations, when required;

7. signature of employer's designated representative who is responsible for such certification; and

8. the date of certification and date of certification expiration.

I. The responsible organization shall identify any special physical characteristics needed in the performance of each activity, including the need for initial and subsequent physical examination.

J. Records of personnel qualification shall be established and maintained by the employer. These records shall include the information required above for certification.

2.4.2.2 Qualification of Nondestructive Examination Personnel

This section identifies the requirements for the qualification of personnel who perform nondestructive examination (NDE) [radiographic (RT), magnetic particle (MT), ultrasonic (UT), liquid penetrant (PT), eddy current (ET), neutron radiographic (NRT), and leak testing (LT], to verify conformance to specified requirements.

A. The American Society of Nondestructive Testing (ASNT) Recommended Practice No. SNT-TC-1A, June 1980 Edition, and its applicable supplements shall apply as requirements for personnel performing the above methods of NDE.

B. The responsible organization shall establish written procedures for the control and administration of the training, examination, and certification of NDE personnel.

C. Records of personnel qualification shall be prepared and maintained by the employer.

2.4.2.3 Inspection Requirements

A. Inspection Planning

Inspection planning shall be performed and documented and shall include the:

1. identification of work operations where inspections are necessary;
2. identification of the characteristics to be inspected and the identification of when, during the work process, inspections are to be performed;
3. identification of inspection or process monitoring methods to be employed;
4. identification of acceptance criteria;
5. identification of sampling requirements;
6. methods to record inspection results;
7. selection and identification of the measuring and test equipment (M&TE) to be used to perform the inspection; and
8. the process used to ensure that the equipment being utilized for inspection or testing is calibrated and is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

B. Inspection Hold Points

When mandatory hold points are used to control work that is not to proceed without the specific consent of the organization placing the hold point, then the specific hold points shall be indicated in implementing procedures. Only the organization responsible for the hold point may waive the hold point. Approval to waive specified hold points shall be documented before continuing work beyond the designated hold point.

C. In-Process Inspections and Monitoring

1. Items in process shall be inspected as necessary to verify quality. If inspection of processed items is impossible or disadvantageous, indirect control by monitoring of processing methods, equipment, and personnel shall be provided. Both inspection and process monitoring shall be conducted when control is deemed inadequate using only one of these methods.
2. When a combination of inspection and process monitoring methods is used, monitoring shall be performed systematically to ensure that the specified

requirements for control of the process and the quality of the item are met throughout the duration of the process.

3. Controls shall be established and documented for the coordination and sequencing of the work at established inspection points during successive stages of the process.

D. Final Inspections

1. Final inspections shall include a review of the results and the verification of the resolution of all nonconformances identified by earlier inspections.

2. Finished items shall be inspected for completeness, markings, calibration, protection from damage, or other characteristics as required to verify the quality and conformance of the item to the applicable requirements.

3. Records review shall be performed to assure adequacy and completeness.

4. Item modifications, repairs, or replacements that are performed subsequent to final inspection shall require reinspection or retest, as appropriate, to verify acceptability.

E. Inservice Inspections

1. Required inservice inspection or surveillance of structures, systems, or components shall be planned and executed by or for the organization responsible for their operation.

2. Inspection methods shall be established and executed to verify that the characteristics of an item continue to remain within specified limits.

3. Inspection methods shall include evaluations of performance capability of essential emergency and safety systems and equipment, verification of calibration and integrity of instruments and instrument systems, and verification of maintenance, as appropriate.

F. Inspection Documentation

Inspection documentation shall identify:

1. the item inspected and the date of the inspection;

2. the name or unique identifier of the inspector that documented, evaluated, and determined acceptability;

3. the method of inspection;

4. the inspection criteria, sampling plan, or reference documents (including revision designation) used to determine acceptance;

5. the results;

6. the measuring and test equipment used during the inspection, including the identification number and the calibration due date; and

7. reference to any information on actions taken in connection with nonconformances, as applicable.

2.4.2.4 Test Requirements

Testing shall be used to determine the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental, or operating conditions. Examples of such tests include prototype qualification tests, production tests, proof tests prior to installation, construction tests, and pre-operational tests.

A. Test Planning

Test planning shall include:

1. the identification of the implementing procedures to be developed to control and perform the test. In lieu of specially prepared written test procedures appropriate sections of related documents such as ASTM methods may be used. If used, they shall incorporate the information directly into the approved test implementing procedure, or shall be incorporated by reference;

2. the identification of the item to be tested and the test requirements and acceptance limits, including the required levels of precision and accuracy;

3. the identification of the M&TE to be used to perform the test to ensure that the equipment being utilized is calibrated and is of the proper type, range, accuracy, and tolerance to accomplish the intended function;

4. any test prerequisites, including: test equipment, instrumentation and software needs, personnel training and qualification, and suitably controlled environmental conditions;

5. any mandatory hold points;

6. the methods that are to be used to record data and results; and

7. the provisions for assuring that prerequisites for the given test have been met.

B. Test Documentation

Test documentation shall identify:

1. the applicable test requirements, plans, and procedures, including revisions;
2. the item or work product tested;
3. the date of the test;
4. the name of the tester and data recorders;
5. the type of observation and method of testing;
6. the identification of test criteria or reference documents used to determine acceptance;
7. the results and acceptability of the test;
8. the actions taken in connection with any noted nonconformances;
9. the name of the person evaluating the test results; and
10. the identification of the measuring and test equipment used during the test (including the identification number and calibration due date).

C. Test Results

Test results shall be documented and their conformance with acceptance criteria shall be evaluated by a qualified individual within the responsible organization to assure that all test requirements have been satisfied.

2.4.3 Monitoring, Measuring, Testing, and Data Collection Equipment

The following sections establish requirements to ensure equipment used for inspection and testing is properly controlled, calibrated, and maintained. Equipment discussed in the following sections includes measuring and test equipment, measuring and data collection equipment, equipment (either hand held or installed) used for data indication, and other equipment used for data indication, collection, or evaluation. These are termed as M&TE.

Calibration and control measures may not be required for rulers, tape measures, levels, and other such devices, if normal commercial equipment provides adequate accuracy.

2.4.3.1 Use and Control of M&TE

Each organization using M&TE shall:

A. establish and document a system to control the use and calibration of M&TE;

B. have a program to recall for calibration, or remove from service, M&TE that has exceeded its calibration interval, has broken calibration seals, has been modified, repaired, or has had components replaced, or is suspected to be malfunctioning because of mishandling, misuse, or unusual results;

C. establish and maintain documented procedures to evaluate the adequacy of the calibration system and to ensure compliance with the requirements of this QAPD, including the acquisition of calibration services from laboratories meeting the requirements of ANSI/NCSL Z540-1, *Calibration Laboratories and Measuring and Testing Equipment - General Requirements*;

D. maintain records documenting that established M&TE schedules and procedures have been followed. These records shall include an individual record of calibration, or other means of control, providing:

1. a description or identification of the item;

2. calibration interval;

3. date calibrated;

4. identification of the calibration source;

5. calibration results (data and status);

6. calibration action taken (adjusted, repaired, new value assigned, derated, etc.); and

7. evaluation and corrective action taken in response to out-of-calibration conditions;

E. label all M&TE to indicate: the calibration status, the date calibrated, the calibration due date or usage equivalent, and the identification of any limitations. (When it is impractical to apply a label directly to an item, the label may be affixed to the instrument container or some other suitable means may be used to reflect calibration status);

F. evaluate the validity of previous inspection and test results and the acceptability of related items, data collected, and processes monitored, when M&TE is found to be out-of-calibration;

G. handle, store, and transport M&TE in a manner that does not adversely affect the calibration or condition of the equipment; and

H. give due consideration to temperature, humidity, lighting, vibration, dust control, cleanliness, electromagnetic interference, and any other factors affecting the results of measurements. Where pertinent, these factors shall be monitored and recorded

and, when appropriate, correcting compensations shall be applied to measurement results.

2.4.3.2 Calibration

A. M&TE requiring calibration shall be calibrated at periodic intervals established and maintained to assure acceptable reliability, where reliability is described as the probability that M&TE will remain in-tolerance throughout the interval.

B. Intervals shall be established for all M&TE requiring calibration unless the equipment is regularly monitored through the use of check standards in a documented measurement assurance process. Check standards must closely represent the item parameters normally tested in the process and the check standard must be verified periodically.

C. Where intervals are used to ensure reliability, the interval setting system must be systematically applied and shall have stated reliability goals and a method of verifying that the goals are being attained.

D. Intervals may be based on usage or time since last calibration.

E. All exemptions from periodic calibration shall be approved and documented.

F. The recall system may provide for the temporary extension of the calibration due date for limited periods of time under specified conditions that do not unreasonably impair the satisfaction of task objectives.

G. Calibration services shall conform to the requirements of ANSI/NCSL Z540-1, *Calibration Laboratories and Measuring and Testing Equipment - General Requirements.*

H. If any M&TE is found to be significantly out-of-tolerance during the calibration process, the cognizant organization shall provide for the notification, to the user and cognizant QA management, of the out-of-tolerance condition with the associated measurement data so that appropriate action can be taken.

SECTION 3 – ASSESSMENT REQUIREMENTS

3.1 MANAGEMENT ASSESSMENT

Managers at every level shall periodically assess the performance of their organization to determine the effectiveness of QA program provisions that enable the organization to meet customer requirements and expectations. This assessment shall place emphasis on the use of human and material resources to achieve organizational goals and objectives.

A. The management assessment should include an introspective evaluation to determine if the entire integrated management system effectively focuses on meeting strategic goals.

B. Managers shall retain overall responsibility for management assessments. Direct participation by senior management is essential to the success of the process because management is in the position to view the organization as a total system.

C. Management assessments should focus on the identification and resolution of both systemic and management issues and problems. Strengths and weaknesses affecting the achievement of organizational objectives should be identified so that meaningful action can be taken to improve quality.

D. Processes being assessed should also include strategic planning, organizational interfaces, cost control, use of performance indicators, staff training and qualifications, and supervisory oversight and support. Effective management assessments should evaluate such conditions as the state of employee knowledge, motivation, and morale; the amount of mutual trust and communication among workers and organizations; the existence of an atmosphere of creativity and improvement; and the adequacy of human and material resources.

E. Management assessments of the QA program shall be conducted regularly and reported at least annually to an identified senior management level with sufficient authority to effect corrective measures, as necessary.

F. Management assessment results should be used as input to the organizational continuous improvement process.

3.2 INDEPENDENT ASSESSMENT

3.2.1 General Requirements

Planned and periodic independent assessments shall be conducted to measure item and service quality, process effectiveness, and to promote improvement. The organization performing assessments shall have sufficient authority and freedom from the activities being assessed to carry out its responsibilities. Persons conducting assessments shall be technically qualified and knowledgeable of the items and activities being assessed.

The types and frequencies of independent assessments shall be based upon the relevant control levels assigned to the items and activities under the cognizance of the organization.

3.2.2 Additional Requirements

The CAO and participant organizations responsible for the performance of activities important to compliance application, nuclear safety, waste characterization or the isolation of waste within the disposal system, shall implement a program of surveillance and audits. The program shall be planned and documented and include both routine surveillance of those activities, and audits to verify compliance with all aspects of the quality assurance program and determine its adequacy and effectiveness. The surveillance and audit program shall be implemented in accordance with the requirements of Sections 3.2.3 and 3.2.4, respectively, in addition to the general requirements above.

3.2.3 Surveillances

A. A program of surveillance of the above referenced activities shall be planned, performed, documented, and reported to appropriate management personnel. The surveillance process consists of monitoring or observing to verify whether an item, activity, system, or process conforms to specified requirements.

B. Surveillances shall accomplish the following:

   1. monitor work in progress;

   2. document compliance or non-compliance with established requirements and procedures;

   3. identify actual and potential conditions adverse to quality;

4. obtain timely corrective action commitment from cognizant managers for identified conditions adverse to quality;

5. provide notification to responsible managers of the status and performance of work under surveillance; and

6. verify timely implementation of corrective action.

C. Surveillances of the subject activities, conducted by the responsible organization, may be counted as satisfying the requirement to do surveillances of related activities in the corresponding surveillance schedule period.

3.2.4 Audits

An audit is a planned and documented independent assessment to determine by investigation, examination, or evaluation of objective evidence, the adequacy of, and compliance with established procedures, instructions, drawings, and other applicable documents, and the effectiveness of implementation. An audit should not be confused with surveillance or inspection activities performed for the sole purpose of process control or product acceptance.

3.2.4.1 Scheduling Audits

A. The CAO and participant organizations shall perform an annual evaluation of audit needs (both internal and external) from which to develop and maintain a schedule of audits. The evaluation shall be documented and include justification for the approach used to determine the subjects, scope, and frequency of the audits scheduled, as well as those areas for which audits have not been scheduled. This evaluation shall include:

1. a review of documentation furnished by, or regarding the work of the organization or supplier (such as certificates of conformance, nonconformance notices, and corrective actions);

2. the results of previous assessments (including assessments from other sources), source verifications, and receiving inspections; and

3. a review of experience from identical or similar products or services furnished by the same organization or supplier.

B. Audits shall be scheduled to begin as early in the life of a project or activity as practicable and continue at intervals consistent with the schedule for accomplishing the work and commensurate with the assigned control level.

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C. Periodically scheduled QA program audits shall be supplemented by, or integrated with, either audits or surveillances a technical nature (e.g., performance based audits) which address the quality of selected work products and work processes.

3.2.4.2 Planning and Preparation for Audits

The organization performing the audit shall develop and document a plan for each audit.

A. The plan shall include the scope, requirements, purpose, audit personnel, activities to be audited, organizations to be notified, applicable documents, schedule, and written procedures or checklists to be used.

B. Audit planning shall include a review of past assessment results to determine the nature of problems that have occurred. When recurring problems are found, the audit team shall review corrective actions that have been taken and attempt to determine whether the corrective actions were effective in preventing recurrence.

C. Audit preparation shall include review of pertinent background information, procedures, and technical documents so that audit team members are familiar with the work being audited.

D. Audits shall include technical evaluations of the applicable procedures, instructions, activities, and items.

E. The scope shall include related corrective actions taken since the previous assessment.

3.2.4.3 Audit Team Selection

Audit team members shall be identified prior to the start of the audit activity. The team members shall be selected on the basis of technical qualifications, knowledge of the item or process being audited, and shall be independent from the items or processes being audited. Audit team members shall have sufficient authority and organizational freedom to carry out their assigned responsibilities. In the case of internal audits, personnel having direct responsibility for performing the activities being audited shall not be involved in the selection of the audit team.

A. An audit team leader shall be appointed to provide indoctrination and supervision of the team, organize and direct the audit, and coordinate the preparation and issuance of the audit report.

B. Before starting the audit, the audit team leader shall ensure that the assigned personnel collectively have experience and training commensurate with the scope, complexity, or special nature of the work to be audited.

C. Technical specialists, with appropriate technical expertise or experience in the work being audited, shall be used when auditing the adequacy of technical processes.

3.2.4.4 Auditor Qualification

Auditors shall be technically qualified in their assigned roles. In addition, they shall have appropriate training or orientation to develop their competence for performing audits. Competence of personnel performing various audit functions shall be developed by the following methods:

A. Orientation to provide a working knowledge and understanding of the program QA requirements and implementing procedures used to perform audits and report audit results.

B. Training that provides fundamentals, objectives, and techniques of performing audits. Training shall include methods of examining, questioning, evaluating, and documenting specific audit items and methods of evaluating the effectiveness of corrective actions for conditions adverse to quality.

C. On-the-job training, guidance, and counseling under the direct supervision of a lead auditor may be substituted for the training above. Such training shall include planning, performing, reporting, and follow-up actions.

3.2.4.5 Technical Specialist Qualification

Technical specialists selected for audit assignments shall receive indoctrination commensurate with the scope, complexity, or special nature of the work being audited. In addition they shall be trained to the requirements of the audit process associated with their duties.

3.2.4.6 Lead Auditor Qualification

A lead auditor shall be capable of organizing and directing audits, reporting audit results, and evaluating planned and implemented corrective action. A lead auditor also shall be certified as meeting the requirements provided in this section for education and experience, communication skills, training, audit participation, and the successful completion of a lead auditor examination.

A. Lead Auditor Education and Experience

The prospective lead auditor shall have verifiable evidence that a minimum of 10 credits have been accumulated under the following scoring system:

1. Education (four credits maximum)

    a. An associate's degree from an accredited institution scores one credit. If the degree is in engineering, physical sciences, mathematics, or QA, it scores two credits.

    b. A bachelor's degree from an accredited institution scores two credits. If the degree is in engineering, physical sciences, mathematics, or QA, it scores three credits. In addition, score one more credit for a master's degree (or higher) in engineering, physical sciences, business management, or QA from an accredited institution.

2. Experience (nine credits maximum)

The prospective lead auditor shall have participated in a minimum of five QA audits or equivalent verifications (such as management assessments, pre-award surveys, or comprehensive surveillance, as long as the parameters of the audit process are met) within a period of time not to exceed three years prior to the date of certification. One audit of which shall be a nuclear QA audit within the year prior to qualification. In addition, for technical experience in such areas as scientific investigation, site characterization, nuclear waste management, production, transportation, engineering, manufacturing, construction, operation, maintenance, or experience applicable to the auditing organization's area of responsibility scores one credit for each full year, with a maximum of five credits for this aspect of experience.

a. If two years of this experience have been in a nuclear field, score one additional credit; or

b. If two years of this experience have been in QA, score two additional credits; or

c. If two years of this experience have been in auditing or assessment, score three additional credits; or

d. If two years of this experience have been in nuclear-related QA, score three additional credits; or

e. If two years of this experience have been in nuclear-related QA auditing or assessment, score four additional credits.

3. Professional Competence (two credits maximum)

For certification of competency in engineering, science, or QA specialties, issued and approved by a state agency or national professional or technical society, score two credits.

4. Rights of Management (two credits maximum)

When determined appropriate, the organization performing the qualification may grant up to two credits for other performance factors applicable to auditing that are not explicitly called out in this section (such as leadership, sound judgment, maturity, analytical ability, tenacity, past performance, and completed QA training courses).

B. Lead Auditor Communication Skills

The prospective lead auditor shall have the capability to communicate effectively, both in writing and orally. These skills shall be attested to in writing by the candidate's supervisor.

C. Lead Auditor Training

Prospective lead auditors shall be trained to the extent necessary to ensure their competence in skills as established by the organization responsible for performing audits. Training in the following areas shall be accomplished and its completion verified based upon a management evaluation of the particular needs of each prospective lead auditor:

1. knowledge and understanding of the participant organization's QA Program and other program related procedures, codes, standards, regulations, and regulatory guides;

2. general structure of QA plans and implementation procedures, as a whole.

3. auditing techniques of examining, questioning, evaluating, reporting, methods of identifying, following up, and closing corrective action items; and

4. audit planning in functional areas of nuclear QA.

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D. Lead Auditor Examination

1. The prospective lead auditor shall pass an examination that evaluates the comprehension of and the ability to apply the audit knowledge described in this section. The test shall be oral, written, practical, or any combination of these methods.

2. The development and administration of the examination for a lead auditor is the responsibility of the auditing organization. The auditing organization shall:

   a. Maintain the integrity of the examination through confidentiality of files and, where applicable, proctoring of examinations.

   b. Develop and maintain objective evidence regarding the type and content of the examination.

E. Lead Auditor Certification

Lead auditors shall be certified by the auditing organization as being qualified to lead audits. This certification will document the:

1. name of the organization performing the certification;

2. name of the lead auditor;

3. date of certification or recertification;

4. basis of certification (such as education, experience, communication skills, and training); and

5. signature of the designated representative of the organization responsible for the certification.

F. Lead Auditor Proficiency Maintenance

1. Lead auditors shall maintain their proficiency through one or a combination of the following:

   a. regular and active participation in the audit process;

   b. review and study of codes, standards, QA implementation procedures, instructions, and other documents related to QA program auditing; and

   c. participation in training programs.

2. Management of the auditing organization shall evaluate the proficiency of lead auditors annually. Based on the evaluation, management shall choose to extend the qualification, require retraining, or require requalification. Management evaluations shall be documented.

3. Lead auditors who fail to maintain their proficiency for a two-year period shall require requalification to the requirements of this section of the QAPD. However, participation in only one nuclear audit is required.

3.2.4.7 Performing Audits

A. Audits shall be performed using the written procedures related to the activity being audited or checklists.

B. Elements that have been selected for audit shall be evaluated against specified requirements. Objective evidence shall be examined to the depth necessary to determine if those elements are being implemented effectively.

C. Audit results shall be documented by audit personnel and reported to and reviewed by management having responsibility for the area audited. Conditions requiring prompt corrective action shall be reported immediately to management of the audited organization.

D. Conditions adverse to quality shall be documented and corrected according to the requirements of Section 1.3.2.

3.2.4.8 Reporting Audit Results

The audit report shall be prepared by the audit team leader, and issued to the management of the audited organization and any affected organizations. The audit report shall include the following, as appropriate:

A. a description of the audit scope;

B. the identification of the auditors;

C. the identification of persons contacted during the audit;

D. a summary of the documents reviewed, persons interviewed, and the specific results of the reviews and interviews (i.e., a summary of the checklist contents);

E. a summary of audit results, including a statement of the QA program adequacy, implementation and effectiveness, as appropriate to the scope;

F. a description of each reported condition adverse to quality in sufficient detail to enable corrective action to be taken by the audited organization; and

G. a description of commendable quality practices.

Additionally, audit findings of a common nature shall be grouped in the report whenever possible so that related or systematic breakdowns in the QA program are identified. Findings or deficiencies shall be categorized based on their relative importance, to indicate their degree of impact on compliance assessment, nuclear safety, waste characterization, waste isolation, environmental protection, or the QA program.

3.2.4.9 Audit Response and Follow Up

Management of the audited organization will investigate conditions adverse to quality; determine and schedule corrective action, including measures to preclude recurrence; and notify the auditing organization in writing of the actions planned or taken. The adequacy of audit responses shall be evaluated by or for the auditing organization. Follow-up action shall be taken to verify that corrective action is accomplished as scheduled.

3.2.4.10 Audit Records

The following documents, when developed in fulfillment of the audit requirements of this QAPD, shall be controlled as QA records, in accordance with Section 1.5 of this QAPD: audit plans; audit reports, audit checklists, audit responses, and documentation of corrective action completion and follow-up.

SECTION 4 – SAMPLE CONTROL REQUIREMENTS

This section identifies the requirements for controlling samples of waste and environmental media. The control measures shall include provisions for the identification, handling, storage and shipping, archival, and disposition of the samples, including those identified as nonconforming.

4.1 GENERAL

The following general requirements apply to sample control:

A. Samples shall be controlled and identified in a manner consistent with their intended use.

B. Implementing procedures shall define responsibilities, including organizational interfaces, related to documenting and tracking sample possession from sample collection and identification through handling, preservation, shipment, transfer, analysis, storage, and final disposition.

C. Sample control measures shall include provisions for the identification of the in situ orientation of samples, where appropriate.

D. A chain of custody record form shall be maintained. The chain of custody record shall provide a document trail of all persons that have custody of a given sample, including the date and time of its transfer, from the time the sample is taken until its final disposition.

E. Sample control measures, including identification and documentation, shall ensure that samples can be traced at all times, from collection through final disposition.

F. Where samples have a maximum life expectancy or expiration date, methods shall be employed that preclude the use of the sample beyond its specified life.

G. Representative archival samples from difficult to repeat sample collection activities, such as principal bore holes, shall be maintained.

H. Implementing procedures shall specify the representative samples to be archived if the need to archive samples is identified.

4.2 SAMPLE IDENTIFICATION

A. Each sample shall be uniquely identified from its initial collection through the final disposition of the sample.

B. Sample identification shall be verified and documented before each transfer or release for testing, analysis or disposition.

C. Identification shall be maintained by placing the identification directly on the samples wherever possible or in a manner that ensures that identification is maintained. If direct physical markings are either impractical or insufficient, other appropriate means shall be employed (e.g. physical separation, labels or tags attached to containers, or procedural control). When used, physical markings shall:

1. be applied using materials and methods that provide a clear and legible identification;

2. not affect the sample content or form; and

3. be transferrable to each identified sample part when the sample is subdivided.

D. If sample storage is required, then methods shall be established for the control of sample identification that are commensurate with the planned duration and storage conditions. These methods shall provide for, as applicable:

1. the maintenance or replacement of markings and identification tags that have been damaged during handling or aging; and

2. the protection of identification markings from excessive deterioration due to environmental exposure.

4.3 HANDLING, STORING, AND SHIPPING SAMPLES

Handling, storing, cleaning, packaging, shipping, and preservation of samples shall be conducted in accordance with established work and inspection implementing procedures. Controls shall provide for the maintenance of sample characteristics, sample integrity, and sample identification during storage.

A. The controls shall be consistent with the planned duration and storage conditions, and shall describe actions to be taken where maximum sample life expectancy limits are identified.

B. Storage methodology shall be developed and implemented to ensure that samples are maintained in predetermined environmental conditions commensurate with their intended use and purpose.

C. Samples shall be controlled to preclude the mixing of like samples.

D. Samples on which analysis or tests have been performed shall be identified and maintained in a separate part of the storage area.

E. If required for critical, sensitive, perishable, or high-value samples, specific measures for the handling, storage, cleaning, packaging, shipping, and sample preservation shall be identified and used.

F. Measures shall be established for sample marking and labeling for packaging, shipping, handling, and storage as necessary to adequately identify, maintain, and preserve the sample. Markings and labels shall indicate the need for and the presence of special environments or the need for other special controls, if necessary.

G. Samples requiring special protective equipment (such as containers) and special protective environments (such as inert gas or limits on moisture and temperature) shall be specified, employed, verified, and documented.

4.4 DISPOSITION OF NONCONFORMING SAMPLES

A. Sample requirements that are not met as specified in work controlling documents (such as job packages, travelers, or work requests) shall be identified, documented, evaluated, and segregated in accordance with Section 1.3.

B. The disposition for nonconforming samples shall be identified and documented and shall be limited to "use-as-is," "limited use," or "discard."

C. Samples that have lost their identity shall be documented as nonconforming and shall not be used.

SECTION 5 – SCIENTIFIC INVESTIGATION REQUIREMENTS

This section applies to all technical investigations and design development data collection activities performed in support of the WIPP Compliance Application. Scientific investigations shall be defined, controlled, verified, and documented. Process variables affecting scientific investigations shall be measured and controlled. Test processes conducted in support of such investigations shall be controlled in accordance with the requirements of Sections 2.4, *Inspection and Testing*, 2.4.2.4, *Test Requirements*, and 2.4.3, *Monitoring, Measuring, Testing, and Data Collection Equipment*, as applicable, and as supplemented by the requirements of this section.

5.1 PLANNING SCIENTIFIC INVESTIGATIONS

A. Variables that affect interrelated scientific investigations shall be identified and controlled appropriately in each related investigation.

B. The intended use of the data shall be documented before collection as part of the planning for data processing. Any alternate use of the data shall be evaluated for appropriateness and the justification for use shall be documented.

C. Planning shall consider the compatibility of data processing with any conceptual or mathematical models used at each applicable stage.

D. The technical adequacy of procedures for conducting scientific investigations and their implementation shall be reviewed and approved by qualified persons other than those who prepared the procedures. Changes to procedures for conducting scientific investigations shall be reviewed and approved in a manner commensurate with the original procedure.

E. Development activities used to establish new methods or procedures for conducting scientific investigations shall be documented. The results of developmental testing shall be reviewed for adequacy and approved by qualified persons prior to implementation of the procedures for data collection.

F. Planning shall be coordinated with organizations providing input to or using the results of the investigation.

G. Planning shall include the establishment of acceptance criteria for data quality evaluation, to assure that the data generated are valid, and satisfy documented requirements for the following characteristics, as appropriate: data precision; data accuracy; data representativeness; data comparability; and data completeness.

H. Planning shall include the identification of known sources of error and uncertainty as well as any input data that are suspect or whose quality is beyond the control of the performing organizations.

5.2 PERFORMING SCIENTIFIC INVESTIGATIONS

A. Scientific investigations shall be performed in accordance with requirements documented in test plans, procedures, and scientific notebooks.

B. If deviation from test standards or the establishment of specially prepared test procedures is deemed appropriate (e.g., no nationally recognized test standards exist), the modified or new test procedures shall be documented in sufficient detail to be repeatable, and shall be justified, evaluated, and approved by the cognizant technical organization.

C. Scientific notebooks shall contain, as a minimum:

1. a statement of the objective and description of work to be performed or reference to an approved plan that describes the work;

2. the method(s) used;

3. identification of the samples;

4. the measuring and test equipment used;

5. a description of the work performed and the results obtained, the names of individuals performing the work, and dated initials or signature, as appropriate, of individuals making the entries;

6. a description of changes made to methods used, as appropriate; and

7. the potential sources of uncertainty and error in test plans, procedures, and parameters that must be controlled and measured to assure that tests are valid.

D. Scientific results shall be periodically reviewed, by a qualified individual, to verify that there is sufficient detail to retrace the investigation and confirm the results, if feasible, or repeat the investigation and achieve comparable results without recourse to the original investigator.

E. Practices, techniques, equipment, and manual or computerized methods used to obtain and analyze data shall be verified to assure they are technically sound, and have been properly selected. Controls shall be established for these processes to ensure that they are properly implemented, including controls to prevent tampering.

F. Data collection and analysis shall be controlled by procedures of sufficient detail to allow the processes to be repeated. Where appropriate, quality control checks shall be performed, using recognized methods such as replicate, spike, and split samples; control charts; blanks; reagent checks; replication of the methods used to obtain the results; or alternate analysis methods.

G. Test media (e.g., fluids), when used, shall be characterized and controlled in accordance with test procedures.

H. Scientific notebooks and technical implementation documents shall be maintained as QA records.

5.3 DATA DOCUMENTATION, CONTROL, AND VALIDATION

5.3.1 Data Identification and Usage

A. All data shall be recorded so that they are clearly identifiable and traceable to the test, experiment, study, or other source from which they were generated. Identification and traceability of the data shall be maintained.

B. The method of data recording (e.g., scientific notebooks, log books, data sheets, or computerized instrumentation systems) shall be controlled to avoid data loss and permit data retrievability. Controls shall be established to ensure that data integrity and security are maintained wherever data are stored. Controls shall prescribe how specific types of data will be stored with respect to media, conditions, location, retention time, security, and access. Data shall be suitably protected from damage and destruction during their prescribed lifetime and shall be readily retrievable.

C. Data transfer and reduction controls shall be established to ensure that data transfer is error free (or within a prescribed permissible error rate); that no information is lost in transfer; and that the input is completely recoverable. Data transfer and reduction will be controlled to permit independent reproducibility by another qualified individual. Examples of data transfer include: copying raw data from a notebook into computerized data form or copying from computer tape to disk.

D. Data that are determined to be erroneous, rejected, superseded, or otherwise unsuited for their intended use shall be controlled to prevent their inadvertent use. Controls shall include the identification, segregation, and disposition of inadequate data. The basis for the disposition of erroneous data shall be justified and documented.

E. All processes which change either the form of expression or quantity of data, values, or number of data items (data reduction) shall be controlled by prescribed methods that allow for the validation of the conversion process.

F. Data collection and analysis shall be critically reviewed and questions resolved before the results are either used or reported. Uncertainty limits shall be assigned to the data prior to their use.

5.3.2 Data Validation

Data validation is a systematic process used to review data, to assure that the required data quality characteristics have been obtained. Results of the review may require that qualifiers be placed on the use of the data.

A. Validation methods shall be planned and documented. The documentation shall include the acceptance criteria used to determine if the data is valid.

B. All applicable data collected shall be validated. Validation shall include the following:

   1. the relevant documentation is reviewed to evaluate the technical adequacy, the suitability for the intended use, and the adequacy of the QA record;

   2. the results of the data review shall be documented; and

   3. the reviewer shall be independent of the collection activities.

C. Data validation shall be controlled to permit independent reproducibility by another qualified individual.

D. Data considered as established fact by the scientific and engineering community, such as engineering handbook data, critical tables, etc., do not require validation.

5.4 QUALIFICATION OF EXISTING DATA

This section contains requirements unique to the post qualification of data and information that are relied upon to support the WIPP Compliance Application and were collected prior to the implementation of this QAPD. While the qualification process shall be conducted in accordance with the program control requirements of this QAPD, it is not intended that this QAPD identify the data that are subject to this process, or the technical requirements of the qualification process. The qualification process shall be conducted in accordance with approved procedures that provide for documentation of the decision process, the factors used in arriving at the choice of the qualification method, and the decision that the data are qualified for their intended use.

Existing data shall be qualified using one or a combination of the following methods:

A. Determination that the data were collected under a QA program that is equivalent in effect to ASME NQA-1-1989 edition; ASME NQA-2a-1990 addenda, Part 2.7, to ASME NQA-2-1989 edition; and NQA-3-1989.

B. The use of corroborating data, with the data relationships and inferences clearly identified and justified.

C. Confirmatory testing that is performed and documented.

D. Peer review conducted in a manner that is compatible with NUREG-1297, *Peer Review for High-Level Nuclear Waste Repositories.*

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SECTION 6 — SOFTWARE REQUIREMENTS

6.1 GENERAL

This section of the QAPD establishes Software Quality Assurance (SQA) requirements for CAO participants that develop, procure, maintain, or use computer software that is important to compliance application, and waste characterization.

6.2 APPLICABILITY

A. The requirements in this section apply to computer software that manipulates or produces data that are, in turn, used to process, gather or generate information and whose output is relied upon to make design, analytical, operational, or compliance-related decisions with respect to the performance of the waste confinement, waste characterization, waste transportation, or waste acceptance processes. The application of these requirements shall be prescribed in written plan(s), policies, procedures or instructions.

B. Exempt from the requirements of this section of the QAPD are software that are considered to be "systems software", (e.g., operating systems, administrative and management systems, system utilities, compilers, assemblers, translators, interpreters, query languages, word processing programs, spreadsheets, database managers, and graphing programs) or other software that do not generate data that are used in the formulation of conclusions. However, specific applications supporting Section 6.2A above, written for use within these types of software (e.g. detailed formulas or macros), that can be verified by hand calculations or other means shall meet the following requirements of this section:

1. A listing of the version of the software used, and

2. Documentation that the specific application provides correct results for the specified range of input parameters.

6.2.1 Inventory of Software

An inventory of all software shall be maintained to identify the software name, version, classification, exemption status, operating environment, and the person and organization responsible for the software.

6.2.2 Classification of Software

Software that is not exempt from the provisions of the QAPD shall be classified. The criteria for classification shall be documented in the inventory and shall address the purpose of the software relative to its use in engineering, scientific, testing, data collection, design, analysis, operations activities, and its importance to safety or significance in managing information or augmenting mission-essential decisions.

6.2.3 Software Quality Assurance

Plan(s) for ensuring software quality shall be prepared for each new software project at the start of the software life cycle. For procured software the software quality plan shall be prepared prior to when the software enters the purchaser's organization. Plan(s) may be prepared individually for each software project, or may exist as a generic document to be applied to software prepared within or procured by an organization, or may be incorporated into the overall quality assurance program. The plan shall identify:

A. the software products to which it applies;

B. the types of documentation to be prepared, reviewed, and maintained during the software design, development, implementation, test, and use;

C. the organizations responsible for performing the work and achieving software quality and their tasks and responsibilities;

D. the process for reporting and documenting software discrepancies, evaluating the impact of discrepancies on previous calculations, and determining the appropriate corrective action(s);

E. the standards, conventions, techniques, or methodologies that guide the software development, as well as the methods used to assure implementation of requirements; and

F. the procedure(s) used for establishing and maintaining the integrity of data, embodied mathematical models, and output files.

6.3 SOFTWARE PROCUREMENT

A. The procurement of software and related services shall be performed in accordance with Section 2.3 of this QAPD. This section of the QAPD identifies responsibilities of the sponsoring organization for procured software upon receipt of the software.

B. Once the software has been installed, but prior to its use, the sponsoring organization shall perform user acceptance to verify the functional capability of the software and the acceptability of the supplier supporting documentation (e.g., the user manual, technical specification, and the results of supplier testing).

C. For procured software, the supplier shall report software errors and failures to the sponsoring organization. The sponsoring organization shall also report software errors to the supplier.

6.4 SOFTWARE DEVELOPED UNDER OTHER QA PROGRAMS

Software that has not been developed or approved in accordance with this QAPD shall be evaluated using the criteria of this section. The software shall be uniquely identified and controlled prior to the evaluation, accepted by the sponsoring organization, and placed under configuration control prior to use. This evaluation shall serve as the basis to:

A. Determine the adequacy of existing verification and validation activities, and software documentation to support operation and maintenance; and

B. Identify the activities to be performed and the documentation necessary to accept the software for its intended use and place it under configuration control. The evaluation shall be documented and contain as a minimum:

1. user application requirements;

2. test plans and test cases required to validate the software acceptability; and

3. user documentation per Section 6.8.6.

6.5 SOFTWARE DEVELOPMENT & LIFE CYCLE

A. The activities associated with the evolution of the software shall use an iterative or sequential approach. The approach shall address the analysis of the problem under study, the transformation of the analysis into the design, the implementation of the design into validated computer software, and the development of sufficient documentation to demonstrate that the specified requirements have been successfully implemented in the computer software.

B. The iterative or sequential approach to software development consists of phases, with each phase leading to the development of a specific work product representing components of the software baseline. The software phases are:

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1. definition of requirements;
2. design;
3. implementation;
4. testing;
5. installation and checkout;
6. operations and maintenance; and
7. retirement.

C. Following the development of the Software Quality Plan, no strict sequence of performing activities is required (i.e., activities, may be performed serially or recursively) provided that all the specified requirements for each software development phase are met and the intent of the requirements are not subverted.

6.5.1 Requirements

Software requirements shall be specified, documented, and reviewed. These requirements shall pertain to functionality, performance, design constraints, data attributes, and external interfaces (e.g. hardware limitations) as outlined in Section 6.8.2. Each requirement shall be specified in sufficient detail to permit the accomplishment of design and validation activities. Software requirements shall be traceable throughout the software development cycle, and a verification and validation plan shall be prepared at the conclusion of documenting and approving software requirements.

6.5.2 Design

The software design shall be based on the software requirements, and shall be documented and reviewed. The design shall specify the overall structure (control and data flow) and the reduction of the overall structure into physical solutions (algorithms, equations, control logic, and data structures). The design may necessitate the modification of the requirements documentation and the verification and validation plans.

6.5.3 Implementation

The software design shall be translated into a form (e.g., programming language) suitable for processing by a computer. The executable software shall be analyzed to identify and correct errors.

6.5.4 Testing

A. Test requirements and acceptance criteria shall be specified, documented, and reviewed and shall be based upon applicable design or other pertinent technical bases. Appropriate tests, such as verification tests, hardware integration tests, and in-use tests, shall be controlled. Software testing, using documented test plans, test cases, and test results, is the primary method of software validation.

B. Testing of software shall be performed to the extent that unintended functions are identified, reviewed, and their impact determined and corrected. If appropriate, determine if modifications of the requirements, the design, the implementation, or the test plans and test cases are required.

6.5.4.1 Verification Tests

Verification tests are design-driven and shall be used to demonstrate the capability of the software to produce valid results for test problems encompassing the range of intended use as defined by the software documentation. Testing of software used for operational control shall demonstrate the required performance over the entire range of the controlled function or process. Acceptable test problem methods consist of:

A. hand calculations;

B. calculations using comparable proven problems;

C. empirical data and information from confirmed published data and correlations or technical literature;

D. comparison with other validated software of similar purpose; and

E. manual inspections or qualitative checks, not involving numerical manipulation such as visual inspection of table reformatting (or plotting).

6.5.4.2 Validation Tests

Validation tests are requirements-driven and shall be used to validate software by comparing tests results of software execution with objective evidence obtained by other acceptable means. The results of this evaluation shall be of sufficient scope and depth to prove the capabilities and limitations delineated in the software documentation.

6.5.5 Installation and Checkout

A. During installation and checkout, the software becomes part of a system consisting of applicable software components, hardware, and data. The process of integrating the software with other applicable components may consist of installing both the hardware and software, initializing or creating databases, and verifying that all components of the system have been included in the installation. Test problems shall be developed and documented to permit confirmation of the acceptable performance of the software in its operating environment. Installation and checkout of software shall consist of the:

1. execution of tests for installation and integration;

2. documented acceptance of the software for operational use; and

3. the placement of the software under configuration control prior to use.

B. Completion of the installation and checkout activities establishes the software baseline.

6.5.6 Operations and Maintenance

A. Operation of the software is conducted by the user in accordance with the operation and usage instructions described in the user's documentation. Once the software is made available for use, the software requirements and the design integrity shall be maintained. Sustaining activities shall be performed in a traceable, planned, and orderly manner.

B. In all cases, verification and validation of software shall be completed and approved and corrective actions performed, as necessary, prior to relying upon the software to perform its intended function.

6.5.6.1 Post Installation Maintenance

Software shall be maintained to remove latent errors (corrective maintenance), to respond to new or revised requirements (perfective maintenance), or to adapt the software to changes in the operating environment (adaptive maintenance). Software modifications shall be approved by authorized personnel, documented, verified, validated, and controlled.

6.5.6.2 In-Use Tests

A. Test problems shall be run whenever the software is installed on a different computer or when significant hardware or system software configuration changes are made. These tests shall be documented, performed by an individual technically competent in the subject area(s), and serve as the basis for determining if the software still meets specified requirements.

B. Periodic in-use manual or automatic self-check routines shall be prescribed and performed for those software where computer failure or electronic drift can affect required outcomes.

6.5.7 Retirement

Criteria shall be developed to determine when software can be retired from use. Methods shall be developed to prevent the use of software which is no longer controlled. Upon retirement the support for a software product is terminated.

6.6 SOFTWARE VERIFICATION AND VALIDATION

A. Verification and validation of software shall include the review of software activities, documentation, and tests to ensure that the software:

1. adequately and correctly performs all intended functions; and

2. does not perform any unintended function that either by itself or in combination with other functions can degrade the intended outcomes of the software.

B. Verification and validation shall be performed by any competent individual(s) or group(s) other than those who performed the software design, but the individuals may be from the same organization, including the designer's supervisor, provided the supervisor:

1. did not specify a singular design approach;

2. did not rule out certain design considerations;

3. did not establish the design inputs used; and

4. is the only individual in the organization competent to perform the verification or validation.

6.6.1 Verification

Verification is a formal checking activity performed throughout the evolution of the software life cycle. Verification activities shall be clearly documented, including the identification of those performing and approving the verification. The reviewed documents shall be updated and placed under configuration control. Documentation of review comments and their disposition shall be retained. Comments and their disposition not incorporated shall be retained in accordance with established procedures.

6.6.1.1 Requirements

Verification review(s) of software requirements shall ensure that the requirements are complete, verifiable through testing, consistent, and technically feasible as described in Section 6.5.1.

6.6.1.2 Design

Verification review(s) of software design shall evaluate the technical adequacy of the design approach and ensure that all the requirements have been addressed and that the design is complete, verifiable, (through testing, using approved test plans and test cases) consistent, technically feasible, and traceable to the software requirements as described in Section 6.5.2.

6.6.1.3 Implementation

Verification of the implementation of software design shall consist of the examination of software logic and source code to assure adherence to standards and conventions and to assure that the design has been implemented as described in Section 6.5.3.

6.6.1.4 Testing

Verification of software testing shall consist of reviews to assure that the specified test criteria, the expected results, and the software development documentation have been met as described in Section 6.5.4.

6.6.1.5 Installation and Checkout

Verification of installation and checkout activities consists of reviews to assure that the software baseline has been established.

6.6.2 Validation

A. Software validation is primarily a formal testing activity that shall be performed prior to installation and checkout. It shall be used to demonstrate that the computational model embodied in the software is an acceptable representation of the process or system for which it is intended and that the software produces correct solutions within defined limits for each parameter employed.

B. Validation methods, test data, software-generated results, and conclusions shall be documented in a form that can be understood by an independent individual technically competent to use the software for the particular problem under study. The documentation shall be reviewed to assess the adequacy and correctness of the documentation in meeting the requirements of this section of the QAPD, and the overall acceptability of the software for the intended use.

C. When the adequacy of the conceptual, mathematical, or computational models or the suitability of procedures and methods cannot be established through testing, alternate calculations or reference to previously established standards and practices, a documented peer review shall be performed to meet the software validation requirements.

D. The validation of software modifications shall be subject to selective regression testing to:

1. detect errors introduced during the modification of the systems or system components;

2. verify that the modifications have not caused unintended adverse effects; and

3. to verify that the modified system(s) or system component(s) still meets specified requirements.

6.7 SOFTWARE CONFIGURATION MANAGEMENT

Implementation of baseline and change control processes are fundamental to configuration management. A baseline is a collection of all approved components of the software development cycle. As each component is approved it is added to the overall software baseline. A software baseline serves as the basis for further development and maintenance that can be changed only through the use of formal change control procedures. Change control is the process by which a change to a baseline is proposed, evaluated, and approved or rejected.

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6.7.1 Configuration Identification

Software shall be placed under configuration control as each configuration item is approved. A software baseline shall define the most recent approved software configuration. The configuration items and their associated documentation shall be traceable to one another. A labeling system for configuration items shall be implemented that:

1. uniquely identifies each configuration item;

2. identifies changes to configuration items by revision or version identifier; and

3. provides the ability to uniquely identify each approved configuration of the revised software that is available for use.

6.7.2 Configuration Change Control

A. Changes to software shall be systematically proposed, evaluated, documented, and approved to ensure that the impact and rationale for making the change is carefully assessed prior to updating the software baseline. Changes to previously accepted software shall be subject to the same level of control as the original software.

B. Information concerning approved changes shall be transmitted to all affected organizations. All changes shall be formally evaluated and approved by the organization responsible for the original design, unless an alternate organization has been given the authority to approve the changes. Only authorized changes shall be made to software baselines. Software verification activities shall be performed for the change as necessary to assure that the change is appropriately reflected in the software documentation, and to assure that document traceability is maintained. The degree of software validation shall be commensurate with the nature and scope of the change.

6.7.3 Configuration Status Accounting

Information shall be maintained that reflects the current status of the software baseline. This includes the identity and version of the approved configuration and the status of any proposed and approved changes to the baseline components. This information shall be available to all designated users of the software upon request.

6.8 DOCUMENTATION

Software shall be described in one or more documents that detail user instructions, technical basis, functional requirements, and maintenance-related information sufficient

to allow independent verification allow maintenance, and provide traceability of the documentation to the software. The documentation shall be reviewed by an individual competent in the technical subject area for which the use of the software is intended. The review shall verify that the documentation adequately and accurately reflects the software that comprise the system and it is sufficient to objectively demonstrate that the software requirements have been successfully implemented. Appropriate documentation shall be made available to all designated users of the software.

6.8.1 Procurement Documentation

The applicable quality assurance requirements shall be specified and the required vendor-supplied software documentation, plans, and procedures shall be identified in the software procurement documentation.

6.8.2 Requirements Documentation

A. Software requirements documentation shall outline the requirements that the proposed software must satisfy. The software requirements shall, as applicable, address the following:

1. Functionality - the functions the software is to perform;

2. Performance - the time-related issues of software operation such as speed, recovery time, response time, etc.;

3. Constraints - those imposed on implementation activities - any elements that will restrict design options;

4. Attributes - non time-related issues of software operation such as portability, acceptance criteria, access control, maintainability, etc.; and

5. External interfaces - interactions with people, hardware, and other software.

B. Software requirements shall be traceable throughout the software development cycle.

6.8.3 Design and Implementation Documentation

Software design and implementation documentation consists of a document or series of documents that:

1. Describe the major components of the software design as they relate to the software requirements;

2. Describe the theoretical basis, embodied mathematical model, control flow, control logic, and data structure(s) of the software;

3. Describe the allowable or prescribed ranges for inputs and outputs; and

4. Describe the design in a manner that can be translated into code.

6.8.4 Verification and Validation Documentation

A. Software verification and validation documentation shall consist of associated plans and describe the activities, including the results of reviews and tests, and the criteria for accomplishing the verification of the software throughout the software evolution. The documentation shall also specify the hardware and software configurations pertinent to the software verification and validation.

B. Software verification and validation documentation shall be organized in a manner that allows traceability from the software requirements to both the software design and to the validated capabilities of the software.

6.8.5 Change Documentation

Changes to software shall be formally documented. This documentation shall contain a description of the change, the rationale for the change, and the identification of affected configuration items of the software baseline.

6.8.6 User Documentation

User documentation should be sufficient to allow any qualified user (i.e., one having adequate technical background) to "set up" and run the software and properly respond to errors. User documentation, as a minimum, shall include:

A. the software name and version identifier;

B. statement(s) of functional requirements and system limitations, including hardware;

C. an explanation of the mathematical model(s) and derivation of the numerical methods used in the software design. Physical and mathematical assumptions on which the software is based shall be included along with an explanation of the capabilities and limitations inherent in the software;

D. user instructions that describe user interaction with the software, user messages initiated as a result of improper input and how the user can respond, the identification and description of input and output specifications and formats, and input parameters;

E. a description of any required training necessary to use the software; and

F. user information for obtaining user and maintenance support.

6.8.7 Error Documentation

Documentation of errors detected during the use of the software following installation and checkout shall be maintained. This documentation can be used for process improvement and to prevent future recurrence of errors during the development and maintenance of other software. This documentation shall contain the identity of the software, the classification of the error in terms of its significance to the integrity of the software output, and the disposition of the error corrective action(s).

6.9 PROBLEM REPORTING AND CORRECTIVE ACTION

A. A system shall be established and maintained to record, classify, analyze, track, and report software problems (in released versions) and the associated corrective actions. Problems shall be promptly reported to any affected organizations and the resolution shall be formally processed.

B. When problems are discovered in software or software results, the sponsoring organization shall determine the affect on previous use(s) and the need for corrective action based on sufficient information obtained from the affected users. Corrective action shall ensure that:

1. problems are identified, evaluated, documented, and, if required, corrected;

2. problems are assessed for their impact on past and present uses of the software;

3. changes to software are in accordance with the software configuration management requirements of this section of the QAPD; and

4. results are provided to the affected users along with any revised software documentation.

C. Problems that could significantly impact decisions based upon prior use or that require significant modification to the software shall be identifiable to all users. Errors that have been determined to represent a condition adverse to quality shall be controlled in accordance with Section 1.3 of this QAPD.

6.10 ACCESS CONTROL

To the extent appropriate, controls shall be established to permit authorized and prevent unauthorized access to software that has been accepted in accordance with this section of the QAPD.

APPENDIX A – GLOSSARY

Alternative Calculations: Calculations that are made with alternative methods to verify correctness of the original calculation.

Approval: The documented determination by a responsible individual that a work product is suitable for the intended purpose and shall be used as required.

Assessment/Verification: The act of reviewing, inspecting, testing, checking, conducting surveillances, auditing, or otherwise determining and documenting whether items, processes, or services meet specified requirements. Assessments are performed by or for management. Verifications are performed by the line organization.

Assessment, Internal: An assessment of those portions of an organization's quality assurance program retained under its direct control and within its organizational structure.

Assessment, External: An assessment of those portions of an organizations's quality assurance program not under the direct control or within the organizational structure of the auditing organization.

Assessor: An individual who is qualified to perform assigned portions of an assessment.

Audit: A planned and documented independent assessment to determine by investigation, examination, or evaluation of objective evidence, the adequacy of, and compliance with established procedures, instructions, drawings, and other applicable documents, and the effectiveness of implementation. An audit should not be confused with surveillance or inspection activities performed for the sole purpose of process control or product acceptance.

Auditor: An individual who is qualified to perform assigned portions of an audit.

Calibration: The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, and the corresponding standard or known values derived from the standard.

Certificate of Conformance: A document signed or otherwise authenticated by an authorized individual certifying the degree to which items or services meet specified requirements.

Certification: The act of determining, verifying, and attesting in writing the qualifications of personnel, processes, procedures, or items in accordance with specified requirements.

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Characteristic: A property of a work product that is distinct, describable, and measurable.

Commercial Grade Item: An item that is: (1) not subject to design or specification criteria unique to a CAO program or facility, (2) used in applications other than the nuclear industry, and (3) ordered from the manufacturer or supplier on the basis of specifications set forth in the manufacturer's published product description.

Compliance Application: The compliance certification application submitted to the EPA pursuant to Section 8 (d) (1) of the WIPP Land Withdrawal Act of 1992 (Pub.L. 102-579, 106 Statue 4777) or any compliance re-certification applications submitted to the EPA pursuant to Section 8(f) of the WIPP Land Withdrawal Act.

Condition Adverse to Quality: An all-inclusive term used in reference to any of the following: failures, malfunctions, deficiencies, defective items, and nonconformances, and technical inadequacies. A significant condition adverse to quality is one which, if uncorrected, could have a serious effect on safety, operability, waste confinement, compliance demonstration, or the reliability of the QA program.

Configuration Control: The process of identifying and defining the configuration items in a system, controlling the release and change of these items throughout the system life cycle, and the recording and reporting of the status of configuration items and change requests.

Configuration Item: A collection of hardware or software elements treated as a unit for the purpose of configuration control.

Controlled Document: A document that is prepared, reviewed, approved, and distributed in accordance with established implementation procedures. Controlled documents are subject to controlled distribution and to a defined and controlled change process.

Corrective Action: Measures taken to rectify conditions adverse to quality and, where necessary, to preclude recurrence.

Data Accuracy: The degree to which data agree with an accepted reference or true value. Accuracy is a measure of the bias in a system.

Data Comparability: A measure of the confidence with which one data set can be compared to another.

Data Completeness: A measure of the amount of valid data obtained, compared to the amount that was planned.

Data Precision: A measure of the mutual agreement between comparable data gathered or developed under similar conditions, usually expressed in terms of a standard deviation.

Data Representativeness: The degree to which data accurately and precisely represent a characteristic of a population, a parameter, variations at a sampling point or environmental conditions.

Design Basis: Information that identifies the specific functions to be performed by items and the specific values or ranges of values chosen for controlling parameters as reference bounds for design.

Design Input: Those criteria, parameters, bases, or other design requirements upon which the detailed final design is based.

Design Output: Drawings, specifications, and other documents resulting from the translation of design input requirements.

Design Process: The technical process that commences with the identification of design input and ends with the issuance of design output documents.

Design Review: A documented evaluation of design output during the design process to determine the design adequacy and the conformance to specified acceptance criteria.

Disposal System: The disposal system is any combination of engineered and natural barriers that isolate transuranic waste after disposal. For the purposes of the WIPP, this will include the combination of the repository/shaft system and the controlled area.

Document: Written or pictorial information that describes, specifies, reports, or certifies activities, requirements, procedures, or results.

Document Control: The process that provides for document adequacy review, approval for release by authorized personnel, and distribution for use at the prescribed work locations.

Error: A discrepancy between a computed, observed, or measured value or condition and the true, specified, or theoretically correct value or condition.

Fissionable Materials: A nuclide capable of sustaining a neutron-induced fission chain reaction (e.g., uranium-233, uranium-235, plutonium-238, plutonium-239, plutonium-241, neptunium-237, americium-241, and curium-244).

Graded Approach: The process by which the level of analysis, documentation, verification, and other controls necessary to comply with QA program requirements are developed commensurate with specified factors.

Hazard: A source of danger (e.g., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to a facility or to the environment (without regard to the likelihood or credibility of accident scenarios or consequence mitigation).

Independent Assessment: An assessment that is conducted by a group or organization, having authority and freedom from the line organization, to evaluate the scope, status, adequacy, programmatic implementation, or the effectiveness of a program or process.

Item: An all-inclusive term used in place of any of the following: appurtenance, assembly, component, equipment, material, module, part, structure, subassembly, subsystem, system, unit, or support system.

Lead Auditor: An individual trained, qualified, and certified to organize and direct an audit, report audit findings, and evaluate corrective actions.

Lifetime Records: Records required to be maintained for the useful life of the items to which they pertain while the items are installed in the plant or facility (life of the item), or for the lifetime of the equipment, facilities, or programs to which the records apply.

Line Management: Those management positions that are directly responsible for task products and services. Includes CAO supervisors and team leaders; and contractor management within the context of the definition.

Line Organization: The organization directly responsible for task products and services. Includes CAO offices and teams; and contractor organizations within the context of the definition.

Management Assessment: Assessment performed by management that focuses on how well the integrated quality assurance program is working and should identify management problems that hinder the organization from achieving its objectives in accordance with quality, safety, and environmental requirements.

Measuring and Test Equipment (M&TE): All devices used to measure, gage, test, inspect, or otherwise determine compliance with prescribed technical requirements. Measuring instruments used in taking quantitative or qualitative measurements.

Monitoring and Data Collection Equipment (M&DC): A subcategory of M&TE that is used in the collection of measurement data for the establishment of test conditions and general information and the collection of general measurement data not utilized to verify the conformance of an item or equipment to specified criteria.

Nonconformance: A deficiency in characteristic or record that renders the quality of an item or sample unacceptable or indeterminate.

Nonpermanent Records: Records having value for a specific, limited time and authorized by the National Archives and Records Administration to be destroyed after that time.

Nonreactor Nuclear Facility: Those activities or operations that involve radioactive or fissionable materials in such form and quantity that a nuclear hazard potential exists to the employees or the general public. Incidental use and the generation of radioactive materials in a facility operation (e.g., check and calibration sources, radioactive isotopes used in research and experimental and analytical laboratory activities, electron microscopes, and x-ray machines) would not ordinarily require the facility to be included in this definition. The transportation of radioactive materials , accelerators and reactors, and their operations are not included.

Participant: A DOE contractor organization that furnishes items or services in support of CAO sponsored programs, including those TRU waste generator and storage sites participating in the National TRU Waste Program.

Peer: A person having technical expertise in the subject matter to be reviewed to a degree at least equivalent to that needed for the original work.

Peer Review: A documented, critical review performed by peers who are independent of the work being reviewed. A peer review is an in-depth critique of assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn in the original work. Peer reviews confirm the adequacy of work.

Permanent QA Record: A QA record which is maintained for the life of the Republic.

Permanent Records: Records that have been determined by the National Archives and Records Administration to have historical or other value warranting permanent preservation in the National Archives.

Procedure: A document that specifies or describes how an activity is to be performed. The term "procedure" is also inclusive of instructions and drawings.

Process: A series of actions that achieves an end or result.

Procurement Document: Purchase orders, contracts, specifications, or other documents used to define technical and quality assurance requirements for the procurement of items or services.

Qualification (Personnel): The characteristics or abilities gained through education, training, or experience, as measured against established requirements, such as standards or tests, that qualify an individual to perform a required function.

Qualification Testing: A test that is intended to provide a desired level of confidence that an item meets specified criteria.

Quality: The condition achieved when an item, service, or process meets or exceeds the user's requirements and expectations.

Quality Assurance: All those planned and systematic actions necessary to provide adequate confidence that an item will perform satisfactorily in service.

Quality Assurance Program: The program established to assign responsibilities and authorities, define policies and requirements, and provide for the performance and assessment of work.

Quality Assurance Record: A completed record, or any authenticated portion of a record that provides objective evidence of the quality of items or activities.

Quality System: See *Quality Assurance Program.*

Receipt Inspection: A method of accepting an item or related service from a supplier by examination or testing of the item or related service to verify conformance to specified requirements.

Records: Books, papers, maps, photographs, machine readable materials or other documentary materials, regardless of physical form or characteristics, made or received by an agency of the United States Government under Federal law or in connection with the transaction of public business and preserved or appropriate for preservation by that agency or its legitimate successor as evidence of the organization, functions, policies, decisions, procedures, operations or other activities of the government or because of the informational value of the data in them.

Records Holding Facility: A CAO records storage facility meeting regulatory requirements for the storage of inactive records pending their final disposition.

Repair: The process of restoring an item to a condition such that the capability of an item to function reliably and safely is unimpaired even though that item still does not conform to the original requirement.

Rework: The process by which an item is restored to original specifications by completion or correction.

Sample: A subset of a population (e. g. wastes, environmental media, materials, cores) whose properties are used to gain information about the population.

Scientific and Engineering Software: Software that uses numerical methods to complete scientific, engineering, and mathematical calculations.

Scientific Investigation: Any research, experiment, test, study, or activity that is performed for the purpose of investigating a natural system or the man-made aspects of a geologic repository, including the investigations that support design of the facilities and the waste package.

Scientific Notebook: A record of the methods and results of scientific investigations that is used when the work involves a high degree of professional judgment or trial and error methods or both.

Service: The performance of work, such as design, construction, fabrication, inspection, nondestructive examination, testing, environmental qualification, equipment qualification, repair, installation, or the like.

Significant Condition Adverse to Quality: See Condition Adverse to Quality.

Site Characterization: The program of exploration and research both in the laboratory and the field that is undertaken to establish the natural conditions and the ranges of parameters of a particular site.

Software: Computer programs, procedures, rules, and associated documentation and data pertaining to the operation of a computer system.

Software Baseline: An item or product that has been formally reviewed and agreed upon, and that serves as the basis for further development and that can be changed only through formal change control procedures.

Software Validation: The process of test and evaluation of the completed software to ensure compliance with software requirements.

Software Verification: The process of determining whether or not the product of a given phase of the software development cycle fulfills the requirements imposed by the previous phase.

Software Verification and Validation (V&V): The process of determining whether the requirements for a system or component are complete and correct, the products of each development phase fulfill the requirements or conditions imposed by the previous phase, and the final system or component complies with specified requirements.

Source Verification: A purchaser method of accepting an item or related service from a supplier by monitoring, auditing, surveillance, witnessing, or observing activities performed by the supplier.

Special Process: A process, the results of which are highly dependent on the control of the process or the skill of the operators, or both, and in which the specified quality cannot be readily determined by inspection or test of the product.

Supplier: Any individual or organization who furnishes items or services in accordance with a contract. An all-inclusive term used in place of any of the following: vendor, seller, source, participant, contractor, or subcontractor.

Surveillance: The act of monitoring or observing to verify whether an item, activity, system, or process conforms to specified requirements. Surveillance of a technical work activity is normally done in real time (i.e., the surveillance is accomplished as the work is being performed).

System Software: Software which is used exclusively in the preparation, installation, or operation of executable software applications. Examples of such software include Operating Systems, Administrative and Management Systems, System Utilities, Compilers, Assemblers, Translators, Interpreters, Automated Protocols, Utilities and Tools, Teleprocessing Managers, and Query Languages.

Technical Review: A documented critical review of work that has been performed within the state of the art. The review is accomplished by one or more qualified reviewers who are independent of the work but collectively have equivalent technical expertise to those who performed the original work. The review is an in-depth analysis and evaluation of documents, activities, material, data, or items that require technical verification or validation for applicability, correctness, adequacy, completeness, and assurance that established requirements are satisfied.

Technical Specialist: An individual assigned to an assessment team when the scope, complexity, or special nature of the work to be examined warrants assessment of the technical adequacy of the work or the effectiveness of the technical process.

Testing: An element of verification for the determination of the capability of an item to meet specified requirements, or processes that facilitate the collection of data in conducting scientific investigations, by subjecting the item or environment to a set of physical, chemical, environmental, or operating conditions.

Traceability: The ability to trace the history, application, and location of an item, data, or sample using recorded documentation. As related to metrology, traceability means, the ability to relate individual measurement results through an unbroken chain of calibrations to one or more of the following:

(a) U.S. national standards maintained by National Institute of Standards and Technology or the U.S. Naval Observatory;

(b) fundamental or natural physical constants with values assigned or accepted by the National Institute of Standards and Technology, or

(c) national standards of other countries which are correlated with NIST.

Use As Is: A disposition permitted for a nonconforming item when it can be established that the item is satisfactory for its intended use

Validation: An activity that demonstrates or confirms that a process, item, data set, or service satisfies the requirements defined by the user.

Verification: See Assessment.

WIPP: The Waste Isolation Pilot Plant, as authorized pursuant to Section 213 of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (Pub.L. 96-164; 93 Stat. 1259, 1265) to provide a research and development facility for demonstrating the safe disposal of radioactive wastes produced by national defense activities.

Work: The process of performing a defined task or activity, for example, research and development, operations, maintenance and repair, administration, software development and use, inspection, safeguards and security, data collection, and analysis.

Work Suspension Order: A formal directive issued by management that work must be stopped until resolution of the related significant condition adverse to quality or nonconformance has been achieved.

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APPENDIX B - REFERENCES

National Fire Protection Association (NFPA) Standard 232-1986, *Standards for the Protection of Records*

SNT-TC-1A, June 1980, *The American Society of Nondestructive Testing (ASNT) Recommended Practice*

10 CFR Part 71, Subpart H, *Packaging and Transportation of Radioactive Material, Quality Assurance*

10 CFR Part 830, *Nuclear Safety Management*

40 CFR Part 194, *Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with 40 CFR Part 191 Disposal Regulations*

ASME NQA-1-1989, *Quality Assurance Program Requirements for Nuclear Facilities*

ASME NQA-2a-1990 addenda, Part 2.7, *Quality Assurance Requirements of Computer Software for Nuclear Facility Applications*

ASME NQA-3-1989, *Quality Assurance Program Requirements for the Collection of Scientific and Technical information for Site Characterization of High-Level Nuclear Waste Repositories*

NUREG-1297 (1988), *Peer Review for High-Level Nuclear Waste Repositories*

DOE Order 5700.6C, *Quality Assurance*

DOE Order 5700.6C, *Attachment 1, Quality Assurance Program Implementation Guide*

DOE-EM QARD, *U.S. Department of Energy - Office of Environmental and Waste Management (EM) Quality Assurance Requirements and Description Document*

ANSI/NCSL Z540-1, *General Requirements for Calibration Laboratories and Measuring and Test Equipment*

DOE, Division of Nuclear Safety, G-830.120, *Implementation Guide for use with 10 CFR Part 830.120 Quality Assurance*

NUREG/BR-0167 (1993), *Software Quality Assurance Program and Guidelines*

WIPP/CAO-95-1127, *CAO Operational Plan*

U.S. DEPARTMENT OF ENERGY

CARLSBAD AREA OFFICE

QUALITY ASSURANCE PROGRAM DOCUMENT

REVISION 1

Prepared by: R. Donna Brown 4/22/96
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Manager, CAO **Date**

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APPENDIX RA

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APPENDIX RA

RA.1 INTRODUCTION

The purpose of this analysis is for the assessment of potential human exposure to waste emissions in the atmosphere, and a comparison of that potential exposure to acceptable regulatory levels. 20 NMAC 4.1, Subpart V, §264.601 requires such an assessment for disposal of hazardous waste in a miscellaneous unit.

This assessment applies only to potential air emissions from waste containers during normal operations and the closure period of the Waste Isolation Pilot Plan (WIPP) facility. After final facility closure of the repository, no credible pathway will exist for air emissions. Once sealed, the waste is confined by engineered and natural barriers, which prevent the release of waste constituents into the atmosphere. In this assessment, only gaseous emissions will be considered as a source, because any particulate matter will be contained in the waste containers or panel closures and no liquid waste will be accepted for disposal. Of the gaseous constituents, the assessment is limited to volatile organic compounds (VOCs), which comprise approximately 99 percent of the risk.

This appendix provides calculation details and summaries of risk assessments and worker exposures for the operational phase of the WIPP facility. The analyses included here are the

- risk to a hypothetical member of the public at the boundary of the site
- risk to potential members of the public within the boundary of the site
- assessments of worker exposure on the surface within the site
- assessments of worker exposure in the underground portion of the facility

The exhaust shaft concentration of VOCs, which are used in the exposure and risk assessments included in this appendix, are given in Section RA.2. The exposure scenarios are described in Section RA.3. The air dispersion modeling factors for the assessments are given in Section RA.4. Section RA.5 details the calculations for each risk and worker exposure assessment, and Section RA.6 summarizes the assessment results.

RA.2 EXHAUST SHAFT CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS

During waste disposal at the WIPP facility, closure systems will be used to isolate waste in a filled panel and to eliminate ventilation through these filled panels. Similarly, as individual rooms within a panel are filled, ventilation barriers will be placed on the filled rooms to prevent the flow of ventilation air through these filled rooms and to isolate the rooms. Exhaust shaft concentrations of VOCs will thus vary with the number of filled, closed panels, the number of filled rooms with ventilation barriers within an open panel, and the number of drums in an open room.

RA.2.1 Exhaust Shaft Concentrations of Volatile Organic Compounds from a Closed Panel

Exhaust shaft concentrations of VOCs from a single closed panel are calculated as follows:

$$SCPE = \frac{X \times GR \times HS \times \left(\frac{1\ mole\ fraction}{1 \times 10^6\ ppmv}\right) \times MW \times (1 \times 10^6\ \mu g/g) \times P_c}{V \times 0.0283\ m^3/ft^3 \times (525{,}600\ \text{min/year})} \quad \text{(RA-1)}$$

where,

$SCPE$	=	exhaust shaft concentration of the VOC from a single closed panel, $\mu g/m^3$
X	=	number of drums in a closed panel, 81,000 drums/panel
GR	=	effective gas generation rate, 0.5 moles/drum/year
HS	=	weighted average headspace concentration of the VOC, ppmv
MW	=	molecular weight of the VOC, g/mole
P_c	=	number of closed panel equivalents, 1 panel
V	=	mine ventilation exhaust rate, 425,000 ft^3/min (12,036 m^3/min)

Weighted average headspace concentrations are based on sampling and analysis of wastes from the Idaho National Engineering Laboratory (INEL) and the Rocky Flats Environmental Technology Site (RFETS). The weighted average headspace concentrations are derived in Appendix VOC.

During the placement of waste at WIPP, closure systems will be used to isolate wastes in a full panel and to eliminate ventilation through these filled panels. Assuming a continuous fresh air flow across the filters, VOCs will diffuse from the drums at a rate that is dependent on the concentration gradient across the filters and the diffusion properties of the VOCs, as described in Appendix DIF. After a panel is filled and the ventilation barrier is installed, which is the first step in the closure process, fresh air will no longer flow across the waste drums, and VOC concentrations in the dead air space above the filter will begin to build up and approach the concentrations in the drum headspace. Therefore, the maximum concentration of VOCs that would be present in the panel atmosphere would be equivalent to the average drum headspace concentration. For the risk assessments, it is conservatively assumed that the average drum headspace concentrations serve as a constant source of VOCs.

The ventilation barrier design includes the use of low-permeability materials that restrict the diffusion of VOCs from the panel; therefore, gas pressurization is assumed to be the only process that would cause VOCs to migrate beyond a panel with a ventilation barrier installed (Appendix CLP, Attachment I1). Pressurization within a panel will be caused by gas generation and volume reduction due to creep closure of the repository. The panel closure systems will be designed to withstand some pressure buildup; however, for this

evaluation, the leakage rate from the panel closure system is conservatively assumed to be equivalent to the effective gas generation rate.

Appendix GAS includes information on gas generation by WIPP waste. Of the gas-generating mechanisms described in Appendix GAS, microbial degradation will contribute the most to the generation rate during the time periods of interest. The best estimate for gas generation from microbial degradation under humid conditions is 0.1 moles of gas per drum per year (see Appendix GAS). The recommendation in Appendix GAS is for a rate of 0.02 moles/kg/year. This results in 0.2 moles/drum/year, based on 10kg of cellulosics per drum. However, the memo in Appendix GAS states that mocrobial degradation only occurs half of the time. This time results in a 0.1 mole/drum/year rate. For the period of time in this analysis, there is not expected to be enough brine flow into panels to create an inundated environment, which would be necessary to produce these and higher gas generation rates. This analysis conservatively assumes that a humid condition will exist to produce gas at a rate of 0.1 moles per drum per year.

Although Appendix GAS states that the maximum expected value for any one drum of waste is 0.4 moles per drum per year, the lowest expected value for any one drum is 0 moles per drum per year. A discussion of the relationship between gas generation, brine inflow, and creep closure can be found in Appendix CLP, Section I-1e(4). In reality, under the conditions that will initially exist in a closed panel, the predominant degradation mechanisms may consume gas at a rate faster than it is produced. This outcome is a function of the availability of nutrients to sustain microbial activities. Indications of gas consumption activities are in Francis and Gillow (1994), where they reported 200-day experiments (see Appendix GAS).

The average creep closure rate, as discussed in Appendix CLP, Attachment I1, will result in a reduction of the panel void volume of 28,672 ft^3 (812 m^3) per year for each panel. Converting this volumetric reduction rate to a molar (gas) displacement rate, using the Ideal Gas Law:

$$GDR = \frac{812\ m^3}{panel/year} \times \frac{P}{RT} \qquad \text{(RA-2)}$$

Because one full panel contains 81,000 drums of waste, this rate expressed on a drum basis is:

$$GDR = \frac{812\ m^3}{panel/year} \times \frac{1\ atm}{\left(\frac{0.082\ L \cdot atm}{mole \cdot K}\right) \times (298K)} \times \left(\frac{1\times10^3\ L}{m^3}\right) \times (panel/81{,}000drum)$$

$$GDR = 0.4\ mole/drum/year$$

An effective gas generation rate (gas generation rate plus gas displacement rate) can be calculated as follows:

$$GR = GGR + GDR \qquad \text{(RA-3)}$$

where

$$GDR = (4.74 \times 10^3 \ mole/panel/year) \times (panel/81{,}000 drum)$$

- GR = effective gas generation rate, mole/drum/year
- GGR = gas generation rate due to microbial degradation in a humid environment, 0.1 mole/drum/year
- GDR = gas displacement rate due to salt creep (creep closure), 0.4 mole/drum/year

$$GR = (0.1 \ mole/drum/year) + (0.4 \ mole/drum/year)$$

$$GR = 0.5 \ mole/drum/year$$

RA.2.2 Exhaust Shaft Concentrations of Volatile Organic Compounds from an Open Panel without Ventilation Barriers

Exhaust shaft concentrations of VOCs from an open panel without ventilation barriers on the filled rooms are calculated using the equation

$$SOPE = \frac{X \times ADE_{VOC} \times MW \times (1 \times 10^6 \ \mu g/g) \times P_o}{V \times 0.0283 \ m^3/ft^3 \times \left(\frac{1}{60 \ s/min}\right)} \qquad \text{(RA-4)}$$

where

- $SOPE$ = exhaust shaft concentration of the VOC from a full open panel without ventilation barriers on the filled rooms, $\mu g/m^3$
- X = number of drums in a full panel, 81,000 drums/panel
- ADE_{VOC} = the average drum VOC emission rate, mole/s/drum
- MW = molecular weight of the VOC, g/mole
- P_o = number of open panel equivalents, 1 panel
- V = mine ventilation exhaust rate, 425,000 ft^3/min (12,036 m^3/min)

The average drum emission rate for each VOC is calculated from the diffusion rate using the following equation:

$$ADE_{VOC} = D_{VOC} \times MF_{VOC} \times 31{,}536{,}000\ s/year \qquad \text{(RA-5)}$$

where

ADE_{VOC}	=	average drum VOC emission rate, mole/drum/year
D_{VOC}	=	the VOC diffusion characteristic through a model NFT-013 carbon composite filter, mole/s/mole fraction/drum
MF_{VOC}	=	mole fraction of the VOC, mole/mole

The mole fraction of each VOC is calculated from its weighted average headspace concentration by:

$$MF_{VOC} = (HS_{VOC}) \times (10^{-6}\ mole\ fraction/ppmv) \qquad \text{(RA-6)}$$

where

MF_{VOC}	=	mole fraction of the VOC, mole/mole
HS_{VOC}	=	average headspace concentration for VOC, ppmv.

For filter-specific diffusion characteristics, the ratio of VOC-to-H_2 diffusivities in air are calculated as follows:

$$\frac{D_{VOC\ -\ air}}{D_{H_2\ -\ air}} = \left(\frac{P_{c,VOC}}{P_{c,H_2}}\right)^{1/3} \times \left(\frac{T_{c,VOC}}{T_{c,H_2}}\right)^{-1/2} \times \left[\frac{\left(\frac{1}{MW_{air}} + \frac{1}{MW_{VOC}}\right)}{\left(\frac{1}{MW_{air}} + \frac{1}{MW_{H_2}}\right)}\right]^{1/2} \qquad \text{(RA-7)}$$

where

$D_{VOC\text{-}air}$	=	diffusivity of the VOC in air, mole/s/mole fraction/drum
$D_{H2\text{-}air}$	=	diffusivity of hydrogen in air, mole/s/mole fraction/drum
$P_{c,\,VOC}$	=	critical pressure of the VOC, atm
$P_{c,H2}$	=	critical pressure of hydrogen, 12.8 atm
$T_{c,VOC}$	=	critical temperature of the VOC, K
$T_{C,H2}$	=	critical temperature of hydrogen, 33.2K
MW_{VOC}	=	molecular weight of the VOC, g/mole
MW_{H2}	=	molecular weight of hydrogen, 2.016 g/mole
MW_{air}	=	molecular weight of air, 28.946 g/mole

The filter-specific VOC diffusion characteristics from the ratio of VOC-to-H_2 diffusivities in air are calculated using the following equation:

$$D_{VOC} = \left(\frac{D_{VOC\ -\ air}}{D_{H_2\ -\ air}} \right) \times D_{H_2} \qquad \text{(RA-8)}$$

where

D_{VOC} = the VOC diffusion characteristic through a model NFT-013 carbon composite filter, mole/s/mole fraction/drum

D_{H2} = the diffusion characteristic for hydrogen through a model NFT-013 carbon composite filter, 1.17E-5 mole/s/mole fraction/drum.

VOC-specific properties for calculating diffusion rates, the SOPE, and the SCPE are given in Table RA-1.

VOCs considered in all calculations are indicator VOCs selected using the screening technique in EPA (1989, 5-23). These indicator VOCs represent approximately 99 percent of the risk due to air emissions. This screening methodology is described in detail in Appendix VOC.

Table RA-1. Properties Used in Calculating Diffusion Rates and Emission Concentrations

Constituent	*Pc* Critical Pressure (atm)	*Tc* Critical Temperature (K)	*MW* Molecular Weight (g/mole)	*Dvoc* Diffusivity (mole/s/mole fraction/ drum)	*HS* Weighted Average Concentration (ppmv)
Carbon Tetrachloride	45	556.4	153.84	1.21E-06	375.5
Chlorobenzene	44.6	632.4	112.56	1.16E-06	12.5
Chloroform	54	536.4	119.39	1.34E-06	25.3
1,1-Dichloroethylene	51.3	495	96.95	1.40E-06	11.5
1,2-Dichloroethane	53	561.6	98.97	1.32E-06	9.1
Methylene Chloride	60	510	84.94	1.47E-06	368.5
1,1,2,2-Tetrachloroethane	57.6	644.5	167.86	1.21E-06	9.4
Toluene	40.6	591.7	92.13	1.19E-06	19.4
1,1,1-Trichloroethane	42.4	545	133.42	1.21E-06	317.1

ppmv = parts per million by volume

RA.2.3 Public Exposure Concentrations of Volatile Organic Compounds

As the waste disposal operations proceed, an increasing number of drums are emplaced in the open panel contributing to the exhaust shaft concentration. In addition, an increasing number of closed panels contribute to the exhaust shaft concentration over time.

The exhaust shaft concentrations for nine closed and one open panel are conservative for any exposure prior to filling the last panel. From the full open panel, maximum VOC emissions will depend on the presence of ventilation barriers outside the filled rooms. Two levels of conservatism are possible: (1) assuming that rooms in the full panel do not have ventilation barriers installed and VOC emissions are from all drums (i.e., 81,000) in the panel and (2) assuming that the filled rooms within the open panel have ventilation barriers installed and only the drums (i.e., 11,571) in the last room are freely contributing to VOC emissions. The average exhaust shaft VOC concentration over the operational period of the facility will be lower than the maximum for nine closed panels and one full open panel.

The maximum exhaust shaft concentrations of VOCs from nine closed panels and one open panel without ventilation barriers outside the filled rooms is calculated as EC_{max} using the equation

$$EC_{max} = \left(P_c \times SCPE \right) + \left(P_o \times SOPE \right) \qquad \text{(RA-9)}$$

where

EC_{max} = exhaust shaft concentration of the VOC from nine closed panels and ome full open panel without ventilation barriers outside the filled rooms, $\mu g/m^3$

P_c = number of closed panel equivalents, nine panels

P_o = number of open panel equivalents, one panel

RA.2.4 Surface Worker Exposure Concentration

The maximum exposure concentration for the worker on the surface of the facility is based on emissions from nine closed and one full open panel with ventilation barriers on six of the seven rooms. The surface worker exposure concentration is calculated from the exhaust shaft concentration multiplied by the ADF. The exhaust shaft concentration is calculated:

$$ECS_{MAX} = \frac{(AOPE_{VOC}) + (P_C \times R_C \times ACRE) \times MW \times 1 \times 10^6 \ \mu g/g}{Q \times 0.0283 \ m^3/f^3 \times 525{,}600 \ \text{min/yr}} \qquad \text{(RA-10)}$$

where

ECS_{MAX}	=	exhaust shaft concentration of the VOC from nine closed panels and one full open panel with ventilation barriers, μg/m^3
$AOPE_{VOC}$	=	average open panel VOC emission rate, mole/panel/year
P_c	=	number of closed panel equivalents, nine panels
R_c	=	number of closed rooms in the open panel, seven rooms/panel
$ACRE_{VOC}$	=	average closed room VOC emission rate, mole/room/year
MW	=	molecular weight of the VOC, g/mole
Q	=	ventilation rate through the mine, 425,000 ft^3 /minute (12,036 m^3/min)

The average open panel yearly emission rate (AOPE) for each VOC is based on the number of full rooms, the number of drums in the open room, and the emission rates from each type of room. AOPE for one open and six closed rooms is calculated as:

$$AOPE_{VOC} = (R_o \times AORE_{VOC}) + (R_c \times ACRE_{VOC}) \qquad \text{(RA-11)}$$

where

$AOPE_{VOC}$	=	average open panel VOC emission rate, mole/panel/year
$AORE_{VOC}$	=	average open room VOC emission rate, mole/room/year
$ACRE_{VOC}$	=	average closed room VOC emission rate, mole/room/year
R_o	=	number of open rooms in the open panel, one room/panel
R_c	=	number of closed rooms in the open panel, six room/panel

The average open room emission rate (AORE) is dependent on the number of drums that have been emplaced in the room and the diffusion of VOCs across the drum vent filters. Assuming a continuous fresh air flow across the filters, VOCs will diffuse from the drums at a rate that is dependent on the concentration gradient across the filters and the diffusion properties of the VOCs, as described in Appendix DIF. The AORE is calculated using the equation

$$AORE_{VOC} = ADE_{VOC} \times D \qquad \text{(RA-12)}$$

where

$AORE_{VOC}$	=	average open room VOC emission rate, mole/room/year
ADE_{VOC}	=	average drum VOC emission rate, mole/drum/year
D	=	number of drums in the room, drum/room.

The average yearly closed room emission rate (ACRE) for each VOC is calculated as:

$$ACRE_{VOC} = (GR) \times (11{,}571\ drum/room) \times MF_{VOC} \qquad \text{(RA-13)}$$

where

$ACRE_{VOC}$ = average yearly closed room VOC emission rate, mole/room/year
GR = effective gas generation rate, mole/drum/year
MF_{VOC} = VOC mole fraction, mole/mole

GR is defined as above for gas generation through closed panels. Similar to panel closures, ventilation barriers will be used to isolate wastes in a full room and to eliminate ventilation through these filled rooms. As for panels (Section RA.2.1), gas pressurization is assumed to be the only process that would cause VOCs to migrate beyond a closed room. The effective gas generation rate used for calculating ACRE, then, is 0.5 moles/drum/year.

RA.2.5 Underground Worker Exposure Concentration

The maximum exposure concentrations of VOCs to workers is the hazardous waste worker who is emplacing waste at the beginning of the next open room, which will place the worker downstream in the ventilation air of previously filled rooms with ventilation barriers, but always upstream of the open room waste. This concentration is calculated as follows:

$$ECU_{max} = \frac{(R_C \times ACRE_{VOC}) \times MW \times 10^6\ \mu g/g \times P_o}{Q \times 0.0283\ m^3/ft^3 \times 525{,}600\ \text{min/year}} \qquad \text{(RA-14)}$$

where

ECU_{max} = exposure concentration of the VOC from one full open panel with ventilation barriers on the filled rooms, $\mu g/m^3$
R_c = number of closed rooms in the open panel, six room/panel
$ACRE_{VOC}$ = average closed room VOC emission rate, mole/room/year
MW = molecular weight of the VOC, g/mole
P_o = number of open panel equivalents, one panel
Q = ventilation rate through the open room, 35,000 ft^3 /minute (991 m^3/min)

RA.3 EXPOSURE ASSESSMENT

In order to assess the potential public exposure to hazardous constituents in the air, first the probable public activities both outside and inside the WIPP site boundary during the 35-year operational/closure time frame are evaluated. Exposure scenarios for potential receptors both outside and inside the WIPP site boundary are then described.

RA.3.1 Public Activity Outside the WIPP Site Boundary

The most prevalent public activity currently outside the WIPP site boundary is oil and gas production. Several wells are located along the boundary, and drilling activities may

require oil workers to be present continuously, but not for several years at a time. Oil activities could be ongoing 24 hours a day, seven days a week, up to six months at a time, but the same oil workers are not likely to be present for several years.

Since the land immediately adjacent to the WIPP site boundary is federal or state land, a family could not theoretically build a house or dwelling at the boundary; however, one could potentially occupy that space for long periods of time. Currently, there are only 27 residents within a 10-mi (16-km) radius of the WIPP facility, and the closest dwelling is the Mills ranch house approximately 0.75 mi (1.2 km) south of the southwest corner of the WIPP site boundary (Figure RA-1).

RA.3.2 Public Activity Inside the WIPP Site Boundary

As shown in Figure RA-1, the area of land that lies within the WIPP site boundary contains approximately 10,240 acres (4,144 hectares) including Sections 15-22 and 27-34 in Township 22 South and Range 31 East. This area contains three other distinct boundaries that limit public access. The innermost boundary, which contains most of the WIPP facility structures, is surrounded by a chain link fence and covers approximately 35 acres (14 hectares) in Sections 20 and 21. This fenced area is known as the Property Protection Area. Only persons on official business are allowed within this area. Access is controlled by a 24-hour per day security force. The next area is surrounded by a barbed wire fence, covers approximately 424 acres (172 hectares), and is posted "No Trespassing." This area is known as the Exclusive Use Area. The public may access this area for short periods of time for limited purposes. This area is patrolled frequently by the security force. The third area covers approximately 1,450 acres (587 hectares), is posted "No Trespassing," and is known as the Off Limits Area. Within this area, certain activities, such as hunting, are prohibited. Other forms of public access are allowed with permission of the DOE. The fourth area covers approximately 10,240 acres (4,144 hectares) and is leased for cattle grazing.

Public access is allowed inside the WIPP site boundary for various activities and for various periods of time. Activities that take place inside the WIPP site boundary are described in detail in DOE (1993).

RA.3.2.1 Agricultural Uses

All the land within the WIPP site boundary outside the Exclusive Use Area has been leased for grazing, which is the only significant agricultural activity in the vicinity. There are two leaseholders, as shown in Figure RA-1. The Livingston Ridge Allotment, currently leased by Kenneth Smith, Inc., of Carlsbad, New Mexico, includes 2,880 acres (1,166 hectares) within the northern portion of the WIPP Site. J.C. Mills of Abernathy, Texas, current lessee of the Antelope Ridge Allotment, has lease rights to 7,360 acres (2,979 hectares) within the southern portion of the WIPP Site.

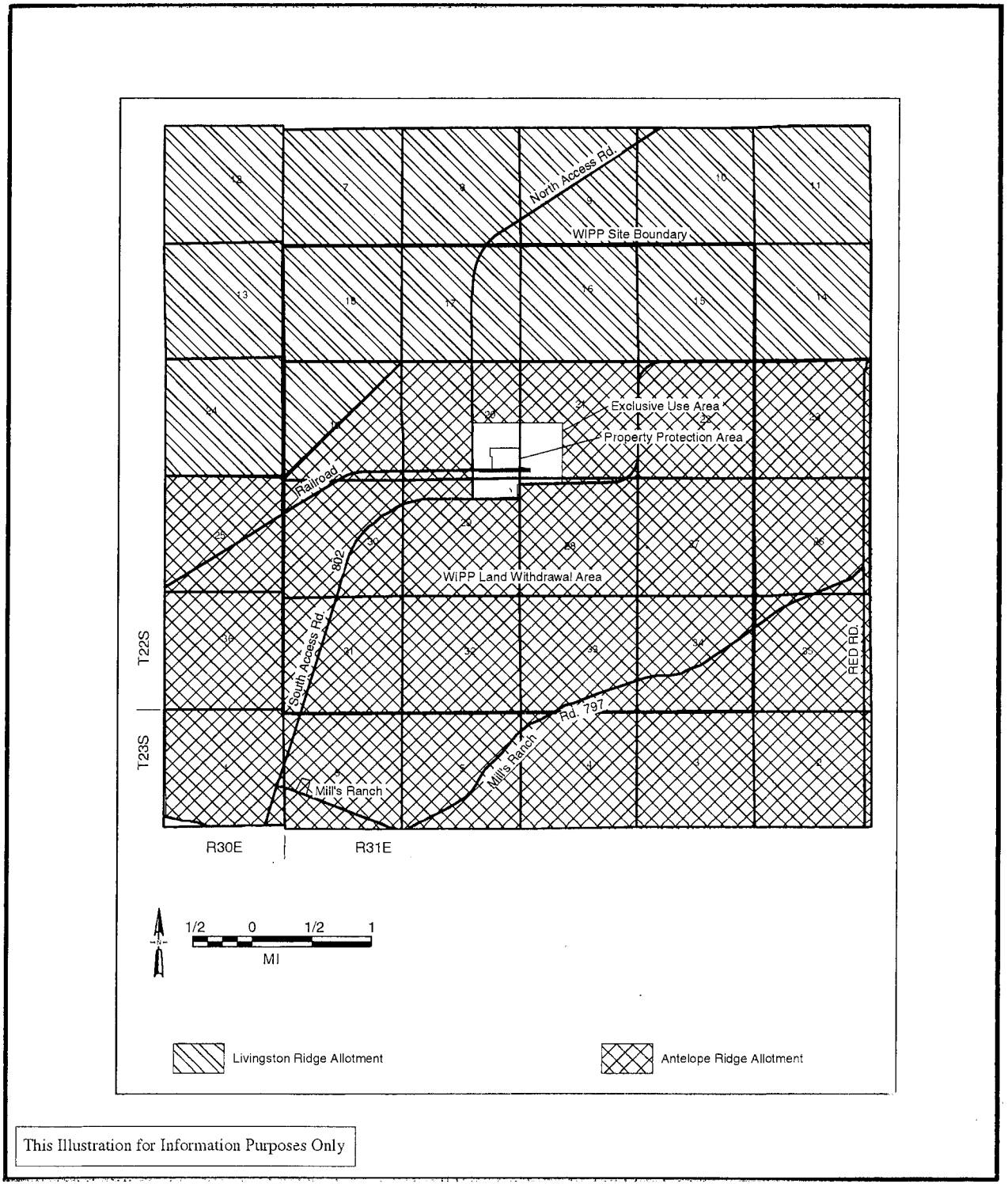

Figure RA-1. Grazing Allotments in the Vicinity of the WIPP Land-Withdrawal Area

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RA.3.2.3 Recreational Activities

Hunting, camping, horseback riding, hiking, wildlife watching, and sightseeing are all activities that may be permitted inside the WIPP site boundary up to the boundaries marked "No Trespassing." Campers are required to check in with WIPP Security personnel before establishing camp. Although all of these activities are allowed and managed (DOE 1993), no member of the public is expected to perform any of these activities on WIPP property for long periods of time. Hunting durations are short and are established and enforced by the State of New Mexico. The other activities mentioned above are not likely to occur, because the WIPP facility is in a hot, arid environment, and much more scenic areas are in the vicinity for these activities (e.g., Guadalupe Mountains).

RA.3.2.4 Scientific Research

Some scientific research is conduced for WIPP-related activities (i.e., archaeological and geological studies), but public research inside the WIPP site boundary does not typically occur. If such studies were to occur in the future, the time frame for such studies would be short (hours, days, or weeks at most), and would not pose significant exposure concerns for the public.

RA.3.3 Public Exposure Outside the WIPP Site Boundary

The worst-case exposure just outside the WIPP site boundary is conservatively assumed to occur to the hypothetical member of the public who could occupy space on the boundary up to 24 hours a day, 365 days a year, for 35 years (EF = 8760 hours/year, ED = 35 years, AT = 613,200 hours). This exposure scenario is referred to in following sections as the ***Boundary Public Receptor***. The Boundary Public Receptor exposure scenario is not considered a realistic scenario because residents around the facility live some distance away from the site boundary. More realistic exposure scenarios are those relating to ranching activities within the site boundary, as discussed below.

RA.3.4 Public Exposure Inside the WIPP Site Boundary

The worst-case exposure of a member of the public to hazardous constituents released into the air around the WIPP facility is assumed to occur to the rancher who may be on land leased for cattle grazing. The exposure is assumed to be equally likely for any point within the area. The assumption is conservative, because the ranch hand is typically inspecting fences and watering facilities, which takes him to isolated locations either on the periphery of the grazing area or to locations which are not principle downwind locations. DOE is responsible for inspecting the fence on the boundary of the grazing allotment adjacent to WIPP. Because no actual statistics exist regarding the amount of time a ranch hand may spend at any field location on a ranch, the DOE had to make several assumptions in order to prepare the exposure analysis. The exposure time assumptions have been made in a manner that tends to overestimate exposures. First, it is assumed that a ranch hand spends eight hours per day, five days per week (EF = 2080

hours/year) for 35 years (ED = 35 years, AT = 613,200 hours) working the ranch. This is conservative, because ranchers rotate pastures to protect them from overgrazing. As a result, there will be extended periods of time when there will be no activity in the grazing areas within the WIPP site boundary. Second, it is assumed that a single ranch hand from each ranch works only on the portions of the leases within the WIPP site boundary. This is conservative, because the lease covers a much larger area than what lies within the WIPP site boundary. Third, the exposure assessment is based on the average ground level, rather than inhalation level, concentrations of hazardous constituents for each area of grazing-leased land between the WIPP site boundary and the Exclusive Use Area.

For the exposure assessment, two hypothetical receptors are evaluated, corresponding to ranchers working on each of the two grazing allotments within the WIPP site boundary. The exposure scenarios are referred to in following sections as ***Livingston Ridge Rancher*** and ***Antelope Ridge Rancher***.

RA.3.5 Occupational Exposure Inside the WIPP Site Boundary

Two additional exposure scenarios that hypothetically occur within the WIPP site boundary are also evaluated in this appendix. One additional scenario is that of a worker who works on site 1,920 hours/year (EF = 1,920 hours/year), for ten years (ED = 10 years, AT = 613,200 hours) on the surface near the exhaust shaft. The 1,920 hours are the hours for an employee after removing vacations and holidays. This is conservative, since workers spend approximately ten percent of their time off site at training, travel, and meetings. The ten-year exposure duration represents normal turnover in employees. Turnover, in this case, includes new employment, new positions, and new locations at the facility. The exposure location chosen corresponds to the maximum VOC exposure at the surface within the site boundary and is located in the property protection area. The scenario is referred to in following sections as ***Surface Worker***.

The second scenario is that of an underground worker who works "downwind" of a full, but closed room. This worker performs hazardous waste duties and is estimated to be working downstream of a closed room while beginning to fill each subsequent room 33 hours/year for ten years. The underground worker exposure scenario is a worst-case exposure scenario, and is referred to in the following sections as ***Underground Worker***. The exposure frequency was developed based on the expected operational throughput times in Figure 3-5, Chapter 3 of the NMVP and the number of waste locations in the area of a room (130) that is downwind from a room exhaust. The 130 positions represents stacks that are three high, so 390 waste units (seven-pack, Standard Waste Box (SWB), four-pack, or ten-drum overpack (TDOP)) are involved. These configurations represent approximately 100 pallets of waste, which take 30 minutes per pallet to emplace or 50 hours per room. Backfill requires 30 minutes every time a row of five stacks is complete. Since there are 26 rows in this area (130 ÷ 5), 13 hours for emplacing backfill is needed. This results in a total of 63 hours per room that are spent downwind from full rooms. Finally, a waste worker will be downwind for Rooms 6 through 1; however, the amount of waste in the Room 1 entry is 32 positions (1/4 of Rooms 2-6), so that the total exposure time in a panel is 63 × 5.25 = 330 hours. This exposure occurs over the 2.5

years required to fill the panel and is shared equally by four waste workers resulting in an annual exposure of 330 ÷ 2.5 ÷ 4 = 33 hours/year.

RA.4 AIR DISPERSION MODELING

This section presents the results of specific air dispersion modeling performed inside and outside the WIPP site boundary that are used in assessing the scenarios described in Section RA.3 for exposures at the surface, that is, for the Boundary Public, Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker. The Long-Term Version of the Industrial Source Complex (ISCLT3) model, (EPA 1995) was used for the air dispersion modeling. Concentrations were modeled in accordance with EPA (1992). Details of the modeling described in Appendix ADM.

To determine areas where the maximum concentrations may occur, the air dispersion model was run with a coarse receptor grid of 437 yds (400 m) (see Figure RA-2). To model the boundary public exposures, the air dispersion model was run with a fine receptor grid of 11 yds (10 m) around the point of highest concentration predicted on the boundary during the coarse grid run. To determine the exposure concentrations at the WIPP site boundary, the annual average concentration anywhere on the boundary is used to determine the Air Dispersion Factor (ADF) for the boundary public receptor. That average concentration, which was modeled from an arbitrary 1,000 $\mu g/m^3$ source, is divided by 1,000 $\mu g/m^3$ to arrive at the ADF used in the risk calculations presented in Section RA.5. The ADF for the boundary public receptor is 1.2×10^{-4} (Table RA-2).

For the rancher exposure assessments, the coarse grid run mentioned above was used. This grid covers all of the leased land within the WIPP site boundary, as shown in Figure RA-1. All concentrations derived in the model run were then averaged for each lease, representing an average exposure concentration throughout the leased land inside the boundary. The resulting ADF for the Livingston Ridge Allotment is 9.8×10^{-5} and the ADF for the Antelope Ridge Allotment is 6.7×10^{-5}.

For determining the exposure concentrations to the surface worker, the model was run with a fine receptor grid of 11 yds (10 m) around the area with the highest concentration inside the WIPP site boundary predicted during the coarse grid run (see Figure RA-3). This area was near the exhaust fans. The ADF for the surface worker is 1.23×10^{-2}.

RA.5 RECEPTOR CONCENTRATIONS AND RISK CALCULATIONS

Risks and hazards for the public exposure scenarios described in Section RA.3 are described in this section. Also presented are evaluations of VOC concentration levels to worker receptors. The equations used in assessing excess risk from carcinogens and hazard from noncarcinogens are derived and given. The calculations use exposure factors as appropriate for the exposure scenarios. ADFs are used for the Boundary Public, Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker scenarios. The calculations assume the receptors are subjected to concentrations based on maximum exhaust shaft VOC concentrations, which are those concentrations that result from

emissions from nine closed and one full open panels. The full open panel is conservatively assumed to contain no room closures for assessing impacts to the public at the surface, that is, the Boundary Public, Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker scenarios. These scenarios also include model estimates of concentrations from air dispersion. For assessing impact to an underground worker, only one full open panel is used and is assumed to contain room closures. Since this worker is exposed to underground concentrations, no air dispersion takes place before exposure.

RA.5.1 Public Risk Outside the WIPP Site Boundary

The Boundary Public exposure scenario is evaluated in this section. An ADF of 1.2×10^{-4} is used in assessing risk from emissions from nine closed and one open panel equivalents, with no credit taken for room closures within the open panel.

RA.5.1.1 Carcinogens

For carcinogens, risk is calculated as follows:

$$Risk = \frac{EC \times ADF \times URF \times EF \times ED}{AT} \qquad \text{(RA-15)}$$

where

- $Risk$ = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
- EC = maximum exhaust shaft concentration for the VOC, µg/m^3, EC_{max}
- ADF = air dispersion factor, unitless, 1.2×10^{-4}
- URF = unit risk factor for VOC, $(\mu g/m^3)^{-1}$
- EF = exposure frequency, 8,760 hours/year (24 hours/day × 365 days/year)
- ED = exposure duration, 35 years
- AT = averaging time, 613,200 hours (24 hours/day × 365 days/year × 70 years)

Equation (RA-15) was derived from equations in EPA (1989); the derivation is shown below.

EPA (1989, 6-44), provides the calculation of residential exposure from inhalation of airborne (vapor phase) chemicals as:

$$Intake = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad \text{(RA-16)}$$

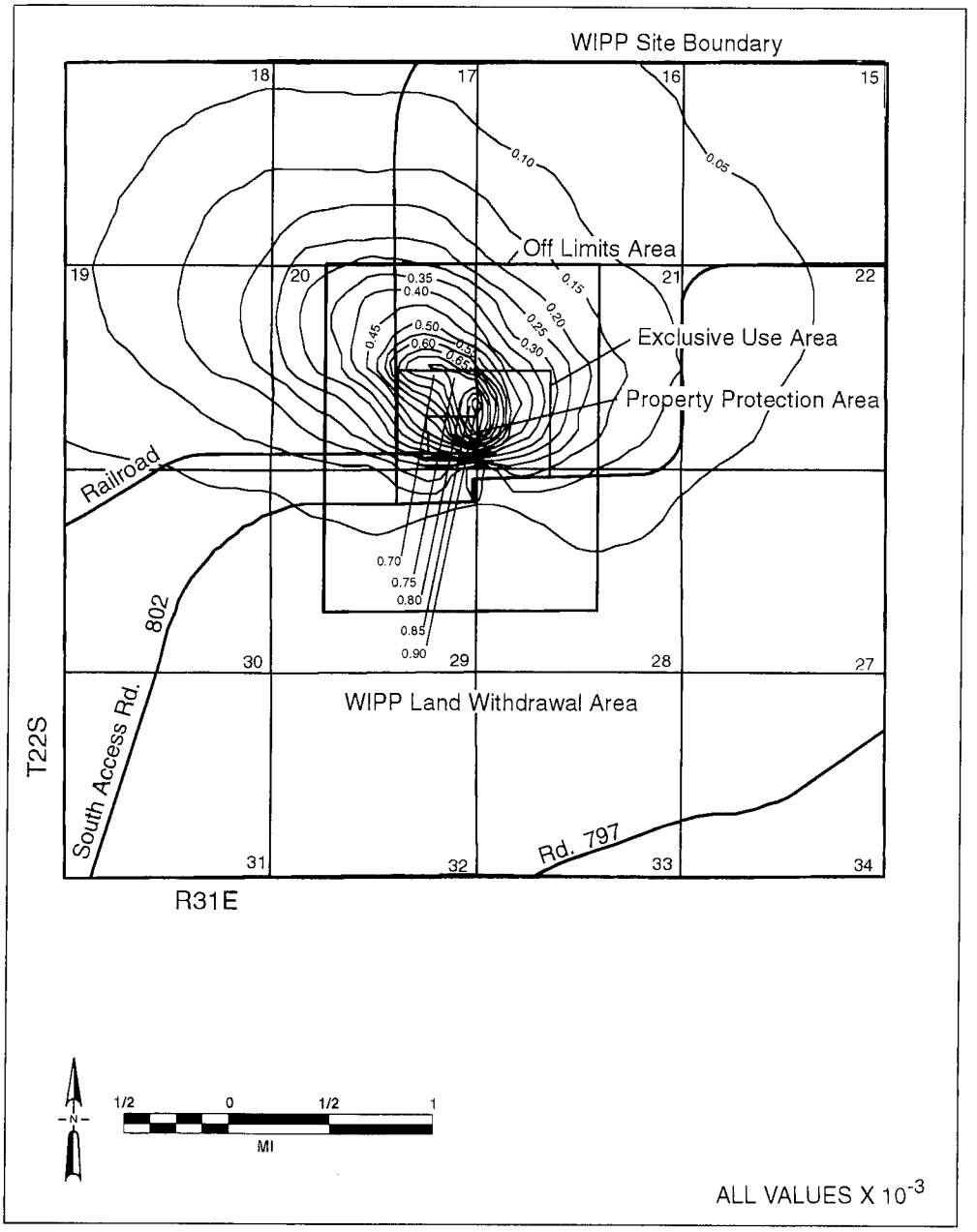

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Figure RA-2. Air Dispersion Factors for the WIPP Site

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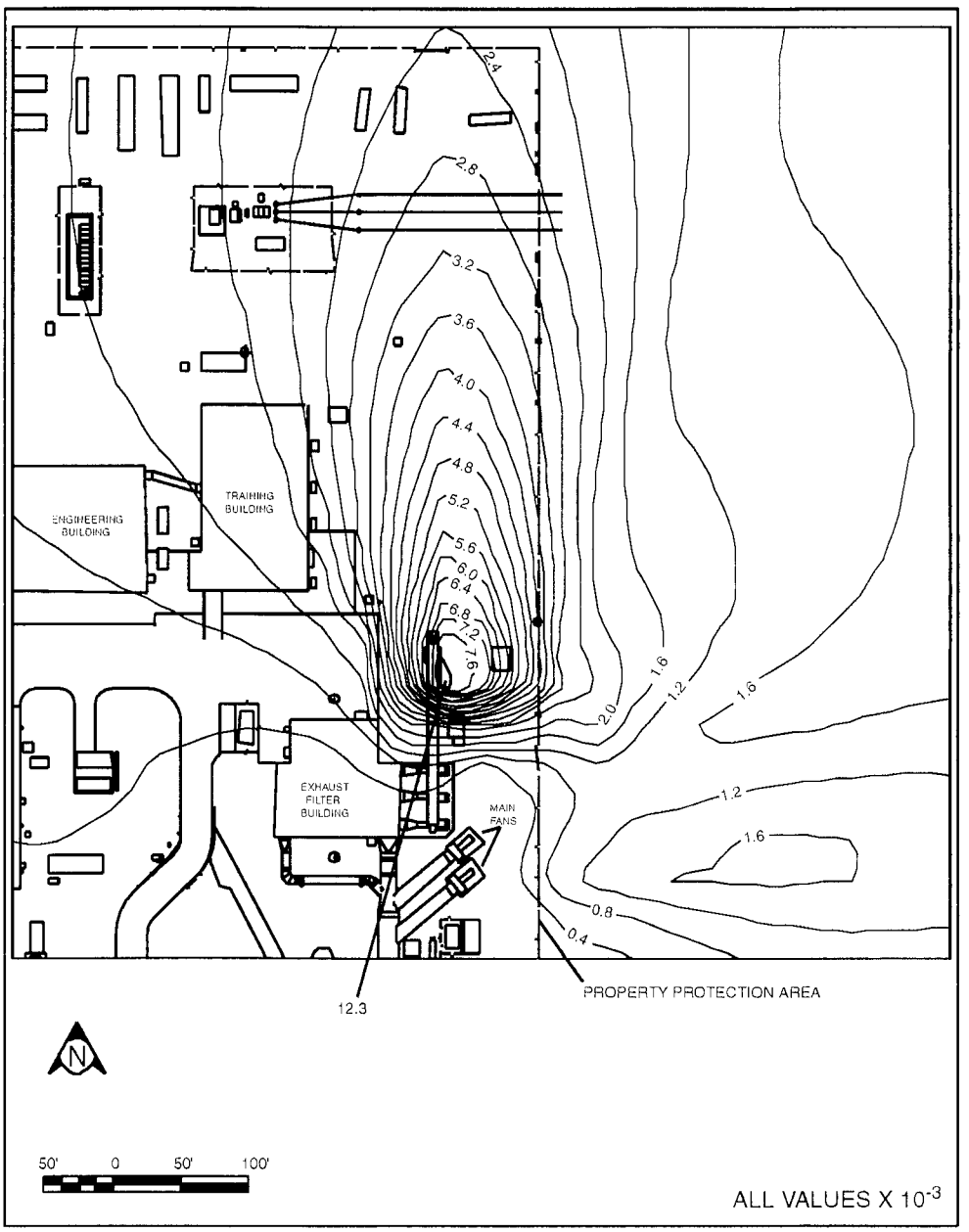

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Figure RA-3. Air Dispersion Factors Inside the Property Protection Area

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Table RA-2. ADFs for WIPP Site Areas

Area	Averaged/Modeled Concentration ($\mu g/m^3$)	ADF
WIPP Site Boundary	1.2E-01	1.2E-04
Livingston Ridge Allotment	9.8E-02	9.8E-05
Antelope Ridge Allotment	6.7E-02	6.7E-05
WIPP Property Protection Area	1.23E+01	1.23E-02

where

Intake = receptor intake, mg/kg-day
CA = contaminant concentration in air, $\mu g/m^3$
IR = inhalation rate, 20 m^3/day
EF = exposure frequency, hours/year
ED = exposure duration, years
BW = body weight, 70 kg
AT = averaging time, days

EPA (1989, 8-6) also describes chronic intake as:

$$Intake = \frac{Risk}{SF} \qquad \text{(RA-17)}$$

where

Intake = receptor intake, mg/kg-day
Risk = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
SF = cancer slope factor, $(mg/kg\text{-}day)^{-1}$

To express the carcinogenic effect in terms of unit risk factor, as provided in EPA (1989, 7-13), the following equation is used:

$$URF = \frac{SF \times IR}{BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad \text{(RA-18)}$$

where

URF = unit risk factor, unitless
IR = inhalation rate, 20 m^3/day
BW = body weight, 70 kg
SF = cancer slope factor, $(mg/kg\text{-}day)^{-1}$

Solving for slope factor in equation (RA-19):

$$SF = \frac{URF \times BW}{IR} \times \left(\frac{1 \times 10^3\ \mu g}{mg} \right) \qquad \text{(RA-19)}$$

where

SF = cancer slope factor, $(mg/kg\text{-}day)^{-1}$
URF = unit risk factor, unitless
BW = body weight, 70 kg
IR = inhalation rate, 20 m^3/day

Combining equation (RA-17) and (RA-19):

$$Intake = \frac{Risk \times IR}{URF \times BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad \text{(RA-20)}$$

where

Intake = receptor intake, mg/kg-day
Risk = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
IR = inhalation rate, 20 m^3/day
URF = unit risk factor, unitless
BW = body weight, 70 kg

Setting equations (RA-16) and (RA-20) equal to each other:

$$\frac{Risk \times IR}{URF \times BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right)$$

and solving for risk yields equation (RA-21):

$$Risk = \frac{CA \times URF \times EF \times ED}{AT} \qquad \text{(RA-21)}$$

where

Risk = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
CA = contaminant concentration in air, $\mu g/m^3$
URF = unit risk factor, unitless
EF = exposure frequency, hours/year
ED = exposure duration, years
AT = averaging time, days

For this assessment, the contaminant concentration in air is the exhaust shaft concentration (EC) in air multiplied by the ADF as follows:

$$CA = EC \times ADF \qquad \text{(RA-22)}$$

where

CA = contaminant concentration in air, $\mu g/m^3$
EC = exhaust shaft concentration for the VOC, $\mu g/m^3$
ADF = air dispersion factor, unitless

Combining equations (RA-21) and (RA-22) yields equation (RA-15):

$$Risk = \frac{EC \times ADF \times URF \times EF \times ED}{AT}$$

Excess cancer risks to the Boundary Public Receptor are calculated using equation (RA-15) with an ADF of 1.2×10^{-4} and are presented in Table RA-3. For this assessment, excess cancer risk to the public ranges from one and one-half to three and one-half orders of magnitude below acceptable risk levels. All risks given in Table RA-3 are for a receptor being subjected to concentrations based on maximum exhaust shaft VOC concentrations, that is, those resulting from emissions from nine closed and one full open panels, over the entire exposure period. Room closures within the open panel are not considered.

RA.5.1.2 Noncarcinogens

For noncarcinogens, excess health effects are quantified in terms of a hazard quotient. The hazard quotient is computed as:

$$Hazard\ Quotient = \frac{EC \times ADF \times EF \times ED}{AT \times RfC} \times \left(\frac{1\ mg}{1 \times 10^3 \mu g}\right) \qquad \text{(RA-23)}$$

where,

$Hazard\ Quotient$ = receptor hazard quotient, unitless
EC = exhaust shaft concentration for the VOC, $\mu g/m^3$
ADF = air dispersion factor, unitless
ED = exposure duration, years
RfC = reference concentration, mg/m^3
AT = averaging time, 306,600 hours (24 hours/day × 365 days/year × 35 years)

Table RA-3. Excess Cancer Risks Outside the Wipp Site Boundary

Compound	*Receptor Concentration (EC x ADF)* Boundary Public Receptor ($\mu g/m^3$)	*URF* Unit Risk Factor	Carcinogen Class	*Risk* Boundary Public Receptor	Acceptable Risk Level
Carbon Tetrachloride	3.79E-03	1.50E-05[a]	B2	3E-08	1E-06
Chloroform	2.17E-04	2.30E-05[a]	B2	2E-09	1E-06
1,1,-Dichloroethylene	8.34E-05	5.00E-05[a]	C	2E-09	1E-05
1,2-Dichloroethane	6.38E-05	2.60E-05[a]	B2	8E-10	1E-06
Methylene Chloride	2.45E-03	4.70E-07[a]	B2	6E-10	1E-06
1,1,2,2-Tetrachloroethane	1.03E-04	5.80E-05[b]	C	3E-09	1E-05
1,1,1-Trichloroethane	2.77E-03	1.60E-05[b]	C	2E-08	1E-05

a. Data from EPA (1994a)
b. Data from Superfund Technical Support Center

Note that the averaging time for noncarcinogens is one-half that for carcinogens. If the hazard quotient is below 1.0, no excess health effects to the receptor is expected. Equation (RA-23) was derived from equations in EPA (1989); the derivation is shown below.

EPA (1989, 8-11) provides the calculation for intake as:

$$Intake = Hazard\ Quotient \times RfD \qquad \text{(RA-24)}$$

where

Intake = receptor intake, mg/kg-day

Hazard Quotient = receptor hazard quotient, unitless

RfD = reference dose, mg/kg-day

EPA (1989, 8-5) provides the calculation for the reference dose as:

$$RfD = \frac{RfC \times IR}{BW} \qquad \text{(RA-25)}$$

where

RfD	=	reference dose, mg/kg-day
RfC	=	reference concentration, mg/m^3
IR	=	inhalation rate, 20 m^3/day
BW	=	body weight, 70 kg

Combining equations (RA-24) and (RA-25):

$$Intake = \frac{Hazard\ Quotient \times RfC \times IR}{BW} \qquad \text{(RA-26)}$$

where

Intake	=	receptor intake, mg/kg-day
Hazard Quotient	=	receptor hazard quotient, unitless
RfC	=	reference concentration, mg/m^3
IR	=	inhalation rate, 20 m^3/day
BW	=	body weight, 70 kg

Setting equations (RA-15) and (RA-26) equal to each other:

$$\frac{Hazard\ Quotient \times RfC \times IR}{BW} = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{1\ mg}{1 \times 10^3\ \mu g}\right)$$

and solving for Hazard Quotient:

$$Hazard\ Quotient = \frac{CA \times EF \times ED}{AT \times RfC} \times \left(\frac{1\ mg}{1 \times 10^3\ \mu g}\right) \qquad \text{(RA-27)}$$

where

Hazard Quotient	=	receptor hazard quotient, unitless
CA	=	contaminant concentration in air, $\mu g/m^3$
EF	=	exposure frequency, hours/year
ED	=	exposure duration, years
AT	=	averaging time, 306,600 hours (24 hours/day × 365 days/year × 35 years)
RfC	=	reference concentration, mg/m^3

Combining equations (RA-22) and (RA-27) yields equation (RA-23):

$$Hazard\ Quotient = \frac{EC \times ADF \times EF \times ED}{AT \times RfC} \times \left(\frac{1\ mg}{1 \times 10^3\ \mu g}\right)$$

Excess noncancerous health effects to a Boundary Public Receptor are calculated using equation (RA-23) with an ADF of 1.2×10^{-4} and are presented in Table RA-4. Noncancerous health effects range from five and one-half to six and one-half orders of magnitude below acceptable levels for a hypothetical Boundary Public Receptor. All hazard quotients given in Table RA-4 are a receptor being subjected to concentrations based on maximum exhaust shaft VOC concentrations, that is, those resulting from emissions from nine closed and one full open panels, over the entire exposure period.

Table RA-4. Excess Noncancerous Health Effects Outside the Wipp Site Boundary

	Receptor Concentration (EC x ADF)	*RfC*	*Hazard Quotient*	
Compound	**Boundary Public Receptor (µg/m³)**	**Reference Concentration (mg/m³)**	**Boundary Public Receptor**	**Acceptable Hazard Level**
Chlorobenzene	8.88E-05	2.00E-02[a]	4E-06	1E+00
Toluene	1.15E-04	4.00E-01[b]	3E-07	1E+00

a. Data from EPA (1994b)
b. Data from EPA (1994a)

RA.5.2 Receptor Concentrations and Risk Inside the WIPP Site Boundary

The Livingston Ridge Rancher, Antelope Ridge Rancher, Surface Worker, and Underground Worker exposure scenarios are evaluated in this section. ADFs of 9.8×10^{-5}, 6.7×10^{-5}, and 1.23×10^{-2} are used for the Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker exposure scenarios, respectively. For all public exposure scenarios, the maximum exhaust concentration from emissions from nine closed and one open panel equivalents is used in assessing risk, with no credit taken for room closures within the open panel. Room closures are used in evaluating the Underground Worker exposure scenario.

RA.5.2.1 Carcinogens

The excess cancer risks calculated for each VOC inside the WIPP site boundary for the Livingston Ridge Rancher and the Antelope Ridge Rancher are presented in Table RA-5. The excess cancer risks to the Livingston Ridge Rancher and the Antelope Ridge Rancher range from two and one-half to four and one-half orders of magnitude below acceptable levels. Acceptable levels for these receptors are 1×10^{-6} for Class B carcinogens and 1×10^{-5} for Class C carcinogens.

Risks given in Table RA-5 are for receptors being subjected to concentrations based on maximum exhaust shaft VOC concentrations, that is, those resulting from emissions from nine closed and one full open panels, over the entire period of exposure.

RA.5.2.2 Noncarcinogens

The excess noncancerous health effect calculation results for each VOC inside the WIPP site boundary are presented in Table RA-6. The ADFs used are the same as those described in Section RA.5.2.1. Excess non-cancer health effects range from six to seven and one-half orders of magnitude below a hazard quotient of one; this implies that there will be no adverse health effects from noncarcinogens to any of the evaluated receptors inside the WIPP site boundary. All hazard quotients given in Table RA-6 are for receptors being subjected to concentrations based on exhaust shaft VOC concentrations for emissions from nine closed panels and one full open panel over the entire period of exposure.

RA.5.3 Worker Concentrations and Risk on the Surface and Underground Facilities

Worker concentrations are calculated using the maximum allowable average VOC headspace concentration as established in Table C-5 of Appendix WAP. The Table C-5 limits are the highest average concentrations that can exist in any waste room. This assumption is very conservative, since the average headspace concentration clearly shows that concentrations are much lower on average. The Table C-5 limits are listed in Table RA-7.

RA.5.3.1 Carcinogens

VOC contaminant concentrations in air for the Surface Worker and the Underground Worker are given in Table RA-8 along with Occupational Safety and Health Administration (OSHA) eight-hour, time-weighted averages (TWAs). This information provides a mechanism for evaluating occupational exposures. The receptor concentrations for the Surface Worker range from four to nearly seven orders of magnitude below the TWAs. The receptor concentrations for the Underground Worker range from two to nearly six orders of magnitude below the TWAs.

RA.5.3.2 Non-Carcinogens

As for carcinogens, noncarcinogen VOC contaminant concentrations in air for the Surface Worker and the Underground Worker and OSHA eight-hour TWAs are presented (Table RA-9). This information provides a mechanism for evaluating occupational exposures in addition to the risk assessment approach. The receptor concentrations for the Surface Worker are seven orders of magnitude below the TWAs and those for the Underground Worker are more than six orders of magnitude below the TWAs.

Table RA-5. Excess Cancer Risks Inside the Wipp Site Boundary for Livingston Ridge Rancher and Antelope Ridge Rancher Scenarios

	Receptor Concentration (EC x ADF)		*URF*		*Risk*		
Compound	**Livingston Ridge Rancher (µg/m³)**	**Antelope Ridge Rancher (µg/m³)**	**Unit Risk Factor**	**Carcinogen Class**	**Livingston Ridge Rancher Risk**	**Antelope Ridge Rancher Risk**	**Acceptable Risk Level**
Carbon Tetrachloride	3.09E-03	2.11E-03	1.50E-05	B2	6E-09	4E-09	1E-06
Chloroform	1.77E-04	1.21E-04	2.30E-05	B2	5E-10	3E-10	1E-06
1,1,-Dichloroethylene	6.81E-05	4.65E-05	5.00E-05	C	4E-10	3E-10	1E-05
1,2-Dichloroethane	5.21E-05	3.56E-05	2.60E-05	B2	2E-10	1E-10	1E-06
Methylene Chloride	2.00E-03	1.37E-03	4.70E-07	B2	1E-10	8E-11	1E-06
1,1,2,2-Tetrachloroethane	8.45E-05	5.78E-05	5.80E-05	C	6E-10	4E-10	1E-05
1,1,1-Trichloroethane	2.27E-03	1.55E-03	1.60E-05	C	4E-09	3E-09	1E-05

Table RA-6. Excess Noncancerous Health Effects Inside the Wipp Site Boundary for Livingston Ridge Rancher and Antelope Ridge Rancher Scenarios

Compound	*Receptor Concentration (EC x ADF)* Livingston Ridge Rancher ($\mu g/m^3$)	*Receptor Concentration (EC x ADF)* Antelope Ridge Rancher ($\mu g/m^3$)	*RfC* Reference Concentration (mg/m^3)	*Calculated Hazard Quotient* Livingston Ridge Rancher	*Calculated Hazard Quotient* Antelope Ridge Rancher	*Calculated Hazard Quotient* Acceptable Hazard Level
Chlorobenzene	7.25E-05	4.96E-05	2.00E-02	9E-07	6E-07	1E+00
Toluene	9.43E-05	6.45E-05	4.00E-01	6E-08	4E-08	1E+00

Table RA-7. Maximum Average Headspace Concentration Limits

Compound	Appendix WAP, Table C-5 Limit (ppmv)
Carbon Tetrachloride	7,510
Chlorobenzene	17,660
Chloroform	6,325
1,1,-Dichloroethylene	28,750
1,2-Dichloroethane	9,100
Methylene Chloride	100,000
1,1,2,2-Tetrachloroethane	7,924
Toluene	41,135
1,1,1-Trichloroethane	100,000

Table RA-8. VOC Contaminant Concentrations in Air for the Surface Worker and the Underground Worker

Compound	ECS_{max} Exhaust Shaft Concentration for Surface Worker (µg/m³)	ECU_{max} Exposure Concentration for Underground Worker (µg/m³)	Receptor Concentration (ECS x ADF) Surface Worker (ppmv)	Underground Worker (ppmv)	OSHA TWA[a] (ppmv)
Carbon Tetrachloride	1.54E+02	7.70E+01	3.00E-04	1.22E-02	10
Chloroform	1.06E+02	5.03E+01	2.67E-04	1.03E-02	50
1,1,-Dichloroethylene	4.01E+02	1.86E+02	1.24E-03	4.68E-02	5[b]
1,2-Dichloroethane	1.25E+02	6.00E+01	3.81E-04	1.48E-01	100
Methylene Chloride	1.26e+02	5.66E+02	4.45E-03	1.63E-02	500
1,1,2,2-Tetrachloroethane	1.77E+02	8.86E+01	3.17E-04	1.29E-02	5
1,1,1-Trichloroethane	1.77E+03	8.89E+02	4.00E-03	1.63E-01	350

a. eight-hour TWAs except chloroform TWA for up to a ten-hour day in a 40 hour work week.
b. TWA from American Conference of Governmental Industrial Hygienists (ACGIH)

Table RA-9. VOC Contaminant Concentrations in Air for the Surface Worker and the Underground Worker

Compound	ECS_{max} Exhaust Shaft Concentration for Surface Worker (µg/m³)	ECU_{max} Exposure Concentration for Underground Worker (µg/m³)	Receptor Concentration Surface Worker (ppmv)	Underground Worker (ppmv)	OSHA TWA (ppmv)
Chlorobenzene	2.58E+02	1.32E+02	6.91E-04	2.88E-02	75
Toluene	4.99E+02	2.53E+02	1.63E-03	6.70E-02	200

RA.6 SUMMARY

Based on estimated maximum VOC emissions from emplaced waste, there are no significant exposures expected to occur to the public or workers. Risks and hazards to members of the public range from one and one-half to seven and one-half orders of magnitude below acceptable levels. Worker exposure VOC concentrations are approximately two to over five orders-of-magnitude below eight-hour OSHA TWAs.

The worker exposure and public risk assessment used the following conservative assumptions:

1. Appendix WAP, Table C-5 limits for headspace concentrations of VOCs represent the average container concentration
2. All drums are fitted with the model NFT-013 carbon composite filter
3. The effective gas generation rate is constant in closed panels
4. The actual source of VOCs will exist throughout the operational/closure phase and will maintain the average concentrations in drum and panel headspaces (i.e., no depletion of the source over time)
5. VOC concentrations in the closed panel atmosphere are instantaneously equivalent to the drum average headspace concentrations
6. There is no decrease in closure system permeability due to creep closure over time
7. The hypothetical Boundary Public receptor is exposed every hour of every day during the span of facility operations
8. Public risk to developing excess cancer does not include the probability that the receptor is one of the 27 residents within ten mi (16 km) of WIPP
9. Enough moisture will exist to create humid environmental conditions for gas generation
10. A full repository of waste exists for the duration of the operational/closure
11. There will be 81,000 drums disposed of in each panel. The actual configuration may include 60 percent SWBs (two vents, seven-drum equivalent) and 40 percent drums (one vent), meaning less than 81,000 filter vents will be venting in a panel (approximately 58,000)
12. The assessments for the public and surface worker assume that no room ventilation barriers are installed, and emissions from nine closed and one open panel full of waste exists for 35 years

Other assumptions that may contribute to the overall uncertainty of the receptor concentration and risk estimates are as follows:

- The mine ventilation flow rate will remain constant throughout the operational/closure phase
- Weighted average drum headspace concentrations of VOCs are representative of all waste to be disposed of at the WIPP

Although the uncertainties in the receptor concentration and risk estimates that result from these assumptions are not quantifiable, it is believed that they are far outweighed by the conservative assumptions used in the estimates.

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APPENDIX RM

March 27, 1995

Systems Prioritization Method - Iteration 2 Baseline Position Paper:

Rock Mechanics: Creep, Fracture, and Disturbed Rock Zone (DRZ)

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ABSTRACT

The Rock Mechanics Program is important to the establishment of a radioactive waste repository in salt because rock mechanics deals with the prediction of creep closure and eventual encapsulation of the waste. The intent of this paper is to give the current status of the program. This program consists of three major modeling efforts: continuum creep, fracture, and the disturbed rock zone. These models, together with laboratory material parameters, plastic flow potentials, initial and boundary input data, and other peripheral information forms the predictive technology. The extent to which the predictive technology is validated against in situ test data adds certainty to the method. Application of the technology is through simulations of the test results, design, or performance using numerical codes. In summary, the predictive capabilities are technically sound and reasonable. The current status of the program is that which would be advanced for compliance.

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ACRONYMS

CFR	Code of Federal Regulations
DC	Direct Current
DRZ	Disturbed Rock Zone
EATF	Engineered Alternatives Task Force
EM	Electromagnetic
MD	Multimechanism Deformation (model)
MDCF	Multimechanism Deformation Creep Fracture
NAS	National Academy of Sciences
PA	Performance Assessment
WIPP	Waste Isolation Pilot Plant

1.0 INTRODUCTION

An important aspect of radioactive waste disposal is the ability of the repository to ensure public safety through isolation of the waste from the accessible environment until the waste is no longer radioactive. The fact that salt slowly deforms or "creeps" with time and that fractures in salt heal under load suggests that in a radioactive waste repository in a natural salt formation the rooms would eventually creep closed and encapsulate the waste, isolating it from the accessible environment for the relevant regulatory time period. The technical question concerns the need to know exactly how and when this creep process occurs with respect to other possible events so that we may state with reasonableness that repository safety is ensured. To answer this concern, a predictive technology is required. The technology is based on establishing a mathematical equation which simulates the known salt behavior as accurately as possible based on laboratory data and validated against measured short-term *in situ* data. This mathematical equation or constitutive model can then be used to answer the important questions about the repository condition far into the future—in other words to predict the behavior. The description of this predictive technology and its technical basis follows.

The disposal of radioactive waste imposes unique engineering requirements in that it is necessary to predict the behavior of the repository perhaps as much as 10,000 years. Even though the rock mechanics processes discussed here will occur on a faster time scale, usually a few hundred years, the only way such predictions can be made is through calculations based on an understanding of the behavior obtained over a relatively short interval of contemporary observation. Predictive calculations such as these require three elements: a *model*, which is a mathematical description of the behavior; *material parameters*, which are the values (numbers) relating an individual material to the behavior; and a calculational method, which may be an analytic method but which is often a computer program or *numerical code*. Together with other important peripheral information, these three fundamental elements form a predictive technology. The subject of this paper is essentially a discussion of the specific models and predictive technology developed for the Rock Mechanics Program under the auspices of the Waste Isolation Pilot Plant (WIPP) Project.

In the Rock Mechanics Program, there are both discrete material response models and process models. A list of these models and an evaluation of their status is given in Table I. Although the discrete material behavior model may be quite complicated, it is always related to one type of material, such as salt. The process model is actually a collection of several types of other models, assembled to describe a more complicated physical situation, such as the behavior of a disturbed rock zone (DRZ) which forms around underground openings. For example, in this case, the process model must include, at least, models that determine the

Table I. Rock Mechanics Models

Phenomenon	Model	Status
Creep	Multimechanism Deformation (M-D) Model	Technically Sound, Validated Against In Situ Data
Fracture	M-D Coupled Fracture (MDCF) Model	Technically Sound, Partially Validated Against In Situ Data
DRZ	Process Model (involving several models)	Still in Development, Usable

formation of microfractures, the creep closure, the potential healing of microfractures, and the relation between fracture and permeability.

The Rock Mechanics Program considers *creep*, the time-dependent deformation of salt; *fracture*, the time-dependent development of creep-induced microfracture formation and damage; and the *disturbed rock zone* (DRZ), the region adjacent to the excavated openings affected by the development of damage with attendant changes in permeability. The understanding of the rock mechanical or structural response of the underground excavations in the salt is one of the critical applied engineering areas of study for the WIPP Program. It is utilized either (1) directly through performance calculations of repository room and shaft closure or (2) indirectly through the prediction of coupled behavior of room contents under concurrent gas generation, the crushed salt backfill, the compaction of crushed salt seal components, the formation of the DRZ adjacent to rooms and seals, and the potential increases in permeability and eventual healing adjacent to seal locations. The full array of fundamental behaviors or processes covered by the Rock Mechanics Program are given in Table II (Rechard et al., 1989; WIPP PA, 1992a,b).

Table II. Relevant Performance Assessment (PA) References

Phenomenon or Process	PA (1992) Reference
Creep Closure	Vol. 2 p. 2-55 (2.3.5) Vol. 3 p. A109
Seal System Performance* DRZ	Vol. 2 P. 2-45 (2.3.2) Vol. 2 p. 2-45 (2.3.2.2) and p. 2-42 (2.3.1)
Compaction Processes* (e.g., back stress development, etc.)	Vol. 2 p. 2-28 (2.3.2.3)
Fracture (propagation)	Vol 2 p. 2-42 (2.3.1)

* Not part of Rock Mechanics Program but included for completeness.

In those cases where the understanding of individual process has progressed sufficiently, the constitutive models and the associated material parameters have been specified. In addition, to establish the relevance to performance assessment and regulatory requirements, the appropriate reference is made to the Performance Assessment documentation (WIPP PA, 1992a,b). However, mathematical definition of individual models, parameter lists, and databases are too extensive to repeat here, but will be summarized by example throughout the paper as appropriate.

The basis for the mechanical performance of a radioactive waste repository was initially defined by the National Academy of Sciences, Committee on Waste Disposal (NAS, 1957) based on the ability of rooms in natural salt deposits to creep closed with time and ensure the isolation of the waste for sufficient time to render it harmless. The NAS recommended a natural deposit of salt for three reasons: (1) its thermal properties, (2) its physical properties (e.g., creep deformation), and (3) the very existence of the salt deposit for hundreds of millions of years demonstrates its isolation from circulating groundwater and the stability of the geologic formation in which it is located. For non-heat producing waste, such as that proposed for the WIPP, only the last two reasons pertain. Because the Rock Mechanics (Creep, Fracture, and DRZ) Program incorporates processes affecting total repository performance (e.g., room and seal performance, migration pathways, etc.), this program bears on compliance issues in both *40 CFR 191* and *40 CFR 268.6*. With the citations in the 92 PA document, further specific references to the regulations will not be made, except for well defined cases.

As a result of the basic NAS premise and the subsequent regulations, the principal direct application of the models developed by the Rock Mechanics Program is the calculation of the creep closure of the rooms and shafts, with or without contributions from the development of the DRZ. In addition to providing the primary compliance evaluation of the creep closure of the repository to ensure the encapsulation of the waste, the general application of the constitutive models and results of the Rock Mechanics Program directly and indirectly support technical goals of other WIPP programs. The most direct support is of the Disposal Room and Drift Systems and the Seal Design and Modeling Programs, as shown in Table III. The Rock Mechanics Program also provides indirect support to other programs of the WIPP Project, although these will not be discussed here.

As is evident, the current status of the three elements of the Rock Mechanics Program are in fact statements of the rock mechanics *program position* and the technology base that would currently support any formal compliance submittal.

Table III. Rock Mechanics Program Support Correlations

Activity	Creep	Fracture	DRZ
Repository Creep Closure	X		
Room and Drift Systems			
Backfill	X		
Waste	X		
Disposal Room	X	X	X
Eng. Alt. Sys. Analy.	X		
Seal Design and Modeling			
Components	X	X	X
Seal and System Design	X	X	X
Small-Scale Seal Test	X	X	X
Large-Scale Seal Test			
Large-Seal Brine Inflow	X	X	X
Salado Permeability vs. Stress	X	X	X

The three major areas of the Rock Mechanics Program will be discussed separately because they represent somewhat discrete but closely related efforts at different stages of development. In each area, a brief status summary is given which will be indicative of the technical soundness and level of validation of the model involved. Significant aspects of the model development, parameter evaluations, and data will be traced through important references, and in some cases will be included in the paper. The major consequences for compliance are noted for each model area.

2.0 CREEP

As previously noted, one of the advantages of placing radioactive waste in natural salt deposits is that the salt undergoes time-dependent deformation or creep and therefore will eventually close the repository rooms and encapsulate the waste. Even in more complex situations, such as concurrent gas generation, the mechanical or structural response of the repository or shaft is governed by the creep of the salt. In fact, the mechanical behavior of salt, as expressed by creep, is one of the fundamental inputs to the design and performance assessment of the repository and seal systems. It has already proven influential in repository design through structural evaluation of several room configurations (Krieg et al., 1980). In this regard, it is critical that the creep process be adequately understood and properly described to permit reasonable long-term predictions of the repository performance required by the regulatory standards.

A simple representation of a standard creep curve is given in Figure 1, which shows the strain as a function of time for a specimen under a constant stress and temperature. This figure indicates the customary decomposition of the curve into a steady-state creep and transient creep components. Also, two different creep curves are indicated, one with tertiary creep behavior as marked by an accelerated creep rate caused by progressive failure of the material, and one denoted as a continuum creep curve matching the continuum creep model in which the tertiary behavior is suppressed. Tertiary creep contains all of the aspects of the development of the DRZ, in that the early stage of tertiary creep is caused by the generation of microfractures; as the microfractures increase, grow, and coalesce to form discrete cracks in the late stage of tertiary creep, the material ultimately fails.

The detailed technology that permits the prediction of the structural response consists of a constitutive model for creep, the material parameters for all of the materials in the site stratigraphy, and a numerical code for calculation of the response of the repository structure. In addition, because the actual stress fields involved are three-dimensional, there must be a flow potential which describes the deformation of salt in response to a three-dimensional stress state. Two other inputs are required: the stratigraphy which gives the materials and elevations of the bedded layers in the natural salt (evaporite) deposit, and the initial stress condition.

The constitutive model of salt creep, the experimentally determined parameter values, and the numerical codes required for simulation of WIPP structural problems, at the current stage of development, are well established on technically sound principles and data. At this

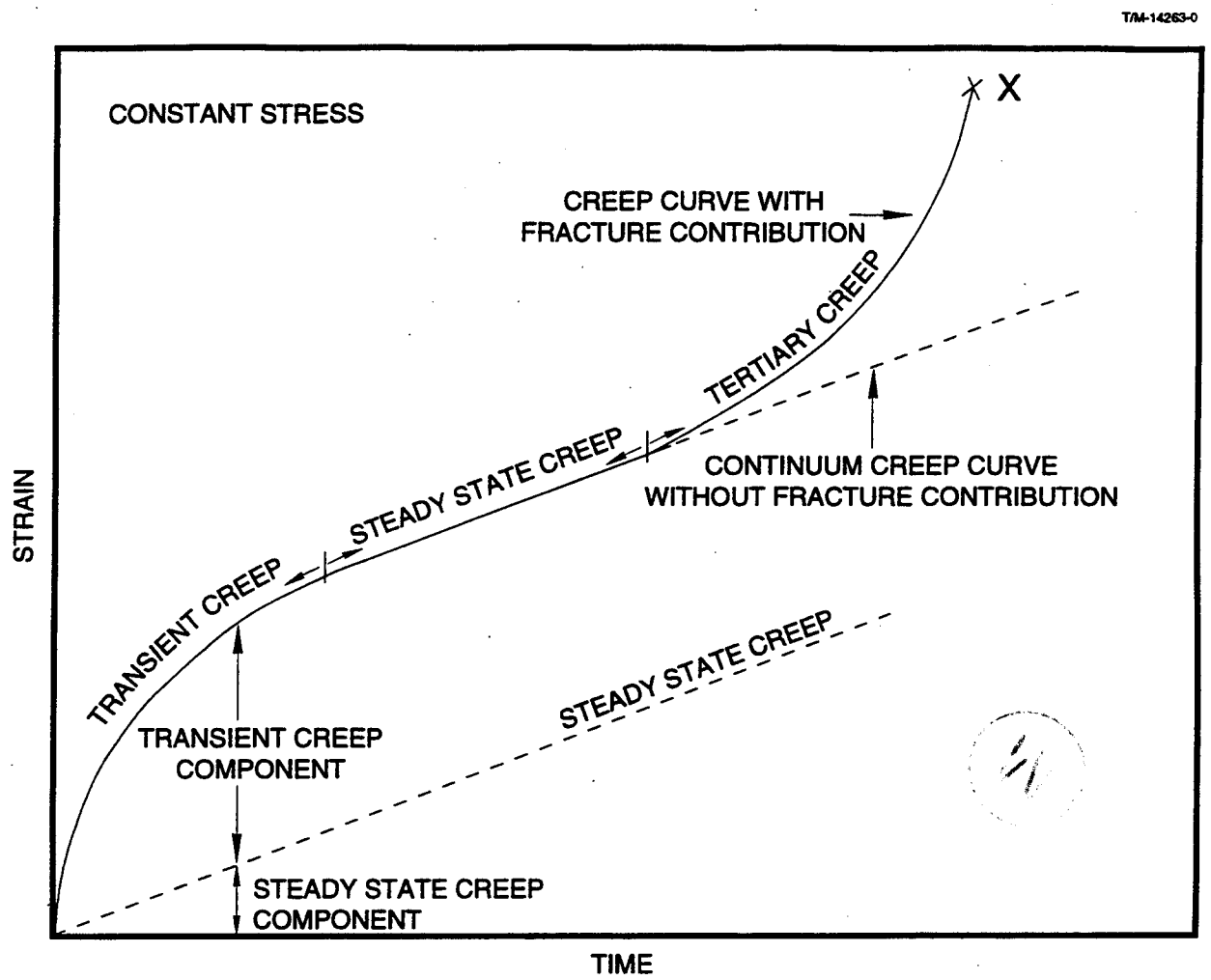

Figure 1. Tertiary creep curve schematic with continuum model and fracture contribution noted.

time, the creep predictive technology is the most sound and best validated of the models and technologies of the Rock Mechanics Program. However, to establish site-specific compliance criteria and demonstrate compliance with general regulatory criteria, completion of ongoing efforts in several areas will potentially assist in demonstrating regulatory compliance. Briefly, these are the determination of the creep parameter distribution functions for argillaceous salt, further definition of the fast probability integration methodology, additional improvements in calculational speed of the codes, probabilistic evaluation of room and shaft closure, and some minor additional improvements in the current three-dimensional code capability.

2.1 Constitutive Model

During the course of the project, two constitutive models of continuum creep have been used for performance assessment: the multimechanism deformation steady-state creep response with workhardening/recovery transient creep model (Munson et al., 1989a), and a steady-state, reduced modulus model (Morgan et al., 1986).

The model that produces very reasonable agreement with the extensive in situ test data and is proposed as the new reference model is the multimechanism deformation steady-state creep response with workhardening/recovery transient (M-D) model. Room closures (as required by *40 CFR 268.6(b)(3)* and *40 CFR 268.6(b)(5)* and environmental performance standard *40 CFR 264.601*) as measured from a number of *in situ* tests have been successfully predicted using this model, together with the recommended updated stratigraphy (Munson et al., 1989a). The agreement between calculated and measured room closures is typically better than 10%, with the longest current comparison of 3.5 years. This indicates that the model and predictive technology may be valid within acceptable uncertainty (Munson and DeVries, 1991). A plan view of the WIPP underground together with designations of the *in situ* test rooms is given in Figure 2. The updated stratigraphy is as shown in Figure 3. The simulations included both heated (Room B) and unheated (Room D and G) single rooms, a multiple room complex (Rooms A), a cylindrical room (Room Q) and a shaft (Air Intake Shaft - Shaft V), a cylindrical pillar (Room H), and the computationally complicated, three-dimensional, intermediate-scale borehole test (Rooms C). As a result of the success of this model in simulating the room closure of a range of significantly different room and shaft geometries, which implies different stress fields, using a single reference set of parameters (see Table IV), suggests that this model is reasonable for WIPP use (WIPP PA, 1992a,b). As examples of the ability of this model, and associated predictive technology, the calculated and measured vertical and horizontal closures of Rooms D and B, both isolated 5.5-m-square cross-section rooms some 5.5 m above the WIPP horizon, but with the latter heated after one year, are shown in Figure 4 (Munson et al., 1990a).

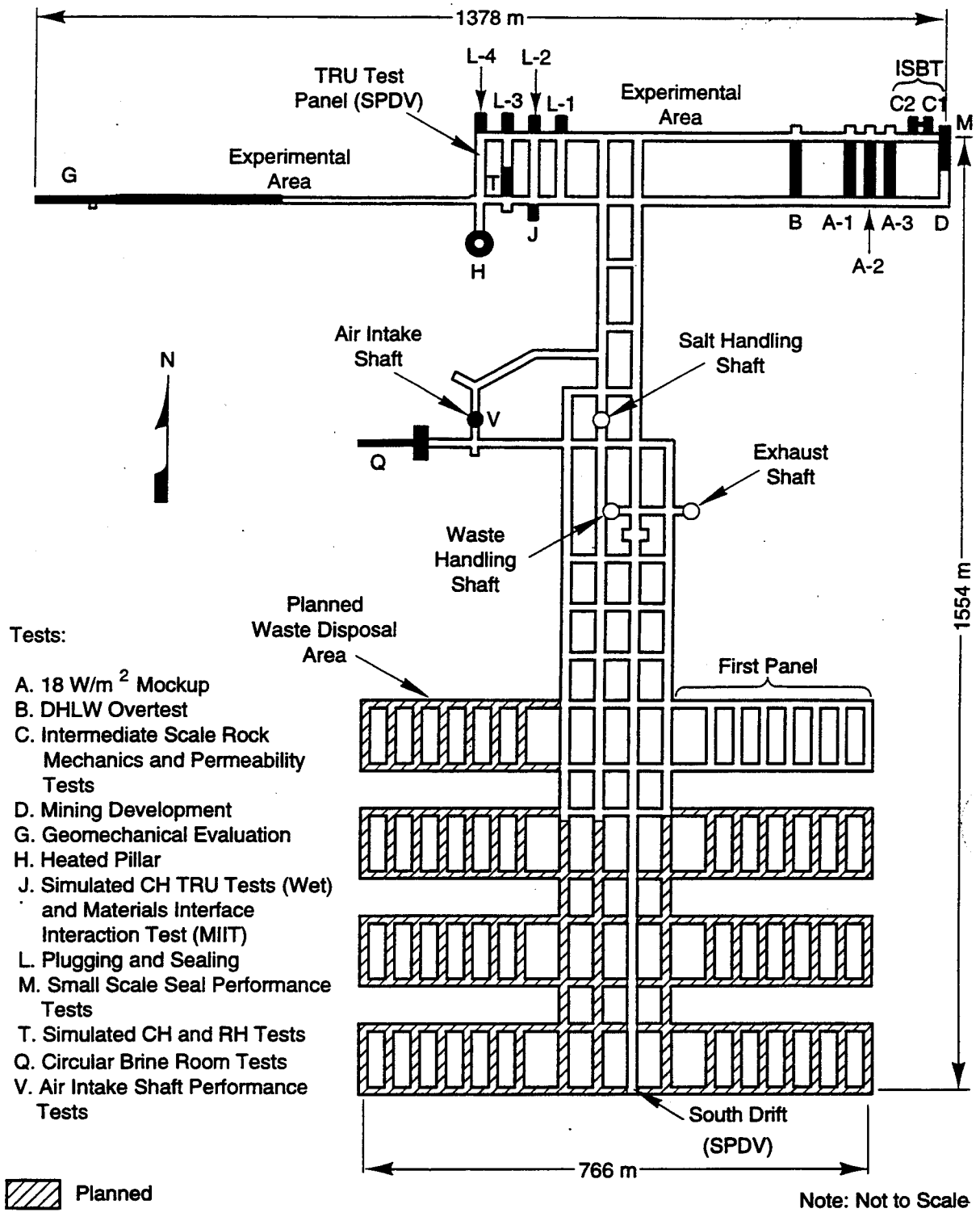

Figure 2. Plan view of the *in situ* tests in the WIPP facility.

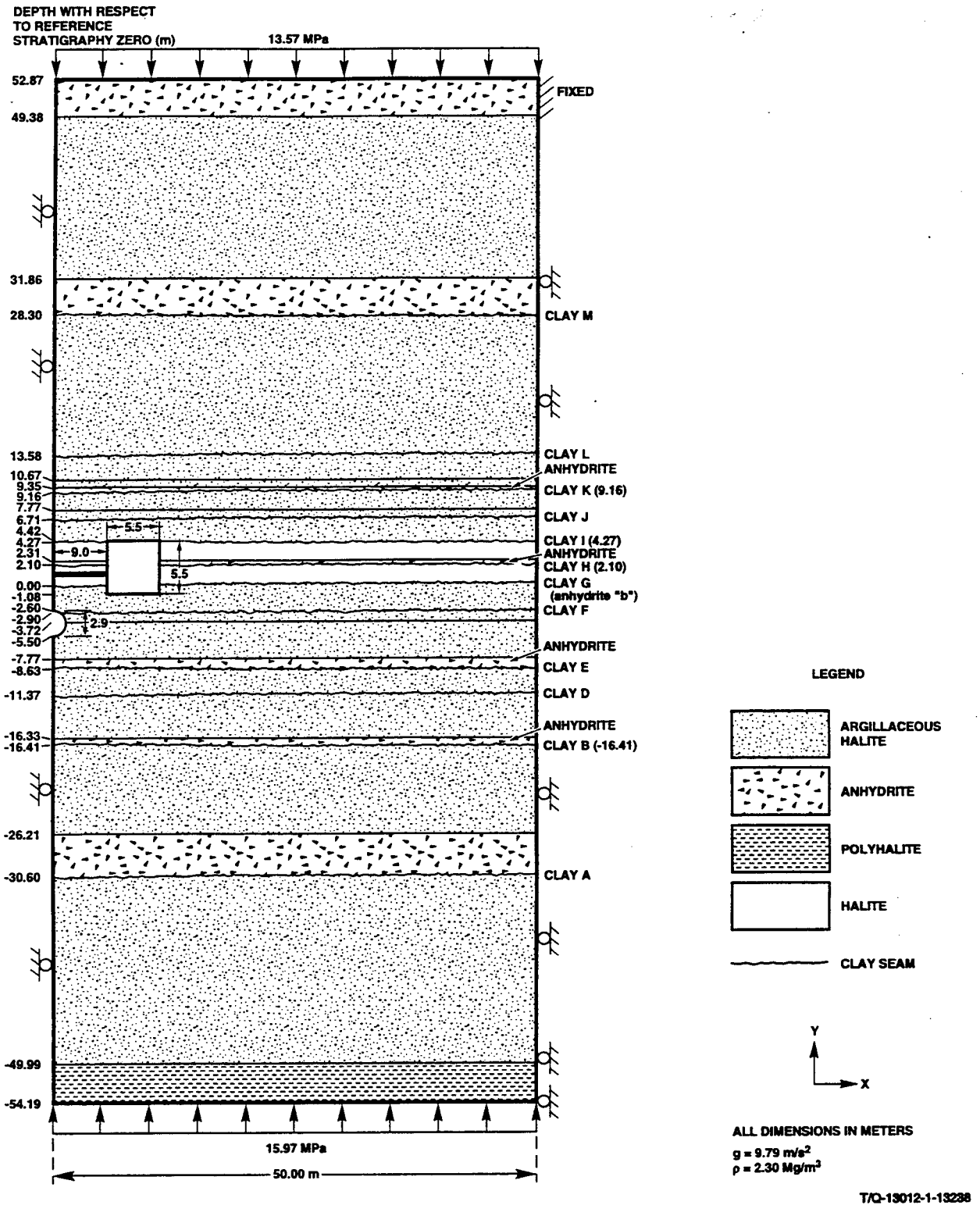

Figure 3. Local stratigraphy at the WIPP horizon.

Agreement between measured and calculated closure is within 10% except for the vertical closure of Room B where progressive roof failure leads to a high apparent measured closure rate. The continuum creep model does not include fracture and cannot simulate the roof response once fracture becomes a significant mechanism. In Figure 5, the comparison is shown between calculated and measured horizontal and vertical closures (Munson et al., 1993) for the entirely different geometry of Room Q. This room is a horizontal, cylindrical room with a diameter of 2.9 m, at the WIPP horizon, which differs from the previous rooms. Here, the agreement of both horizontal and vertical calculated and measured closures is within 3%, for the nearly 3 years' duration of comparison. These results, together with similar results in the other comparisons of calculation to in situ test data, have been the basis for suggesting the M-D model is technically sound and an indication of the validity of the predictive technology.

The technical basis of the model is supported by fundamental concepts where this is possible. The M-D model is based on the deformation mechanism map for steady-state creep. A deformation mechanism map for salt is given in Figure 6 (Munson, 1979). This map describes those regions of stress (plotted as the non-dimensionalized modulus reduced stress) and temperature (plotted as the homologous temperature) where a specific dislocation mechanism controls the creep process. For the conditions of the WIPP, there are potentially three distinct mechanisms involved: (1) a high temperature and low stress region based on a dislocation climb mechanism, (2) a low temperature and low stress undefined mechanism (e.g., no theoretical micromechanical mechanism is known in this region), but the region is empirically well characterized, and (3) a high stress dislocation slip mechanism. Although the WIPP conditions are expected to be isothermal at the ambient natural underground temperature, all of the stated mechanisms could still be involved because of the large range of stress states that occur around underground rooms and shafts. These mechanisms conform to the requirements for additive processes and the total steady-state creep rate is then the sum of the rates of the individual mechanisms. The boundaries between regions of the deformation map are defined as the locus where the strain rates of the adjacent mechanism regime are equal. Transient creep strain is incorporated into the model through a multiplier on the steady-state rate. Transient creep is described through a state parameter which obeys a higher order (quadratic) kinetic equation. Both stress loading and unloading changes of the long transient (single-state parameter) type can be accommodated by the model. Initial state values less than the transient strain limit will increase through workhardening until the transient strain limit is reached, while initial state values greater than the limit will decrease through recovery. At the transient strain limit, the material continues to accumulate further, unlimited strain by steady-state creep.

Table IV. Parameter Values for the M-D Model

ELASTIC PROPERTIES (DENOTED WIPP-D)
μ 12.4 GPa E 31.0 GPa υ 0.25

CREEP PROPERTIES (DENOTED WIPP-D)				
PARAMETERS	CLEAN SALT	ARGILLACEOUS SALT	UNITS	REMARKS
A_1	8.386 E22	1.407 E23	/s	FROM ERDA-9
Q_1	25,000	25,000	cal/mol	FROM ERDA-9
n_1	5.5	5.5		FROM ERDA-9
B_1	6.086 E6	8.998 E6	/s	FROM ERDA-9
A_2	9.672 E12	1.31984 E13	/s	
Q_2	10,000	10,000	cal/mol	FROM ERDA-9
n_2	5.0	5.0		FROM ERDA-9
B_2	3.034 E-2	4.289 E-2	/s	
σ_0	20.57	20.57	MPa	
q	5.335 E3	5.335 E3		FROM ERDA-9
m	3.0	3.0		THEORETICAL
K_0	6.275 E5	1.783 E6		
c	0.009198	0.009198	/T	DeVRIES [1988]
α	-17.37	-14.96		FROM ERDA-9
β	-7.738	-7.738		
δ	0.58	0.58		FROM ERDA-9

NOTE: THE ERDA-9 VALUES WERE OBTAINED FROM MUNSON AND DAWSON [1979; 1982]. HERE, M IS THE SHEAR MODULUS, E IS YOUNG'S MODULUS, AND N IS POISON'S RATION. THE A'S AND B'S ARE CREEP STRUCTURE FACTORS, THE Q'S ARE ACTIVATION ENERGIES, THE N'S ARE POWER EXPONENTS OF THE STRESS DEPENDENCIES, Q IS THE EXPONENTIAL STRESS DEPENDENCY, σ_0 IS THE CUT-OFF STRESS FOR THE SLIP MECHANISM, M IS A THEORETICAL VALUE, K_0 IS THE CONSTANT FOR THE TRANSIENT STRAIN LIMIT, C IS THE TEMPERATURE DEPENDENCE OF THE TRANSIENT STRAIN LIMIT, AND α, β, AND δ THE ARE PARAMETERS THAT GOVERN THE CURVATURE OF THE TRANSIENT CREEP RESPONSE.

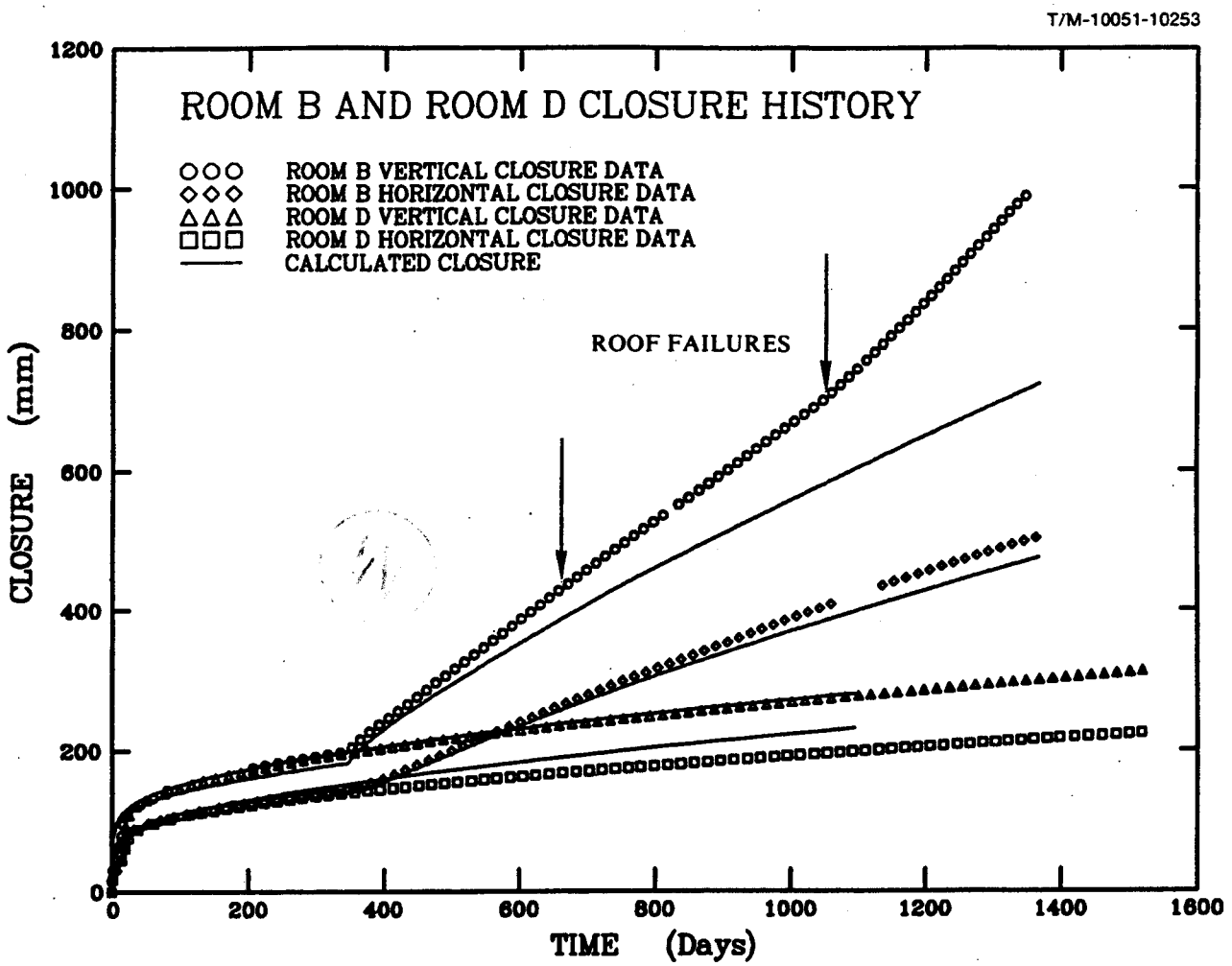

Figure 4. Calculated and measured closures of Room D and Room B.

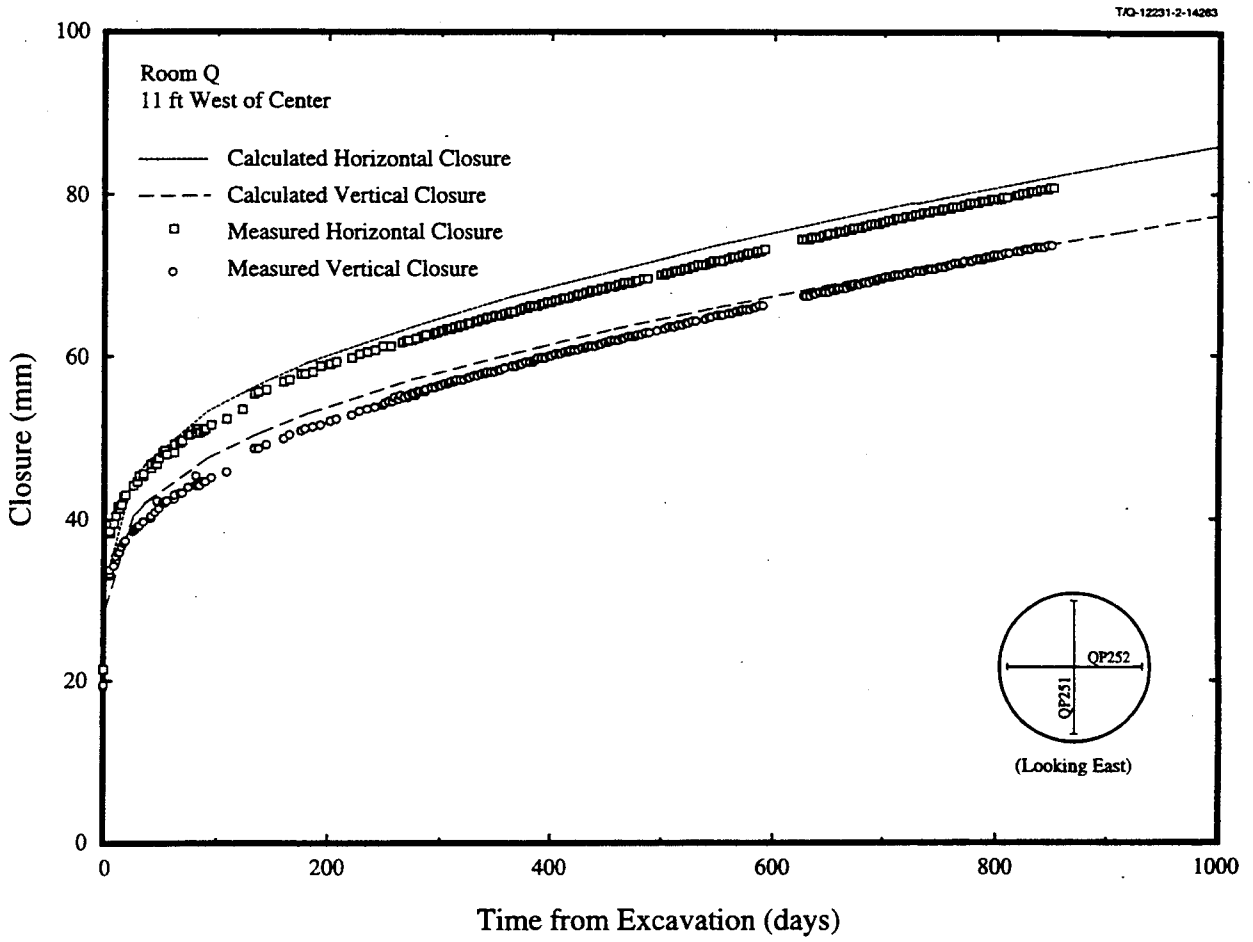

Figure 5. Comparison of calculated and measured Room Q closures.

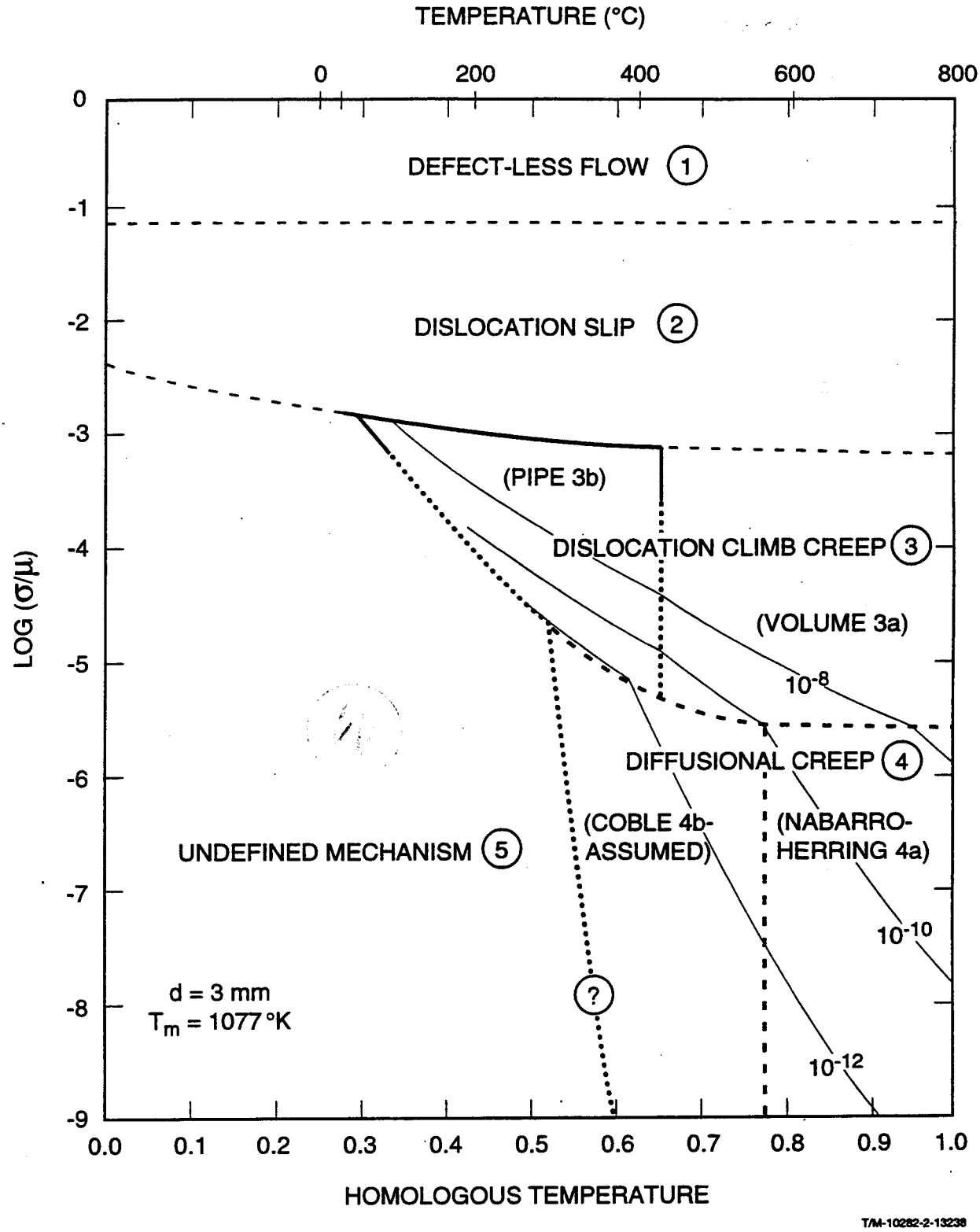

Figure 6. Deformation mechanism map for salt.

In addition, the M-D model, with the large strain SPECTROM-32 code, has been used successfully to calculate the closure of the quite complicated Engineered Alternatives Task Force (EATF) Baseline configuration, which is a repository room containing waste and crushed salt with the conditions of concurrent gas generation.

A somewhat simpler constitutive model was developed early in the project based entirely on the steady-state creep behavior in the undefined mechanism region (Morgan et al., 1986). Unlike the M-D model, this model required an arbitrary reduction of elastic moduli by a factor of 12.5 to obtain adequate agreement with the measurements in the South Drift (Morgan et al., 1985). In certain situations, this constitutive model has been used for WIPP calculations (Butcher and Mendenhall, 1993). However, the reduced modulus model is no longer used unless the M-D model has unacceptably long computation times and the simpler model has been shown to be accurate.

2.2 Flow Potential

Selection of the proper plastic flow potential is critical because this potential makes it possible to obtain the response of a material to the three-dimensional stress fields found around the underground openings. A series of thin walled, hollow salt cylinders was subjected in the laboratory to various loading paths chosen to explore the angles between the conditions of uniaxial compression and pure shear. Significantly, these experimental results can be interpreted directly, without recourse to structural calculation, to show that a Tresca plastic flow potential based on a maximum shear stress criterion describes salt creep and is therefore preferred over the von Mises criterion (Mellegard et al., 1992), which is based on the octahedral shear stress criterion. Although the difference in stress in pure shear is only 15.7%, the strong stress dependence of creep causes this to become a factor of two in creep rate in pure shear. This effect is important for closure of underground rooms in salt where significant amounts of salt can be in shear. In confirmation of the choice of the plastic flow potential, the structural calculations using the Tresca flow potential make possible the very reasonable agreements obtained.

2.3 Material Parameters

The material parameters required for the M-D model have all been determined from laboratory triaxial, compressive creep tests, except where a theoretical value exists. The reference values proposed which are the values used for all M-D model simulations of the in situ experiments (as discussed previously) are given in Table IV. As is apparent, the parameters have been determined for the two dominant types of salt layers in the stratigraphy, clean salt and

argillaceous (containing clay) salt layers. Because the wastes intended for the WIPP are not heat producing, except for limited amounts of remote-handled TRU, the thermal parameters are not important and have no influence on the typical WIPP structural problems. Other evaporite materials, such as anhydrite and polyhalite, when sufficiently close to the excavation that it is necessary to treat their explicit behavior, are treated as elastic or elastic-plastic materials. The interbeds found between the layers of salt are represented as planes of frictional slip with a coefficient of friction of 0.2, taken as a constant for all calculations and based on qualitative evaluation of in situ behavior.

At this time, the principal parameters for clean salt of the M-D model have been framed in terms of probability distribution functions (Fossum et al., 1994) and the analysis has been made to determine a distribution function for creep closure of a simulated crushed-salt-filled shaft seal configuration. Calculated creep closure was to a selected crushed salt density (Fossum and Munson, 1995). The distribution functions for argillaceous salt still have to be determined and additional evaluations of shaft closure have to be made. Comparisons must be made of the fast probability integration and Monte Carlo methods.

2.4 Stratigraphy and Initial Conditions

The stratigraphic detail for the numerical simulations is the updated version given by Munson et al. (1989a), as shown in Figure 3, which modified that given earlier by Krieg (1984). This updated stratigraphy is specialized to capture those aspects of the materials important to the mechanical behavior, and therefore differs from those reflecting more common geological aspects. Features of geological importance often are not influential in terms of mechanical behavior.

The initial stress condition of the site is essentially one of uniform rock pressure ($\sigma_1 = \sigma_2 = \sigma_3$) due to the overburden (Wawersik and Stone, 1989).

2.5 Numerical Codes

Essentially, three distinct numerical structural codes have the necessary (as noted previously in *40 CFR 268.6(b)(3)*, *40 CFR 268.6(b)(5)*, and *40 CFR 264.601*) capabilities to simulate the major aspects of the WIPP underground as follows: SANTOS, JAC-3D (Biffle, 1993), and SPECTROM-32 (Callahan et al., 1989). These codes use finite-element, numerical solution methods. Their current capabilities include a choice of flow potential, multiple material layers, slide lines to emulate interbed seams, and birth/death options simulating mining. Two codes are limited to two-dimensional simulations, while one code, JAC-3D, has the capability

for either two- or three-dimensional simulations. All of these codes can account for large (finite) strains, a feature of some importance in treating the long times and large deformations involved in some WIPP problems. All codes currently incorporate the M-D model; however, JAC-3D and SPECTROM-32 have the most experience with simulations using this model. SPECTROM-32 is rated as a Level A code according to Sandia QAP 19-1 quality assurance requirements.

2.6 Remarks

The creep models are "continuum" models and, as a result, they do not allow fracture. However, if we are addressing the long-term creep closure effects, such as that of complete repository creep closure to encapsulate the waste, the problem, in fact, is relatively simple. The creep closure involves the removal of all underground void, regardless of whether the void volume is that of the original repository room or some redistribution of this volume, such as occurs with the formation of microfractures around the room. In this case, then, the prediction involves only the general response of the entire salt body to eliminate the underground void volume; and, therefore, the use of a continuum creep model is both adequate and sufficient. Certainly, there are temporary situations, such as formation of a potentially permeable DRZ around seals, that must be considered. In fact, the calculated creep strain caused by the formation of the DRZ is quite small (3%) compared to the continuum creep stains, so that it does not affect significantly the comparison between measured and calculated continuum creep closure. However, the small strains associated with the development of microfractures can have a large effect on changes in permeability. Again, in the long-term closure, the microfractures, because of the conservation of mass (or void) do not change the encapsulation process. In the more complicated situation of concurrent gas generation, the gas will potentially act as a source within the repository to increase the required void volume and alter the encapsulation process.

The proper form of the plastic flow potential remains an issue within the technical community. Historically, most structural analysts continue to use the von Mises potential in creep structural problems. However, based on the definitive thin-walled cylinder results and the success of the calculations of *in situ* behavior, the Tresca potential should be considered the proper plastic flow criterion for creep of salt.

Currently, an issue to be resolved concerns whether the fast probability integration (FPI) methods produce the same results as the Monte Carlo or Latin Hypercube methods currently used for the WIPP program. For very complex structural calculations, Monte Carlo or Latin Hypercube methods require too many realizations or calculations to be economical. Perhaps only FPI methods are efficient enough to permit probabilistic analysis of structural responses.

However, because no mathematical proof of equivalency of the methods exist, direct comparisons of simple problems will be necessary to establish confidence in the FPI method.

2.7 Continuum Creep Data to Analysis Guide

The database and analysis history is too extensive to be included directly in this paper. As a alternative, a partial reference guide is given in Table V.

Table V. Continuum Creep Data and Analysis Guide

Conceptual Model	Model	Analysis	References (partial)
Creep closure of rooms expected to encapsulate the waste (NAS 1957) and assure sealing of shafts	M-D Multi-mechanism deformation model	Numerical finite element simulations	Model -- Munson et al. 1989a PA 1992, Vol. 3 Parameters -- Munson et al. 1989a PA 1992, Vol. 3 Flow potential -- Mellegard et al. 1992 PA 1992, Vol. 3 *In situ* data -- Matalucci et al. 1982 Munson 1991 Munson & others 1987b, 1988b, 1990b, 1991b, 1991c, 1992b, 1992c, etc. Stratigraphy -- Munson et al. 1989a PA 1992, Vol. 3 Initial conditions -- Wawersik & Stone 1985 Munson et al. 1989a PA 1992, Vol. 3 Analysis -- Munson & DeVries 1991 Munson & others 1987a, 1988a, 1989b, 1990a, 1991a, 1992a, 1993, etc.

3.0 FRACTURE

It is known that, as the continuum creep deformation of the salt immediately adjacent to the underground openings occurs, conditions for the formation of microfractures become favorable and the salt experiences a progressive increase in microfracturing. This process is evident as damage which evolves with time. These microfractures may eventually link to form discrete cracks. At late times, the discrete cracks propagate and link until the salt fails. Expression of this process *in situ* leads to the creation and accumulation of damage in the rock, which gives rise to the DRZ. The material expression of this process in the laboratory is the tertiary creep behavior, as shown in the curve which incorporates fracture in Figure 1. These details of fracture development become relevant in two specific cases: (1) At relatively small amounts of damage which is the early portion of the tertiary behavior, the formation of microfractures may cause an increase of permeability, and consequently, a potential loss of long-term seal system integrity and performance that may be reasonably expected for regulatory compliance (as given in *40 CFR 191.13*, *40 CFR 191.14*, and *40 CFR 191.24*). As a result, this effort supports the performance response of the repository rooms and drifts, especially for Disposal Room models and seal systems through Seal Design and Modeling. (2) The development of fractures and a DRZ must be recognized and appropriate steps taken to deal with the conditions encountered during operational activities, such as construction, for example. Of these two cases, the Rock Mechanics Program is primarily concerned with the first case in which only relatively small amounts of damage occur.

As previously mentioned, the relationship of the fracture model to the M-D continuum creep model and the DRZ process model is to add a crucial component to the modeling capability. The development of microfractures described by the fracture model contributes only a few percent to the closure strain, and even that strain eventually is removed by continuum creep. However, the small amount of fracture strain or damage may in fact be responsible for marked changes in permeability and deterioration of the performance of seals. This is why the fracture model is important to the compliance goal. The DRZ process model combines individual models, such as functional forms for damage healing and permeability changes with damage together with the creep and fracture models, to assess the DRZ growth evolution (growth or healing) with time.

The study to understand fracture is an important area of development of the Rock Mechanics Program and it is currently the most active. This activity includes the additional theoretical inputs to define the cleavage modes of fracture and complete the fracture model, the development of the capability to handle bed separation, the generation of the experimental

database for the argillaceous salt material, the final parameter selection for the fracture model, and the further comparisons to the underground observations of damage to demonstrate validity.

3.1 Fracture Constitutive Model

The constitutive model of fracture has been formulated to address progressive, time-dependent development of damage (Chan et al., 1992). This model, which is the multimechanism deformation (M-D) continuum creep model coupled to fracture (MDCF), is based on the Bodner-Partom (Bodner, 1985) description of tertiary creep, with the parameters determined from laboratory creep tests (Fossum et al., 1993). The Bodner-Partom description for tertiary creep is a very non-linear evolutionary equation for damage. The MDCF model defines from the damage a new strain contribution, due to deformation of the microfractures, which evolves with time. Damage enters the model directly through the damage strain and indirectly through reduction of the loaded area to increase the effective stress. From the fracture mechanism map (Gandhi and Ashby, 1979), this formulation represents two separate fracture mechanisms, one of which, stress rupture, is very relevant to the WIPP conditions. The model accounts for important effects of confining pressure in that microfracture is sensitive to confining pressure and can be completely suppressed. The model also contains a feature that permits the elimination of damage, which simulates the rehealing process, as the damaged salt is repressurized. Such repressurization is expected to occur around seals as they take up load from the overburden as the creep-closure process continues.

As in the case of the continuum creep model, the attempt during the development of the fracture model is to maintain a fundamental basis wherever possible. The fracture model is based on a fracture mechanism map which defines the regions in non-dimensionalized stress and homologous temperature that different fracture mechanisms dominate. Just as for the deformation mechanism map, the fracture mechanism map can be used as a guide to the model development. In contrast to the deformation mechanisms, fracture mechanisms are very sensitive to confining pressure. In certain instances, the confining pressure will suppress the fracture process completely. As a result, the fracture model imposes the effect of confining pressure on fracture. Of the possible fracture mechanisms, three relate directly to the conditions of the WIPP underground. These are a brittle grain boundary fracture mechanism of short-time failure which is strain-rate dependent, a stress rupture mechanism which is the long-time failure mode, and a cleavage failure mechanism. The fracture mechanism of stress rupture dominates the formation of microfractures during the development of the DRZ and is considered the most important mechanism. This mechanism appears to obey the Monkman and Grant (1956) criterion of a constant strain to long-term failure.

The MDCF model is a "ubiquitous" model in the sense that it describes the damage as though it is smoothly distributed throughout a material volume. That is, the presence of discrete fractures is not modeled or tracked in the MDCF formulation. However, this is not a significant problem in addressing the issue of the formation, growth, and healing of the DRZ for use in sealing system performance assessment and design where the damage is limited to small values. For these conditions the model is thought to be accurate. In terms of the level of validation of the fracture model, it is much less advanced than the M-D continuum creep model. As is apparent, some work remains to be done to achieve reasonable expectation of regulatory compliance. The remaining work involves further refinement of the fracture constitutive model, determination of material properties, comparison of model predictions to underground observations, and the proper incorporation of the interbed behavior. Regardless, the model is currently developed adequately to be used for seal design studies of the influence of the DRZ on seal performance.

Several "stress-based" fracture models have been used on WIPP analyses. In the analysis of the permeability changes in the DRZ, Stormont et al. (1992) used a time-independent representation of the stress strain curve and calculated changes in volumetric (dilatant) strain with increase in stress. A similar approach has been used in support of the study of design alternatives for seal systems (Van Sambeek et al., 1993). Unless specifically modified, stress-based models in general do not permit the damage to evolve independently with time as a separate material behavior, a characteristic feature that is known to occur in salt. In these models, changes in damage may occur only as the stress field changes in time. In fact, if the stress field around an opening decreases with time, accumulated damage would incorrectly appear to decrease also. In general, the stress-based fracture models need to be replaced by the time-dependent evolutionary formulation of the MDCF.

3.2 Fracture Model Parameters

The MDCF fracture material parameters have been determined for clean salt, and preliminary parameters are now becoming available for argillaceous salt. It appears based on experimental evidence that the small quantity (<4 %) of clay content in argillaceous salt has a marked effect on the microfracture behavior, increasing the rate of damage evolution and decreasing the time to failure. A comparison of creep and fracture behavior shows that, although clay increases the creep rate and the transient strain, an equivalent clay content has a much more marked influence on the fracture response. Apparently, the overall effect of clay content is quite important in that it causes argillaceous salt layers to accumulate damage at a higher rate than the clean salt layers, which appear to match the underground response. However, until the entire available database has been evaluated, the fracture model parameters will not be given.

3.3 Numerical Code MDCF Model Incorporation

The MDCF model has been incorporated into SPECTROM-32 and a number of preliminary simulations made of the WIPP underground room configurations, including the storage room configuration. It has been possible to make a preliminary comparison to the formation of the damage, as measured by ultrasonic wave speed, around the Air Intake Shaft. Although further analysis is required, the model calculation compares qualitatively with the measured results, especially in the radial extent of the damage, as shown in Figure 7. The nature of the fracture model is such that it will also predict the accumulation of large amounts of damage, essentially that equivalent to failure. In a preliminary sense, it has been used to calculate the accumulation of damage around a room of the Transuranic (TRU) Test Panel, as shown in Figure 8. While direct comparison is not yet possible because the ubiquitous model does not permit localization, the initial fracture pattern is certainly suggestive of the fracture trajectories observed in these rooms. These simulations have been encouraging because they show development of damage around the underground opening with time, which matches in a qualitative sense the general observations. The predicted behavior is thought to be more realistic than previously possible with the earlier, stress-based, time- independent fracture models which cannot evolve with time and do not have a true tertiary creep- related measure of damage.

3.4 Discrete Fracture - Fracture Mechanics Approach

For the more extreme conditions of damage accumulation, it is necessary to treat discrete crack formation and propagation; this technology is not so well developed. Work is in progress to address the problem of the localization of the damage to produce a discrete fracture. There are two distinct approaches to this problem: global and local. The classic or global approach is to convert at some point the ubiquitous results in a mesh to a discrete element with an advancing crack tip, which presents mathematical and numerical difficulties. The simplest of these global approaches (linear elastic fracture mechanics) has been applied to the WIPP problem of the response of interbeds to the pressurization of the repository by gas generation. However, with a simplistic linear elastic approximation what is often found is that the linear elastic energies misestimate severely the actual conditions of an elastic-plastic, creeping crack tip. A common assumption of a characteristic length to control the energy release has not always proven satisfactory because of difficulty in rationally specifying the length. In fact, in some cases where the "process" zone is very complicated, the mathematical representation has no

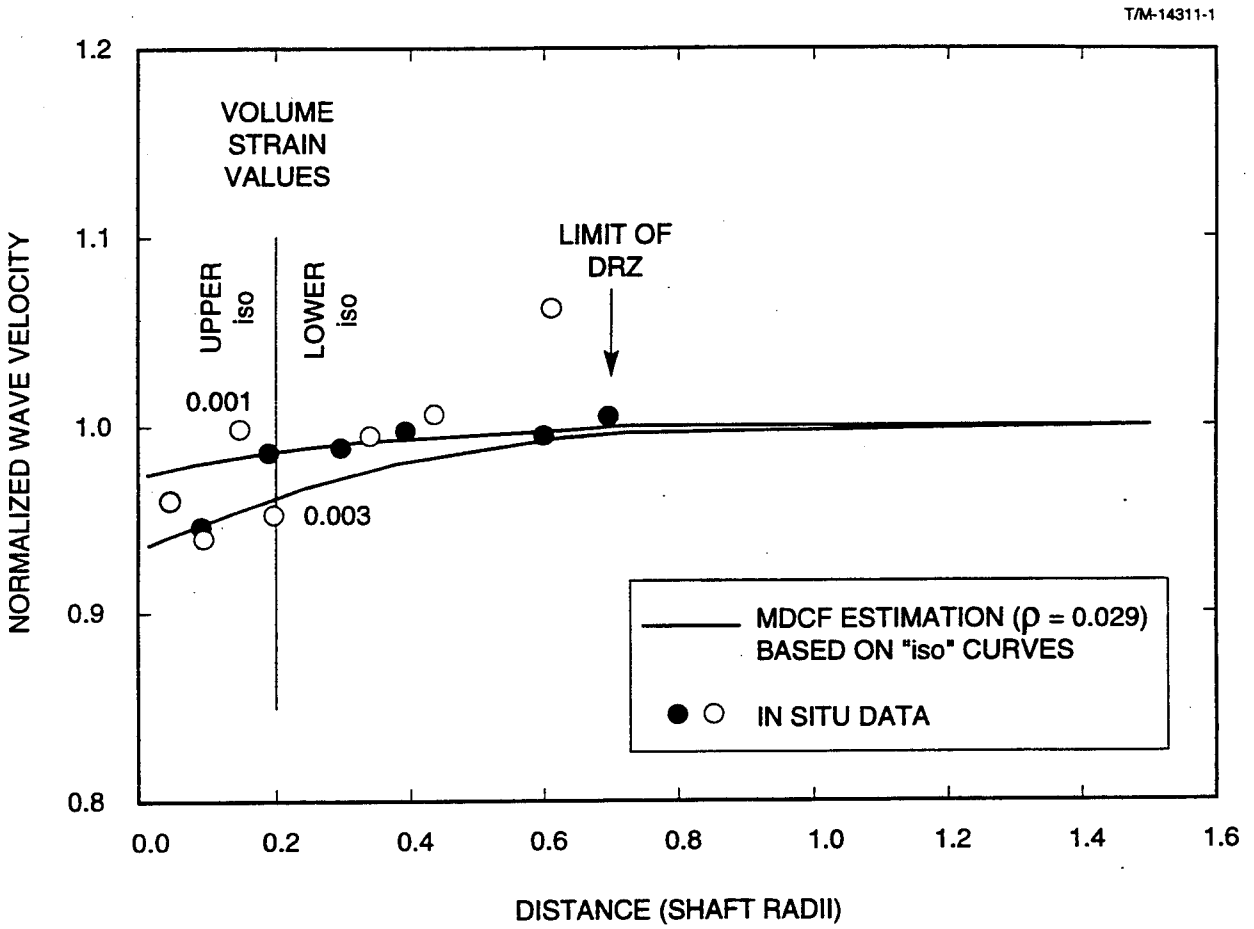

Figure 7. Comparison of in situ ultrasonic equivalent of damage against MDCF model calculation. Comparison based on isotropic ("iso") distribution of microfractures, with the upper and lower MDCF estimations obtained from the range of laboratory data of the change in ultrasonic velocity with volume dilatancy.

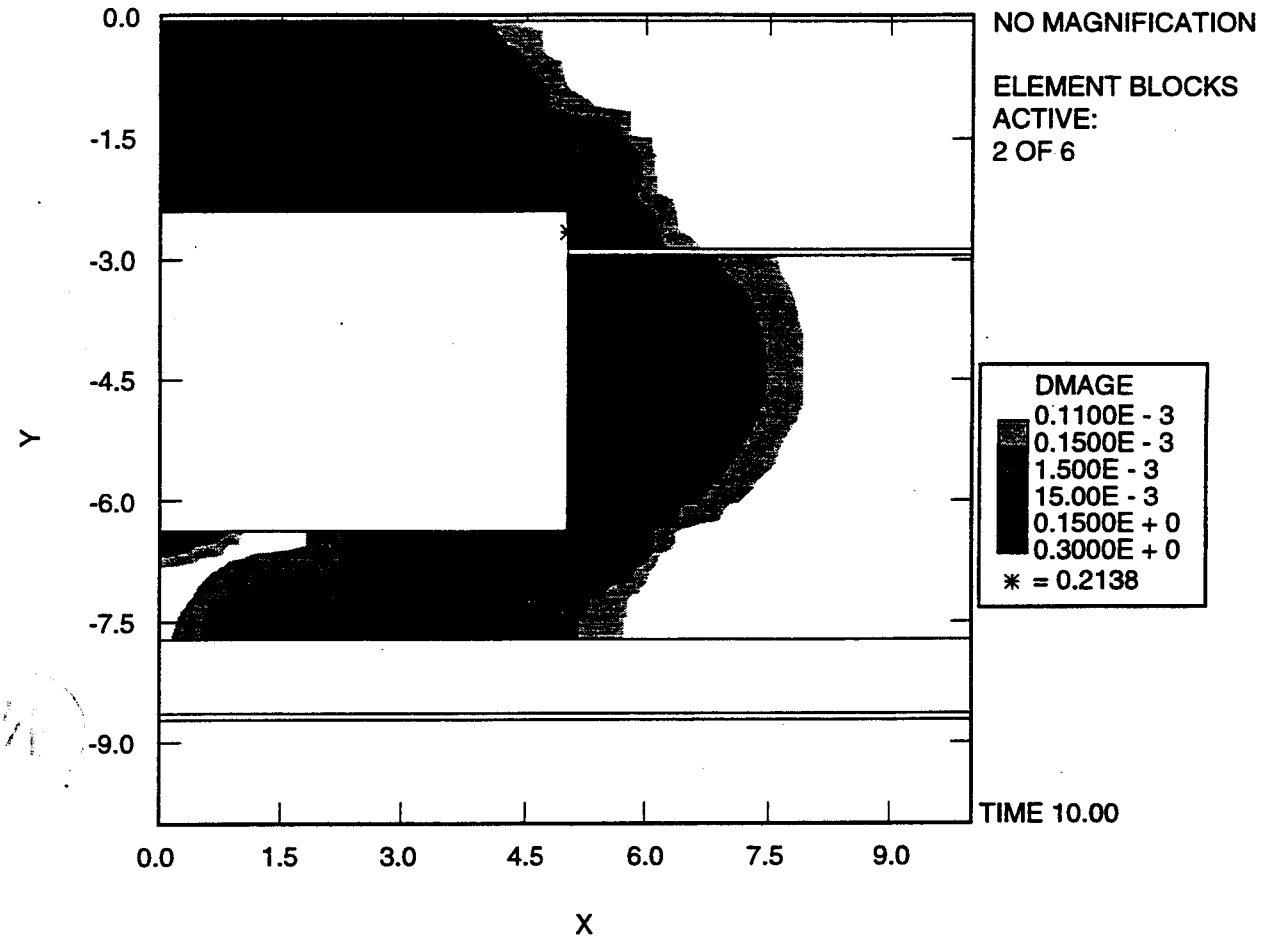

Figure 8. Predicted damage around a TRU test panel room.

independent parameter available in the solution to take the role of the fracture toughness, and the crack tip conditions no longer can be described by global parameters. In this case the stress field becomes independent of the applied stress and may become geometry dependent.

3.5 Discrete Fracture - Local Approach

A more recent development, which is an alternative to the global approach, is to use a local approach based on "adaptive meshing" where the gradients of damage or energy across a mesh serve as a measure of the need to refine the mesh. As mesh refinement occurs at regions of high damage gradients, the highly refined mesh generates a trajectory of the crack. Adaptive meshing requires only the definition of the ubiquitous model, without the need to introduce special elements to define the discrete crack. Although coding of adaptive meshing is not an easy task, this is the reason the rock mechanics program has chosen the adaptive meshing approach.

3.6 Remarks

Although the predictive technology for fracture damage and failure is not as well developed as for creep deformation, several significant advances have been made. The MDCF model already incorporates the necessary features and is capable of simulating the shaft sealing systems. The important contribution of the MDCF model is that the time-dependent accumulation of damage is strain based, in marked contrast to earlier models based on stress related quasistatic onset of dilatancy. This model is expected to replace the earlier stress-based models for use in WIPP shaft seal design calculations.

As noted, the uncertain aspects of fracture modeling appear in the manner in which the fracture damage is extended to discrete cracks. The proper, and physically correct, choice between global (fracture mechanics) and local (ubiquitous models) is not yet settled. For very complex situations, such as those around a moving crack tip in a creeping material, no global solution appears to be available so the use of fracture mechanics is not possible. Thus, for salt, at this time, a local approach appears more reasonable.

3.7 Fracture Model Data to Analysis Guide

The database and analysis history is too extensive to be included directly into this paper. As a alternative, a partial reference guide is given in Table VI.

Table VI. Fracture Model Data and Analysis Guide

Conceptual Model	Model	Analysis	References (partial)
Creep closure is accompanied by fracture evolution around shafts and rooms (PA 1992) which makes a small contribution to strain but a large potential change in permeability	MDCF Multi-mechanism deformation model coupled to	Numerical finite element simulations	Model -- Chan et al. 1992 Parameters -- (in progress) Fossum et al. 1994 Flow potential -- Mellegard et al. 1992 PA 1992, Vol. 3 *In situ* data -- (in progress) Stratigraphy -- Munson et al. 1989a PA 1992, Vol. 3 Initial conditions -- Wawersik & Stone 1985 Munson et al. 1989a PA 1992, Vol. 3 Analysis -- (in progress)

4.0 DISTURBED ROCK ZONE (DRZ)

The DRZ is the zone of rock immediately surrounding underground openings in which the mechanical and hydrologic properties have changed in response to the excavation and subsequent creep. Since the existence of the DRZ was documented (Borns and Stormont, 1988, 1989; Holcomb, 1988) and accepted at the WIPP (Lappin et al., 1990) the Project has postulated that the DRZ has an impact on (1) gas and brine storage relocation, (2) localized hydrologic response of the Salado Formation, (3) design and performance of seals, and (4) repository design. DRZ investigations address compliance issues for the Seals Program through Seal Design and Modeling and Seal Field Studies programs, since the DRZ development at the proposed seal locations determine changes in hydraulic and mechanical properties of the seal system with time. Compliance issues are addressed for Salado Hydrology by supporting Flow and Transport Modeling, Hydrologic Field Studies and Large-Scale Brine Inflow Experiment.

Except for some laboratory, numerical simulations, and minor field studies, the investigations of the DRZ were largely ended in 1991. The exceptions are the Large-Scale Brine Inflow Experiment (Room Q), where studies of hydrologic and physical behavior continue, and the Air Intake Shaft, where ultrasonic studies are still in progress. However, the current technical position would benefit from additional information, which it appears may eventually be needed. It appears especially important to monitor the time-dependent hydrologic behavior of the DRZ (e.g., water saturation, porosity, and permeability). Monitoring the time-dependent behavior of the DRZ will be of great significance from initial excavation and, when possible, during and after seal emplacement tests. Characterization is required of the DRZ in proposed seal locations. Also, the extent and propensity for fracturing in the Salado marker beds needs to be more fully investigated. Some of these concerns are being addressed by a current investigation of the DRZ developed around the small-scale seals tests.

4.1 Process Model of DRZ

As shown in Table I, the model for describing the DRZ is classified as a *process* model. This implies that the model is actually a collection of individual physical elements that describe mechanical and hydrological behavior of the DRZ behavior. Thus, the DRZ process model must, at least, incorporate the creep response through the creep model, the formation of microfractures through the MDCF fracture model for predicting damage evolution, the model for describing healing of microfractures under pressure, and a physical model relating the damage to permeability. Application of this process model to seal design, for example, permits a test of the design against performance criteria over the critical recompaction period of the crushed salt seal components.

As is evident from the results in Figures 7 and 8, some elements of the DRZ process model are currently operational, while others are well advanced and eminently available. The constitutive model of the damage evolution (MDCF) has been developed which can be applied to predict the time-dependent details of the evolution of damage. The model is able to simulate the fractional damage surrounding an excavation, either shaft or room. Because the damage measure determined by the model is not a physical quantity, a correlation function to volume dilatancy in the form of a non-associated flow rule has been established. To provide the physical link to hydrological performance, the permeability, as previously mentioned, as a function of the volume dilatancy completes the predictive capability. A functional form of the healing relationship has been established based on laboratory results. This relationship is the sum of two first-order kinetics equations and is now incorporated into the DRZ model.

Two of the elements of the DRZ process model are major models: the M-D model of continuum creep and the MDCF model of damage evolution. These models of mechanical behavior have been fully treated in the earlier discussions. The other elements will be discussed here.

4.2 Kinetics of Healing

The kinetics of the microfracture healing process have been determined through laboratory tests (Brodsky and Munson, 1994). Damaged dry salt specimens heal, as measured by the return of volume strain and ultrasonic wave speed, according to the sum of two first-order kinetic equations. The characteristic time constant of the process is on the order of days, which is short compared to that of the creep process. In seal system performance, this suggests that the damage healing depends only on the rate that the creep process repressurizes the seal. Because of the short time constants and based on void geometry, the healing process is thought to differ significantly from the compaction process of final void elimination in crushed salt.

4.3 Permeability Relationship to Damage

Although a measure of the relationship between permeability and damage can be obtained from back correlations of damage calculations to the permeabilities measured *in situ*, the most direct measure will come from laboratory experiments. In these experiments, previously damaged specimens with known volume dilatancies are used to determine permeability. Relatively few laboratory experiments are currently available from which to deduce a relationship. Consequently, additional studies will probably be necessary to improve the definition of the permeability-damage relationship.

4.4 Peripheral Inputs

There are some critical peripheral inputs to the analysis of the DRZ under the actual conditions as they pertain to seals and seal systems. It is of interest to mention the most important of these inputs here for completeness. The analysis of a seal system requires a description of the mechanical and hydrological behavior of the seal components. This especially means the behavior of the concrete and crushed salt components, because these are the principal materials being considered. In general, these peripheral inputs are being developed in WIPP Programs on Seals, external to the Rock Mechanics Program.

4.5 DRZ Characterization

The DRZ has been characterized by three approaches: visual observation, geophysical methods, and *in situ* hydrologic testing (Borns, 1985; Bechtel National, 1985; USDOE, 1988). Geophysical studies have utilized seismic refraction, seismic tomography, surface wave analysis, electromagnetic (EM) methods, and direct current (DC) methods (Borns and Stormont, 1989; Borns et al., 1990; Holcomb, 1988; Jung et al., 1991; Pfeifer et al., 1989). Taken in conjunction with the *in situ* hydrologic tests, these studies define a DRZ extending to a depth of 1 to 5 meters throughout the underground facility (Borns and Stormont, 1988; Stormont et al., 1991). The DC and EM methods indicate that fracture saturation or fracture density may vary laterally along the excavations. These *in situ* studies also demonstrate that microfracturing and desaturation of the pore space have occurred within the DRZ. The dilation that results from the microfracturing in the DRZ provides a small component of the observed room closure. The processes involved in the development of the DRZ are complex, although basically related to the strain and strain rates of the salt adjacent to the underground opening. The redistribution of stress around the excavation with the development of the DRZ drives coupled processes such as changes in permeability and porosity in response to fracture growth.

Gas flow measurements have previously been conducted in the Salado Formation immediately surrounding excavations. Measurements taken in small diameter boreholes (50 to 150 mm) show that, within 1 to 2 m of the excavation, the halite has very little resistance to fluid flow. Tracer tests (Stormont et al., 1987; Stormont, 1990) demonstrate that flow paths are consistent with the elliptical fracture pattern generally applied to describe fracture distribution around excavations. These tests have provided a qualitative description of the fluid flow properties of a DRZ adjacent to the facility rooms and drifts at the WIPP. However, such a description is difficult to accommodate from the performance assessment perspective. In fact, a conceptual model of the repository zone requires as input the quantitative distributions for the porosity, permeability, and initial saturation of the DRZ. At the present time, the fluid flow

characteristics of the DRZ have not been described by an experimentally derived conceptual model. Models of the DRZ have thus far been limited to constitutive modeling of the structural deformation processes. These observations relate to the formation of the DRZ adjacent to rooms specifically and, while the formation of the DRZ adjacent to shafts has similar characteristics, the DRZ at the shaft will differ significantly in detail.

The well instrumented Air Intake Shaft (Munson et al., 1992a) at the WIPP facility has formed the nucleus of several important studies. It has already been noted that shaft creep closure aided in the validation study of the creep model and the preliminary comparisons of the calculated MDCF damage with *in situ* ultrasonic measurements in the shaft. This shaft will undoubtedly continue to provide data for DRZ characterization. Although initially planned, permeability testing in the shaft has not been possible to date.

An *in situ* test is currently in progress to characterize the hydrological behavior of the DRZ in the vicinity of earlier small-scale concrete seal test configurations emplaced in salt. The intent of this test is to provide a linkage between the MDCF model and the needed fluid flow parameters for the DRZ. The analysis will include modeling of the excavated borehole and the seal.

4.6 Remarks

Perhaps the most relevant issue at this time regarding the DRZ concerns general agreement on a reasonable description, essentially quantitative, of the time-dependent evolution of damage, porosity, permeability, and hydrologic processes. These basic pieces of knowledge have not been completely determined, *in situ*, to provide the parameters and processes for the repository performance models or to validate current damage models. The existence of the DRZ is not in question, but the role it plays in the room response and in the shaft sealing is not currently settled. Considerable work must be done to quantify the *in situ* properties and extent to the DRZ. Certainly, a continuation of the validation effort is required to iteratively and painstakingly compare the quantitative *in situ* studies to the current and refined constitutive descriptions which predict the evolution of the damage. Other important issues that remain to be resolved are the relationships between deformation in the DRZ and the hydrologic process of the Salado and the DRZ, including evolution of porosity and permeability. The effects and significance of chemical precipitation in fractures and pores of the DRZ, which can be taken as part of the healing process, have not been investigated nor incorporated into any of the numerical models.

4.7 DRZ Process Model to Analysis Guide

As noted previously for the other rock mechanics models, the database and analysis history of the DRZ is also too extensive to be included directly into this paper. As an alternative, a partial reference guide is given in Table VII.

Table VII. DRZ Process Model Data and Analysis Guide

Conceptual Model	Model	Analysis	References (partial)
Complex fracture and deformation processes under actual conditions may alternately degrade and heal the disturbed zone with time, with changes in permeability, a potential critical performance issue for shaft seals.	Combination of several deformat-mechanical, and hydro models.	Numerical finite element simulations	Model -- (in progress) Parameters -- (in progress) *In situ* data -- Borns & Stormont 1988 Borns & Stormont 1989 Stormont 1990 Stormont et al. 1991 Healing kinetics -- Brodsky & Munson 1994 Permeability/Damage -- (in progress) Analysis -- (in progress)

5.0 SUMMARY

Although there remain small areas of incomplete development and perceived further needs, the technology produced by the Rock Mechanics Program is basically sound and reasonable. The fundamental understanding of the creep process, together with a capable predictive technology, is well developed and technically sound. This predictive technology is essential to the WIPP Program because ultimately continuum creep determines the time required for closure of the rooms and the eventual encapsulation of the waste. The creep closure response is also responsible for recompaction of the crushed salt seal components.

The level of understanding of the fracture process is not as well developed as that of continuum creep. However, significant progress has been made in that the constitutive models of fracture now are closely tied to theory and laboratory data, and moreover describe the fracture modes thought essential for the WIPP conditions. The fracture model can lead to a reasonable description of the evolution of damage in the disturbed rock zone or DRZ. Such a damage prediction capability facilitates understanding the long-term response of sealing systems, especially where the DRZ has the potential to form a detrimental high permeability path to deteriorate seal performance. Detailed examination and evaluation of the DRZ remains an issue because this will form the validation basis to decrease the level of uncertainty in our predictive capability. Evaluations and testing of the DRZ also should include the aspects of coupling the damage evolution to changes in permeability and porosity.

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APPENDIX SCR

This appendix discusses natural Features, Events and Processes (FEPs) (SCR.1), waste-induced or facility-induced FEPs (SCR.2), and human-induced Events and Processes (EPs) (SCR.3) consistent with draft guidance contained in *"No-Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guide Manual for Petitioners* (Environmental Protection Agency [EPA] 1992, 34-35). EPA (1992) contains additional details for preparing a No-Migration Variance Petition (NMVP) in accordance with the performance requirements provided in Title 40 Code of Federal Regulations (CFR) Part 268.6. Where relevant, EPA (1992, 38) Information Checklist Criteria are discussed within the context of the Uncertainty Analysis Criteria in a manner consistent with the discussion of FEPs addressed in other Waste Isolation Pilot Plant (WIPP) compliance documents.

This appendix:

- identifies which FEPs are considered in the no-migration demonstration calculations, and which ones are screened out on the basis of consequence or low probability
- makes points concerning the conservative or reasonable nature of model assumptions
- identifies uncertainty and describes how uncertainty is accounted for in the no-migration demonstration. Assessment of uncertainty in this appendix focuses on conceptual model uncertainty. Parameter uncertainty is addressed in Appendix PAR

The FEPs identified and discussed in this appendix have been classified according to whether they were included in no-migration demonstration calculations or were screened out using two criteria: probability and consequence.

FEPs that have a low probability of occurring within the geological setting of the WIPP, or within the chemical and physical conditions expected within the disposal unit, have been screened out. By analogy with EPA guidance in appendix C of 40 CFR 194.32(d), the Department of Energy (DOE) has assumed that FEPs with a probability of less than 10^{-4} over 10,000 years can be excluded from consideration in no-migration demonstration calculations. Quantitative assessments of probability cannot be made for all FEPs, and qualitative arguments based on reasonableness have been made for a number of FEPs.

There are three categories of FEPs that have been screened out from no-migration demonstration calculations on the basis of consequence. The first category includes those FEPs the DOE believes have negligible consequences (e.g., FEP does not affect the source term, the mobility of hazardous constituents, the integrity of the disposal unit, or a simulated process modeled as part of the larger disposal system).

The second category of FEPs screened out on the basis of consequence includes those FEPs that would reduce the source term of hazardous constituents and/or reduce the mobility of those constituents. The inclusion of these FEPs in the no-migration demonstration calculations would have a beneficial consequence by reducing the amount of hazardous constituents calculated to reach the disposal unit boundary. Screening out FEPs with a beneficial consequence therefore constitutes a set of conservative assumptions and provides additional levels of assurance that the amount of hazardous constituents reaching the disposal unit boundary will not exceed the appropriate health-based limits (HBLs).

The third category of FEPs screened out on the basis of consequence includes those that affect the source term or mobility of hazardous constituent metals. Two alternative bounding approaches selected by the DOE to demonstrate no-migration of hazardous-constituent metals in the liquid phase do not require detailed evaluation of chemical mobility. The primary bounding compliance measure is migration away from the waste-disposal panels, assumed to be contaminated through potential contact with waste. In the event contaminated brine leaves the waste area, an alternative strategy would be to track the migration of a surrogate tracer, representing a liquid-phase hazardous constituent, to the unit boundary.

SCR.1 NATURAL FEATURES, EVENTS, AND PROCESSES

The natural FEPs discussed in this section are potentially relevant to the analyses conducted to support the NMVP required by 40 CFR § 268.6. The NMVP is required to evaluate the consequences of predictable future events. The U.S. DOE believes that natural events that are unlikely to occur in the region of the WIPP are not predictable in this sense, and, hence, the consequence of unlikely events has not been evaluated. Natural events and processes that are occurring in the region of the WIPP, or are expected to occur in the future, are evaluated in terms of their effect on the disposal unit and/or the disposal system.

In the remainder of Section SCR.1, the DOE discusses natural FEPs in the context of the FEP categorization scheme presented in Table SCR-1. The categories concerned with geology (1.1), hydrology (1.2), and geochemistry (1.3) relate to the subsurface structure, fluid flow, and fluid chemistry, respectively. The categories concerned with geomorphology (1.4), surface hydrology (1.5), climate (1.6), marine environment (1.7), and ecology (1.8) relate to natural FEPs occurring at and near the ground surface that may affect subsurface conditions. FEPs presented in Table SCR-1 are printed in bold in the text of the FEP screening discussions.

Table SCR-1. Natural FEPs and Their Screening Classifications

FEPs		Screening Classification	Comments	Reference Appendix SCR Section
GEOLOGICAL				1.1
Stratigraphy				1.1.1
	Stratigraphy	NMD		
Tectonics				1.1.2
	Changes in regional stress	SO-C		
	Regional tectonics	SO-C		
	Regional uplift and subsidence	SO-C		
Structural effects				1.1.3
Deformation				1.1.3.1
	Salt deformation	NMD near repository.	SO-P elsewhere	
	Diapirism	SO-P		
Fracture development				1.1.3.2
	Formation of fractures	NMD near repository.	SO-P elsewhere	
	Changes in fracture properties	NMD near repository.	SO-C elsewhere	
Fault movement				1.1.3.3
	Formation of new faults	SO-P		
	Movement along faults	SO-P		
Seismic activity				1.1.3.4
	Earthquakes	NMD	DRZ assumptions	
	Ground shaking	NMD	DRZ assumptions	
Crustal processes				1.1.4
Igneous activity				1.1.4.1
	Volcanic activity	SO-P		
	Magmatic activity	SO-C		
Metamorphism				1.1.4.2
	Metamorphism	SO-P		
Geochemical effects				1.1..5
Dissolution				1.1.5.1
	Shallow dissolution	SO-C		
	Lateral dissolution	SO-C		
	Deep dissolution	SO-P		
	Solution chimneys	SO-P		
	Breccia pipes	SO-P		
	Collapse breccias	SO-P		
Mineralization				1.1.5.2
	Fracture infilling	SO-C		
	Hydrothermal alteration	SO-P		
SUBSURFACE HYDROLOGICAL				1.2
Groundwater flow characteristics				1.2.1
	Saturated groundwater flow	SO-C		
	Unsaturated groundwater flow	SO-C		
	Groundwater flow: fractures	SO-C		
	Effects of preferential pathways	SO-C		
Changes in groundwater flow				1.2.2
	Thermal effects on groundwater flow	SO-C		
	Saline groundwater intrusion	SO-P		
	Fresh groundwater intrusion	SO-C		
	Density effects on groundwater flow	SO-C		
	Hydrological response to earthquakes	SO-C		

Legend:

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table SCR-1. Natural FEPs and their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
SUBSURFACE GEOCHEMICAL			1.3
Groundwater geochemistry			1.3.1
Groundwater geochemistry	NMD		
Changes in groundwater chemistry			1.3.2
Saline groundwater intrusion	SO-C		
Fresh groundwater intrusion	SO-C		
Changes in groundwater Eh	SO-C		
Changes in groundwater pH	SO-C		
Effects of dissolution on groundwater chemistry	SO-C		
GEOMORPHOLOGICAL			1.4
Physiography			1.4.1
Physiography	NMD		
Meteorite impact			1.4.2
Meteorite impact	SO-P		
Denudation			1.4.3
Weathering			1.4.3.1
Mechanical weathering	SO-C		
Chemical weathering	SO-C		
Erosion			1.4.3.2
Aeolian erosion	SO-C		
Fluvial erosion	SO-C		
Mass wasting	SO-C		
Sedimentation			1.4.3.3
Aeolian deposition	SO-C		
Fluvial deposition	SO-C		
Lacustrine deposition	SO-C		
Mass wasting	SO-C		
Soil development			1.4.4
Soil development	SO-C		
SURFACE HYDROLOGICAL			1.5
Fluvial			1.5.1
Surface flow characteristics: stream/river flow	SO-C		
Lacustrine			1.5.2
Surface water bodies	SO-C		
Infiltration / recharge / discharge			1.5.3
Groundwater discharge	SO-C		
Groundwater recharge	SO-C		
Infiltration	SO-C		
Changes in surface hydrology			1.5.4
Changes in groundwater recharge / discharge	SO-C		
Lake formation / infilling	SO-C		
River flooding	SO-C		
CLIMATIC			1.6
Climate			1.6.1
Precipitation	SO-C		
Temperature	SO-C		
Wind	SO-C		
Climate change			1.6.2
Meteorological			1.6.2.1
Climate change	NMD		
Drought	SO-C		

Legend:

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table SCR-1. Natural FEPs and their Screening Classifications (continued)

FEPs		Screening Classification	Comments	Reference Appendix SCR Section
Glaciation				1.6.2.2
	Glaciation	SO-P		
	Permafrost	SO-P		
MARINE				1.7
Seas				1.7.1
	Coastal waters	SO-C		
	Ocean waters	SO-C		
	Estuaries	SO-C		
Marine sedimentology				1.7.2
	Coastal erosion	SO-C		
	Marine sediment transport and deposition	SO-C		
Sea level change				1.7.3
	Sea level change	SO-C		
ECOLOGICAL				1.8
Flora & fauna				1.8.1
	Plants	SO-C		
	Animals	SO-C		
	Microbes	SO-C		
Changes in flora & fauna				1.8.2
	Natural ecological development	SO-C		

Legend:

NMD	FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C	FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P	FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

SCR.1.1 Geological

SCR.1.1.1 Stratigraphy

The stratigraphy of the geological formations in the region of the WIPP is accounted for in no-migration demonstration calculations. The ***stratigraphy*** *and geology of the region around the WIPP are discussed in detail in Section 2.1 of the NMVP.*

SCR.1.1.2 Tectonics

The effects of regional tectonics, regional uplift or subsidence, and changes in stress are not included in no-migration demonstration calculations on the basis of low consequence to the performance of the disposal unit.

Regional tectonics encompasses two related issues of concern: the overall level of regional stress and whether or not any significant **changes in regional stress** might occur.

The tectonic setting and structural features of the area around the WIPP are described in Section 2.1.5 of the NMVP. In summary, there is no geological evidence for Quaternary regional tectonics, epeirogenic displacement, or orogenic diastrophism in the Delaware Basin. The eastward tilting of the region has been dated as mid-Miocene to Pliocene by King (1948, 120-121) and is associated with the uplift of the Guadalupe Mountains to the west. Fault zones along the eastern margin of the basin, where it flanks the Central Basin Platform, were active during the late Permian period. Evidence of this includes the displacement of the Rustler Formation (hereafter referred to as the Rustler) observed by Holt and Powers (1988, 4-14) and the thinning of the Dewey Lake Redbeds (hereafter referred to as the Dewey Lake) reported by Schiel (1994). There is, however, no surface displacement along the trend of these fault zones, indicating that there has been no significant Quaternary movement. Other faults identified within the evaporite sequence of the Delaware Basin are inferred by Barrows in Borns et al. (1983, 58-60) to be the result of salt deformation, rather than regional tectonic processes. According to Muehlberger et al. (1978, 338), the nearest faults on which Quaternary movement has been identified lie to the west of the Guadalupe Mountains and are of minor regional significance.

There are no reported stress measurements from the Delaware Basin, but a low level of regional stress has been inferred from the geological setting of the area (see Section 2.1.5 of the NMVP). The inferred low level of regional stress and the lack of Quaternary tectonic activity indicate that regional tectonics will be of low consequence to the performance of the disposal unit. Even if rates of regional tectonic movement experienced over the past 10 million years continue, the extent of **regional uplift or subsidence** over the next 10,000 years would only be on the order of several feet (approximately 1 m). This amount of uplift or subsidence would not lead to a breach of the Salado, because the salt would deform plastically to accommodate this slow rate of movement. Uniform regional uplift or a small increase in regional dip consistent with this past rate could give rise to downcutting by rivers and streams in the region. The extent of this downcutting would be little more than the extent of uplift, and reducing the overburden by one or two m would have no significant effect on the disposal unit.

SCR.1.1.3 Structural Effects

SCR.1.1.3.1 Deformation

Natural salt deformation at the WIPP site over the next 10,000 years severe enough to significantly affect performance of the disposal unit is not included in no-migration demonstration calculations on the basis of low probability of occurrence. However, local deformation of the Salado around repository excavations is accounted for in no-migration demonstration calculations (see Sections 2.1.6, 8.2.3.1, and 8.2.5.3 of the NMVP).

Deformed salt in the lower Salado and upper Castile has been encountered in a number of boreholes around the WIPP site; the extent of existing salt deformation is summarized in Section 2.1.6.1 of the NMVP, and further detail is provided in Appendix DEF.

A number of mechanisms may result in **salt deformation**; in massive salt deposits, buoyancy effects or **diapirism** may cause salt to rise through denser, overlying units, and in bedded salt with anhydrite or other interbeds, gravity foundering of the interbeds into the halite may take place. Results from rock mechanics modeling studies indicate that the time scale for the deformation process is such that significant natural deformation is unlikely to occur at the WIPP site over any time frame significant to waste isolation. Thus, natural salt deformation severe enough to alter existing patterns of groundwater flow or the behavior of the disposal system over the regulatory period is not included in no-migration demonstration calculations on the basis of low probability of occurrence.

SCR.1.1.3.2 Fracture Development

The formation of new fracture sets that could affect the disposal system is not included in no-migration demonstration calculations on the basis of a low probability of occurrence over 10,000 years. Naturally-induced changes in fracture properties are not included in no-migration demonstration calculations on the basis of low consequence to the performance of the disposal unit. Repository-induced fracturing of the disturbed rock zone (DRZ) and Salado interbeds is included in no-migration demonstration calculations.

The **formation of fractures** requires significant changes in stress to overcome the shear and tensile strength of the rock. The regional tectonic setting of the Delaware Basin is described in Section 2.1.5 of the NMVP. It is concluded that no significant changes in regional stress are expected over the regulatory period (see also Section SCR.1.1.2). The formation of new fracture sets, is, therefore, not included in no-migration demonstration calculations on the basis of a low probability of occurrence over 10,000 years.

Changes in fracture properties can arise through smaller changes in the local stress field; for example, through erosion changing the amount of overburden, or by dissolution or precipitation of mineral infillings. The extent of natural changes in fracture properties in undisturbed Salado potentially affecting brine and gas flow calculations are expected to be small. Changes in fracture properties are not included in no-migration demonstration calculations on the basis of low consequence.

SCR.1.1.3.3 Fault Movement

Naturally induced fault generation and fault movement of sufficient magnitude to significantly affect the performance of the disposal unit are not included in no-migration demonstration calculations on the basis of low probability of occurrence over 10,000 years.

Faults are present in the Delaware Basin in both the units underlying the Salado and in the Permian evaporite sequence (see Section 2.1.5.3 of the NMVP). According to Powers et al. (1978, 4-57), there is evidence that movement along faults within the pre-Permian units affected the thickness of Early Permian strata, but these faults did not exert a structural control on the deposition of the Castile Formation (hereafter referred to as the Castile), the Salado, or the Rustler. Fault zones along the margins of the Delaware Basin were active during the late Permian period. Along the eastern margin, where the Delaware Basin flanks the Central Basin Platform, Holt and Powers (1988, 4-14) note there is displacement of the Rustler, and Schiel (1994) notes there is thinning of the Dewey Lake. There is, however, no surface displacement along the trend of these fault zones, indicating that there has been no significant Quaternary movement. Muehlberger et al. (1978, 338) note that the nearest faults on which Quaternary movement has been identified lie to the west of the Guadalupe Mountains.

The absence of Quaternary fault scarps and the general tectonic setting and understanding of its evolution indicate that large-scale tectonically-induced **fault movement** within the Delaware Basin can be eliminated from no-migration demonstration calculations on the basis of low probability. The stable tectonic setting also means that the **formation of new faults** within the basin over the next 10,000 years is not included in no-migration demonstration calculations on the basis of low probability of occurrence.

Subsidence above natural dissolution features could lead to the formation of, and movement along, local faults. However, significant dissolution in the region of the waste panels is not included in no-migration demonstration calculations on the basis of low probability of occurrence (see Section SCR.1.1.5.1), and, therefore, faults arising from dissolution are also not included on the basis of low probability of occurrence.

SCR.1.1.3.4 Seismic Activity

The postclosure effects of seismic activity on the repository and the DRZ are accounted for in no-migration demonstration calculations through the treatment of the DRZ as a zone of permanently high permeability. The effects of seismic activity beyond the DRZ are not included in no-migration demonstration calculations on the basis of low consequence.

This section is concerned with the effects of seismic activity away from the immediate source region, and only the effects of groundshaking are discussed. Other SCR sections discuss the direct effects of fault movement (SCR.1.1.3.3), and changes in hydrogeology induced by seismic activity (SCR.1.2.2).

Causes of Seismic Activity

Seismic activity describes transient ground motion that may be generated by a variety of energy sources. There are two possible causes of seismic activity that could potentially affect the WIPP site: natural and human-induced. Natural seismic activity is caused by

fault movement (**earthquakes**) when the buildup of strain in rock is released through sudden rupture or movement. Human-induced seismic activity may result from a variety of surface and subsurface activities, such as explosions, mining, fluid injection, and fluid withdrawal, discussed in SCR.3.

Groundshaking

Ground vibration and the consequent shaking of buildings and other structures are the most obvious effects of seismic activity. Once the repository and shafts have been sealed, however, existing surface structures will be dismantled. Postclosure performance assessments are concerned with the effects of seismic activity on the closed repository.

An assessment of the extent of damage in underground excavations caused by **groundshaking** largely depends on observations from mines and tunnels. Because such excavations tend to take place in rock types more brittle than halite, these observations cannot be related directly to the behavior of the WIPP. According to Wallner (1981, 244), the DRZ in brittle rock types is likely to be more highly fractured, and, hence, more prone to spalling and rockfalls, than an equivalent zone in salt. Relationships between groundshaking and subsequent damage observed in mines will, therefore, be conservative with respect to the extent of damage induced at the WIPP by seismic activity.

Dowding and Rozen (1978) classified damage in underground structures following seismic activity and found that no damage (cracks, spalling, or rockfalls) occurred at accelerations below 0.2 gravities (g) and that only minor damage occurred at accelerations up to 0.4 g. Lenhardt (1988) derived an empirical relationship to show that a magnitude 3 earthquake would have to be within 0.6 mi (1 km) of a mine to result in falls of loose rock. The risk of seismic activity in the region of the WIPP reaching these thresholds is discussed below.

Seismic Risk in the Region of the WIPP

Prior to the introduction of a seismic monitoring network in 1960, the majority of recorded earthquakes in New Mexico were associated with the Rio Grande Rift, although small earthquakes were felt in other parts of the region. In addition to continued activity in the Rio Grande Rift, the instrumental record has shown a significant amount of seismic activity originating from the Central Basin Platform and a number of small earthquakes in the Los Medaños area. Seismic activity in the Rio Grande Rift is associated with extensional tectonics in that area. Seismic activity in the Central Basin Platform may be associated with natural earthquakes, but there are also indications that this activity occurs in association with oil-field activities, such as fluid injection. Small earthquakes in the Los Medaños region have not been precisely located, but may be the result of mining activity in the region. Section 2.6.2 of the NMVP contains additional discussion of seismic activity and risk in the WIPP region.

The instrumental record was used as the basis of a seismic risk study primarily intended for design calculations of surface facilities, rather than postclosure performance assessments. The use of this study to define probable ground accelerations in the WIPP region over the next 10,000 years is based on the assumptions that hydrocarbon extraction and potash mining will continue in the region and that the regional tectonic setting precludes major changes over the next 10,000 years.

Three source regions were used in calculating seismic risk: the Rio Grande Rift, the Central Basin Platform, and part of the Delaware Basin province (including the Los Medaños). Using conservative assumptions about the maximum magnitude event in each zone, the study indicated a period of about 10,000 years (annual probability of occurrence of 10^{-4}) for events giving ground accelerations of 0.1 g. Ground accelerations of 0.2 g would have an annual probability of occurrence of about 5×10^{-6}.

Combining the results of the seismic risk study, considering the observations of damage in mines due to groundshaking, gives an estimated annual probability of occurrence of between 10^{-6} and 10^{-8} for events that could increase the permeability of the DRZ. The DRZ is accounted for in no-migration demonstration calculations as a zone of permanently high permeability; this treatment is considered to account for the effects of any potential seismic activity.

SCR.1.1.4 Crustal Processes

SCR.1.1.4.1 Igneous activity

Volcanic activity is not included on the basis of low probability of occurrence over 10,000 years, and the effects of magmatic activity are not included on the basis of low consequence.

Volcanic Activity

The Paleozoic and younger stratigraphic sequences within the Delaware Basin are devoid of locally derived volcanic rocks. Volcanic ashes (dated at 13 million years and 0.6 million years) do occur in the Gatuña Formation (hereafter referred to as the Gatuña), but these are not locally derived. Within eastern New Mexico and northern, central, and western Texas, the closest Tertiary volcanic rocks with notable areal extent or tectonic significance to the WIPP are approximately 100 mi (160 km) to the south in the Davis Mountains volcanic area. The closest Quaternary volcanic rocks are 150 mi (241 km) to the northwest in the Sacramento Mountains. No volcanic rocks are exposed at the surface within the Delaware Basin.

Volcanic activity is associated with particular tectonic settings: constructive and destructive plate margins, regions of intraplate rifting, and isolated "hot-spots" in intraplate regions. The tectonic setting of the WIPP site and the Delaware Basin is remote from plate margins, and the absence of past volcanic activity indicates the absence

of a hot-spot in the region. Intraplate rifting has taken place along the Rio Grande some 120 mi (193 km) west of the WIPP site during the Tertiary and Quaternary periods. Igneous activity along this rift valley is comprised of sheet lavas intruded on by a host of small to large plugs, sills, and other intrusive bodies. However, the tectonic setting of the WIPP site allows volcanic activity in the region of the WIPP repository to be eliminated from performance calculations on the basis of low probability of occurrence.

Magmatic Activity

Magmatic activity is defined as the subsurface intrusion of igneous rocks into country rock. Deep intrusive igneous rocks, such as granites, form at depth and have no surface or near-surface expression until after considerable erosion has taken place. Alternatively, intrusive rocks may form from magma that has risen to near the surface or in the vents that give rise to volcanoes and lava flows. Magma near the surface may be intruded along subvertical and subhorizontal discontinuities (forming dikes and sills, respectively), and magma in volcanic vents may solidify as plugs. The formation of such features close to a repository, or the existence of a recently intruded rock mass, could impose thermal stresses inducing new fractures, altering the hydraulic characteristics of existing fractures, or initiating hydrothermal activity.

The principal area of magmatic activity in New Mexico is the Rio Grande Rift, where extensive intrusions occurred during the Tertiary and Quaternary Periods. The Rio Grande Rift, however, is in a different tectonic province than the Delaware Basin, and its magmatic activity is related to the extensional stress regime and high heat flow in that region.

Within the Delaware Basin, there is a single identified outcrop of a lamprophyre dike about 40 mi (64 km) southwest of the WIPP (see Section 2.1.5.4 of the NMVP and Chapter 3 of Appendix GCR for more detail). Closer to the WIPP site, similar rocks have been exposed within potash mines some ten mi (16 km) to the northwest, and igneous rocks have been reported from petroleum exploration boreholes. Material from the subsurface exposures has been dated at around 35 million years. Some recrystallization of the host rocks took place alongside the intrusion, and there is evidence that minor fracture development and fluid migration also occurred along the margins of the intrusion. However, the fractures have been sealed, and there is no evidence that the dike acted as a conduit for continued fluid flow.

Aeromagnetic surveys of the Delaware Basin have shown anomalies on a linear southwest-northeast trend that coincide with the surface and subsurface exposures of magmatic rocks. There is a strong indication, therefore, of a dike or a closely related set of dikes extending for at least 70 mi (113 km) across the region. The aeromagnetic survey conducted to delineate the dike showed a magnetic anomaly that is several km wide at depth and narrows to a thin trace near the surface. This pattern is interpreted as the result of an extensive dike swarm at depths of less than 2.5 mi (approximately 4.0 km) near the Precambrian basement, from which a limited number of dikes have extended

towards the surface. If magmatic activity is continuing at depth, it could potentially lead to the extension of another dike or dike swarm towards the surface. Continuing magmatic activity would lead to a heat flow anomaly in the region, but measurements from the AEC-8 borehole (see Chapter 2, Figure 2-2) show a geothermal heat flux of around 44 mWm^{-2}. This heat flux is typical of regional heat flows in the Southern Great Plains and is significantly less than that in regions of active or recent magmatic activity, such as the Rio Grande Rift.

Magmatic activity has taken place in the vicinity of the WIPP site in the past, but the igneous rocks have cooled over a long period of time. Any enhanced fracturing or conduits for fluid flow have been sealed by salt creep and mineralization. The existence of a broad magnetic anomaly at depth suggests that the dike found near the surface is derived from a larger dike swarm at depth, but heat flow measurements indicate that this magmatic activity has ceased. Continuing magmatic activity in the Rio Grande Rift is too remote from the WIPP location to be of consequence to the performance of the disposal unit. Thus, the effects of magmatic activity are not included in no-migration demonstration calculations on the basis of low consequence.

SCR.1.1.4.2 Metamorphism

Metamorphic activity is not included in no-migration demonstration calculations on the basis of low probability of occurrence.

Metamorphic activity, that is, changes to rock properties and geologic structures through the effects of heat and/or pressure, requires depths of burial much greater than that of the repository. Regional tectonics that would result in the burial of the repository to the depths at which the repository would be affected by metamorphic activity are not included in no-migration demonstration calculations on the basis of low probability of occurrence; therefore, metamorphic activity is also not included in no-migration demonstration calculations on the basis of low probability of occurrence.

SCR.1.1.5 Geochemical Effects

SCR.1.1.5.1 Dissolution

Shallow and lateral dissolution are not included in no-migration demonstration calculations on the basis of low consequence. Deep dissolution and the formation of associated features (e.g., solution chimneys, breccia pipes, collapse breccias) at the WIPP site are not included in no-migration demonstration calculations on the basis of low probability of occurrence.

This section discusses a variety of styles of dissolution that have been active in the region of the WIPP or in the Delaware Basin. A distinction has been drawn between **shallow dissolution**, percolation of groundwater and mineral dissolution into the Rustler, **lateral dissolution**, involving dissolution at the top of the Salado, and **deep dissolution** taking

place in the Castile and the base of the Salado. Dissolution will initially enhance porosities, but continued dissolution may lead to compaction of the affected units with a consequent reduction in porosity. Compaction may result in fracturing of overlying brittle units and increased permeability. Extensive dissolution may create cavities (karst) and result in the total collapse of overlying units. This topic is discussed further in Section 2.1.6.2 of the NMVP.

Shallow Dissolution

Flow through fractures is an important contributor to groundwater flow in the Culebra and other units of the Rustler, and the conductivity of fractures is the principal control of this flow. Dissolution of fracture infillings and any subsequent changes in groundwater flow in the Rustler will, however, be of low consequence to the disposal unit and disposal system. Thus, shallow dissolution is not included in no-migration demonstration calculations on the basis of low consequence.

Lateral Dissolution

Lateral dissolution takes place when percolating groundwater dissolves halite at the top of the Salado, causing collapse of the overlying Rustler with consequent changes in hydrogeological properties. Nash Draw, some 5 mi (8 km) to the west of the WIPP site, is the most prominent lateral dissolution feature in the region. An average lateral dissolution rate of from 6 to 8 mi (10 to 13 km) per million years has been calculated by Bachman and Johnson (1973) for the Salado based on the assumption that the edge of the salt has moved from the Capitan Reef to its present position over a period of from 7 to 8 million years. A vertical dissolution rate of 0.06 mi (0.09 km) per million years has similarly been calculated by Bachman (1980, 1981) using dated ash layers. Although these are average rates and may be exceeded during particular climate states or by advancing tongues ahead of the main dissolution front, these rates indicate that dissolution of the Salado at the edge of the WIPP site would not take place for some 225,000 years, and an additional 2 to 3 million years would be required for dissolution to reach the repository horizon. Lateral dissolution, therefore, has been screened out on the basis of low consequence to the performance of the disposal system.

Deep Dissolution

Deep dissolution refers to the dissolution of salt or other evaporite minerals in a formation at depth (see Section 2.1.6.2 of the NMVP). Deep dissolution is distinguished from shallow and lateral dissolution not only by depth, but also by the origin of the water. Dissolution by groundwater from deep, water-bearing zones can lead to the formation of cavities. Collapse of overlying beds leads to the formation of **collapse breccias**, if the overlying rocks are brittle, or to deformation if the overlying rocks are ductile. If dissolution is extensive, **breccia pipes** or **solution chimneys** may form above the cavity. These pipes may reach the surface or pass upwards into fractures and then into microcracks that do not extend to the surface. Breccia pipes may also form through the

downward percolation of meteoric waters, as discussed earlier in this section. Deep dissolution is of concern, because it could accelerate hazardous constituent transport through the creation of vertical flow paths.

Features identified as the result of deep dissolution are present along the northern and eastern margins of the Delaware Basin. In addition to features that have a surface expression or that appear within potash mine workings, deep dissolution has been cited by Anderson et al. (1972) as the cause of lateral variability within evaporite sequences in the lower Salado. Observations concerning various features ascribed to deep dissolution are considered below.

Solution Chimneys

Exposures of the McNutt Potash Member of the Salado within a mine near Nash Draw have shown a solution pipe containing cemented brecciated fragments of formations higher in the stratigraphic sequence. At the surface, this feature is marked by a dome, and similar domes have been interpreted as dissolution features. The depth of dissolution has not been confirmed, but the collapse structures led Anderson (1978) and Snyder and Gard (1982) to postulate dissolution of the Capitan Limestone at depth, collapse of the Salado, Rustler, and younger formations, and subsequent dissolution and hydration by downward percolating waters. San Simon Sink (see Section 2.1.6.2 of the NMVP), some 20 mi (32 km) east-southeast of the WIPP site, has also been interpreted as a solution chimney. Subsidence has occurred here in historical times according to Nicholson and Clebsch (1961), suggesting that dissolution at depth is still taking place. Whether this is the result of downward-percolating surface water or of deep groundwater has not been confirmed. The association of these dissolution features with the inner margin of the Capitan Reef suggest that they owe their origins, if not their continued development, to groundwaters derived from the Capitan Limestone.

Dissolution within the Castile and Lower Salado Formations

The Castile contains sequences of varved anhydrite and carbonate (that is, laminae deposited on a cyclical basis) that can be correlated between several boreholes. On the basis of these deposits, a basin-wide uniformity in the depositional environment of the Castile evaporites was assumed. The absence of varves from all or part of a sequence and the presence of brecciated anhydrite beds was interpreted by Anderson et al. (1972) as evidence of dissolution. Holt and Powers (1988) questioned the assumption of a uniform depositional environment and contend that the anhydrite beds are lateral equivalents of halite sequences without significant post-depositional dissolution. Wedges of brecciated anhydrite along the margin of the Castile were interpreted by Robinson and Powers (1987) as gravity-driven clastic deposits, rather than the result of deep dissolution.

Localized depressions at the top of the Castile and inclined geophysical marker units at the base of the Salado were interpreted by Davies (1983) as the result of deep dissolution and subsequent collapse or deformation of overlying rocks. The postulated cause of this

dissolution was circulation of undersaturated groundwaters from the Bell Canyon Formation (hereafter referred to as the Bell Canyon). Additional boreholes (notably WIPP-13, WIPP-32, and DOE-2) and geophysical logging led Borns and Shaffer (1985) to conclude that the features interpreted by Davies as being dissolution features are the result of irregularities at the top of the Bell Canyon. These irregularities led to localized depositional thickening of the Castile and lower Salado sediments.

Collapse Breccias at Basin Margins

Collapse breccias are present at several places around the margins of the Delaware Basin. Their formation is attributed to relatively fresh groundwater from the Capitan Limestone that forms the margin of the basin. Collapse breccias corresponding to features on geophysical records ascribed to deep dissolution have not been found in boreholes away from the margins. These features have been reinterpreted as the result of early dissolution prior to the deposition of the Salado. This topic is discussed further in Section 2.1.6.2 of the NMVP.

Deep dissolution features have been identified within the Delaware Basin, but only in marginal areas underlain by the Capitan Reef. There is a low probability that deep dissolution will occur sufficiently close to the waste panels over the regulatory period to affect the integrity of the disposal unit in the immediate region of the WIPP. Deep dissolution at the WIPP site is, therefore, not included in no-migration demonstration calculations on the basis of low probability of occurrence.

SCR.1.1.5.2 Mineralization

The effects of fracture infilling are not included in no-migration demonstration calculations on the basis of low consequence. The effects of hydrothermal alteration are not included in no-migration demonstration calculations on the basis of low probability.

Precipitation of minerals as **fracture infills** can reduce hydraulic conductivities. An increase in the proportion of infilled fractures in the Rustler and any subsequent changes in groundwater flow patterns will be of low consequence. There is no evidence of any fracture infills within the anhydrite interbeds in the Salado; any such infills that form in the future would serve to reduce the permeability of the interbeds and reduce the quantity of brine that might reach the disposal unit boundary. Infilling of fractures is, therefore, not included in no-migration demonstration calculations.

The groundwater temperatures and geothermal gradient in the region around the WIPP are too low for **hydrothermal alteration** of minerals to take place. No mechanism has been identified that could significantly increase the geothermal gradient at the WIPP over the next 10,000 years.

SCR.1.2 Subsurface Hydrological

SCR.1.2.1 Groundwater Flow Characteristics

The effects of groundwater flow are not included in no-migration demonstration calculations on the basis of low consequence.

Groundwater flow is discussed in Chapter 2 of the NMVP. The hydraulic gradient in the Salado is too low for natural groundwater flow to take place in this unit. Groundwater flow, including **unsaturated flow**, **preferential pathways**, and **fracture flow** does take place in the units overlying the Salado, but does not affect the disposal unit. The effects of naturally-driven groundwater flow are, therefore, not included in no-migration demonstration calculations on the basis of low consequence.

SCR.1.2.2 Changes in Groundwater Flow

The effects of changes in groundwater flow arising from climate change, natural thermal variation, and earthquakes are not included in no-migration demonstration calculations on the basis of low consequence. Changes in groundwater flow arising from saline intrusion are not included on the basis of a low probability of occurrence over 10,000 years.

SCR.1.2.2.1 Infiltration and Recharge Effects

A number of FEPs, including climate change, can result in changes in infiltration and recharge, and, hence, on groundwater flow in the Rustler. These FEPs are discussed in Section SCR.1.5.3. Changes in infiltration could alter the density of the groundwater, but such **density effects on groundwater flow** will be of low consequence, because it would not affect potential brine and gas flow in Salado.

SCR.1.2.2.2 Saline Intrusion

No natural events or processes have been identified that could result in significant **saline intrusion** or cause a significant increase in fluid density.

SCR.1.2.2.3 Thermal Effects

The geothermal gradient in the region of the WIPP has been measured at about 50°C per mi (30°C per km). Given the generally low permeability in the region, any natural convection will be too weak to affect groundwater flow significantly. No natural FEPs have been identified that could significantly alter the temperature distribution of the disposal system or give rise to **thermal effects on groundwater flow**, because it would not affect potential brine and gas flow in Salado.

SCR.1.2.2.4 Hydrological Effects of Seismic Activity

There are a variety of **hydrological responses to earthquakes**. Some of these responses, such as changes in surface-water flow directions, result directly from fault movement. Others, such as changes in subsurface water chemistry and temperature, probably result from changes in flow pathways along the fault or fault zone. The expected level of seismic activity in the region of the WIPP will be of low consequence in terms of groundwater flow. Changes in groundwater levels resulting from more distant earthquakes will be of too short a duration to be significant.

Changes in groundwater flow arising from natural events and processes are not included in no-migration demonstration calculations, because it would not affect potential brine and gas flow in Salado.

SCR.1.3 Subsurface Geochemical Effects

SCR.1.3.1 Groundwater Geochemistry

The geochemistry of brine in the Salado is accounted for in no-migration demonstration calculations.

Groundwater geochemistry is discussed in detail in Section 2.2 of the NMVP. The Delaware Mountain Group, Castile, and Salado all contain basinal brines, which in the Salado are at or near halite saturation. Physical effects of brine composition on calculated flow and brine migration are accounted for in no-migration demonstration calculations.

SCR.1.3.2 Changes in Groundwater Chemistry

The effects of future natural changes in groundwater chemistry are not included in no-migration demonstration calculations on the basis of low probability of occurrence.

Changes in the groundwater chemistry of the Salado could potentially affect solubility and the stability of colloids. No natural events or processes have been identified that could result in **saline or freshwater intrusion** into the Salado or result in **changes in groundwater Eh and pH.** Dissolution of halite at the top of the Salado that could cause changes in groundwater chemistry is not expected to be significant in the region of the WIPP (see Section SRC.1.1.5.1). The **effects of dissolution** and other natural changes in groundwater geochemistry are not included in no-migration demonstration calculations on the basis of low probability of occurrence.

SCR.1.4 Geomorphological

SCR.1.4.1 Physiography

The effect of physiography on the elevation of the water table and hydrostatic conditions in the disposal system are accounted for in no-migration demonstration calculations.

Physiography and geomorphology are discussed in detail in Section 2.1.4 of the NMVP.

SCR.1.4.2 Meteorite Impact

Meteorite impact is not included in no-migration demonstration calculations on the basis of low probability of occurrence over 10,000 years.

Meteors frequently enter the earth's atmosphere, but the majority of these are small and burn up before reaching the ground. Of those that reach the ground, most produce only small impact craters that would have no effect on the postclosure integrity of a repository 2,150 ft (655 m) below the ground surface. While the depth of a crater may be only one-eighth of its diameter, the depth of the disrupted and brecciated material is typically one-third of the overall crater diameter (Grieve 1987, 248). Direct disruption of waste at the WIPP would only occur with a crater larger than 1.1 mi (1.8 km) in diameter. Even if waste were not directly disrupted, the **impact of a large meteorite** could create a zone of fractured rocks beneath and around the crater. The extent of such a zone would depend on the rock type. For sedimentary rocks, the zone may extend to a depth of half the crater diameter or more (Dence et al. 1977, 263). The impact of a meteorite causing a crater larger than 0.6 mi (1 km) in diameter could, thus, fracture the Salado above the repository.

Geological evidence for meteorite impacts on earth is rare, because many meteorites fall into the oceans, and erosion and sedimentation serve to obscure craters that form on land. Dietz (1961) estimated that meteorites that cause craters larger than 0.6 mi (1 km) in diameter strike the earth at the rate of about one every 10,000 years (equivalent to about 2×10^{-13} impacts per km^2 per year). Using observations from the Canadian Shield, Hartmann (1965) estimated a frequency of between 0.8×10^{-13} and 17×10^{-13} per km^2 per year for impacts causing craters larger than 0.6 mi (1 km). Frequencies estimated for larger impacts in studies reported by Grieve (1987, 263) can be extrapolated to give a rate of about 1.3×10^{-12} per km^2 per year for craters larger than 0.6 mi (1 km). It is commonly assumed that meteorite impacts are randomly distributed across the earth's surface, although Halliday (1964) calculated that the rate of impact in polar regions would be some 50 to 60 percent of that in equatorial regions. The frequencies reported by Grieve would correspond to an overall rate of about one per 1,000 years on the basis of a random distribution.

Assuming the higher estimated impact rate of 17×10^{-13} impacts per km^2 per year for impacts leading to fracturing of sufficient extent to affect a deep repository, and assuming

a repository footprint of 1.4 km × 1.6 km for the WIPP, yields a frequency of about 4×10^{-12} impacts per year for a direct hit above the repository. This impact frequency is several orders of magnitude below the screening limit of 10^{-8} per year (10^{-4} over 10,000 years) adopted by the DOE.

Meteorite hits directly above the repository footprint are not the only impacts of concern, however, because large craters may disrupt the waste panels even if the center of the crater is outside the repository area. It is possible to calculate the frequency of meteorite impacts that could disrupt a deep repository such as the WIPP by using the conservative model of a cylinder of rock fractured to a depth equal to one-half the crater diameter, as shown in Figure 1. The area within which a meteorite could impact the repository is calculated by

$$S_D = (L + 2\times\frac{D}{2}) \times (W + 2\times\frac{D}{2}) \qquad \text{(SCR-1.1)}$$

where

L = length of the repository footprint (km)
W = width of the repository footprint (km)
D = diameter of the impact crater (km)
S_D = area of the region where the crater would disrupt the repository (km^2).

There are insufficient data on meteorites that have struck the earth to derive a distribution function for the size of craters directly. Using meteorite impacts on the moon as an analogy, however, Grieve (1987, 257) derived the following distribution function:

$$F_D \propto D^{-1.8} \qquad \text{(SCR-1.2)}$$

where

F_D = frequency of impacts resulting in craters larger than D ($impacts/km^2/year$).

If f(D) denotes the frequency of impacts giving craters of diameter D, then the frequency of impacts giving craters larger than D is

$$F_D = \int_D^{\infty} f(D)dD \qquad \text{(SCR-1.3)}$$

Area S_D is the critical region for meteorite impacts that could result in fracturing at the repository horizon. The inner rectangular block represents the repository and the cylinder represents the disrupted volume associated with a meteorite crater of diameter D,

and

$$f(D) = F_1 \times 1.8 \times D^{-2.8} \qquad \text{(SCR-1.4)}$$

where

F_1 = frequency of impacts resulting in craters larger than 1 km (impacts/km^2/year)

f(D) = frequency of impacts resulting in craters of diameter D (impacts/km^2/year).

The overall frequency of meteorite impacts that could disrupt or fracture the repository is thus given by

$$N = \int_{2h}^{\infty} f(D) \times S_D \, dD \qquad \text{(SCR-1.5)}$$

where

h = depth to repository (km)

N = frequency of impacts leading to disruption of the repository (impacts/year) and

$$N = 1.8F_1[1.8LW(2h)^{-1.8} + 0.8(L+W)(2h)^{-0.8} - 0.2(2h)^{0.2}]. \qquad \text{(SCR-1.6)}$$

If it is assumed that the repository is located at a depth of 2,150 ft (655 m) and has a footprint area of 1.4 km × 1.6 km and that meteorites creating craters larger than 1 km in diameter hit the earth at a frequency (F_1) of 17×10^{-13} impacts per km^2 per year, then the above equation gives a frequency of approximately 1.3×10^{-11} impacts per year for impacts disrupting the repository. If impacts are randomly distributed over time, this corresponds to a probability of 1.3×10^{-7} over 10,000 years.

Similar calculations have been performed that indicate rates of impact of between 10^{-12} and 10^{-13} per year for meteorites large enough to disrupt a deep repository (see, for example, Hartmann 1979; Kärnbränslesakerhet 1978; Logan and Berbano 1978; Claiborne and Gera 1974; Cranwell et al. 1990; and Thorne 1992). Meteorite impact can thus be eliminated from no-migration demonstration calculations on the basis of low probability of occurrence over 10,000 years.

Assuming a random or nearly random distribution of meteorite impacts, cratering at any location is inevitable given sufficient time. Although repository depth and host-rock lithology may reduce the consequences of a meteorite impact, there are no repository locations or engineered systems that can reduce the probability of impact over 10,000 years.

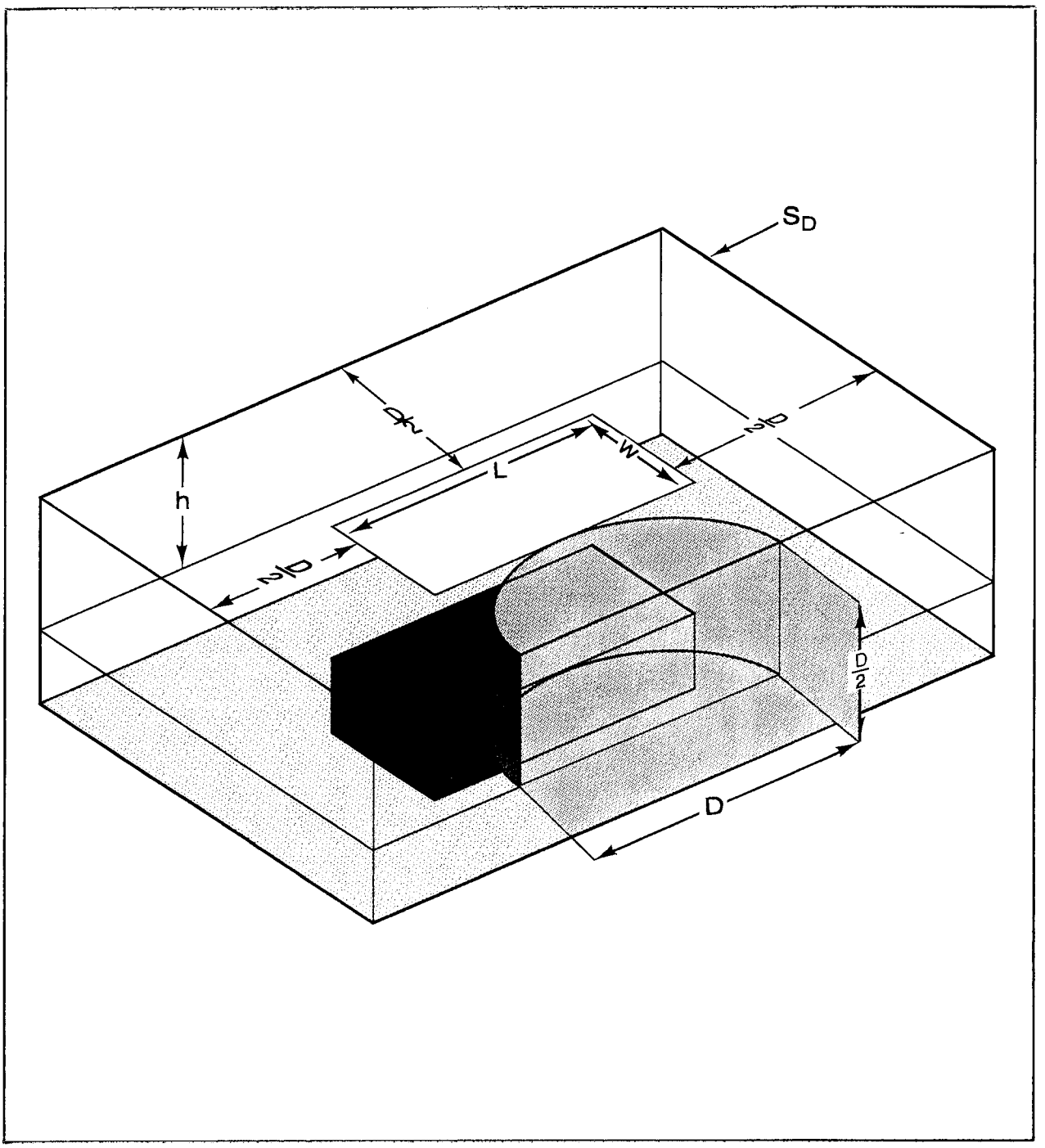

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Figure SCR-1. The Critical Region for Meterorite Impacts That Could Result in Fracturing of the Repository Horizon

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SCR.1.4.3 Denudation

SCR.1.4.3.1 Weathering

The effects of weathering are not included in no-migration demonstration calculations on the basis of low consequence.

Mechanical weathering and **chemical weathering** is assumed to be occurring at or near the surface around the WIPP site, through processes such as exfoliation and leaching. The extent of these processes is limited and will contribute little to the overall rate of erosion in the area or to the availability of material for other erosional processes. The effects of weathering are, therefore, not included in no-migration demonstration calculations.

SCR.1.4.3.2 Erosion

The effects of erosion in the region of the WIPP are not included in no-migration demonstration calculations on the basis of low consequence.

The geomorphological regime on the Mescalero Plain (Los Medaños) in the region of the WIPP is dominated by aeolian processes. Dunes are present in the area, and although some are stabilized by vegetation, **aeolian erosion** will occur as they migrate across the area. Old dunes will be replaced by new dunes, and no significant changes in the overall thickness of aeolian material are likely to occur.

Presently, precipitation in the region of the WIPP is too low (about 13 in. [33 cm] per year) to cause perennial streams, and the relief in the area is too low for extensive sheet flood erosion during storms. An increase in precipitation in cooler climatic conditions (Appendix CLI) could result in perennial streams; however, significant **fluvial erosion** is not expected during the next 10,000 years.

Mass wasting (the downslope movement of material caused by the direct effect of gravity) is only important in terms of sediment erosion in regions of steep slopes. In the vicinity of the WIPP, mass wasting will be insignificant under the climatic conditions expected over the next 10,000 years.

Erosion from wind, water, and mass wasting will continue in the WIPP region throughout the next 10,000 years at rates similar to those occurring at present. These rates are too low to significantly affect the performance of the disposal unit.

SCR.1.4.3.3 Sedimentation

The effects of sedimentation in the region of the WIPP are not included in no-migration demonstration calculations on the basis of low consequence.

The geomorphological regime on the Mescalero Plain (Los Medaños) in the region of the WIPP is dominated by aeolian processes. Vegetational changes during periods of wetter climate may act to further stabilize existing dune fields, but **aeolian deposition** is not expected to significantly increase the overall thickness of the superficial deposits.

The limited extent of water courses in the region of the WIPP, under both present-day conditions and under the expected climatic conditions, will restrict the amount of **fluvial and lacustrine deposition** in the region.

Mass wasting may be significant if it results in dams or modifies streams. In the region around the WIPP, the Pecos River forms a significant water course some 12 mi (19 km) away, but broadness of its valley precludes either significant mass wasting or the formation of large impoundments.

Sedimentation from wind, water, and mass wasting are expected to continue in the WIPP region throughout the next 10,000 years at the low rates similar to those occurring at present.

SCR.1.4.4 Soil Development

Continued soil development in the region of the WIPP is not included in no-migration demonstration calculations on the basis of low consequence.

In the region of the WIPP, an extensive caliche has developed through reprecipitation of calcium carbonate. Formation of the caliche began in the middle Pleistocene (see Section 2.1.3.9 of the NMVP). Continued growth of caliche or other soil types may occur in the future, but will be of low consequence to the performance of the disposal unit.

SCR.1.5 Surface Hydrological

SCR.1.5.1 Fluvial

Surface flow features are not included in no-migration demonstration calculations on the basis of low consequence.

No perennial streams are present at the WIPP site, and there is no evidence in the literature indicating that such features existed at this location since the Pleistocene (see, for example, Powers et al. 1978; Bachman 1974, 1981, 1987). The Pecos River is approximately 12 mi (19 km) from the WIPP site and more than 300 ft (90 m) lower in elevation. **Stream and river flow**, therefore, is a low consequence process.

SCR.1.5.2 Lacustrine

Surface water bodies are not included in no-migration demonstration calculations on the basis of low consequence.

No standing **surface water bodies** are present at the WIPP site, and there is no evidence in the literature indicating that such features existed at this location during or after the Pleistocene (see, for example, Powers et al. 1978; Bachman 1974, 1981, 1987). In Nash Draw, lakes and spoil ponds associated with potash mines are located at elevations 100 ft (30 m) below the elevation of the land surface at the location of the waste panels. There is no evidence in the literature to suggest that Nash Draw was formed by stream erosion or was at any time the location of a deep body of standing water, although shallow playa lakes have existed there at various times. Based on these factors, the formation of large lakes is unlikely and the formation of smaller lakes and ponds is of little consequence.

SCR.1.5.3 Infiltration/Recharge/Discharge

Infiltration, recharge, and discharge are not included in no-migration demonstration calculations on the basis of low consequence.

Infiltration, **recharge**, and **discharge** are important controls on groundwater flow in unconfined and semi-confined aquifers such as the Culebra. Groundwater flow in the Rustler does not, however, affect the disposal unit, and infiltration, recharge, and discharge are not included in no-migration demonstration calculations on the basis of low consequence.

SCR.1.5.4 Changes in Surface Hydrology

The effects of climate change, flooding, and lake formation on groundwater recharge and discharge are not included in no-migration demonstration calculations on the basis of low consequence.

Changes in the surface environment driven by natural climate change are expected to occur over the next 10,000 years. Consequent **changes in groundwater recharge** may increase the rate of groundwater flow in the Rustler or result in changes in flow direction, but will not affect the disposal unit.

Flooding of streams and the **formation of shallow lakes** will occur in the WIPP region over the next 10,000 years. Many of these floods will be too short-lived to affect the deep groundwater systems. Future occurrences of playa lakes or other longer-term floods will be remote from the WIPP and will have little consequence on system performance in terms of groundwater flow at the site. There is no reason to believe that any impoundments or lakes could form over the WIPP site itself.

Thus, changes in surface hydrology are not included in no-migration demonstration calculations on the basis of low consequence.

SCR.1.6 Climatic

This section discusses climate change and glaciation in the WIPP region.

SCR.1.6.1 Climate

The effects of climatic variables, precipitation, temperature, and wind patterns are not included in no-migration demonstration calculations on the basis of low consequence.

The climate and meteorology of the region around the WIPP are described in Section 2.5.2 of the NMVP. **Precipitation** in the region is low (about 13 in. [33 cm] per year), and **temperatures** are moderate with a mean annual temperature of about 63°F (17°C). Precipitation and temperature influence the amount of recharge that reaches the groundwater system but have no significant effect on the disposal system. **Wind** strength, including the effects of any hurricanes or tornadoes that may occur, also have low consequence. The present-day climate of the region around the WIPP is, therefore, not included in no-migration demonstration calculations on the basis of low consequence to the performance of the disposal unit.

SCR.1.6.2 Climate Change

SCR.1.6.2.1 Meteorological

Climate change (including temperature changes, precipitation changes, and consequential vegetational changes) is not included in no-migration demonstration calculations on the basis of low consequence.

Climate changes are instigated by changes in the earth's orbit (which affects the amount of insolation) and by a variety of feedback mechanisms within the atmosphere and hydrosphere. Models of these mechanisms, combined with interpretations of the geological record, suggest that the climate will become cooler and wetter in the WIPP region during the next 10,000 years as a result of natural causes.

Changes in climate are expected to cause changes in the rates and patterns of groundwater flow in the Rustler, but these changes will not affect the disposal unit. Consequently, climate change is not included in no-migration demonstration calculations.

SCR.1.6.2.2 Glaciation

Glaciation and periglacial processes are not included in no-migration demonstration calculations on the basis of low probability of occurrence over 10,000 years.

No evidence exists to suggest that the northern part of the Delaware Basin has been covered by continental glaciers at any time since the beginning of the Paleozoic Era. During the maximum extent of continental **glaciation** in the Pleistocene Epoch, glaciers extended into northeastern Kansas at their closest approach to southeastern New Mexico. There is no evidence that alpine glaciers formed in the region of the WIPP during the Pleistocene glacial periods.

According to the theory that relates the periodicity of climate change to perturbations in the earth's orbit, a return to a full glacial cycle within the next 10,000 years is highly unlikely (Imbrie and Imbrie 1980). In addition to eliminating glaciation from no-migration demonstration calculations on the basis of probability of occurrence, the screening argument above has been used to eliminate a number of processes associated with the proximity of an ice sheet or valley glacier, such as **permafrost** and accelerated slope erosion (solifluction).

SCR.1.7 Marine

SCR.1.7.1 Seas

The marine environment is not included in no-migration demonstration calculations on the basis of low consequence.

The WIPP site is more than 480 mi (770 km) from both the Pacific Ocean and the Gulf of Mexico. **Estuaries, coastal waters**, and **ocean waters** are, therefore, not included in no-migration demonstration calculations.

SCR.1.7.2 Marine Sedimentology

The effects of marine sediment erosion, transport, and sedimentation are not included in no-migration demonstration calculations on the basis of low consequence.

The WIPP site is not located near the Pacific Ocean or the Gulf of Mexico. Consequently, **coastal erosion** and **marine sediment transport** are not included in no-migration demonstration calculations.

SCR.1.7.3 Sea Level Change

The effects of both short-term and long-term variations in sea level are not included in no-migration demonstration calculations on the basis of low consequence.

The WIPP site is some 0.63 mi (1.01 km) above sea level. Global **sea level change** may result in sea levels as much as 460 ft (140 m) below that of the present day during glacial periods according to Chappell and Shackleton (1986). This can have marked effects on coastal aquifers. During the next 10,000 years, the global sea level can be expected to drop towards this glacial minimum, but this will not affect the groundwater system in the vicinity of the WIPP. Short-term changes in sea level, brought about by events such as meteorite impact, tsunamis, seiches, and hurricanes may raise water levels by several tens of m. Such events have a maximum duration of a few days and will have no effect on the surface or groundwater systems at the WIPP site. Anthropogenic-induced global warming has been conjectured by Warrick and Oerlemans (1990) to result in longer-term sea level rise. The magnitude of this rise, however, is not expected to be more than a few m, and such a variation will have no effect on the groundwater system in the WIPP

region. Thus, the effects of both short-term and long-term variations in sea level are not included in no-migration demonstration calculations.

SCR.1.8 Ecological

SCR.1.8.1 Flora and Fauna

The presence of the natural flora and fauna in the region of the WIPP is not included in no-migration demonstration calculations on the basis of low consequence.

The terrestrial and aquatic ecology of the region around the WIPP is described in Section 2.4.1 of the NMVP. The **plants** in the region are predominantly shrubs and grasses. The most conspicuous **animals** in the area are jackrabbits and cottontails. **Microbes** are presumed to be present within the thin soil horizons. Because there is no credible influence of terrestrial process, in general, on the disposal unit, the presence of this flora and fauna in the region is not included in no-migration demonstration calculations.

SCR.1.8.2 Changes in Flora and Fauna

The effects of natural vegetational changes likely to occur in the region of the WIPP are not included in no-migration demonstration calculations on the basis of low consequence.

The region around the WIPP is sparsely vegetated as a result of the climate and poor soil quality. Wetter periods are expected during the regulatory period, but botanical records indicate that, even under these conditions, dense vegetation will not be present in the region (Swift 1992). Because of the depth of the disposal unit below the land surface, indigenous fauna and flora are of low consequence. No FEPs related to changes in fauna and flora, including those that might result from climatic change, fire, or human land use, have been identified that would be of any consequence to performance of the disposal unit.

SCR.2 WASTE-INDUCED OR FACILITY-INDUCED FEPS

This section describes how waste-induced or facility-induced FEPs are considered in the no-migration demonstration. Consistent with EPA (1992) guidance, waste-induced or facility-induced FEPs are discussed under the following sections:

- mechanical effects
- chemical and biochemical effects
- thermal effects
- waste mobility and transport

Selected information requirements listed in the EPA (1992) guidance checklist under "Waste Characteristics" and "Waste Transformation and Immobilization" are discussed within the context of Chemical and Biochemical Effects. Modification of the hydrologic regime is covered under Fluid Dynamics within the context of Mechanical Effects. The category "Waste Mobility and Transport" is added to discuss other NMVP information requirements, such as solid, liquid, and gas phase mobility and chemical transport mechanisms. A comprehensive key to all EPA information requirements is located in Chapter 1 of the NMVP. The discussion categories and the FEPs in each category are listed in Table SCR-2. The FEPs are highlighted in bold in the text.

SCR.2.1 Mechanical Effects

SCR.2.1.1 Subsystem Characteristics

SCR.2.1.1.1 Host Rock Characteristics

The geological characteristics of the Salado that contain the WIPP repository form an integral part of the no-migration demonstration calculations.

The **geological characteristics** of the Salado are described in Section 2.1 of the NMVP. The Salado, which is mostly impure halite, has low permeability and therefore forms a natural barrier to prevent the migration of hazardous constituents from the repository.

SCR.2.1.1.2 Repository Characteristics

The WIPP repository geometry, seal characteristics, and waste disposal locations are accounted for in the no-migration demonstration calculations.

Repository characteristics are described in Chapter 3 of the NMVP.

SCR.2.1.1.3 Waste and Container Characteristics

The waste and container inventories are accounted for in the no-migration demonstration calculations.

Waste and container characteristics are described in Chapter 4 of the NMVP.

SCR.2.1.1.4 Backfill Characteristics

Physical and chemical properties of backfill are screened from the no-migration demonstration on the basis of low and/or beneficial consequence.

A chemical conditioner (hereafter referred to as backfill) will be added to the disposal room to buffer the chemical environment and reduce actinide solubility. **Backfill**

Table SCR-2. Waste-Induced or Repository-Induced FEPs and Their Screening Classification

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
MECHANICAL EFFECTS			2.1
Subsystem Characteristics			2.1.1
Geological Characteristics	NMD		2.1.1.1
Repository Characteristics	NMD		2.1.1.2
Waste and Container Characteristics	NMD		2.1.1.3
Backfill Characteristics	SO-C		2.1.1.4
Seal Characteristics	NMD		2.1.1.5
Post-Closure Monitoring	SO-C		2.1.1.6
Gas Generation			2.1.2
Microbial Gas Generation			2.1.2.1
Microbial degradation of organic material	NMD		
Effects of temperature on microbial degradation	NMD		
Effects of pressure on microbial degradation	SO-C		
Effects of radiation on microbial degradation	SO-C		
Effects of biofilms on microbial degradation	NMD		
Corrosion			2.1.2.2
Gases from metal corrosion	NMD		
Effects of galvanic coupling on gas generation rates	SO-P		
Chemical effects from corrosion on gas generation rates	NMD		
Radiolytic Gas Generation			2.1.2.3
Radiolysis of brine	SO-C		
Radiolysis of cellulosics	SO-C		
Helium production	SO-C		
Radioactive gas production	SO-C		
Rock Mechanics			2.1.3
Excavation-Induced Fracturing			2.1.3.1
Formation of DRZ	NMD		
Excavation-induced local changes in stress	NMD		
Salt Creep			2.1.3.2
Salt creep	NMD		
Changes in stress field due to salt creep	NMD		
Roof Falls			2.1.3.3
Roof falls	NMD		
Mechanical Effects of Gas Generation			2.1.3.4
Mechanical effects of gas generation	NMD		
Effects of Explosions			2.1.3.5
Gas effects: explosions	NMD		
Explosions due to nuclear criticality	SO-P		
Mechanical Effects of Materials			2.1.3.6
Consolidation of waste	NMD		
Backfill	SO-C		
Movement of canisters	SO-C		
Mechanical failure of canisters	NMD		
Consolidation of seals (salt)	NMD		
Mechanical failure of seals (salt)	SO-P		

Legend:

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table SCR-2. Waste-Induced or Facility-Induced FEPs and Their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
Mechanical failure of seals (concrete)	SO-P		
Mechanical failure of seals (clay)	SO-P		
Investigation borehole seal failure	SO-C		
Subsidence			2.1.3.7
Subsidence	SO-C		
Large-scale fracturing	SO-P		
Fluid Dynamics			2.1.4
Repository-Induced Flow			2.1.4.1
Brine inflow	NMD		
Capillary Rise			2.1.4.2
Wicking	NMD		
Effects of Gas Generation			2.1.4.3
Two-phase flow of brine and gas	NMD		
Backfill-hydraulic effects	SO-C	Beneficial	2.1.4.4
CHEMICAL AND BIOCHEMICAL EFFECTS			2.2
Repository			2.2.1
Metal Corrosion	SO-C		2.2.1.1
Microbial Processes	SO-C		2.2.1.2
Radiolysis	SO-C		2.2.1.3
Dissolution Reactions	SO-C		2.2.1.4
Dissolution Reaction kinetics	SO-C	Beneficial	2.2.1.4
Decomposition of Cementitious Sludges	SO-C	Beneficial	2.2.1.5
Chemical Effects of Backfill	SO-C	Beneficial	2.2.1.6
Leachate			2.2.2
Initial liquid content	NMD		
Brine inflow	NMD		
Leachate Formation	NMD		
Waste/Waste Container Persistence			2.2.3
Waste persistence	NMD		
Container persistence	SO-C	Beneficial	
Oxidation/Reduction Potential			2.2.4
Organics			2.2.4.1
Degradation of organics	SO-C	Beneficial	
Metals			2.2.4.2
Metal speciation	SO-C		
Redox kinetics	SO-C		
Localized reducing zones	SO-C		
Redox fronts	SO-P		
Adsorptivity			2.2.5
Organics			2.2.5.1
Post-closure volatile organic compound (VOC) release mechanisms and increased volatilization potential	SO-C		
Metals			2.2.5.2
Sorption	SO-C	Beneficial	
Sorption kinetics	SO-C		
Changes in sorptive surfaces	SO-C		

Legend:

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table SCR-2. Waste-Induced or Facility-Induced FEPs and Their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
Hydrolysis			2.2.6
Organics			2.2.6.1
Organic hydrolytic degradation	SO-C	Beneficial	
Organic half-lives	SO-C	Beneficial	
Metals			2.2.6.2
Metal hydrolysis reactions	SO-C		
Reaction kinetics	SO-C		
Hazardous Constituent Degradation			2.2.7
Organics			2.2.7.1
Aerobic degradation	SO-C	Beneficial	
Anaerobic degradation	SO-C	Beneficial	
Hydrolysis/substitution	SO-C	Beneficial	
Degradation of organic products	SO-C		
Metals			2.2.7.2
Metals	SO-P		
THERMAL EFFECTS			2.3
Heat Generation			2.3.1
Radioactive decay	SO-C		2.3.1.1
Nuclear criticality	SO-P		2.3.1.2
Exothermic reactions	SO-C		2.3.1.3
Thermo-Mechanical Effects			2.3.2
Thermally-induced stress and fracturing	SO-C		
Thermal-Fluid Dynamic Effects			2.3.3
Convection	SO-C		
Thermo-Chemical Effects			2.3.4
Chemical changes (brine chemistry)	SO-C		
WASTE MOBILITY AND TRANSPORT			2.4
Liquid Phase Source Term			2.4.1
Organics			2.4.1.1
Solubility of hazardous VOC/semi-volatile organic compounds (SVOCs)	SO-C	Beneficial	
Non-aqueous phase liquids	SO-P		
Metals			2.4.1.2
Hazardous metal solubility	SO-C		
Reaction kinetics	SO-C	Beneficial	
Organic complexation	SO-C		
Colloid complexation	SO-C		
Gas Phase Source Term			
Organics			
VOC/SVOC volatilization	NMD		2.4.2
Inner layer correction factors	SO-C		2.4.2
Retardation of Hazardous Constituents			2.4.3
Organics			2.4.3.1
Retardation of VOC/SVOC	SO-C	Beneficial	

Legend:

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

Table SCR-2. Waste-Induced or Facility-Induced FEPs and Their Screening Classifications (continued)

FEPs	Screening Classification	Comments	Reference Appendix SCR Section
			2.4.3.2
Metals			
Sorption processes	SO-C	Beneficial	
Sorption kinetics	SO-C		
Precipitation	SO-C	Beneficial	
Transport Modes			2.4.4
Solute Transport			2.4.4.1
Transport of dissolved, aqueous metals	NMD		
Colloid Transport			2.4.4.2
Colloid transport	SO-C		
Colloid filtration	SO-C	Beneficial	
Colloid agglomeration and stability	SO-C	Beneficial	
Colloid sorption	SO-C	Beneficial	
Particulate Transport			2.4.4.3
Particle suspensions	SO-C		
Rinse	SO-C		
Microbial Transport			2.4.4.4
Microbial transport of hazardous metals	SO-C		
Retardation of microbes carrying metals	SO-C	Beneficial	
Gas Transport			**2.4.4.5**
Transport of hazardous organic gases	NMD		
Transport Mechanisms			2.4.5
Advection			2.4.5.1
Advection	NMD		
Unsaturated flow	NMD		
Diffusion			2.4.5.2
Diffusion of hazardous constituents	SO-C		
Matrix diffusion	SO-C	Beneficial	
Thermo-Chemical Transport Phenomena			2.4.5.3
Soret effect	SO-C		
Electrochemical Transport Phenomena			
Electrochemical effects	SO-C		2.4.5.4
Galvanic coupling	SO-P		
Electrophoresis	SO-P		
Physicochemical Transport Phenomena			2.4.5.5
Dilution	NMD		
Alpha recoil	SO-C		
Enhanced diffusion due to chemical gradients	SO-C		
Formation of colloids due to chemical gradients	SO-C		
Mixing of waters of different salinities	SO-C		
Osmosis	SO-C	Beneficial	

Legend:

NMD FEPs accounted for in the no-migration demonstration calculations for 40 CFR § 268.6.
SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability.

characteristics are discussed in the following sections: (1) mechanical and hydraulic effects in Sections SCR.2.1.3.6 and SCR.2.1.4.4, respectively, and (2) chemical effects in Section SCR.2.2.1.6.

SCR.2.1.1.5 Seal Characteristics

The seal characteristics are accounted for in the no-migration demonstration calculations.

Seal characteristics considered include geometry and physical properties described in Chapter 3 of the NMVP. The sorptive capacity of shaft seals is screened on the basis of beneficial consequence in Section SCR.2.2.5.2.

SCR.2.1.1.6 Post-Closure Monitoring

The potential effects of post-closure monitoring are not included in the no-migration demonstration calculations on the basis of low consequence to the performance of the disposal unit or influence on the disposal system.

The DOE will implement post-closure **monitoring** in accordance with 40 CFR 191.14(b) to "detect substantial and detrimental deviations from expected performance." The DOE will design the monitoring program so that the monitoring methods employed will not effect the integrity of the disposal unit. Therefore, the effects of monitoring are not included in the no-migration demonstration calculations.

Monitoring is described in Chapter 6 of the NMVP.

SCR.2.1.2 Gas Generation

Non-hazardous gas generation can affect the transport of hazardous constituents both directly, in the case of VOCs, and indirectly by affecting the mechanical behavior of the host rock and engineered barriers, chemical conditions, and brine flow. Potential gas generation processes include corrosion, microbial degradation, radiolysis, and helium production.

The amount of water available for gas generation will have a major impact on the amounts and types of gases produced. WIPP waste may contain small amounts of water as residual liquid; the Waste Acceptance Criteria (WAC) require that the waste containers have no free liquids. For storage sites with no capability to repackage waste, approval may be given for containers that contain residual liquids in well-drained containers as long as such residuals do not exceed one percent of the volume of the container. Such residual liquids are expected to be an insignificant source of liquid in the repository. Water may also be introduced by the influx of brine from the Salado.

The following sections discuss gas generation by microbial degradation and corrosion and radiolytic gas generation.

SCR.2.1.2.1 Microbial Gas Generation

Microbial gas generation is accounted for in the no-migration demonstration calculations, and the effects of temperature and biofilm formation on microbial gas generation are incorporated in the gas generation rates used. The effects of pressure and radiation on microbial gas generation are not included in the no-migration demonstration calculations on the basis of low consequence.

Microbial breakdown of cellulosic material, and possibly plastics and other synthetic materials, will produce mainly CO_2, but also N_2O, N_2, H_2S, H_2, and CH_4. The rate of microbial gas production will depend upon the nature of the microbial populations established, the prevailing conditions, and the substrates present. **Microbial gas generation** is accounted for in the no-migration demonstration calculations.

The following subsections discuss the effects of temperature, pressure, radiation, and biofilms on gas production rates via their control of microbial gas generation processes.

Effects of Temperature on Microbial Gas Generation

The effects of temperature on microbial degradation and gas generation is considered in the demonstration. An average temperature increase of 3 to 5 degrees in Farenheit (2 to 3 degrees in Celsius) from radioactive decay, discussed in Section SCR.2.3.1.1, suggests the expected maximum temperature in the repository will be 86°F (30°C). Experiments have been conducted over a range of temperatures and chemical conditions and for different substrates (Molecke 1979, 4; Francis and Gillow 1994). Gas generation rates reported by Molecke (1979, 7) were evaluated at conservatively high temperatures. Later experiments reported by Francis and Gillow (1994) investigated the effects of microbial inoculum, humid and inundated conditions, cellulosic substrates, additional nutrients, electron acceptors, bentonite, and oxic and anoxic initial conditions. Experiments by Francis and Gillow (1994) were carried out at a reference temperature of 86°F (30°C). Gas generation rates used in the simulation, recommended by Wang and Brush (1996), implicitly incorporate the effects of temperature based on these available experimental results.

Effects of Pressure on Microbial Gas Generation

Chemical reactions may occur depending on the concentrations of available reactants, the presence of catalysts and the accumulation of reaction products, biological activity, and the prevailing conditions (e.g., temperature and pressure), among other things. Reactions that involve the production or consumption of gases are often particularly influenced by pressure, because of the high molar volume of gases. The effect of high total pressures on chemical reactions is generally to reduce, or limit, further gas generation. Gas generation

rates used in the no-migration demonstration are documented in Appendix PAR (pp.PAR-53–PAR-63).

Few data exist from which the **influence of pressure on the microbial gas generation** reactions that may occur in the WIPP can be assessed and quantified. Studies of microbial activity in deep-sea environments (for example, Kato et al. 1994, 153) suggest that microbial gas generation reactions are less likely to be limited by increasing pressures in the disposal rooms than inorganic gas generation reactions (e.g., corrosion). Consequently, the effects of pressure on microbial gas generation are not included in no-migration demonstration calculations.

Effects of Radiation on Microbial Gas Generation

Experimental investigations of microbial gas generation rates suggest that the effects of alpha radiation from transuranic (TRU) waste is not likely to have significant effects on microbial activity (Barnhart et al. 1980; Francis 1985). Consequently, the **effects of radiation on microbial gas generation** are not included in the no-migration demonstration calculations.

Effects of Biofilms on Microbial Gas Generation

The location of microbial activity within the repository is likely to be controlled by the availability of substrates and nutrients. **Biofilms** may develop on surfaces where nutrients are concentrated. These consist of one or more layers of cells with extra-cellular polymeric material and serve to maintain an optimum environment for growth. Within such a biofilm ecosystem, nutrient retention and recycling maximize microbe numbers on the surface (see, for example, Stroes-Gascoyne and West 1994, 9-10). Biofilms may affect gas generation through their control of microbial population size.

Molecke (1979, 4) summarized microbial gas generation rates observed during a range of experimental studies. The experiments were conducted over a range of temperatures and chemical conditions and for different substrates. However, the quantitative effects of biofilm formation in these experiments were uncertain. Gas generation rates were presented as ranges, with upper and lower bounds as estimates of uncertainty. Later experiments reported by Francis and Gillow (1994) support the gas generation rate data reported by Molecke (1979). Under the more favorable conditions for microbial growth established during the Francis and Gillow (1994, 59) experiments, the development of populations of halophilic microbes and associated biofilms was evidenced by observation of an extra-cellular, carotenoid pigment, bacterioruberin, in the culture bottles used. As suggested, the recommendations reported by Wang and Brush (1996) implicitly incorporate the results of this experimental data.

Biofilms may also influence hazardous constituent transport rates through their capacity to retain, and therefore retard, both the microbes themselves and the hazardous

constituents. As discussed in Sections SCR.2.2.5 and SCR.2.4, no credit is taken for this beneficial process in the no-migration demonstration calculations.

SCR.2.1.2.2 Corrosion

Gas generation due to corrosion is accounted for in the no-migration demonstration calculations. Galvanic coupling, and the effects of electrochemical gradients on gas generation due to corrosion, are not included in the no-migration demonstration calculations on the basis of low probability. The influences of chemical changes due to metal corrosion on gas generation rates are accounted for in the no-migration demonstration calculations via the rates used.

Oxic corrosion of waste drums and metallic waste will occur at early times following closure of the repository and will deplete its oxygen content. Anoxic corrosion will follow the oxic phase and will produce much more significant quantities of gas (H_2) while consuming water. **Gas generation due to anoxic corrosion** is accounted for in the no-migration demonstration calculations.

The following subsections discuss the effects of galvanic coupling, electrochemical gradients, and chemical changes due to metal corrosion on gas production rates via their control of gas generation due to corrosion.

Galvanic Coupling and the Effects of Electrochemical Gradients

Galvanic coupling refers to the establishment of an electrical current through chemical processes. Galvanic coupling could lead to the establishment of potential gradients between metals in the waste form, canisters, and other metals external to the waste form. Such electrochemical effects can potentially influence corrosion processes and, therefore, gas generation rates and chemical migration.

Metals other than those in the waste form and canisters could potentially include natural metallic ore bodies in the host rock and metallic elements in other parts of the repository. However, the absence of metallic ores in the region (Powers et al. 1978) allows galvanic coupling between the waste and metals external to the repository to be eliminated from no-migration demonstration calculations on the basis of low probability.

A range of metals will be present within the repository (e.g., waste metals and canisters), and the possibility exists for galvanic cells to be established over short distances. For example, the presence of copper could influence rates of hydrogen gas production resulting from the corrosion of iron.

The precise interactions that may occur are complex and depend on the metals involved, their physical disposition, and the prevailing conditions (for example, salinity). Good physical and electrical contact between the metals involved is critical to the establishment of galvanic cells. Experience with experimental investigations suggests that this

condition is unlikely to be achieved in the repository conditions. In the laboratory, significant efforts are required to assure metal-to-metal contact sufficient for galvanic coupling to occur. Such contact is unlikely to occur to a significant extent in the repository. Consequently, given the preponderance of iron over other metals within the repository, the influence of these electrochemical interactions on corrosion and, therefore, gas generation, is not included in the no-migration demonstration calculations on the basis of low probability.

Effects of Chemical Changes Due to Metal Corrosion on Gas Generation Rates

The predominant effect of corrosion reactions on the chemical environment of disposal rooms will be to lower the oxidation state of the brines and maintain reducing conditions.

Experiments have investigated gas generation due to corrosion under a wide range of possible conditions in the repository. Molecke (1979, 4) summarized experimentally-derived gas generation rates and later experiments reported by Telander and Westerman (1993) support the gas generation rate data generated from this early work. The Telander and Westerman (1993) studies included corrosion of low-carbon steel waste packaging materials in synthetic brines, representative of intergranular Salado brines at the repository horizon, under anoxic (reducing) conditions.

The no-migration demonstration calculations employ gas generation rates due to corrosion constructed from Molecke's data (1979, 7), which are consistent with the data of Telander and Westerman (1993). Gas-generation rates used in the no-migration demonstration are documented in Appendix PAR (pp. PAR-53–PAR-63). The no-migration demonstration calculations, therefore, incorporate the **effects of chemical changes due to metal corrosion.**

SCR.2.1.2.3 Radiolytic Gas Generation

Gas generation due to radiolysis of brine and cellulosics, and helium production, is not included in the no-migration demonstration calculations on the basis of low consequence. Generation of radioactive gases is also not included in the no-migration demonstration calculations on the same basis.

This section discusses gas generation resulting from the radiolysis of brine and cellulosics, helium production, and the generation of radioactive gases.

Radiolysis of Brine

Radiolysis of brine in the WIPP disposal rooms, and of water in the waste, will lead to the production of gases, which could contribute to the total volume of gas generated in the repository[1].

The overall reaction for the radiolysis of water in the waste and brine is:

$$H_2O = H_2 + {}^1/_2O_2 \qquad \text{(SCR-2.1)}$$

However, the production of intermediate oxygen-bearing species that may subsequently undergo reduction, such as H_2O_2, ClO_3-, and ClO_4-, will lead to reduced oxygen gas yields.

Reed et al. (1993) studied radiolytic gas generation during experiments lasting between 155 and 182 days. These experiments involved both synthetic brines similar to those sampled from the Salado at the WIPP repository horizon and brines occurring in reservoirs in the Castile, as well as natural brines sampled from the Salado in the repository workings. The brines were spiked with $^{239}Pu(VI)$ at concentrations between 6.9×10^{-9} and 3.4×10^{-4} M. During these relatively short-term experiments, hydrogen gas was observed as the product of radiolysis. Oxygen gas was not observed; this was attributed to the formation of intermediate oxygen-bearing species. However, given sufficient exposure to alpha-emission, oxygen production may reach 50 percent that of hydrogen.

An estimate of the maximum rate of gas generation due to the radiolysis of brine, R_{RAD}, can be made by making the following assumptions:

- gas production occurs following the reaction above, so that 1.5 moles of gas are generated for each mole of water consumed
- gas production occurs as a result of the alpha-decay of ^{239}Pu
- ^{239}Pu concentrations in the disposal room brines are controlled by solubility equilibria
- all of the dissolved plutonium is ^{239}Pu

R_{RAD} is then given by

[1] Radiolysis will also increase the oxygen content of the rooms. This in turn will affect the prevailing chemical conditions and potentially the concentrations of hazardous constituents that may be mobilized in the brines.

$$R_{RAD} = \frac{1.5 \; x \;\; 3.15 \; x \; 10^7 C_{Pu} Sa_{Pu} G E_a V_B}{N_D N_A} \qquad \text{(SCR-2.2)}$$

where

- R_{RAD} is the rate of gas production (mol/drum/year),
- C_{Pu} is the maximum dissolved concentration of plutonium (M),
- Sa_{Pu} is the specific activity of ^{239}Pu (5.42×10^{11} Bq/mol),
- E_a is the average energy of alpha-particles emitted by ^{239}Pu decay (5.15×10^6 eV),
- G is the number of moles of molecules split per eV (eV^{-1}),
- V_B is the volume of brine in the disposal room (l),
- N_D is the number of contact handled (CH) drums in the disposal room (6800),
- N_A is the Avogadro constant (6.0×10^{23} mol^{-1}).

The maximum dissolved concentration of plutonium, C_{pu}, for this screening analysis has been taken as 5.5×10^{-4} M, as derived during estimation of the actinide source term for preliminary WIPP performance assessments. The value of G used in this calculation has been set at 1.4, the upper limit of the range of values observed (1.1 to 1.4) during experimental studies of the effects of radiation on WIPP brines (Reed et al. 1993). Estimates of the volume of brine that could potentially be present in the disposal rooms vary up to 815,000 liters. For the purposes of this calculation, the upper limit of the range has been used. These parameter values lead to an estimate of the rate of gas production due to the radiolysis of brine of 2.02×10^{-1} mol/drum/year. Gas production rates due to other processes that will occur in the WIPP are likely to be significantly greater than this (Wang and Brush 1996). Even if gas production by these processes is minimal and radiolytic gas production dominated gas generation, the effects would be of low consequence because of the low total volumes.

In addition to the assessment of the likely maximum gas generation by radiolysis of brine given above, an evaluation of the likely consequences of considering this process in the simulation is considered by Vaughn et al. (1995). A model was implemented in BRAGFLO to estimate radiolytic gas generation in the disposal region according to the chemical equation given above. A series of BRAGFLO simulations were performed to assess the magnitude of the influence of the radiolysis of brine on brine migration. The calculations considered radiolysis of H_2O by 15 isotopes of thorium, plutonium, uranium, and ^{241}Am. The study indicates that radiolysis does not significantly affect brine migration outward to the disposal unit boundary (Vaughn et al. 1995). Therefore, radiolysis of brine is not included in the no-migration demonstration calculations.

Radiolysis of Cellulosics

Drums emplaced in the WIPP repository are likely to contain, on average, approximately 10 kg of cellulosic material, approximately 70 percent of which will be paper.

Experimental data on gas production rates due to **radiolysis of cellulosic and other waste materials** have been reported by Molecke (1979). These data were considered by Wang and Brush (1996), who indicate that the likely gas generation rates will be significantly less than those associated with the radiolysis of brine (not included in the no-migration demonstration calculations on the basis of low consequence). Consequently, the production of gases by radiolysis of cellulosic materials is also not included in the no-migration demonstration calculations.

Helium Production

Within the WIPP, **helium gas** will be produced by the reduction of alpha-particles (helium nuclei) emitted from the waste. An estimate of the maximum amount of helium that could be produced can be made by assuming that all of the alpha-particles generated during radioactive decay are converted to helium gas by the following reaction:

$$({}^{4}_{2}He^{2+},\ \alpha\text{-}particle) + 2e^{-} \rightarrow He_{(g)}$$

The total inventory (I) that may be emplaced in the repository is approximately 9 million Ci, or 3.3×10^{17} Bq (DOE 1995). Assuming that the inventory continues to yield alpha-particles at this rate throughout the 10,000-year regulatory period (i.e., that the source does not diminish even though the alpha-particles are produced during radioactive decay), the maximum rate of helium gas produced (R_{He}) may be calculated from

$$R_{He} = \frac{I}{N_A} \qquad \text{(SCR-2.3)}$$

where

R_{He} is the rate of helium gas production in the repository (mol/s),
I is the waste inventory (3.3×10^{17} Bq),
N_A is the Avogadro constant (6.0×10^{23} mol^{-1}).

These assumptions regarding the inventory lead to maximum estimates for helium production because, in reality, the total activity will decrease with time, and because some of the hazardous constituents will decay by beta and gamma emission.

Based on the figures and equation given above, $R_{(He)}$ is approximately 5.5×10^{-7} mol/s. Assuming ideal gas behavior and repository conditions of 27°C and 14.8 MPa (lithostatic pressure), this is equivalent to approximately 3.0 liters/year (2.2×10^{-5} mol/drum/year).

Production of other gases due to other processes that will occur in the repository are likely to occur at rates significantly greater than this (Wang and Brush 1996). Even if gas production by these processes is minimal, and helium production dominates gas generation, the effects will be of low consequence because of the low total volumes.

Therefore, by estimation of the maximum possible generation rate, the effects of helium production are not included in the no-migration demonstration calculations.

Radioactive Gases

Based on the anticipated waste inventory, the radioactive gases likely to be generated in the repository are radon (Rn), carbon dioxide (CO_2), and methane (CH_4) containing ^{14}C. Radon will contain the alpha emitters ^{219}Rn, ^{220}Rn, and ^{222}Rn. All of these have short half-lives, but ^{222}Rn is potentially the most important isotope both volumetrically and because it has the longest half-life (≈ four days). ^{222}Rn will be produced throughout the 10,000-year period of interest by decay of ^{226}Ra, which is produced from the decay of ^{238}U and ^{238}Pu. $^{14}CO_2$ and $^{14}CH_4$ may be derived during microbial degradation of cellulosic wastes, rubbers, and plastics.

The inventories of ^{238}U, ^{238}P, and ^{14}C are low, and such that the volume of radioactive gas will be insignificant in comparison with gas production by other processes. Therefore, the formation of radioactive gases has been eliminated from the no-migration demonstration calculations on the basis of low consequence.

SCR.2.1.3 Rock Mechanics

SCR.2.1.3.1 Excavation-Induced Host Rock Fracturing

Excavation-induced host rock fracturing is accounted for in the no-migration demonstration calculations.

Excavation of the repository has caused **local stress redistribution** in the surrounding rock as discussed in Section 3.7.1 of the NMVP. This has led to failure of intact rock around the opening, **creating a DRZ** of fractures. On completion of the WIPP excavation, the extent of the induced stress field perturbation will be sufficient to have caused dilation and fracturing in the anhydrite layers a and b, marker bed (MB) 139, and, possibly, MB 138 (Section 2.1 of the NMVP). The creation of the DRZ around the completed excavation and the disturbance of the anhydrite layers and marker beds will alter the permeability and effective porosity of the rock around the repository, providing enhanced pathways for flow of gas and brine between the waste-filled rooms and the nearby interbeds. This excavation-induced host rock fracturing is accounted for in the no-migration demonstration calculations. The DRZ around repository shafts could provide pathways for flow from the repository. The effectiveness of long-term shaft seals is dependent upon the seals providing sufficient backstress for salt creep to heal the DRZ around them, so that connected flow paths out of the repository will cease to exist. These factors are considered in the current seal design.

SCR.2.1.3.2 Salt Creep

Salt creep in the Salado is accounted for in the no-migration demonstration calculations.

Salt creep will compact the waste and containers and consolidate the long-term components of the sealing system and will tend to close fractures in the DRZ, leading to reductions in porosity and permeability, increases in pore fluid pressure, and reductions in fluid flow rates in the repository. Salt creep in the Salado is accounted for in the no-migration demonstration calculations. The long-term repository seal system relies on the consolidation of the crushed-salt seal material and healing of the DRZ around the seals to achieve a low permeability under **stresses induced by salt creep**. Seal performance is discussed further in Section SCR.2.1.3.6.

SCR.2.1.3.3 Roof Falls

The potential effects of roof falls on flow paths are accounted for in the no-migration demonstration calculations through appropriate ranges of the parameters describing the DRZ.

Instability of the DRZ is likely to lead to **roof falls** in the first few hundred years of post-closure. Development of the DRZ and roof falls may be sufficient to disrupt the anhydrite layers above the repository, which may create a zone of rock containing anhydrite extending from the interbeds toward a waste-filled room. Fracture development is most likely to be induced as the rock stress and strain distributions evolve due to salt creep. Because of uncertainty in the process by which the disposal room DRZ heals, the flow model used in the no-migration demonstration calculations assumes that a higher permeability zone remains for the long term. Thus, the potential effects of roof falls on flow paths are accounted for in the no-migration demonstration calculations through appropriate ranges of the parameters describing the DRZ. In the long term, the effects of roof falls in the repository are likely to be minor, because salt creep will reduce the void space and the potential for roof falls as well as lead to healing of any roof material that has fallen into the rooms.

SCR.2.1.3.4 Mechanical Effects of Gas Generation

The mechanical effects of gas generation are accounted for in the no-migration demonstration calculations.

Simulation of the **mechanical effects of gas generation** is discussed in Section 8.2 of the NMVP. One important modeled process is dilation or fracturing of interbeds, a process capable of increasing the mass transport of hazardous constituents. In response to pressure increases approaching lithostatic pressure, NMVP calculations provide for increases in anhydrite permeability and porosity.

SCR.2.1.3.5 Effects of Explosions

The potential effects of gas explosions are included in the no-migration demonstration calculations through the treatment of the DRZ. Nuclear explosions are not included in the no-migration demonstration calculations on the basis of low probability.

The analysis of Slezak and Lappin (1990) indicates that there is little likelihood of a **gas explosion** in the long term, because the rooms and panels are expected to become anoxic and compaction through salt creep will greatly reduce any void space. The possibility of an explosion prior to the occurrence of anoxic conditions is considered in the design of the operational panel closure. The effect of such an explosion on the DRZ is expected to be no more severe than a roof fall, which is accounted for in the no-migration demonstration calculations.

For a **nuclear explosion** to occur, a critical mass of plutonium would have to undergo rapid compression to a high density. Even if a critical mass of plutonium could form in the system, there is no mechanism for rapid compression. Thus, nuclear explosions are not included in the no-migration demonstration calculations on the basis of low probability.

SCR.2.1.3.6 Mechanical Effects on Materials

Consolidation of waste, mechanical failure of canisters, and consolidation of shaft seals are accounted for in the no-migration demonstration calculations. Mechanical failure of seals, canister movement, and the MgO backfill are not included in the no-migration demonstration calculations on the basis of low consequence (canister movement/backfill) and low probability (shaft seals). Likewise, flow through sealed WIPP investigation boreholes drilled from the surface is not included in the no-migration demonstration calculations, also on the basis of low probability.

Waste consolidation

After closure of the repository, salt creep will compact and **consolidate the waste** and other repository components. The consequent reduction in waste porosity and permeability is accounted for in the no-migration demonstration calculations.

Backfill

Backfill is expected to occupy only about ten percent of the available void volume at repository closure. As creep closure proceeds, backfill will act to resist creep closure. Neglecting any decrease in pore volume caused by the addition of **backfill** is potentially conservative: the rate and magnitude of gas pressurization would increase in response to a decrease in gas-available porosity.

Canister movement and mechanical failure

Movement of canisters within the repository panels is not included in the no-migration demonstration calculations because this process will have no effect on the mobility of the hazardous constituents. However, the **mechanical failure of the canisters** is implicitly accounted for in the no-migration demonstration calculations by the assumption of instantaneous release of hazardous constituents.

Repository and Investigation Borehole Seal Performance

The shafts leading to the repository provide a potential significant transport pathway to the disposal unit boundaries. Assumptions made regarding the seals in the no-migration demonstration calculations are discussed in Appendix PAR and Sections 8.2.4 and 8.4 of the NMVP. Consolidation of the shaft seals constructed from crushed salt is accounted for in the no-migration demonstration calculations through the permeability range assumed for the seal system. Field testing of seals has been conducted to investigate the effects of high-pressure gas flow on concrete and clay (bentonite) seal materials placed in WIPP halite at the repository horizon. The results of these tests are summarized by Knowles and Howard (1996). No large-scale mechanical degradation of either material has been observed. No gas flowed through the clay seal, and gas permeability of the concrete seal system (concrete, salt and concrete interface, and DRZ) was low. In addition, favorable hydrologic conditions (no hydraulic gradient), precludes mechanical degradation from chemical deterioration due to contact with brine migrating laterally to the shaft seal.

WIPP **investigation boreholes** drilled from the surface provide a less significant transport pathway than the shafts, primarily because boreholes do not intersect the underground excavation. The NMVP simulation considers borehole pathways to be low probability based on their relative distance from the repository, and low consequence relative to the shaft pathway in the event mechanical failure does occur. The cross-sectional area of the WIPP investigation boreholes (typically 0.34 ft^2 [0.03 m^2] each) is small in comparison to that of the shafts (which total about 1,025.8 ft^2 [95.3 m^2]).

The site investigation program has also involved the drilling of boreholes from within the excavated part of the repository. Following their use for monitoring or other purposes these **underground boreholes** will be sealed where practical, and salt creep will also serve to consolidate the seals and to close the boreholes. Simulation calculations account for fluid flow to and from the interbeds by assuming that the DRZ has a permanently enhanced permeability that allows flow of repository brines into specific anhydrite layers and interbeds. This treatment is considered to account for the effects of any unsealed boreholes.

SCR.2.1.3.7 Subsidence

The potential for subsidence to create fluid flow paths between the repository and the disposal unit boundary is not included in the no-migration demonstration calculations on the basis of low probability. Fracturing within units overlying the Salado and surface displacement caused by subsidence associated with repository closure is not included in the no-migration demonstration calculations on the basis of low consequence.

Subsidence associated with repository closure through salt creep or roof collapse might cause **large-scale fracturing** between the repository horizon and the disposal unit boundary, and might affect the hydrologic properties of units above the repository.

The amount of subsidence that can occur as a result of salt creep closure in the waste-filled and sealed areas of the repository depends on the extraction ratio, the initial and compressed porosities of various waste types, the amount of inward creep of the repository walls, and the gas and fluid pressures within the repository. The DOE (Westinghouse 1994) has analyzed potential excavation-induced subsidence at the WIPP. Estimates of the amount of subsidence expected as a result of repository excavation were made using analytical, empirical, and numerical techniques.

For an empty repository, the DOE estimated potential subsidence at the surface to be less than 2 ft (0.6 m). The surface topography in the WIPP area varies by more than 10 ft (3 m), and this amount of subsidence will not create a basin and will not affect surface hydrology significantly. Subsidence at the depth of the Culebra was also estimated to be less than 2 ft (0.6 m), and the horizontal displacement at the depth of the Culebra was estimated to be less than 0.1 ft (0.03 m), with a maximum horizontal strain of 0.007 percent. The induced strains will be uniformly distributed, because no known faults or discontinuities occur in the vicinity of the WIPP. Strains of this magnitude would not be expected to cause cracking or extensive fracturing.

The DOE (Westinghouse 1994) also reported investigations of subsidence associated with potash mining operations located near the WIPP site to gain insight into the expected subsidence conditions at the WIPP. Subsidence over potash mines in the area will be much greater than at the WIPP, because of the significant differences in stratigraphic position, depth, extraction ratio, and layout. The proposed WIPP rock extraction ratio is about 22 percent, as compared to over 50 percent for the lowest extraction ratios within local potash mines. Also, the WIPP site is located stratigraphically much lower than the lowest potash mine, which is near the base of the McNutt Potash Zone. The base of the McNutt Potash Zone is about 490 ft (150 m) above the repository horizon.

The reported maximum total subsidence at potash mines is about 5 ft (1.5 m). Although this level of subsidence has been observed to have caused surface fractures, subsidence associated with the WIPP will be less than that associated with potash mining (as confirmed by the calculations reported above). In addition, relatively shallow potash-related subsidence did not cause fracturing sufficient to connect the mining horizon to water-bearing units or to the surface.

Based on the results of numerical analyses and observations of subsidence associated with potash mines, the potential for subsidence to create fluid flow paths between the repository and the disposal unit boundary is not included in the no-migration demonstration calculations on the basis of low probability.

SCR.2.1.4 Fluid Dynamics

SCR.2.1.4.1 Repository-Induced Flow

Brine inflow into the repository in response to a change in the pressure gradient around the excavation is accounted for in the no-migration demonstration calculations.

Brine inflow into the repository may occur in response to pressure gradients created by the excavation, with flow potentially taking place through the DRZ, impure halite, anhydrite layers, or clay layers. Pressurization of the repository through gas generation could limit the amount of brine that flows into the rooms and drifts. Brine flow into the repository is accounted for in the no-migration demonstration calculations.

SCR.2.1.4.2 Capillary Rise

Capillary rise is accounted for in the no-migration demonstration calculations.

Capillary rise (or **wicking**) is a potential mechanism for liquid migration through unsaturated zones in the repository. Capillary rise in the waste material could affect gas generation rates, which are dependent on water availability. Capillary rise is therefore accounted for in the no-migration demonstration calculations.

SCR.2.1.4.3 Effects of Gas Generation

Two-phase brine and gas flow in the repository and the Salado is accounted for in the no-migration demonstration calculations.

Pressurization of the repository through gas generation could limit the amount of brine that flows into the rooms and drift. If gas pressures are sufficiently high, brine may be expelled from the repository through the DRZ, impure halite, anhydrite layers, or clay layers. The amount of water available for reactions and microbial activity will affect the amounts and types of gases produced (Section SCR.2.1.2). Gas generation rates, and, therefore, repository pressure, may change as the water content of the repository changes. **Two-phase flow of brine and gas** in the repository and the Salado is accounted for in the no-migration demonstration calculations.

SCR.2.1.4.4 Hydraulic Effects of Backfill

Hydraulic effects of backfill are screened from the demonstration on the basis of beneficial consequence.

Adding backfill to an empty cavity or a waste-filled room would cause the initial intrinsic permeability of these regions to decrease. Placement of backfill in unoccupied void space can only decrease brine flow by increasing the tortuosity of resulting flow paths through

backfill pores. Consequently, neglecting the **hydraulic effects of backfill** is conservative: backfill is expected to decrease the potential for brine flow through the waste region.

SCR.2.2 Chemical and Biochemical Effects (Transformation and Immobilization)

Long-term chemical and biochemical FEPs occurring in the disposal room environment and along migration pathways will influence the mobility and transport of hazardous constituents. Decomposition and dissolution of waste forms will influence the chemical environment, and by introducing by-products such as colloids and organic complexing agents, could also affect hazardous constituent concentrations and mobility. This section reviews the extent to which these processes are considered in the conceptual model supporting this no-migration demonstration.

SCR.2.2.1 Repository Environment

A general discussion of post-closure repository evolution provides an introduction to hazardous constituent-specific assessments of chemical and biochemical FEPs. Those chemical and biochemical FEPs occurring in the repository and having the potential to affect hazardous constituent transformation and mobility include:

- corrosion
- microbial activity
- radiolysis
- dissolution reactions
- reactions with cementitious materials

SCR.2.2.1.1 Corrosion

The effects of corrosion on the chemical conditions in the disposal rooms are not included in the no-migration demonstration calculations on the basis of low consequence with respect to the bounding approaches used to demonstrate no-migration for liquid-phase hazardous constituents.

Other than gas generation, which is discussed in Section SCR.2.1.2, the main effect of **metal corrosion** will be to influence the chemical conditions that prevail within the repository. Ferrous metals will be the most abundant metals in the WIPP, and these will corrode on contact with any brines entering the repository. Initially, corrosion will occur

under oxic conditions owing to the atmospheric oxygen present in the repository at the time of closure. However, consumption of the available oxygen by corrosion reactions will rapidly lead to anoxic (reducing) conditions. These changes and controls on conditions within the repository will affect the chemical speciation of the brines and, in particular, the oxidation states of the hazardous-constituent metals present. Changes to the speciation and oxidation states of the hazardous-constituent metals will lead to changes in the concentrations that may be mobilized during brine flow. However, this demonstration uses bounding approaches to demonstrate no migration of brine potentially containing hazardous constituents, and does not require characterization of chemical speciation and other factors influencing metal solubility. Consequently, the effects of corrosion on chemical conditions are not included in the no-migration demonstration calculations on the basis of low consequence.

SCR.2.2.1.2 Microbial Activity

The effects of microbial activity on disposal room conditions are not included in the no-migration demonstration calculations on the basis of low consequence with respect to the bounding methods used in the NMVP simulation.

Microbial processes may decompose waste and generate gas, affecting brine chemistry and possibly degrading hazardous constituents. Although non-halophilic microbes may be introduced to the waste during generation and packaging in the waste container, halophilic or halo-tolerant bacteria are expected to prevail following room closure. Studies related to long-term microbial activity in the repository have focused on potential gas generation rates associated with degradation of cellulosic waste, and, to some extent, of plastic materials.

Uncertainty exists regarding the magnitude of microbial processes in the post-closure environment. A complex series of chemical and physical steps must occur for significant microbial activity to occur: brine must enter the repository, electron acceptors and nutrients must be available, and metabolic pathways must be established to sustain continued degradation by microbes. For purposes of gas generation modeling, it is assumed that viable populations of microbes will be sustained over the 10,000-year compliance period. Given the assumption that some level of microbial activity is achieved over the long-term, anaerobic microbial activity is expected to dominate.

Potentially significant long-term anaerobic microbial processes influencing brine chemistry in the repository include: denitrification, SO_4^{2-} reduction, fermentation, and methanogenesis. Anaerobic microbial reactions will produce the following gases: CO_2, N_2, NH_3, H_2S, H_2, and CH_4. The CO_2 fugacity and organic acids produced by microbial degradation will have an influence on the chemical conditions in the disposal room environment. However, this demonstration uses a bounding approach to simulate the migration of contaminated brine and does not require characterization of chemical speciation and other factors influencing metal solubility. Consequently, the effects of

microbial activity on chemical conditions and source-term chemistry in the brine are not included in the no-migration demonstration calculations on the basis of low consequence.

SCR.2.2.1.3 Radiolysis

The effects of radiolysis on disposal room conditions are not included in the no-migration demonstration calculations on the basis of low consequence.

Radiolysis refers to the rupture of chemical bonds by alpha-particles emitted during the radioactive decay of the actinide elements in TRU waste. Although the overall gas and H_2O budget of the repository will not be significantly affected during the post-closure phase, radiolysis of water and brine in the WIPP disposal rooms may significantly affect the O_2 content. Because this demonstration uses a bounding approach to simulate the migration of contaminated brine, and does not require characterization of chemical speciation and other factors influencing metal solubility, the effects of radiolysis on chemical conditions in the brine have been eliminated from the no-migration demonstration calculations on the basis of low consequence.

SCR.2.2.1.4 Dissolution Reactions

Dissolution of hazardous-constituent metals is not included in no-migration demonstration calculations on the basis of low consequence. The effect of reaction kinetics in controlling the rate of hazardous-constituent metal dissolution within the disposal rooms is not included on the basis of beneficial consequence to the performance of the disposal unit.

Dissolution of hazardous-constituent metals and precipitation of secondary minerals are relevant because of their influence on metal concentrations in brine. It is expected that a range of kinetic behavior will be exhibited by different mineral precipitation and dissolution reactions in different geochemical systems. The assumption of equilibrium waste dissolution represents a conservative approach to predicting hazardous-constituent metal concentrations in the disposal room brines, because it yields maximum concentration estimates. Accounting for the effects of **reaction kinetics** in controlling the rate of hazardous-constituent metal dissolution within the disposal rooms would serve to reduce these concentrations. Reaction kinetics have, therefore, not been included in no-migration demonstration calculations.

This demonstration uses a bounding approach to simulate the migration of contaminated brine and does not require characterization of chemical speciation and other factors influencing metal solubility. Consequently, hazardous-constituent metal dissolution is not included in the no-migration demonstration calculations.

SCR.2.2.1.5 Cementitious Materials

The effects of cementitious materials on hazardous-constituent metal solubility are not included in the no-migration demonstration calculations on the basis of beneficial consequence to the performance of the disposal unit.

Cement-based materials are known to decompose in the presence of brine. The **decomposition of cementitious sludges** and other materials in the repository suggests the possibility of buffering of pH by the presence of $Ca(OH)_2$. Such buffering of brines to high pH would tend to decrease hazardous-constituent metal solubility and, therefore, impede the mobility of hazardous-constituent metals. Consequently, excluding the effects of cementitious materials on hazardous-constituent metal solubility from the no-migration demonstration calculations is a conservative assumption. The effects of cementitious materials have, therefore, not been included in the no-migration demonstration calculations.

SCR.2.2.1.6 Chemical Effects of Backfill

Chemical effects of backfill are screened from the demonstration on the basis of beneficial consequence.

A backfill chemical conditioner will be added to the disposal room to buffer the chemical environment and reduce actinide solubility. The MgO backfill will also inhibit mobility of hazardous constituent metals. On these grounds, neglecting the **chemical effects of the backfill** is conservative.

SCR.2.2.2 Leachate

Leachate quantity and quality is represented in the no-migration calculations by the brine saturation attained in the waste region. The NMVP assumes that the quantity of brine predicted in the waste region is contaminated as a result of potential contact with waste materials.

Leachate is defined as water that has become contaminated by soluble chemicals resulting from leaching of waste contained within a disposal unit. For the purpose of this no-migration demonstration, leachate includes hazardous constituents mobilized in the liquid phase. Organic hazardous constituents may be a component of the leachate; however, as a conservative assumption, all VOCs and SVOCs are included in the gas-phase source term used in the no-migration demonstration calculations.

As applied to the WIPP disposal unit, **brine inflow** to the repository is the only significant source of liquid solvent capable of mobilizing hazardous constituents from the waste (see Appendix MASS). The **initial liquid content** of the waste, consisting mostly of water, is not a viable source of solvent. As stated in Section SCR.2.1.2, the WAC require that the waste containers have no free liquids, and residual liquids in well-drained

containers are only permitted as long as such residuals do not exceed one percent of the volume of their container.

The release of bound water from sludges may also be a source of water in the disposal room environment. However, water transfer between sludge sorbents and their surroundings is a complex tradeoff between the sorbents' chemical affinity for water and the ability of the chemical processes to extract water from the sorbents. As a coupled diffusion/vapor transport process, extraction of water from sludge would be slow and insignificant in comparison to the likely brine inflow.

Over the long-term, therefore, the quantity of leachate is directly proportional to the volume of brine inflow and the degree to which the brine comes into contact with the waste. Estimates of the total potential brine inflow depend upon the mechanisms assumed to dominate the fluid flow processes in the Salado and are accounted for in no-migration demonstration calculations (see Sections 2.1.4 and 8.2.3.2 of the NMVP).

The **quality of the leachate** resulting from brine inflow and contact with waste is considered in the no-migration demonstration; the simulation assumes brine mixed with waste in the waste region is contaminated. The assumption is the basis for two alternative bounding approaches: one that uses BRAGFLO to demonstrate that potentially contaminated brine does not leave the repository, or another that tracks migration of a surrogate hypothetical tracer to the disposal unit boundary.

SCR.2.2.3 Waste and Waste Container Persistence

The persistence of waste is accounted for in the no-migration demonstration calculations by the use of constant gas and liquid phase source term concentrations. Container and waste form persistence are not included in the no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

Persistence can be interpreted as a measure of how long a parent organic chemical will be present (Ney 1995). Conservatively, bounding approaches described in Chapter 8 of the NMVP assume persistence (i.e., constant concentration). No credit is taken for organic degradation. The initial mass of hazardous-constituent metals in the waste will not change, i.e., the metals will persist, although the prevalent chemical species may be altered with time due to changes in brine chemistry.

Steel waste containers and the majority of waste forms are not expected to persist under long-term repository conditions, but the assumption of instantaneous release used in the no-migration demonstration calculations does not take credit for any persistence. This is a conservative assumption and container and waste persistence have, therefore, not been included no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

SCR.2.2.4 Assessment of Oxidation/Reduction Potential

The prevailing oxidation/reduction potential within the disposal room brines will affect the speciation and solubility of hazardous-constituent metals. The redox environment can also influence the rate of biodegradation of hazardous organic constituents, and will control abiotic chemical oxidation of hazardous organic constituents as a degradation mechanism. Anoxic (reducing) conditions are likely to predominate in the post-closure disposal room environment.

The development of redox fronts in the waste region may also affect the chemistry and mobility of hazardous constituents. The following subsections discuss the influences of oxidation/reduction potentials within the waste region on hazardous organic and metal constituents.

SCR.2.2.4.1 Organics

The degradation of hazardous organic constituents is not included in no-migration demonstration calculations based on beneficial consequence to the performance of the disposal unit.

Given sufficient concentrations of oxygen, oxidative **degradation of hazardous organic** constituents may occur (e.g., the conversion of aromatics to CO_2). However, the long-term post-closure environment is expected to be reducing and such oxidative degradation reactions may be limited in the WIPP. Although there may be hazardous organic constituents that are rapidly reduced under such reducing conditions, e.g., nitroaromatics (Howard et al. 1991), trichloroethene, in particular, is expected to be stable (Mackay et al. 1992a,b). As a conservative approach, therefore, the degradation of hazardous organic constituents is not included in no-migration demonstration calculations.

SCR.2.2.4.2 Metals

The influences of the prevailing oxidation/reduction potential within the disposal room brines on chemical speciation and hazardous-constituent metal solubilities and the effects of redox kinetics are not included in the no-migration demonstration calculations on the basis of low consequence. The influences of large-scale redox fronts on hazardous-constituent metal migration are not included in the no-migration demonstration on the basis of low probability. The formation of localized reducing zones in the disposal rooms is not included in no-migration demonstration calculations on the basis of low consequence.

The following subsections discuss chemical speciation in the disposal rooms and the potential influence of redox fronts on hazardous-constituent metal migration.

Disposal Room

Chemical speciation refers to the form in which elements and/or compounds occur under a particular set of chemical or environmental conditions. For the purposes of this section, chemical speciation refers to groundwaters and brines and encompasses all truly dissolved chemical species, formed, for example, by complexation. Conditions affecting chemical speciation include the temperature, pressure, pH, redox potential, and salinity (ionic strength) of the solution. The importance of chemical speciation lies in its control of the geochemical reactions likely to occur and its influence on the composition of the water.

The concentrations of hazardous-constituent metals that dissolve in any brines present in the disposal rooms after repository closure will depend on the stability of the chemical species that form under the prevailing conditions (e.g., temperature, pressure, and ionic strength). Chemical reactions, such as the production of gas, have the potential to affect the prevailing chemical conditions in the room. Therefore, the solubilities of the hazardous-constituent metals and the potential for their mobilization are also dependent on gas generation and other reactions. For example, microbial gas generation may lead to acidic pH values due to the development of high partial pressures of CO_2 (and/or possibly H_2S). Chemical reactions with cementitious materials in sludge wastes may, however, result in alkaline conditions. Chemical speciation and changes in chemical speciation resulting from chemical reactions are, however, not included in no-migration demonstration calculations because the bounding methods selected by the DOE to demonstrate no-migration do not require detailed chemical models.

Redox Kinetics

In general, investigation of the redox couples present in natural, aqueous geochemical systems suggests that redox reactions are not in thermodynamic equilibrium due to sluggish **redox kinetics** (e.g., Wolery 1992, 27). However, unlike natural environments where there will be a number of significant competing redox-controlling reactions, in the engineered chemical environment of the repository, Fe(II)/Fe(III) is expected to be the predominant redox couple and can be assumed to be close to equilibrium. The effects of redox kinetics are not included in the no-migration demonstration calculations on the basis of low consequence. The rationale for this decision is that the bounding approach used in this demonstration to simulate the migration of contaminated brine does not require characterization of redox processes.

Redox Fronts

The development of **redox fronts** in the waste region and in potential pathways in the disposal unit may affect the chemistry and migration of hazardous-constituent metals. Redox fronts separate regions that may be characterized, in broad terms, as having different oxidation potentials. On either side of a redox front, the behavior of redox-sensitive elements may be controlled by different geochemical reactions. Elements that

exhibit the greatest range of oxidation states (e.g., Cr) will potentially be the most affected by redox front development and migration. The migration of redox fronts may occur as a result of diffusion processes, or in response to groundwater flow, but will be restricted by the occurrence of heterogeneous buffering reactions (e.g., certain mineral dissolution and precipitation reactions). Indeed, it is these buffering reactions that cause the typically sharp, distinct nature of redox fronts.

It is possible that fluids with different oxidation potentials from those established within the repository might lead to the development and migration of a large-scale redox front. Redox fronts have been observed in natural systems to be the loci for both the mobilization and concentration of metals. However, the available geochemical evidence from radionuclide analogue sites suggests that large-scale redox fronts at these sites migrate only slowly, at most on the order of a few tens of m per million years (Waber 1991; Snelling 1992). These rates of migration are controlled by a range of factors including the rates of erosion, infiltration of oxidizing waters, geochemical reactions, and diffusion processes. The migration of large-scale redox fronts through the repository is considered unlikely over the regulatory period on the basis of a comparison with these slow rates of migration in natural system, and because the relatively impermeable nature of the Salado suggests that migration rates at the WIPP are likely to be even slower than those observed in the more permeable lithologies of the natural systems. Large-scale redox fronts are, therefore, not included in no-migration demonstration calculations on the basis of low probability.

Within the repository, **localized reducing zones**, bounded by redox fronts, may develop centered on metals undergoing corrosion. However, the formation of such zones is considered to be of low consequence owing to the small scale over which these zones and associated redox fronts could exert an influence on hazardous constituent migration. The formation of localized reducing zones is, therefore, not included in no-migration demonstration calculations on the basis of low consequence.

SCR.2.2.5 Assessment of Adsorptivity

The following subsections describe the potential influences of sorption processes on the release and migration of hazardous constituents.

SCR.2.2.5.1 Organics

In the waste drums, VOCs exist in vapor phase equilibrium with an adsorbed phase bound to the surface of the solid waste materials. Organic constituents also occur sorbed within sludges or to materials intentionally added to the waste to immobilize excess liquid in the void spaces (e.g., dry portland cement, vermiculite).

Several long-term desorption processes could affect VOC concentrations and the quantities available for gas transport from the waste region. These processes have been referred to as **post-closure release mechanisms** and are discussed in the following

subsections. Based on consideration of the likely effects of these processes, and the uncertainties that exist, a conservative source term model for VOCs has been developed using measured VOC concentrations from the headspaces of existing waste drums (see Section 8.3.2 of the NMVP). The DOE believes that the conservative nature of these assumptions outweighs any uncertainty introduced by post-closure release mechanisms.

Compressional Desorption of VOCs

Compressional desorption of VOCs from the waste is not included in no-migration demonstration calculations on the basis of low consequence.

The mass of VOCs adsorbed to the waste forms in the drum exist in vapor phase equilibrium with gas-phase VOCs. Physical compression of the waste matrix will lead to reduced pore space. In an open system, where gas can escape, this could potentially lead to a shift in the equilibrium and, thus, higher headspace consequence.

In the repository, there are two ways in which pressure could be exerted on the waste to cause compression:

- gas generation causes pressurization of the disposal rooms
- rock creep, in the absence of significant gas generation, exerts pressure on the waste forms

However, in the closed-system of the disposal room, both of these mechanisms will lead to increased total gas pressures, which will act against further generation of gas through desorption. Consequently, compressional desorption of VOCs from the waste is expected to be negligible.

Chemical Desorption of VOCs

Chemical desorption of VOCs from the waste is not included in no-migration demonstration calculations on the basis of low consequence.

Chemical dissolution and desorption reaction processes acting on the waste have the potential to mobilize sorbed VOCs from the waste.

Uncertainty is associated with the possible occurrence of chemical processes that could lead to the release of VOCs from the waste. For example, anoxic corrosion of Fe and Al-alloy metals will result in corrosion products, which themselves will act as substrates for sorption of VOCs. Similarly, degradation products of cement and gypsum-based materials and cellulosics will also provide new substrates for sorption of VOCs. Consequently, DOE believes that there is no viable chemical desorption mechanism that could lead to a significant further release of gaseous VOCs. Chemical desorption of

VOCs is, therefore, not included in no-migration demonstration calculations on the basis of low consequence to the performance of the disposal system.

Thermal Desorption of VOCs

Thermal desorption of VOCs from the waste is not included in no-migration demonstration calculations on the basis of low consequence.

Theoretically, an increase in repository temperature could result in an increased rate of desorption of VOCs sorbed to the surface of the solid waste materials. Those organics that are adsorbed onto solid materials will require a significant temperature increase to undergo desorption.

Calculations and experimental studies of induced temperature distributions within the repository have been undertaken and are described in Section SCR.2.3.1. In summary, numerical analysis has shown that the average temperature increase in the WIPP repository, due to radioactive decay of the emplaced contact-handled (CH) and remote-handled (RH) TRU waste, is likely to be less than 3 degrees in Farenheit (2 degrees in Celsius). Experimental studies have shown that the temperature increase close to the containers will be as much as 5 degrees in Farenheit (3 degrees in Celsius) where RH-TRU waste containers are located (See Section SCR.2.3.1.1). This will be a short-lived thermal pulse of a few hundred years or less, because the heat-generating decay process in RH-TRU waste is short.

In order for thermal desorption of VOCs from solid waste to become significant, temperatures would have to rise far more than the maximum temperatures estimated for the WIPP disposal rooms. Consequently, thermal desorption of VOCs from the waste is expected to be an inconsequential process.

SCR.2.2.5.2 Metals

Sorption to fixed substrates is not included in the no-migration demonstration calculations on the basis of beneficial consequence to the performance of the disposal unit. Sorption kinetics and changes in sorption surfaces are not included in no-migration demonstration calculations on the basis of low consequence.

Sorption may be defined as the accumulation of matter at the interface between a solid and an aqueous solution. Several sorption mechanisms relevant to hazardous metal constituents may occur in the repository environment. Adsorption mechanisms serve to either immobilize or mobilize metals and include surface complexation, cation-exchange, and chelation. Each of these processes may be time-dependent due to **changes in sorptive surfaces**.

Sorption of hazardous-constituent metals to static surfaces, such as shaft seals, backfill, panel closures, and host rocks, acts to retard chemical transport. Sorption of hazardous-

constituent metals to potentially mobile surfaces, such as colloids and microbes, however, may act to enhance chemical transport, particularly if the kinetics of desorption are slow or the process is irreversible (disequilibrium). The effects of colloids and microbes on waste mobility are discussed in Section SCR.2.4.4.

Disposal Room

The concentrations of hazardous metal constituents that dissolve in brines entering the disposal room will be controlled by a combination of sorption and dissolution reactions. Sorption on waste, containers, and backfill within the disposal rooms would serve to reduce hazardous-constituent metal concentrations.

Shaft Seals and Panel Closures

Chapter 3 of the NMVP describes the seals that are to be placed at various positions in the access shafts. The materials to be used include crushed salt, bentonite clay, and concrete. Of these, the latter two, in particular, possess significant sorption capacities. Similarly, concrete to be used in panel closures in the waste-disposal region will also possess sorptive capacity.

The no-migration demonstration calculations do not take account of sorption to fixed substrates within the repository or along migration pathways. This is a conservative assumption, since sorption would decrease the concentration and mobility of hazardous-constituent metals.

The mechanisms that control the rates of sorption processes are, in general, poorly understood. Often, sorption of inorganic ions on mineral surfaces is a two-step process consisting of a short period (typically minutes) of diffusion-controlled, rapid uptake, followed by slower processes (typically weeks to months) that include surface rearrangement, aggregation and precipitation, and solid solution formation (Davis and Kent 1990, 202). Available data concerning rates of sorption reactions involving the important metals indicate that, in general, a range of kinetic behavior is to be expected. Due to the selected bounding approach for demonstrating no-migration for hazardous-constituent metals in the liquid phase, uncertainties associated with sorption kinetics and time-dependent changes in sorptive surfaces do not require consideration in the NMVP.

SCR.2.2.6 Assessment of Hydrolysis

Hydrolysis is a potential abiotic degradation mechanism for organic constituents and an important process that may affect chemical speciation of brine in the repository.

SCR.2.2.6.1 Hydrolytic Degradation of Organic Constituents

Hydrolytic degradation of hazardous organic constituents is not included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

The rate of hydrolysis of a chemical may be characterized in terms of half-life: the time ($t_{1/2}$) it takes to reach one-half of its original amount. **Hydrolytic degradation** applies to a limited number of organic compounds in the WIPP inventory, and for those constituents, degradation rates vary. Longer-lived organic constituents include bromoform (686 years), carbon tertrachloride (7,000 years), chloroform (3,500 years), methylene chloride (704 years), chlorobenzene and dichlorobenzene (879 years) and 1,2-Dichloroethane (five to 50,000 years) (Mackay et al. 1992a, b; Mackay et al. 1993; Howard et al. 1991). Examples of shorter-lived constituents include methyl ethyl ketone (50 years), toluene (37 years), 1,1,2-trichloroethane (37 years), ethyl acetate (two years), trichloroethylene (0.90 years), 1,1,1-trichloroethane (0.73 years), and 1,1,2,2-tetrachloroethane (0.12 years).

The DOE believes that hydrolysis will be an active process in the post-closure environment. Ney (1995) reports that hydrolysis occurs in soil environments, which in terms of humidity and/or degree of saturation, are comparable to conditions expected in the post-closure repository. Alkaline earth and hazardous-constituent metal ions can also catalyze hydrolysis reactions (Mackay et al. 1992a, b). Although unquantified for site-specific conditions through experimental data, hydrolytic degradation will reduce the source term for several constituents over the 10,000-year regulatory period. Nevertheless, owing to uncertainty regarding the actual hydrolytic half-lives in the WIPP disposal unit, hydrolytic degradation of hazardous organic constituents is not accounted for in no-migration demonstration calculations. This is a conservative assumption, since hydrolysis would decrease the source term.

SCR.2.2.6.2 Hydrolysis of Metals

Hydrolysis reactions of metals and the effects of reaction kinetics in hydrolysis reactions are not included in the no-migration demonstration calculations on the basis of low consequence.

Chemical speciation refers to the form in which elements and/or compounds occur under a particular set of chemical or environmental conditions. In this appendix, chemical speciation refers to groundwaters and brines and encompasses all truly dissolved chemical species, formed, for example, by **hydrolysis** or complexation. Conditions affecting chemical speciation include the temperature, pressure, pH, redox potential, and salinity (ionic strength) of the solution. The importance of chemical speciation lies in its control of the geochemical reactions likely to occur and its influence on the composition of the solution.

The concentrations of hazardous metals that dissolve in any brines present in the disposal rooms after repository closure will depend on the stability of the chemical species that form under the prevailing conditions. Chemical reactions, such as the production of gas, have the potential to affect the prevailing chemical conditions in the room. Therefore, the solubilities of the hazardous-constituent metals and the potential for their mobilization

are also dependent on gas generation and other reactions. For example, microbial gas generation may lead to acidic pH values due to the development of high partial pressures of CO_2 (and/or possibly H_2S). Chemical reactions with cementitious materials in sludge wastes may, however, result in alkaline conditions. Under more alkaline conditions, hydrolysis reactions occur to a greater degree. Because a bounding simulation is used to model migration of contaminated brine, hydrolysis reactions are not included on the basis that chemical speciation and other factors influencing metal solubility do not have to be characterized.

The effects of reaction kinetics in aqueous systems are discussed by Lasaga et al. (1994), who suggest that aqueous geochemical speciation reactions involving relatively small inorganic species occur rapidly and are accurately described by thermodynamic equilibrium models that neglect explicit consideration of reaction kinetics (e.g., Lasaga et al. 1994, 2361). Consequently, the effects of **reaction kinetics** in chemical speciation and hydrolysis reactions are not included in the no-migration demonstration calculations on the basis of low consequence.

SCR.2.2.7 Assessment of Hazardous Constituent Degradation

This section discusses the degradation of hazardous constituents.

SCR.2.2.7.1 Organics

Degradation of hazardous organic constituents is not included in no-migration demonstration calculations on the basis of beneficial consequence to the performance of the disposal unit. Formation of hazardous constituents through degradation is not included in no-migration demonstration calculations on the basis of low consequence.

Biotic and abiotic degradation of organic chemicals may occur through several processes expected in the post-closure environment: biodegradation, radiolysis, and hydrolysis. The disintegration of organic chemical bonds through degradation can result in two consequences:

- transformation into another hazardous constituent or nonhazardous organic compound (e.g., 1,1,2 trichloroethene to vinyl chloride) (EPA 1987)
- degradation of the compound into smaller organic molecules, and ultimately into simple molecules such as water, carbon dioxide, nitrogen, and methane

Degradation mechanisms may be classified as either biotic or abiotic depending on whether or not the transformations are biologically mediated (Howard et al. 1991; Vogel et al. 1987). **Biodegradation** can also be classified as **aerobic** and **anaerobic** (Mackay et al. 1992a, b; Mackay et al. 1993). Rates of chemical transformation are controlled by intrinsic properties of the specific organic compound, the degradation process, and the conditions of exposure, including variables such as environmental media, moisture

content, temperature, pH, and the type, density, and long-term viability of microbial populations (Mackay et al. 1992a, b; Mackay et al. 1993). Consequently, half-lives reported in the literature commonly reference a range of values depending on the media and exposure conditions.

Table SCR-3 presents a compilation of organic degradation rates for VOCs and SVOCs subject to this petition. Where available in the literature, soil is selected as the reference media for biotic degradation half-life data. **Hydrolysis/substitution** is the only abiotic degradation/transformation mechanism reported.

Biotic degradation is typically much faster than abiotic degradation, ranging on the order of days to years. With few exceptions, noted in Table SCR-3, anaerobic biodegradation is much slower than aerobic biodegradation (Vogel et al. 1987). Abiotic degradation by hydrolysis is slower still. Compounds listed as having no significant hydrolyzable groups are not significantly affected by abiotic hydrolysis.

There are uncertainties in site-specific organic degradation rates and also in the long-term viability of microbial populations that can be affected by the presence of hazardous constituents and alpha-emitting radioactive species present in the TRU waste. It is, however, reasonable to expect that significant degradation will occur over the 10,000-year time frame, especially when considered relative to literature-based anaerobic degradation rates on the order of 10-1,000s of days. The DOE, therefore, believes that biotic and abiotic degradation will occur in the post-closure environment. Because the uncertainties cannot be quantified, however, degradation of hazardous organic constituents is not accounted for in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration. This assumption is conservative, considering that the BRAGFLO simulation assumes that microbial degradation of cellulosics, plastics, and rubbers will occur and generate gas.

Degradation of high molecular weight compounds generally results in the formation of lower molecular weight, less toxic compounds. Biodegradation reactions can give rise to higher molecular weight compounds (Ney 1995). Under repository conditions, these reactions will be slow or result in only trace amounts of the high molecular weight compounds, and the products will generally have lower solubilities and greater sorptive capacities than the reactants. Other types of reactions can result in the formation of hazardous constituents, but, again, these reactions will be slow or result in only trace amounts of the high molecular weight compounds. An example is the radiolysis of polyethylene in the presence of oxygen and carbon tetrachloride generating a trace VOC reaction product—chloroform (DOE 1992). The consequences of the **formation of hazardous constituents** through degradation or other reactions are, therefore, expected to be insignificant and are not included in the no-migration demonstration.

Table SCR-3. Organic Degradation Half-Life Data From Literature

VOCs	Biodegradation (Days)[1] Aerobic		Anaerobic		Hydrolysis[1] (Years)
Benzene	(16)	(5)	(720)	(112)	NS
Bromoform	(180)	(28)	(720)	(112)	686
Carbon Disulfide	-		-		-
Carbon tetrachloride	(360)	(180)	(28)	(7)	7000
Chlorobenzene	(150)	(68)	(600)	(272)	879
Chloroform	(180)	(28)	(28)	(7)	1.25
	1800[2]				3500[2]
1,2-Dichloroethane	(180)	(100)	(720)	(400)	5-50,000
1,1-Dichloroethylene (-ene)	(180)	(28)	(173)	(81)	2
					NS[2]
cis 1,2-dichloroethylene (-ene)	(180)	(28)	(720)	(112)	NS[2]
Isobutanol	(7)	(1)[2]	(5)	(1)[2]	-
Methylene chloride	(28)	(7)	(112)	(28)	704
1,1,2,2-Tetrachloroethane	(<10)		(28)	(7)	.12[2]
Methyl Ethyl Ketone (2-Butanone)	(7)	(1)[2]	(28)	(4)[2]	50[2]
Tetrachloroethylene (-ene)	(360)	(180)	(1653)	(98)	.73
					NS[2]
Toluene (methyl benzene)	(28)	(7)	(210)	(56)	37
					NS[2]
1,1,2-Trichloroethane	(365)	(136)	(1460)	(720)	37[2]
1,1,1-Trichloroethane	(273)	(140)	(1092)	(560)	.5
					.73[2]
Trichloroethylene (-ene)	(360)	(180)	(1642)	(98)	.90
Trichlorofluoromethane	(360)	(180)	(1482)	(720)	-
Vinyl chloride	(180)	(28)	(720)	(112)	10
	2851[2]				NS[2]

SVOCs	Biodegradation (Days)[1] Aerobic		Anaerobic		Hydrolysis[1] (Years)
Cresols					
o	(7)	(1)[2]	(28)	(4)[2]	-
m	(29)	(2)[2]	(49)	(15)[2]	-
p	(.66)	(.04)[2]	(28)	(10)[2]	-
ortho-Dichlorobenzene	(180)	(28)	(720)	(120)	879
1,4-Dichlorobenzene	(180)	(28)	(720)	(120)	879
2,4-Dinitrotoluene	(180)	(78)	(10)	(2)	NS[2]
2,4-Dinitrophenol	(263)	(13)	(7)	(3)	-
Hexachloroethane	-		-		NS[2]
Hexachlorobenzene	(2089)	(969)	(1520)	(42)	NS
Nitrobenzene	(197)	(13)	(13)	(2)	NS[2]
Pentachlorophenol	(178)	(23)	(8356)	(3876)	NS
Pyridine	(7)	(2)	(28)	(5)	NS[2]

[1] Unless otherwise indicated, reference source is Mackay et al. (1992a,b); Mackay et al. (1993); Mackay et al. (1995)

[2] Reference is Howard et al. (1991) for biotic degradation; however, media and conditions are not specified.

NS: No significant hydrolyzable groups

- : Not Available

SCR.2.2.7.2 Metals

Degradation of hazardous metal constituents is not included in no-migration demonstration calculations on the basis of low probability.

The initial mass of hazardous-constituent metals in the waste will not change, i.e., the **metals will not degrade**, although the prevalent chemical species may be altered with time due to changes in brine chemistry.

SCR.2.3 Thermal Effects

Temperature rises in and around the repository could potentially affect mechanical properties of the waste and host-rock and change the source term and mobility of hazardous constituents. The following sections discuss heat generation and the effects of temperature rises on the stress field and on flow and transport.

SCR.2.3.1 Heat Generation

SCR.2.3.1.1 Heat from Radioactive Decay

The effects of temperature increases as a result of radioactive decay are not included in the no-migration demonstration calculations on the basis of low consequence.

Radioactive decay of the CH- and RH-TRU waste emplaced in the repository will generate heat. The importance of heat generation depends on the effects that the induced temperature changes would have on rock and waste mechanics, fluid flow, and geochemical processes. For example, temperature increases could result in thermally induced fracturing or thermally driven flow of gas and brine in the vicinity of the repository.

According to the WAC (see Chapter 4 of the NMVP), the design basis for the WIPP requires that the thermal loading does not exceed 10 kilowatts per acre. RH-TRU waste canisters, CH-TRU waste drums, and CH-TRU standard waste boxes (SWBs) have estimated average thermal power of 60 watts, 0.5 watts, and 0.8 watts, respectively. The WAC requires that the thermal power generated by waste in an RH-TRU canister shall not exceed 300 watts.

A numerical study to calculate induced temperature distributions was undertaken by Thorne and Rudeen (1980). The background to this numerical study is presented in DOE (1980). The Thorne and Rudeen (1980) analysis assumed:

- all CH-TRU waste drums and boxes contain the maximum permissible quantity of plutonium. According to the WAC, the fissionable hazardous constituent content for CH-TRU waste containers shall be no greater than 200 g per 0.21 m^2 drum and 350 g per 1.8 m^2 SWBs (in Pu-239 fissile gram equivalents).

- the plutonium in CH-TRU waste containers is weapons-grade material producing heat at 0.0024 watts per g. Thus, the thermal power of a drum is approximately 0.5 watts and that of a box is approximately 0.8 watts.

- approximately 3.7×10^5 m^3 of CH-TRU waste are distributed within a repository enclosing an area of 7.3×10^5 m^2. This is a conservative assumption in terms of quantity and density of waste within the repository, because the maximum capacity of the WIPP is 6.2×10^6 ft^3 (1.756×10^5 m^3) for all waste (as specified by the Land Withdrawal Act [LWA]) to be placed in an enclosed area of approximately 5.1×10^5 m^2.

- half of the CH-TRU waste volume is placed in drums and half in boxes so that the repository will contain approximately 9×10^5 drums and 10^5 boxes. Thus, a calculated thermal power of 2.8 kilowatts per acre (0.7 watts per m^2) of heat is generated by the CH-TRU waste.

Under these assumptions, Thorne and Rudeen (1980) estimated the long-term temperature response of the disposal system to waste emplacement. Calculations assumed a uniform initial power density of 0.7 watts per m^2 that decreases over time. Thorne and Rudeen (1980) estimated the maximum rise in temperature at the center of a repository to be 3 degrees in Farenheit (1.6 degrees in Celsius) at 80 years after waste emplacement. Although the calculations did not include the effects of RH-TRU waste, they reasoned that the thermal effects of RH-TRU waste would approximately double the estimated average temperature increase in the repository.

More recently, Sanchez and Trellue (1996) evaluated the thermal effect of an RH-TRU container corresponding to the maximum permissible surface dose; according to the WAC, the maximum allowable surface dose equivalent for RH-TRU containers is 1,000 rem per hour. Calculating the absorbed dose rate for gamma-ray radiation corresponding to the maximum surface dose equivalent rate of 1,000 rem per hour, they back-calculated the total curie load of an RH-TRU container (including alpha and beta radiation) from the gamma load, and derived the thermal load of an RH-TRU container from the total curie load. For a gamma source of 2×10^4 curies per m^3, the maximum permissible thermal load of an RH-TRU container is found to be 70 watts per m^3. Thus, the maximum thermal load of an RH-TRU container is about 60 watts, suggesting that the WAC upper limit of 300 watts should not be used to calculate elevation in temperature from RH-TRU waste.

Sanchez and Trellue (1996) estimated the temperature increase at the surface of a 60 watt RH-TRU waste container to be about 5 degrees in Farenheit (3 degrees in Celsius). Their analysis involved solution of a steady-state thermal conduction problem with a constant heat source term of 70 watts per m^3. Assumption of a constant heat source is conservative; the RH-TRU thermal load will actually decrease relatively rapidly because heat-generating decay processes in RH-TRU waste are short-lived. Heat-producing nuclides in RH-TRU waste, such as ^{137}Cs, ^{90}Sr, ^{241}Pu, and ^{147}Pm have half-lives that are

approximately 30, 29, 14, and three years, respectively. In addition, based on the information in the WIPP Baseline Inventory Report (BIR) (DOE 1995), Sanchez and Trellue (1996) suggested that the actual average thermal load for an RH-TRU container will actually be less than 1 watt, and reasoned that the total RH-TRU heat load will be less than 10 percent of the total heat load in the WIPP. Thus, the total thermal load of the RH-TRU waste will not significantly affect the average rise in temperature in the repository.

In summary, analysis has shown that the average temperature increase in the WIPP repository, due to radioactive decay of the emplaced CH- and RH-TRU waste, will be less than 3 degrees in Farenheit (2 degrees in Celsius). Temperature increases of about 5 degrees in Farenheit (3 degrees in Celsius) may occur in the vicinity of RH-TRU containers with the limiting thermal load of about 60 watts (based on the maximum allowable surface dose equivalent for RH-TRU containers), but the temperature increase will be short-lived, on the order of a few hundred years or less.

SCR.2.3.1.2 Nuclear Criticality

Nuclear criticality is not included in no-migration demonstration calculations on the basis of low probability.

Nuclear criticality refers to a sustained fission reaction that may occur if fissionable materials reach critical mass at sufficiently high concentration. This type of reaction produces heat, or, under a specific set of conditions, causes an explosion.

The WAC limits the fissionable content of CH- and RH-TRU waste canisters, so a post-closure concentration process would be required to create a critical mass. Precipitation and sorption are potential mechanisms. However, for credible geometries of material, a neutron moderator (such as hydrogen in water) would be required for criticality to occur. In the event of criticality occurring, the heat generated would result in self-shutdown of the reaction via a combination of thermally induced flow, voiding, and a rise in the temperature of the fissile material. Nuclear criticality is, therefore, not included in no-migration demonstration on the basis of low probability.

SCR.2.3.1.3 Exothermic Reactions

The effects of exothermic reactions are not included in the no-migration demonstration calculations on the basis of low consequence.

Exothermic reactions could alter the temperature of the disposal system, and affect the properties of the repository and surrounding materials. In particular, the hydration reactions that will occur in the cementitious materials that form parts of the WIPP seal system will generate heat and may lead to elevated temperatures (Van Sambeek 1987). This will influence rates of salt creep in the surrounding rock and may lead to cracking of the seals. However, the duration of any temperature increases due to concrete hydration

is likely to be short and, therefore, the effects of exothermic reactions are not included in the no-migration demonstration calculations on the basis of low consequence. Other exothermic chemical reactions will also occur and evolve small quantities of heat (for example, gas generation, container corrosion, waste dissolution, hydration of chemical conditioners, etc.), but the thermal effects of these reactions will be insignificant.

SCR.2.3.2 Thermally-Induced Stress

The effects of thermally induced stress in the repository are not included in the no-migration demonstration calculations on the basis of low consequence.

Thermally induced stress could result in pathways for groundwater flow in the DRZ, in the anhydrite layers and marker beds, and through seals, or it could enhance existing pathways. Conversely, elevated temperatures will accelerate the rate of salt creep and mitigate fracture development.

Radioactive decay (Section SCR.2.3.1.1), nuclear criticality (Section SCR.2.3.1.2), and exothermic reactions (Section SCR.2.3.1.3) are three possible sources of heat in the WIPP repository. The average thermal load is expected to be less than 3 degrees in Farenheit (2 degrees in Celsius). Temperature increases near RH-TRU canisters are also expected to be insignificant. Consequently, rheological response to the thermal contrasts in the repository is not included in no-migration demonstration calculations on the basis of low consequence.

SCR.2.3.3 Thermal Convection

Thermal convection is not included in no-migration demonstration calculations on the basis of low consequence.

Temperature differentials in the repository could initiate **thermal convection** and influence hazardous constituent transport.

Radioactive decay (Section SCR.2.3.1.1), nuclear criticality (Section SCR.2.3.1.2), and exothermic reactions (Section SCR.2.3.1.3) are three possible sources of heat in the WIPP repository. The average thermal load is expected to be less than 3 degrees in Farenheit (2 degrees in Celsius), and significant thermal contrasts are not expected to develop in the vicinity of RH-TRU waste canisters. Thus, thermal convection is not included in no-migration demonstration calculations.

SCR.2.3.4 Thermally-Induced Chemical Changes

The effects of thermally-induced chemical changes are not included in the no-migration demonstration calculations based on the low consequence of expected temperature changes in the repository.

Calculations and experimental studies of induced temperature distributions within the repository have been undertaken and are described in Section SCR.2.3.1. In summary, numerical analysis has shown that the average temperature increase in the WIPP repository, due to radioactive decay of the emplaced CH- and RH-TRU waste, will be less than 3 degrees in Farenheit (2 degrees in Celsius). As a consequence of these results, the effects of **thermally-induced chemical changes** are not included in the no-migration demonstration calculations.

SCR.2.4 Waste Mobility and Transport

Hazardous constituents in the WIPP may occur in the vapor and liquid phases, as well as in solids, such as metals and sludges. For solid hazardous metal constituents in the waste to be mobilized and become available for transport from the waste region, containers must be breached and dissolution reactions must occur. Similarly, gaseous hazardous organic constituents will not be fully available for transport until drums are crushed and internal layers of the drum are breached.

Controlling factors on hazardous constituent mobility and transport include

- the initial source term (e.g., the **volatilization potential** of organic hazardous constituents and subsequent partitioning of the gaseous phase into the brine phase, and the solubility of metal hazardous constituents in brine)
- the potential for retardation of hazardous constituent mobility (e.g., by sorption or precipitation)
- the mode of transport (i.e., whether in gaseous, dissolved, colloidal, or particulate form)
- the mechanism of transport (e.g., by advection, diffusion, or other)

The following sections discuss hazardous metal and organic constituent mobility and transport in light of these controlling factors.

SCR.2.4.1 Liquid Phase Hazardous Constituent Source Term

SCR.2.4.1.1 Organics

Organic Solubility/Partitioning

The partitioning of hazardous organic constituents between the liquid and gas phases is not explicitly included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

Concentrations of hazardous-constituent VOCs in brine are governed by the laws of thermodynamic equilibrium between the gas and liquid phases. Based on Henry's Law relation, the concentration of an organic constituent in the liquid phase (i.e., liquid phase source term) is related to the chemical's concentration in the gas phase. Phase equilibrium thermodynamics dictates that if a gaseous phase and liquid phase are in thermodynamic equilibrium, the fugacities in both phases must be equal, and the concentrations can be estimated using the Henry's Law constant. As concluded in Section SCR.2.2.2, the only significant source of liquid is brine. Consequently, the DOE assumes that the liquid phase results from partitioning of gaseous phase VOCs and SVOCs into brine that flows into the waste region.

Based on such considerations, the **solubility of hazardous-constituent VOCs** in the high ionic strength WIPP brines is concluded to be sufficiently low that their transport in the liquid phase would be negligible. Any dissolution of VOCs or SVOCs into the liquid phase would act to reduce the gaseous organic hazardous-constituent source term. As a conservative modeling simplification, therefore, it is assumed that hazardous organic constituents remain in the gas phase.

Organic Phase Liquids

The presence of an immiscible liquid organic phase is not included in no-migration demonstration calculations on the basis of low probability.

If organic constituents are present in concentrations in excess of their water solubility limits, a **non-aqueous phase liquid** (NAPL) may form. The presence of nonaqueous phase liquids in the post-closure environment is unlikely for the following reasons:

- measured headspace concentrations have been observed to be a fraction to two orders of magnitude lower than their water solubility limits

- the absence of free liquids is assured through the screening process used to certify the WAC criteria. Experience at Idaho National Engineering Laboratory (INEL) indicates an overall miscertification rate of two percent for the measurable WAC, including operational safety and transportation related limits, as well as the lack of free liquids in drums and containers

Therefore, the presence of an immiscible liquid organic phase is not included in no-migration demonstration calculations on the basis of low probability.

SCR.2.4.1.2 Metals

Solubility

Hazardous-constituent metal dissolution and speciation in the disposal rooms, and the effects of organic and colloid complexation reactions on metal source term

concentrations are not included in the no-migration demonstration calculations on the basis of low consequence. The effect of reaction kinetics in controlling the rate of waste dissolution is not included on the basis of beneficial consequence to the demonstration.

Dissolution of waste is relevant, because of its influence on the **solubility of hazardous-constituent metals** in brine and the rate of hazardous constituent transport.

The assumption of equilibrium waste dissolution represents a conservative approach to predicting hazardous metal solubilities in the disposal room brines, because it yields maximum concentration estimates. Accounting for the effects of **reaction kinetics** in controlling the rate of waste dissolution within the disposal rooms would serve to reduce these concentrations.

Organic complexation and the formation of colloids may influence the hazardous metal source term. These effects are discussed below.

Organic Complexation

The formation of aqueous complexes between hazardous-constituent metals and organic materials has the potential to increase the total dissolved hazardous-constituent metal load in the source term, because further dissolution will take place to maintain the free metal activity.

Both naturally occurring and anthropogenic organic materials may be important, and include

- anthropogenic organics associated with the waste
- degradation products from cellulose that may be present in the waste itself
- naturally occurring low molecular weight organics, such as carboxylic acids, phenols, and alcohols
- naturally occurring high molecular weight organics, including humin, humic acids, and fulvic acids derived from soil waste

The stability of hazardous-constituent metal-organic complexes is affected by concentration and environmental factors. In general, complexing is favored by increased concentration of **organic complexants**, increased pH, and decreased ionic strength. Humic acid levels within the Salado are likely to be lower than those in the disposal room, because of the presence of soil waste in the latter.

Colloid Complexation

The formation of **complexes** between hazardous-constituent metals and **colloids** (including microbes) has the potential to enhance the total dissolved hazardous-constituent metal load in the source term, and thus the potential for hazardous-constituent metal migration.

However, the salinities of the Salado brines are well above those observed to cause agglomeration and destabilization of inorganic colloids, including mineral fragments and aged or crystalline intrinsic metal colloids. These salinities also suggest that there is a low probability that significant dispersions of organic colloids, including humic substances and microbes, will be stable. Therefore, colloid concentrations are expected to be low.

Because a bounding approach is used to demonstrate no-migration for liquid-phase hazardous constituents, metal dissolution and speciation in the disposal rooms, and the effects of organic and colloid complexation reactions on metal source term concentrations are not included in no-migration demonstration conceptual model. The effect of reaction kinetics is not included on the basis of beneficial consequence to the demonstration.

SCR.2.4.2 Gas-Phase Hazardous-Constituent Source Term

SCR.2.4.2.1 Volatile Organic Compounds

***Volatilization** of **VOCs** from the waste is accounted for in the no-migration demonstration as the VOC source term. Relative to conservative assumptions incorporated into the VOC source term model, correction factors to account for increased concentrations within internal layers of confinement (e.g., internal packages) are considered low consequence and are not included in the NMVP calculations.*

In the waste drums, VOCs exist in vapor phase equilibrium with an adsorbed phase bound to the surface of the solid waste materials. Organic constituents also occur sorbed within sludges or to materials intentionally added to the waste to immobilize excess liquid in the void spaces (e.g., dry portland cement, vermiculite).

As discussed in Section SCR.2.2.5.1, the release of additional VOCs adsorbed to materials in the waste due to processes in the post-closure environment is low. However, VOC concentrations are known to vary between samples taken in the headspace of drums and those extracted from within inner layers of confinement (e.g., polymer bags). Because the representativeness of headspace sampling depends on achieving steady state conditions in a waste container, methods have been developed to approximate the maximum drum concentration of VOCs based on the vented or nonvented history of a waste container prior to sampling (Connolly 1995). Correction factors for unvented drums range from 1.13 to 9.53 for sludge waste to 1.73 to 39.12 for solid waste. The DOE believes that the VOC source term model defined in NMVP Section 8.3.2.1

adequately accounts for using uncorrected concentrations in this demonstration. The method for determining the headspace-measured VOC source term is summarized as follows:

- each VOC headspace concentration is assumed to represent the concentration of the entire initial waste-disposal region,
- for each VOC, an initial mass is derived based on the initial waste region volume - $m_i = \rho_i \times v_i$, where ρ_i is the assumed VOC concentration (mass/volume) for the initial waste-disposal region and v_i is the initial waste region volume, and
- to derive the VOC source term concentration held constant over the 10,000-year compliance period, the initial mass (m_i) is assumed to occupy the final void volume of the repository (v_f).

For VOCs not characterized by headspace data, saturated vapor concentrations are used to conservatively bound the VOC source term by maintaining this concentration constant over the 10,000-year compliance period.

SCR.2.4.2.2 Semi-Volatile Organic Compounds

***Volatilization** of **SVOCs** from the waste is accounted for in the no-migration demonstration as the SVOC source term.*

By definition, SVOCs generally have lower vapor pressures than VOCs. Saturated vapor concentrations are used to conservatively bound the SVOC source term by maintaining the resulting concentration constant over the 10,000-year compliance period.

SCR.2.4.3 Retardation of Hazardous Constituent Transport

SCR.2.4.3.1 Organics

The retardation of organic constituents is not included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

All VOCs are conservatively assumed to be in the gas phase and available for transport. **Retardation of VOCs** is not considered in the no-migration demonstration calculations.

SCR.2.4.3.2 Metals

Sorption

Sorption to fixed substrates, serving to reduce hazardous constituent concentrations, is not included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration. Sorption kinetics are not included in no-migration

demonstration calculations on the basis of low consequence. Sorption of metals to colloids is also not included on the basis of low consequence.

Sorption to fixed substrates and **sorption kinetics** are discussed in Section SCR.2.2.5.2. Sorption to colloids is discussed in Section SCR.2.4.1.2.

Precipitation

The formation of hazardous-constituent metal-bearing precipitates from WIPP brines, and their subsequent retardation following release from the waste form, is not included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

During migration, **precipitation** processes that occur will lead to reduced **hazardous-constituent metal** transport. Excluding these processes from the no-migration demonstration calculations is, therefore, a conservative assumption, and the formation of hazardous-constituent metal-bearing precipitates from brines is not included in no-migration demonstration calculations.

SCR.2.4.4 Transport Modes

Following closure of the repository, brine may contact the waste, and hazardous-constituent metals will dissolve. Chemical and microbial decomposition of organics in the waste may result in the transport of such hazardous-constituent metals as organic complexes, colloids, and particulate material. Hazardous-constituent metals bound to or within microbes might also be transported. Dissolved metals will migrate with the brine by advection and diffusion through the repository, seals, DRZ, and pores and fractures in the rock matrix. Organic gas-phase hazardous constituents released from the waste will migrate in association with other gases as dictated by two-phase flow of gas and brine.

The following subsections discuss briefly the transport of hazardous-constituent metals in a number of different forms: fully dissolved, colloidal, particulate, and bound to microbes. The transport of hazardous-constituent VOCs and SVOCs in the gas phase is also addressed.

SCR.2.4.4.1 Solute Transport

Transport of dissolved, heavy hazardous-constituent metals is accounted for in the no-migration demonstration.

Transport of dissolved, heavy metals may occur by advection, dispersion, and diffusion down chemical potential gradients. The transport of dissolved hazardous-constituent metals by advection and dispersion is accounted for in the no migration demonstrations by the ability to track the movement of brine potentially containing hazardous constituents.

SCR.2.4.4.2 Colloid Transport

Transport of colloidal hazardous-constituent metals is not included in no-migration demonstration calculations on the basis of low consequence. Colloid agglomeration, destabilization, and sorption are not included in the no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

Colloids typically have sizes of between 1 nanometer and 1 micrometer and may form stable dispersions in groundwaters depending on their composition and the prevailing chemical conditions (e.g., salinity). Depending on their size, **colloid transport** can occur at different rates than fully dissolved species. Colloids may be physically excluded from fine porous media, and their migration may be accelerated through fractured media in channels where velocities are greatest. However, they can also interact with the host rocks during transport and become retarded. These interactions may be of a chemical or physical nature and include electrostatic effects, leading to **agglomeration, kinetic destabilization** and **colloid sorption,** and **filtration**, leading to pore blocking.

The salinities of the Salado brines are well above those observed to cause agglomeration and destabilization of inorganic colloids, including mineral fragments and aged or crystalline intrinsic metal colloids, and suggest also that there is a low probability that dispersions of organic colloids, including humic substances and microbes, will be stable and could influence hazardous-constituent metal transport.

Uncertainty surrounding the potential role of colloids in hazardous-constituent metal transport has not been quantified. However, quantification is not necessary, since the approach for assessing transport of hazardous constituents in the liquid phase is bounding (see Section 8.3.3 of the NMVP). Conservatively, processes leading to the retardation of colloids, such as agglomeration, destabilization, and sorption, are not included in the no-migration demonstration calculations.

SCR.2.4.4.3 Particulate Transport

The transport of hazardous-constituent metals as particulates larger than colloids in groundwater and brine is not included in no-migration demonstration calculations on the basis of low consequence.

Suspensions of particles having sizes above the colloidal range are, by definition, unstable, because they are subject to gravitational settling. Within the WIPP disposal rooms, it is unlikely that brine flow will be rapid enough to generate particulate suspensions (through **rinse**) or transport them. Mobilization of any suspensions that may form would have the effect of a local and minor redistribution of hazardous-constituent metals within the room and is unlikely, therefore, to result in significantly increased hazardous-constituent metal transport from the repository.

SCR.2.4.4.4 Microbial Transport

Transport of hazardous-constituent metals sorbed to microbes is not included in no-migration demonstration calculations on the basis of low consequence. The potential retarding influence of biofilms on microbial transport is not included in performance assessment calculations on the basis of beneficial consequence to the demonstration.

Microbes will be introduced into the disposal rooms during the operational phase of the repository, and may occur naturally in the Salado Formation. Because of their colloidal size, microbial transport of hazardous-constituent metals can be accounted for in the same manner as colloidal transport.

Biofilms (see Section SCR.2.1.2.1) may influence microbial and hazardous-constituent metals rates through their capacity to retain, and therefore, **retard**, both the microbes themselves and hazardous-constituent metals. This effect is not included in performance assessment calculations on the basis of beneficial consequence to the demonstration.

SCR.2.4.4.5 Gas Transport

The transport of hazardous-constituent organic gases is accounted for in the no-migration demonstration calculations.

The transport of hazardous-constituent organic gases generated in the disposal room is simulated by BRAGFLO and is discussed in Section 8.2 of the NMVP.

SCR.2.4.5 Hazardous Constituent Transport Mechanisms

SCR.2.4.5.1 Advection

Advection of brine and gas is accounted for in the no-migration demonstration calculations. The effects of unsaturated conditions in the repository and the Salado are accounted for in no-migration demonstration calculations by the explicit treatment of two-phase flow.

Potentially, **advection** of hazardous constituents may occur through interconnected porosity in the waste, the DRZ, and the shaft seals and panel closures. Advection in the Salado could occur via interconnected porosity in the impure halite and anhydrite interbeds that comprise its stratigraphy.

Under hydrologically **unsaturated conditions** arising from the presence of gas within the repository, transport may be influenced by the degree of saturation, as well as by a number of small-scale processes, such as those relating to wetting and capillarity. The effects of unsaturated conditions in the repository and the Salado are accounted for in no-migration demonstration calculations by the explicit treatment of two-phase flow.

Advection is discussed further in Section 8.2 of the NMVP.

SCR.2.4.5.2 Diffusion

Diffusion of hazardous constituents is not included in no-migration demonstration calculations on the basis of low consequence. Matrix diffusion is not included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

Diffusion of hazardous constituents may occur via porosity in the waste, DRZ, shaft seals, and panel closures. Diffusion in the Salado may occur via porosity in the impure halite and anhydrite interbeds that comprise its stratigraphy. Diffusion along concentration gradients is assumed to be negligible, with respect to the uncertainties associated with the modeling of advective flow. Consequently, diffusion is not included in no-migration demonstration calculations.

Matrix diffusion reduces hazardous-constituent concentrations in brine moving by advective flow by allowing solutes to diffuse into pore spaces adjacent to fractures or into dead-end pores away from the advective flow. The exclusion of matrix diffusion from the no-migration demonstration calculations is, therefore, a conservative assumption, and it is not included in no-migration demonstration calculations.

SCR.2.4.5.3 Thermochemical Transport Phenomena

The effects of thermochemical transport phenomena are not included in the no-migration demonstration calculations on the basis of low consequence.

Calculations and experimental studies of induced temperature distributions within the repository have been undertaken and are described in Section SCR.2.3.1. In summary, numerical analysis has shown that the average temperature increase in the WIPP repository, due to radioactive decay of the emplaced CH- and RH-TRU waste, will be less than 3 degrees in Farenheit (2 degrees in Celsius). Under certain circumstances, temperature gradients can cause changes in concentration gradients without fluid flow (the **Soret effect**). The limited spatial scale of this effect, the high temperature gradients required, and the likely temperature distributions within the repository all suggest that the Soret effect cannot affect system performance. Thus, the effects of thermochemical transport phenomena are not included in the no-migration demonstration calculations.

SCR.2.4.5.4 Electrochemical Transport Phenomena

The effects of electrochemical reactions are not included in the no-migration demonstration calculations on the basis of low consequence. The effects of galvanic coupling and electrophoresis are not included in the no-migration demonstration calculations on the basis of low probability.

This section discusses electrochemical transport phenomena, including galvanic coupling, electrochemical reactions, and electrophoretic effects.

Potential gradients may exist in the subsurface as a result of groundwater flow and **electrochemical reactions**. The development of such potentials may be associated with the weathering of sulfide ore bodies, variations in rock properties at geological contacts, bioelectric activity associated with organic matter, natural corrosion reactions, and temperature and pressure gradients in groundwaters. With the exception of mineralization potentials associated with metallic sulfide ores (see following paragraph), the magnitude of such potentials is usually less than about 100 mV, and the potentials tend to average to zero over distances on the order of several thousand feet (Telford et al. 1976). Temporary currents may be induced over larger distances by activity in the ionosphere, thunderstorms, and nuclear blasts. The short duration and spasmodic nature of these effects is such that they are not included in no-migration demonstration calculations.

With regard to the WIPP, **galvanic coupling** refers to the establishment of electrical potential gradients between metals in the waste form, canisters, and other metals external to the waste form. Such electrochemical effects have the potential to influence corrosion processes, gas generation rates, and chemical migration. Metals other than those in the waste form and canisters can potentially include natural metallic ore bodies in the host rock and metallic elements emplaced in other parts of the repository. The absence of metallic sulfide ores in the region (Powers et al. 1978) allows galvanic coupling between the waste and metals external to the repository to be eliminated from no-migration demonstration calculations on the basis of low probability.

A range of metals will be present within the repository (e.g., waste metals and metal packaging), and cells can be established over short distances. The precise interactions that may occur are complex and depend on the metals involved, their physical characteristics, and the prevailing conditions. Good physical and electrical contact between the metals involved is critical to the establishment of galvanic cells. Experimental investigations suggest that good electrical contact is not likely to be established under repository conditions (Telander and Westerman 1993). Consequently, given the preponderance of iron over other metals within the repository and the likely passivation of many nonferrous materials, the influence of these interactions on corrosion reactions and gas generation is, therefore, not included in no-migration demonstration calculations on the basis of low probability. Similarly, the effect of such cells on the migration of hazardous constituents (e.g., by **electrophoresis**) is also not included in no-migration demonstration calculations on the basis of low probability.

SCR.2.4.5.5 Physicochemical Transport Phenomena

Dilution is accounted for in the no-migration demonstration calculations via the incorporation of hazardous-constituent transport processes. The effects of alpha-recoil processes on hazardous constituent transport are not included in the no-migration

demonstration calculations on the basis of low consequence. The effects of enhanced diffusion, geochemical mixing, and colloid generation at chemical gradients between material boundaries are not included in the no-migration demonstration calculations on the basis of low consequence. The effects of osmotic processes are not included in the no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

Physicochemical transport phenomena discussed in this section are associated with dilution, alpha-recoil, and chemical gradients. Such FEPs have the potential to influence the transport of hazardous constituents.

Dilution

Dilution of hazardous constituents in the disposal unit is a result of transport and is, therefore, accounted for in no-migration demonstration calculations via the incorporation of advection of hazardous constituents in aqueous form.

Alpha Recoil

During decay of certain radioactive constituents, alpha particles may be emitted with sufficiently high energies that the daughter nuclide recoils appreciably to conserve system momentum. The potential relevance of these **alpha-recoil processes** to the demonstration lies in the energy imparted to the daughter nuclide, which can be great enough to cause the nuclide to move a short distance through a crystal lattice. If it is close enough to the surface of the crystal, it will be ejected into the surrounding groundwater or transferred to an adjoining solid phase, potentially affecting the dissolution and mobility of hazardous constituents.

The DOE considers the effects of the alpha-recoil processes on hazardous constituent transport to be minor, and they are not included in the no-migration demonstration calculations.

Chemical Gradients

The existence of **chemical gradients** within the disposal unit, induced naturally or resulting from repository and waste emplacement, may influence the transport of hazardous constituents in a number of ways. Such gradients may exist at the interfaces between different repository materials and between repository and geological materials. For example, distinct chemical regimes are likely to be established within the concrete seals and the adjoining host rocks. Similarly, chemical gradients will exist between the waste and the surrounding rocks of the Salado. Other chemical gradients may exist as a result of the juxtaposition of relatively dilute groundwaters and brines or between groundwaters with different chemistries.

A possible consequence of chemical gradients that occur at material boundaries is the **enhanced diffusion** of materials. However, it is likely that the distance scales over which such enhanced diffusion might occur will be small in comparison to the scale of the disposal unit. Furthermore, a significant amount of diffusion across such interfaces will tend to reduce the driving force for migration. Therefore, the effects of enhanced diffusion across chemical gradients at material boundaries are not included in the no-migration demonstration.

Other processes may be induced by the existence of chemical gradients at material boundaries, including the **formation or destabilization of colloids**. The existence of distinct **interfaces between waters of different salinities** (and therefore different densities) may limit the mixing of the water bodies and affect flow and hazardous constituent transport. Such effects are not included in no-migration demonstration calculations on the basis of low consequence.

Under appropriate circumstances, **osmotic processes** may occur at interfaces between waters of different salinities. Osmosis is the process by which water (or any other solvent) diffuses through a semipermeable (or differentially permeable) membrane in response to a concentration gradient. In geologic settings, osmotic processes can occur if waters of different salinities and/or chemistries exist on either side of a particular lithology (e.g., clay) or a lithological boundary that behaves as a semipermeable membrane. At the WIPP, clay layers within the Salado may act as semipermeable membranes across which osmotic processes could occur.

In the absence of hydrological gradients across a semipermeable membrane, water will move by osmosis from the more dilute water into the more saline water. However, because of the nature of the membrane, the migration of dissolved contaminants across the interface may be restricted. The existence of a hydrological gradient across a semipermeable membrane may enhance or oppose water movement by osmosis, depending on its direction and magnitude. When advection dominates over osmosis and reverse osmosis occurs, dissolved contaminants that cannot pass through the semipermeable membrane may be advected towards the membrane and concentrated along the interface. Thus, both osmosis and reverse osmosis can restrict the migration of dissolved hazardous constituents and possibly lead to their concentration along interfaces between different water bodies. These effects of osmotic processes are, therefore, not included in no-migration demonstration calculations on the basis of beneficial consequence to the demonstration.

SCR.3 HUMAN-INITIATED EVENTS AND PROCESSES

The discussion of human-initiated events and processes (EPs) in this section is divided between (1) human-initiated events and processes that are currently taking place or that have recently taken place within or outside the disposal unit, and (2) human-initiated EPs that might take place in the future within or outside the disposal unit.

- Recent and ongoing human-initiated EPs taking place within the disposal unit area are essentially those associated with development of the WIPP repository. Recent and ongoing human-initiated EPs taking place outside the disposal unit area include potash mining and hydrocarbon exploration and extraction. Recent and ongoing human-initiated EPs are of potential significance insofar as they could affect the geological, hydrological, or geochemical characteristics of the disposal unit and disposal system.

- Future human-initiated EPs could result in direct intrusion into the disposal unit or alteration of the geological, hydrological, or geochemical characteristics of the disposal system. Such EPs could potentially influence the transport of hazardous constituents within and outside the disposal unit.

The observational data obtained as part of the WIPP site characterization reflect any effects that human-initiated EPs may have had up to the time of submission of this NMVP. The DOE has determined that recent and ongoing human-initiated EPs outside the disposal unit will not significantly affect the long-term simulation. The DOE has documented the basis for this determination in this section for the events and processes of potential concern.

Human-initiated EPs that take place at or near the surface may potentially affect sub-surface conditions by influencing the amount of infiltration and recharge in the region. Such changes in recharge will not, however, affect conditions within the Salado. Surface EPs are not included in no-migration demonstration calculations on the basis of low consequence.

Human-initiated EPs that take place in the subsurface could potentially affect the Salado. Outside the disposal unit, such subsurface EPs include recent and ongoing hydrocarbon exploration and extraction, and potash mining. Inside the disposal unit there are no recent or ongoing subsurface EPs other than those associated with the development of the WIPP. Potential future subsurface EPs both outside and inside the disposal unit include those types of EPs that have recently taken place in the vicinity of the WIPP (defined by the DOE in this context as the Delaware Basin).

The following subsections are organized to be consistent with Table SCR-4.

SCR.3.1 Drilling

This section includes a discussion of the direct effects of drilling activities (SCR.3.1.1), and of the effects of drilling-induced flow (SCR.3.1.2), fluid extraction (SCR.3.1.3), fluid injection (SCR.3.1.4), and borehole-induced solution and subsidence (SCR.3.1.5). The section on drilling activities includes a discussion of potential reasons for future drilling both inside and outside the disposal unit. The remaining sections discuss only the potential effects of drilling-related EPs taking place outside the disposal unit.

SCR.3.1.1 Drilling activities

The direct effects of drilling associated with water, potash, oil, and gas exploration and production outside the disposal unit boundaries are not included in no-migration demonstration calculations on the basis of low consequence. Drilling associated with other resources and future drilling for water, potash, oil, and gas within the disposal unit are not included in the demonstration on the basis of a low probability of occurrence.

This section discusses drilling activities that may result in direct releases of hazardous constituents to the disposal unit boundary.

SCR.3.1.1.1 Reasons for Drilling

Resource exploration and exploitation are the most common reasons for deep drilling in the Delaware Basin and are the most likely incentives for drilling in the future. **Potash** and **oil and gas** reserves are currently exploited in the vicinity of the disposal unit and represent possible targets for future exploratory drilling. The McNutt Potash Zone, which forms part of the Salado above the repository horizon, contains the only exploitable potash resource. Potash is currently mined in the vicinity of the WIPP. Gas is extracted from reservoirs in the Morrow Formation, some 14,000 ft (4,300 m) below the surface. Oil is extracted from shallower units within the Delaware Mountain Group some 4,000–8,000 ft (1,220–2,440 m) below the surface. **Other natural resources**, such as caliche and lithium, are not present in economically viable quantities in the vicinity of the WIPP (Powers et al. 1978) and are unlikely to be exploited in the future.

Water is currently extracted from formations above the Salado as discussed in Section 2.2 of the NMVP. However, no potable groundwater is known to exist directly over the waste panels, and drilling for groundwater will not affect the disposal unit.

Geothermal energy is not considered to be a potentially exploitable resource, because economically attractive geothermal conditions do not exist in the northern Delaware Basin.

Other activities that could require drilling include **enhanced oil and gas production, fluid disposal, oil and gas storage, and archeological investigations**. Secondary and tertiary oil and gas production techniques can involve the drilling of additional wells for the injection of fluid to enhance recovery. As indicated by the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) in their 1995 report, secondary production (waterflooding) is employed in the Delaware Basin, the nearest location to the WIPP site being approximately 2 mi (3 km) from the disposal unit boundary.

The DOE has taken a number of steps to reduce the likelihood of human intrusion after closure of the facility. The federal government owns the entire surface and subsurface estate at the WIPP site, with the exception of a portion below 6,000 ft (1,830 m) that is leased for oil and gas production. The DOE will notify all state and county planning,

Table SCR-4. Human-Initiated Events and Processes and Their Screening Classifications

FEPs	Screening Classification			Reference Appendix SCR Section
	Recent & Ongoing	Future Outside	Future Inside	
DRILLING				3.1
Drilling Intrusion				3.1.1
Oil & gas exploration	SO-C	SO-C	SO-P	
Potash exploration	SO-C	SO-C	SO-P	
Water resources exploration	SO-C	SO-C	SO-P	
Oil & gas exploitation	SO-C	SO-C	SO-P	
Groundwater exploitation	SO-C	SO-C	SO-P	
Enhanced oil & gas recovery	SO-C	SO-C	SO-P	
Oil & gas storage	SO-C	SO-C	SO-P	
Fluid disposal	SO-C	SO-C	SO-P	
Archeology	NA	SO-P	SO-P	
Geothermal	NA	SO-P	SO-P	
Other resources	NA	SO-P	SO-P	
Deliberate intrusion	NA	NA	SO-P	
Drilling-Induced Flow				3.1.2
Drilling fluid loss (e.g. thief zones)	SO-C	SO-C	SO-P	
Blowouts	SO-C	SO-C	SO-P	
Fluid Extraction				3.1.3
Oil & gas extraction	SO-C	SO-C	SO-P	
Water extraction	SO-C	SO-C	SO-P	
Fluid Injection				3.1.4
Enhanced oil and gas production	SO-C	SO-C	SO-P	
Hydraulic fracturing	SO-C	SO-C	SO-P	
Waterflooding	SO-C	SO-C	SO-P	
Liquid waste disposal	SO-C	SO-C	SO-P	
Hydrocarbon storage	SO-C	SO-C	SO-P	
Borehole-Induced Solution and Subsidence				3.1.5
Borehole-induced solution and subsidence	SO-C	SO-C	SO-P	
EXCAVATION ACTIVITIES				3.2
Mining				3.2.1
Potash mining	SO-C	SO-C	SO-P	
Excavation-Related Flow				3.2.2
Hydrological effects of potash mining	SO-C	SO-C	SO-P	
Geochemical Effects of Excavations				
Solution mining	SO-C	SO-C	SO-P	
Improper Design and Operation	SO-P	SO-P	SO-P	3.3
Biosphere Alterations	SO-C	SO-C	SO-C	3.4

Legend:

SO-C FEPs eliminated from the no-migration demonstration calculations on the basis of consequence.
SO-P FEPs eliminated from the no-migration demonstration calculations on the basis of low probability
NA Not applicable.

deed and record offices, oil and gas commissions, and other agencies to prevent access by unknowing parties. The DOE will also place permanent warning markers (see Appendix PMR) at the site that will be implemented with a "defense in depth" approach ensuring durability of the marker system and the ability to interpret messages. The DOE believes that these measures will be effective in reducing the likelihood of drilling taking place within the

disposal unit so that future drilling for resources can be eliminated from consideration on the basis of a low probability of occurrence.

Drilling related to **deliberate intrusions** into the repository could take place in an attempt to recover material at a future date. However, the DOE assumes that deliberate intrusion and exploratory drilling for resources need not be considered in no-migration demonstration calculations.

SCR.3.1.1.2 Summary

Drilling associated with water, potash, oil, and gas exploration and production is currently taking place outside the disposal unit in the Delaware Basin. The direct effects of these activities and of future drilling outside the disposal unit are considered of low consequence. Future drilling inside the disposal unit is considered unlikely, because of the steps that the DOE will take to mark the site and ensure that access is restricted.

Future drilling relating to deliberate intrusion into the disposal unit is not included in no-migration demonstration calculations

SCR.3.1.2 Drilling-Induced Flow

Hydrological disturbances resulting from drilling outside the disposal unit are not included in no-migration demonstration calculations on the basis of low consequence to the demonstration and the performance of the disposal unit.

Drilling associated with water, potash, oil, and gas exploration and production is currently taking place outside the controlled area in the Delaware Basin. Hydrological disturbances resulting from these activities (loss to "**thief zones**" or fluid flow from pressurized zones encountered during drilling - "**blow out**") have not affected the disposal unit, and these drilling-related EPs are not included in no-migration demonstration calculations on the basis of low consequence.

SCR.3.1.3 Fluid Extraction

The effects of fluid extraction through boreholes outside the disposal unit are not included in no-migration demonstration calculations on the basis of low consequence.

Water, oil, and gas production represent the only activities involving fluid extraction through boreholes that currently take place in the vicinity of the WIPP.

Extraction of water from formations above the Salado outside the disposal unit could affect groundwater flow. Water in the vicinity of the WIPP is currently routinely extracted outside the disposal unit. This extraction does not affect the disposal unit and is not included in no-migration demonstration calculations on the basis of low consequence.

The horizons that act as **hydrocarbon reservoirs** are sufficiently below the repository for changes in fluid-flow patterns to be of low consequence. Also, hydrocarbon production horizons in the Delaware Basin are well-lithified rigid strata, so hydrocarbon extraction is not likely to result in compaction and subsidence (Brausch et al. 1982). Furthermore, the plasticity of the salt formations in the Delaware Basin will limit the extent of any fracturing caused by compaction of underlying units. Thus, neither the extraction of gas from reservoirs in the Morrow Formation (some 14,000 ft [4,300 m] below the surface), nor extraction of oil from the shallower units within the Delaware Mountain Group (some 4,000–8,000 ft [1,220–2,440 m] below the surface) will lead to compaction and subsidence. Activities involving fluid extraction in the Delaware Basin are unlikely to affect the characteristics of the disposal unit.

In summary, the effects of recent and ongoing fluid extraction through boreholes are not included in no-migration demonstration calculations on the basis of low consequence to the demonstration.

SCR.3.1.4 Fluid Injection

The effects of fluid injection through boreholes outside the disposal unit are not included in no-migration demonstration calculations on the basis of low consequence to the demonstration.

The injection of fluids could alter fluid-flow patterns in the target horizons or, if there is accidental leakage through a borehole casing, in any other intersected hydraulically conductive zone.

The only recent and ongoing activities involving fluid injection through boreholes in the Delaware Basin are **enhanced oil and gas production**, reinjection of **hydrocarbons for storage** purposes, and the **disposal of liquid by-products** from oil and gas production.

Hydraulic fracturing of oil- or gas-bearing units is currently used to improve the performance of hydrocarbon reservoirs in the Delaware Basin. Fracturing is induced during a short period of high-pressure fluid injection, resulting in increased hydraulic conductivity near the borehole. Normally, this controlled fracturing is confined to the pay zone and is unlikely to affect overlying strata.

Secondary production techniques, such as **waterflooding**, that are used to maintain reservoir pressure and displace oil are currently employed in hydrocarbon reservoirs in the Delaware Basin (see, for example, NMBMMR 1995). Reinjection of gas for storage currently takes place in a depleted gas field in the Morrow Formation of the Delaware Basin (Burton et al. 1993). Such fluid injection results in repressurization of the depleted target reservoir and mitigates any effects of fluid withdrawal.

Activities involving fluid injection in the Delaware Basin are unlikely to affect the characteristics of the disposal unit. Consequently, the effects of fluid injection through

boreholes outside the disposal unit are not included in no-migration demonstration calculations.

SCR.3.1.5 Borehole-Induced Solution and Subsidence

The effects of solution and subsidence around boreholes outside the disposal unit are not included in no-migration demonstration calculations on the basis of low consequence to the demonstration.

Boreholes represent potential pathways for the percolation of surface-derived water or groundwater through low-permeability strata and into formations containing soluble minerals. Large-scale dissolution through this mechanism could lead to subsidence and to disruption of the disposal unit.

An example of dissolution and subsidence occurred about 100 mi (160 km) southeast of the WIPP site (outside the Delaware Basin) at the Wink Sink (Johnson 1987); percolation of shallow groundwater through abandoned boreholes, dissolution of the Salado, and subsidence of overlying units led to a surface collapse feature 360 ft (110 m) in width and 110 ft (34 m) deep.

Three features are required for significant dissolution to occur through percolation of freshwater through boreholes: a borehole, an energy gradient to drive freshwater downward through underlying brines to the Salado, and a sink or conduit to allow migration of brine away from the site of dissolution. Without these features, minor dissolution in the immediate vicinity of a borehole could occur, but percolating water would become saturated and prevent further dissolution.

At Wink Sink, the Salado is underlain by the Tansill, Yates, and Capitan Formations, which contain vugs and solution cavities through which brine could migrate. Also, the hydraulic head of the Santa Rosa (the uppermost aquifer) is greater than those of the deep aquifers (Tansill, Yates, and Capitan Formations), suggesting downward flow if a connection were established.

The size of the dissolution cavity that caused Wink Sink is not known, but the size of the surface hollow suggests that, of existing boreholes that penetrate below repository depth near the WIPP, only ERDA-9 is close enough to the repository to be of concern. Sealing of WIPP investigation boreholes is discussed in Chapter 3 of the NMVP. Boreholes outside the disposal unit are sealed in compliance with State of New Mexico rules (New Mexico Oil Conservation Division 1988). However, corrosion of the well casing over the long term could allow percolation of surface-derived and shallow-formation waters into the borehole. Even if extensive seals are emplaced, casing corrosion could still allow a flow path to develop in strata where salt creep is not active.

In the vicinity of the WIPP, the Salado is underlain by the Castile and the Bell Canyon formations. Beauheim (1986) examined hydraulic heads measured using drill stem tests in

the Bell Canyon and the Culebra at well DOE-2 (location shown in Figure 2-27 of Chapter 2 of the NMVP) and concluded that the direction of flow in a cased borehole open only to the Bell Canyon and the Culebra would be upward. However, dissolution of halite in the Castile and the Salado would increase the relative density of the fluid in an open borehole, causing a reduction in the rate of upward flow. Potentially, the direction of borehole fluid flow could reverse, but such a flow could be sustained only if sufficient driving pressure, porosity, and permeability exist for fluid to flow laterally within the Bell Canyon. A further potential sink for Salado-derived brine is the Capitan Limestone. However, the subsurface extent of the Capitan Reef is approximately 10 mi (16 km) from the WIPP at its closest point, and this unit will not provide a sink for brine derived from boreholes in the vicinity of the disposal unit. A similar screening argument is made for natural deep dissolution in the vicinity of the WIPP (see Section SCR.1.1.5.1.).

SCR.3.2 Excavation Activities

This section includes a discussion of the direct effects of mining activities (SCR.3.2.1), of the effects of mining-induced flow (SCR.3.2.2), and the geochemical effects of mining (SCR.3.2.3). The section on mining activities includes a discussion of potential reasons for future mining both inside and outside the disposal unit and determines that future mining within the disposal unit is unlikely. The remaining sections, therefore, discuss only the potential effects of EPs taking place outside the disposal unit.

SCR.3.2.1 Mining

The direct effects of potash mining outside the disposal unit are not included on the basis of low consequence. Mining for other resources and future potash mining within the disposal unit are not included in the demonstration on the basis of a low probability of occurrence.

Potash is the only known economically viable resource at the WIPP site that is recovered by mining. Potash is mined extensively in the region east of Carlsbad and up to 3.1 mi (5 km) from the boundaries of the disposal unit. Future potash mining inside the disposal unit is considered unlikely, because of the steps that the DOE will take to mark the site and ensure that access is restricted.

Additionally, any mining for potash that does take place either outside or within the disposal unit will be within the McNutt Potash Zone that is at least 490 ft (150 m) above the repository horizon. Hydraulic studies suggest that migration will be constrained to anhydrite marker beds close to the repository horizon and much lower than the McNutt Potash Zone.

SCR.3.2.2 Excavation-Related Flow

The hydrological effects of excavation activities outside the disposal unit are not included in no-migration demonstration calculations on the basis of low consequence to the demonstration.

Excavation activities may result in hydrological disturbances of the disposal system. In particular, subsidence associated with excavations may affect groundwater flow patterns by providing pathways for increased recharge or discharge (through increased conductivity within or between units).

Potash is the only known economically viable resource at the WIPP site that is recovered by mining, and it is extracted from horizons stratigraphically above the repository horizon. Subsidence above potash mines may, therefore, have hydrological effects on the overlying Rustler, but will not affect the disposal unit. Thus, the hydrological effects of mining are not included in no-migration demonstration calculations.

SCR.3.2.3 Geochemical Effects of Excavations

The geochemical effects of excavation activities outside the disposal unit are not included in no-migration demonstration calculations on the basis of low consequence to the demonstration.

Fluid flow associated with excavation activities may result in geochemical disturbances of the disposal system.

Potash is the only known economically viable resource at the WIPP site that is recovered by mining. **Solution mining**, which involves the injection of fresh water to dissolve the ore body, may be used for extracting sylvite. The lack of fresh water has resulted in limited use of this mining technique in the vicinity of the WIPP site. However, some waters from the Culebra reflect the influence of potash mining activities, having elevated potassium to sodium ratios, although this has had no significant effect on the geochemical characteristics of the disposal unit. Thus, the geochemical effects of mining are not included in no-migration demonstration calculations.

SCR.3.3 Improper Design and Operation

The effects of improper design and operation are not included in the no-migration demonstration calculations on the basis of low probability.

All portions of the facility **design**, construction, and **operation** have been and will be carried out under a strict QA Program (Chapter 7 of the NMVP). The WIPP QA Program meets the federally-mandated requirement of a nuclear facility QA Program. In view of the documented enforcement of the QA Program, it is considered unlikely that any aspect of the design or operation could impact the integrity of the disposal unit.

SCR.3.4 Biosphere Alterations

The effects of biosphere alterations are not included in the no-migration demonstration calculations on the basis of low consequence.

Upon final closure, the WIPP facility will be completely sealed from the biosphere. No **alterations** in the **biosphere** are expected to occur from the WIPP facililty.

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APPENDIX SER

WIPP

Annual

Site

Environmental

Report for

Calendar Year 1994

DOE/WIPP 95-2094

Issued June 1995

Under Contract DE-AC04-86AL31950

1994 WIPP Site Environmental Report
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ACRONYMS AND ABBREVIATIONS

AA	Atomic Absorption
AEC	United States Atomic Energy Commission
AHPA	Archaeological and Historic Preservation Act
AMS	Ambient Air Monitoring Station
AQCR	Air Quality Control Regulation
ARA	Archaeological Recovery Act
ASER	Annual Site Environmental Report
ASME	American Society of Mechanical Engineers
BECR	Biennial Environmental Compliance Report
BMP	Best Management Practices
BLM	Bureau of Land Management
C and C	Consultation and Cooperation
CAA	Clean Air Act
CDC	Centers for Disease Control
CED	Committed Effective Dose
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act

ACRONYMS AND ABBREVIATIONS

(continued)

CMS	Central Monitoring System
CRRMP	Cooperative Raptor Research and Management Program
CRA	Carlsbad Resource Area
CRF	Central Records Facility
CWA	Clean Water Act
CY	Calendar Year
DMR	Discharge Monitoring Report
DOE	United States Department of Energy
DOL	Department of Labor
DOI	United States Department of the Interior
DOT	Department of Transportation
DP	Discharge Plan
ECAP	Environmental Compliance Assessment Program
EEG	Environmental Evaluation Group
ELP	Environmental Leadership Program
EML	Environmental Measurements Lab
EMP	Environmental Monitoring Plan

ACRONYMS AND ABBREVIATIONS

(continued)

EO	Executive Order
EPA	United States Environmental Protection Agency
EPCRA	Emergency Planning Community Right-to-Know Act
ESA	Endangered Species Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ESH&RC	Environment, Safety, Health and Regulatory Compliance
FEIS	Final Environmental Impact Statement
FLPMA	Federal Land Policy and Management Act of 1976
FSAR	Final Safety Analysis Report
GSP	Groundwater Surveillance Program
HAP	Hazardous Air Pollutant
HEPA	High Efficiency Particulate Air
HMP	Habitat Management Plan
HPIC	High Pressure Ionization Chamber
HSWA	Hazardous and Solid Waste Amendments of 1984 (to RCRA)
ICAP	Inductively Coupled Argon Plasma
LDR	Land Disposal Restrictions

ACRONYMS AND ABBREVIATIONS

(continued)

LEPC	Local Emergency Planning Committee
LLCL	Low-Level Counting Laboratory
LMIP	Land Management Implementation Plan
LMP	Land Management Plan
LS	Liquid Scintillation
LWA	Land Withdrawal Act
MAP	Mitigation Action Plan
MBTA	Migratory Bird Treaty Act
MET	Meteorological Station
MOC	Management and Operating Contractor
MOU	Memorandum of Understanding
MSHA	Federal Mine Safety and Health Act
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NES	Nonradiological Environmental Surveillance
NESHAPS	National Emissions Standards for Hazardous Air Pollutants

ACRONYMS AND ABBREVIATIONS

(continued)

NHPA	National Historic Preservation Act
NMD	No-Migration Determination
NMED	New Mexico Environment Department
NMIMT	New Mexico Institute of Mining Technology
NMVP	No-Migration Variance Petition
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission/National Response Center
NWPA	Nuclear Waste Policy Act
OSHA	Occupational Safety and Health Administration
PCB	Poly-chlorinated Biphenyl
PESP	Performance Evaluation Study Program
PI	Principal Investigator
PPOA	Pollution Prevention Opportunity Assessment
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAP	Quality Assurance Program

ACRONYMS AND ABBREVIATIONS

(continued)

QC	Quality Control
QSL	Qualified Suppliers List
RBP	Radiological Baseline Program
RCRA	Resource Conservation and Recovery Act
REMP	Radioactive Effluent Monitoring Program
RES	Radiological Environmental Surveillance
RIDS	Records Inventory and Disposition Schedule
RL	Radiochemistry Laboratory
RMP	Resource Management Plan
ROD	Record of Decision
RRMP	Raptor Research and Management Program
SAA	Satellite Accumulation Area
SARA	Superfund Amendments and Reauthorization Act
SERC	State Emergency Response Commission
SDWA	Safe Drinking Water Act
SEIS	Supplemental Environmental Impact Statement
SHPO	State Historic Preservation Officer

ACRONYMS AND ABBREVIATIONS

(continued)

SNL	Sandia National Laboratories
SPDV	Site Preliminary Design and Validation
TDS	Total Dissolved Solids
TPY	Ton Per Year
TRU	Transuranic Waste
TRUPACT-II	Transuranic Package Transporter Model II
TSCA	Toxic Substances Control Act
TSDF	Treatment Storage Disposal Facility
TSP	Total Suspended Particulates
USF&WS	United States Department of the Interior, Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound
VPP	Voluntary Protection Program
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plan
WQSP	WIPP Groundwater Quality Surveillance Program

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PREFACE

1994 WIPP Site Environmental Report
Preface

This is the eleventh Annual Site Environmental Report (ASER), documenting the progress of environmental programs at the U.S. Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP).

Although the cancellation of the Test Phase, during 1993, was a significant change in work scope for the WIPP, there are still numerous environmental monitoring and reporting activities that must be performed as a routine part of daily operations. These activities, and the WIPP's ability to demonstrate compliance with both state and federal environmental compliance requirements, are documented in this report.

This report is a compilation and summarization of environmental data collected at the WIPP site during the calendar year 1994. Should a reader of this report desire to obtain copies of the raw data used to generate this document, please write the U.S. Department of Energy, Manager of the Environment, Safety and Health Department, at P.O. Box 3090, Carlsbad, NM 88221.

CHAPTER 1

EXECUTIVE SUMMARY

Chapter 1
Executive Summary

The U.S. Department of Energy (DOE) Order 5400.1 *General Environmental Protection Program,* requires each DOE facility that conducts significant environmental protection programs to prepare an Annual Site Environmental Report (ASER). The purpose of the ASER is to summarize environmental data in order to characterize site environmental management performance, to confirm compliance with environmental standards and requirements, and to highlight significant programs and efforts. This ASER not only documents the required data, it also documents new and continued monitoring and compliance activities during the 1994 calendar year.

Data contained in this report are derived from those monitoring programs directed by the Waste Isolation Pilot Plant (WIPP) *Environmental Monitoring Plan* (EMP) (DOE/WIPP 94-024). The EMP defines a comprehensive set of parameters that must be monitored to detect potential impacts to the environment and to establish baseline measurements for future environmental evaluations. Surface water, groundwater, air, soil, and biotics are monitored for radiological and nonradiological activity levels. The baseline radiological surveillance program covers the broader geographic area that encompasses nearby ranches, villages, and cities. Nonradiological studies focus on the area immediately surrounding the WIPP site.

To date, the WIPP is still in a preoperational phase. As a result, certain operational requirements specified in DOE Order 5400.1 and in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T) are not yet applicable. This report does not address programs and activities that will be developed to meet future (operational) requirements such as radionuclide emissions and effluents and respective impacts upon the public and the environment.

1.1 Compliance Summary

A summary of significant compliance-related activities at the WIPP during Calendar Year (CY) 1994 is presented in this chapter. Chapter 3 will address environmental statutes and executive orders. These important statutes and orders will be comprehensively discussed in terms of compliance status, significant issues, actions, and accomplishments specific to WIPP.

On January 13, 1994, the DOE recommended that the New Mexico Environmental Department (NMED) allow the DOE to modify the Resource Conservation and Recovery Act (RCRA) permit

1.1 Compliance Summary (continued)

application to reflect disposal rather than test-phase operations. On September 2, 1994, the NMED rescinded the draft permit issued in August 1993 and ordered the submittal of a revised permit application due May 31, 1995. As of January 1995, the DOE has submitted nine chapters to NMED for review.

The *No-Migration Determination Annual Report for the Period of September 1993 through August 1994* (DOE/WIPP 94-2029) was submitted to the Environmental Protection Agency (EPA) Region VI, and to EPA Headquarters on November 14, 1994. This report was prepared to satisfy the annual reporting requirements contained in the *Conditional No-Migration Determination for the U.S. Department of Energy Waste Isolation Pilot Plant* (NMD), published in the *Federal Register* on November 14, 1990. Although the NMD was written specifically for the WIPP test phase, compliance conditions mandated by the first WIPP NMD will continue until issuance of a Disposal Phase NMD. A Disposal Phase No-Migration Variance Petition is being developed, based on waste characterization data and applicable modeling results. It is expected to be submitted to the EPA in CY 96.

The Land Withdrawal Act (LWA), Section 8, requires the DOE to submit to EPA an application for certification of compliance with EPA's final disposal regulations. The EPA finalized disposal regulations (40 CFR 191) in December of 1993. Currently, the EPA is developing criteria for certifying compliance with these regulations. After EPA has finalized the compliance criteria, a compliance certification application, in accordance with the mandates of the WIPP LWA, will be developed.

1.1.1 The No-Migration Variance Petition

In 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to the RCRA which established, in Sections 3004(d) through (n), a stringent regulatory program to prohibit the land disposal of hazardous waste unless: (1) the waste is treated to meet treatment standards or other requirements established by the EPA under Section 3004 (n), or (2) the EPA determines that the Land Disposal Restrictions (LDR) are not applicable in order to protect human health and the environment. With respect to the second condition, if it can be demonstrated, ". . . to a reasonable degree of certainty that there will be no migration of hazardous constituents from the disposal unit . . . for as long as the wastes remain hazardous," a No-Migration Variance Petition (NMVP) is

1.1.1 The No-Migration Variance Petition (continued)

submitted to the EPA, and upon approval by the EPA, a no-migration variance may be granted according to the requirements of 40 CFR Section 268.6.

The WIPP facility qualifies as a land disposal unit under the following definition in 40 CFR Section 268.2:

> "Land disposal" means placement in or on the land and includes . . . placement in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, underground mine or cave, or concrete vault or bunker intended for disposal purposes [emphasis added].

Pursuant to the provisions of 40 CFR Section 268.6, the DOE submitted an NMVP for the WIPP facility in March 1989 and a revision in 1990. A final No-Migration Determination (NMD) was granted by the EPA in November 1990. The NMD allows the DOE to emplace a limited quantity of untreated transuranic (TRU)-mixed waste in the WIPP facility for the purpose of testing. In order to proceed with the disposal phase, the DOE must seek another variance from the EPA for permanent disposal of TRU-mixed waste.

The disposal-phase NMVP is currently being developed and will be submitted to the EPA in phases. The Draft NMVP will address a no-migration demonstration for disposal operations and is scheduled for submittal to the EPA in May 1995. The Final NMVP is the long-term (post closure) portion and is scheduled for submittal to EPA in June 1996.

1.1.2 NEPA Annual Mitigation Report

The 1994 Annual Mitigation Report for the Waste Isolation Pilot Plant (NEPA ID# WIP:94:0001) was issued July 1994 in accordance with the requirement of DOE Order 5440.1E *National Environmental Policy Act Compliance Program*. This Order further requires DOE facilities to "track and report annually to EH-1 the progress made in implementing and the effectiveness of any mitigation action plan ... until mitigation is completed."

1.1.3 SARA Title III Emergency and Hazardous Chemical Inventory

On February 9, 1994, the WIPP submitted the *Emergency and Hazardous Chemical Inventory Report* for CY 1993 to the New Mexico State Emergency Response Commission, the Eddy County Local Emergency Planning Committee, and the local fire department with jurisdiction over the WIPP site, as required by Section 312 of the *Superfund Amendments and Reauthorization Act* (SARA) Title III. In March 1994, the WIPP submitted the Emergency and Hazardous Chemical Inventory Report for CY 1993 to appropriate organizations.

1.1.4 New Mexico Air Quality Permit 310-M-2

On February 26, 1994, the WIPP completed the emission monitoring requirements established in the New Mexico Air Quality Permit 310-M-2. With the submittal of the *Final Compliance Sampling Report* on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit.

1.1.5 Environmental Leadership Program

On September 21, 1994, the WIPP submitted a proposal application to the EPA's Environmental Leadership Program. The purpose of the program is to recognize and reward facilities that have developed innovative environmental management systems. From the pool of proposal applications, three to five pilot projects are selected.

1.1.6 Biennial Environmental Compliance Report

In October 1994, the DOE submitted the *Biennial Environmental Compliance Report* (BECR) to the EPA Region VI Office, and to the NMED. The submittal of this report was mandated in section 9(a)(2) of the WIPP LWA. The BECR documents WIPP's compliance with applicable federal and state laws, regulations, and permit conditions pertaining to public health and safety or the environment.

1.1.7 NEPA Training

A new computer-based National Environmental Policy Act (NEPA) training module was released in December 1994. This program provides to trainees, current NEPA guidelines in the planning, coordination, and performance of work.

1.1.8 Environmental Compliance Assessments

During 1994, 21 environmental compliance assessments were conducted. Many improvements were identified and implemented as a result of these assessments. Some of the assessed areas included: RCRA Training; Satellite Accumulation Areas; Equipment Inspections, New Mexico Special Waste; Occupational, Safety, and Health Administration (OSHA) Bloodborne Pathogens; Diesel Generator Permit; HAZMAT Inventories; Waste Characterization; Construction and Demolition Landfill; Hazardous Waste Generator Requirements; and New Mexico Discharge Plan and Water Supply Regulations.

1.2 Environmental Monitoring Program Information

In 1975, efforts to establish site characterization and environmental baseline measurements at the WIPP were initiated. These baseline measurements continue to be maintained on radiological and nonradiological databases. When the WIPP becomes operational, these baseline measurements will be transitioned to the "operational phase" and will be constantly monitored throughout the life of the project.

1.2.1 Environmental Monitoring Plan

The WIPP's EMP provides schedules and guidelines for monitoring a comprehensive set of parameters to detect and quantify present or potential environmental impacts, both nonradiologically and radiologically, Nonradiological surveillance covers the immediate area surrounding the WIPP site. Radiological surveillance covers a broader geographic area that includes nearby ranches, villages, and cities. Both nonradiological and radiological parameters involve sampling activities. Sampling activities conducted during CY 1994 were performed at the monitoring locations established by the EMP. Monitoring parameters may need to be modified from time-to-time to ensure a technically sound program. Environmental Monitoring will continue at the WIPP site during project operations and throughout decommissioning activities.

1.3 Environmental Radiological Program Information

The following presents monitoring topics for the subprograms of the EMP. These subprograms are consistent with policies established in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, (DOE/EH-0173T).

1.3 Environmental Radiological Program Information (continued)

DOE Order 5400.1 requires that a radiological baseline be established during the preoperational phase. Once a radiological baseline has been established, applicable radiological sampling programs can be maintained or can be modified to improve sampling efficiency. As radiological sampling protocol evolves to reflect program requirements (e.g., DOE Orders, EPA directives), the continuation of baseline sampling is necessary to provide adequate and timely measurements prior to waste receipt. As specifically outlined in the EMP, five subprograms are being conducted to document the background levels of potential radionuclide pathways leading from the WIPP to the environment and the public. These five subprograms are presented in the *Statistical Summary of the Radiological Baseline Program (RBP) for the Waste Isolation Pilot Plant* (DOE/WIPP 92-037).

1.3.1 Airborne Particulate and Effluent Monitoring

The WIPP began sampling airborne aerosol particulates in 1985 and this sampling activity continues to be an important subprogram of the EMP. The *Final Safety Analysis Report* (FSAR) (DOE, 1990) identifies the atmosphere pathway as the most credible exposure pathway for the public to radiation. To monitor this pathway, particulate aerosol samplers continuously operated at eight locations during 1994; three, within 1000 meters of the facility boundary; four, at local ranches and communities; and one, at a sample control site. On November 2, 1994, the sample location situated in Eunice, New Mexico, was evaluated and determined to be of no added value because its location on the roof of the Eunice City Hall exceeded the height recommendations for sampler configuration, and additionally, presented a personnel safety hazard. Accordingly, it was decommissioned.

The continuous aerosol samplers presently being used to collect particulates maintain a regulated flow rate of .057 cubic meters per minute (approximately two cubic feet per minute) of air through a 47-millimeter (1.9 inch) fiber filter. Particulate filters are collected weekly at all locations and counted at the WIPP Site Low-Level Counting Laboratory (LLCL). Samples are further analyzed at an off site contract analytical laboratory (see Table 5-1 for contract lab preliminary results). The weekly filters are counted for gross alpha and beta activity. The data are then grouped into 13-week segments or calendar quarters and are presented as a calculated quarterly average. Table 5-1 lists the quarterly alpha and beta concentrations for each sampling location.

1.3.2 Soil Sampling

Soil Samples were collected and analyzed in accordance with applicable guidance (e.g. DOE EH/0173T) and sampling procedures. Results from the radiological analysis of subject samples are provided in Chapter 5, *Environmental Radioactivity Monitoring*. Chapter 6, *Environmental Nonradiological Program Information,* contains results from nonradiological analysis.

1.3.3 Groundwater

Groundwater surveillance activities during CY94 consisted of two separate programs: Groundwater Quality Sampling and Groundwater Level Surveillance Measurements. Groundwater quality samples were gathered from nine well locations completed in the Culebra dolomite. Groundwater level surveillance measurements were recorded at 58 well bores. During CY 1994, seven new monitoring wells were drilled; six, in the Culebra dolomite; and one, into the Dewey Lake. Results pertaining to groundwater sampling activities are provided in Chapter 7, *Groundwater Surveillance.*

1.3.4 Surface Water and Sediment Sampling

Surface water was collected at 12 locations with concurrent sediment samples taken at 10. Analysis revealed no unusual levels of background radioactivity. Discussions pertaining to surface water and sediment sampling are provided in Chapter 5, *Environmental Radiological Program Information.*

1.3.5 Game Animals and Fish Samples

Because of profound drought conditions during CY 1994, quail and rabbit populations were drastically low. Quail sampling was postponed until the population increases to the capacity that sampling will not adversely affect population status. Sampling of rabbits was restricted to only two individual road kills. Mule Deer, killed by automobile strikes, were also sampled.

Discussions pertaining to the radiological analysis of game animals and fish are presented in Chapter 5, *Environmental Radiological Program Information.* Results from the laboratory analysis of tissue is contained in Appendix A *Radiological Sample Analysis for Calendar Year 1994.*

1.4 Nonradiological Environmental Monitoring Information

Nonradiological environmental surveillance was also conducted in accordance with the EMP. This program was preceded by the WIPP Biology Program (1975-1982). An extensive baseline of information describing the major components of the Los Medaños ecosystem, prior to the initiation of the WIPP site construction activities, was developed. Six universities participated in the initiation of the characterization and baseline surveillance programs.

A significant portion of the nonradiological surveillance documented the effect fugitive salt dust generated by the surface stockpiling activities has on the surrounding ecosystem see (Reith, et al., 1985). This study is described in the *Summary of the Salt Impact Studies at the Waste Isolation Pilot Plant 1984 to 1990* (DOE/WIPP 92-038).

1.4.1 Land Management

On July 19, 1994, in response to the LWA, a new Memorandum of Understanding (MOU) between the U.S. Department of the Interior Bureau of Land Management (BLM) and the DOE was finalized. This MOU outlines the responsibilities of each agency with regard to land use management for the withdrawal area. The MOU also provides an additional mechanism to protect the withdrawal area from unallowable or inadvertent uses.

In August 1994, the DOE issued the *Waste Isolation Pilot Plant Land Management Implementation Plan* (LMIP) (DOE/WIPP 94-026). The need for a comprehensive, "living" land management document for the WIPP was identified in the 1993 *Waste Isolation Pilot Plant Land Management Plan*. The *Land Management Plan* (LMP) was submitted to Congress in accordance with requirements contained in the LWA, on October 30, 1993. The LMIP encourages direct communication among stakeholders, including federal and state agencies involved in managing the resources within, or activities impacting the areas adjacent to, the WIPP land withdrawal area. The LMIP focuses on management protocol related to the following issues: execution of the plan; environmental compliance; emergency management; industrial safety; maintenance and work control; minerals/oil and gas; reclamation; cultural resources; access/rights-of-way; recreation; security; wildlife; and grazing.

1.4.2 Meteorology

The WIPP Nonradiological Environmental Surveillance (NES) includes a primary meteorological (MET) station that provides support for various programs at the WIPP. The primary function of the MET is to generate data to model atmospheric conditions for Radiological Environmental Surveillance (RES). The station records standard meteorological measurements for wind speed, wind direction, and temperatures at a radius of 3, 10, and 40 meters (10, 30, and 130-feet respectively) with dew point and precipitation monitored at ground level. These parameters are measured continuously, and the data are logged, at fifteen minute intervals, in the Central Monitoring System (CMS).

In 1994, the annual rate of precipitation at the WIPP site was 16.58 cm (6.53 inches), which is 7.29 cm (2.87 inches) below last year's rate. The annual precipitation for 1994 was 31 percent less moisture than that recorded for 1993 and 74 percent less moisture than recorded for 1992, indicating drought conditions.

The wind direction at the WIPP site is predominately from the southeast. In CY 1994, the data collected on wind direction in the WIPP area were consistent with data previously collected on wind direction in the same area. Discussions pertaining to meteorological monitoring are contained in Chapter 6, *Environmental Nonradiological Program Information,* pages 6-2 and 6-3.

1.4.3 Air Quality Monitoring

Seven pollutant gases were monitored at the WIPP site on a continuous basis. These gases are sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), hydrogen sulfide (H_2S), nitrous oxide (NO), nitrogen dioxide (NO_2), and oxides of nitrogen (NO_x). In addition, weekly measurements of Total Suspended Particulates (TSP) were collected by the low-volume continuous air sampler at the far-field air sampling location.

On October 30, 1994, per DOE notification and subsequent approval, the monitoring of ambient levels of noxious gas emissions at the WIPP Ambient Air Monitoring Station (AMS) was discontinued because no compliance related driver exists.

1.4.4 Wildlife Population Monitoring

Population density measurements of various species of wildlife are performed annually to assess the effects of the WIPP's activities on transient and resident wildlife populations.

1.4.4.1 Bird Densities

Prior to 1994, distribution patterns of species living between the WIPP transects and the control transects remained constant, with the most significant changes occurring near the facility. It was speculated that more abundant food (i.e., insects drawn to the lights of the facility) and greater habitat diversity accounted for the increase in the number of species near the WIPP transects, compared to those of the control transects. Insect-dependant species such as barn swallows, ash-throated flycatchers, and king birds were the prominent species on the increase in the immediate vicinity of the facility. Rock doves, the common city pigeon, have been observed around the WIPP site. During 1994, investigations into population densities of transient species were postponed pending reassessment of the value added to baseline appraisals. Resident species (i.e. quail) are currently being considered for more specialized evaluations as they are considered non-migratory and are sampled annually as radiological sentinels.

1.4.4.2 Small Nocturnal Mammal Population Densities

Reports of the presence of the Hantavirus in West Texas and other neighboring states prompted the suspension of small nocturnal mammal population studies, pending the collection of evidence to ascertain the status (presence or absence) of the Hantavirus in local populations of small mammals. Midway through the census period of CY 1993, reported outbreaks of the virus in New Mexico and every state bordering New Mexico occurred. The primary pathogen for the disease is a virus endemic in particular populations of mice common to the genus *Peromyscus* (e.g. Brush Mice, Cactus Mice, Deer Mice). To assess the small mammals near the WIPP for the presence of the pathogen, staff from the Environmental Monitoring section of the WIPP attended training seminars conducted by the Centers for Disease Control (CDC). The training provided instruction regarding the appropriate protocol for Hantavirus sampling. Subsequently, an appraisal was conducted. Trapping and blood collection was performed in accordance with CDC recommended protocol. Results from the CDC indicate the Hantavirus was not detected in the WIPP samples.

1.4.5 Vegetation Monitoring

The CY 1994 ecological vegetation monitoring was postponed because the data indicated negligible effects of salt tailings on the peripheral environment. A pattern was observed from the 1989-1992 data which was repeated in the 1993 data. The pattern confirms an increased progression in shrub cover near salt tailings. This increase is a result of the colonization of more saline-tolerant species

1.4.5 Vegetation Monitoring (continued)

(e.g. 4-winged saltbush) in close proximity to the salt piles. Cursory observations of peripheral effects resulting from salt-induced physiological stress near the salt tailings was not observed during 1993 or 1994. Responses of these plots to seasonal precipitation rates should reveal whether this pattern is reflecting the beginning of significant changes in the structure of the plant community or whether it is only a short-term effect caused by seasonal conditions. Abnormally dry conditions during CY 1994 (Figure 6-1) prohibited any validation of assumptions regarding repercussions of salt migration from the tailings piles into the adjacent environment.

1.4.6 Raptor Research and Management Program

The 1994 field season culminated a three year program reorganization regarding investigations into the life history, ecology and impact of human-related activities on transient and resident raptor populations occupying the Los Medaños. Nest locations of the hawks were identified and approximated with Loran navigators. Nestlings, if present, were banded with U.S. Fish and Wildlife Service (USFWS) bands. Additionally, Harris' Hawks were banded with anodized aluminum bands inscribed with unique alphanumeric codes. These bands afforded biologists the ability to identify entities within groups, while conducting inquiries into the territorial demeanor of the species. In accordance with commitments in existing MOUs and Interagency Agreements, research results have been transmitted to the local BLM for consideration in land use decisions.

1.4.7 Reclamation of Disturbed Lands

Reclamation activities during CY 1994 consisted of the decommissioning of numerous fenced areas that had been constructed for site characterization studies in the late 1970s. In addition to the exclosures, re-bar that had been emplaced within these study areas to delineate sampling points was removed to alleviate safety hazards to personnel and livestock. Problem areas (e.g. drainages, eroded slopes, etc.) in existing reclamation sites received additional stabilization that included seeding and straw mulching.

1.5 Quality Assurance

Programs described in this document adhere to policies set forth by federal Quality Assurance (QA) regulations including: American Society of Mechanical Engineers (ASME) NQA-1, Quality Assurance Program (QAP) Requirements for Nuclear Facilities (ASME, 1989) and EPA,

1.5 Quality Assurance (continued)

QAMS-005/80, Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans (EPA, 1980), and fulfills the requirements of the QA plans specified in DOE Orders 5400.1 (DOE, 1988d), 5400.3 (DOE, 1988e), 5700.6C (DOE, 1991) and the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T).

Chapter 2
Introduction

This 1994 Annual Site Environmental Report (ASER) is prepared in accordance with the guidance contained in the 1990 DOE Order 5400.1, *General Environmental Protection Program*; DOE/WIPP 91-054, *Environmental Protection Implementation Plan*, and DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. The above orders and guidance documents require that DOE facilities submit an ASER to DOE Headquarters, Office of the Assistant Secretary for Environment, Safety and Health.

The ASER provides a comprehensive description of operational environmental monitoring activities at the WIPP during CY 1994. This report also discusses the Quality Assurance (QA) and Quality Control (QC) programs, which ensure that samples collected and the analytical data obtained are representative of actual conditions at the WIPP site. The requirements and goals driving these activities are more fully described in the *Environmental Monitoring Plan for the Waste Isolation Pilot Plant* (DOE/WIPP 94-024).

The Environmental Monitoring Plan (EMP) was drafted in accordance with the guidelines contained in the *General Environmental Protection Program* (DOE Order 5400.1). The EMP defines the scope and extent of the WIPP Environmental Monitoring Programs and ensures that all appropriate sampling efforts are in place to generate the following: (1) The amount and type of naturally occurring radioactivity in the WIPP area prior to operational status. This quantitative data will support comparisons between preoperational and operational environmental conditions, once the WIPP site is operating as a waste repository for TRU waste. (2) A comparison between preoperational and operational radiological emissions, once the WIPP site is operating as a waste repository for TRU waste. Since waste has not yet been received, certain elements of DOE Order 5400.1 are not relevant to the WIPP Environmental Monitoring Program (i.e., no discussion is included in this report of radionuclide emissions with subsequent calculation of doses to the public). The EMP is reviewed annually and updated every three years, as required by DOE Order 5400.1. The revisions/updates address general changes, improvements, and enhancements to be implemented based upon the data generated from the monitoring programs.

2.1 Description of the WIPP Project

The WIPP project is authorized by the DOE, National Security, and Military Applications of Nuclear Energy Authorization Act of 1980 (i.e., Public Law 96-164). The legislative mandate is to demonstrate the safe disposal of transuranic wastes resulting from national defense activities and programs. To fulfill this mandate, the WIPP has been designed to scientifically investigate:

2.1 Description of the WIPP Project (continued)

(1) the behavior of bedded salt and the interactions between the salt and radioactive wastes and (2) to demonstrate safe and efficient handling, transport, and emplacement of transuranic (TRU) waste in a fully operational disposal site.

The first radioactive wastes will be emplaced once permitting activities are completed. Subsequent to successful permit completion, the WIPP site will be designated as an operational facility. TRU wastes will then be transported from generator/storage sites throughout the United States to the WIPP site.

The TRU waste received from the generator sites will be transported to the WIPP site via tractor-trailer trucks. Each truck can carry up to three TRU Package Transporters (TRUPACT IIs), and each transporter may contain fourteen 55-gallon drums or two standard waste boxes. The TRUPACT II is a durable, reusable container that has been certified by the Nuclear Regulatory Commission (NRC) to transport contact-handled (waste containers that can be handled without shielding) transuranic waste to the WIPP.

Once TRU wastes have arrived at the WIPP, they are transported into the Waste Handling Building. The waste containers will be removed from the TRUPACT IIs, placed on the waste hoist, and lowered to the repository level of 655 m (2150 feet) below the surface. During the disposal phase, waste drums will be removed from the hoist and emplaced in excavated storage rooms in the Salado formation, a thick sequence of salt beds deposited approximately 250 million years ago in the Permian Age. After the disposal areas have been filled, specially designed closures will be placed in the excavated disposal rooms and seals will be placed in the shafts. The self-healing nature of the salt formation will aid in gradual closure causing encapsulation and isolation of the waste within the Salado formation.

During site operations, the underground area will be ventilated with ambient air that enters the Air Intake Shaft, the Salt Handling Shaft, the Waste Handling Shaft, and exits through the Exhaust Shaft. In the event of an underground accident involving radioactivity, exhaust air can be circulated at a reduced flow rate through the Exhaust Filter Building. This building contains banks of High Efficiency Particulate Air (HEPA) filters that remove contaminated particulates.

2.2 Description of the Environment and Lands

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 2-1, page 2-5). The WIPP site is 40 kilometers (26 miles) east of Carlsbad, New Mexico, in an area known as the Los Medaños (the dunes). The unique diversity of plant and animal communities is representative of the convergence between the northern region of the Chihuahuan Desert and the Llano Estacado (staked plains). The majority of the lands outside the WIPP site boundary, are managed under the jurisdiction of the U.S. Department of the Interior's (DOI) Bureau of Land Management (BLM) Carlsbad Resource Area (CRA) local office. Land uses in the surrounding areas include livestock grazing, potash mining, oil and natural gas production, and recreational uses. Recreational uses include hunting, trapping, birdwatching and other uses as permitted by the BLM.

The WIPP site boundary extends at least 1.6 kilometers or one mile beyond any of the WIPP underground developments and is defined on the surface by the 16-section (4,146 ha) Land Withdrawal Area. On October 30, 1992, the WIPP Land Withdrawal Act, Public Law 102-579, was signed by President Bush transferring the land from the Department of Interior (DOI) to the DOE. A WIPP Land Management Plan, DOE/WIPP 93-004, was then prepared and submitted to Congress in October 1993.

Consisting of 16 sections (4,146 ha) of federal land, the WIPP site is located in Eddy County, New Mexico in Township 22 South, Range 31 East. With the exception of properties located within the boundaries of the posted 1454 acre (589 ha) area, the surface land uses remain largely unchanged and are managed in accordance with accepted practices for multiple land use. Mining and drilling for purposes other than those which support the WIPP project are prohibited within the 16-section (4,146 ha) area.

The WIPP site is divided into sectors as represented in Figure 2-2. The sector identified as the "Property Protection Area" is surrounded by a chain-link fence that encompasses all major surface facilities. The sector identified as the "Off Limits Area" is the area surrounded by a four-strand barbed wire fence. This fence encircles the Property Protection Area in addition to outlying properties and structures used in the operation of the WIPP (e.g. salt tailings piles, meteorological station) that are necessary to secure from public access. The Exclusive Use Area represents an expanded secure area, posted against trespass, but unfenced. Although livestock grazing will continue inside the 1454 acre sector, other activities associated with the concept of multiple land use (e.g., hunting, camping, etc.) are prohibited. The aforementioned sectors are posted against trespass

2.2 Description of the Environment and Lands (continued)

under the authority of Section 229 of the Atomic Energy Act, 42 U.S.C. 2278a, and pursuant to the regulations set forth in 10 CFR 860 and DOE Order 5632.6, *Physical Protection of DOE Property and Unclassified Facilities*. These sectors are patrolled by the WIPP security and regulations are enforced commensurate with laws pertaining to property protection. The sector identified as "Zone II" is not a surface sector. This designation illustrates the surface image of the original conception of the maximum extent of the proposed underground repository. The WIPP site boundary (4 miles x 4 miles) provides a functional barrier of intact salt between the underground region defined by the Exclusive Use Area and the accessible environment.

There are 26 permanent residents within ten miles of the WIPP site. Most of the population within 50 miles of the site is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal, and Artesia, New Mexico. The two nearby ranch residences (Smith Ranch and Mills Ranch) are continuously monitored as part of the Environmental Monitoring Program. Detailed demographic summaries and projections are listed in the *WIPP Final Environmental Impact Statement* (FEIS) (DOE, 1980), the *Final Supplement Environmental Impact Statement* (SEIS) (DOE, 1990), the WIPP Land Management Plan (LMP) (DOE/WIPP 93-004) and the *WIPP Final Safety Analysis Report* (DOE, 1990).

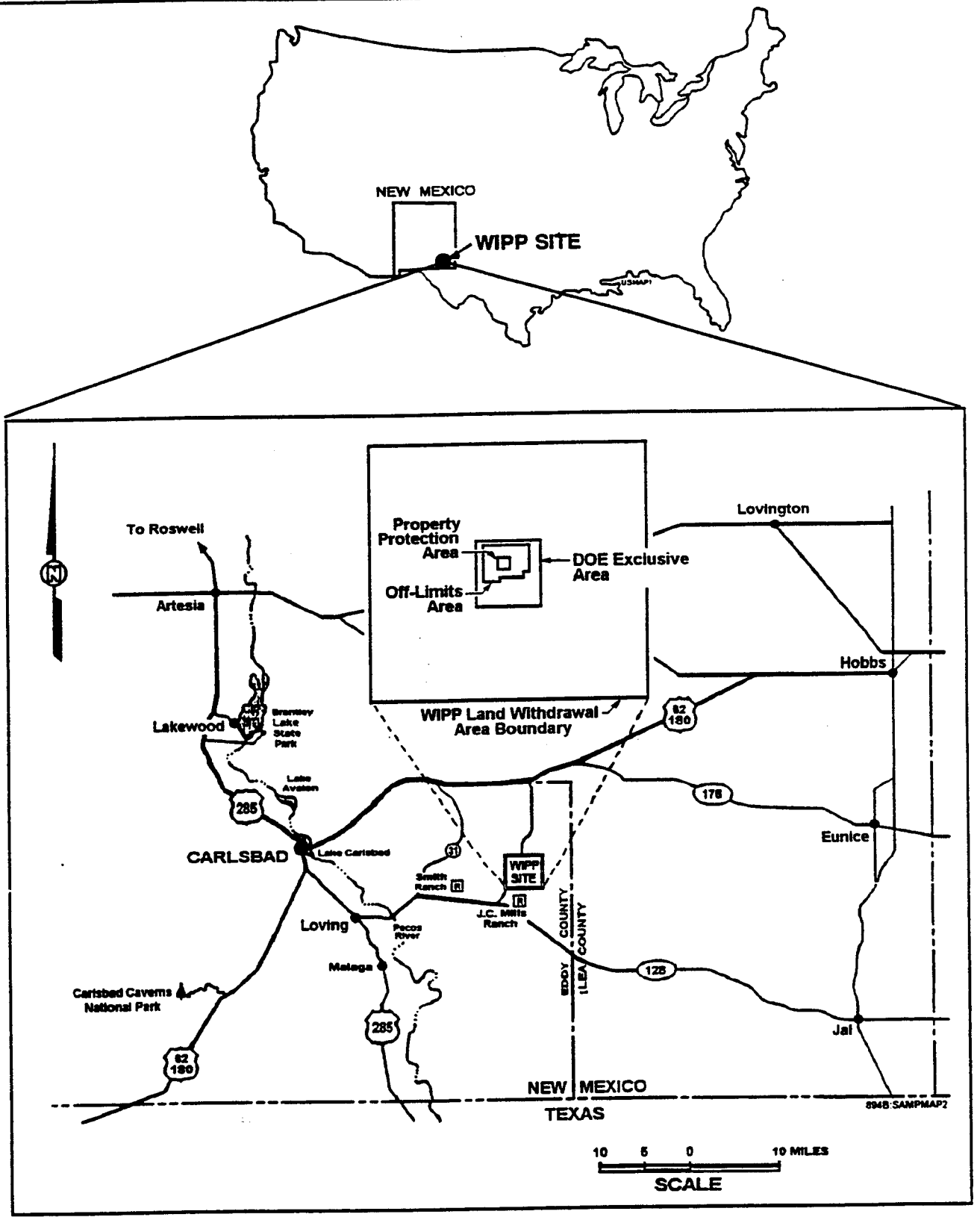

Figure 2-1
Location of the WIPP Site

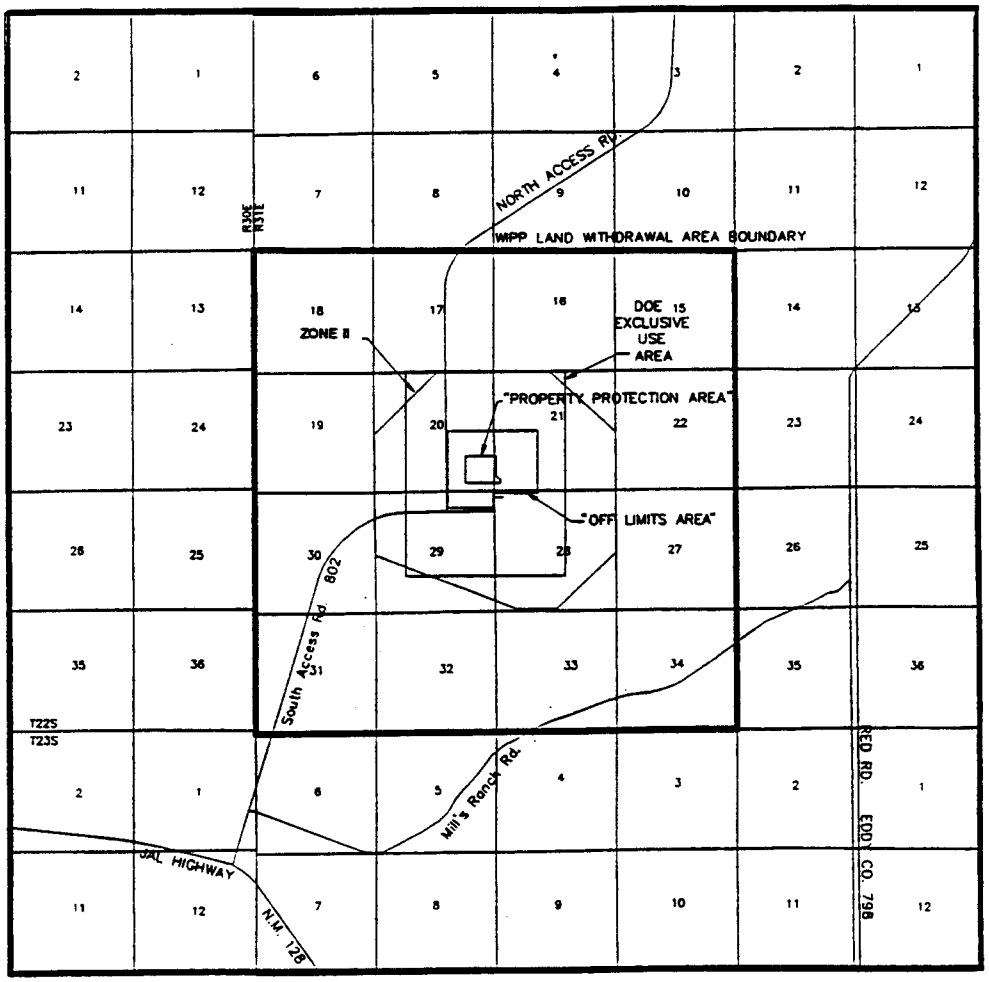

Figure 2-2
WIPP Sectors

CHAPTER 3

COMPLIANCE SUMMARY

Chapter 3
Compliance Summary

The WIPP is required to comply with all applicable DOE Orders and federal and state laws and regulations. Documentation of required federal and state permits, notifications, and approvals is maintained by the Environment, Safety, Health and Regulatory Compliance (ESH&RC) Department of the Management and Operating Contractor (MOC). Regulatory requirements are incorporated in facility plans and implementing procedures.

Table 3-1, pages 3-29 through 3-30, provides a summary of the major federal and state statutes applicable to the WIPP Project. Table 3-2, pages 3-33 through 3-37, presents DOE Orders and agreements affecting the WIPP environmental program. Table 3-3, pages 3-33 through 3-34, is a summary of agreements between the DOE and the State of New Mexico that affect the environmental programs of the WIPP. Table 3-4, pages 3-35 through 3-37, details active/pending environmental permits for the WIPP in CY 1994.

3.1 Compliance Assessment for Calendar Year 1994

In 1994 the WIPP maintained compliance with applicable federal and state environmental regulations. Section 3.2 lists the compliance status of each major environmental statute and executive order applicable to the WIPP, including significant issues generated by, and actions and accomplishments driven by these statutes and orders. Section 3.3 describes other significant compliance accomplishments at the WIPP facility in CY 1994.

3.2 Compliance Status

This section documents compliance with the following regulatory requirements at the WIPP:

- Atomic Energy Act of 1954 (AEA)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (includes the Superfund Amendments and Reauthorization Act of 1986)
- Resource Conservation and Recovery Act (RCRA)
- National Environmental Policy Act (NEPA)
- Clean Air Act (CAA)
- Clean Water Act (CWA)
- Safe Drinking Water Act (SDWA)
- Toxic Substances Control Act (TSCA)

3.2 Compliance Status (continued)

- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Endangered Species Act (ESA)
- National Historic Preservation Act (NHPA)
- Floodplain Management Executive Order
- Protection of Wetlands Executive Order
- Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
- Hazardous Materials Transportation Act (HMTA)
- Packaging and Transportation of Radioactive Materials
- Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
- Waste Isolation Pilot Plant Land Withdrawal Act (LWA)
- Taylor Grazing Act
- Federal Land Policy and Management Act (FLPMA)
- Public Rangelands Improvement Act
- Grazing Fees Executive Order
- Materials Act of 1947
- Federal Mine Safety and Health Act of 1977 (MSHA)
- Occupational Safety and Health Administration Regulations (OSHA)
- Noise Control Act of 1972
- Bald and Golden Eagle Protection Act
- Migratory Bird Treaty Act (MBTA)
- National Defense Authorization Act - Fiscal Year 1989
- Protection and Enhancement of Environmental Quality Executive Orders
- Federal Compliance with Pollution Control Standards Executive Order

3.2.1 Atomic Energy Act of 1954 (AEA)
(42 U.S.C. § 2011 et seq.)

The AEA established a national program for research, development, and atomic energy for both national defense and domestic civilian purposes. Section 161 (i) (3) of the AEA provides that the Atomic Energy Commission (succeeded by the DOE for national defense purposes) is authorized to prescribe regulations and orders to:

3.2.1 Atomic Energy Act of 1954 (AEA) (continued)

> . . . govern any activity authorized pursuant to this Act [the AEA], including standards and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property . . .

The authority of the DOE to develop policies, issue orders, and promulgate regulations addressing environment, safety and health protection standards regarding radioactive waste and nuclear materials is derived directly from the AEA. The EPA has also derived its authority to establish standards for the protection of the public and the environment from ionizing radiation from the AEA. The DOE, under the authority of the AEA and in accordance with various Executive Orders (EOs), uses a system of Orders, Notices, and Directives to carry out the mandate to implement effective and consistent programs to protect the public, the environment, and employees from adverse consequences resulting from the DOE operations. Implementation of those Orders, Notices, and Directives dealing with environmental monitoring and surveillance is addressed in the *Waste Isolation Pilot Plant Environmental Monitoring Plan* (DOE/WIPP 94-024).

Much of the waste to be emplaced at the WIPP is mixed (i.e., radioactive waste with hazardous constituents). This waste is subject to dual regulation: the radioactive constituents of the waste are regulated under the AEA, whereas the hazardous constituents are regulated under RCRA. Standards contained in 40 CFR 191, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Waste*, will become applicable when waste receipt begins.

The EPA's authority to establish standards for the protection of the public and the environment from radiation is derived from the AEA, as amended; Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act (NWPA) (PL 97-425). The protection standards found at 40 CFR 191 apply to spent nuclear fuel and high-level radioactive waste, as defined by the NWPA, and to TRU waste that contains more than 100 nanocuries per gram of waste of alpha-emitting TRU isotopes with half-lives greater than 20 years. These standards consist of three subparts A, B, and C. Each subpart will be discussed in the following paragraphs.

Subpart A, *Standards for Management and Storage*, sets the operational term requirements limiting annual doses to members of the public. These annual dose requirements are established from the management and storage operations at disposal facilities that are operated by the DOE, not regulated

3.2.1 Atomic Energy Act of 1954 (AEA) (continued)

by either the National Regulatory Commission (NRC) or by agreement states. The annual dose equivalent to any member of the public in the general environment may not exceed 25 millirem (mrem) to the whole body and 75 mrem to any critical organ.

Subpart B, *Environmental Protection Standards For Management And Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, sets the long term repository performance standards applicable to the WIPP. As the result of a legal challenge, Subpart B had been remanded by "the court" in 1987. The Land Withdrawal Act (LWA) reinstated the standard with the exception of 40 CFR 191.15, *Individual Protection Requirements* and 191.16, The *Ground-Water Protection Requirements*, which were subject to the remand order. The LWA also directed the EPA to expedite issuance of final disposal standards. On December 20, 1993 (FR Vol. 58, No 242, 66398) the EPA issued the final disposal standards in the form of amendments to Subparts B (including 40 CFR 191.15 and 191.16) and the addition of Subpart C. The primary changes to Subpart B are as follows: The individual protection requirements in 191.15 were replaced with a new set of requirements. Part 191.15 now requires that the disposal system be designed to provide reasonable expectation that for 10,000 years (not 1,000 years) after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose (CED) to any member of the public to exceed 15 millirems. The changes are in the time frame for individual protection requirements (1,000 years to 10,000 years) and in the dose calculation methodology (previously "whole body/specific organ," now CED). Although Subpart B had been remanded, the WIPP previously committed to compl with Subpart B until the EPA issues the final standards. The WIPP's compliance issues and long-term disposal standards are addressed through the use of performance assessments. Sandia National Laboratory (SNL) periodically issues the performance assessment report, which models results. The report analyzes the performance of the WIPP repository using available operational parameters.

Subpart C, *Environmental Standards for Ground-Water Protection*, was added and 40 CFR 191.16 was deleted. This standard essentially requires that the disposal system be designed to provide reasonable expectation that for 10,000 years of undisturbed performance disposal will not cause the levels of radioactivity in any underground source of drinking water, in the accessible environment, to exceed the limits specified in 40 CFR 141, *National Primary Drinking Water Regulations*, as they existed on January 19, 1994.

The Land Withdrawal Act directed the EPA to issue final criteria for certifying the DOE's compliance with the final repository disposal standards (40 CFR 191) and to issue

3.2.1 Atomic Energy Act (AEA) (continued)

the criteria in a rulemaking procedure conducted under 5 U.S.C. 553. The LWA directed the EPA to issue draft criteria within one year of enactment (i.e., by November 1993) and final criteria, within two years of enactment (i.e., by November 1994). In response to these directives, the EPA issued draft criteria for comments on March 8, 1995, *Criteria for the Certification and Determination of the Waste Isolation Pilot Plant's Compliance with Environmental Standards for the Management and Disposal of Spent Nuclear Fuel,* 40 CFR 194. The DOE provided comments on the draft criteria to the EPA on March 8, 1995. The EPA then hosted public hearings to consider public comments on the draft criteria. After finalization of the criteria, the WIPP will submit an application for certification of compliance with the final disposal standards per the LWA.

3.2.2 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 U.S.C. § 9601 et seq.), (including the Superfund Amendments and Reauthorization Act of 1986)

The CERCLA, or "Superfund," and the Superfund Amendments and Reauthorization Act (SARA) establish a comprehensive federal strategy for responding to, and establishing liability for, releases of hazardous substances from a facility to the environment. Hazardous substance cleanup procedures are specified in the National Contingency Plan (NCP), 40 CFR 300. No release sites have been identified at the WIPP that would require cleanup under the provisions of the CERCLA. Any spill of hazardous substances that exceeds a reportable quantity, must be reported to the National Response Center (NRC) under the provisions of Section 103 of CERCLA and 40 CFR 302.

3.2.2.1 Accidental Releases of Reportable Quantities of Hazardous Substances

During 1994, there were two spills of ethylene glycol that exceeded reportable quantity limits. The reportable quantity for ethylene glycol is one pound. Both spills were less than one gallon and were reported to the NRC, the State Emergency Response Commission (SERC), and the Local Emergency Planning Committee (LEPC). A follow-up report was sent to the SERC and the LEPC. All spills were immediately contained and remediated in accordance with the WIPP Spill Response Procedures. All contaminated soils and spill containment pads were drummed, manifested, and transported to an offsite disposal facility.

3.2.2.1 Accidental Releases of Reportable Quantities of Hazardous Substances (continued)

The WIPP facility is required to report such events under Sections 311 and 312 of SARA Title III, also known as the *Emergency Planning and Community Right-to-Know Act* (EPCRA). Reports required by these two sections are submitted to the SERC, the LEPC, and the local fire department. The WIPP also submits Section 311 data and Section 312 annual reports to the Carlsbad Fire Department, the Hobbs Fire Department, and the Otis Fire Department. For emergency response purposes, the DOE maintains Memoranda of Understanding (MOU) with each of these agencies.

The WIPP facility is currently exempt from the reporting requirements in Section 313 of the EPCRA. Section 313 lists the following toxic chemicals, currently in use at WIPP, that exceed the 10,000 pound threshold level: ethylene glycol, sulfuric acid, toluene, and xylene. Ethylene glycol and sulfuric acid meet the 10,000 pound reporting threshold, however, these chemicals are used as a structural component of the facility and are subject to the use exemption. Toluene and xylene are contained in unleaded gasoline and are subject to the vehicle maintenance exemption. Documentation of this exempt status is reviewed annually.

3.2.2.2 Waste Minimization and Pollution Prevention Programs

In May 1994, the first revision to the *WIPP Waste Minimization and Pollution Prevention Awareness Program Plan* was issued. This plan is reviewed annually and updated at least once every three years.

On December 1, 1993, the WIPP began recycling white bond paper, corrugated cardboard, and aluminum cans. All project participants, including the DOE, Westinghouse, Sandia National Laboratories, and minor subcontractors are involved in this recycling effort. In 1994, the WIPP site recycled 44.2 tons of paper and cardboard and approximately 800 pounds of aluminum cans.

In March 1994, the WIPP initiated a printer toner cartridge recharging program. The WIPP now recharges toner cartridges for a cost of $40 per recharge, instead of discarding them and purchasing new cartridges for $70-$130. After the cartridges have been recharged three times, they are sent for recycling. In 1994, the WIPP recharged 246 cartridges for a savings of over $13,000.

3.2.2.3 Waste Minimization and Pollution Prevention Programs (continued)

In December 1994, the aerosol can puncturing program began with surface operations. This program allows cans to be punctured and emptied thereby reducing the amount of hazardous waste and saving on disposal costs.

3.2.3 Resource Conservation and Recovery Act (RCRA) (42 U.S.C. § 3251 et seq.)

The RCRA was enacted in 1976 and implementing regulations were promulgated in May 1980. This body of regulations ensures that hazardous wastes are managed and disposed in an environmentally safe manner. Facilities that store, treat, or dispose of hazardous waste also must protect human health and the environment. The Hazardous and Solid Waste Amendments (HSWA) of 1984 prohibit land disposal of hazardous wastes unless certain treatment standards are satisfied or unless the EPA approves a petition to receive a variance from Land Disposal Restriction (LDR) standards. The HSWA also places increased emphasis on waste minimization activities and serves as a mechanism to enforce the RCRA cleanup requirements.

The WIPP facility is subject to the permitting requirements under the RCRA and the New Mexico Hazardous Waste Act. Title 40 CFR 264 outlines the technical standards for Treatment, Storage, and Disposal facilities that must be addressed in a permit application (as applicable). Title 40 CFR 270 outlines the requirements of the RCRA permitting program with respect to general format and content for applications, and the administrative aspects of the permitting and modification processes. The WIPP RCRA permit application will address TRU mixed waste management activities for surface facilities and in the repository as required for disposal operations. This application is being prepared for submittal to the NMED in May 1995. In general, programmatic changes reflected in this application center on the DOE decision to forego test phase activities at the WIPP. The RCRA permit is expected to be issued by the NMED in December 1997.

In order to permanently dispose of TRU mixed waste, the DOE has petitioned the EPA for a variance from the LDR of the RCRA, codified in 40 CFR 268. As defined in the provisions of 40 CFR 268.6, the DOE must demonstrate "to a reasonable degree of certainty" that hazardous constituents will not migrate from the disposal unit in concentrations exceeding health-based levels. The WIPP is currently developing a new No Migration Variance Petition (NMVP). The NMVP will be submitted to the EPA in two phases. The first phase will address a no-migration demonstration within the WIPP operational time frame (waste emplacement). This phase of the

3.2.3 Resource Conservation and Recovery Act (continued)

petition is near completion and will be submitted to the EPA in fiscal year 1995. The second phase consists of a complete NMVP, all-inclusive of the first submittal, and will demonstrate no migration after closure of the facility.

3.2.3.1 Mixed-Waste Management

In August 1993, the New Mexico Environment Department (NMED) issued, for public comment, a draft permit for the WIPP facility. In October 1993, the DOE made the decision not to conduct tests with radioactive wastes at the WIPP. At that time the DOE also requested an extension to the public comment period. On January 13, 1994, the DOE submitted a request to modify the RCRA permit application to reflect disposal, rather than test-phase operations. The NMED granted an extension to the public comment period until January 15, 1994. On September 2, 1994, NMED requested that a revised permit application be submitted by May 31, 1995, to accurately reflect future WIPP activities. As of January 19, 1995, the DOE has submitted nine chapters to the NMED for their review.

3.2.3.2 Hazardous Waste Generator Compliance

Nonradioactive hazardous waste is currently generated through normal facility operations. These wastes are managed in Satellite Accumulation Areas (SAA) and "less than 90-day" storage areas. In addition, hazardous waste generated at the WIPP is characterized, packaged, labeled, and manifested prior to shipment to an offsite Treatment Storage Disposal Facility (TSDF) in accordance with those requirements as codified in 40 CFR 262. Various waste minimization activities have been implemented at the site. One such activity is the Aerosol Can Puncturing Program. Once a can is punctured and drained of the contents, it is then classified as RCRA "empty" and managed as nonhazardous. The remaining residual liquids are the only portion of the waste managed as hazardous, which substantially reduces the volume of this particular waste stream.

3.2.4 National Environmental Policy Act (NEPA) (42 U.S.C. § 4321 et seq.)

The National Environmental Policy Act (NEPA) requires the federal government to use all practicable means to consider potential environmental impacts of proposed projects as part of the decision-making process. The NEPA dictates that the public shall be allowed to review and comment on proposed projects that have the potential to significantly affect the environment. The

3.2.4 National Environmental Policy Act (continued)

NEPA also directs the federal government to use all practicable means to improve and coordinate federal plans, functions, programs, and resources relating to human health and the environment. NEPA procedural objectives and public involvement requirements are detailed in the Council on Environmental Quality (CEQ) regulations implementing the NEPA in 40 CFR 1500-1508. DOE codified its requirements for implementing CEQ's regulations in 10 CFR 1021. Further procedural NEPA compliance guidance is provided in DOE Order 5440.1E, *National Environmental Policy Act Compliance Program.*

Title 10 CFR 1021.331 requires that ". . . following the completion of each environmental impact statement and its associated Record of Decision (ROD), the DOE shall prepare a Mitigation Action Plan (MAP) that addresses mitigation commitments expressed in the ROD." DOE Order 5440.1E further requires DOE facilities to "track and report annually to EH-1 the progress made in implementing and the effectiveness of any mitigation action plan until mitigation is completed." *The 1994 Annual Mitigation Report for the Waste Isolation Pilot Plant* (NEPA ID# WIP:94:0001) was issued July 1994.

In December 1994, a new computer-based NEPA training module was released for use at the WIPP. The training module provides specific instructions to workers for completing environmental checklists, which assess the impacts of their proposed actions.

Two WIPP NEPA procedures are currently being revised. These procedures provide directions to personnel responsible for the planning, coordination, and performance of work. At the WIPP site purchase requisitions and engineering work packages, which initiate modifications to the facility, are reviewed in accordance with these procedures to assess their potential environmental impacts and their compliance with the DOE's NEPA regulation and Order. The procedure revisions will simplify day-to-day WIPP NEPA compliance and facilitate a more thorough, expedient review/approval process.

Planning for the preparation of the second Supplemental Environmental Impact Statement (SEIS-II) is underway. The SEIS-II document originated from a commitment made in the Final Supplemental Environmental Impact Statement (FSEIS) to prepare another environmental impact statement prior to the decision to proceed with waste disposal activities at the WIPP site.

3.2.5 Clean Air Act (CAA)
(42 U.S.C. § 7401 et seq.)

The CAA provides for the preservation, protection, and enhancement of air quality, particularly at locations of special interest such as areas of natural, recreational, scenic, or historic value. Under Section 109 of the Clean Air Act, the EPA established the National Ambient Air Quality Standards (NAAQS) for six "criteria" pollutants: sulfur dioxide, total suspended particulates, carbon monoxide, ozone, nitrogen oxide, and lead. These standards establish primary and secondary standards for ambient air quality that the EPA considers necessary to protect public health and welfare.

In 1993, Westinghouse Electric Corporation, Waste Isolation Division (WID), completed the *WIPP Hazardous Air Pollutant (HAP) Emission Inventory* (WP 02-15). The HAP's inventory was developed as a baseline document to calculate maximum potential hourly and annual emissions of both hazardous and criteria air pollutants. Emission estimates were used to determine if the WIPP is required to obtain an air permit as specified in the following regulations:

- Clean Air Act § 112 National Emission Standards for Hazardous Air Pollutants
- Clean Air Act Part C (Prevention of Significant Deterioration - Criteria Pollutants)
- New Mexico Air Quality Control Regulation 752
- New Mexico Air Quality Control Regulation 702.

The CAA, Section 112 establishes emission standards for Hazardous Air Pollutants. The 1990 Clean Air Act Amendments (CAAA) increased to 189 the number of hazardous air pollutants regulated under the CAA. Hazardous air pollutant emissions are regulated under 40 CFR 61, the *National Emission Standards for Hazardous Air Pollutants* (NESHAP). The NESHAP establishes permitting and reporting requirements for facilities that have the potential to emit hazardous air pollutants. At the WIPP, the majority of hazardous air pollutants are regulated in Subpart A of the NESHAP. Radionuclide emissions other than radon are regulated in Subpart H of the NESHAP.

Based on an MOU with the EPA, the DOE committed to compliance with the requirements of 40 CFR 61, Subpart H, through the disposal phase of operations at the WIPP. A revised standard for radionuclide emissions was promulgated by the EPA in a final ruling published in the *Federal Register*, effective December 15, 1989 (54 FR 51654). In the *1990 Final Safety Analysis Report* (FSAR) for the WIPP facility, the anticipated dose from future WIPP facility emissions was calculated to be less than one percent of the allowable effective dose equivalent of 10 millirem per

3.2.5 Clean Air Act (CAA) (continued)

year to any one member of the public. The DOE documented the expected emission levels in 1990 data submitted to the EPA.

A revised data package will be submitted to the EPA prior to waste receipt. An emissions monitoring system was installed to comply with the periodic confirmatory monitoring compliance requirements established in NESHAP. On November 21, 1994, the EPA approved the use of a single-point source shrouded probe for compliance sampling. The shrouded probe will be used to conduct periodic confirmatory monitoring at the WIPP.

Based on the HAP's inventory, WIPP operations do not exceed the 10 ton per year (TPY) emission limit for any individual HAP or the 25-tpy limit for any combination of HAPs emissions established in Subpart A. The WIPP does not have any NESHAP Subpart A permitting or reporting requirement at this time. However, 40 CFR 61, Subpart A, Section 61.09(a)(1), requires that the WIPP facility notify the EPA of its anticipated date of initial startup (i.e., receipt of wastes) not more than 60 days and not less than 30 days before actual startup date. In addition, the EPA required that notification of the actual date of initial startup must be made within 15 days after startup.

Based on emission estimates generated in the HAPs inventory, the WIPP site is not required to obtain any federal CAA permits. The WIPP, in consultation with the NMED Air Quality Bureau, working in concert with data provided in the HAP's inventory, was required to obtain a New Mexico Air Quality Control Regulation (AQCR) 702 Operating Permit for two primary backup, diesel generators at the site. The only emission points where the WIPP site exceeds state threshold criteria is with the WIPP backup diesel generators. On June 18, 1993, the DOE submitted an AQCR 702 permit application for the WIPP backup diesel generators. On December 7, 1993, the New Mexico Air Quality Bureau issued Air Quality Permit 310-M-2. On February 26, 1994, the WIPP completed the emission monitoring requirements established in the permit. With the submittal of the *Final Compliance Sampling Report* on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit.

3.2.6 Clean Water Act (CWA)

Section 402 of the CWA, establishes provisions for the issuance of permits for discharges into waters of the United States. Regulations promulgated to define this permitting process are contained in 40 CFR 122. Subpart A, Section (b)(1), and state that ". . . National Pollutant Discharge

3.2.6 Clean Water Act (CWA) (continued)

Elimination System (NPDES) program requires permits for the discharge of "pollutants" from any "point source" into "waters of the United States." The WIPP has no pollutant discharges from point sources and is currently exempted from obtaining a standard NPDES permit.

On September 9, 1992, the EPA issued the final requirements for NPDES *General Permits for Storm Water Discharges Associated with Industrial Activity*. The storm water regulations establish requirements for managing industrial storm water runoff that has the potential to discharge into waters of the United States. The WIPP submitted a Notice of Intent (NOI) to the EPA to obtain a NPDES Storm Water General Permit on December 31, 1992. The NOI describes how the WIPP site mitigates the discharge of contaminated storm water through the use of Best Management Practices (BMPs). These BMPs include engineering controls such as storm water retention basins, the covering of materials storage areas, and the reclamation of disturbed areas. The EPA issued a New Mexico NPDES Storm Water General Permit (NMR00A021) on January 31, 1992. As part of the Nationwide General Permit Program, the WIPP is included in the New Mexico General Permit.

No sampling is required to demonstrate compliance with the WIPP Storm Water Permit unless a release occurs from one of the BMPs. Operational permit compliance activities are limited to quarterly inspections of retention basins, spill containment devices, reclamation sites, and site housekeeping practices.

The NPDES sewage sludge regulations promulgated in 40 CFR 122.21 require all facilities that generate or dispose of sewage sludges to submit an information package describing sewage sludge management and disposal practices. This information is reviewed by the EPA to determine if a NPDES permit will be required for the disposal of sewage sludges at a facility.

On February 14, 1994, the DOE submitted an information package to the EPA Water Management Division and requested a written determination whether a NPDES permit would be required for sewage sludges generated at the WIPP. On March 31, 1994, the EPA Region VI Permits Issuance Section notified the DOE that they had received the information package. The agency determined that the information package was complete and stated they would notify the DOE if a full and complete sewage sludge permit application would be required at a future date.

On January 16, 1992, the NMED issued the Discharge Plan (DP-831) for the WIPP sewage facility. The approved Discharge Plan superseded an Emergency Discharge Permit issued on September 18, 1991. In addition to sewage effluent, the Discharge Plan allows for the disposal of a maximum of

3.2.6 Clean Water Act (CWA) (continued)

1500 gallons a day of nonhazardous brines generated by seepage into shaft sumps and from pumping of observation wells at the site. Brine waters are collected in portable tanks and transported to the north sewage system evaporation basin. Characterization samples were collected throughout 1994 to demonstrate that site-generated brines are nonhazardous and can be disposed in the sewage evaporation pond. The DOE submits quarterly Discharge Monitoring Reports (DMR) to the NMED to demonstrate compliance with the inspection, monitoring, and reporting requirements identified in the plan.

3.2.7 Safe Drinking Water Act (SDWA)
(42 U.S.C. § 300f et seq.)

The SDWA of 1974 provides the regulatory strategy for protecting public water supply systems and underground sources of drinking water. The NMED notified the WIPP in a September 9, 1992, letter that the WIPP Public Water Supply was categorized as a nontransient, noncommunity system for reporting and testing requirements. At that time, the NMED determined that the WIPP was required to sample drinking water for total coliform bacteria, lead, copper, nitrate and nitrite. In a March 11, 1994, letter the NMED again modified compliance sampling requirements, stating that only lead, copper, and bacteriological samples are required. The modification was based upon New Mexico Water Supply Regulations which mandate that when a public water supply system supplements other systems, that water system is treated as a single system for compliance sampling purposes.

On June 2, 1994, lead and copper samples were collected from 20 locations to demonstrate compliance with the newly identified SDWA sampling requirements. Five of the 20 samples exceeded the SDWA lead action levels. At the direction of the NMED, these five locations were resampled on June 30, 1994. Based on the results of these five samples, three locations (site drinking fountains) were permanently taken out of service and the faucets at the two remaining locations were replaced. Follow-up sampling was conducted at each of these locations and all were below the SDWA action levels. Bacterial samples were collected monthly throughout 1994. All bacteriological/analytical results were below the SWDA regulatory limits.

The Carlsbad Municipal Public Water Supply System is contracted to provide drinking water to the WIPP from city-owned wells located 31 miles north of the site. Because of this contractual agreement, the city of Carlsbad completes the source or point-of-entry samples for the various chemical constituents at each wellfield source.

3.2.8 Toxic Substances Control Act (TSCA)
(15 U.S.C. § 2601 et seq.)

The TSCA applies primarily to manufacturers, importers, and processors of toxic chemicals for commercial purposes. The WIPP is not considered a manufacturer or processor of chemical products, therefore, most of the provisions of TSCA do not apply. The TSCA regulates the use of Poly-chlorinated Biphenyls (PCBs), asbestos, and materials containing PCBs and asbestos. Current DOE policy prohibits the use of PCB-containing materials in DOE-installed equipment at facilities like the WIPP; therefore, the TSCA does not apply to DOE-installed equipment at the WIPP. In the future, relative to received waste, the TSCA will not apply to future WIPP repository activities because disposal of PCB-contaminated wastes is excluded by the WIPP Waste Acceptance Criteria (WAC). The WIPP site will comply with the TSCA regulations contained in 40 CFR 761.60 and 761.65 with respect to any possible future storage or disposal of PCB-contaminated materials. Future procurement of asbestos containing materials is also prohibited at the WIPP site.

3.2.9 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
(7 U.S.C. § 136 et seq).

The FIFRA authorizes the EPA to regulate the registration, certification, use, storage, disposal, transportation, and recall of pesticides. Recommended procedures for storage and disposal of pesticides and pesticide containers are contained in 40 CFR 165. The EPA at its discretion may exempt federal agencies from any FIFRA provisions if emergency conditions exist (40 CFR 166). FIFRA standards are considered mandatory for regular conditions at DOE facilities. The DOE will continue to comply with the standards of the FIFRA at the WIPP site.

3.2.10 Endangered Species Act (ESA)
(16 U.S.C. § 1531 et seq.)

The Endangered Species Act (ESA) provides protection for threatened or endangered species of flora and fauna. Under Section 7 of the Act and its implementing regulations in 50 CFR 402, the EPA is prohibited from authorizing activities ". . . likely to jeopardize the continued existence of any endangered species or threatened species or result in destruction or adverse modification of habitat of such species. . . ." The Section 7 process may involve a biological assessment and "formal consultation" followed by the issuance of a "nonbiological opinion" by the U.S. Fish and Wildlife Service ". . . for any species that is determined to be in potential jeopardy."

3.2.10 Endangered Species Act (ESA) (continued)

In compliance with Section 7, Consultation Requirement, the DOE requested a list of endangered species from the U.S. Department of the Interior, Fish and Wildlife Service (USF&WS) to determine if such species are known to have a critical habitat on or in the vicinity of the WIPP site. As required by Section 7(c) of the Endangered Species Act Amendments of 1978, Mr. J. L. Stegman, USF&WS Region 2, acting regional director, provided correspondence on November 15, 1979, that:

1. Identified those species, both proposed and listed, that could occur in the WIPP's proposed project area.

2. Determined that no critical habitat for endangered species had been identified at the WIPP site.

3. Requested a biological assessment that included the listed species.

This correspondence also established that if the biological assessment revealed the proposed project had no affect on the listed species, there was no need for further consultation. As requested by this correspondence, the DOE prepared a *Biological Assessment* for the purpose of identifying listed species that were likely to be affected by the Site Preliminary Design and Validation (SPDV) program and other potential site usage. The *Biological Assessment*, conducted during CY 1978, documented that the listed species would not be affected by the project. The assessment was forwarded to the USF&WS for their review, completing the requirement for the consultation process mandated by the Endangered Species Act.

3.2.11 National Historic Preservation Act (NHPA)
(16 U.S.C. § 470 et seq.)

The NHPA was enacted to protect the nation's cultural resources and to establish the National Register of Historic Places. Other related legislation affecting the WIPP facility lands include the Archeological Recovery Act (ARA), which was amended by the Archeological and Historic Preservation Act (AHPA) (16 U.S.C. § 469a et seq.).

Throughout June and July 1994, a comprehensive WIPP site archaeological database was created. Research revealed that 60 archaeological sites and 91 isolated occurrences had been discovered

3.2.11 National Historic Preservation Act (NHPA) (continued)

within the WIPP land withdrawal area. During the creation of the database some inconsistencies were discovered with regard to the number of archaeological sites (eligible and ineligible for inclusion in the National Register) reported to exist within the WIPP land withdrawal area. Some sites previously included as "WIPP archaeological sites" are located within the outer perimeters of the WIPP's Control Zone IV. The boundary of Control Zone IV was later annulled, consequently, when the WIPP site was configured to the present sixteen section square, much of Control Zone IV reverted to the management of the Department of Interior. Therefore, the archaeological sites located in those areas are no longer the responsibility of the DOE.

Of the 60 WIPP archeological sites, 33 sites recorded within the central 4-square mile area of the WIPP land withdrawal area were subjectively determined, by the archaeologists conducting the surveys, to be potentially eligible for inclusion in the National Register.

Prior to the issuance of the WIPP Land Withdrawal Act, the Bureau of Land Management (BLM) was responsible for archaeological resource management on the WIPP site. The BLM served as the DOE's liaison with the State Historic Preservation Officer (SHPO). Following the issuance of the WIPP Land Withdrawal Act, the BLM continued to serve in this capacity until July 19, 1994, when the *Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Department of Interior* was finalized. At that time, the WIPP began communicating directly with the SHPO regarding archaeological concerns.

On July 15, 1994, the BLM, using provisions contained in their *Memorandum of Agreement with the State Historic Preservation Officer*, processed and approved WIPP surface disturbing activities associated with the construction of six new well-pads. On September 7, 1994, the State Historic Preservation Officer granted the DOE approval to construct a short access road, and on September 27, 1994, the SHPO granted the DOE approval to construct another well pad. During 1994 WIPP archaeological surveys, no new archaeological sites were discovered, and stipulations for avoidance of previously known sites were observed during construction activities.

3.2.12 Floodplain Management
(Executive Order 11988)

Floodplain Management, Executive Order (EO) 11988 directs federal agencies to avoid making modifications that adversely impact floodplains, to consider alternatives to a proposed action, to provide early public review of proposed actions, and to propose mitigation measures for proposed actions within floodplains. Because the WIPP site is not located within a floodplain zone, EO 11988 does not apply to the WIPP facility.

3.2.13 Protection of Wetlands
(Executive Order 11990)

Protection of Wetlands, Executive Order (EO) 11990 requires that federal agencies consider the effects of proposed actions in wetlands, determine whether wetlands are present, assess the impacts, consider alternatives to a proposed action, provide for early public review, and propose mitigation measures for proposed actions that could affect wetlands. The WIPP facility is neither located within nor will it impact a wetlands area; therefore, EO 11990 does not apply to the WIPP facility.

3.2.14 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes
(40 CFR 191)

The authority of the EPA to establish radiation protection standards for nuclear wastes is derived from the Atomic Energy Act, as amended; the Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act (NWPA) (PL 97-425).

Since the mid-1970s, the EPA has been developing guidance and standards for the management and disposal of radioactive wastes. The EPA's final rule, 40 CFR 191, was published on September 19, 1985 (50 FR 38066). In a challenge by a coalition of environmental organizations and states, the U.S. Court of Appeals for the First Circuit vacated and remanded Subpart B of the 1985 standard for further consideration by the EPA. The Court found, among other things, that the EPA did not protect groundwater as stringently as provided under the SDWA underground injection provisions [NRDC v EPA 824 F.2d 1258 (1st cir. 1987)].

The Second Modification to the Agreement for Consultation and Cooperation between the DOE and the State of New Mexico dated August 4, 1987, specified that, although the standards were on

3.2.14 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes (continued)

remand status, the DOE would continue to guide its performance assessment planning efforts as though the vacated regulations were still in effect. In the WIPP Land Withdrawal Act of 1992 (PL 102-579), Congress reinstated all of the 40 CFR 191, Subpart B regulations with the exception of those that were specifically questioned by the court (i.e., Sections 191.15, *Individual Protection Requirements* and 191.16, *Ground Water Protection Requirements*). Congress also required the EPA to issue final disposal regulations by April 30, 1993. On February 10, 1993, the EPA proposed revised disposal regulations under 40 CFR 191, Subpart B (58 FR 7924). On December 20, 1993, the EPA promulgated amendments to the final standard pertaining to individual and groundwater protection requirements (58 FR 66398). The three subparts have been thoroughly discussed under **3.2.1 Atomic Energy Act of 1954**, pages 3-3 through 3-5.

3.2.15 Hazardous Materials Transportation Act (HMTA)
(49 App. U.S.C. § 1801 et seq.; 49 CFR 106-179)

The HMTA provides for safe intra and inter-state transportation of hazardous/nuclear materials. The HMTA allows states to regulate the transport of hazardous/nuclear materials if regulations are consistent with the HMTA or U.S. Department of Transportation (DOT) regulations. The DOT regulations for hazardous/radioactive materials are contained in 49 CFR 171-177. Specifications for the kinds and designs of packages to be used for the transport of various types of radionuclides are contained in 49 CFR 173, Subpart I (and parallel NRC regulations in 10 CFR 71). The DOT regulations in 49 CFR 177 provide a routing and quantity rule for highway shipments of radioactive material; 49 CFR 174 contains segregation rules for shipment by rail. In the Second Modification to the
C and C Agreement dated August 4, 1987, the DOE agreed to comply with all applicable DOT regulations and the corresponding NRC regulations by way of the Trupact Safety Analysis Report (SAR), the Trupact Consultation and Cooperation (C and C), and Waste Acceptance Criteria (WAC) requirements.

3.2.16 Packaging and Transportation of Radioactive Materials
(10 CFR 71)

Regulations for shipping containers and safe packaging and transportation of radioactive materials are under the authority of the NRC and the DOT. Packaging requirements for radioactive materials, including the Type B packages to be used to transport waste to the WIPP facility, are detailed in

3.2.16 Packaging and Transportation of Radioactive Material (continued)

the DOT regulations (49 CFR 173, Subpart I). This references the NRC regulations. The NRC regulations in 10 CFR 71 reference the DOT regulations in 49 CFR 173.

The NRC requirements for shipping containers apply to the certification of the TRUPACT-II shipping container, the container that will be used to transport radioactive waste to the WIPP facility. The NRC certified the TRUPACT-II container August 30, 1989, after compliance with the 10 CFR 71 requirement for Type B packaging was demonstrated.

A container supplier inspection audit was conducted by the NRC from January 12-14, 1993. The scope of the inspection audit was to determine whether procedures have been established, documented, and executed at the DOE's WIPP facility to meet the quality assurance requirements of 10 CFR 71. The audit also determined whether containers were fabricated and maintained in accordance with the design approved by the Commission. The NRC had no findings and stated that all quality assurance requirements of 10 CFR 71 were being followed.

3.2.17 Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
(PL 96-164)

This Act, which authorized the WIPP Project, follows:

> Not withstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy . . . for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States . . .

The statute provides for the DOE consultation and cooperation with appropriate officials of the State of New Mexico with respect to public health and safety concerns. It also provides for a written agreement between the DOE and the appropriate officials of the State of New Mexico, setting forth consultation and cooperation. In compliance, the DOE has entered into two agreements with the State of New Mexico: the C and C Agreement and the Working Agreement for the C and C. Both agreements have been modified several times (see Table 3-3). The most recent modification of the C and C Agreement is the Second Modification to the Consultation and Cooperation Agreement dated August 4, 1987. The Working Agreement for the C and C Agreement was last modified in

3.2.17 Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
(PL 96-164) (continued)

March 1988. These agreements are implemented through the DOE and the New Mexico Radioactive Waste Consultation Task Force. In addition, the DOE interfaces regularly with the NMED and the New Mexico Legislature's Radioactive and Hazardous Waste Committee.

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act (LWA)
(PL 102-579)

On October 30, 1992, the Waste Isolation Pilot Plant Land Withdrawal Act withdrew land from the public domain for use by the Department of Energy (DOE) for the construction, experimentation, operation, maintenance, disposal, shutdown, monitoring, and decommissioning activities at the WIPP.

As a result of the LWA, the Secretary of Energy is required to develop a management plan to provide for grazing, hunting and trapping; wildlife habitat; the disposal of salt tailings; and mining. The *WIPP Land Management Plan* (LMP) was submitted to Congress in October 1993 establishing management guidelines to be used throughout the life of the facility, including decommissioning activities. In accordance with the LMP, the DOE identified the need for the development of a concurrent *Land Management Implementation Plan* (LMIP). The design of this plan was developed with consultation from the U.S. Department of the Interior's Bureau of Land Management (BLM) and the State of New Mexico. Guidelines prescribed in the LMIP provide for the management and oversight of the WIPP lands under the jurisdiction of the DOE. In addition, these guidelines provide for the management and oversight of lands outside the WIPP boundary that are used in the operation of the WIPP (e.g., groundwater surveillance well pads outside the withdrawn area). The LMIP provides for multiagency involvement in the administration of the DOE land management actions.

On July 19, 1994, the Memorandum of Understanding (MOU) between the U.S. Department of Energy and the (U.S. Department of Interior) BLM was finalized. This new MOU outlines the responsibilities of each agency with regard to land use management for the withdrawal area and provides an additional mechanism to protect the area from unallowable or inadvertent uses. The LMIP and the MOU serve to provide equitable and consistent administration of archaeological resources within the WIPP withdrawal area.

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act (LWA) (continued)

Compliance with the following statutes or regulations is also required under the Land Withdrawal Act:

- Taylor Grazing Act
- Subchapter IV of the Federal Land Policy and Management Act
- Public Rangelands Improvement Act
- Materials Act of 1947
- Federal Mine Safety and Health Act of 1977
- Solid Waste Disposal Act
- 40 CFR 191
- 29 CFR 1910.120
- Clean Air Act
- Safe Drinking Water Act
- Toxic Substance Control Act
- Comprehensive Environmental Response, Compensation, and Liability Act
- All other applicable federal laws pertaining to public health and safety of the environment.

A summary of the provisions of the LWA are as follows:

- The EPA must publish final radioactive waste disposal standards (40 CFR 191).
- The EPA must certify the WIPP's compliance with 40 CFR 191, Subparts B and C.
- The EPA must determine that the DOE has complied with the terms and conditions of the NMD issued on November 14, 1990 (55 FR 47700).
- The federal Occupational Safety and Health Administration (OSHA) must certify that it has reviewed the DOE emergency response training programs and has concurred that such programs are in compliance with 29 CFR 1910.120.

In October 1994, the DOE submitted the *Biennial Environmental Compliance Report* (BECR) to the Environmental Protection Agency Region VI Office and to the New Mexico Environment Department. The submittal of this report was mandated in Section 9(a)(2) of the WIPP Land

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act (LWA) (continued)

Withdrawal Act of 1992. The BECR documents the WIPP's compliance with applicable federal and state laws, regulations, and permit conditions pertaining to public health and safety and/or the environment.

3.2.19 Taylor Grazing Act
(43 U.S.C. § 315 et seq.)

The Taylor Grazing Act is intended to prohibit injury to public grazing lands by preventing overgrazing and soil deterioration. The Act promotes the orderly use and/or improvement to public grazing lands by establishing grazing districts and a grazing permit system. As defined in the LWA, the DOE may allow grazing to continue on the WIPP facility land where grazing districts had been established prior to the date of enactment of the Land Withdrawal Act. The Department of Interior, in consultation with the DOE, will issue any future grazing permits on WIPP lands.

3.2.20 Federal Land Policy and Management Act (FLPMA)
(43 U.S.C. §1701-1782)

The Federal Land Policy and Management Act was enacted to ensure, among other things, that

> . . . public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use . . .

The Secretary of Energy is required to comply with Subchapter IV of the Federal Land Policy and Management Act. Subchapter IV establishes the authority for grazing fees, range betterment funds, grazing permits, and grazing advisory boards. Under the LWA, the Secretary of Energy is empowered to administer these programs.

3.2.21 Public Rangelands Improvement Act
(43 U.S.C. § 1901 et seq.)

The Public Rangelands Improvement Act establishes a national policy and commitment to

- Inventory and identify current public rangeland conditions and trends.
- Manage, maintain, and improve the condition of public rangelands in a manner that the land becomes as productive as is feasible.
- Continue the policy of protecting wild free-roaming horses and burros and of removing and disposing of those excess animals that pose a threat to themselves, their habitat, and other rangeland values.

The DOE administers the WIPP facility lands as public rangelands in accordance with the guidelines prescribed in the LMP.

3.2.22 Executive Order (EO) 12548 -- Grazing Fees

Executive Order (EO) 12548 orders the establishment of fees for grazing of domestic livestock on public rangelands. The Department of Interior, in consultation with the DOE, will establish grazing fees for the WIPP facility lands.

3.2.23 Materials Act of 1947
(30 U.S.C. § 601 et seq.)

The Materials Act of 1947 addresses the disposal of mineral materials (e.g., sand, stone, gravel, pumice, cinders, and clay etc.) on public lands. The disposal of vegetative materials (e.g., yucca, manzanita, mesquite, cactus, and timber or forest products) is also addressed. Under the LWA, the WIPP facility must dispose of those salt tailings not used for backfill, in accordance with the bidding, advertising, contract negotiation, and disposition of monies provisions (Sections 602-603) of the Materials Act.

3.2.24 Federal Mine Safety and Health Act of 1977 (MSHA)
(30 U.S.C. § 801 et seq.)

Under the Federal Mine Safety and Health Act of 1977, the U.S. Department of Labor (DOL) is responsible for developing and enforcing regulations and standards to protect mine workers. In an MOU between the DOE and the DOL, effective July 9, 1987, the Mine Safety and Health Administration (MSHA) conducts periodic health and safety compliance inspections of WIPP facility underground operations. When the WIPP Land Withdrawal Act was signed into law on July 10, 1993, MSHA became the agency responsible for conducting at least four surface and underground safety inspections per year at the WIPP.

MSHA conducted four quarterly inspections in 1994. During three of these quarterly inspections, no Compliance Assistance Visit Notices were issued. During one inspection, two Compliance Assistance Visit Notices were issued. Neither of these two notices were marked as "Significant and Substantial" indicating that the violations would not significantly or substantially contribute to an accident. The conditions responsible for the notices were abated before the inspection was completed

3.2.25 Occupational Safety and Health Administration (OSHA) Regulations
(29 CFR 1900-1999)

The 1970 Williams-Steiger Occupational Safety and Health Act Section 6 (a) provides that the Department of Labor (DOL) establish employee safety and health standards compatible with those that are commonly practiced in industry and that have been found to meet national consensus standards or established federal standards. The DOE complies with OSHA standards and the OSHA safety and health management guidelines for all WIPP facility activities. In addition, the WIPP facility has established safety procedures in accordance with DOE policy.

Secretary of Energy Hazel R. O'Leary inducted the WID as the first Star Site in the Department of Energy's Voluntary Protection Program (DOE-VPP). Modeled after the OSHA VPP, the DOE-VPP was initiated in January 1994 to recognize exemplary contractor safety and health programs. An eleven member onsite review team representing a cross-section of environment, safety and health disciplines unanimously voted to recommend the WID as operating a Star Site after an August 29 - September 2, 1994, evaluation of the WID's safety and health program. The team's evaluation included review of records and over 160 interviews with managers and staff.

3.2.26 Noise Control Act of 1972
(42 U.S.C. § 4901 et seq.)

According to the policy clause in Section 2(a)(3) of the Noise Control Act of 1972, the primary responsibility for noise control is vested in state and local governments. Federal regulation is deemed essential only for commercial noise sources requiring national uniformity of treatment (e.g., aircraft noise). However, federal agencies are required to comply with federal, state, interstate, and local requirements respecting control and abatement of environmental noise ". . . to the fullest extent consistent with their authority . . . " (Section 4[a] and [b][1], [2]).

DOE facilities are required to comply with OSHA standards in 29 CFR 1910, which include the Occupational Noise Exposure standards in 29 CFR 1910.95. Any WIPP facility noise sources that exceed these standards have been mitigated (e.g., noise dampers have been installed in the WIPP facility underground air exhaust fans). There are no noise sources at the WIPP facility that could affect the general public.

3.2.27 Bald and Golden Eagle Protection Act
(16 U.S.C. § 668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to capture, kill, molest, or disturb these eagles, their nests, or their eggs anywhere in the United States. A permit must be obtained from the U.S. Department of the Interior to relocate a nest that interferes with resource development or recovery operations. The Act potentially applies to the WIPP facility because there is a possibility that these birds could be present on facility lands.

Surveys to identify raptor nests on the WIPP facility lands since 1985 have thus far failed to locate any bald or golden eagle nests near operational activities. Through the Cooperative Raptor Research and Management Program (CRRMP) at the WIPP facility the DOE will continue to monitor for raptor nests on WIPP lands and near operational buildings.

3.2.28 Migratory Bird Treaty Act (MBTA)
(16 U.S.C. § 703 et seq.)

The Migratory Bird Treaty Act is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. The Act stipulates that it is unlawful to indiscriminately ". . . kill . . . any migratory bird." It regulates the harvest of

3.2.28 Migratory Bird Treaty Act (MBTA) (continued)

migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. Although the WIPP facility is not located within a major migration corridor, there are migratory birds present on WIPP facility lands. As required by the MBTA, the DOE will consult annually with the U.S. Fish and Wildlife Service with respect to impacts on migratory birds from the hunting activities permitted on WIPP facility lands.

3.2.29 National Defense Authorization Act - Fiscal Year 1989

The DOE has contracted the New Mexico Institute of Mining and Technology (NMIMT) to conduct independent reviews of the health and safety aspects of the design, construction, and operations of the WIPP facility, as required by the National Defense Authorization Act of 1989. The Environmental Evaluation Group (EEG) at the Institute performs the reviews. The DOE will cooperate, as appropriate, with the EEG reviews of health and safety practices at the WIPP facility.

3.2.30 Protection and Enhancement of Environmental Quality
(Executive Order 11514, as amended by Executive Order 11991)

Executive Order 11514 directs federal agencies to perform the following:

- Monitor, evaluate, and control activities so as to protect and enhance the quality of the environment.
- Review statutory authority, regulations, policies, and procedures in order to identify any deficiencies or inconsistencies that limit compliance with the NEPA.
- Develop procedures to ensure the public is informed of federal programs with environmental impact.
- Ensure that information regarding existing or potential environmental problems brought to light by research, development, demonstration, test, or evaluation activities are made available to federal agencies, states, counties, municipalities, institutions, and other appropriate entities.
- Comply with statutory authority, regulations, policies, and procedures in order to identify any deficiencies or inconsistencies that limit compliance with the NEPA.

3.2.30 Protection and Enhancement of Environmental Quality (continued)

The DOE complies with the CEQ regulations and public disclosure requirements by preparing NEPA documentation on WIPP Project activities as necessary. The DOE also conducts continuing, comprehensive environmental monitoring programs at the WIPP site.

3.2.31 Federal Compliance with Pollution Control Standards (Executive Order 12088)

Executive Order (EO) 12088 advises the director of each federal agency to ensure that all necessary actions are taken for the prevention, control, and abatement of environmental pollution. Each agency is responsible for compliance with applicable pollution control standards established by such statutes as the CWA, the CAA, the AEA of 1954, and others. Each agency must submit an annual plan for the control of environmental pollution at its facilities. This EO mandates that the DOE control pollution at the WIPP facility.

The *Waste Minimization and Pollution Prevention Awareness Plan* was updated on May 31, 1994. This plan is reviewed annually and updated at least every three years. Pollution prevention awareness guidance is contained in the *Resource Conservation and Recovery Act Compliance Manual* (WP 02-6, 02-7) and its implementing procedures, as well as in the *Environmental Compliance Manual* (WP 02-5). These environmental compliance manuals are currently being revised to incorporate elements of the Waste Minimization and Pollution Prevention Awareness Program.

The WIPP has developed a central inventory database to track the type and quantity of hazardous materials on site. The software for the inventory database was installed in December 1993. In 1994, WIPP inventory data were entered in the database. Currently, inventory is performed on a quarterly basis.

3.3 Other Significant Accomplishments and Ongoing Compliance Activities for Calendar Year 1994

3.3.1 Environmental Leadership Program

A proposal for the WIPP's inclusion in the EPA's Environmental Leadership Program (ELP) was submitted to EPA on September 21, 1994. The ELP is designed to recognize and reward facilities that develop innovative environmental management systems and thereby commit to achieving notable compliance and pollution-prevention results. The ELP pilot project phase will help EPA design a

3.3.1 Environmental Leadership Program (continued)

full-scale leadership program. The ELP will also serve as a vehicle for analyzing the EPA's audit policies and voluntary disclosure approaches. The program has the potential to not only build and strengthen liaisons among the EPA, the states, and the regulated community, but to implement new environmental performance measures that foster employee and community involvement.

3.3.2 Environmental Compliance Assessment Program (ECAP)

The ECAP plays a major role in the overall program for environmental protection activities at the WIPP. The ECAP was developed to determine if impactive or potentially impactive facility activities protect human health and the environment and if these activities are in compliance with applicable federal, state, and local requirements; with permit condition/requirements; and with best management practices. This program provides a comprehensive system, not only to assess compliance with applicable environmental statutes and requirements at the WIPP, but also to identify operationally feasible and environmentally sound corrective action measures for nonconformances or observations identified. The ECAP is designed to address five compliance assessment processes: (1) environmental compliance appraisals; (2) environmental audits; (3) independent review group evaluations; (4) environmental event evaluations; and (5) environmental compliance status tracking and reporting process.

During 1994, 21 assessments were conducted. Some of the assessed areas included: RCRA Training, Satellite Accumulation Areas, Equipment Inspections, New Mexico Special Waste, OSHA Bloodborne Pathogens, Diesel Generator Permit, HAZMAT Inventories, Waste Characterization, Construction Landfill, Hazardous Waste Generator Requirements, and New Mexico Discharge Plan and Water Supply Regulations.

Table 3-1
Compliance Status with Major Environmental Regulations
Applicable to the WIPP Project

Statute/Regulation	Status
Atomic Energy Act	No radioactive waste was received during CY 1994.
Clean Air Act	NESHAP data package and letter of notification submitted. No monitoring/reporting required until after receipt of waste.
Clean Water Act	Quarterly inspections of best management practices to comply with (stormwater retention basins) NPDB storm water general permit (NMR00A021).
Comprehensive Environmental Response, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act	No Land Disposal Units (LDUs) exist at the site. No CERCLA site cleanup required. Reports filed as required under SARA for hazardous substances are maintained onsite.
Endangered Species Act	Permits to collect biological samples and to band nonendangered species of raptors are maintained.
Federal Land Policy and Management Act	An MOU between the DOE and the BLM was issued in July 1994. This MOU outlines the responsibilities the BLM and the DOE have with regard to land use management for the withdrawal area. The WIPP Land Management Implementation Plan was issued August 1994.
Federal Insecticide, Fungicide, and Rodenticide Act	All use of pesticides is approved by Industrial Safety and is performed by subcontractors.
Hazardous Materials Transportation Act	Hazardous wastes to be sent offsite are reviewed to ensure compliance with HMTA.
National Environmental Policy Act (as supplemented by DOE Order 5440.1E, and 10 CFR 1021)	The 1994 *Annual Mitigation Report for the Waste Isolation Pilot Plant* (NEPA ID# WIP:94:0001) was issued July 1994. This provides a status of the commitments made in the WIPP's Records of Decision. A new computer-based NEPA training module was released for use in December 1994. Purchase requisitions and engineering work packages which initiate changes and modifications to the WIPP facility continue to be reviewed for potential environmental impacts.
National Historic Preservation Act	Activities requiring excavation in previously undisturbed areas are surveyed by licensed, permitted archaeologists. Required reports are submitted to the New Mexico State Historic Preservation Officer.

Table 3-1
Compliance Status with Major Environmental Regulations
Applicable to the WIPP Project

Statute/Regulation	Status
New Mexico Air Quality Control Act	The New Mexico Air Quality Bureau issued Air Quality Permit 310-M-2 on December 7, 1993. On February 26, 1994, the WIPP completed the emission monitoring requirements established in the permit. With the submittal of the *Final Compliance Sampling Report* on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit. New Mexico does not yet have primacy for NESHAP for radionuclide emissions from DOE facilities. New Mexico Hazardous Waste Management Regulations See "Resource Conservation and Recovery Act." NMED does not yet have primacy for all areas by the RCRA.
New Mexico Radioactive Materials Act	No radioactive wastes had been received at the WIPP in CY 1994.
New Mexico Water Quality Act	The DOE submits quarterly discharge monitoring reports to the NMED Groundwater Quality Bureau to comply with the requirements of the WIPP Discharge Plan, DP-831.
New Mexico Wildlife Conservation Act	See "Endangered Species Act."
Resource Conservation and Recovery Act	*Hazardous-waste generator compliance:* All site-generated hazardous wastes were transported off-site within the 90-day accumulation period. *No-Migration Determination compliance:* The fourth annual report was submitted to EPA on November 14, 1994. *Mixed-waste management:* On January 13, 1994, the DOE formally requested that the NMED allow the DOE to modify the RCRA permit application to reflect disposal operations. In September 1994, the NMED ordered the submittal of a complete revised permit application by May 31, 1995. DOE has submitted Chapters B, D, E, F, G, H, I, J & K to the NMED for their review. *Underground Storage Tanks:* Annual registration fee paid. Maintenance of inventory control records continues.
Toxic Substances Control Act	Procurement of asbestos-/PCB-containing materials not allowed. Other portions of TSCA not applicable.

Table 3-2

DOE Orders Affecting the WIPP Environmental Program

ORDER NO.	DATE	TITLE	ANNOTATION
DOE 5400.1	11/09/88 Change 1- 06/29/90	General Environmental Protection Program	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for ensuring compliance with federal and state environmental protection laws and regulations, federal executive orders, and internal department policies.
DOE 5400.2A	01/31/89	Environmental Compliance Issue Coordination	Establishes DOE requirements for coordination of significant environmental compliance issues.
DOE 5400.4	10/06/89	Comprehensive Environmental Response, Compensation, and Liability Act Requirements	Establishes basic requirements for implementation of the Superfund at DOE facilities.
DOE 5400.5	02/08/90 Change 2- 01/07/93	Radiation Protection of the Public and the Environment	Establishes standards and requirements for operations of the DOE and DOE contractors with respect to protection of the public and the environment against undue risk from radiation.
DOE 5440.1E	11/10/92	National Environmental Policy Act	Establishes DOE policy for implementation of the National Environmental Policy Act of 1969 (PL 91-190).
DOE 5480.1B	03/27/90 Change 5- 05/10/93	Environment, Safety, and Health Program for DOE Operations	Establishes overall framework of program requirements for safety, environmental, and health protection.
DOE 5480.3	07/09/85	Safety Requirements for the Packaging of Fissile and Other Radioactive Materials	Establishes requirements for packaging and transportation of radioactive materials for DOE facilities.
DOE 5484.1	02/24/84 Change 7- 10/17/90	Environmental Protection, Safety, Health Protection Information Reporting Requirements	Establishes requirements and procedures for reporting information having environmental protection, safety, or health significance to DOE operations.
AL 5484.1	08/23/82 Change 1- 10/24/86	Environmental Protection, Safety and Health Protection Information Reporting Requirements	Albuquerque Operations Office implementation of 5484.1.

Table 3-2

DOE Orders Affecting the WIPP Environmental Program
(continued)

ORDER NO.	DATE	TITLE	ANNOTATION
DOE 5480.23	04/30/92 Change-1 3/10/94	Nuclear Safety Analysis Reports	To establish uniform requirements for the preparation and review of safety analyses of DOE operations which include the following: identification of hazards, their elimination or control, assessment of the risk, and documented management authorization of their operation.
DOE 5482.1B	9/23/86 Change-5 05/10/93	Environmental, Safety and Health Appraisal Program	To establish the Environmental Protection, Safety, and Health (ES&H) appraisal program for the DOE.
DOE 5500.3A	04/30/91 Change 1- 02/27/92	Planning, and Preparedness, for Operational Emergencies	To establish requirements for the development of DOE site-specific emergency plans and procedures for radiological emergencies occurring in existing or planned DOE reactors and non-reactor nuclear facilities. It also requires that comprehensive emergency actions are planned, coordinated, and implemented to respond effectively to the onsite and offsite consequences of a radiological emergency at these facilities, and it provides for appropriate coordination between DOE and offsite officials to ensure the protection of onsite personnel, public health and safety, and the environment.
DOE 5700.6C	08/21/91	Quality Assurance	To provide DOE policy, set forth principles, and assign responsibilities for establishing, implementing, and maintaining programs of plans and actions to ensure quality achievement in DOE programs.
DOE 5820.2A	09/26/88	Radioactive Waste Management	Establishes policies and guidelines by which DOE manages radioactive waste, waste byproducts, and radioactively contaminated surplus facilities.
DOE 6430.1A	04/06/89	General Design Criteria	To provide general design criteria for use in the acquisition of DOE facilities and to establish responsibilities and authorities for the development and maintenance of these criteria.

Table 3-3

Summary of Agreements Between the DOE and the State of New Mexico That Affect the WIPP Environmental Program

Stipulated Agreement on Civil Action No. 81-0363 JB - This agreement, approved by the U.S. District Court proceedings, held in abeyance in the lawsuit against the DOE by the State of New Mexico, was executed on July 1, 1981. The eight-page agreement assures that a binding, enforceable "consultation and cooperation" agreement will be entered into by the DOE and the state, and that the DOE will make a "good faith effort" to resolve certain state offsite concerns (which are covered in the Supplemental Stipulated Agreement). The Stipulated Agreement also addresses a number of additional studies and experiments to be conducted by the DOE for the Site Preliminary and Design Validation Phase of the WIPP facility. This agreement was signed by Jeff Bingaman (Attorney General, State of New Mexico) and Myles Flint (Attorney, U.S. Department of Justice), and was issued July 1, 1981, by Juan G. Burciaga (U.S. District Judge, District of New Mexico).

Agreement for Consultation and Cooperation – Usually referred to as the "C&C Agreement," this agreement is contained in Appendix A to the Stipulated Agreement. It affirms the intent of the Secretary of Energy to consult and cooperate with New Mexico with respect to state public health and safety concerns. It was signed in July 1981 by Bruce King (Governor, State of New Mexico) and James B. Edwards (Secretary, U.S. Department of Energy).

Working Agreement for Consultation and Cooperation, Appendix B, Article IV, Revision I – This agreement, Appendix B to the Stipulated Agreement, identifies in Article IV over 60 "key events" and "milestones" in the construction and operation of the WIPP facility that must be reviewed by the state before they are commenced. Many environmental items are included. It was signed in March 1983 by Robert McNeill (Chairman, Radioactive Waste Task Force), and R. G. Romotowski, (Manager, Albuquerque Operations Office, U.S. Department of Energy). (Article IV of the Working Agreement was revised on April 8, 1983).

Supplemental Stipulated Agreement Resolving Certain State Off-Site Concerns Over WIPP – This agreement dated December 27, 1982, addresses five state concerns including the need for state "verification" of the WIPP Environmental Monitoring Program. The concerns addressed are: state liability for a nuclear incident, emergency response preparedness, transportation monitoring of the WIPP facility waste, the WIPP facility environmental monitoring by the state, and upgrading of state highways. It was signed in December 1982 by Bruce King (Governor, State of New Mexico) et al., and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

First Modification to the July 1, 1981, Agreement for Consultation and Cooperation on WIPP by the State of New Mexico and the U.S. Department of Energy – This modification was signed November 30, 1984, wherein the DOE and the state agree to address certain concerns of the state regarding: (1) the specific mission of the WIPP Project, (2) a demonstration of retrievability prior to waste emplacement, (3) post-closure control and responsibility, (4) completion of certain additional scientific testing and reports, (5) compliance with applicable federal regulatory standards for waste repositories, and (6) a program for encouraging and reporting on the hiring of New Mexico residents at the WIPP Project. It was signed in November 1984 by Joseph Goldberg (Secretary, Health and Environment Department, State of New Mexico), and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Second Modification to the July 1, 1981, Agreement for Consultation and Cooperation on the WIPP by the State of New Mexico and the U.S. Department of Energy – Signed August 4, 1987, wherein the DOE and the state agree to address certain concerns of the state regarding: (1) surface and subsurface mining and drilling after closure of the WIPP site, (2) the disposal of salt tailings at the WIPP site, and (3) compliance with U.S. Environmental Protection Agency, U.S. Department of Transportation, and U.S. Nuclear Regulatory Commission regulations. It was signed in August 1987 by Garrey Carruthers (Governor, State of New Mexico) et al., and R. G. Romotowski, (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Table 3-3
Summary of Agreements Between the DOE and the State of New Mexico That Affect the WIPP Environmental Program
(continued)

1988 Modification to the Working Agreement of the Consultation and Cooperation Agreement Between the U.S. Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant – This modification deleted the sorbing tracer test from the list of required reports and substituted additional tests. In addition, the state is allowed to operate a fixed-air sampler in the mine ventilation effluent air stream. It was signed in March 1988 by Kirkland Jones (Deputy Director, New Mexico Environmental Improvement Division, State of New Mexico) et al., and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Environmental Oversight and Monitoring Agreement – This agreement states that the DOE will provide additional technical and financial support for state activities in environmental oversight, monitoring, access, and emergency response to ensure compliance with applicable federal, state, and local laws at several DOE facilities including the WIPP facility. It was signed in October 1990 by Garrey Carruthers (Governor, State of New Mexico; Dennis Boyd (Secretary, Health and Environment Department), and Bruce G. Twining (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Site-Specific Protocol for Implementation of the Environmental Oversight and Monitoring Agreement – Signed October 23, 1992, this protocol describes the site-specific protocol for day-to-day activities involving the NMED and the DOE contract personnel stationed at the WIPP. This protocol is a result of the "Environmental Oversight and Monitoring Agreement of 1990" between the State of New Mexico and the DOE. It is designed within the context of the unique nature and purpose of the WIPP.

Table 3-4
Active/Pending Permits for the Waste Isolation Pilot Plant During 1994

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	1994 Permit Status
Department of the Interior, Bureau of Land Management	Right-of-Way for Water Pipeline	NM53809	8/17/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for the North Access Road	NM55676	8/24/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Railroad	NM55699	9/27/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Dosimetry and Aerosol Sampling Sites	NM63136	7/31/86	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Seven Subsidence Monuments	NM65801	11/7/86	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Aerosol Sampling Site	NM77921	8/18/89	8/18/2019	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Ten Raptor Nesting Platforms	NM82212	9/12/89	12/13/2019	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Survey Monument Installation	NM82245	12/13/89	12/13/2019	Active
Department of the Interior, Bureau of Land Management	Approval to Drill 2 new test wells on existing pads at P-1 and P-2	None	9/18/86	None	Active
Department of the Interior, Bureau of Land Management	Free Use Permit for Caliche	NM-FU3-91183	7/27/94	7/27/95	Active
New Mexico Environment Department	Open Burning Permit to train fire control Crews	None	3/1/94	3/1/95	Active
New Mexico Environment Department	Operating Permit for two backup generators	310-M-2	12/7/93	None	Active

Table 3-4

Active/Pending Permits for the Waste Isolation Pilot Plant During 1994 (continued)

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	1994 Permit Status
New Mexico Environment Department	Submittal of Part B RCRA Permit Application		Submitted to the NMED and EPA Region VI on 2/26/92 and on 2/27/92. Revisions were delivered to the NMED on 3/4/92 and 1/27/93.		NMED declared permit administratively complete 7/22/92. Draft permit issued 8/24/93. Public comment period was held open to 7/14/94.
New Mexico Environment Department	Acknowledgement of Notification of Hazardous Waste Activity	NM4890139 088	1/88 Latest report delivered on 2/28/92	None - Contingent upon delivery of biennial report	Active
New Mexico Department of Game and Fish	Individual Banding	1,961.00	4/1/94	3/31/95	Active
New Mexico Department of Game and Fish	Master Collecting	1,894.00	4/5/94	3/31/95	Active
New Mexico Department of Game and Fish	Concurrence that WIPP construction activities will have no significant impact on State-listed threatened or endangered species	None	5/26/89	None	Active
U.S. Department of the Interior, Fish and Wildlife Service	Master Personal Banding	22,478.00	5/19/93	6/30/95	Active
U.S. Department of the Interior, Fish and Wildlife Service	Concurrence that WIPP construction activities will have no significant impact on Federally-listed threatened or endangered species	None	5/29/80	None	Active

Table 3-4

Active/Pending Permits for the Waste Isolation Pilot Plant During 1994
(continued)

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	1994 Permit Status
New Mexico Department of Finance and Administrative Planning Division, Historic Preservation Bureau	Concurrence that the DOE Archaeological Resources Protection Plan is adequate to mitigate any adverse impacts upon cultural resources resulting from construction of the WIPP facility	None	7/25/83	None	Active
U.S. Environmental Protection Agency	Notification of the presence of 2 Underground Storage Tanks	None	4/15/86	None	Active
U.S. Environmental Protection Agency	New Mexico NPDES Storm Water General Permit	NMR00 A021	12/31/92	12/31/97	Active
New Mexico Commissioner of Public Lands	Right-of-Way for High Volume Air Sampler	RW-22789	10/3/85	10/3/2020	Active

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CHAPTER 4

ENVIRONMENTAL PROGRAM INFORMATION

Chapter 4
Environmental Program Information

The WIPP's policy is to conduct its operations in a manner that complies with all applicable environmental laws and regulations.

4.1 Environmental Monitoring Plan (EMP)

The WIPP's Environmental Monitoring Plan outlines a program that monitors a comprehensive set of parameters to detect and quantify present and future environmental impacts. Nonradiological portions of the plan focus on the immediate area surrounding the site.

The goal of the EMP is to identify what impacts may exist from the WIPP on the local ecosystem. Evaluation of the severity, geographic extent, and environmental significance of these impacts is important to the mission of the facility and future research. Although the WIPP has performed a detailed study of these impacts, additional samples will be collected and analyzed to investigate and explain trends or anomalies that may have a bearing on environmental impacts. The EMP sampling schedule is provided in Table 4-1, page 4-6.

As recommended in DOE/EP-0023 (i.e., Corley et al. 1981) and DOE/EH-0173T, the EMP monitors levels of naturally occurring radionuclides. This surveillance includes the monitoring of world-wide fallout and fallout expected from the WIPP waste. The geographic scope of radiological sampling is based on projections of potential release pathways (see Figure 5-1, Primary Pathway Exposure model, page 5-8) and those in WIPP waste. The surrounding population centers are also monitored as sampling devices. Table 4-2, pages 4-7 through 4-8, represents the EMP analytical array.

As required by DOE Order 5400.1, the EMP is to be reviewed annually and updated every three years. The most recent EMP was updated in March 1994 (DOE/WIPP 94-024).

4.2 Baseline Data

Within the WIPP Environmental Monitoring section there are five programs currently in place: the Nonradiological Environmental Surveillance (NES), the Radiological Environmental Surveillance (RES), the Cooperative Raptor Research and Management Program, Land Management, and the WIPP Groundwater Surveillance Programs (WQSP). The purpose of these programs is to collect

4.2 Baseline Data (continued)

the data needed to detect and quantify possible impacts that construction and operational activities at the WIPP may have on the surrounding ecosystem and, when necessary, provide technical support for issues that require expertise in the disciplines of environmental science or land management. The data are used to assess impacts of WIPP operations on the environment and to demonstrate compliance with applicable standards for radiological and nonradiological programs.

Preliminary studies must be considered when evaluating environmental monitoring efforts. These preliminary studies have contributed to baseline data gathered during the construction phase, as well as the long-term monitoring programs. These studies include the following:

- WIPP Site Characterization Program - instituted in 1976 by Sandia National Laboratories (SNL) to monitor air quality, background radiation levels, and groundwater quality (Pocalujka et al., 1979; 1980a, b, c; 1981a, b; Powers et al., 1978; Lappin, 1989).

- WIPP Biology Program - began in 1975 with site characterization studies of climate, soils, vegetation, arthropods, and vertebrates (Best, 1980).

- Investigations of the Site Geohydrology - conducted by the U.S. Geological Survey (USGS) at the request of the DOE. In addition, the NRC issued a contract to Columbia University to perform a study of radionuclide mobility in the highly saline groundwaters of the Delaware Basin (USGS, 1983).

- Radiological Monitoring of Air, Water, and Biological media - conducted by the Atomic Energy Commission (ACE) before and after the Project Gnome nuclear detonation (U.S. AEC, 1962a, b, c, d).

4.3 Environmental Monitoring and Planning Activities

This section addresses significant environmental activities that occurred during CY94.

4.3.1 Waste Minimization Committee

The Waste Minimization Committee was formed in 1993 with representatives from groups generating or working with hazardous and/or large volumes of waste. The Committee prepared a Waste Minimization Charter, which outlines the Committee's responsibilities.

The Waste Minimization Committee is split into separate subcommittees to concentrate on different areas of pollution prevention. These subcommittees are the Employee Awareness, Community Outreach, Waste Assessments, and Hazardous Solvent Substitution.

In 1994, the Employee Awareness Subcommittee participated in the Six Weeks of Safety and National Quality Month. Articles were printed in the *TRU-News* periodically to educate employees on the importance of waste minimization. Another project conducted in 1994 was in conjunction with the Quality Improvement Program. Plastic reusable cups were distributed to all employees at WIPP for use in the cafeteria thereby reducing the amount of waste generated.

The Community Outreach subcommittee worked with the NMED to conduct source reduction surveys of local businesses. These source reduction surveys assisted businesses in identifying large volume waste and subsequently integrate waste minimization practices.

A Pollution Prevention Opportunity Assessment (PPOA) was conducted by the Waste Assessments Subcommittee. The PPOA Subcommittee investigated the disposal of fluorescent tubes onsite and alternatives to their disposal as hazardous waste. The PPOA was completed at the end of 1994 and awaits implementation. In addition, an informal survey was conducted on the existing recycling programs onsite to ensure that all employees had the opportunity to participate.

The Hazardous Solvent Substitution Subcommittee concentrated on products that contained extremely hazardous substances. This Subcommittee worked with the Chemical Management Committee to develop a purchase requisition sign-off system to ensure that environmentally sound products were being purchased and that excess products were used promptly.

Other waste minimization activities for 1994 include:

- Recycling of white bond paper, corrugated cardboard, and aluminum cans
- Recharging of toner cartridges
- Puncturing of aerosol cans to reduce hazardous waste volumes

4.3.1 Waste Minimization Committee (continued)

- Recycling of waste oil offsite
- Reusing cold-degreasing solvents at six solvent stations used for cleaning parts
- Reclaiming cold-degreasing solvents offsite
- Using recycled janitorial paper products exclusively
- Recycling of lead-acid batteries offsite

4.3.2 Environmental Training

Environmental training was provided to personnel associated with environmental operations at the WIPP. Training courses ranged from technical topics (e.g. RCRA sampling), to basic ES&H training. These courses were conducted both onsite by WIPP personnel and offsite by various contractors.

4.3.3 WIPP Land Management Plan

On October 30, 1992, the WIPP Land Withdrawal Act (i.e., Public Law 102-579) was signed into law by former President George Bush. The WIPP Land Withdrawal Area is comprised of 10,240 acres (4145 ha) that have been transferred from the Department of Interior to the Department of Energy.

A requirement of the Act was the preparation of a land management plan. The WIPP's *Land Management Plan* (LMP) completed in October 1993, fulfills this requirement. This plan was drafted by the DOE and the BLM in consultation with the State of New Mexico. The LMP assures that future management of the withdrawal area will be consistent with the Federal Land Policy Management Act (FLPMA), the WIPP Land Withdrawal Act, and other applicable laws. The Land Management Plan is in effect through the decommissioning phase of the WIPP facility. A separate plan for the post-decommissioning phase is required by the Act with submittal to Congress within five years from the date of enactment of the Act.

4.3.3.1 Management Goal

The goal of the LMP is to manage the withdrawal area as it has been traditionally managed and to avoid, whenever possible, placing restriction on land use. It is not the intent of the DOE to make

4.3.3 WIPP Land Management Plan (continued)

4.3.3.1 Management Goal (continued)

the withdrawal area an exclusive-use area. However, some restrictions are needed to protect the long-term integrity of the WIPP repository. During operations, the safety and security of the facility must be maintained. The Act gives the DOE the authority to restrict activities in the land withdrawal area to whatever extent the DOE deems necessary to ensure the protection of the facility, the staff, and the public.

As a complement to this land use plan, a concurrent Land Management Implementation Plan (LMIP) and a MOU, executed between the DOE and the BLM as required by the Act, were developed. The LMIP was issued August of 1994, the MOU was signed into effect July 19, 1994. The MOU outlines responsibilities of each agency with regard to requests for the use of the withdrawal area. The MOU also defines the consultation role of other land management agencies adjacent to and in the vicinity of the withdrawal, (including the State of New Mexico and other federal agencies).

Guidelines prescribed in the LMIP provide for the management and oversight of WIPP lands under the jurisdiction of the DOE, in addition to lands outside the WIPP boundary that are used in the operation of the WIPP (e.g. groundwater surveillance well pads outside the withdrawn area). The plan also provides for multiagency involvement in the administration of DOE land management actions. Accordingly, commitments contained in existing permits or agreements (e.g. MOUs) are adhered to when contemplating proposed land use actions. The LMIP provides guidelines for the comprehensive administration and execution of land use decisions to include:

- Environmental Compliance
- Safety
- Maintenance and Work Control
- Energy and Mineral Resources
- Reclamation/Environmental Restoration
- Cultural Resources
- Access/Rights of Way
- Recreation
- Security
- Wildlife
- Grazing

Table 4-1
EMP Sampling Schedule

Type of Sample	Sampling Locations	Sampling Frequency
Liquid Influent	1	Semiannual
Liquid Effluent	1	Semiannual
Airborne Effluent	8	Continuous
Meteorology	2	Continuous
Exposure Rate Meter	1	Continuous
Atmospheric Particulate	7	Weekly
Air Quality	1	Continuous (Discontinued)
Vegetation-Radioanalysis	4	Annual
Beef/Deer	2*	Annual
Game Birds	2	Annual
Rabbits	2	Annual
Soil-Radioanalysis	7	Biennial
Surface Water	8	Annual
Groundwater	14	Annual
Fish	2	Annual
Sediment	6	Biennial
Aerial Photography Salt Impact Studies	Site Wide	Annual
Surface Photography	7	Biannual
Soil Chemistry	7	Quarterly
Wildlife Survey	4	Continuous

* Or as available

Table 4-2

EMP Analytical Array

Type of Sample	Analysis
Liquid Influent	Specific Radionuclides
Liquid Effluent	Specific Radionuclides, Chemical Constituents
Airborne Effluent	Gross α, Gross β, Specific Radionuclides
Meteorology	Temperature, Wind Speed, Wind Direction, Precipitation, Dew Point, Barometric Pressure
Exposure Rate Meter	Penetrating Radiation
Atmospheric Particulates	Gross α, Gross β, TSP, Specific Radionuclide
Air Quality	O_3, CO, H_2S, SO_2, NO_x
Vegetation Radioanalysis	Specific Radionuclides
Beef	Specific Radionuclides
Game Birds	Specific Radionuclides
Rabbits	Specific Radionuclides
Soil Radioanalysis	Specific Radionuclides
Surface Water	Specific Radionuclides
Groundwater	Specific Radionuclides, Chemical Constituents
Fish	Specific Radionuclides
Sediment	Specific Radionuclides

Table 4-2
(continued)
EMP Analytical Array

Type of Sample	Analysis
Aerial Photography	Area of Land Disturbed
Salt Impact Study	
Soil Chemistry	pH, Na, Cl, Mg, Ca, K
Ecology Investigations	
Wildlife Survey	Cooperative Raptor Research and Management Program

TSS = Total Suspended Solids
TSP = Total Suspended Particulates
EC = Electrical Conductivity
pH = Hydrogen - Ion Activity

Specific Radionuclides = ^{238}Pu, $^{239/240}Pu$, ^{241}Pu, ^{233}U, ^{235}U, ^{241}Am, ^{232}Th, ^{226}Ra, ^{228}Ra, ^{210}Po, ^{210}Pb, ^{137}Cs, ^{90}Sr, ^{40}K, ^{7}Be, ^{60}Co, U_{nat} Th_{nat}

Chemical Constituents = Chloride, iron, magnesium, phenols, sodium, sulfate, pH, specific conductance, total organic carbon, total organic halogen, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, silver, alkalinity, bromide, iodide, orthophosphate, beryllium, calcium, boron, lithium, potassium, silica, carbon tetrachloride, methalene chloride, trichloroethylene, 1,1,1 trichlorethane, freon-113, TSS, TDS

CHAPTER 5

ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

Chapter 5
Environmental Radiological Program Information

The following subsections provide a description of the various radiological programs constituting the Environmental Monitoring Program at the WIPP. The media that are analyzed radiologically are airborne particulates, soil, surface water, groundwater, and biotics.

5.1 Radioactive Effluent Monitoring

The Radioactive Effluent Monitoring Program (REMP) is described in the WIPP Environmental Monitoring Plan (EMP). This plan defines the scope of the WIPP's effluent and environmental monitoring programs during the operational life of the facility. Figure 5-1, page 5-8 illustrates the primary pathways to the public for radioactive releases from the WIPP site.

The Environmental Regulatory Guide for Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T), (DOE, 1991), requires that monitoring of liquid waste effluent streams be adequate to demonstrate compliance with dose limits in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE, 1990). This order also requires that potential sources of contaminated airborne emissions be monitored. In CY 1994 no radioactive waste was received at the WIPP site, and as a result, no effluent sampling or release data are reported in this document.

5.2 Environmental Radioactivity Monitoring

The following subsections present the monitoring results of the EMP for CY94. These results include monitored subprograms such as aerosols, ambient radiation, terrestrial radioactivity, hydrologic radioactivity, and biotic radioactivity. Table 5-1, pages 5-6 through 5-7, and figures 5-2 through 5-9 illustrate gross alpha and beta analysis of WIPP air filters conducted at the WIPP Low Level Counting Lab (LLCL). The attached appendices (A1-A6) provide analytical results from an offsite laboratory. For certain elements, there is a minor deviation from previous data reported in the *Statistical Summary of the Radiological Baseline Program for the WIPP* (DOE/WIPP 92-037). These outliers ($\geq \pm 2$ standard deviations from the mean) are denoted in Appendix A1, with an asterisk. Data inconsistencies (< 5 percent) are most likely due to laboratory variables pertaining to analytical techniques. These variables are being evaluated to assist in outlier determination. Subsequent analytical data (e.g., CY 1995-1998) will provide supplementary radiological data to support and update established radiological baselines.

5.2.1 Atmospheric Radiation Baseline

During CY 1994, continuous particulate aerosol samplers operated at eight locations, three, within 1000 meters of the facility; four, at local ranches and communities; and one, as a sample control site (Figure 5-10).

The continuous aerosol samplers presently in use maintain a regulated flow rate of approximately 950 milliliters per second (two cubic feet per minute) of air through a 47-millimeter (1.9-inch) glass fiber filter. Table 5-1 depicts the 1994 quarterly average concentrations of the alpha and beta activity on the low-volume aerosol filters from each location and illustrates the mean gross alpha concentrations for all eight sampling locations. Mean gross alpha concentration shows limited fluctuation throughout the year, as illustrated in Table 5-1. These fluctuations appeared to be consistent among all sampling locations.

Gross alpha and beta measurements provide an indication of naturally occurring radionuclide concentrations or changes in a specific radionuclide concentration. These measurements are screened to ensure that important radionuclides are not overlooked when measurements are performed.

Airborne particulate sampling was initiated in July 1985. Weekly filter collections and subsequent radiochemical analyses began in early 1986, except in the Far Field location where data collection began in October 1986. Particulate filters were collected weekly at all locations in CY 1994. These filters were analyzed at WIPP's LLCL where a weekly gross alpha and beta count of each filter was completed.

Appendix A1 provides results from the radiological analysis of CY 1994 air filters.

5.2.2 Ambient Radiation Baseline

A Reuter-Stokes High Pressure Ionization Chamber (HPIC) designed to monitor low levels of gamma radiation in the environment was put into operation in May 1986. In 1988, the unit was moved to the current location at the WIPP Far Field location, which is 1000 meters northwest of the Waste Handling Building. The detector used to measure low levels of gamma radiation, a pressurized ion chamber, measures levels of radiation from 1 to 100 microroentgen per hour (μR/hr). Using the average rate of 7.4 μR/hr, the estimated annual dose is approximately 65

5.2.2 Ambient Radiation Baseline (continued)

millirem. The fluctuations noted are primarily due to calibration of the system and meteorological events (e.g., the high intensity thunderstorms that frequent this area in late summer).

A seasonal drop in ambient radiation has been observed in the first and fourth quarters of each year. As stated in previous reports, this fluctuation may be due to variations in the emission and dispersion of Radon-222 from the soil around the WIPP site. These variations can be caused by meteorological conditions, (i.e., inversions), which would slow the rate of dispersion of radon and its progeny.

5.2.3 Radiological Soil Monitoring

Radiological soil samples were collected, during CY 94, at six separate locations. A template insert allows for the collection of samples at three depths per location that includes:

1. 0 - 2 centimeters
2. 2 - 5 centimeters
3. 5 - 10 centimeters.

Each complete sample was a composite of 10 randomly selected subsamples. As illustrated in Appendix A2, data results do not indicate any unusual levels of environmental radioactivity.

5.2.4 Hydrologic Radioactivity

The hydrologic radioactivity subprogram is designed to establish characteristic radioactivity levels in surface water bodies, bottom sediments, and groundwater. The following discussion of the hydrologic program includes sampling locations, data collected, and time these data were collected during 1993. It also details refinements made to the program since the publication of the *Radiological Baseline Program Sampling Plan* (Reith and Daer, 1985).

5.2.4.1 Radiological Surface Water and Sediment Monitoring

Surface water samples were collected at 12 locations during CY 94. Of these subject locations, sediment samples were collected at 10. The data from the analysis of these samples does not indicate any unusual levels of environmental radioactivity. Analytical results from surface water and sediment samples are illustrated in Appendix A3 and A4 respectively.

5.2.4 Hydrologic Radioactivity (continued)

5.2.4.2 Radiological Groundwater Characterization

Groundwater samples were collected in accordance with the Water Quality Sampling Program (WQSP). The primary objective of the WQSP is to obtain, using rigorous field and laboratory procedures and protocols, representative groundwater data from selected wells. At each wellsite, the well is purged and the groundwater serially analyzed for specific field parameters. Once the field parameters have stabilized denoting a chemical steady state with respect to those parameters analyzed, a final groundwater sample is collected and analyzed for radionuclides. The controlling document for the WQSP is the *WIPP Water Quality Sampling Plan and Procedures Manual* (WP 02-1, Rev 2).

The primary water-bearing units being evaluated by the WQSP are the Culebra and Magenta Dolomite members of the Rustler Formation. In 1994, groundwater data were gathered at nine well locations completed in the Culebra dolomite. Water quality data were also collected from two privately owned wells in the area near the WIPP site. These two private wells provide water for area livestock. An in-depth discussion of groundwater hydrology and a figure showing well locations is presented in Chapter 7, *Groundwater Surveillance*. Results from the radiological analysis of groundwater are provided in Appendix A5.

5.2.5 Biotic Radioactivity

Biotic media used for radiologic analysis consisted of vegetation, fish, rabbit, and deer. Unusually low numbers of resident quail prompted the suspension of sampling quail, after only two specimens had been collected, until numbers increase to the degree that attrition by sampling will not adversely affect the status of the resident population.

Fish samples were collected at two locations; Brantley Lake and the Pecos River. Low population numbers of rabbits resulted in the collection of only two specimens (road kills) for analysis. Several deer, however, were killed on roads adjacent to the WIPP, thus providing adequate availability for tissue collection and subsequent analysis. Vegetation was collected at six locations that are analogous to soil sample locations.

Appendix A6 provides preliminary data regarding the radiological analysis of biotic vegetation, quail, fish, rabbits, and deer samples.

5.3 Assessment of Potential Dose to the Public

In 1994, no waste was received at the WIPP; therefore, the public could not be exposed to radiation due to WIPP operations. Documentation of naturally occurring background radiation is discussed in Chapter 5, *Environmental Radiological Program Information* and Chapter 7, *Ground Water Surveillance,* of this report.

ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

TABLE 5-1

ACTIVITY CONCENTRATIONS IN QUARTERLY AVERAGES OF THE LOW VOLUME AEROSOL FILTERS (Bq/ml)

FIRST QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	2.13 E-10	1.068E-09
Smith Ranch	1.90 E-10	1.07 E-09
Mills Ranch	2.72 E-10	1.03 E-09
WIPP Far Field	2.26 E-10	1.05 E-09
WIPP South	2.84 E-10	1.09 E-09
WIPP East (1)	2.39 E-10	1.01 E-09
Eunice	3.02 E-10	9.70 E-10
South East Control	2.11 E-10	1.00 E-09

SECOND QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	8.80 E-11	8.99 E-10
Smith Ranch	4.77 E-11	9.10 E-10
Mills Ranch	9.31 E-11	9.73 E-10
WIPP Far Field	8.06 E-11	9.16 E-10
WIPP South	9.17 E-11	9.54 E-10
WIPP East (1)	9.06 E-11	9.14 E-10
Eunice	8.30 E-11	8.13 E-10
South East Control	7.57 E-11	8.45 E-10

THIRD QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	1.52 E-10	1.07 E-09
Smith Ranch	1.20 E-10	1.04 E-09
Mills Ranch	1.69 E-10	1.11 E-09
WIPP Far Field	1.84 E-10	1.09 E-09
WIPP South	1.75 E-10	1.05 E-09
WIPP East (1)	1.56 E-10	1.05 E-09
Eunice	1.76 E-10	1.16 E-09
South East Control	1.23 E-10	9.98 E-10

TABLE 5-1
(CONTINUED)

FOURTH QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	1.71 E-10	1.27 E-09
Smith Ranch	1.40 E-10	1.25 E-09
Mills Ranch	1.74 E-10	1.13 E-09
WIPP Far Field	1.53 E-10	1.07 E-09
WIPP South	1.72 E-10	1.16 E-09
WIPP East (1)	1.51 E-10	1.18 E-09
Eunice	3.13 E-10	5.45 E-10
South East Control	1.40 E-10	1.15 E-09

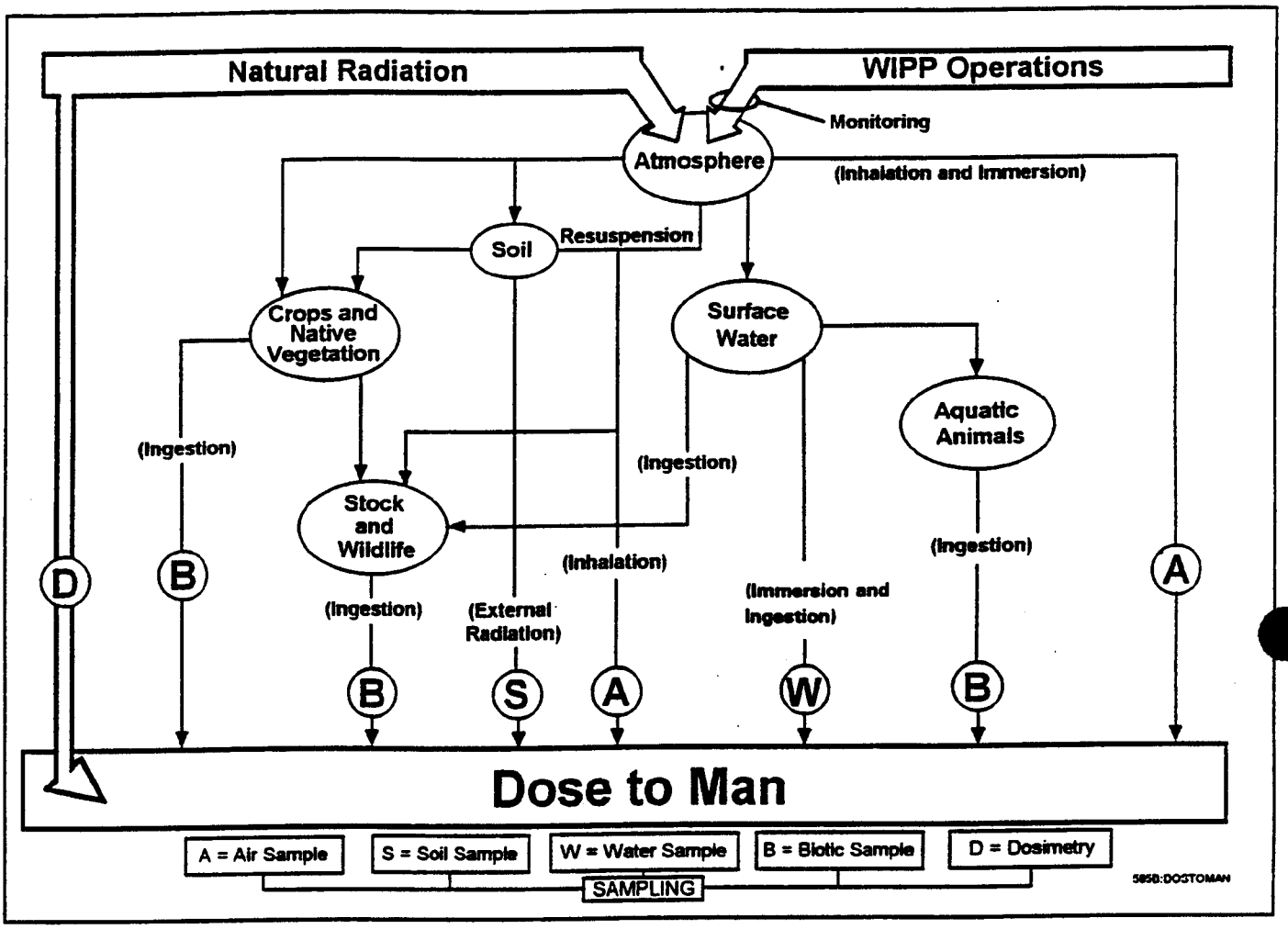

Figure 5-1
Primary Pathways to Man for Radioactive Releases from the WIPP Site

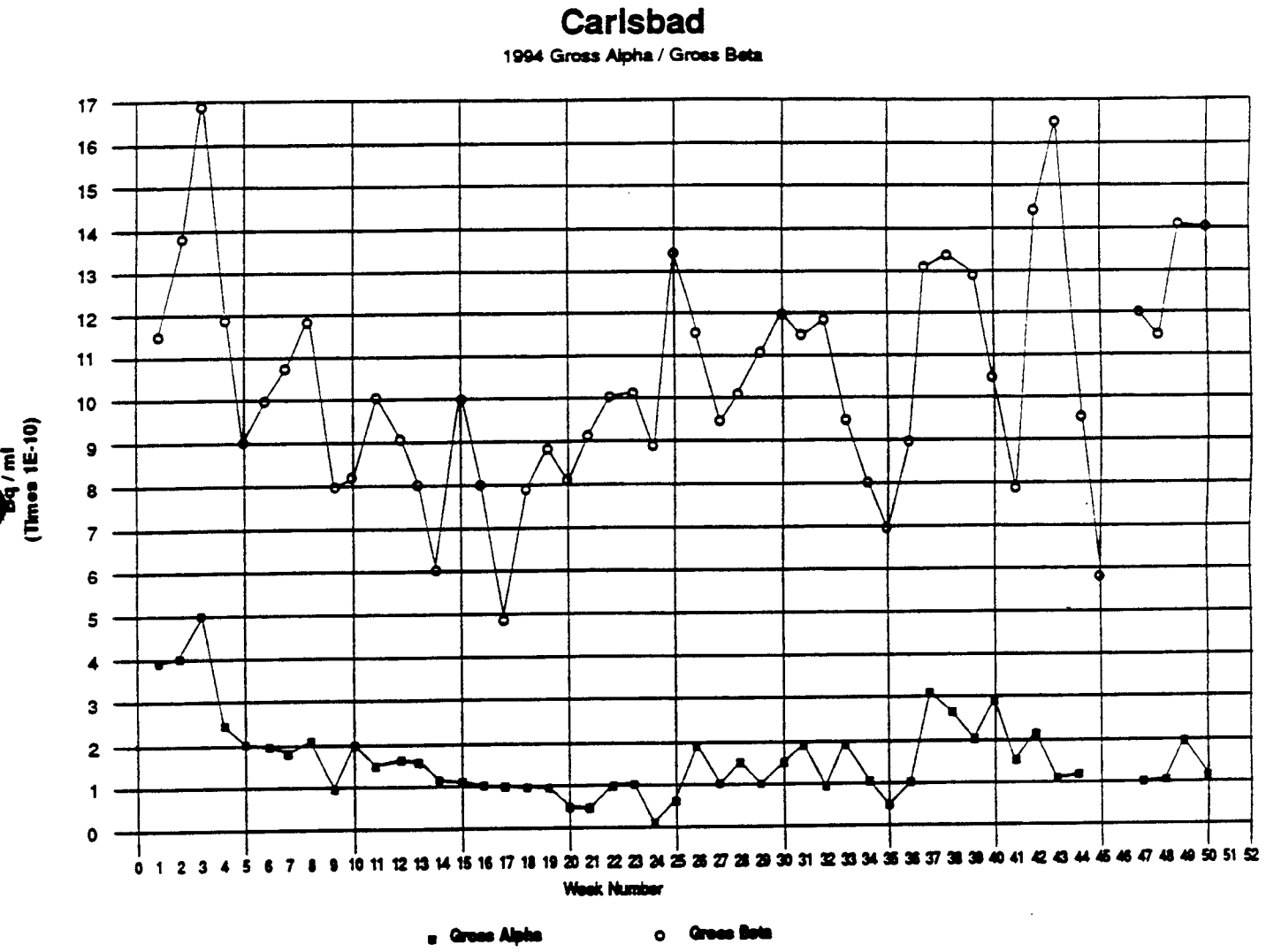

Figure 5-2
1994 Gross Alpha/Beta
Carlsbad

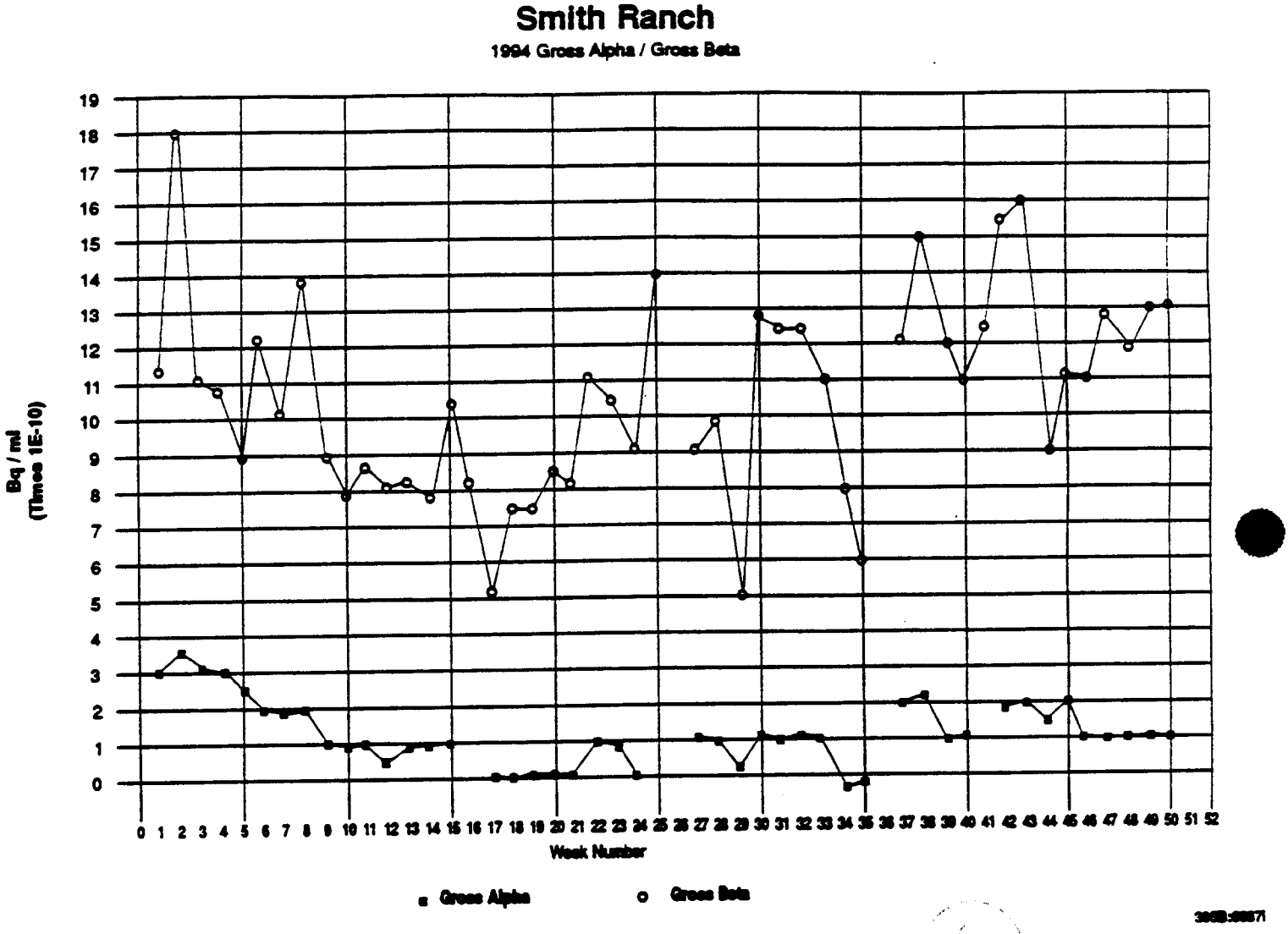

Figure 5-3
1994 Gross Alpha/Beta
Smith Ranch

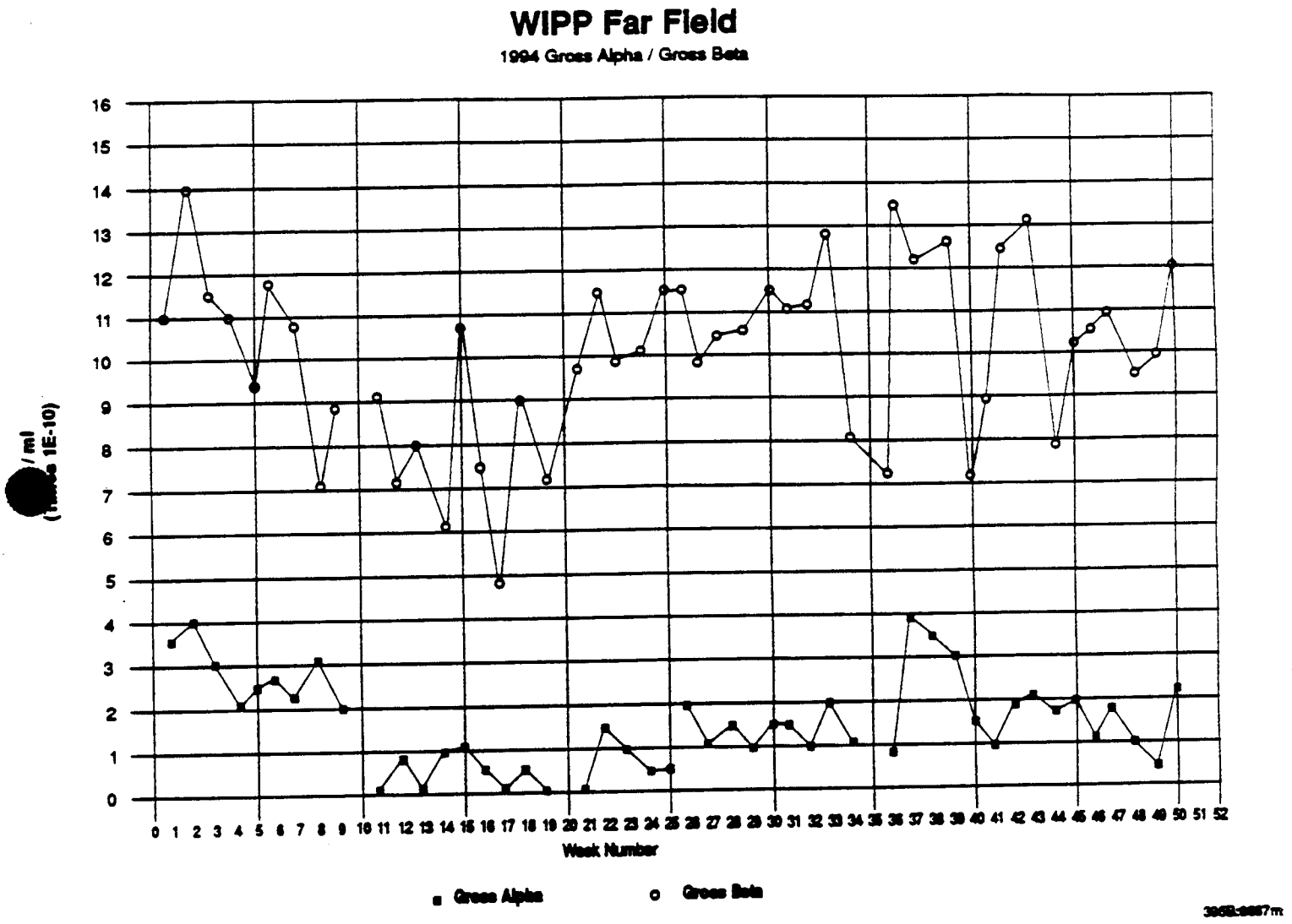

Figure 5-4
1994 Gross Alpha/Beta
WIPP Far Field

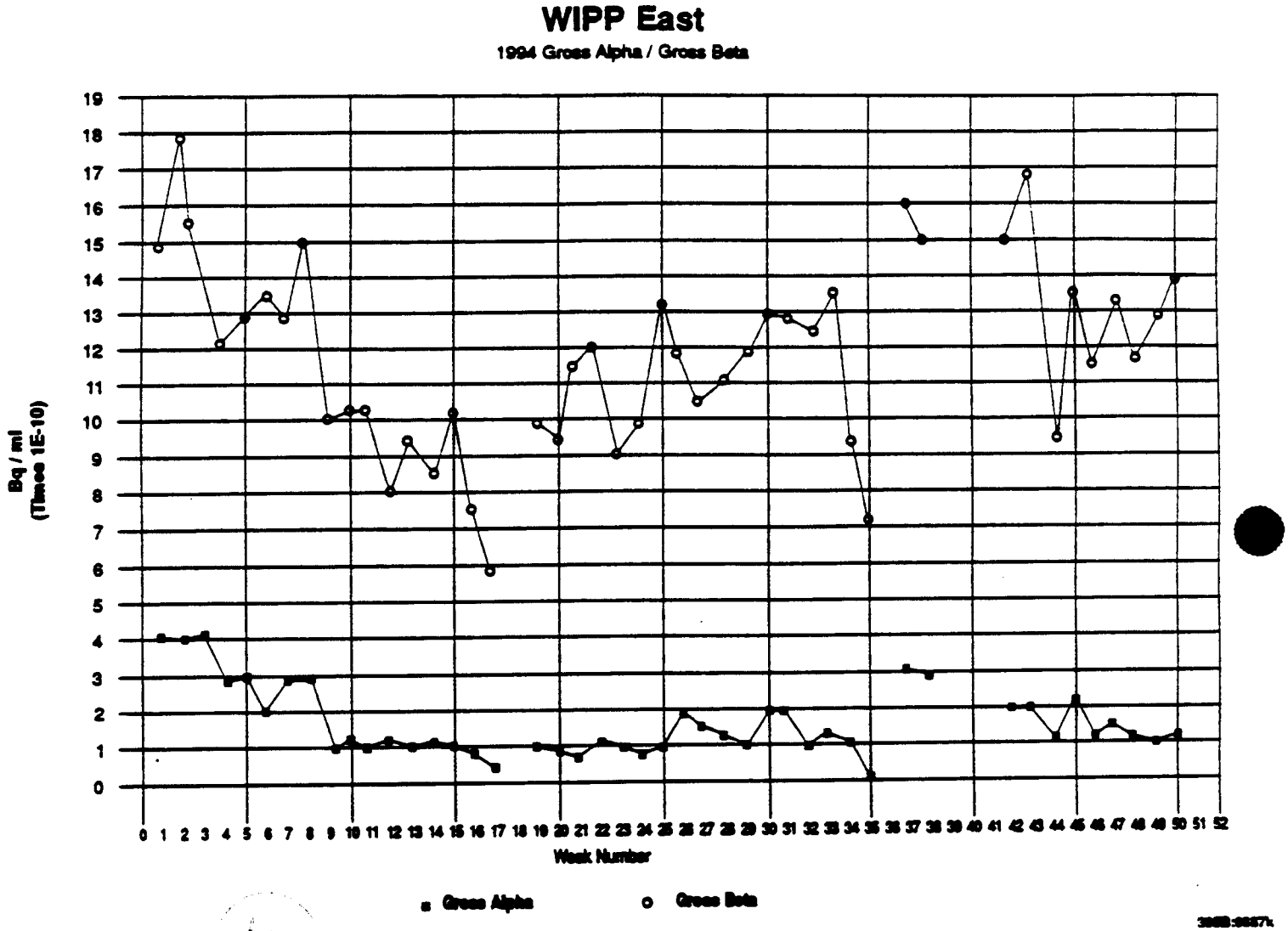

Figure 5-5
1994 Gross Alpha/Beta
WIPP East

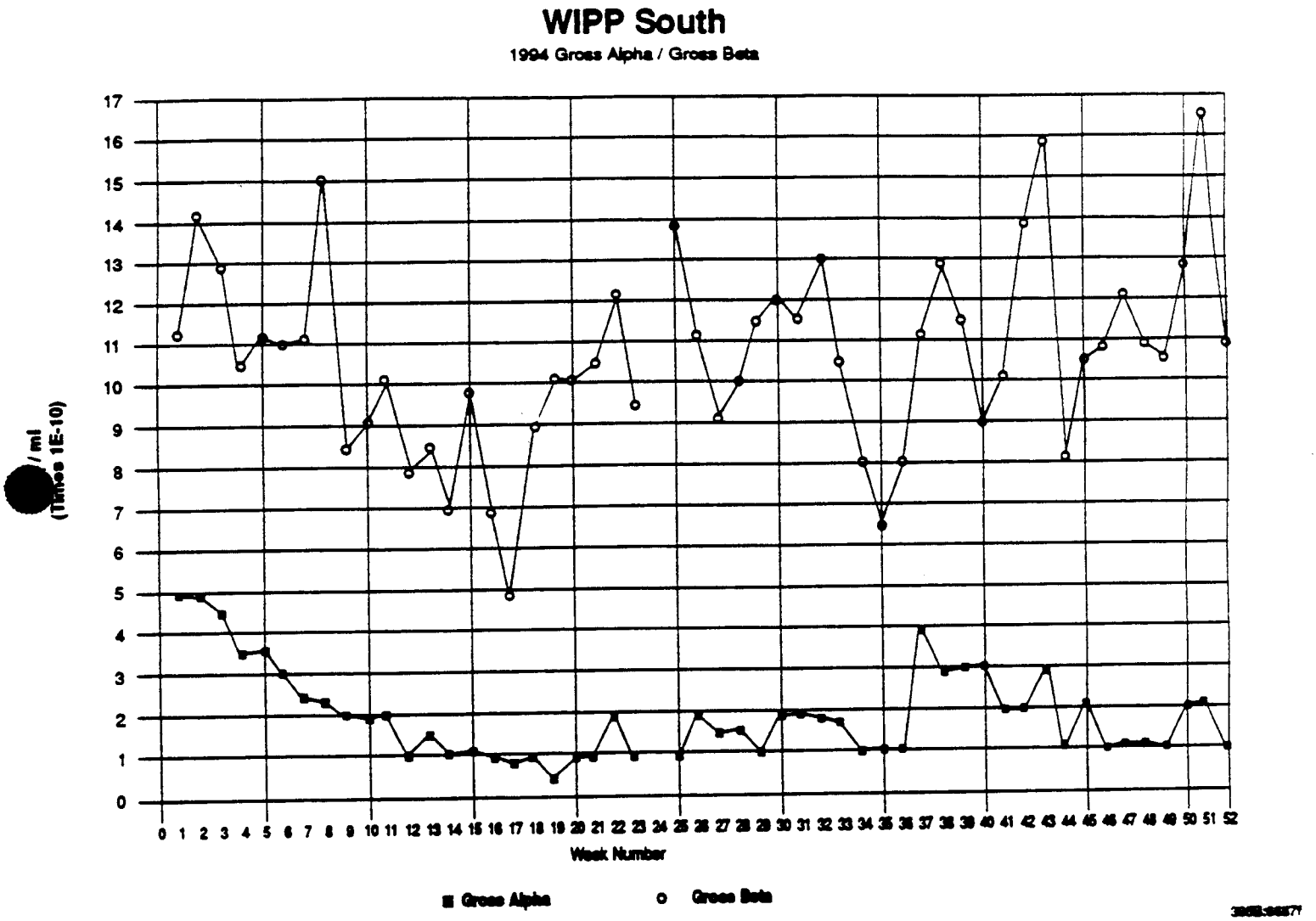

Figure 5-6
1994 Gross Alpha/Beta
WIPP South

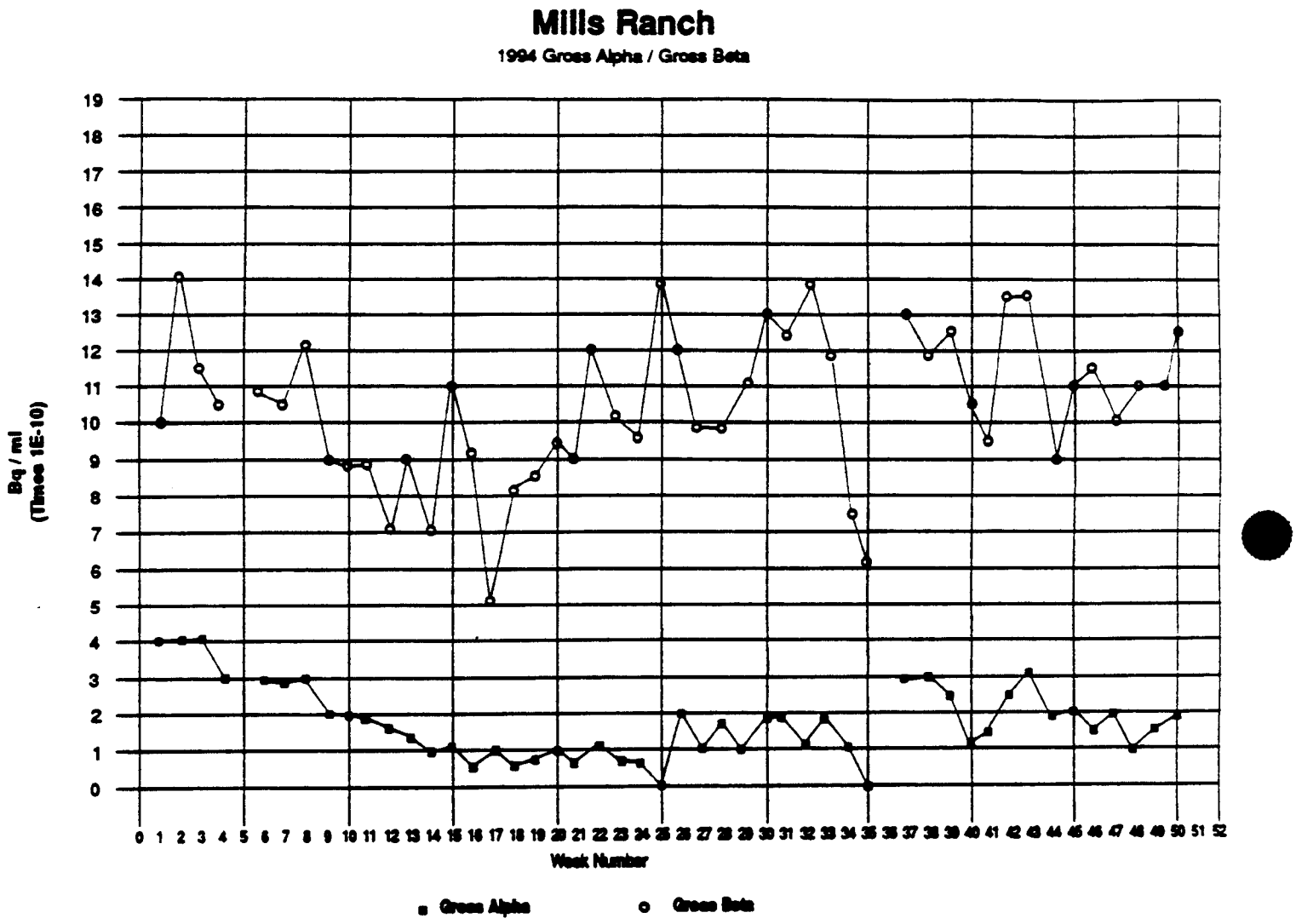

Figure 5-7
1994 Gross Alpha/Beta
Mills Ranch

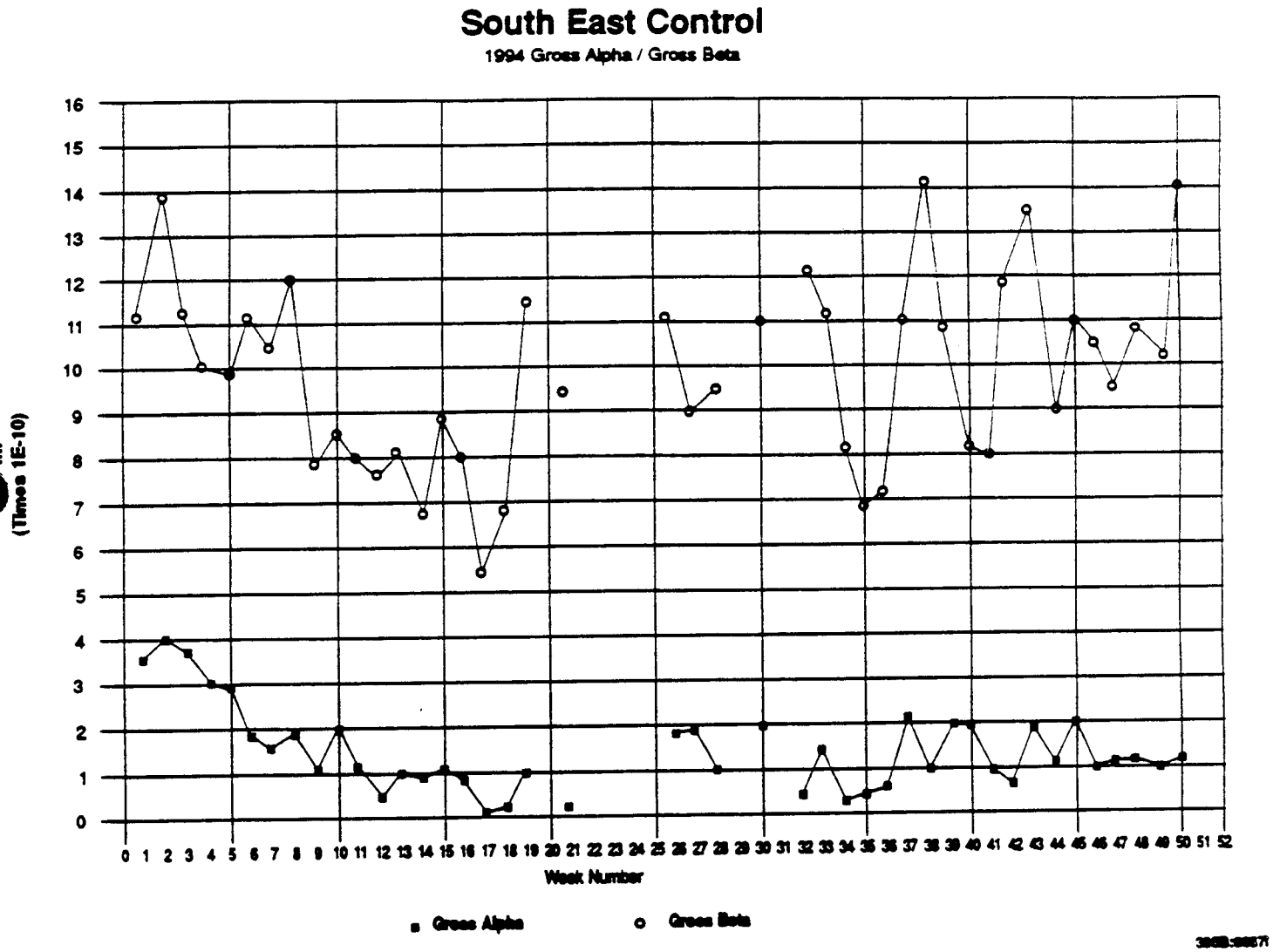

Figure 5-8
1994 Gross Alpha/Beta
Southeast Control

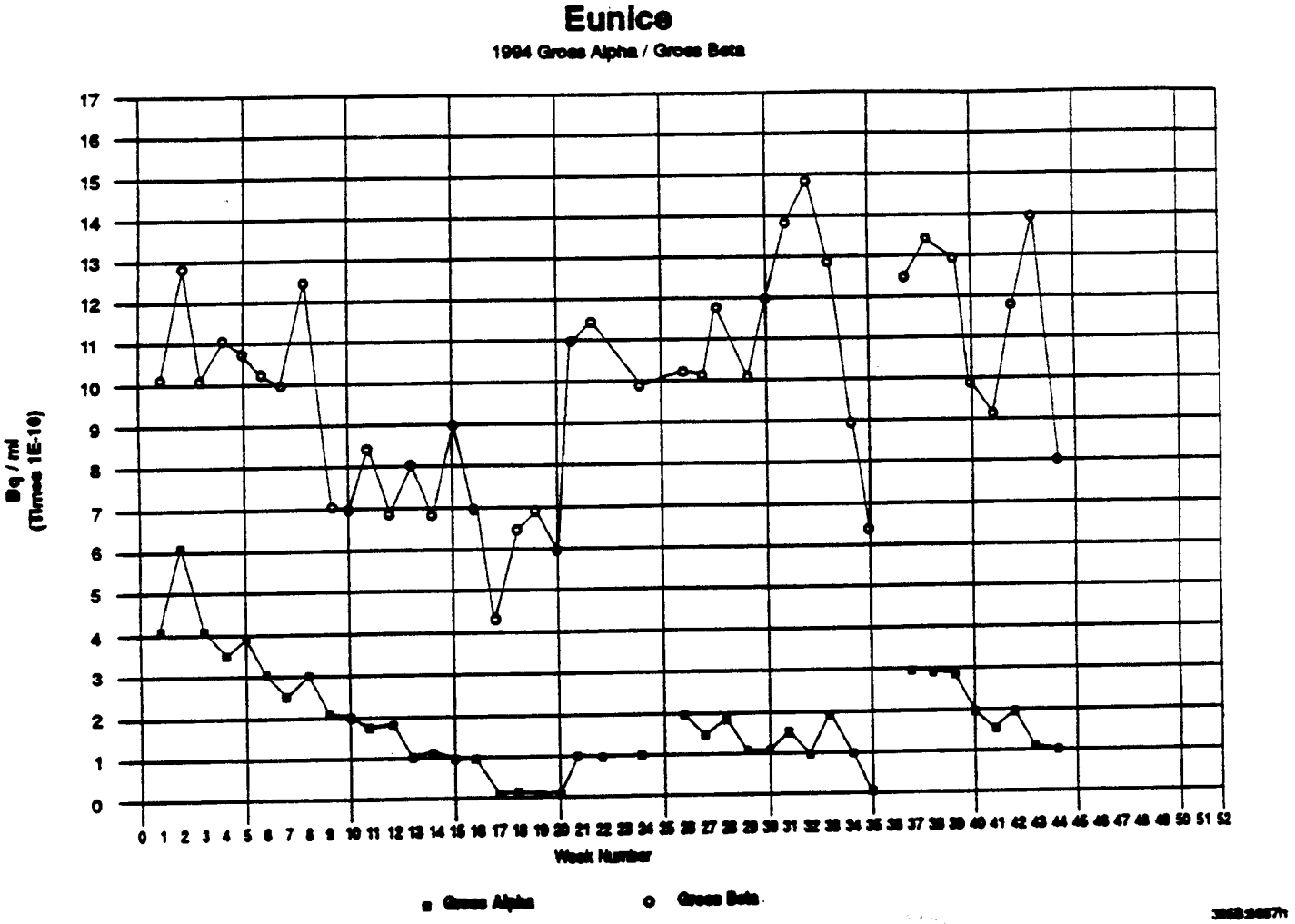

Figure 5-9
1994 Gross Alpha/Beta
Eunice

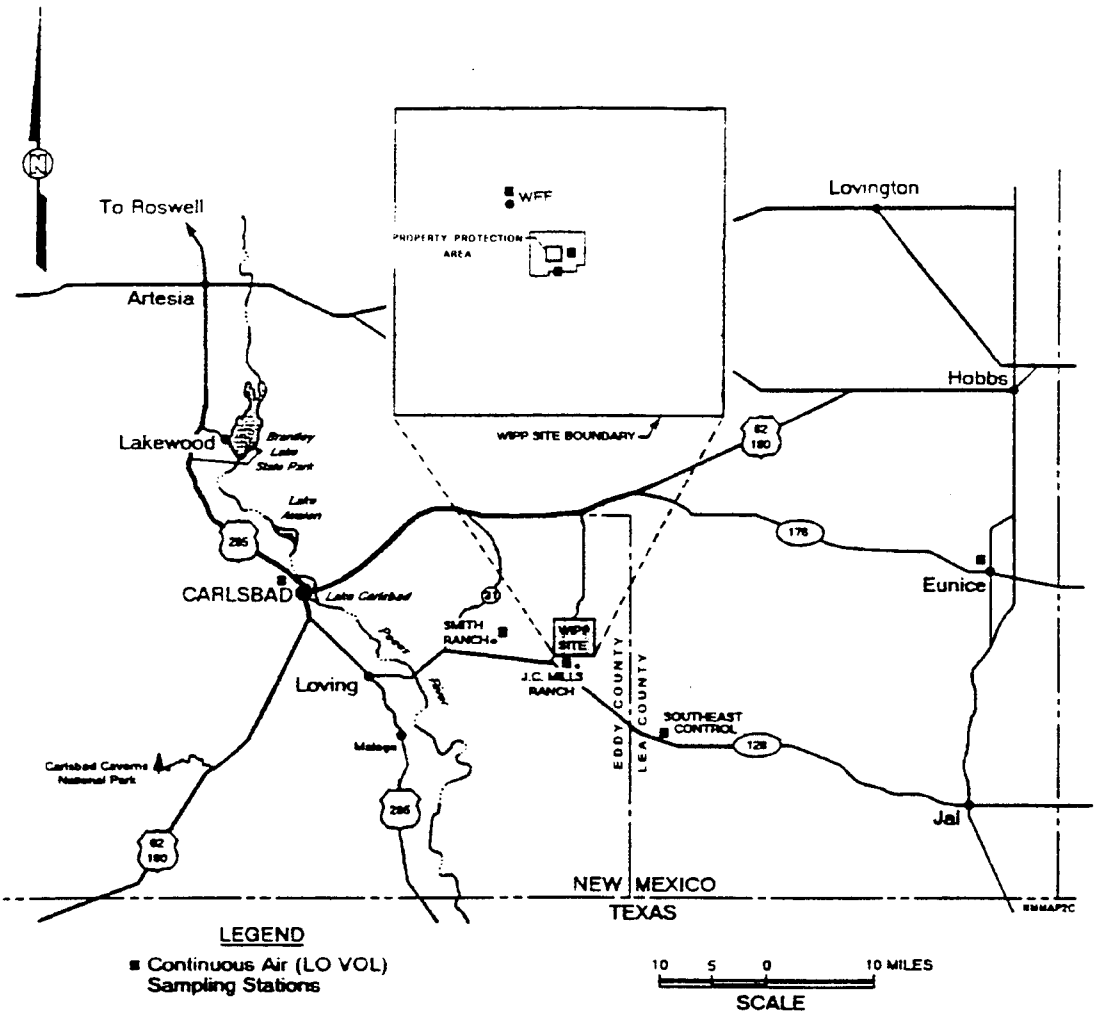

Figure 5-10
Continuous Air Sampling Locations

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CHAPTER 6

ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

Chapter 6
Environmental Nonradiological Program Information

This chapter of the ASER presents and discusses Nonradiological Environmental Sampling (NES) data collected between January 1, 1994, and December 31, 1994. Ecological monitoring at the WIPP include the following six subprograms: meteorological monitoring, air quality monitoring, wildlife population monitoring, surface disturbance and soil monitoring, vegetation monitoring, and water quality monitoring. In addition to the NES programs, Volatile Organic Compounds (VOCs) are monitored to comply with provisions of the WIPP's current No Migration Determination (NMD) and liquid effluent monitoring is conducted in accordance with *Sewage Systems Discharge Monitoring and Compliance* (DP-831) criteria. The results of the environmental monitoring activities and discussions of significant findings are presented in this report.

6.1 Principal Functions of Nonradiological Sampling

The principal functions of the NES are to:

- Detect and quantify the impacts of construction and operational activities from the WIPP on the surrounding ecosystem.
- Continue to administer and update an ecological database for the Los Medaños Area.
- Investigate unusual or unexpected elements in the ecological databases.
- Provide environmental data that are important to the mission of the WIPP project, but which have not or will not be acquired by other programs.

6.2 Meteorology

A principle component of the NES is a primary meteorological (MET) station located 600 meters northeast of the Waste Handling Building. The main function of the MET is to generate data for modeling atmospheric conditions. The station documents standard meteorological measurements of wind speed, wind direction, and temperatures, with dew point and precipitation monitored at ground level. These parameters are measured continuously and the data are stored in the Central Monitoring System (CMS).

6.2 Meteorology (continued)

In addition to the primary meteorological station, the Atmospheric Monitoring Station (AMS) is located 1000 meters northwest of the Waste Handling Building. At the AMS a secondary meteorological station measures and records temperature and barometric pressure at ground level and wind speed and wind direction at 10 meters (30 feet).

6.2.1 Climatic Data

The mean annual temperature for the WIPP area in 1994 was 18°C (64°F). The mean monthly temperatures for the WIPP area ranged from 6°C (43°F) during January to 31°C (88°F) in June. Generally, maximum temperatures occur in June through September, while minimum temperatures occur in December through February as illustrated in Figure 6-3, page 6-15.

The first freezing day of the 1994-95 winter season occurred October 21, with 0°C (32°F). The last freezing day of the 1994-95 winter season was April 23, with a temperature of -3°C (27°F). The maximum temperature recorded was 50°C (122°F) on June 26.

The annual rate of precipitation at the WIPP site for 1994 was 16.58 cm (6.53 in), which is 7.29 cm (2.87 in) below last year's rate. The annual precipitation for 1994 was 31 percent less than that recorded for 1993 and 74 percent less than CY 1992, resulting in profound drought conditions. Figure 6-1, page 6-13, displays the monthly precipitation at the WIPP.

6.2.2 Wind Direction and Wind Speed

The predominate wind direction in the WIPP area was from the southeast sector (135°). However, winds occurring in late spring were primarily from the west. Various weather systems move through this area briefly altering the predominate southeasterly winds and sometimes resulting in violent convectional storms. Wind speed noted as calm (less than 0.5 meters per second [mps]) occurred 7 percent of the time. Winds of 1.4 through 2.7 mps were the most prevalent over 1994, accounting for 25.5 percent of the time. Figure 6-2, page 6-14, displays the annual wind data at the WIPP for CY 1994.

6.3 Environmental Photography

Surface photography was conducted at seven ecological study plots from 1984 through 1993. Photographs are used to document year-to-year surface impacts at the study plots and are archived

6.3 Environmental Photography (continued)

for future reference. The use of environmental photographs, with the exception of aerial photography, was postponed during 1994 pending reassessment. Because archival photographs showed no obvious negative impacts to the surface environment from WIPP activities, this endeavor was deferred for at least one calendar year.

6.4 Air Quality Monitoring

During CY 1994, five classes of pollutant gases are monitored continuously 1000 meters (0.6 mile) northwest of the exhaust shaft at the WIPP site. These gases are sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), hydrogen sulfide (H_2S), and oxides of nitrogen (NO, NO_2, NO_x). The data generated indicates these gases to be at the lower limit of detection--that is, below the baseline concentrations set by the State of New Mexico.

The permissible New Mexico State Standard for the gases monitored at the WIPP are listed below:

Gases	PPM	Intervals
Sulphur Dioxide (SO_2)	**0.02 ppm** **0.10 ppm**	**Annual Average** **24-hour Average**
Carbon Monoxide (CO)	**8.70 ppm**	**Per Eight Hour Average**
Ozone (O_3)	**0.06 ppm**	**Per One Hour Average**
Hydrogen Sulfide (H_2S)	**0.10 ppm**	**Per One-Half Hour Average**
Nitrogen Dioxide (NO_2)	**0.10 ppm**	**24-Hour Average**

Results from CY 1994 demonstrated SO_2, H_2S, and NO_x data values at or below the lower level of detection limits.

During CY 1994, monitoring for ambient levels of noxious gas emissions at the AMS was discontinued per DOE authorization. The AMS was not used to gather regulatory or compliance data, nor was it capable of monitoring point source emissions for demonstrating compliance with mandated air permits.

6.4 Air Quality Monitoring (continued)

The WIPP has completed all regulatory sampling identified in the air permit and does not plan to conduct any additional sampling. Based on permit modeling and current requirements on the backup diesel generators, the WIPP does not anticipate the need for any regulatory air monitoring involving the AMS.

Weekly measurements of Total Suspended Particulates (TSPs) (micrograms per cubic meter) are made from the particulates collected onto glass fiber filters, by the low-volume continuous air sampler at the Far-Field air sampling location. These filters can load with dust particles due to the arid climate of this area; however, this poses no health concern.

6.5 Wildlife Population Monitoring

Since 1985, population density measurements of birds and small nocturnal mammals were performed to annually assess the effects of WIPP activities on wildlife populations. Typically, comparative data analysis was conducted between two outlying or "control" plots and two experimental plots situated in proximity to WIPP operations. A Hantavirus investiation during CY 1994, prompted the temporary postponement of small nocturnal mammal surveys. Re-implementation of these surveys is contingent on the results from the Hantavirus study.

6.5.1 Cooperative Raptor Research and Management Program

The ASER normally encompasses one calendar year's events, however, this section provides a comparison of three consecutive years' data. This three-year investigation is based upon commitments contained in the BLM/DOE Raptor Research Interagency Agreement and by request from external regulatory agencies such as the New Mexico Department of Game and Fish.

CY 1994 culminated a three-year evaluation and reorganization of the Raptor Research and Management Program (CRRMP). With the advent of an Interagency Agreement between the Carlsbad Area Office of the BLM and the WIPP in 1992, the research emphasis of the Raptor Program was modified from questions of a purely scientific nature to questions having direct applications to conservation and resource management. The following provides a summary of results and data comparisons from observations conducted during CY 1992, 1993, and 1994.

6.5.1 Cooperative Raptor Research and Management Program (continued)

During CY 1992, concerns were posed to WIPP researchers by the BLM regarding the status of resident populations of Harris' Hawks. Information disseminated prior to this time contended that a "precipitous decline" had been incurred by the regional population. This suggested decline, however, contradicted reports of the increasing range of the Harris' Hawk, in particular, the expanding northward progression of the species. The diametric opinions related primarily to assertions that the reported declines were attributable to human interference in the areas where the research was being conducted. By way of an Interagency Agreement, the BLM requested an assessment be conducted. The assessment would examine the extent and diversity of the local raptor population, the extent of human impacts on the raptor population, and provide recommendations to incorporate into future management strategies such as BLM Resource Management Plans (RMP) and BLM Habitat Management Plans (HMP).

In an effort to evaluate the dimensionality of the regional population of Harris' Hawks WIPP researchers, in cooperation with BLM biologists, conducted assays encompassing over 25,000 acres (50,600 ha). The survey results indicated that the regional population of Harris' Hawks was more widespread and extensive than previously assumed. During the initial investigation, 74 distinct groups of Harris' Hawks were identified with active nests confirmed in 53. Nest site locations were approximated with hand-held Loran Navigators and Global Positioning System (GPS) instruments. Locations were expressed in latitude/longitude coordinates and logged into an AutoCad program for plotting on maps. Maps with nest locations were remanded to the BLM for incorporation in their resource planning objectives. Accordingly, nest locations became the first priority in the research design.

Twenty delegate groups were subjectively chosen for monitoring in CY 1992. These delegate groups were indicative of the diverse preference of Harris' Hawks to nest substrates and territories. During the first year of the investigation, good-to-average precipitation rates (16.21 in.) and corresponding high prey densities influenced the success of delegate nests that fledged a mean of 2.3 offspring (n=20), an unusually high recruitment rate. Availability of preferable nest substrates, prey densities, habitat alteration/loss, and persecution were the principal limiting factors during this year's investigations.

During 1993, a year of below normal precipitation (9.4 in.), 13 of the 20 delegate groups reinitiated nesting activities and fledged an average of one nestling per nest. WIPP biologists focused primarily on evaluating the impacts of human-related activities on four distinct groups of Harris'

6.5.1 Cooperative Raptor Research and Management Program (continued)

Hawks residing in close proximity to either the WIPP site or areas where activities associated with WIPP were being conducted. The most successful nests during this season were those located in the proximity of agricultural or analogous-type habitat that sustained a vegetative density conducive to higher prey densities. In addition to Harris' Hawk nest sites, nest site locations of divergent species (e.g., Swainson's Hawks, Chihuahuan Raven) were also identified. As with 1992 data, nest locations were approximated with Loran Navigators and provided to the BLM for incorporation into its land use determinations (e.g., oil and gas activities).

CY 1994 was a record-setting year for low precipitation rates (6.53 inches) and high temperatures. The WIPP recorded a high temperature of 122 degrees Fahrenheit on June 26. Of the original 20 delegate groups identified for investigation during 1992, only seven made spring nest attempts and all but two had eggs addle in the nest. This resulted in an average of 0.28 nestlings fledged per nest attempt. A mean of 0.1 offspring fledged per subject group graphically illustrates the disparity between the 1992 and 1994 data. Two nestlings fledged from separate spring nests, however, they have not been observed since two days post-fledging.

Large groups, consisting of as many as 13 mature adult Harris' Hawks are becoming increasingly more common. Mader (1972), was one of the first to document the Harris' Hawks inclination to hunt cooperatively. Subject groups usually consist of breeding adults and related immatures (Dawson and Manaan 1989, 1991b). WIPP biologists surmised that the organization of multiple collectives, consisting of adults, is an inherent response to drought conditions and concurrent low prey availability. Combining the efforts of multiple, experienced hunters greatly increases the likelihood of successful kills. This response to adverse environmental conditions has also been observed in geographically divergent populations of Harris' Hawks (e.g. Arizona).

The New Mexico falconry community participated in the 1994 evaluations by providing assistance in the development of a non-intrusive skeletal measurement technique for sex determination of the Harris' Hawks. The falconers provided an array of measurements from known egg layers and semen donors to WIPP biologists, who then validated the measurement protocol. This cooperative arrangement provided a more accurate, extensive, and less intrusive means for the field collection of data regarding sex determination, in addition to providing an alternative to more aggressive protocol (e.g. laparotomy and/or necropsy). Subsequently the discipline of raptor research has a reliable, safe field procedure for sex determination of Harris' Hawks. The applicability of this protocol to other species of raptors is being investigated.

6.5.1 Cooperative Raptor Research and Management Program (continued)

During 1995, WIPP biologists will examine the relatedness of entities within groups of Harris' Hawks by way of DNA electrophoretic analysis. In addition, investigations into the widely debated territorial demeanor of the species will be conducted to ascertain the historical status of Harris' Hawk territories (e.g. how long have subject territories been established) and the dimensionality (e.g. size and configuration) of subject territories. This data should provide greater insight into the ecology and life history of the species thus affording for the development and progression of more accurate and reliable methods for the conservation and management of the species.

6.5.2 Breeding Bird Densities

During CY 1994, censusing of birds (e.g. emlen transects and 25 mile breeding bird surveys) was discontinued. Nearly 10 years of data revealed no discernable impacts from WIPP activities on densities and distributions of breeding birds. The majority of bird species encountered during these surveys were transients (migrants), consisting primarily of smaller songbirds that pass through the area seasonally. Although migratory birds represent a significant order of birds from the standpoint of population numbers and diversity, the information they provide is not evaluated using them as radiological sentinels. Assessments of environmental conditions using migrating birds as bioindicators are of much merit; however, a re-evaluation of the program resulted in the theory that species that permanently reside in the immediate vicinity of the WIPP would provide more accurate evaluations regarding the impacts of activities associated with the WIPP on the peripheral environment. As resident quail are accessed for radiological biotic analysis, they were chosen as the logical species for an intensive ecological inquiry.

From 1984 through 1993, WIPP avian surveys have identified 98 species that inhabit or migrate through the areas. Extensive avian studies in southeastern New Mexico suggest that there could be up to 300 species onsite. Insect-dependant species continue to predominate onsite nesting species. The most common are Barn Swallows (*Hirundo rustica*) and Western King Birds (*Tyrannus verticalis*).

The usefulness of birds as monitors of radionuclides or any other form of environmental contaminant is proportional to the degree of knowledge regarding their basic ecology, biology, natural history, and particularly, movement and behavior in the area being studied. Failure to take into consideration the behavior, for instance, of a biomonitor such as birds, can result in a possible misinterpretation of data obtained from well-designed, well-intended studies of contaminant body

6.5.2 Breeding Bird Densities (continued)

burdens (Furness and Greenwood 1993). As considerable data has been accrued at the WIPP, pertaining to the radiological analysis of skeletal-muscular tissue in quail, WIPP biologists plan to augment the data by investigating the facets of life history and behavior of resident populations.

Resident quail populations are more tolerant and tend to be more adaptable in response to environmental disturbances, thus providing a more accurate indicator of regional ecological conditions. As the WIPP traps resident quail for radiological tissue analysis, a program is being developed to enhance data collection by investigating the ecology and life history of the quail species of the area. Relationships between quail production and climate, predation, and the effects of hunting in the immediate area will be considered in the final analysis. This information will assist investigators in the following ways: (1) by eliminating seasonal responses of migratory species; and (2) by allowing the opportunity to monitor the influences of WIPP activities on the year-round ecology of resident populations that are concurrently accessed for radiological appraisals.

6.5.3 Small Nocturnal Mammal Population Densities

The reportable presence of the Hantavirus in West Texas and other neighboring states prompted the suspension of small nocturnal mammal appraisals. The appraisals are to be resumed after evidence, to ascertain the status (presence or absence) of the Hantavirus in local populations of small mammals, had been collected and evaluated. Midway through the CY 1993 census period, outbreaks of the virus, not only in New Mexico, but every state bordering New Mexico, was reported.

The primary pathogen for the disease is a virus, endemic in particular populations of mice common to the genus *Peromyscus* (e.g. Brush Mice, Cactus Mice, Deer Mice). In order to legitimately sample small nocturnal mammals, near the WIPP, for the presence of the virus, two personnel from the Environmental Monitoring section of the WIPP attended training seminars. Conducted by the Centers for Disease Control (CDC), in conjunction with the University of New Mexico and the Museum of Southwestern Biology, the training provided instruction in the appropriate protocol for blood extraction techniques and specimen handling. Safety procedures and precautions were implemented using CDC etiquette for blood serum extraction and appropriate preservation techniques for perishable samples.

Hantavirus sampling required five months of preparation and two weeks of subsequent trapping sessions. Approximately 200 traps were set and baited with small grains (e.g., milo, millet) nightly

6.5.3 Small Nocturnal Mammal Population Densities (continued)

for eight nights, resulting in a total of 1600 individual trap attempts. Trapping protocols were modified from the standard practices of alternating trapping grids to focusing on the control grid nearest the WIPP site. Additionally, traps were positioned along proximal roads and near outlying buildings (e.g., meteorological tower building) to increase the likelihood of captures by concentrating efforts in areas conducive to rodent activity. Twenty eight animals were captured and sampled for a success rate of .018 captures per trap night. WIPP personnel extracted blood samples only, no tissue samples were acquired. Specimens were preserved in liquid nitrogen and shipped in dry ice to maintain sample integrity. Diversity of nocturnal species encountered included Ord Kangaroo Rat (*Dipodomys ordi*), Southern Plains Woodrat (*Neotoma micropus*), Silky Pocket Mouse (*Perognathus flavus*), and Cactus Mouse (*Peromyscus eremicus*).

The capture of diurnal species was infrequent as traps were typically baited late in the day, however, several Spotted Ground Squirrels (*Spermophilus spilosoma*) were captured, sampled, and released. The abnormally low numbers of captures, in comparison to previous years trapping events, correlates to the extreme drought conditions during CY 1994. Moreover, in contrast to the previous years' events, no Grasshopper Mice (*Onychomys leucogaster*) were captured.

Analysis of blood samples extracted by WIPP personnel, tested negative for the presence of Hantavirus.

6.6 Surface and Subsurface Soil Monitoring

Surface and subsurface soil monitoring was conducted during CY 1994. A detailed discussion of the nonradiological soil monitoring program is available in the report titled *Summary of the Salt Impact Studies at the WIPP, 1984 to 1990* (DOE/WIPP 92-038). Analytical results from the nonradiological soil sampling program are presented in Appendix B.

6.7 Vegetation Monitoring

Because of drought conditions during CY 1994, the plant community of the Los Medaños area globally exhibited distinctive signs of physiological stress (e.g. stem and leaf necrosis, chlorosis). As no discernable variations in stress could be identified, delineating subtle variations in plants growing near salt tailings piles in comparison to plants growing varying distances from the tailings, evaluations of the effects of salt on proximal plant communities was postponed for at least one

6.7 Vegetation Monitoring (continued)

calendar year. Data collected to date indicate "marginal" to "no negative" impacts on the surrounding plant communities in the form of eolian salt deposition from the mine tailings. The nature of the salt is to become compacted and solidified by the heavy machinery and moisture.

Runoff is collected in the catchment basin, where it is evaporates into the atmosphere and is absorbed into the soil. Any resulting salt crust is then weathered and partially dispersed to the surrounding area. This represents only a minimal deposit. Interestingly, wildlife has been observed using the salt tailings as a source of salt, similar to cattle using salt licks.

6.8 Volatile Organic Compounds (VOC) Monitoring

As stated in Section 3.2.3, **Resource Conservation and Recover Act (RCRA) page 3-7,** the WIPP has developed and implemented a VOC monitoring program to satisfy the air monitoring requirements of the NMD for the WIPP (55 FR 47700). The data resulting from this program are reported in the NMD annual reports submitted to the EPA.

The WIPP VOC Monitoring Program is referenced in the EMP for the WIPP (DOE/WIPP 94-024). Implementing documents specific to the VOC monitoring program include the *VOC Monitoring Plan* (WP 12-6) and *Volatile Organic Compounds Monitoring Quality Assurance Program Plan* (WP 12-7). The *VOC Monitoring Plan* (WP 12-6) is currently under revision. These revisions will reflect present VOC Monitoring activities to support the No-Migration Variance Petition for the Disposal Phase.

6.9 Reclamation of Disturbed Lands

Reclamation activities during CY94 consisted of the decommissioning of numerous existing fenced areas that had been constructed during much of the initial site characterization studies in the late 1970s. In addition to the exclosures, re-bar that had been emplaced within these study areas, to delineate sampling points, was removed to alleviate safety hazards to personnel and livestock. Problem areas (e.g. drainages, eroded slopes, etc.) in existing reclamation sites received additional stabilization measures which include seeding and the spreading of straw. Existing fences left in place, were repaired as necessary.

6.10 Seismic Activity

Geologic structures and tectonism of the Permian Basin are associated with large-scale basin, inter-basin, and basin-margin subsidence or emergence that occurred during the Paleozoic era. The WIPP facility is about 60 miles from the western margin of the Permian Basin. The basin is a broad structural feature made up of a series of Paleozoic sedimentary basins whose last episodes of major subsidence occurred during late Permian time. The area today is characterized by the basin filled with thick evaporite layers and bordered by the Amarillo uplift to the north, the Marathon thrust belt to the south, and the Diablo Platform, Sacramento and Guadalupe Mountain orogenies to the west.

All major tectonic elements of the Permian Basin were completely formed before deposition of the Permian salt-bearing rocks, and the region has been relatively stable since that time. Deep-seated faults are rare, except along the west margin of the basin and no indications of younger deep-seated faults are noted. On June 16, 1978, an earthquake near Snyder, Texas lead researchers to conclude that the earthquake may have been induced from secondary oil recovery operations and hydrocarbon production. The depth of the earthquake closely approximated the bottom of drillholes located in the gas-producing area.

Historically, the seismic information for the WIPP facility region before 1962 was based on chronicles of the effects of those tremors on people, structures, and land forms. Seismicity, prior to 1962, reported in New Mexico, occurred in the Rio Grande area between Albuquerque and Socorro and was associated with a structure known as the Rio Grande Rift. These earthquakes had intensities of Modified Mercalli V or greater, based upon the perceptions of people experiencing these quakes.

Since 1962, virtually all seismic information is based on instrumental data recorded at various seismograph stations. Currently, seismicity is being monitored at the New Mexico Institute of Mining and Technology (NMIMT), Socorro, using data from a seven-station network located at the WIPP (Figure 6-4). The stations are telemetered to the NMIMT Seismological Observatory in Socorro. Readings from the WIPP network stations are combined with readings from an additional New Mexico Tech network which is located in Socorro in the central Rio Grande rift. The annual mean for the operational efficiency of seismic monitoring stations is 94.5 percent.

There were a total of 24 earthquakes located within 300 kilometers of WIPP in 1994. The maximum intensity for an earthquake during CY 1994 registered at a magnitude of 2.7 and was located 34 km south of Snyder,Texas. The nearest earthquakes to the WIPP site were at distances

6.10 Seismic Activity (continued)

greater than 100 kilometers. Earthquake activity within 300 km of the WIPP site remained below normal during 1994. Seismicity near the site has been registered as high as 5.0 in magnitude.

6.11 Liquid Effluent Monitoring

On January 16, 1992, the NMED issued the Discharge Plan (DP-831) for the WIPP sewage facility. The approved Discharge Plan superseded an Emergency Discharge Permit issued in January, 1992. In addition to sewage effluent, the Discharge Plan allows for the disposal of 1500 gallons a day of nonhazardous brines generated by seepage into shaft sumps and from the pumping of observation wells at the site. Characterization samples were collected throughout 1994 to demonstrate that site-generated brines are nonhazardous and can be disposed in the sewage evaporation pond. The DOE submits quarterly Discharge Monitoring Reports (DMRs) to the NMED to demonstrate compliance with the inspection, monitoring, and reporting requirements identified in the plan. No effluent limits were established in DP-831. The NMED Groundwater Protection and Remediation Bureau established a list of analytes to be sampled on a quarterly basis to be used as indicators of sewage system performance. Figures 6-5 through 6-8 depict analytical results from DP-831 sampling activities.

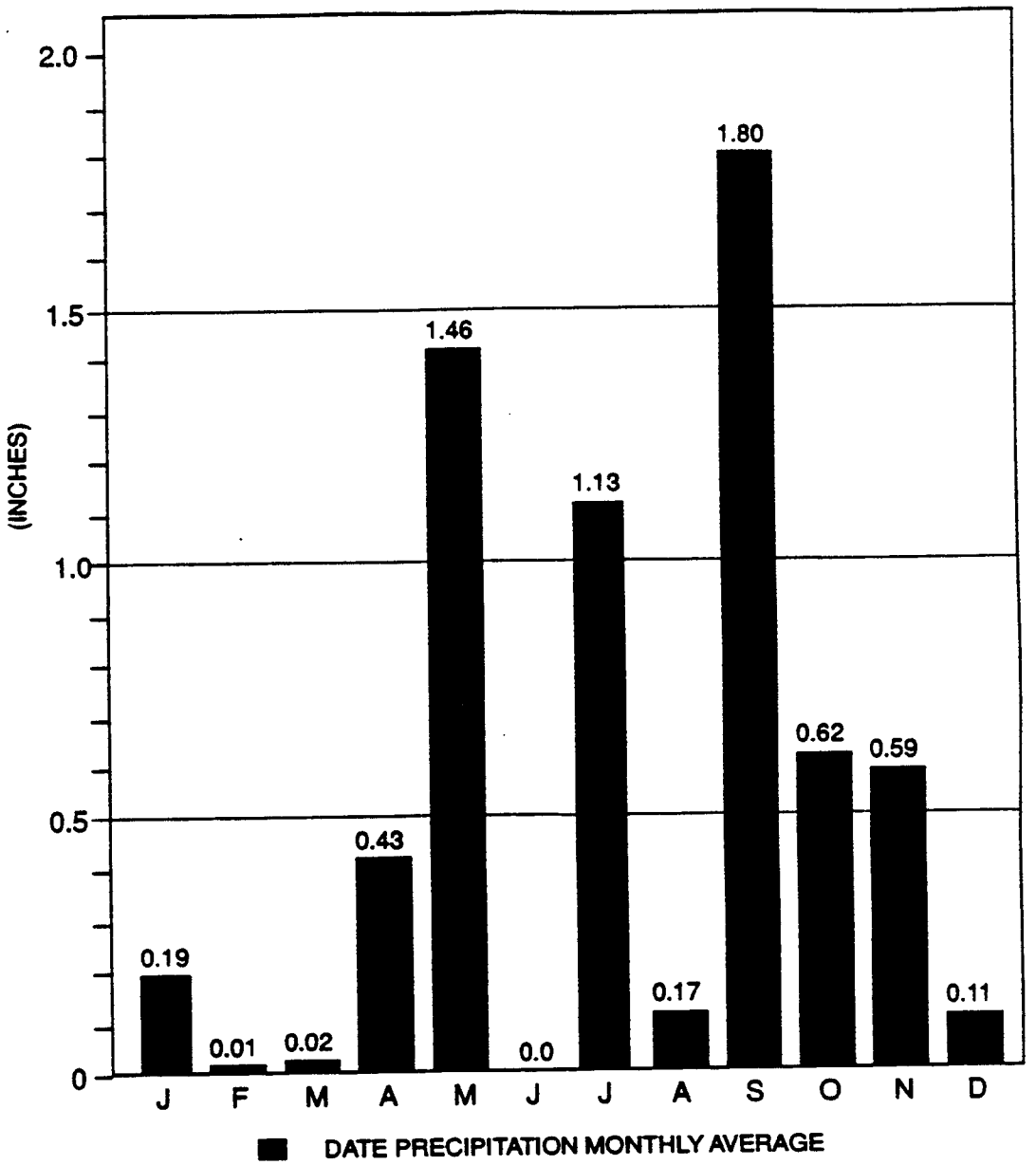


Figure 6-1
1994 Precipitation

WIND ROSE
for the Period
01/01/94 through 12/31/94

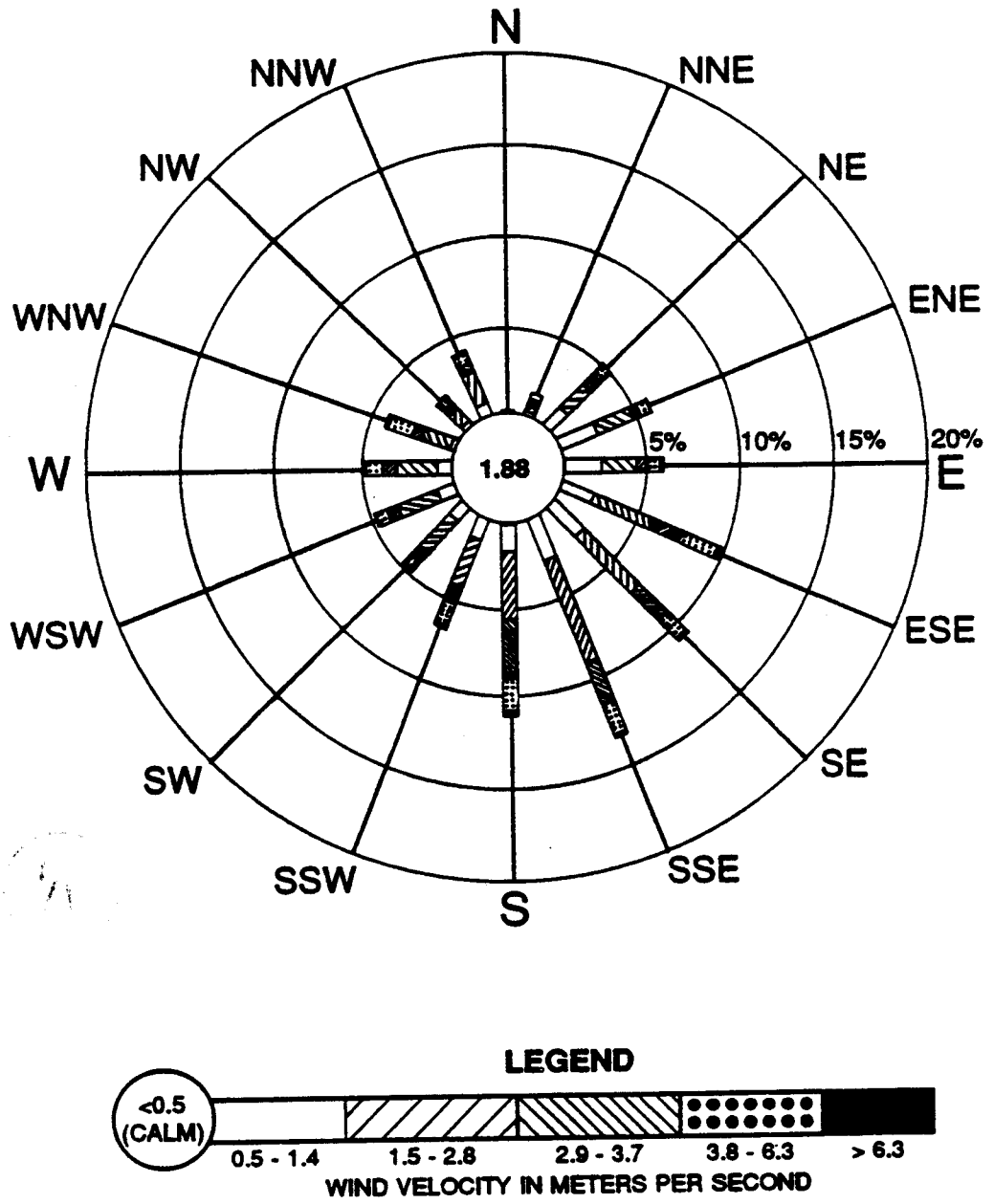


Figure 6-2
Annual Windrose

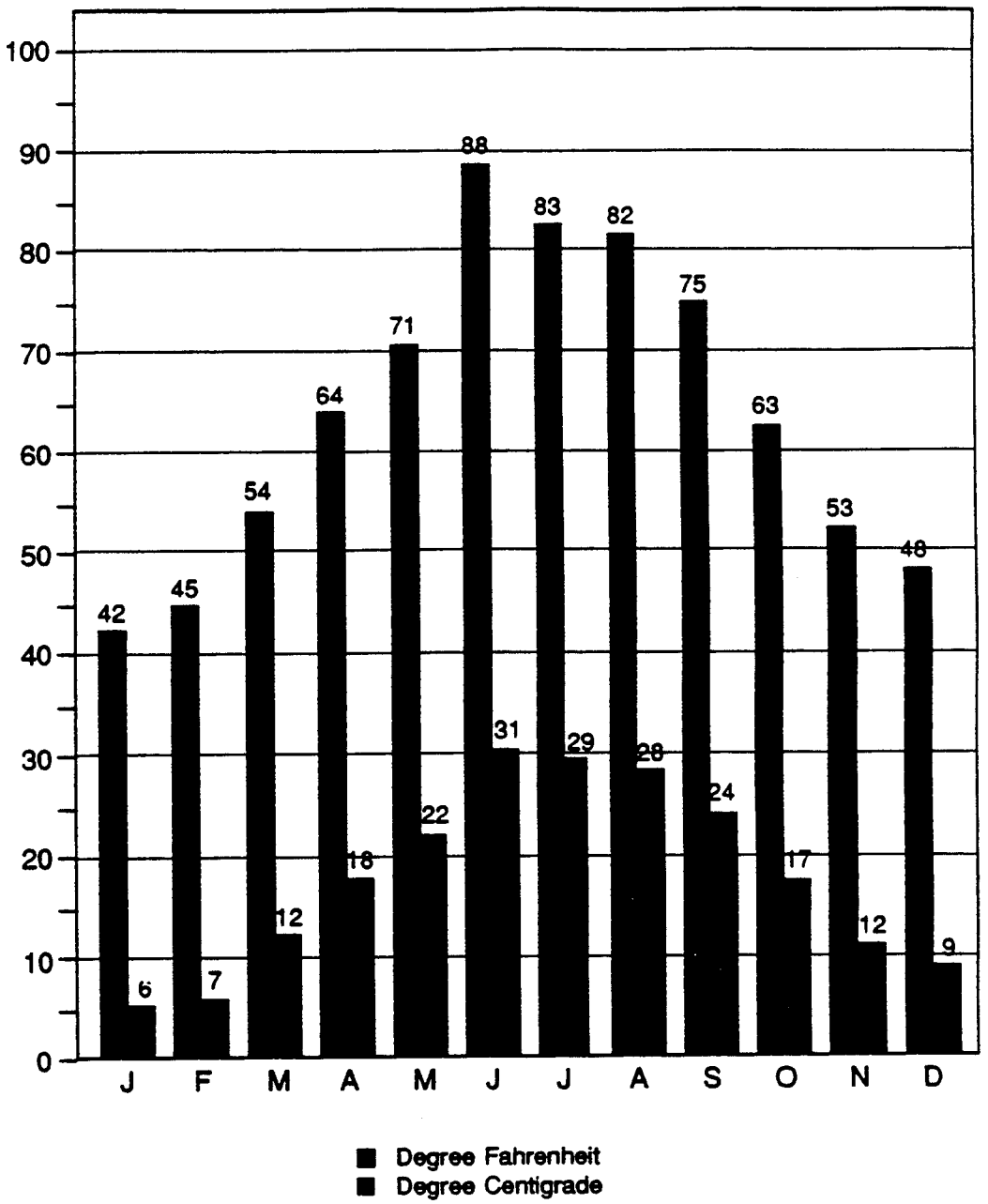
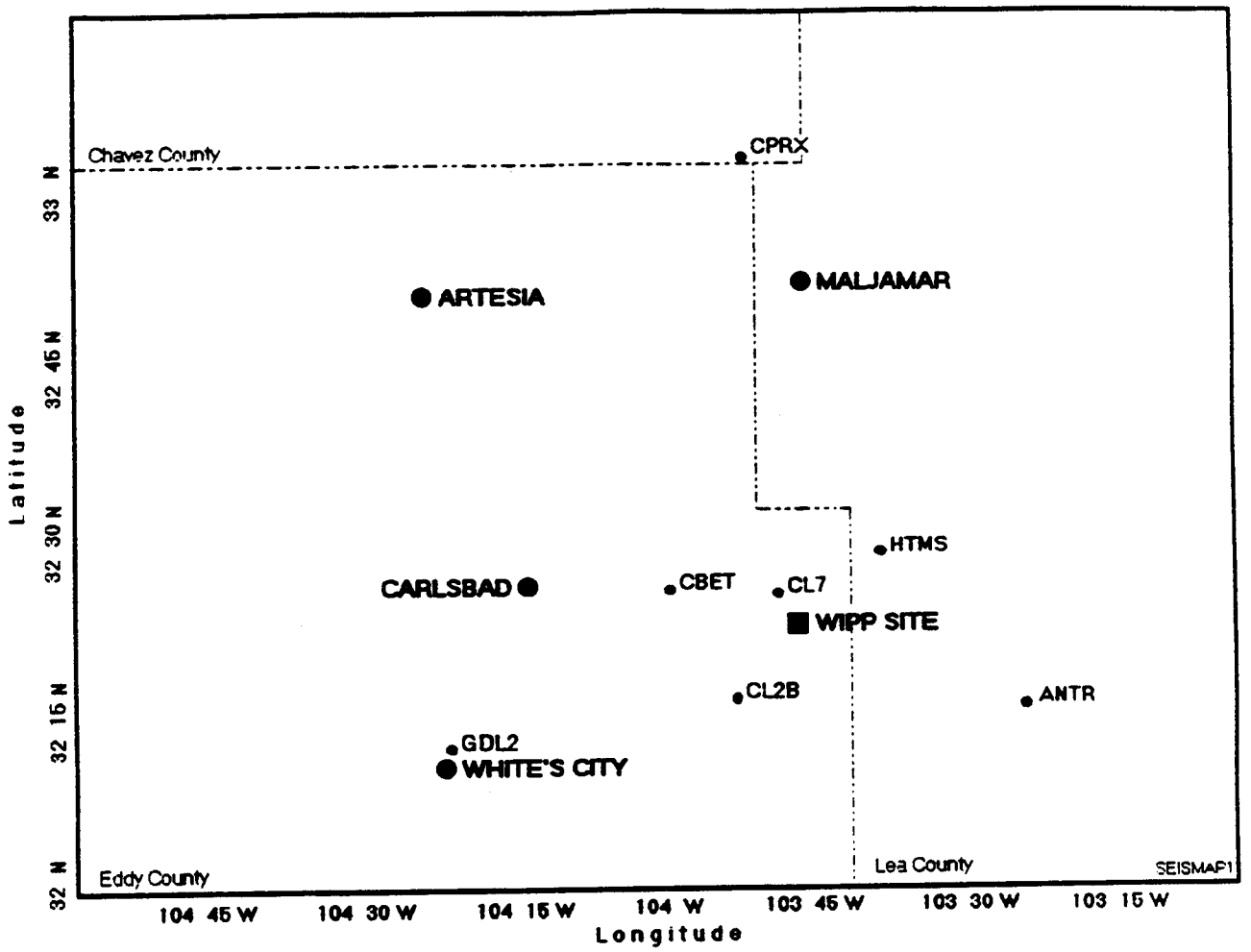


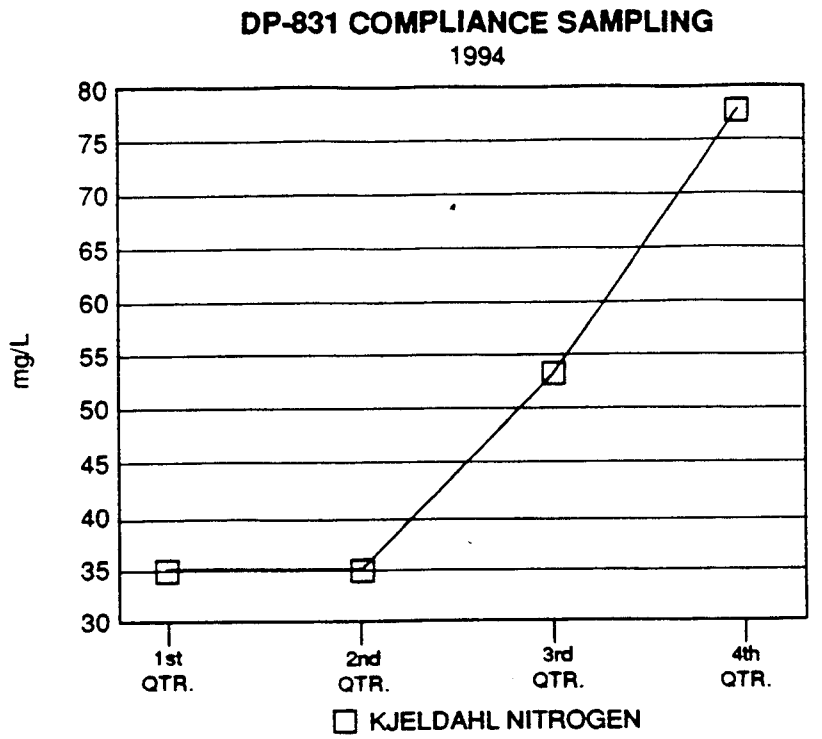
Figure 6-3
1994
Average Monthly Temperatures



Definitions of Aconyms

ANTR - Antelope Ridge
CBET - Carlsbad East Tower
CL2B - Carlsbad Station 2B
CL7- Carlsbad Station 7
CPRX - Caprock
GDL2 - Guadalupe Mountains
HTMS - Hat Mesa

Figure 6-4
WIPP Seismograph Station Locations



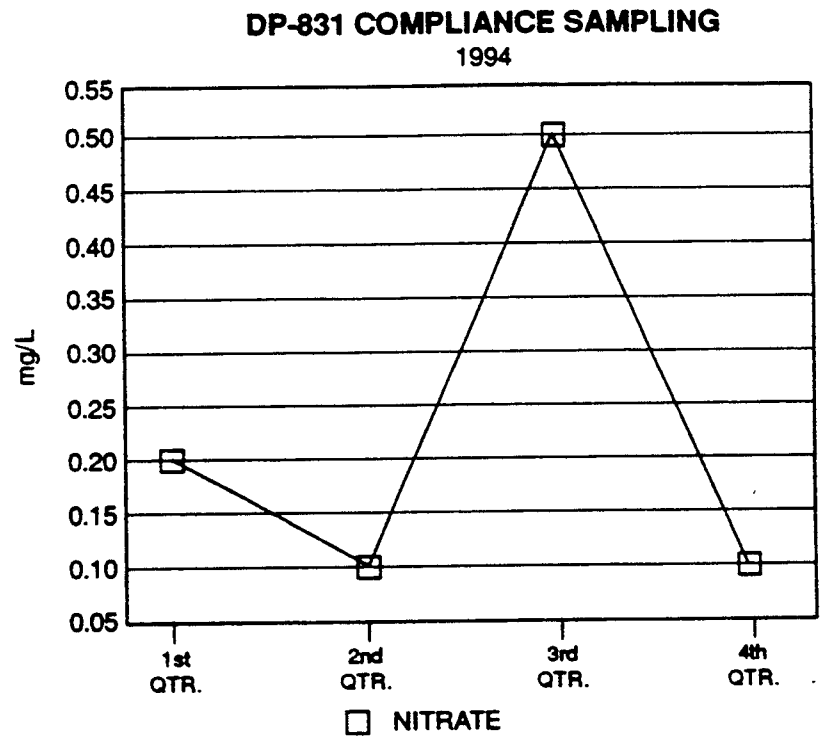
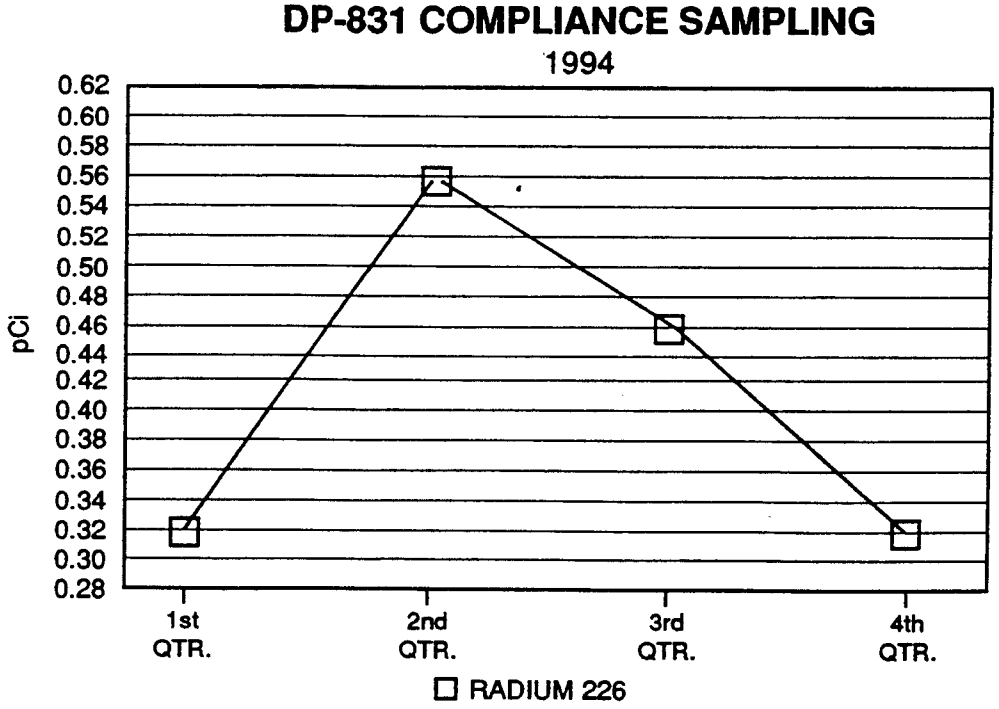


Figure 6-5
DP-831 Compliance Sampling Analysis
Kjeldahl Nitrogen and Nitrates



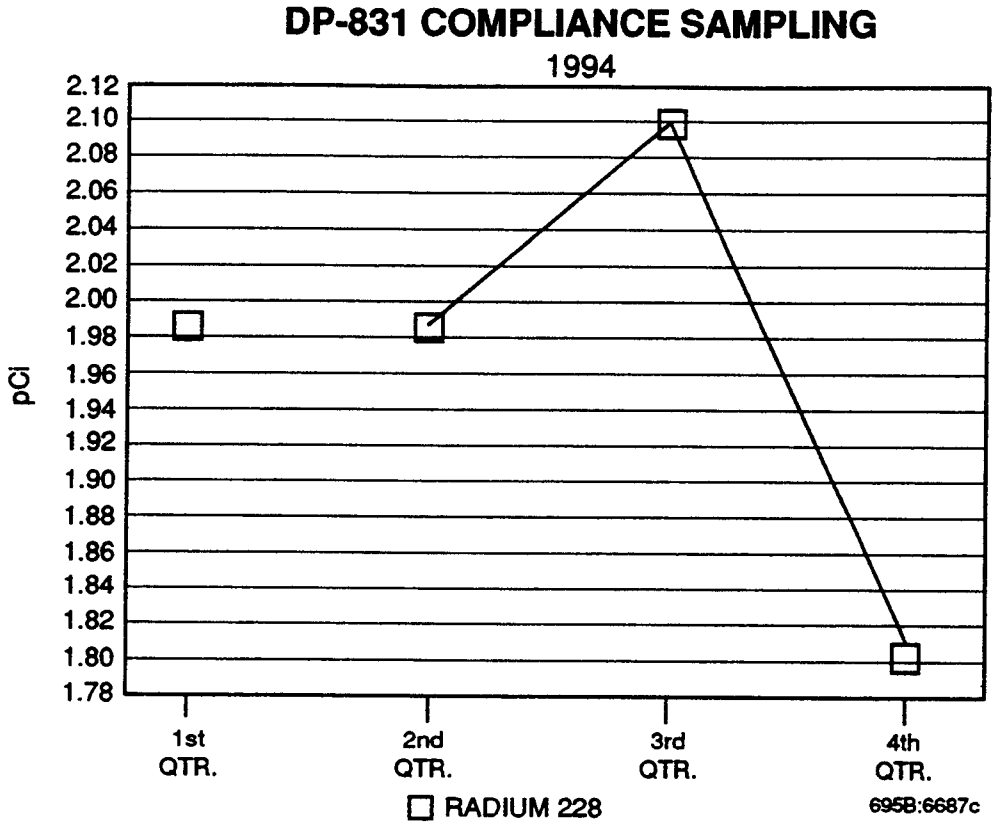
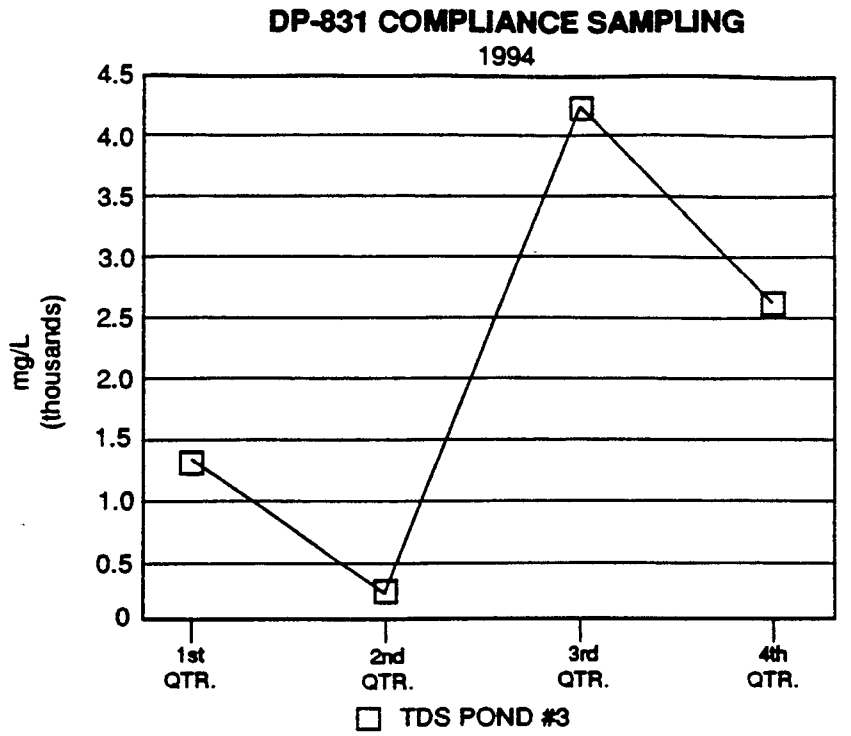


Figure 6-6
DP-831 Compliance Sampling Analysis
Radium 226 and 228



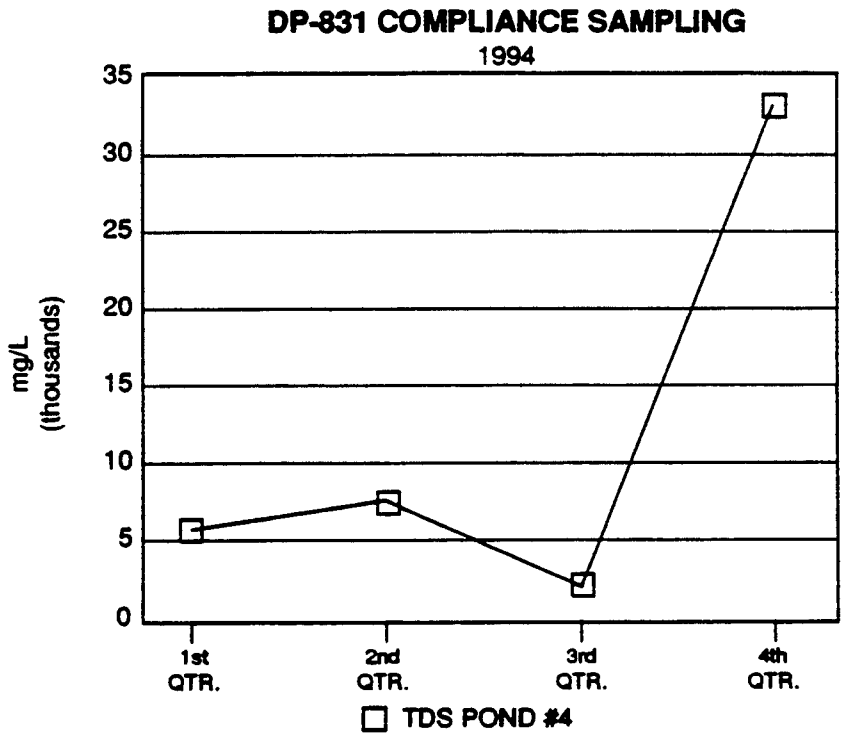


Figure 6-7
DP-831 Compliance Sampling Analysis
TDS - Ponds 3 and 4

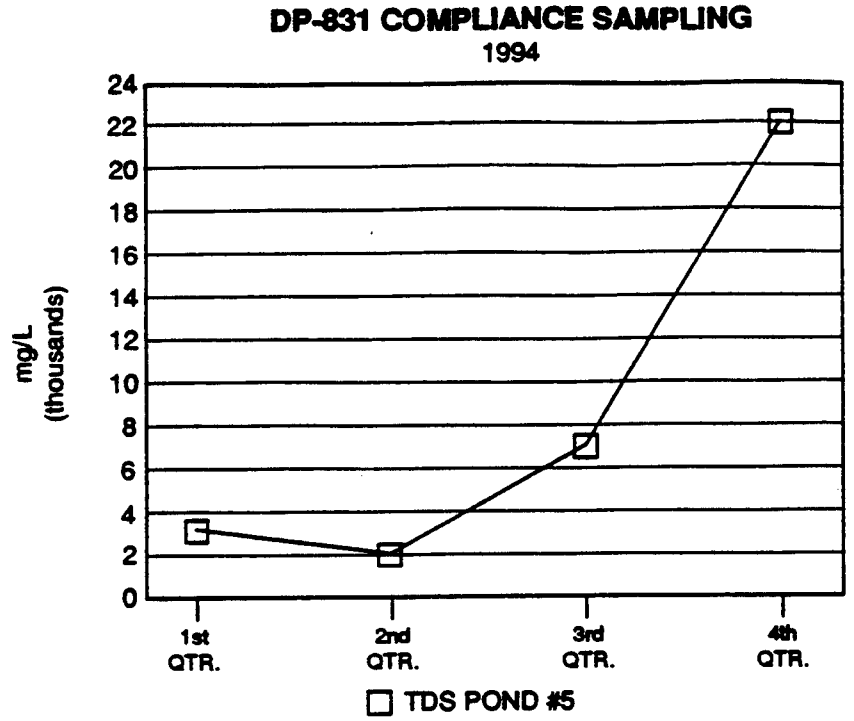


Figure 6-8
DP-831 Compliance Sampling Analysis
TDS - Ponds 5

CHAPTER 7

GROUNDWATER SURVEILLANCE

Chapter 7
Groundwater Surveillance

Current groundwater surveillance activities at the WIPP are outlined in the WIPP *Groundwater Monitoring Program Plan and Procedure Manual* (WP 02-1 Rev 2). This monitoring plan is a Quality Assurance (QA) document that contains program plans for each of the activities performed by groundwater surveillance personnel. In addition, WP 02-1, Rev 2 provides detailed procedures for performing specific activities such as pumping system installations, field parameter analysis and document, and QA records management. Groundwater surveillance activities are also defined in the EMP.

The objective of the Groundwater Surveillance Program (GSP) is to determine the physical and chemical characteristics of groundwater, maintain surveillance of groundwater levels surrounding the WIPP facility, both before and throughout the operational lifetime of the facility, and fulfill the requirements set forth in DOE order 5400.1, *General Environmental Protection Program.*

Background water quality data were collected from 1985 through the 1990 sampling period as reported in DOE/WIPP 92-013, *Background Water Quality Characterization Report for the Waste Isolation Pilot Plant.* This background data will be compared to water quality data collected throughout the operational life of the facility. Pre-operational data gathered in the interim period will be used to strengthen the background data, to evaluate the need to make adjustments to comparison criteria, and to determine future regulatory needs and land-use decisions.

The data obtained by the Water Quality Sampling Program (WQSP) in 1994 supported two major programs at the WIPP: Site Characterization and Performance Assessment in compliance with 40 CFR 191. Each of these programs requires a unique set of analyses and data. Particular sample needs are defined by each program. In addition to the characterization of groundwater, the WQSP supported radionuclide monitoring for the Environmental Analysis and Compliance Section of WIPP. Results of radionuclide sampling are discussed in Chapter 5, *Envrionmental Radiological Program Information,* pages 5-3 through 5-4. The NMED and the EEG were on hand at each sampling event to collect samples for independent evaluation.

The WIPP is located within the Pecos Valley section of the Southern Great Plains physiographic province (Powers et al., 1978). Geologic and lithologic descriptions of the area surrounding the WIPP site can be found in documents such as the EMP, DOE/WIPP 90-008 *Groundwater Protection Management Program Plan*, and USGS 83-4016 (Mercer, 1983). Industries in the vicinity which

Groundwater Surveillance (continued)

could potentially contribute to the pollution of the groundwater are potash mining, oil and gas exploration/production, and cattle ranching.

The Culebra is the most significant water-bearing unit within the vicinity of the WIPP. No known hydrologic connection exists between the repository horizon and the Culebra. Surveillance of hydrological characteristics in the Culebra provides data which can be used to detect changes in water characterization. It also provides additional data for use in hydrologic models designed to predict long term performance of the repository. Data is gathered from 58 well bores; 6 of which are equipped with production-inflated packers to allow groundwater level surveillance of more than one producing zone through the same well bore.

Groundwater Quality data were gathered from nine wells completed in the Culebra. The water quality sampling process has been developed using logistics from groundwater wells originally constructed for characterization, not intended for groundwater monitoring activities. The WIPP site has been given a conditional No-Migration determination and is not required to have a groundwater monitoring program. The original wells are, therefore, being used for surveillance. Most of the wells are constructed with J-55 or K-55 iron casing. In order to decrease the sampling bias created by well construction deficiencies, combined with the low transmissibilities of the formations involved, a labor intensive sampling process has been initiated. Because of the time involved in collection of representative samples, the predetermined wells are sampled only once per year. Sampling episodes are referred to as a "sampling round." Each yearly sampling round consists of the collection of two types of samples: (1) serial samples and (2) final samples. Serial samples are taken periodically while the well is being purged. Key physical and chemical parameters (known as field parameters) are analyzed and compared with past serial sampling data until a chemical steady state has been reached. A chemical steady state is usually defined as +\- 5 percent of the average of the three to five preceding parameter measurements made on the final day of serial sampling from preceeding sampling rounds. Stabilization of these field parameters is a function of purging and is used as an indicator to determine if the groundwater is representative of the zone being sampled. A final sample is collected, once it has been determined that the pumped groundwater has achieved a representative state, and is sent off site to a contract laboratory for analysis. Groundwater surveillance activities during CY 1994 consisted of two separate programs: Groundwater Quality Sampling and Groundwater Level Measurements. These two programs will be discussed below:

7.1 Groundwater Quality

Sampling for groundwater quality was performed at nine well sites during CY 1994 (Figure 7-1, page 7-7). Each well was purged a minimum of 24 hours prior to the commencement of the serial sampling phase. Field analysis for Eh, pH, Specific Gravity, Specific Conductance, Alkalinity, Chloride, Divalent Cations, and Total Iron were performed on a periodic basis during the serial sampling. These field parameters were used as indicators, during the purging process to better determine when the formation water being pumped had reached a representative state. Normally this process required seven to ten days to complete. Following the field analysis of the final serial sample, samples were collected and shipped to an independent, contracted, laboratory for analysis. Parameters of analysis by the contracted laboratory are listed in Table 7-1, page 7-7.

The total gallons of water removed from the Culebra as a result of groundwater surveillance activity was approximately 28,547 gallons throughout the year. The results of final sample analysis show relative consistency when compared to background data. Tables 7-1.1 through 7-1.9, pages 7-9 through 7-17, contain average results of data collected from the Culebra dolomite during 1994 as compared to background data for major constituents of the background matrix. None of the waste stream Volatile Organic Compounds for which analysis were run showed any detectable concentrations.

Water quality of the Culebra in the vicinity of the WIPP is naturally poor and is not suitable for human consumption or for agricultural purposes. The water contains naturally high concentrations of total dissolved solids (TDS) and mineral constituents primarily of chloride, calcium, magnesium, sodium and potassium (Mercer, 1983). The high concentration of TDS results in water of generally poor quality. This has historically posed problems for laboratories performing analysis because the water interferes with the normal operation of standard laboratory equipment such as Atomic Absorption (AA) or Iductively Coupled Argon Plasma (ICAP), causing detection limits to be inconsistent.

7.2 Groundwater Level Surveillance

In October 1988, WIPP was tasked with conducting a Groundwater Level Surveillance Program. Fifty eight well bores were utilized to perform surveillance of six water bearing zones in the WIPP area. The two zones of primary interest are the Culebra and Magenta. Forty six measurements are taken in the Culebra; 10, in the Magenta. Two measurements are taken in the Rustler/Salado contact and Dewey Lake formation; one measurement each is taken in Bell Canyon, Forty-niner, and

7.2 Groundwater Level Surveillance (continued)

unnamed lower member. Locations of groundwater level surveillance sites are pictured in Figure 7-2, page 7-18.

Groundwater elevation measurements in the Culebra indicate that the generalized directional flow of groundwater is north to south in the vicinity of WIPP (Figure 7-3, page 7-19). However, caution should be used when making assumptions based on groundwater level data alone, studies in the Culebra have shown that fluid density variations in the Culebra can affect flow direction (Crawley, 1988 and Davies, 1989). One should also be aware that the fractured media of the Culebra, coupled with variable fluid densities, can cause localized flow patterns to have little or no relationship to general flow patterns (Mercer 1983, Crawley 1988).

Regional groundwater levels taken in the Culebra showed no significant increase or decrease in the water level elevation over the period of January 1994 through December 1994. Localized groundwater elevations near the site showed higher than normal increases in water levels, probably due to shaft grouting activities completed in the latter part of 1993. The groundwater levels in the following wells were effected by shaft grouting activities :

- ERDA - 9
- H-01
- H-02a
- H-02b2
- H-02c
- H-03b2
- H-03b3
- H-14
- H-15
- WIPP-12
- WIPP-18
- WIPP-19
- WIPP-21
- WIPP-22

Groundwater levels in the above listed wells ranged from 1½ to 14 feet increases during the calendar year 1994.

7.2 Groundwater Level Surveillance (continued)

Moderate decreases in three wells, H-04b, H-09b, and H-11b3 may have been influenced by pumping events to obtain water quality data during the latter part of the year. Two other wells, DOE-1 and Cabin Baby Federal Number 1, were influenced by an obstruction in the well casing in DOE-1 and a leaky bridge plug below the Culebra in Cabin Baby. Both problems were corrected in September and October of 1994. Groundwater flow directions in the Magenta appear to be generally from an east to west direction across the WIPP site (Figure 7-4, page 7-20). No studies have been performed in the Magenta to determine spacial variations in the fluid densities of the magnitude studied in the Culebra. It is probable that density variations do occur in the Magenta; therefore, the potential may exist that flow patterns in the Magenta may be affected by variations in fluid density. Also, flow through the fractured media of the Magenta may dictate the behavior of localized flow patterns.

Regional groundwater level measurements taken in the Magenta dolomite indicate that water levels are increasing. All of the wells monitored for groundwater levels in the Magenta dolomite showed a trend for increasing water-level elevations. Two wells, H-01 and H-02b1, showed higher than normal increases; however, these wells are close to the site and were probably influenced by the shaft grouting activities in 1993.

7.3 Program Changes

In September and October 1994 the Department of Energy installed six new wells in the Culebra dolomite for the purpose of water quality sampling (Figure 7-5, page 7-21). The new wells are constructed to EPA standards and have the potential to meet detection monitoring standards. Recommended EPA drilling methods were used to minimize the introduction of foreign materials into the well bore and prevent contamination of the aquifer. The addition of the new wells to the program is expected to improve the quality of the data collected and reduce the time and cost of sampling. The results of the first samples taken from the new wells are expected to be reported in the 1995 Site Environmental Report.

A significant program change developed when Cabin Baby was turned over to private enterprise for the purpose of re-entry for oil and gas development. The request for re-entry was denied by the Bureau of Land Mangement, and the status of Cabin Baby as a monitoring well is pending.

TABLE 7-1
PARAMETERS ANALYZED
DURING
CALENDAR YEAR 1994

SPECIFIC CONDUCTANCE	BORON
SULFATE	CADMIUM
TOTAL DISSOLVED SOLIDS	CALCIUM
TOTAL SUSPENDED SOLIDS	CHROMIUM
DENSITY	IRON
pH	LEAD
ALKALINITY	LITHIUM
BROMIDE	MAGNESIUM
CHLORIDE	MERCURY
FLUORIDE	POTASSIUM
IODIDE	SELENIUM
NITROGEN, NO3 (AS N)	SILICA
TOTAL ORGANIC CARBON	SILVER
TOTAL ORGANIC HALOGENS	SODIUM
PHENOL, TOTAL	CARBON TETRACHLORIDE
ORTHOPHOSPHATE (AS P)	METHYLENE CHLORIDE
ARSENIC	TRICHLOROETHYLENE
BARIUM	1,1,1-TRICHLOROETHANE
BERYLLIUM	FREON-113

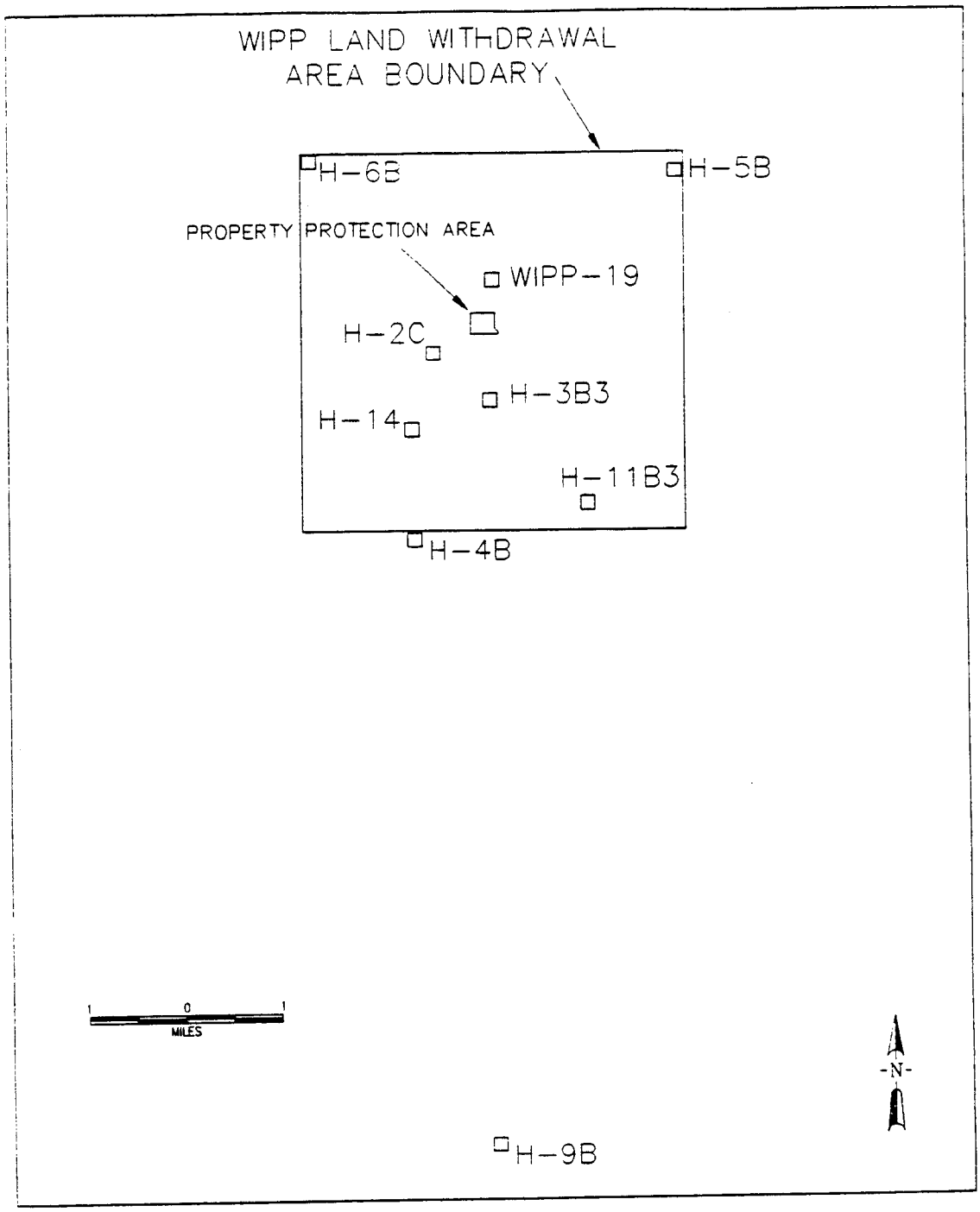


FIGURE 7-1 WATER QUALITY SAMPLING PROGRAM
SAMPLE WELLS 1994

TABLE 7-1.1
H-02c, CULEBRA
ROUND 6 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	12.20	9-12
CALCIUM	751	589-841
IRON	1.32	0-1.9
LITHIUM	0.246	0.26-0.72
MAGNESIUM	239	152-181
POTASSIUM	112	86-119
SODIUM	2,190	0-5,270
ALKALINITY	47.0	52-60
BROMIDE	11.2	0-5
CHLORIDE	3,210	2,396-6,737
FLUORIDE	<3.0	0-2.2
pH	7.63	7.38-8.04
SULFATE	3,035	2,061-3,806
TOTAL DISSOLVED SOLIDS	11,000	7,612-15,689
ARSENIC	<0.006	≤0.014
BARIUM	0.011	<0.05
BERYLLIUM	0.0055	<0.05
CADMIUM	<0.0013	≤0.08
CHROMIUM	<0.005	≤0.4
LEAD	<0.013	≤0.5
MERCURY	<0.002	<0.0002
SELENIUM	<0.006	<0.05
SILICA	9.77	6.1-14
SILVER	<0.013	≤0.20
IODIDE	4.44	1-9
NITRATE AS (N)	<0.10	≤0.30
PHENOLICS	<0.1	≤0.097
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	2.70	5-7
TOTAL ORGANIC HALOGEN	0.0323	≤0.14

TABLE 7-1.2

H-03b3, CULEBRA

ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	24.4	19-32
CALCIUM	1,485	1,193-1,527
IRON	<2.00	0.14-0.47
LITHIUM	0.48	0.15-0.82
MAGNESIUM	768	710-826
POTASSIUM	408	372-534
SODIUM	16,550	16,140-17,900
ALKALINITY	39.6	46-54
BROMIDE	27.8	7-41
CHLORIDE	31,100	26,742-36,838
FLUORIDE	<3.00	1.5-1.8
pH	7.74	6.85-7.66
SULFATE	5,297	4,537-4,823
TOTAL DISSOLVED SOLIDS	54,900	53,130-55,170
ARSENIC	<0.006	<0.10
BARIUM	<0.04	≤0.06
BERYLLIUM	<0.02	≤0.15
CADMIUM	<0.0013	≤0.07
CHROMIUM	<0.01	0.007-0.4
LEAD	<0.013	≤0.58
MERCURY	<0.002	<0.001
SELENIUM	<0.006	<0.50
SILICA	8.09	4.5-13
SILVER	<0.013	≤0.10
IODIDE	<2.00	<2.0
NITRATE AS (N)	<1.00	<0.20
PHENOLICS	<0.10	≤0.033
PHOSPHATE AS (P)	<0.02	≤0.06
TOTAL ORGANIC CARBON	2.65	≤2.0
TOTAL ORGANIC HALOGEN	0.033	0.14-0.42

TABLE 7-1.3
H-04b, CULEBRA
ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	16.7	14-21
CALCIUM	723	684-741
IRON	<2.00	0.48-0.55
LITHIUM	0.39	0.25-0.58
MAGNESIUM	443.5	385-468
POTASSIUM	195	179-281
SODIUM	5,750	5,825-6,255
ALKALINITY	48.0	51-72
BROMIDE	38.5	31-83
CHLORIDE	9,175	1,900-12,000
FLUORIDE	<3.00	1.7-2.2
pH	7.38	6.38-7.82
SULFATE	5,585	4,447-6,513
TOTAL DISSOLVED SOLIDS	19,000	17,810-23,050
ARSENIC	<0.006	<0.10
BARIUM	<0.04	<0.10
BERYLLIUM	<0.02	<0.05
CADMIUM	<0.0017	<0.005
CHROMIUM	<0.01	≤0.30
LEAD	<0.013	<0.05
MERCURY	<0.002	≤0.0017
SELENIUM	<0.006	<0.05
SILICA	12.4	5.8-14
SILVER	0.013	<0.10
IODIDE	<2.00	≤2.0
NITRATE AS (N)	<0.10	<0.10
PHENOLICS	<0.10	<0.026
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	2.77	3.0-5.0
TOTAL ORGANIC HALOGEN	0.4315	0.06-0.04

TABLE 7-1.4

H-05b, CULEBRA

ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	33.9	28-35
CALCIUM	1,490	1,205-1,875
IRON	<2.0	1.8-3.2
LITHIUM	0.88	0.6-1.3
MAGNESIUM	1,880	1,586-2,094
POTASSIUM	1085	1,014-1,362
SODIUM	49,800	44,528-65,955
ALKALINITY	31.1	39-47
BROMIDE	68.2	24-99
CHLORIDE	86,850	84,885-91,835
FLUORIDE	<3.0	0.7-1.2
pH	7.06	6.88-7.11
SULFATE	9,085	5,914-7,846
TOTAL DISSOLVED SOLIDS	157,000	142,508-164,093
ARSENIC	<0.10	<0.1
BARIUM	<0.02	<0.5
BERYLLIUM	<0.02	<0.05
CADMIUM	<0.0010	≤0.11
CHROMIUM	<0.005	≤0.3
LEAD	<0.013	≤1.0
MERCURY	<0.002	≤0.0005
SELENIUM	<0.05	≤7.3
SILICA	5.43	<21
SILVER	0.024	≤0.1
IODIDE	1.82	<2.0
NITRATE AS (N)	0.27	≤0.4
PHENOLICS	<0.10	≤0.51
PHOSPHATE AS (P)	<0.02	<0.13
TOTAL ORGANIC CARBON	<0.5	≤4.0
TOTAL ORGANIC HALOGEN	0.58	≤7.6

TABLE 7-1.5

H-06b, CULEBRA

ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	9.15	7.7-10.7
CALCIUM	2,390	1,702-2,138
IRON	<2.00	0.2-0.6
LITHIUM	7.58	0.3-0.7
MAGNESIUM	1,110	791-1,005
POTASSIUM	463	330-858
SODIUM	19,700	14,230-17,710
ALKALINITY	75.3	91-101
BROMIDE	24.4	12-62
CHLORIDE	35,400	28,816-34,462
FLUORIDE	<3.00	1.2-1.5
pH	8.00	6.18-7.37
SULFATE	3,402	3,093-3,527
TOTAL DISSOLVED SOLIDS	82,250	58,831-64,589
ARSENIC	<0.005	<0.5
BARIUM	0.04	< 0.1
BERYLLIUM	<0.02	0.05
CADMIUM	<0.001	<0.05
CHROMIUM	<0.005	0.22-0.45
LEAD	<0.013	≤0.03
MERCURY	<0.0002	≤0.0012
SELENIUM	<0.005	≤1.3
SILICA	15.3	8.3-25
SILVER	<0.015	≤0.1
IODIDE	<2.0	<2.0
NITRATE AS (N)	<0.20	≤0.2
PHENOLICS	<0.10	0.004-0.016
PHOSPHATE AS (P)	<0.02	≤0.02
TOTAL ORGANIC CARBON	0.73	≤7.0
TOTAL ORGANIC HALOGEN	0.50	0.16-3.0

TABLE 7-1.8

H-09b, CULEBRA

ROUND 5 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	<0.13	0.5-0.9
CALCIUM	634	554-672
IRON	<0.5	≤0.11
LITHIUM	0.15	0.15-0.23
MAGNESIUM	144	128-155
POTASSIUM	6.49	6.8-8.6
SODIUM	131	98-163
ALKALINITY	93.8	120
BROMIDE	<2.00	0.5-1.3
CHLORIDE	172.5	155-210
FLUORIDE	<3.00	2.5-3.7
pH	7.17	6.99-7.81
SULF)E	2,075	1,382-1,918
TOTAL DISSOLVED SOLIDS	2,545	3,091-3,489
ARSENIC	<0.006	<0.01
BARIUM	0.011	<0.2
BERYLLIUM	<0.005	<0.05
CADMIUM	<0.0013	≤0.05
CHROMIUM	<0.01	<0.1
LEAD	<0.013	<0.50
MERCURY	<0.002	≤0.0041
SELENIUM	<0.006	<0.5
SILICA	28.4	12-30
SILVER	<0.013	≤0.1
IODIDE	<2.00	<2.0
NITRATE AS (N)	0.18	0.11-0.5
PHENOLICS	<0.10	<0.05
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	<0.5	≤3.0
TOTAL ORGANIC HALOGEN	0.06	≤0.22

TABLE 7-1.7
H-11b3, CULEBRA
ROUND 8 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	28.4	29-31
CALCIUM	1,685	1,329-1,655
IRON	0.96	<1.8
LITHIUM	6.885	6.5-6.6
MAGNESIUM	1,290	1,838-1,272
POTASSIUM	887	854-890
SODIUM	39,000	35,169-45,432
ALKALINITY	47.4	44-68
BROMIDE	46.1	18-90
CHLORIDE	65,500	57,963-72,497
FLUORIDE	<3.00	1.0-1.2
pH	7.23	6.95-7.22
SULFATE	7,110	5,843-7,397
TOTAL DISSOLVED SOLIDS	118,500	113,795-123,895
ARSENIC	<0.006	≤0.15
BARIUM	0.014	<0.10
BERYLLIUM	0.005	<0.05
CADMIUM	<0.0013	0.06-0.09
CHROMIUM	<0.01	0.32-.40
LEAD	0.013	≤0.60
MERCURY	<0.002	<0.0004
SELENIUM	<0.006	<0.50
SILICA	6.38	4.1-15
SILVER	<0.013	0.1-0.2
IODIDE	<2.00	<2.0
NITRATE AS (N)	<0.1	<0.30
PHENOLICS	<0.10	≤0.02
PHOSPHATE AS (P)	<0.02	≤0.04
TOTAL ORGANIC CARBON	0.89	≤3.0
TOTAL ORGANIC HALOGEN	0.91	≤1.5

TABLE 7-1.8

H-14, CULEBRA

ROUND 7 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	9.81	11
CALCIUM	1,627	1,584-2,129
IRON	1.28	0.1-0.8
LITHIUM	0.47	.039-0.56
MAGNESIUM	497	451-613
POTASSIUM	224	233-257
SODIUM	3,360	2,750-4,184
ALKALINITY	32.8	35-43
BROMIDE	10.9	9-18
CHLORIDE	8,872	6,954-8,779
FLUORIDE	<3.00	0.1-2.8
pH	7.54	5.89-8.58
SULFATE	2,025	1,209-2,291
TOTAL DISSOLVED SOLIDS	18,925	14,066-19,867
ARSENIC	<0.006	<0.05
BARIUM	0.041	<0.05
BERYLLIUM	<0.014	<0.05
CADMIUM	<0.0022	≤0.06
CHROMIUM	<0.01	0.2-0.4
LEAD	<0.013	≤0.5
MERCURY	<0.002	≤0.0004
SELENIUM	<0.006	<0.05
SILICA	11.00	5.5-14
SILVER	<0.013	≤0.1
IODIDE	<2.00	<2.0
NITRATE AS (N)	<.10	≤0.40
PHENOLICS	<0.10	0.068-0.14
PHOSPHATE AS (P)	<0.02	≤0.05
TOTAL ORGANIC CARBON	1.27	≤2.0
TOTAL ORGANIC HALOGEN	0.11	0.08-1.1

TABLE 7-1.9

WIPP-18, CULEBRA

ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	35.6	27-34
CALCIUM	2,110	1,441-1,919
IRON	2.46	≤2.9
LITHIUM	0.59	0.3-1.1
MAGNESIUM	1335	961-2,239
POTASSIUM	670	585-813
SODIUM	32,900	23,982-32,658
ALKALINITY	44.4	51-70
BROMIDE	45.3	22-126
CHLORIDE	41,000	33,281-54,526
FLUORIDE	<3.00	0.8-1.1
pH	7.29	6.75-7.33
SULFATE	6,790	5,897-6,783
TOTAL DISSOLVED SOLIDS	78,450	68,389-103,151
ARSENIC	<0.006	<0.5
BARIUM	<0.02	<0.50
BERYLLIUM	<0.03	<0.50
CADMIUM	<0.0016	<0.50
CHROMIUM	<0.005	≤2.0
LEAD	<0.013	<5.0
MERCURY	<0.002	<0.002
SELENIUM	<0.006	<0.50
SILICA	7.25	≤4.40
SILVER	<0.015	<1.0
IODIDE	<2.00	<2.0
NITRATE AS (N)	<0.10	≤0.12
PHENOLICS	<0.1	≤0.019
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	1.10	2-7
TOTAL ORGANIC HALOGEN	.039	0.57-3.2

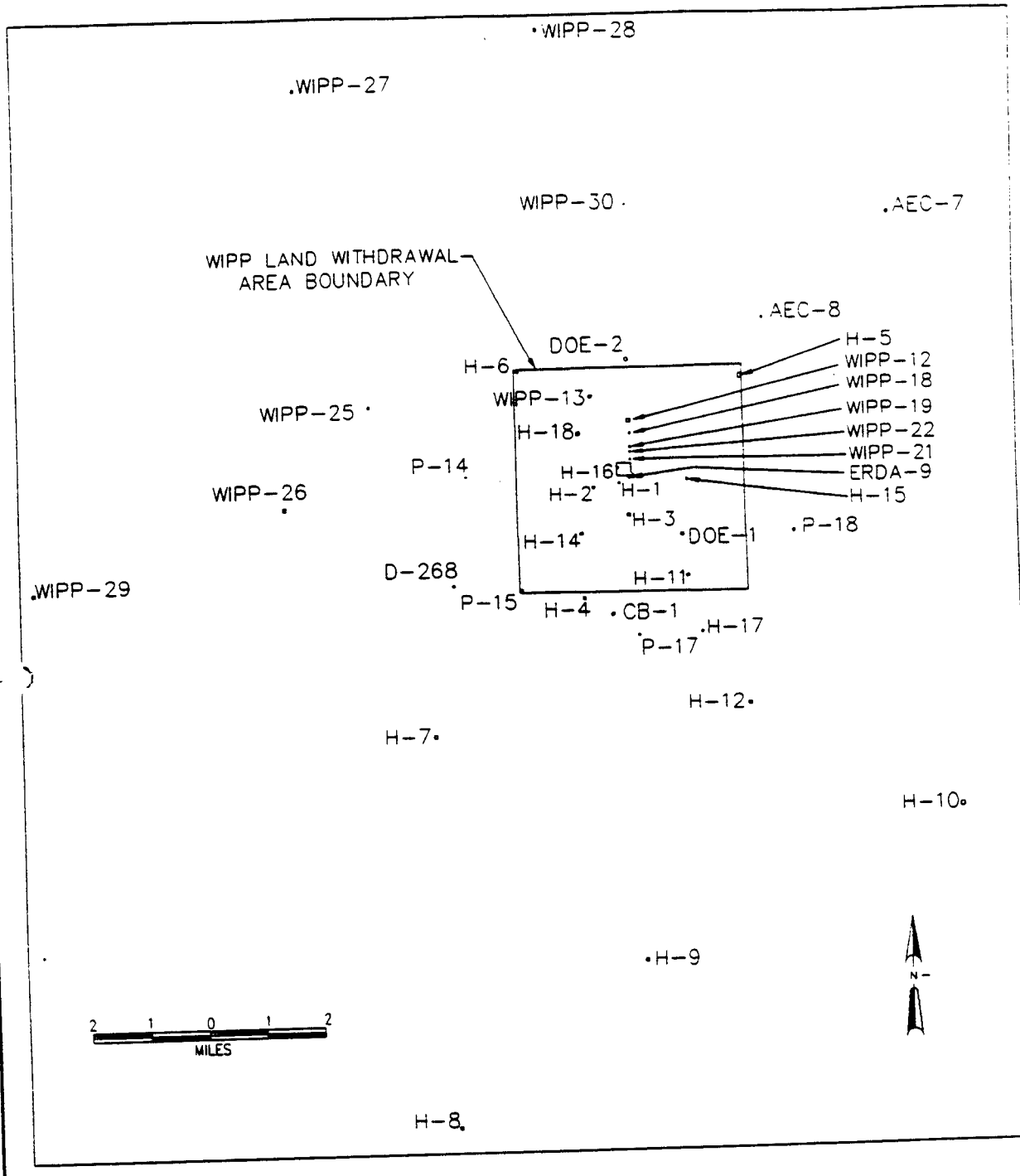


FIGURE 7-2 GROUND WATER LEVEL SURVEILLANCE WELLS

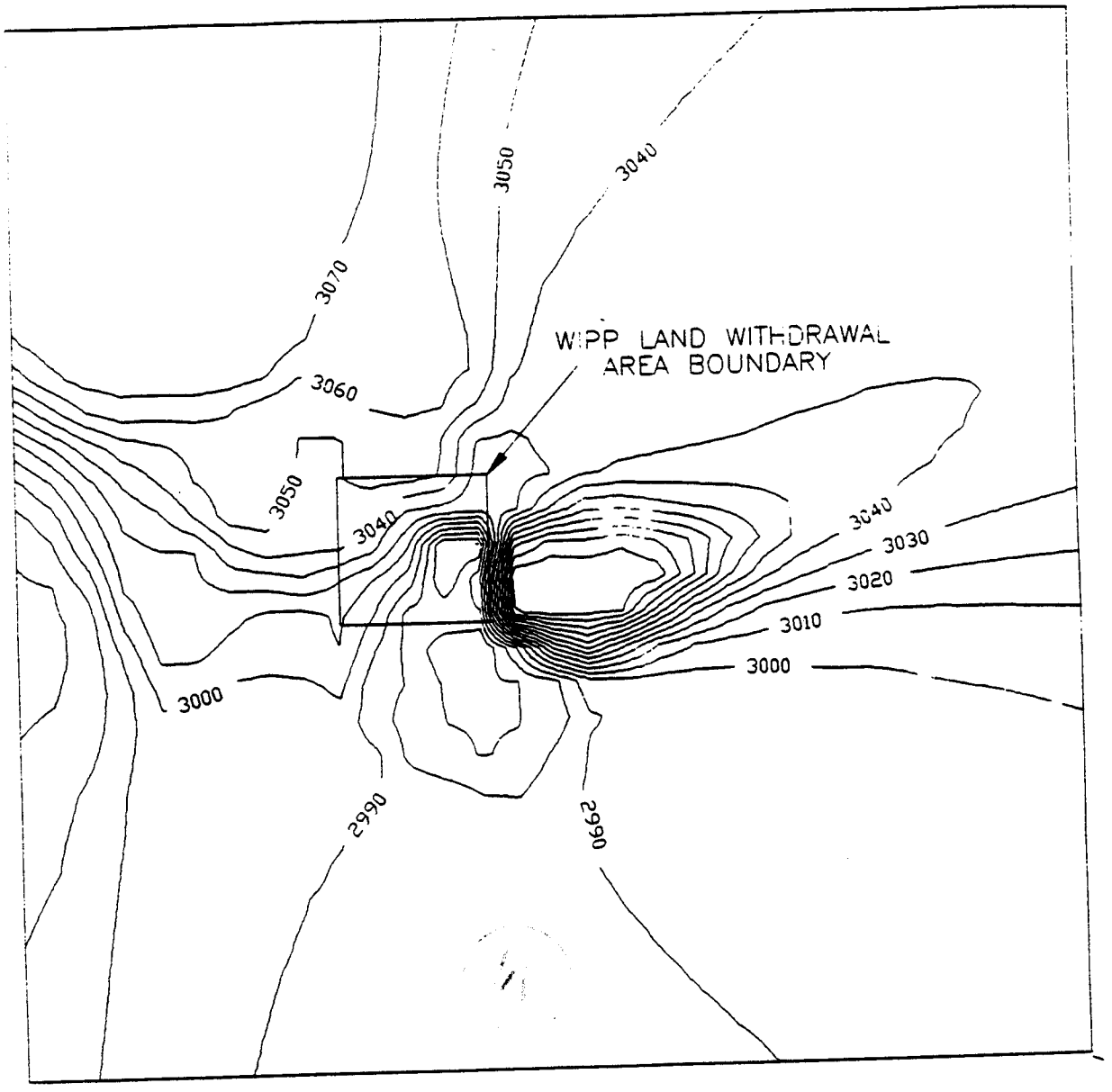


FIGURE 7-3 POTENTIOMETRIC SURFACE OF THE CULEBRA DOLOMITE MEMBER OF THE RUSTLER FORMATION NEAR THE WIPP SITE AS OF 12-94

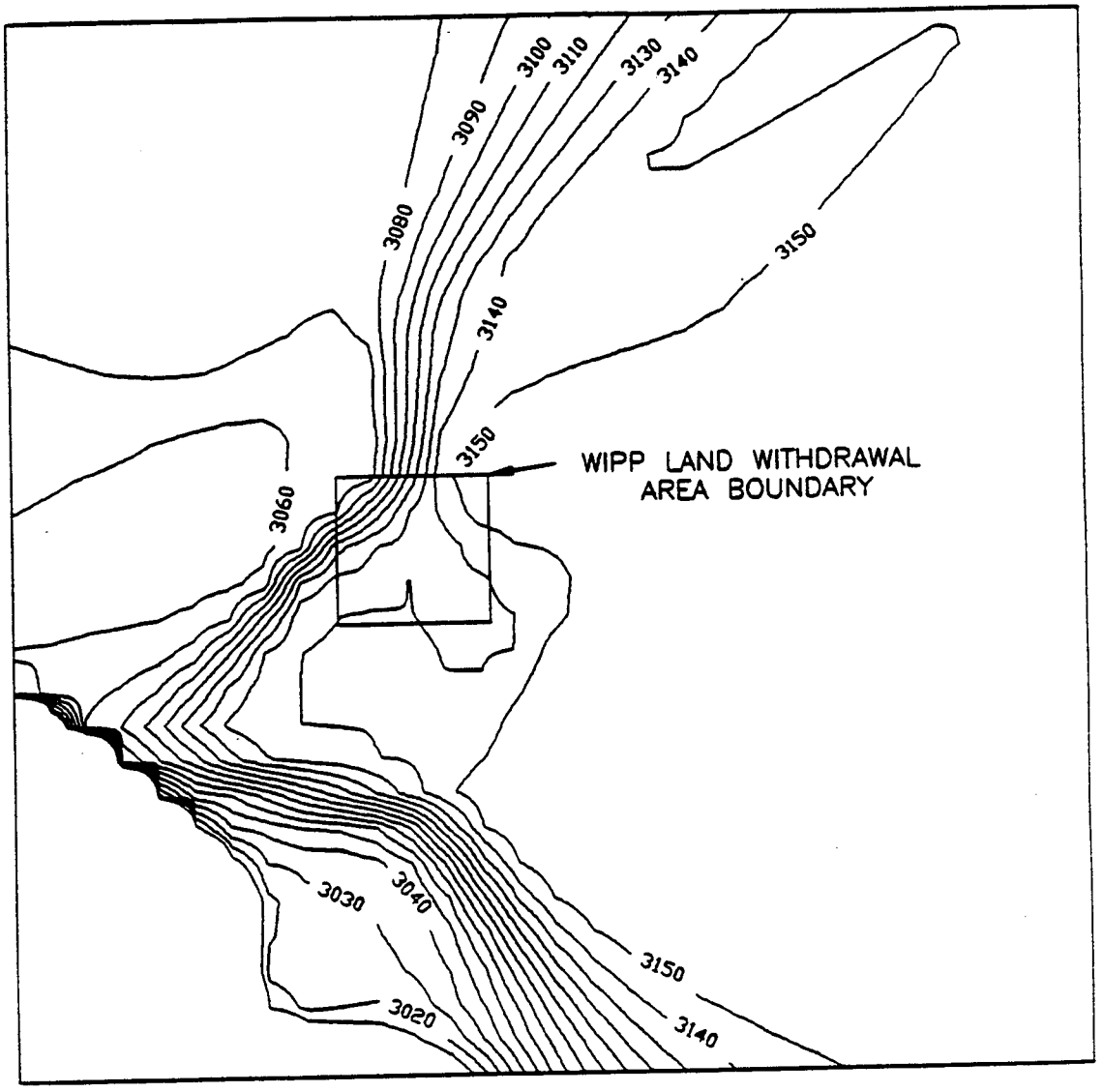


FIGURE 7–4 POTENTIOMETRIC SURFACE OF THE MAGENTA DOLOMITE MEMBER OF THE RUSTLER FORMATION NEAR THE WIPP SITE AS OF 12–94

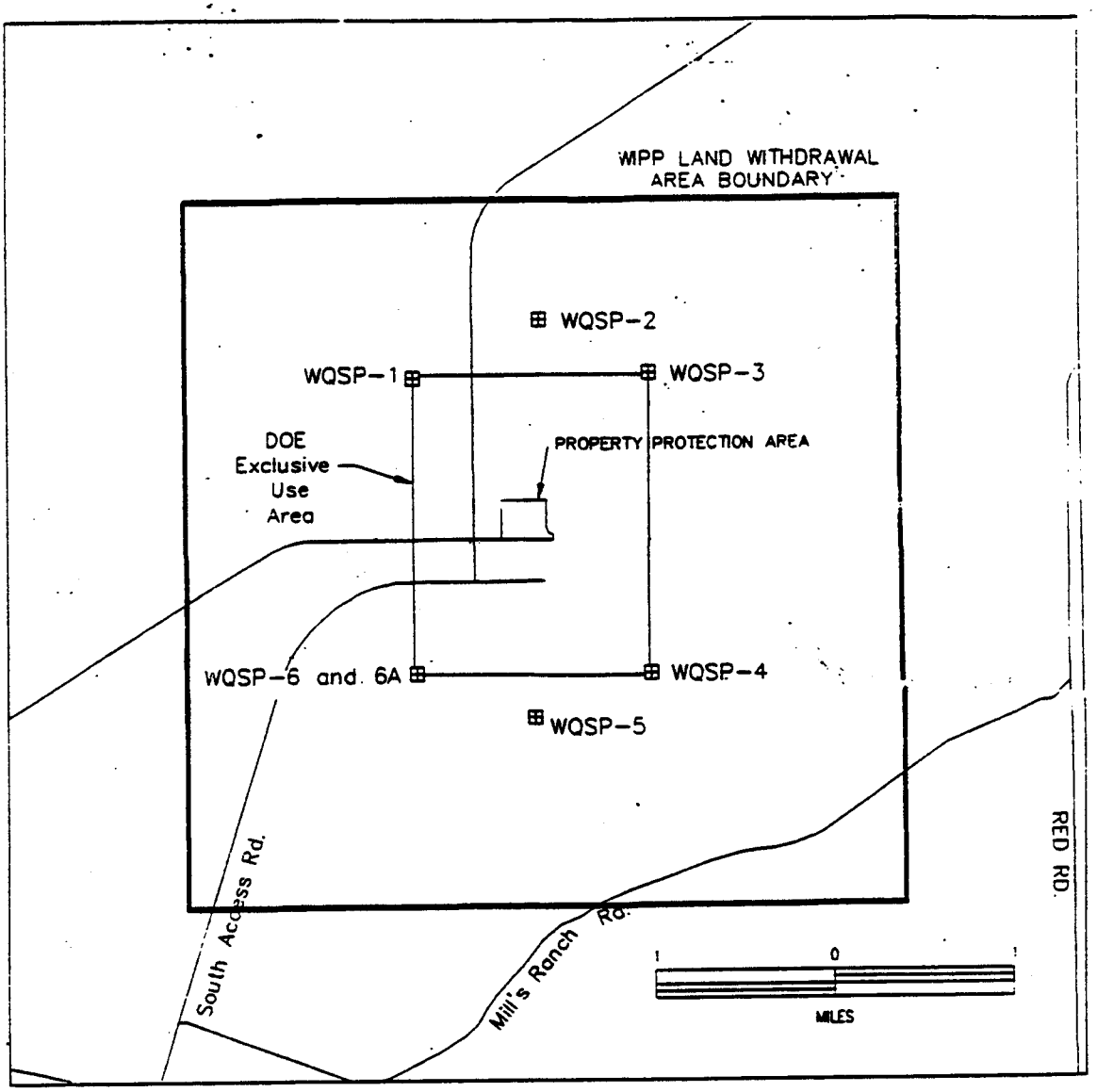


FIGURE 7-5 NEW MONITORING WELL LOCATIONS

⊞ WELL PAD LOCATIONS
(WELL PAD -- 100'X100')

CHAPTER 8

QUALITY ASSURANCE

Chapter 8
Quality Assurance

The purpose of the quality assurance (QA) program is to ensure that processes, activities, and products that potentially impact health, safety, and the environment are appropriately planned, implemented, and assessed. The goal of the QA program is twofold: (1) to provide confidence that the data used in demonstrating regulatory compliance are adequate and (2) to promote continuous improvement in WIPP's operations. The QA program is successful when risks and environmental impacts are identified and minimized, and when safety, reliability, and performance are maximized.

This chapter outlines the QA processes applicable to the radiological and nonradiological environmental monitoring programs. The QA Program is used to monitor the reliability, accuracy, and precision of environmental data, and to detect and correct problems in the sample collection, preparation, analysis, and the data evaluation phases.

A comprehensive QA program has been implemented to ensure that the data collected reflect selected parameters of the environment. The data have been obtained prior to commencement of operations, providing a sound baseline for comparison with operational-phase data. The data will be evaluated to determine future impacts of the WIPP on the environment.

The focus of this program includes the following areas:

- Sample collection at specified locations in accordance with approved procedures. These procedures are based on established and accepted practices.

- Procedure review and revision to minimize uncertainties introduced through sampling and analysis, while maintaining comparability and continuity between past and future data.

- Verification of data through a continuing program of analytical laboratory quality control, including the performance of interlaboratory cross-checks, duplicate and split sample radiological analysis, and sample splits provided to the EEG, and to the NMED.

Quality Assurance (continued)

Requirements and guidance sources for QA Program content include the following: Title 10 CFR 830.120, *Nuclear Safety Management, Quality Assurance*; (CAO-94-1012), *DOE Carlsbad Area Office Quality Assurance Program Description*; (ASME NQA-1), *Quality Assurance Program Requirements for Nuclear Facilities*; (DOE Order 5700.6C), *Quality Assurance*, (DOE/EH-0173T), *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, and SW-846, *Test Methods for Evaluating Solid Waste*.

8.1 Sample Collection Methodologies

The WID follows approved sampling plans and procedures in the collection and handling of samples used in environmental monitoring. The sampling plans and procedures specify proper sampling techniques for the particular sample medium.

Elements of sample QA include specifying the following:

- Method used to select sampling sites
- Specific sampling methods to be used
- Containers, preservatives, transportation, and storage requirements
- Labeling requirements
- Preparatory measures for sampling equipment and containers
- Preservation methods and allowable hold times, including transportation
- Sample chain-of-custody
- Documentation used to record sample history, sampling conditions, and analyses

Sampling procedures are contained in the following documents:

- *WIPP Groundwater Monitoring Program Plan and Procedure Manual* (WP 02-1)
- *WIPP Environmental Procedures Manual* (WP 02-3)
- *Nonradioactive Hazardous Materials Environmental Compliance Manual* (WP 02-5)
- *Quality Assurance Project Plan for WIPP Site Effluent and Hazardous Materials Sampling* (WP 02-EM1)
- *WIPP Site Effluent and Hazardous Materials Sampling Plan* (WP 02-EM2)
- *WIPP VOC Operating Procedures Manual* (WP 12-VC)
- *Quality Assurance Project Plan for Sampling Emissions of Radionuclides to the Ambient Air at the WIPP* (DOE-WIPP 93-042)

8.1 Sample Collection Methodologies (continued)

Chapter 11 of the EMP defines the policies and practices that are followed to ensure the data are accurate, complete, representative, and comparable. The data collected in the Nonradiological Environmental Surveillance monitoring programs are analyzed as stated in DOE/EH-0023 (Corley et al., 1981). Section 8.0 of the EMP discusses, at length, the statistical procedures used to analyze the data.

8.2 Revision of Procedures

Written procedures are essential in providing instruction to field personnel for sample collection. As data are collected, and records are generated, these procedures form the basis for an auditable program. The Q&RA Department and the Environmental Compliance Assessment Program (ECAP) periodically conduct assessments of environmental monitoring activities to determine the degree of compliance and effectiveness in implementation of the procedures.

In addition to independent assessment, one of the responsibilities of data collection personnel is to assess collection and analysis methodologies on a routine and ongoing basis. Field procedures, analytical procedures, and laboratory methodologies are periodically assessed for adequacy and effectiveness. Processes that require improvement are modified according to established document control procedures. The EEG and the NMED act as the performance based check-point to ensure that radiological sampling procedures are adequately implemented and that data are comparable among the WIPP, EEG, and the NMED samples.

8.3 Interlaboratory Comparisons

The WIPP is in the process of upgrading its analytical capabilities. As part of the process, each LLCL staff member received over 184 hours of training in detector theory, gamma spectroscopy, and gamma spectroscopy software. To support the LLCL, the WIPP is developing a radiochemistry laboratory. Environmental sample preparation and radiochemical separation will be performed in the laboratory. In 1994, WIPP personnel had the opportunity to obtain valuable experience with radiochemical procedures and methods through collaborative work conducted, with the EEG Radiochemistry Laboratory in Carlsbad, New Mexico.

8.3 Interlaboratory Comparisons (continued)

The collaborative efforts resulted in the completion of three tasks:

1. Testing of radiochemical separation procedures for americium, plutonium, thorium, and strontium.

2. Comparison of radionuclide mounting methods.

3. Study of liquid scintillation quenching effect of salt loading.

Sample preparation was conducted at the EEG laboratory and sample counting was done at the WIPP LLCL.

Results from the testing of separation procedures and comparison of mounting methods were used by the WIPP LLCL personnel for the selection of radiochemistry methods and procedures. The study of the quenching effect of salt loading on liquid scintillation (LS) counting efficiency provided valuable information on the types of corrections which need to be made when performing LS counting on samples containing salt content. The results of the salt loading study were presented at the 40th Conference on Bioassay, Analytical, and Environmental Radiochemistry in October 1994. Staff from the WIPP LLCL participated in both the DOE Environmental Measurements Laboratory Quality Assessment Program (DOE-EML QAP) and the Environmental Protection Agency's Performance Evaluation Study Program (EPA PESP). Participation in these programs provides a means for LLCL staff to upgrade analytical methodology, as well as provide hands-on experience in analysis of environmental samples for radionuclides. These programs provide the simulated environmental samples which contain known amounts of one or more radionuclides. The samples are prepared and distributed to laboratories. Using standard analytical methods specific to that laboratory, the samples are then statistically analyzed and compared with known values. Results are reported electronically.

Because the LLCL lacks sample preparation facilities, performing analysis on a wide variety of sample matrices is limited. In 1994, these sample matrices included air filters and water samples. The analysis performed on the air filters were gross alpha/beta and gamma spectroscopy. The analysis performed on the water matrix were tritium and gamma spectroscopy. It is expected that in 1995, a 550 square-foot laboratory space will be made available for radiological sample preparation

8.3 Interlaboratory Comparisons (continued)

and chemical separation. The LLCL will be renamed the Radiochemistry Laboratory (RL) due to the commencement of radiochemical analytical capabilities.

Neither the DOE EML-QAP nor the EPA-PESP set criteria for judging the "pass/fail" status of a laboratory. The following standard, from the draft ANSI N13.30, *Performance Criteria for Radiobioassay*, is used by the staff of WIPP LLCL.

$$-0.25 \leq Br \leq 0.5$$

Relative bias is calculated using the following equation:

$$Br = (\text{reported results} - \text{known value}) \div (\text{known value})$$

8.4 Analytical Laboratory Quality Assurance and Quality Control

During CY 1994 the WIPP extended contracts to the following analytical laboratories: Ross Analytical Services Inc. in Strongsville, Ohio; Accu-Labs in Golden, Colorado; and Datachem Laboratories in Salt Lake City, Utah. The contract laboratories are required to follow established Quality Assurance/Quality Control (QA/QC) procedures as specified in the contract statement of work. Successful bidders performing environmental analyses are required to be on the Qualified Suppliers List (QSL) and must undergo program reviews and assessments.

Laboratory QA/QC includes the following:

- Reviewing and approving of the laboratory QA plan
- Qualifying and training staff
- Specifying acceptable tolerances in data quality
- Performing internal laboratory QC
- Analyzing blind samples
- Calibrating and maintaining analytical equipment
- Reporting on the performance of measurement systems and data quality
- Reporting the performance of demonstration programs

8.5 Data Handling

Field data are collected and recorded in data books, organized by sample location and sampling round. Separate data books are prepared for sampling, field notes, and contract laboratory data. If samples are sent to more than one laboratory for analysis, then each lab has its own data book. Samples are collected and sent to the laboratory for analysis, accompanied by QC samples. Analytical results are verified through specifying method blanks, duplicates, spikes, and trip blanks. The Principle Investigator (PI) reviews the QC data against specified limits to determine whether the data set is suitable for inclusion in the report. The data are reported in the ASER.

8.6 Records Management

Documents and records generated under the CAO QA program are specified, prepared, reviewed, approved, controlled, and maintained in accordance with the *Carlsbad Area Office Quality Assurance Program Description (QAPD)*. The QAPD provides a single reference for all WIPP project participants in meeting records management requirements as specified in DOE orders and regulations. Further records management requirements and procedures are provided in the *Carlsbad Area Office Information Management Plan* (CAO-94-1001).

All original records are maintained in fire resistant file cabinets until they are transmitted to the CAO Central Records Facility (CRF) for permanent filing. All records, including raw data, calculations, computer programs, or other data manipulation media are subject to review and verification under the WIPP QAP and the ECAP. The Environmental Monitoring Section is responsible for validating these records before transmitting them to the CAO Central Records Facility in accordance with an approved Records Inventory Disposition Schedule (RIDS).

Records (i.e., reports of analyses and sample receipt forms transmitted by contract analytical laboratories) are dated upon receipt and a copy made for QC review. Specific record and data management procedures including those referencing data manipulations are implemented according to the approved quality assurance project plan or work plan.

The WIPP complies with the *National Emission Standards for Hazardous Air Pollutants* (NESHAP) record-keeping requirements issued under 40 CFR 61, Subpart H, which addresses atmospheric radionuclide emissions. Unless regulations are amended in the future, records developed pursuant to these criteria (i.e., Medical, Health and Safety Records) will be maintained at least 30 years as specified in DOE Order 1324.2A, *Records Disposition* (DOE, 1992), Chapter V, Attachment 1, Schedule 25.

8.6 Records Management (continued)

Consistent record keeping for all aspects of the Environmental Monitoring Programs is a part of QA requirements. The EMP lists the required records, reports, and laws, regulations, or DOE Orders that contain the requirements.

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CHAPTER 9

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Chapter 9
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APPENDIX A

1994

RADIOLOGICAL ENVIRONMENTAL

SAMPLE ANALYSIS

APPENDIX A1

AIR

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SMR Air Sampling 1st Quarter Smith Ranch	Beryllium-7	7.1E-03	7.9E-03
	Potassium-40	3.2E-04	3.4E-04
	Cobalt-60	1.7E-05	1.7E-05
	Cesium-137	-7.6E-06	1.6E-05
	Lead-210	2.0E-03 *	4.1E-04
	Radium-226	3.7E-04	2.4E-04
	Radium-228	7.3E-05	6.5E-05
	Americium-241	8.8E-07	1.0E-08
	Thorium-228	2.6E-05 *	2.2E-05
	Thorium-230	2.2E-05	2.3E-05
	Thorium-232	1.1E-05 *	1.3E-06
	Uranium-233/234	5.1E-06	1.2E-06
	Uranium-235	3.1E-07	5.3E-07
	Uranium-238	4.5E-06	1.1E-06
	Plutonium-238	1.3E-07	4.5E-09
	Plutonium-239/240	-4E-04	3.6E-09
	Plutonium-241	-4.1E-04	9.0E-05
	Strontium-90	-6.4E-06	1.3E-05
	Polonium-210	3.2E-04 *	1.4E-05
AC-SMR Air Sampling 2nd Quarter Smith Ranch	Beryllium-7	6.0E-03	5.2E-03
	Potassium-40	3.3E-04	3.0E-04
	Cobalt-60	-1.5E-05	2.5E-05
	Cesium-137	-4.3E-06	2.4E-05
	Lead-210	6.4E-04	3.8E-04
	Radium-226	8.1E-04 *	4.0E-04
	Radium-228	7.8E-05	7.6E-05
	Americium-241	1.0E-05	2.1E-08
	Thorium-228	3.8E-06	2.8E-06

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SMR Air Sampling 2nd Quarter Smith Ranch (continued)	Thorium-230	4.6E-05 *	8.8E-06
	Thorium-232	2.1E-06	2.8E-06
	Uranium-233/234	6.4E-06	1.7E-06
	Uranium-235	5.2E-07	6.3E-07
	Uranium-238	4.0E-06	1.4E-06
	Plutonium-238	4.7E-07	5.3E-09
	Plutonium-239/240	4.7E-07	5.3E-09
	Plutonium-241	-9.9E-05	8.2E-05
	Strontium-90	-3.5E-06	1.4E-05
	Polonium-210	2.7E-04	3.7E-05
AC-SMR Air Sampling 3rd Quarter Smith Ranch	Beryllium-7	4.5E-03	1.8E-03
	Potassium-40	2.9E-04	4.4E-04
	Cobalt-60	6.0E-05	1.6E-05
	Cesium-137	-1.4E-05	2.1E-05
	Lead-210	2.0E-03 *	3.8E-04
	Radium-226	3.3E-04	2.6E-04
	Radium-228	1.0E-04	7.2E-05
	Americium-241	5.7E-06	3.7E-08
	Thorium-228	1.1E-06	2.4E-06
	Thorium-230	7.4E-06	3.8E-06
	Thorium-232	2.6E-06	2.2E-06
	Uranium-233/234	9.0E-06	1.6E-06
	Uranium-235	4.5E-07	6.6E-07
	Uranium-238	9.4E-06	1.6E-06
	Plutonium-238	-1E-07	4.5E-09
	Plutonium-239/240	5.2E-07	5.3E-09
	Plutonium-241	-3.7E-04	7.3E-05
	Strontium-90	-1.1E-05	1.5E-05
	Polonium-210	3.3E-04	2.2E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SMR Air Sampling 4th Quarter Smith Ranch	Beryllium-7	4.9E-03	1.1E-03
	Potassium-40	4.7E-05	2.9E-04
	Cobalt-60	-1.3E-05	1.9E-05
	Cesium-137	5.3E-06	1.9E-05
	Lead-210	1.1E-03	3.6E-04
	Radium-226	1.3E-04	3.8E-04
	Radium-228	9.5E-05	7.3E-05
	Americium-241	3.9E-06	1.2E-08
	Thorium-228	2.4E-06	2.0E-06
	Thorium-230	7.1E-06	2.7E-06
	Thorium-232	4.3E-06	2.0E-06
	Uranium-233/234	3.9E-06	1.1E-06
	Uranium-235	1.6E-07	3.2E-07
	Uranium-238	3.1E-06	9.9E-07
	Plutonium-238	0.0E+00	0.0E+00
	Plutonium-239/240	3.4E-07	4.0E-09
	Plutonium-241	1.3E-04	4.9E-05
	Strontium-90	1.9E-06	1.5E-05
	Polonium-210	2.1E-04	2.8E-05
AC-WEE Air Sampling 1st Quarter WIPP East	Beryllium-7	7.6E-03	7.8E-03
	Potassium-40	6.3E-04	3.7E-04
	Cobalt-60	-8.4E-06	1.6E-05
	Cesium-137	7.7E-07	1.7E-05
	Lead-210	1.6E-03	3.8E-04
	Radium-226	1.7E-04	4.0E-04
	Radium-228	8.8E-05	5.5E-05
	Americium-241	2.7E-07	8.4E-09
	Thorium-228	1.4E-06	2.3E-06
	Thorium-230	7.9E-06	3.3E-06

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WEE Air Sampling 1st Quarter WIPP East (continued)	Thorium-232	4.0E-06	2.2E-06
	Uranium-233/234	4.2E-06	1.4E-06
	Uranium-235	7.0E-07	6.5E-07
	Uranium-238	2.5E-06	1.1E-06
	Plutonium-238	-8E-08	2.6E-09
	Plutonium-239/240	5.4E-07	4.0E-09
	Plutonium-241	-2.6E-04	5.4E-05
	Strontium-90	8.4E-07	1.4E-05
	Polonium-210	3.5E-04 *	2.3E-05
AC-WEE Air Sampling 2nd Quarter WIPP East	Beryllium-7	4.3E-03	3.5E-03
	Potassium-40	9.1E-05	3.3E-04
	Cobalt-60	1.0E-05	1.8E-05
	Cesium-137	1.4E-05	2.0E-05
	Lead-210	1.1E-03	3.5E-04
	Radium-226	5.6E-05	3.2E-04
	Radium-228	5.9E-05	6.2E-05
	Americium-241	1.6E-06	9.3E-09
	Thorium-228	4.5E-06	2.6E-06
	Thorium-230	1.5E-05	4.3E-06
	Thorium-232	3.6E-06	2.4E-06
	Uranium-233/234	9.1E-06	1.6E-06
	Uranium-235	9.1E-07	7.7E-07
	Uranium-238	6.9E-06	1.4E-06
	Plutonium-238	-3E-07	3.1E-09
	Plutonium-239/240	1.3E-06	6.6E-09
	Plutonium-241	-2.1E-04	5.7E-05
	Strontium-90	3.3E-05	1.8E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WEE Air Sampling 2nd Quarter WIPP East (continued)	Polonium-210	2.7E-04	1.8E-05
AC-WEE Air Sampling 3rd Quarter WIPP East	Beryllium-7	4.7E-03	1.8E-03
	Potassium-40	1.9E-04	3.7E-04
	Cobalt-60	-1.4E-06	1.7E-05
	Cesium-137	1.0E-06	1.9E-05
	Lead-210	1.6E-03	4.0E-04
	Radium-226	2.9E-04	4.2E-04
	Radium-228	8.9E-05	6.6E-05
	Americium-241	1.5E-06	1.2E-08
	Thorium-228	1.9E-06	1.9E-06
	Thorium-230	1.2E-05	3.2E-06
	Thorium-232	2.8E-06	1.5E-06
	Uranium-233/234	6.3E-06	1.7E-06
	Uranium-235	-4E-07	1.4E-06
	Uranium-238	2.8E-06	1.2E-06
	Plutonium-238	0.0E+00	3.8E-09
	Plutonium-239/240	1.6E-07	3.8E-09
	Plutonium-241	-1.3E-04	5.8E-05
	Strontium-90	-2.6E-07	1.3E-05
	Polonium-210	7.0E-05	1.8E-05
AC-WEE Air Sampling 4th Quarter WIPP East	Beryllium-7	4.6E-03	1.0E-03
	Potassium-40	1.6E-04	2.8E-04
	Cobalt-60	-1.1E-05	2.0E-05
	Cesium-137	2.1E-05	2.2E-05
	Lead-210	1.1E-03	3.6E-04
	Radium-226	7.6E-04	3.8E-04
	Radium-228	7.3E-05	7.1E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WEE Air Sampling 4th Quarter WIPP East (continued)	Americium-241	1.6E-06	7.6E-09
	Thorium-228	1.3E-06	1.6E-06
	Thorium-230	6.4E-06	2.1E-06
	Thorium-232	2.8E-06	1.3E-06
	Uranium-233/234	4.8E-06	1.4E-06
	Uranium-235	8.6E-08	3.8E-07
	Uranium-238	2.2E-06	8.1E-07
	Plutonium-238	1.3E-07	5.7E-09
	Plutonium-239/240	-1E-07	2.5E-09
	Plutonium-241	2.7E-04	7.6E-05
	Strontium-90	-4.1E-06	1.3E-05
	Polonium-210	2.0E-04	2.6E-05
AC-WFF Air Sampling 1st Quarter WIPP Far Field	Beryllium-7	4.3E-03	7.7E-03
	Potassium-40	2.7E-04	3.7E-04
	Cobalt-60	4.7E-06	1.7E-05
	Cesium-137	-6.3E-06	1.7E-05
	Lead-210	1.1E-03	3.3E-04
	Radium-226	1.8E-04	3.4E-04
	Radium-228	7.2E-05	6.0E-05
	Americium-241	-3E-07	5.0E-09
	Thorium-228	2.5E-06	1.7E-06
	Thorium-230	1.1E-05	3.4E-06
	Thorium-232	2.7E-06	1.6E-06
	Uranium-233/234	4.4E-06	1.3E-06
	Uranium-235	2.5E-07	5.4E-07
	Uranium-238	1.5E-06	8.0E-07
	Plutonium-238	1.4E-07	3.3E-09
	Plutonium-239/240	-1E-04	2.7E-09
	Plutonium-241	-1.4E-04	5.1E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WFF Air Sampling 1st Quarter WIPP Far Field (continued)	Strontium-90	9.6E-06	1.5E-05
	Polonium-210	2.9E-04 *	2.2E-05
AC-WFF Air Sampling 2nd Quarter WIPP Far Field	Beryllium-7	5.7E-03	4.7E-03
	Potassium-40	1.1E-03 *	3.8E-04
	Cobalt-60	-2.7E-06	1.8E-05
	Cesium-137	1.1E-05	1.8E-05
	Lead-210	9.8E-04	3.4E-04
	Radium-226	2.6E-04	3.8E-04
	Radium-228	8.2E-05	6.5E-05
	Americium-241	1.6E-04 *	7.7E-08
	Thorium-228	1.7E-06	1.8E-06
	Thorium-230	1.2E-05	3.5E-06
	Thorium-232	2.8E-06	1.7E-06
	Uranium-233/234	2.5E-04 *	9.8E-06
	Uranium-235	1.8E-05 *	3.0E-06
	Uranium-238	2.4E-04 *	9.7E-06
	Plutonium-238	1.8E-07	2.5E-09
	Plutonium-239/240	9.2E-05 *	5.6E-08
	Plutonium-241	6.5E-04 *	8.1E-05
	Strontium-90	6.7E-06	1.6E-05
	Polonium-210	3.2E-04 *	2.1E-05
AC-WFF Air Sampling 3rd Quarter WIPP Far Field	Beryllium-7	6.2E-03	1.9E-03
	Potassium-40	2.5E-04	3.5E-04
	Cobalt-60	1.7E-05	1.5E-05
	Cesium-137	5.1E-06	1.8E-05
	Lead-210	1.4E-03	3.9E-04
	Radium-226	1.3E-04	3.7E-04
	Radium-228	5.2E-05	6.2E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WFF Air Sampling 3rd Quarter WIPP Far Field (continued)	Americium-241	1.2E-06	1.1E-08
	Thorium-228	2.7E-06	2.1E-06
	Thorium-230	1.3E-05	4.5E-06
	Thorium-232	1.5E-06	2.3E-06
	Uranium-233/234	-6E-07	8.2E-07
	Uranium-235	-3E-07	1.1E-06
	Uranium-238	-4E-07	7.7E-07
	Plutonium-238	1.4E-07	1.9E-09
	Plutonium-239/240	6.3E-07	4.5E-09
	Plutonium-241	-2.1E-04	5.0E-05
	Strontium-90	3.5E-06	1.8E-05
	Polonium-210	2.9E-04	2.2E-05
AC-WFF Air Sampling 4th Quarter WIPP Far Field	Beryllium-7	4.3E-03	1.0E-03
	Potassium-40	3.2E-04	2.2E-04
	Cobalt-60	5.2E-06	1.6E-05
	Cesium-137	-6.5E-07	2.2E-05
	Lead-210	9.6E-04	3.0E-04
	Radium-226	3.1E-04	3.0E-04
	Radium-228	3.9E-05	7.6E-05
	Americium-241	2.6E-06	8.8E-09
	Thorium-228	3.4E-06	1.7E-06
	Thorium-230	7.6E-06	2.2E-06
	Thorium-232	2.4E-06	1.3E-06
	Uranium-233/234	5.2E-06	1.3E-06
	Uranium-235	-8E-08	4.9E-07
	Uranium-238	3.0E-06	9.2E-07
	Plutonium-238	-7E-08	3E-09
	Plutonium-239/240	-1E-07	2.0E-09
	Plutonium-241	1.5E-04	4.3E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WFF Air Sampling 4th Quarter WIPP Far Field (continued)	Strontium-90	-3.3E-06	1.5E-05
	Polonium-210	1.60E-04	2.1E-05
AC-SEC Air Sampling 1st Quarter South East Control	Beryllium-7	5.0E-03	7.9E-03
	Potassium-40	1.2E-04	3.5E-04
	Cobalt-60	1.5E-05	1.6E-05
	Cesium-137	1.5E-05	1.9E-05
	Lead-210	1.0E-03	3.2E-04
	Radium-226	1.9E-04	3.8E-04
	Radium-228	7.0E-05	5.6E-05
	Americium-241	1.6E-06	1.1E-08
	Thorium-228	3.1E-06	2.6E-06
	Thorium-230	1.4E-05	5.2E-06
	Thorium-232	8.7E-07	2.1E-06
	Uranium-233/234	5.0E-06	1.2E-06
	Uranium-235	-7E-08	4.4E-07
	Uranium-238	2.9E-06	9.1E-06
	Plutonium-238	2.5E-07	3.0E-09
	Plutonium-239/240	1.9E-07	2.1E-09
	Plutonium-241	-2.3E-04	4.3E-05
	Strontium-90	-5.0E-07	1.1E-05
	Polonium-210	1.8E-04	1.5E-05
AC-SEC Air Sampling 2nd Quarter South East Control	Beryllium-7	3.7E-03	4.5E-03
	Potassium-40	8.5E-04 *	3.6E-04
	Cobalt-60	7.1E-06	3.5E-05
	Cesium-137	1.7E-05	3.5E-05
	Lead-210	5.7E-04	4.7E-04
	Radium-226	1.1E-03 *	5.5E-04
	Radium-228	3.2E-05	1.3E-04

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SEC Air Sampling 2nd Quarter South East Control (continued)	Americium-241	3.5E-06	1.5E-08
	Thorium-228	4.6E-06	2.3E-06
	Thorium-230	2.0E-05	5.3E-06
	Thorium-232	4.0E-06	2.3E-06
	Uranium-233/234	7.0E-06	2.5E-06
	Uranium-235	3.8E-07	5.2E-07
	Uranium-238	4.6E-06	1.8E-06
	Plutonium-238	0.0E+00	1.3E-09
	Plutonium-239/240	-2E-07	3.4E-09
	Plutonium-241	-5.6E-05	9.3E-05
	Strontium-90	1.2E-05	2.1E-05
	Polonium-210	1.5E-04	2.6E-05
AC-SEC Air Sampling 3rd Quarter South East Control	Beryllium-7	6.0E-03	2.1E-03
	Potassium-40	4.6E-04	2.9E-04
	Cobalt-60	-1.5E-05	2.4E-05
	Cesium-137	-9.1E-06	2.7E-05
	Lead-210	9.8E-04	3.9E-04
	Radium-226	1.9E-04	4.8E-04
	Radium-228	3.9E-05	9.5E-05
	Americium-241	3.4E-06	1.3E-08
	Thorium-228	3.5E-06	2.6E-06
	Thorium-230	4.8E-06	3.6E-06
	Thorium-232	4.4E-06	2.6E-06
	Uranium-233/234	4.7E-06	1.5E-06
	Uranium-235	-2E-07	5.3E-07
	Uranium-238	3.5E-06	1.2E-06
	Plutonium-238	-5E-07	4.7E-09
	Plutonium-239/240	6.0E-07	6.2E-09
	Plutonium-241	5.4E-05	6.8E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SEC Air Sampling 3rd Quarter South East Control (continued)	Strontium-90	2.9E-05	2.0E-05
	Polonium-210	2.9E-04 *	3.3E-05
AC-SEC Air Sampling 3rd Quarter South East Control 2 of 2	Beryllium-7	6.2E-03	1.8E-03
	Potassium-40	8.9E-05	3.1E-04
	Cobalt-60	5.0E-07	2.2E-05
	Cesium-137	6.6E-06	2.1E-05
	Lead-210	6.4E-04	3.3E-04
	Radium-226	1.7E-04	4.0E-04
	Radium-228	4.7E-05	8.3E-05
	Americium-241	8.7E-06	1.6E-08
	Thorium-228	4.1E-06	2.8E-06
	Thorium-230	8.6E-06	4.0E-06
	Thorium-232	3.1E-06	2.4E-06
	Uranium-233/234	3.6E-06	1.3E-06
	Uranium-235	2.8E-07	6.1E-07
	Uranium-238	3.1E-06	1.1E-06
	Plutonium-238	3.4E-07	5.3E-09
	Plutonium-239/240	8.6E-08	2.9E-09
	Plutonium-241	9.2E-05	4.9E-05
	Strontium-90	1.0E-05	1.6E-05
	Polonium-210	2.0E-04	2.3E-05
AC-SEC Air Sampling 4th Quarter South East Control	Beryllium-7	4.3E-03	9.8E-04
	Potassium-40	4.6E-04	3.2E-04
	Cobalt-60	8.9E-06	1.8E-05
	Cesium-137	-7.2E-06	2.0E-05
	Lead-210	1.3E-03	3.4E-04
	Radium-226	6.6E-04	3.4E-04
	Radium-228	5.7E-05	7.3E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SEC Air Sampling 4th Quarter South East Control (continued)	Americium-241	4.0E-06	1.3E-08
	Thorium-228	1.4E-06	1.9E-06
	Thorium-230	6.6E-06	2.8E-06
	Thorium-232	2.1E-06	1.9E-06
	Uranium-233/234	7.5E-06	1.7E-06
	Uranium-235	9.5E-07	6.6E-07
	Uranium-238	3.2E-06	1.2E-06
	Plutonium-238	-1E-07	6.1E-09
	Plutonium-239/240	1.0E-07	2.0E-09
	Plutonium-241	2.6E-04	6.5E-05
	Strontium-90	-1.3E-05	1.2E-05
	Polonium-210	1.7E-04	2.3E-05
AC-MLR Air Sampling 1st Quarter Mills Ranch	Beryllium-7	-1.9E-03 *	8.4E-03
	Potassium-40	2.6E-04	3.6E-04
	Cobalt-60	-3.8E-06	1.8E-05
	Cesium-137	-2.6E-05 *	1.9E-05
	Lead-210	1.6E-03	4.0E-04
	Radium-226	1.3E-04	3.1E-04
	Radium-228	5.7E-05	6.2E-05
	Americium-241	7.7E-07	9.1E-09
	Thorium-228	2.8E-06	2.2E-06
	Thorium-230	9.7E-06	3.1E-06
	Thorium-232	3.5E-06	2.0E-06
	Uranium-233/234	2.7E-06	1.2E-06
	Uranium-235	0.0E+00	5.0E-07
	Uranium-238	1.9E-06	7.4E-06
	Plutonium-238	1.3E-07	4.5E-09
	Plutonium-239/240	5.3E-07	6.4E-09
	Plutonium-241	-6.0E-04 *	8.4E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-MLR Air Sampling 1st Quarter Mills Ranch (continued)	Strontium-90	4.1E-07	1.6E-05
	Polonium-210	9.3E-05 *	1.3E-05
AC-MLR Air Sampling 2nd Quarter Mills Ranch	Beryllium-7	7.2E-03	4.4E-03
	Potassium-40	2.0E-04	4.2E-04
	Cobalt-60	5.1E-06	1.9E-05
	Cesium-137	1.3E-05	2.0E-05
	Lead-210	1.3E-03	4.1E-04
	Radium-226	5.8E-04	3.2E-04
	Radium-228	1.3E-04 *	7.3E-05
	Americium-241	1.6E-07	4.8E-09
	Thorium-228	2.1E-06	2.8E-06
	Thorium-230	1.4E-05	4.3E-06
	Thorium-232	3.0E-06	2.0E-06
	Uranium-233/234	5.2E-06	1.3E-06
	Uranium-235	1.2E-06	6.4E-07
	Uranium-238	3.5E-06	1.0E-06
	Plutonium-238	-9E-08 *	3.0E-09
	Plutonium-239/240	5.3E-07	4.2E-09
	Plutonium-241	-3.9E-04	6.2E-05
	Strontium-90	1.8E-05	1.6E-05
	Polonium-210	2.1E-04	1.9E-05
AC-MLR Air Sampling 2nd Quarter Mills Ranch 2 of 2	Beryllium-7	3.6E-03	4.10E-03
	Potassium-40	3.0E-04	4.20E-04
	Cobalt-60	-1.5E-05	1.80E-05
	Cesium-137	-1.4E-05	1.90E-50
	Lead-210	8.5E-04	3.50E-04
	Radium-226	1.4E-04	4.0E-04
	Radium-228	1.1E-05	6.7E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-MLR Air Sampling 2nd Quarter Mills Ranch 2 of 2 (continued)	Americium-241	6.4E-06	1.3E-08
	Thorium-228	1.7E-06	2.0E-06
	Thorium-230	9.3E-06	3.0E-06
	Thorium-232	4.2E-06	1.9E-06
	Uranium-233/234	4.2E-06	1.1E-06
	Uranium-235	5.0E-07	5.1E-07
	Uranium-238	2.5E-06	8.4E-07
	Plutonium-238	-9E-07	5.7E-09
	Plutonium-239/240	5.30E-07	5.4E-09
	Plutonium-241	-3.7E-05	4.9E-05
	Strontium-90	3.4E-05	1.8E-05
	Polonium-210	2.1E-04	2.1E-05
AC-MLR Air Sampling 3rd Quarter Mills Ranch	Beryllium-7	4.5E-03	1.7E-03
	Potassium-40	2.1E-04	3.2E-04
	Cobalt-60	9.2E-06	1.7E-05
	Cesium-137	-1.1E-05	2.0E-05
	Lead-210	8.2E-04	3.1E-04
	Radium-226	6.7E-05	3.9E-04
	Radium-228	4.2E-05	7.4E-05
	Americium-241	3.3E-06	1.2E-08
	Thorium-228	2.4E-06	1.5E-06
	Thorium-230	5.5E-06	2.0E-06
	Thorium-232	2.2E-06	1.3E-06
	Uranium-233/234	4.0E-06	1.3E-06
	Uranium-235	8.9E-07	6.0E-07
	Uranium-238	3.6E-06	1.1E-06
	Plutonium-238	3.5E-07	3.5E-09
	Plutonium-239/240	8.8E-08	3.9E-09
	Plutonium-241	3.4E-05	4.9E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-MLR Air Sampling 3rd Quarter Mills Ranch (continued)	Strontium-90	1.2E-05	1.5E-05
	Polonium-210	3.0E-04 *	2.1E-05
AC-MLR Air Sampling 4th Quarter Mills Ranch	Beryllium-7	4.7E-03	1.0E-03
	Potassium-40	9.4E-05 *	2.5E-04
	Cobalt-60	-6.7E-06	1.8E-05
	Cesium-137	-6.7E-06	2.0E-05
	Lead-210	1.0E-03	3.2E-04
	Radium-226	1.6E-04	3.8E-04
	Radium-228	8.0E-05	6.8E-05
	Americium-241	4.5E-06	1.3E-08
	Thorium-228	2.2E-06	1.4E-06
	Thorium-230	7.1E-06	2.6E-06
	Thorium-232	2.2E-06	1.3E-06
	Uranium-233/234	4.8E-06	1.4E-06
	Uranium-235	0.0E+00	5.3E-07
	Uranium-238	3.2E-06	1.2E-06
	Plutonium-238	0.0E+00	4.7E-09
	Plutonium-239/240	2.0E-07	4.7E-09
	Plutonium-241	3.4E-04	6.5E-05
	Strontium-90	3.4E-06	1.4E-05
	Polonium-210	1.5E-04	2.5E-05
AC-WSS Air Sampling 1st Quarter WIPP South	Beryllium-7	2.1E-03	8.0E-03
	Potassium-40	2.7E-04	2.9E-04
	Cobalt-60	2.0E-05	1.6E-05
	Cesium-137	-3.0E-06	1.6E-05
	Lead-210	1.1E-03	3.4E-04
	Radium-226	2.4E-04	3.6E-04

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WSS Air Sampling 1st Quarter WIPP South (continued)	Radium-228	4.6E-05	5.8E-05
	Americium-241	-1E-07	7.5E-09
	Thorium-228	1.0E-06	1.3E-06
	Thorium-230	1.2E-05	3.4E-06
	Thorium-232	1.8E-06	1.3E-06
	Uranium-233/234	4.0E-06	1.2E-06
	Uranium-235	2.8E-07	4.1E-07
	Uranium-238	3.2E-06	1.0E-06
	Plutonium-238	3.8E-07	4.5E-09
	Plutonium-239/240	3.8E-07	3.3E-09
	Plutonium-241	-2.7E-04	5.4E-05
	Strontium-90	3.3E-05	1.50E-05
	Polonium-210	2.7E-04	1.6E-05
AC-WSS Air Sampling 2nd Quarter WIPP South	Beryllium-7	7.1E-03	3.8E-03
	Potassium-40	2.8E-04	3.5E-04
	Cobalt-60	1.4E-05	1.8E-05
	Cesium-137	2.1E-05	2.0E-05
	Lead-210	1.3E-03	4.2E-04
	Radium-226	4.1E-04	4.7E-04
	Radium-228	5.5E-05	6.2E-05
	Americium-241	1.4E-06	8.0E-09
	Thorium-228	2.2E-06	1.4E-06
	Thorium-230	1.5E-05	3.9E-06
	Thorium-232	2.2E-06	1.5E-06
	Uranium-233/234	6.7E-06	1.7E-06
	Uranium-235	-2E-07	1.3E-06
	Uranium-238	3.9E-06	1.2E-06
	Plutonium-238	-1E-07	2.0E-09
	Plutonium-239/240	1.0E-06	6.4E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WSS Air Sampling 2nd Quarter WIPP South (continued)	Plutonium-241	-3.5E-04	7.2E-05
	Strontium-90	-1.7E-05	1.3E-05
	Polonium-210	1.8E-04	2.2E-05
AC-WSS Air Sampling 3rd Quarter WIPP South	Beryllium-7	5.7E-03	1.7E-03
	Potassium-40	2.3E-04	3.7E-04
	Cobalt-60	-8.1E-07	1.5E-05
	Cesium-137	-8.2E-06	1.8E-05
	Lead-210	1.6E-03	3.7E-04
	Radium-226	2.3E-04	4.0E-04
	Radium-228	9.2E-05	6.1E-05
	Americium-241	6.6E-07	1.4E-08
	Thorium-228	2.1E-06	1.7E-06
	Thorium-230	1.1E-05	3.1E-06
	Thorium-232	1.1E-06	1.3E-06
	Uranium-233/234	7.2E-06	1.4E-06
	Uranium-235	4.7E-07	7.4E-07
	Uranium-238	3.6E-06	9.9E-07
	Plutonium-238	2.2E-07	5.7E-09
	Plutonium-239/240	3.0E-07	4.1E-09
	Plutonium-241	-1.2E-04	5.9E-05
	Strontium-90	1.0E-06	1.4E-05
	Polonium-210	1.2E-04	1.7E-05
AC-WSS Air Sampling 4th Quarter WIPP South	Beryllium-7	4.6E-03	9.9E-04
	Potassium-40	2.0E-04	3.6E-04
	Cobalt-60	-5.9E-06	1.8E-05
	Cesium-137	3.2E-06	1.8E-05
	Lead-210	1.1E-03	3.1E-04
	Radium-226	1.6E-04	3.5E-04
	Radium-228	4.5E-05	7.2E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WSS Air Sampling 4th Quarter WIPP South (continued)	Americium-241	2.3E-06	9.4E-09
	Thorium-228	2.6E-06	1.6E-06
	Thorium-230	7.1E-06	2.1E-06
	Thorium-232	2.2E-06	1.3E-06
	Uranium-233/234	4.1E-06	1.1E-06
	Uranium-235	3.2E-07	4.4E-07
	Uranium-238	2.2E-06	7.6E-07
	Plutonium-238	6.9E-07	5.4E-09
	Plutonium-239/240	1.5E-07	3.7E-09
	Plutonium-241	2.8E-04	4.8E-05
	Strontium-90	2.7E-05	1.5E-05
	Polonium-210	1.4E-04	2.0E-05
AC-CBD Air Sampling 1st Quarter Carlsbad	Beryllium-7	1.2E-02 *	7.6E-03
	Potassium-40	2.2E-04	3.1E-04
	Cobalt-60	2.6E-05	1.6E-05
	Cesium-137	1.3E-05	1.6E-05
	Lead-210	1.1E-03	3.2E-04
	Radium-226	4.3E-04	4.0E-04
	Radium-228	9.3E-05	6.1E-05
	Americium-241	4.6E-07	6.7E-09
	Thorium-228	1.7E-06	2.6E-06
	Thorium-230	1.4E-05	4.6E-06
	Thorium-232	3.1E-06	2.4E-06
	Uranium-233/234	3.4E-06	1.1E-06
	Uranium-235	3.1E-07	3.7E-07
	Uranium-238	2.6E-06	9.2E-07
	Plutonium-238	0.0E-00	1.7E-09
	Plutonium-239/240	-2E-04 *	3.2E-09
	Plutonium-241	-1.6E-04	4.4E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-CBD Air Sampling 1st Quarter Carlsbad (continued)	Strontium-90	2.6E-06	1.2E-05
	Polonium-210	3.6E-04 *	1.8E-05
AC-CBD Air Sampling 2nd Quarter Carlsbad	Beryllium-7	4.5E-03	4.5E-03
	Potassium-40	1.5E-04	3.9E-04
	Cobalt-60	9.1E-06	1.7E-05
	Cesium-137	-6.1E-06	2.0E-05
	Lead-210	1.1E-03	3.6E-04
	Radium-226	3.6E-04	2.7E-04
	Radium-228	1.1E-04	7.0E-05
	Americium-241	1.1E-06	1.2E-08
	Thorium-228	2.3E-06	2.8E-06
	Thorium-230	1.1E-05	4.1E-06
	Thorium-232	3.3E-06	2.4E-06
	Uranium-233/234	4.3E-06	1.2E-06
	Uranium-235	0.0E-00	0.0E00
	Uranium-238	2.9E-06	1.0E-06
	Plutonium-238	1.0E-07	2.0E-09
	Plutonium-239/240	2.0E-07	3.9E-09
	Plutonium-241	-3.2E-04	6.8E-05
	Strontium-90	-6.6E-06	1.3E-05
	Polonium-210	2.4E-04	2.1E-05
AC-CBD Air Sampling 3rd Quarter Carlsbad	Beryllium-7	4.6E-03	1.7E-03
	Potassium-40	4.6E-04	3.5E-04
	Cobalt-60	-7.2.E-07	1.5E-05
	Cesium-137	-1.2E-05	1.8E-05
	Lead-210	1.7E-03	3.6E-04
	Radium-226	4.5E-05	3.5E-04
	Radium-228	4.6E-05	5.7E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-CBD Air Sampling 3rd Quarter Carlsbad (continued)	Americium-241	2.4E-06	1.2E-08
	Thorium-228	2.6E-06	2.4E-06
	Thorium-230	1.2E-05	3.7E-06
	Thorium-232	4.4E-06	2.2E-06
	Uranium-233/234	3.8E-06	1.3E-06
	Uranium-235	2.0E-07	7.5E-07
	Uranium-238	2.3E-06	9.4E-07
	Plutonium-238	4.1E-07	4.E-09
	Plutonium-239/240	-1E-07	3.4E-09
	Plutonium-241	-3.4E-04	7.3E-05
	Strontium-90	-4.8E-06	1.2E-05
	Polonium-210	2.5E-04	2.5E-05
AC-CBD Air Sampling 4th Quarter Carlsbad	Beryllium-7	4.8E-03	1.1E-03
	Potassium-40	3.0E-04	3.5E-04
	Cobalt-60	-1.2E-06	2.0E-05
	Cesium-137	-2.0E-05	2.3E-05
	Lead-210	1.2E-03	3.8E-04
	Radium-226	7.0E-05	3.8E-04
	Radium-228	4.3E-05	7.6E-05
	Americium-241	2.9E-06	1.1E-08
	Thorium-228	3.0E-06	1.9E-06
	Thorium-230	9.3E-06	2.5E-06
	Thorium-232	3.9E-06	1.9E-06
	Uranium-233/234	5.0E-06	1.3E-06
	Uranium-235	0.0E+00	2.4E-07
	Uranium-238	2.9E-06	9.4E-07
	Plutonium-238	8.4E-08	3.7E-09
	Plutonium-239/240	-8E-08	2.9E-09
	Plutonium-241	1.2E-04	4.7E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-CBD Air Sampling 4th Quarter Carlsbad (continued)	Strontium-90	6.7E-06	1.4E-05
	Polonium-210	2.7E-04	2.3E-05
AC-EUN Air Sampling 1st Quarter Eunice	Beryllium-7	3.8E-03	1.2E-02
	Potassium-40	2.8E-04	2.4E-04
	Cobalt-60	6.6E-06	2.1E-05
	Cesium-137	-1.8E-05	2.0E-05
	Lead-210	1.1E-03	3.3E-04
	Radium-226	1.1E-04	3.1E-04
	Radium-228	-9.8E-06 *	6.5E-05
	Americium-241	5.0E-06	1.3E-08
	Thorium-228	3.6E-06	2.4E-06
	Thorium-230	4.3E-06	2.6E-06
	Thorium-232	1.9E-06	1.8E-06
	Uranium-233/234	5.4E-06	1.3E-06
	Uranium-235	4.2E-07	4.3E-07
	Uranium-238	3.0E-06	1.0E-06
	Plutonium-238	-7E-08	3.7E-09
	Plutonium-239/240	1.4E-07	2.8E-09
	Plutonium-241	3.4E-05	4.0E-05
	Strontium-90	7.5E-07	1.2E-05
	Polonium-210	1.6E-04	1.4E-05
AC-EUN Air Sampling 2nd Quarter Eunice	Beryllium-7	3.3E-03	3.1E-03
	Potassium-40	3.3E-04	2.2E-04
	Cobalt-60	5.3E-07	2.1E-05
	Cesium-137	5.4E-06	2.3E-05
	Lead-210	6.4E-04	4.0E-04
	Radium-226	8.3E-05	4.0E-04
	Radium-228	3.3E-05	7.5E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-EUN Air Sampling 2nd Quarter Eunice (continued)	Americium-241	2.7E-06	1.1E-08
	Thorium-228	1.3E-06	1.2E-06
	Thorium-230	1.4E-05	3.2E-06
	Thorium-232	3.0E-06	1.6E-06
	Uranium-233/234	5.6E-06	1.4E-06
	Uranium-235	-3E-07	4.4E-07
	Uranium-238	3.5E-06	1.1E-06
	Plutonium-238	1.3E-06 *	8.4E-09
	Plutonium-239/240	1.3E-06	7.0E-09
	Plutonium-241	-4.4E-05	4.6E-05
	Strontium-90	-1.4E-06	1.3E-05
	Polonium-210	2.3E-04	2.8E-05
AC-EUN Air Sampling 3rd Quarter Eunice	Beryllium-7	4.8E-03	1.7E-03
	Potassium-40	1.3E-04	2.9E-04
	Cobalt-60	9.1E-06	1.7E-05
	Cesium-137	7.3E-06	1.8E-05
	Lead-210	2.1E-03 *	4.0E-04
	Radium-226	5.8E-04	3.1E-04
	Radium-228	-3.0E-05 *	6.6E-05
	Americium-241	5.2E-06	1.3E-08
	Thorium-228	2.5E-06	2.8E-06
	Thorium-230	8.5E-06	3.7E-06
	Thorium-232	3.2E-06	2.1E-06
	Uranium-233/234	5.5E-06	1.2E-06
	Uranium-235	2.6E-07	2.9E-07
	Uranium-238	2.8E-06	9.5E-07
	Plutonium-238	-4E-07	5.1E-09
	Plutonium-239/240	8.6E-08	2.9E-09
	Plutonium-241	-5.4E-05	4.5E-05

* Denotes analytical data outside two standard deviations from the mean.

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-EUN Air Sampling 3rd Quarter Eunice (continued)	Strontium-90	1.7E-05	1.6E-05
	Polonium-210	2.3E-04	3.2E-05
AC-EUN Air Sampling 4th Quarter Eunice	Beryllium-7	7.3E-03	2.5E-03
	Potassium-40	9.4E-04	5.3E-04
	Cobalt-60	-2.0E-05	3.9E-05
	Cesium-137	2.0E-06	5.2E-05
	Lead-210	8.4E-04	6.9E-04
	Radium-226	2.2E-04	6.9E-04
	Radium-228	1.4E-05	1.9E-04
	Americium-241	2.5E-06	1.5E-08
	Thorium-228	-2E-07	1.8E-06
	Thorium-230	1.7E-05	4.3E-06
	Thorium-232	1.2E-06	1.2E-06
	Uranium-233/234	8.5E-06	2.6E-06
	Uranium-235	-2E-07	9.4E-07
	Uranium-238	3.3E-06	1.6E-06
	Plutonium-238	1.2E-07	1.1E-09
	Plutonium-239/240	1.3E-06	9.9E-09
	Plutonium-241	2.0E-04	1.2E-04
	Strontium-90	-3.4E-05 *	2.6E-05
	Polonnium-210	3.1E-04	9.3E-05

* Denotes analytical data outside two standard deviations from the mean.

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APPENDIX A2

SOILS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TS-MLR Terrestrial Surface Mills Ranch	Potassium-40	3.0E-01	5.6E-02
	Cobalt-60	-7.0E-04	8.1E-04
	Cesium-137	1.7E-02	4.3E-03
	Lead-210	4.0E-02	1.4E-02
	Radium-226	2.4E-02	1.9E-02
	Radium-228	1.9E-02	4.5E-03
	Americium-241	8.0E-03	2.6E-03
	Thorium-228	1.8E-02	2.7E-03
	Thorium-230	4.8E-02	4.4E-03
	Thorium-232	1.6E-02	2.5E-03
	Uranium-233/234	2.3E-02	2.9E-03
	Uranium-235	1.4E-03	8.6E-04
	Uranium-238	1.9E-02	2.7E-03
	Plutonium-238	7.4E-04	6.2E-04
	Plutonium-239/240	4.1E-03	1.4E-03
	Plutonium-241	-1.8E-01	8.7E-02
	Strontium-90	-4.8E-04	1.3E-03
	Polonium-210	3.1E-02	1.1E-02
TI-MLR Terrestrial Intermediate Mills Ranch	Potassium-40	3.1E-01	5.7E-02
	Cobalt-60	1.9E-04	7.5E-04
	Cesium-137	1.2E-02	3.5E-03
	Lead-210	2.5E-02	1.3E-02
	Radium-226	3.2E-02	2.0E-02
	Radium-228	2.0E-02	6.3E-03
	Americium-241	6.1E-03	1.8E-03
	Thorium-228	1.7E-02	2.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-MLR Terrestrial Intermediate Mills Ranch (continued)	Thorium-230	1.1E-01	7.0E-03
	Thorium-232	1.8E-02	2.9E-03
	Uranium-233/234	3.2E-01	1.1E-02
	Uranium-235	1.9E-02	3.1E-03
	Uranium-238	3.2E-01	1.1E-02
	Plutonium-238	3.7E-04	5.4E-04
	Plutonium-239/240	6.0E-03	1.7E-03
	Plutonium-241	-2.9E-01	1.1E-01
	Strontium-90	-7.7E-04	1.3E-03
	Polonium-210	1.6E-02	1.1E-02
TD-MLR Terrestrial Deep Mills Ranch	Potassium-40	3.3E-01	5.9E-02
	Cobalt-60	1.5E-04	7.5E-04
	Cesium-137	1.2E-02	3.5E-03
	Lead-210	2.7E-02	1.3E-02
	Radium-226	2.3E-02	1.8E-02
	Radium-228	2.2E-02	6.8E-03
	Americium-241	8.0E-03	2.1E-03
	Thorium-228	1.8E-02	3.2E-03
	Thorium-230	3.3E-02	4.3E-03
	Thorium-232	1.8E-02	3.1E-03
	Uranium-233/234	2.4E-02	3.1E-03
	Uranium-235	7.4E-04	7.6E-04
	Uranium-238	2.4E-02	3.0E-03
	Plutonium-238	-1.8E-04	6.0E-04
	Plutonium-239/240	1.8E-04	3.5E-04
	Plutonium-241	-2.8E-01	1.5E-01

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-MLR Terrestrial Deep Mills Ranch (continued)	Strontium-90	3.2E-03	1.9E-03
	Polonium-210	2.0E-02	9.9E-03
TS-SEC Terrestrial Surface South East Control	Potassium-40	1.7E-01	3.4E-02
	Cobalt-60	-1.1E-04	6.9E-04
	Cesium-137	3.1E-03	1.8E-03
	Lead-210	2.2E-02	1.2E-02
	Radium-226	7.6E-03	1.3E-02
	Radium-228	1.6E-02	5.0E-03
	Americium-241	8.3E-03	1.9E-03
	Thorium-228	8.4E-03	2.2E-03
	Thorium-230	2.4E-02	3.6E-03
	Thorium-232	8.3E-03	2.1E-03
	Uranium-233/234	1.5E-02	2.5E-03
	Uranium-235	1.3E-03	9.1E-04
	Uranium-238	1.4E-02	2.3E-03
	Plutonium-238	-2.9E-04	5.7E-04
	Plutonium-239/240	3.4E-03	1.2E-03
	Plutonium-241	-1.7E-01	8.2E-02
	Strontium-90	-9.8E-05	1.8E-03
	Polonium-210	1.6E-02	1.1E-02
TI-SEC Terrestrial Intermediate South East Control	Potassium-40	1.6E-01	3.2E-02
	Cobalt-60	-1.1E-04	7.4E-04
	Cesium-137	2.8E-03	1.5E-03
	Lead-210	2.2E-02	1.1E-02
	Radium-226	1.3E-02	1.4E-02
	Radium-228	9.5E-03	5.4E-03
	Americium-241	6.0E-03	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-SEC Terrestrial Intermediate South East Control (continued)	Thorium-228	7.7E-03	1.8E-03
	Thorium-230	7.3E-02	5.2E-03
	Thorium-232	9.0E-03	1.9E-03
	Uranium-233/234	1.4E-02	2.3E-03
	Uranium-235	3.4E-04	3.9E-04
	Uranium-238	1.3E-02	2.3E-03
	Plutonium-238	0.0E+00	4.7E-04
	Plutonium-239/240	1.1E-03	6.3E-04
	Plutonium-241	-1.6E-01	8.5E-02
	Strontium-90	1.3E-03	1.5E-03
	Polonium-210	1.1E-02	1.0E-02
TD-SEC Terrestrial Deep South East Control	Potassium-40	1.4E-01	3.0E-02
	Cobalt-60	-1.4E-04	7.2E-04
	Cesium-137	4.9E-03	1.7E-03
	Lead-210	6.1E-03	1.1E-02
	Radium-226	1.8E-02	1.5E-02
	Radium-228	1.1E-02	4.2E-03
	Americium-241	6.1E-03	1.8E-03
	Thorium-228	1.1E-02	2.1E-03
	Thorium-230	6.9E-02	5.0E-03
	Thorium-232	7.7E-03	1.7E-03
	Uranium-233/234	1.6E-02	2.6E-03
	Uranium-235	7.7E-04	6.2E-04
	Uranium-238	8.6E-03	1.9E-03
	Plutonium-238	-9.3E-05	3.1E-04
	Plutonium-239/240	1.5E-03	7.7E-04
	Plutonium-241	-2.0E-01	8.0E-02
	Strontium-90	-7.9E-04	1.5E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-SEC Terrestrial Deep South East Control (continued)	Polonium-210	8.8E-03	9.7E-03
TS-SMR Terrestrial Surface Smith Ranch	Potassium-40	2.8E-01	5.1E-02
	Cobalt-60	-4.0E-05	6.7E-04
	Cesium-137	3.8E-03	1.6E-03
	Lead-210	1.3E-02	1.1E-02
	Radium-226	1.4E-02	1.5E-02
	Radium-228	1.3E-02	5.2E-03
	Americium-241	6.1E-03	1.8E-03
	Thorium-228	9.6E-03	4.5E-03
	Thorium-230	2.6E-02	6.8E-03
	Thorium-232	1.3E-02	4.7E-03
	Uranium-233/234	1.1E-02	2.1E-03
	Uranium-235	9.3E-04	7.9E-04
	Uranium-238	1.2E-02	2.1E-03
	Plutonium-238	-1.0E-04	3.5E-04
	Plutonium-239/240	3.1E-04	4.6E-04
	Plutonium-241	-8.9E-02	9.1E-02
	Strontium-90	-4.1E-04	1.5E-03
	Polonium-210	1.4E-02	1.0E-02
TI-SMR Terrestrial Intermediate Smith Ranch	Potassium-40	3.0E-01	5.4E-02
	Cobalt-60	9.9E-05	7.6E-04
	Cesium-137	6.1E-03	2.0E-03
	Lead-210	1.7E-02	1.2E-02
	Radium-226	1.8E-02	1.6E-02
	Radium-228	1.7E-02	3.8E-03
	Americium-241	6.8E-03	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-SMR Terrestrial Intermediate Smith Ranch (continued)	Thorium-228	1.4E-02	2.5E-03
	Thorium-230	2.7E-02	3.3E-03
	Thorium-232	1.6E-02	2.6E-03
	Uranium-233/234	1.4E-02	2.4E-03
	Uranium-235	9.2E-04	7.2E-04
	Uranium-238	1.3E-02	2.2E-03
	Plutonium-238	-1.9E-04	5.3E-04
	Plutonium-239/240	0.0E+00	4.6E-04
	Plutonium-241	-7.2E-02	8.2E-02
	Strontium-90	-1.4E-03	2.7E-03
	Polonium-210	1.4E-02	1.2E-02
TD-SMR Terrestrial Deep Smith Ranch	Potassium-40	3.0E-01	5.5E-02
	Cobalt-60	1.4E-04	7.2E-04
	Cesium-137	4.6E-03	1.7E-03
	Lead-210	1.5E-02	1.3E-02
	Radium-226	1.9E-02	1.8E-02
	Radium-228	1.6E-02	3.9E-03
	Americium-241	7.2E-03	2.4E-03
	Thorium-228	2.1E-02	3.1E-03
	Thorium-230	2.4E-02	3.4E-03
	Thorium-232	1.6E-02	2.7E-03
	Uranium-233/234	1.7E-02	6.3E-03
	Uranium-235	3.5E-03	3.1E-03
	Uranium-238	2.1E-02	7.3E-03
	Plutonium-238	2.7E-04	5.4E-04
	Plutonium-239/240	-4.1E-04	4.6E-04
	Plutonium-241	-9.5E-02	1.2E-01
	Strontium-90	-2.3E-03	2.3E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-SMR Terrestrial Deep Smith Ranch (continued)	Polonium-210	1.5E-02	1.0E-02
TS-WEE Terrestrial Surface WIPP East	Potassium-40	1.9E-01	3.6E-02
	Cobalt-60	-3.5E-04	6.4E-04
	Cesium-137	4.2E-03	1.7E-03
	Lead-210	1.2E-02	1.0E-02
	Radium-226	8.5E-03	1.4E-02
	Radium-228	1.0E-02	5.2E-03
	Americium-241	7.1E-03	1.7E-03
	Thorium-228	6.9E-03	1.7E-03
	Thorium-230	2.4E-02	3.0E-03
	Thorium-232	8.0E-03	1.8E-03
	Uranium-233/234	3.5E-02	3.4E-03
	Uranium-235	1.8E-03	9.5E-04
	Uranium-238	3.7E-02	3.5E-03
	Plutonium-238	-4.9E-04	6.9E-04
	Plutonium-239/240	7.8E-04	5.4E-04
	Plutonium-241	-1.1E-02	8.5E-02
	Strontium-90	-1.9E-03	1.3E-03
	Polonium-210	1.8E-02	1.0E-02
TI-WEE Terrestrial Intermediate WIPP East	Potassium-40	1.8E-01	3.5E-02
	Cobalt-60	3.5E-04	6.8E-04
	Cesium-137	5.6E-03	1.8E-03
	Lead-210	1.6E-02	1.1E-02
	Radium-226	1.7E-02	1.5E-02
	Radium-228	9.5E-03	4.3E-03
	Americium-241	6.0E-03	1.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-WEE Terrestrial Intermediate WIPP East (continued)	Thorium-228	7.6E-03	1.8E-03
	Thorium-230	4.1E-02	4.1E-03
	Thorium-232	7.5E-03	1.8E-03
	Uranium-233/234	8.1E-03	1.9E-03
	Uranium-235	8.1E-04	8.2E-04
	Uranium-238	7.6E-02	1.7E-03
	Plutonium-238	-2.2E-04	5.2E-04
	Plutonium-239/240	2.2E-03	9.9E-04
	Plutonium-241	0.0E+00	0.0E+00
	Strontium-90	-5.9E-04	1.5E-03
	Polonium-210	1.2E-02	1.1E-02
TD-WEE Terrestrial Deep WIPP East	Potassium-40	1.5E-01	3.1E-02
	Cobalt-60	-7.0E-05	5.5E-04
	Cesium-137	3.9E-03	1.7E-03
	Lead-210	6.3E-03	8.5E-03
	Radium-226	8.0E-03	1.2E-02
	Radium-228	7.5E-03	3.3E-03
	Americium-241	6.2E-03	1.6E-03
	Thorium-228	9.1E-03	2.0E-03
	Thorium-230	1.8E-02	2.5E-03
	Thorium-232	8.1E-03	1.7E-03
	Uranium-233/234	8.9E-03	2.1E-03
	Uranium-235	6.4E-04	5.1E-04
	Uranium-238	7.4E-02	1.6E-03
	Plutonium-238	1.2E-04	4.1E-04
	Plutonium-239/240	6.0E-04	6.3E-04
	Plutonium-241	6.5E-03	1.1E-01
	Strontium-90	5.1E-03	1.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-WEE Terrestrial Deep WIPP East (continued)	Polonium-210	7.2E-01	1.1E-02
TS-WFF Terrestrial Surface WIPP Far Field	Potassium-40	1.2E-01	2.6E-02
	Cobalt-60	-7.3E-04	6.2E-04
	Cesium-137	3.6E-03	1.5E-03
	Lead-210	9.3E-03	1.1E-02
	Radium-226	2.0E-03	1.1E-02
	Radium-228	6.1E-03	3.3E-03
	Americium-241	1.6E-02	2.4E-03
	Thorium-228	6.0E-03	1.7E-03
	Thorium-230	2.3E-02	3.1E-03
	Thorium-232	4.9E-03	1.4E-03
	Uranium-233/234	1.6E-02	2.5E-03
	Uranium-235	1.7E-03	1.0E-03
	Uranium-238	1.9E-02	2.8E-03
	Plutonium-238	5.5E-04	7.8E-04
	Plutonium-239/240	3.0E-03	1.2E-03
	Plutonium-241	-1.7E-01	9.8E-02
	Strontium-90	1.3E-03	1.8E-03
	Polonium-210	1.3E-02	1.0E-02
TI-WFF Terrestrial Intermediate WIPP Far Field	Potassium-40	1.3E-01	2.6E-02
	Cobalt-60	9.2E-05	5.4E-04
	Cesium-137	2.7E-03	1.3E-03
	Lead-210	8.2E-03	9.1E-03
	Radium-226	9.1E-03	1.1E-02
	Radium-228	6.0E-03	3.5E-03
	Americium-241	8.0E-03	1.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-WFF Terrestrial Intermediate WIPP Far Field (continued)	Thorium-228	6.3E-03	1.8E-03
	Thorium-230	3.3E-02	3.8E-03
	Thorium-232	6.0E-03	1.6E-03
	Uranium-233/234	1.6E-02	2.5E-03
	Uranium-235	3.7E-04	4.2E-04
	Uranium-238	7.8E-03	1.7E-03
	Plutonium-238	2.0E-04	4.9E-04
	Plutonium-239/240	4.5E-03	1.3E-03
	Plutonium-241	-2.0E-01	8.5E-02
	Strontium-90	1.7E-03	1.7E-03
	Polonium-210	1.2E-02	1.0E-02
TD-WFF Terrestrial Deep WIPP Far Field	Potassium-40	1.5E-01	3.0E-02
	Cobalt-60	4.9E-05	5.3E-04
	Cesium-137	2.6E-03	1.2E-03
	Lead-210	1.2E-02	8.6E-03
	Radium-226	1.1E-02	1.2E-02
	Radium-228	6.2E-03	3.7E-03
	Americium-241	1.2E-02	2.3E-03
	Thorium-228	7.5E-03	1.8E-03
	Thorium-230	2.7E-02	3.3E-03
	Thorium-232	6.6E-03	1.6E-03
	Uranium-233/234	1.4E-02	2.3E-03
	Uranium-235	9.0E-04	6.2E-04
	Uranium-238	7.1E-03	1.6E-03
	Plutonium-238	1.1E-03	9.2E-04
	Plutonium-239/240	1.0E-02	2.1E-03
	Plutonium-241	-1.4E-01	8.8E-02
	Strontium-90	5.7E-04	1.3E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-WFF Terrestrial Deep WIPP Far Field (continued)	Polonium-210	7.5E-03	1.2E-02
TS-WSS Terrestrial Surface WIPP South	Potassium-40	1.6E-01	3.2E-02
	Cobalt-60	-1.7E-04	6.5E-04
	Cesium-137	3.4E-03	1.5E-03
	Lead-210	1.8E-02	1.1E-02
	Radium-226	2.1E-02	1.5E-02
	Radium-228	8.4E-03	4.7E-03
	Americium-241	5.0E-03	1.5E-03
	Thorium-228	7.7E-03	1.7E-03
	Thorium-230	1.9E-02	2.7E-03
	Thorium-232	6.6E-03	1.7E-03
	Uranium-233/234	1.1E-02	2.0E-03
	Uranium-235	4.5E-04	6.2E-04
	Uranium-238	8.0E-03	1.7E-03
	Plutonium-238	1.9E-04	2.6E-04
	Plutonium-239/240	6.5E-04	6.1E-04
	Plutonium-241	-1.5E-01	8.1E-02
	Strontium-90	4.5E-06	1.5E-03
	Polonium-210	2.1E-02	1.1E-02
TI-WSS Terrestrial Intermediate WIPP South	Potassium-40	2.1E-01	3.9E-02
	Cobalt-60	2.0E-04	6.7E-04
	Cesium-137	4.3E-03	1.8E-03
	Lead-210	1.3E-02	1.1E-02
	Radium-226	2.0E-03	1.2E-02
	Radium-228	1.3E-02	3.0E-03
	Americium-241	5.1E-03	1.5E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-WSS Terrestrial Intermediate WIPP South (continued)	Thorium-228	8.2E-03	1.8E-03
	Thorium-230	1.5E-02	2.4E-03
	Thorium-232	8.3E-03	1.8E-03
	Uranium-233/234	1.2E-02	2.2E-03
	Uranium-235	1.3E-03	7.8E-04
	Uranium-238	8.1E-03	1.8E-03
	Plutonium-238	-1.1E-04	2.1E-04
	Plutonium-239/240	3.2E-04	3.6E-04
	Plutonium-241	-2.0E-01	8.8E-02
	Strontium-90	2.1E-03	1.5E-03
	Polonium-210	1.3E-02	9.5E-03
TD-WSS Terrestrial Deep WIPP South	Potassium-40	1.7E-01	3.3E-02
	Cobalt-60	2.6E-04	6.4E-04
	Cesium-137	4.6E-03	1.8E-03
	Lead-210	5.6E-03	1.3E-02
	Radium-226	8.7E-03	1.4E-02
	Radium-228	1.2E-02	5.1E-03
	Americium-241	6.5E-03	1.8E-03
	Thorium-228	8.2E-03	2.1E-03
	Thorium-230	2.1E-02	3.3E-03
	Thorium-232	7.5E-03	2.0E-03
	Uranium-233/234	1.0E-02	2.1E-03
	Uranium-235	8.9E-04	7.5E-04
	Uranium-238	8.0E-03	1.8E-03
	Plutonium-238	1.0E-04	2.0E-04
	Plutonium-239/240	2.1E-04	4.0E-04
	Plutonium-241	-1.8E-01	8.4E-02
	Strontium-90	-2.8E-04	1.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-WSS Terrestrial Deep WIPP South (continued)	Polonium-210	7.6E-03	1.1E-02

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APPENDIX A3

SURFACE WATER

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-NOY Surface Water Noya Tank	Potassium-40	9.2E+00	2.3E+00
	Cobalt-60	3.4E-02	1.2E-01
	Cesium-137	9.2E-02	1.3E-01
	Lead-210	7.1E+00	2.4E+00
	Radium-226	2.4E-02	3.5E-03
	Radium-228	1.1E-01	4.6E-02
	Actinium-228	2.6E-01	4.9E-01
	Americium-241	2.4E-02	7.1E-03
	Thorium-228	6.6E-03	4.4E-03
	Thorium-230	4.6E-02	9.3E-03
	Thorium-232	1.4E-03	2.1E-03
	Uranium-233/234	2.2E-02	6.7E-03
	Uranium-235	2.3E-03	2.3E-03
	Uranium-238	1.4E-02	5.2E-03
	Plutonium-238	0.0E+00	1.3E-03
	Plutonium-239/240	9.4E-04	2.3E-03
	Plutonium-241	-1.1E+00	2.4E-01
	Strontium-90	2.8E-02	1.8E-02
	Polonium-210	2.8E-03	3.4E-02
HS-UPR Surface Water Upper Pecos River	Potassium-40	8.9E+00	2.3E+00
	Cobalt-60	1.6E-02	1.5E-01
	Cesium-137	2.0E-02	1.1E-01
	Lead-210	1.3E+00	3.5E+00
	Radium-226	2.6E-03	1.5E-03
	Radium-228	4.3E-02	3.6E-02
	Actinium-228	7.1E-01	6.2E-01
	Americium-241	3.5E-02	9.5E-03
	Thorium-228	5.9E-03	4.6E-03
	Thorium-230	6.8E-02	1.1E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-UPR Surface Water Upper Pecos River (continued)	Thorium-232	4.5E-04	2.7E-03
	Uranium-233/234	2.1E-01	2.0E-02
	Uranium-235	8.3E-03	4.3E-03
	Uranium-238	8.6E-02	1.3E-02
	Plutonium-238	4.9E-04	1.7E-03
	Plutonium-239/240	9.9E-04	2.4E-03
	Plutonium-241	-1.3E+00	2.6E-01
	Strontium-90	3.7E-03	1.3E-02
	Polonium-210	0.0E+00	3.7E-02
HS-ION Surface Water Indian Tank Blind Duplicate sample of Indian Tank	Potassium-40	1.5E+00	2.6E+00
	Cobalt-60	7.6E-03	1.4E-01
	Cesium-137	2.8E-02	1.2E-01
	Lead-210	1.0E+00	3.3E+00
	Radium-226	4.0E-02	4.6E-03
	Radium-228	7.6E-02	4.3E-02
	Actinium-228	4.8E-01	5.1E-01
	Americium-241	3.0E-02	8.4E-03
	Thorium-228	0.0E+00	3.2E-03
	Thorium-230	7.6E-02	1.2E-02
	Thorium-232	2.1E-03	2.9E-03
	Uranium-233/234	2.7E-02	7.7E-03
	Uranium-235	-1.2E-03	3.6E-03
	Uranium-238	1.1E-02	5.1E-03
	Plutonium-238	9.7E-04	3.3E-03
	Plutonium-239/240	-4.9E-03	5.0E-03
	Plutonium-241	-3.1E+00	5.2E-01
	Strontium-90	3.8E-02	1.8E-02
	Polonium-210	4.4E-03	3.2E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-IDN Surface Water Indian Tank	Potassium-40	2.5E+00	2.9E+00
	Cobalt-60	6.7E-03	1.4E-01
	Cesium-137	4.4E-02	1.3E-01
	Lead-210	8.7E+00	2.3E+00
	Radium-226	4.4E-02	4.8E-03
	Radium-228	1.8E-01	5.9E-02
	Actinium-228	3.4E-01	5.0E-01
	Americium-241	2.6E-02	8.0E-03
	Thorium-228	2.2E-02	6.7E-03
	Thorium-230	6.4E-02	1.1E-02
	Thorium-232	3.3E-03	2.8E-03
	Uranium-233/234	3.3E-02	8.1E-03
	Uranium-235	1.2E-03	2.3E-03
	Uranium-238	1.7E-02	6.1E-03
	Plutonium-238	4.8E-04	2.5E-03
	Plutonium-239/240	-4.8E-04	1.6E-03
	Plutonium-241	-5.6E-01	2.7E-01
	Strontium-90	1.5E-02	1.9E-02
	Polonium-210	6.0E-03	4.1E-02
HS-CBD Surface Water Carlsbad	Potassium-40	1.8E+00	2.5E+00
	Cobalt-60	9.9E-02	1.3E-01
	Cesium-137	-1.6E-02	1.2E-01
	Lead-210	5.5E-01	3.5E+00
	Radium-226	6.7E-03	2.1E-03
	Radium-228	8.9E-03	4.4E-02
	Actinium-228	3.5E-01	5.1E-01
	Americium-241	3.3E-02	9.3E-03
	Thorium-228	3.8E-03	2.6E-03
	Thorium-230	3.9E-02	8.7E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-CBD Surface Water Carlsbad (continued)	Thorium-232	1.4E-03	2.8E-03
	Uranium-233/234	8.6E-02	1.4E-02
	Uranium-235	2.8E-03	4.0E-03
	Uranium-238	4.9E-02	9.5E-03
	Plutonium-238	-1.1E-03	2.1E-03
	Plutonium-239/240	1.6E-03	1.8E-03
	Plutonium-241	-1.5E+00	3.1E-01
	Strontium-90	1.5E-02	1.4E-02
	Polonium-210	2.0E-03	3.4E-02
HS-RED Water REd Tank	Potassium-40	7.9E-01	2.4E+00
	Cobalt-60	4.3E-02	1.4E-01
	Cesium-137	-1.2E-01	1.2E-01
	Lead-210	8.0E+00	2.4E+00
	Radium-226	6.8E-03	2.0E-03
	Radium-228	3.6E-02	3.9E-02
	Actinium-228	4.3E-01	5.1E-01
	Americium-241	2.8E-02	7.8E-03
	Thorium-228	2.4E-03	3.6E-03
	Thorium-230	6.2E-02	1.1E-02
	Thorium-232	4.7E-04	2.1E-03
	Uranium-233/234	1.2E-02	5.6E-03
	Uranium-235	-5.8E-04	2.0E-03
	Uranium-238	9.9E-03	4.5E-03
	Plutonium-238	-2.8E-03	2.2E-03
	Plutonium-239/240	9.2E-04	1.8E-03
	Plutonium-241	-1.3E+00	2.4E-01
	Strontium-90	1.1E-02	1.5E-02
	Polonium-210	2.4E-03	3.8E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-FWT Surface Water Fresh Water Tank	Potassium-40	7.1E+00	2.1E+00
	Cobalt-60	1.7E-01	1.6E-01
	Cesium-137	-3.6E-02	1.1E-01
	Lead-210	7.9E+00	2.3E+00
	Radium-226	3.1E-03	1.7E-03
	Radium-228	1.6E-02	3.5E-02
	Actinium-228	4.3E-01	5.7E-01
	Americium-241	3.7E-02	1.0E-02
	Thorium-228	7.5E-03	5.3E-03
	Thorium-230	4.5E-02	9.6E-03
	Thorium-232	0.0E+00	1.4E-03
	Uranium-233/234	5.6E-02	1.1E-02
	Uranium-235	2.6E-03	2.5E-03
	Uranium-238	1.6E-02	5.7E-03
	Plutonium-238	-1.9E-03	2.7E-03
	Plutonium-239/240	-1.9E-03	1.9E-03
	Plutonium-241	-1.4E+00	2.8E-01
	Strontium-90	5.4E-04	1.4E-02
	Polonium-210	-8.7E-04	2.7E-02
HS-LGS Surface Water Laguna Grande de la Sol	Potassium-40	1.1E+03	1.3E+02
	Cobalt-60	2.5E-01	3.2E-01
	Cesium-137	6.6E-02	2.1E-01
	Lead-210	7.5E+00	4.0E+00
	Radium-226	3.1E-01	1.3E-02
	Radium-228	2.0E-01	5.6E-02
	Actinium-228	-3.3E-01	9.7E-01
	Americium-241	6.8E-02	3.2E-02
	Thorium-228	1.3E-02	5.8E-03
	Thorium-230	7.4E-02	1.3E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-LGS Surface Water Laguna Grande de la Sol (continued)	Thorium-232	-1.1E-03	2.1E-03
	Uranium-233/234	2.1E+00	6.3E-01
	Uranium-235	2.1E+00	6.3E-01
	Uranium-238	2.7E+00	6.8E-01
	Plutonium-238	9.4E-04	1.8E-03
	Plutonium-239/240	3.8E-03	5.2E-03
	Plutonium-241	-2.3E+00	5.3E-01
	Strontium-90	-2.6E-01	4.7E-01
	Polonium-210	1.4E-01	1.2E-01
HS-LBL Surface Water Lake Brantley	Potassium-40	1.6E+00	2.8E+00
	Cobalt-60	2.3E-02	1.3E-01
	Cesium-137	1.1E-02	1.2E-01
	Lead-210	6.7E+00	2.2E+00
	Radium-226	5.1E-03	1.8E-03
	Radium-228	7.1E-02	3.9E-02
	Actinium-228	1.1E+00	8.1E-01
	Americium-241	2.9E-02	9.7E-03
	Thorium-228	6.2E-03	3.7E-03
	Thorium-230	6.6E-02	1.1E-02
	Thorium-232	0.0E+00	1.7E-03
	Uranium-233/234	1.1E-01	1.5E-02
	Uranium-235	1.9E-03	4.2E-03
	Uranium-238	5.5E-02	1.1E-02
	Plutonium-238	-1.4E-03	2.8E-03
	Plutonium-239/240	1.9E-03	2.7E-03
	Plutonium-241	-1.2E+00	2.6E-01
	Strontium-90	1.4E-02	1.3E-02
	Polonium-210	0.0E+00	3.5E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-SEW Surface Water Sewage Lagoon	Potassium-40	2.2E+00	2.9E+00
	Cobalt-60	1.6E-02	1.3E-01
	Cesium-137	-1.7E-02	1.1E-01
	Lead-210	2.0E-01	3.2E+00
	Radium-226	4.6E-03	2.2E-03
	Radium-228	1.8E-02	6.9E-02
	Actinium-228	2.3E-01	4.8E-01
	Americium-241	3.1E-02	8.6E-03
	Thorium-228	-1.6E-03	2.7E-03
	Thorium-230	6.2E-02	1.1E-02
	Thorium-232	2.1E-03	2.0E-03
	Uranium-233/234	2.3E-02	7.2E-03
	Uranium-235	5.6E-04	2.4E-03
	Uranium-238	4.9E-03	4.2E-03
	Plutonium-238	2.2E-03	5.9E-03
	Plutonium-239/240	1.5E-03	4.1E-03
	Plutonium-241	-1.6E+00	4.0E-01
	Strontium-90	2.3E-03	1.6E-02
	Polonium-210	3.9E-04	3.3E-02
HS-TUT Surface Water Tut Tank	Potassium-40	9.1E+00	2.4E+00
	Cobalt-60	-1.1E-01	1.5E-01
	Cesium-137	1.4E-02	1.2E-01
	Lead-210	9.1E+00	2.3E+00
	Radium-226	9.3E-03	2.4E-03
	Radium-228	1.0E-01	4.6E-02
	Actinium-228	2.3E-01	5.0E-01
	Americium-241	4.4E-02	1.8E-02
	Thorium-228	7.1E-03	5.3E-03
	Thorium-230	5.0E-02	1.2E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-TUT Surface Water Tut Tank (Continued)	Thorium-232	1.3E-03	3.1E-03
	Uranium-233/234	2.3E-02	7.1E-03
	Uranium-235	2.4E-03	3.3E-03
	Uranium-238	1.1E-02	4.9E-03
	Plutonium-238	7.2E-04	4.3E-03
	Plutonium-239/240	1.5E-03	2.8E-03
	Plutonium-241	-1.7E+00	4.1E-01
	Strontium-90	1.5E-02	1.7E-02
	Polonium-210	1.3E-03	2.9E-02
HS-PCN Surface Water Pierce Canyon	Potassium-40	8.2E+00	2.4E+00
	Cobalt-60	1.4E-01	1.3E-01
	Cesium-137	4.8E-02	1.3E-01
	Lead-210	7.5E-01	3.7E+00
	Radium-226	4.5E-03	1.9E-03
	Radium-228	8.0E-03	4.9E-02
	Actinium-228	2.6E-01	5.0E-01
	Americium-241	3.1E-02	1.1E-02
	Thorium-228	4.2E-03	2.8E-03
	Thorium-230	7.7E-02	1.2E-02
	Thorium-232	-1.4E-03	2.1E-03
	Uranium-233/234	1.2E-01	1.6E-02
	Uranium-235	6.3E-03	4.9E-03
	Uranium-238	5.6E-02	1.1E-02
	Plutonium-238	4.4E-04	2.9E-03
	Plutonium-239/240	8.9E-04	1.7E-03
	Plutonium-241	-8.3E-01	2.4E-01
	Strontium-90	-1.1E-02	2.8E-02
	Polonium-210	1.1E-03	4.1E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AS-PCN Surface Water Pierce Canyon	Potassium-40	1.1E-01	2.9E+00
	Cobalt-60	1.0E-01	1.3E-01
	Cesium-137	-4.4E-02	1.2E-01
	Lead-210	8.1E+00	2.3E+00
	Radium-226	3.1E-03	1.6E-03
	Radium-228	2.8E-02	4.5E-02
	Actinium-228	4.2E-01	5.2E-01
	Americium-241	1.6E-02	6.7E-03
	Thorium-228	2.3E-03	5.5E-03
	Thorium-230	5.6E-02	1.6E-02
	Thorium-232	0.0E+00	3.2E-03
	Uranium-233/234	1.2E-01	1.5E-02
	Uranium-235	7.1E-03	4.6E-03
	Uranium-238	5.0E-02	1.0E-02
	Plutonium-238	8.7E-04	2.4E-03
	Plutonium-239/240	1.3E-03	1.9E-03
	Plutonium-241	-7.4E-01	2.5E-01
	Strontium-90	-4.2E-03	1.3E-02
	Polonium-210	4.6E-04	3.7E-02
HS-COY Surface Water Coyote Tank Blind Duplicate sample of Upper Pecos River	Potassium-40	2.8E-01	2.8E+00
	Cobalt-60	-2.4E-02	1.4E-01
	Cesium-137	-7.7E-02	1.2E-01
	Lead-210	2.1E-01	3.4E+00
	Radium-226	3.4E-03	1.7E-03
	Radium-228	3.9E-02	4.4E-02
	Actinium-228	2.4E-01	4.5E-01
	Americium-241	2.2E-02	7.4E-03
	Thorium-228	9.3E-04	2.6E-03
	Thorium-230	2.4E-02	6.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-COY Surface Water Coyote Tank Blind Duplicate sample of Upper Pecos River (continued)	Thorium-232	4.7E-04	9.1E-04
	Uranium-233/234	1.9E-01	1.8E-02
	Uranium-235	7.0E-03	4.1E-03
	Uranium-238	7.3E-02	1.1E-02
	Plutonium-238	0.0E+00	2.1E-03
	Plutonium-239/240	2.1E-03	2.1E-03
	Plutonium-241	-9.2E-01	3.0E-01
	Strontium-90	7.2E-03	1.2E-02
	Polonium-210	2.0E-03	4.7E-02
HS-COW Surface Water Coyote Well blind blank Deionized water	Potassium-40	8.1E+00	2.5E+00
	Cobalt-60	4.8E-02	1.6E-01
	Cesium-137	1.0E-01	1.1E-01
	Lead-210	5.6E-01	3.3E+00
	Radium-226	1.6E-03	1.3E-03
	Radium-228	3.7E-02	3.6E-02
	Actinium-228	2.3E-01	5.1E-01
	Americium-241	2.5E-02	8.4E-03
	Thorium-228	-4.4E-04	1.9E-03
	Thorium-230	4.8E-02	9.1E-03
	Thorium-232	4.4E-04	1.5E-03
	Uranium-233/234	9.5E-03	4.7E-03
	Uranium-235	6.2E-04	2.1E-03
	Uranium-238	2.0E-03	2.4E-03
	Plutonium-238	0.0E+00	1.4E-03
	Plutonium-239/240	1.0E-03	2.4E-03
	Plutonium-241	-6.8E-01	2.9E-01
	Strontium-90	-4.0E-03	1.5E-02
	Polonium-210	-1.1E-03	3.1E-02

APPENDIX A4

BOTTOM SEDIMENTS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-BRA Bottom Sediment Brantley Lake	Potassium-40	2.6E-01	4.7E-02
	Cobalt-60	-5.0E-04	7.8E-04
	Cesium-137	-4.0E-04	8.0E-04
	Lead-210	3.2E-03	1.2E-02
	Radium-226	1.5E-02	1.7E-02
	Radium-228	1.4E-02	3.7E-03
	Americium-241	8.7E-03	2.1E-03
	Thorium-228	1.6E-02	2.6E-03
	Thorium-230	2.6E-02	3.3E-03
	Thorium-232	1.7E-02	2.7E-03
	Uranium-233/234	1.9E-02	2.8E-03
	Uranium-235	1.1E-03	8.9E-04
	Uranium-238	1.9E-02	2.8E-03
	Plutonium-238	1.0E-04	4.4E-04
	Plutonium-239/240	1.0E-04	3.4E-04
	Plutonium-241	-1.9E-01	8.5E-02
	Strontium-90	-1.4E-04	1.3E-03
	Polonium-210	6.4E-03	8.9E-03
HB-CBD Bottom Sediment Carlsbad	Potassium-40	3.6E-01	6.8E-02
	Cobalt-60	6.8E-04	1.3E-03
	Cesium-137	7.1E-03	3.4E-03
	Lead-210	6.4E-02	2.4E-02
	Radium-226	4.9E-02	3.4E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-CBD Bottom Sediment Carlsbad (continued)	Radium-228	2.4E-02	6.1E-0[illegible]
	Americium-241	7.2E-03	2.1E-0[illegible]
	Thorium-228	2.6E-02	4.8E-03
	Thorium-230	3.2E-02	5.4E-03
	Thorium-232	2.4E-02	4.6E-03
	Uranium-233/234	4.9E-02	4.6E-03
	Uranium-235	2.7E-03	1.3E-03
	Uranium-238	3.3E-02	3.8E-03
	Plutonium-238	1.4E-04	2.8E-04
	Plutonium-239/240	5.8E-04	5.6E-04
	Plutonium-241	-3.8E-01	1.2E-01
	Strontium-90	-2.4E-04	1.9E-03
	Polonium-210	4.9E-02	1.0E-02
HB-HIL Bottom Sediment Hill Tank	Potassium-40	8.4E-01	1.4E-01
	Cobalt-60	-4.5E-04	1.1E-03
	Cesium-137	1.2E-02	3.7E-03
	Lead-210	5.9E-02	2.2E-02
	Radium-226	4.1E-02	3.1E-02
	Radium-228	4.0E-02	7.5E-03
	Americium-241	1.0E-02	2.3E-03
	Thorium-228	3.4E-02	9.4E-03
	Thorium-230	5.1E-02	1.1E-02
	Thorium-232	3.7E-02	9.4E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-HIL Bottom Sediment Hill Tank (continued)	Uranium-233/234	2.5E-02	3.1E-03
	Uranium-235	1.7E-03	9.3E-04
	Uranium-238	2.4E-02	3.0E-03
	Plutonium-238	4.2E-04	5.0E-04
	Plutonium-239/240	6.3E-04	5.8E-04
	Plutonium-241	-2.1E-01	8.7E-02
	Strontium-90	2.5E-03	1.9E-03
	Polonium-210	5.7E-02	1.2E-02
HB-IDN Bottom Sediment Indian Tank	Potassium-40	6.2E-01	1.1E-01
	Cobalt-60	-3.2E-04	1.2E-03
	Cesium-137	1.5E-02	4.5E-03
	Radium-226	3.3E-02	2.8E-02
	Radium-228	3.8E-02	7.1E-03
	Lead-210	5.8E-02	2.2E-02
	Americium-241	7.3E-03	2.1E-03
	Thorium-228	4.6E-02	1.4E-03
	Thorium-230	5.2E-02	1.5E-02
	Thorium-232	2.7E-02	1.2E-03
	Uranium-233/234	2.7E-02	3.1E-03
	Uranium-235	2.1E-03	9.9E-04
	Uranium-238	2.8E-02	3.1E-03
	Plutonium-238	0.0E+00	2.8E-04
	Plutonium-239/240	4.1E-04	4.0E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-IDN Bottom Sediment Indian Tank (continued)	Plutonium-241	-2.3E-01	8.5E-02
	Strontium-90	3.4E-03	1.9E-03
	Polonium-210	4.4E-02	1.1E-02
HB-LGS Bottom Sediment Laguna Grande de la Sol	Potassium-40	3.3E-01	6.2E-02
	Cobalt-60	4.3E-04	1.0E-03
	Cesium-137	2.9E-03	1.5E-03
	Lead-210	1.3E-02	1.7E-02
	Radium-226	3.9E-02	2.7E-02
	Radium-228	1.3E-02	1.0E-02
	Americium-241	1.2E-02	3.4E-03
	Thorium-228	1.0E-02	2.7E-03
	Thorium-230	2.6E-02	4.4E-03
	Thorium-232	3.0E-03	1.9E-03
	Uranium-233/234	7.5E-02	5.7E-03
	Uranium-235	3.6E-03	1.5E-03
	Uranium-238	3.9E-02	4.2E-03
	Plutonium-238	-1.0E-04	2.0E-04
	Plutonium-239/240	6.3E-04	5.0E-04
	Plutonium-241	-2.3E-01	8.8E-02
	Strontium-90	-1.1E-03	2.4E-03
	Polonium-210	1.4E-02	1.0E-02
HB-NOY Bottom Sediment Noya Tank	Potassium-40	6.2E-01	1.1E-01
	Cobalt-60	-3.2E-04	9.1E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-NOY Bottom Sediment Noya Tank (continued)	Cesium-137	4.2E-03	1.9E-03
	Lead-210	1.7E-02	1.7E-02
	Radium-226	2.8E-02	2.3E-02
	Radium-228	2.2E-02	5.1E-03
	Americium-241	1.1E-02	2.5E-03
	Thorium-228	2.4E-02	4.9E-03
	Thorium-230	3.5E-02	5.8E-03
	Thorium-232	2.2E-02	4.5E-03
	Uranium-233/234	1.8E-02	2.5E-03
	Uranium-235	1.4E-03	7.6E-04
	Uranium-238	1.9E-02	2.5E-03
	Plutonium-239/240	-1.3E-04	2.5E-04
	Plutonium-238	2.5E-04	6.1E-04
	Plutonium-241	-2.9E-01	1.1E-01
	Strontium-90	-2.4E-04	1.5E-03
	Polonium-210	2.4E-02	1.1E-02
HB-PCN Bottom Sediment Pierce Canyon	Potassium-40	1.5E-01	3.1E-02
	Cobalt-60	6.5E-04	7.3E-04
	Cesium-137	-5.1E-04	8.2E-04
	Lead-210	1.2E-02	1.1E-02
	Radium-226	4.8E-02	2.4E-02
	Radium-228	1.2E-02	5.8E-03
	Americium-241	1.4E-02	2.7E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-PCN Bottom Sediment Pierce Canyon (continued)	Thorium-228	9.0E-03	2.2E-03
	Thorium-230	3.9E-02	4.4E-03
	Thorium-232	7.3E-03	2.0E-03
	Uranium-233/234	1.2E-01	6.7E-03
	Uranium-235	7.5E-03	1.9E-03
	Uranium-238	1.3E-01	6.9E-03
	Plutonium-238	0.0E+00	2.8E-04
	Plutonium-239/240	1.1E-03	6.6E-04
	Plutonium-241	-2.2E-01	8.2E-02
	Strontium-90	-1.6E-03	1.2E-03
	Polonium-210	1.4E-02	9.7E-03
HB-RED Bottom Sediment Red Tank	Potassium-40	4.0E-01	7.2E-02
	Cobalt-60	5.1E-04	9.2E-04
	Cesium-137	7.3E-03	3.0E-03
	Lead-210	3.0E-02	1.6E-02
	Radium-226	4.2E-02	2.6E-02
	Radium-228	2.3E-02	5.7E-03
	Americium-241	1.1E-02	2.4E-03
	Thorium-228	2.2E-02	4.6E-03
	Thorium-230	3.0E-02	5.3E-03
	Thorium-232	1.7E-02	4.1E-03
	Uranium-233/234	3.1E-02	8.3E-03
	Uranium-235	5.9E-04	3.1E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-RED Bottom Sediment Red Tank (continued)	Uranium-238	3.0E-02	7.5E-03
	Plutonium-238	-9.7E-05	1.9E-04
	Plutonium-239/240	1.9E-04	2.7E-04
	Plutonium-241	-2.1E-01	7.8E-02
	Strontium-90	-6.8E-04	1.2E-03
	Polonium-210	2.2E-02	9.5E-03
HB-TUT Bottom Sediment Tut Tank	Potassium-40	7.0E-01	1.2E-01
	Cobalt-60	-5.0E-04	9.8E-04
	Cesium-137	9.4E-04	1.6E-03
	Lead-210	2.5E-02	1.7E-02
	Radium-226	3.0E-02	2.5E-02
	Radium-228	3.0E-02	6.4E-03
	Americium-241	1.1E-02	2.7E-03
	Thorium-228	4.5E-02	1.2E-03
	Thorium-230	4.3E-02	1.1E-03
	Thorium-232	4.5E-02	1.1E-02
	Uranium-233/234	2.8E-02	3.2E-03
	Uranium-235	2.2E-03	9.9E-04
	Uranium-238	2.5E-02	3.0E-03
	Plutonium-238	0.0E+00	0.0E+00
	Plutonium-239/240	4.2E-04	4.1E-04
	Plutonium-241	-1.3E-01	9.0E-02
	Strontium-90	2.6E-03	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-TUT Bottom Sediment Tut Tank (continued)	Polonium-210	3.1E-02	1.2E-02
HB-UPR Bottom Sediment Upper Pecos River	Potassium-40	1.7E-01	3.2E-02
	Cobalt-60	6.7E-05	6.8E-04
	Cesium-137	3.3E-05	6.7E-04
	Lead-210	1.6E-03	1.0E-02
	Radium-226	8.3E-03	1.3E-02
	Radium-228	4.4E-03	4.1E-03
	Americium-241	8.5E-03	2.1E-03
	Thorium-228	8.4E-03	1.8E-03
	Thorium-230	2.4E-02	3.0E-03
	Thorium-232	9.1E-03	1.9E-03
	Uranium-233/234	9.9E-03	2.0E-03
	Uranium-235	4.8E-04	7.5E-04
	Uranium-238	7.9E-03	1.7E-03
	Plutonium-238	-9.9E-05	1.9E-04
	Plutonium-239/240	7.9E-04	5.5E-04
	Plutonium-241	-2.2E-01	7.7E-02
	Strontium-90	-2.1E-04	1.3E-03
	Polonium-210	4.7E-03	1.0E-02

APPENDIX A5

GROUNDWATER

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H05B Groundwater Round 9	Potassium-40	3.7E+01	7.7E+00
	Cobalt-60	5.3E-02	2.0E-01
	Cesium-137	-1.2E-01	1.7E-01
	Lead-210	1.2E+00	4.5E+00
	Radium-226	1.5E+01	9.5E+00
	Radium-228	1.7E+00	1.7E+00
	Americium-241	3.8E-03	3.5E-03
	Thorium-228	3.8E-01	2.7E-02
	Thorium-230	6.7E-02	1.2E-02
	Thorium-232	0.0E+00	1.4E-03
	Uranium-233/234	1.1E-01	1.4E-02
	Uranium-235	3.8E-03	3.8E-03
	Uranium-238	7.0E-03	3.6E-03
	Plutonium-238	5.9E-03	3.6E-03
	Plutonium-239/240	1.8E-03	3.0E-03
	Plutonium-241	-1.9E-01	4.3E-01
	Strontium-90	-5.1E-02	2.4E-02
	Polonium-210	6.1E-02	4.8E-02
H02C Groundwater Round 6	Potassium-40	3.3E+00	3.1E+00
	Cobalt-60	9.5E-02	1.7E-01
	Cesium-137	8.1E-02	1.6E-01
	Lead-210	9.3E-01	3.9E+00
	Radium-226	3.3E+00	5.1E+00
	Radium-228	4.2E-01	6.8E-01
	Americium-241	1.4E-02	7.0E-03
	Thorium-228	2.3E-02	7.2E-03
	Thorium-230	3.6E-02	8.4E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H02C Groundwater Round 6 (continued)	Thorium-232	1.4E-03	2.5E-03
	Uranium-233/234	3.6E-01	5.2E-02
	Uranium-235	6.3E-03	9.1E-03
	Uranium-238	4.1E-02	2.0E-02
	Plutonium-238	1.4E-03	4.5E-03
	Plutonium-239/240	0.0E+00	2.8E-03
	Plutonium-241	-2.4E-01	5.6E-01
	Strontium-90	6.6E-02	1.3E-01
	Polonium-210	9.6E-03	4.8E-02
H09B Groundwater Round 5	Potassium-40	2.6E+00	2.5E+00
	Cobalt-60	-1.2E-01	1.7E-01
	Cesium-137	8.2E-02	1.5E-01
	Lead-210	5.5E-01	3.9E+00
	Radium-226	3.8E+00	4.9E+00
	Radium-228	8.3E-01	8.6E-01
	Americium-241	2.3E-02	8.4E-03
	Thorium-228	9.6E-03	4.5E-03
	Thorium-230	5.8E-02	1.1E-02
	Thorium-232	5.1E-04	9.9E-04
	Uranium-233/234	7.5E-01	3.9E-02
	Uranium-235	2.4E-02	7.9E-03
	Uranium-238	4.1E-01	2.9E-02
	Plutonium-238	4.3E-03	3.6E-03
	Plutonium-239/240	1.2E-03	1.7E-03
	Plutonium-241	1.7E+00	5.1E-01
	Strontium-90	-9.3E-03	2.2E-02
	Polonium-210	6.0E-03	7.3E-02
H3B3 Groundwater Round 9	Potassium-40	1.2E+01	4.2E+00
	Cobalt-60	3.4E-02	1.9E-01

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H3B3 Groundwater Round 9 (continued)	Cesium-137	-2.9E-02	1.6E-01
	Lead-210	2.3E+00	4.0E+00
	Radium-226	7.4E+00	6.1E+00
	Radium-228	1.3E+00	1.5E+00
	Americium-241	3.6E-03	3.7E-03
	Thorium-228	1.3E-01	1.6E-02
	Thorium-230	4.4E-02	9.0E-03
	Thorium-232	-9.6E-04	2.3E-03
	Uranium-233/234	4.8E-01	3.1E-02
	Uranium-235	9.8E-03	5.4E-03
	Uranium-238	6.3E-02	1.1E-02
	Plutonium-238	9.1E-03	5.1E-03
	Plutonium-239/240	-5.1E-04	1.0E-03
	Plutonium-241	9.6E-03	3.9E-01
	Strontium-90	-2.2E-02	3.0E-02
	Polonium-210	1.4E-02	3.5E-02
H11B Groundwater Round 8	Potassium-40	1.8E+01	5.5E+00
	Cobalt-60	-6.5E-02	1.7E-01
	Cesium-137	-4.6E-02	1.6E-01
	Lead-210	1.7E+00	4.1E+00
	Radium-226	7.0E+00	5.9E+00
	Radium-228	9.9E-01	1.1E+00
	Americium-241	8.9E-03	4.8E-03
	Thorium-228	7.1E-02	1.3E-02
	Thorium-230	5.2E-02	1.1E-02
	Thorium-232	-5.4E-04	1.8E-03
	Uranium-233/234	2.5E-01	2.3E-02
	Uranium-235	7.7E-03	5.6E-03
	Uranium-238	3.8E-02	9.5E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H11B Groundwater Round 8 (continued)	Plutonium-238	2.0E-03	3.4E-03
	Plutonium-239/240	4.6E-03	3.4E-03
	Plutonium-241	3.3E+00	6.1E-01
	Strontium-90	9.8E-03	1.4E-02
	Polonium-210	3.5E-02	5.2E-02
H14C Groundwater Round 7	Potassium-40	1.1E+01	4.0E+00
	Cobalt-60	1.4E-01	2.0E-01
	Cesium-137	-4.0E-03	2.0E-01
	Lead-210	1.2E+01	3.3E+00
	Radium-226	9.5E+00	7.6E+00
	Radium-228	6.9E-01	9.2E-01
	Americium-241	1.5E-02	5.8E-03
	Thorium-228	5.6E-02	1.1E-02
	Thorium-230	2.9E-02	8.3E-03
	Thorium-232	1.0E-03	2.0E-03
	Uranium-233/234	3.2E-01	3.1E-02
	Uranium-235	7.1E-03	6.0E-03
	Uranium-238	4.9E-02	1.2E-02
	Plutonium-238	4.6E-03	4.2E-03
	Plutonium-239/240	5.7E-04	1.9E-03
	Plutonium-241	7.0E-01	4.7E-01
	Strontium-90	5.4E-03	9.5E-03
	Polonium-210	7.9E-03	3.5E-02
H04B Groundwater Round 9	Potassium-40	7.1E+00	3.5E+00
	Cobalt-60	8.2E-02	1.7E-01
	Cesium-137	-1.3E-01	1.6E-01
	Lead-210	8.9E-01	4.0E+00
	Radium-226	3.3E+00	4.2E+00
	Radium-228	5.4E-01	7.3E-01

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H04B Groundwater Round 9 (continued)	Americium-241	1.3E-02	5.4E-03
	Thorium-228	6.7E-03	4.6E-03
	Thorium-230	3.9E-02	9.7E-03
	Thorium-232	-6.1E-04	1.2E-03
	Uranium-233/234	5.7E-01	3.6E-02
	Uranium-235	1.6E-02	7.2E-03
	Uranium-238	1.0E-01	1.5E-02
	Plutonium-238	-3.3E-03	4.6E-03
	Plutonium-239/240	-1.6E-03	5.6E-03
	Plutonium-241	-1.3E-01	1.2E+00
	Strontium-90	1.1E-01	5.9E-02
	Polonium-210	7.8E-03	3.6E-02
H06B Groundwater Round 9	Potassium-40	1.1E+01	4.1E+00
	Cobalt-60	-7.8E-02	1.9E-01
	Cesium-137	-2.0E-02	1.5E-01
	Lead-210	3.1E+00	3.7E+00
	Radium-226	7.3E+00	4.8E+00
	Radium-228	8.7E-01	8.8E-01
	Americium-241	8.3E-03	4.9E-03
	Thorium-228	4.2E-02	1.4E-02
	Thorium-230	2.5E-02	1.4E-02
	Thorium-232	2.2E-03	5.3E-03
	Uranium-233/234	2.9E-01	2.5E-02
	Uranium-235	1.4E-02	7.0E-03
	Uranium-238	7.7E-02	1.3E-02
	Plutonium-238	8.9E-03	6.6E-03
	Plutonium-239/240	2.5E-03	5.0E-03
	Plutonium-241	-1.4E+00	9.5E-01
	Strontium-90	-2.7E-02	1.6E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H06B Groundwater Round 9 (continued)	Polonium-210	7.3E-03	3.6E-02
WIPP 19 Groundwater Round 9	Potassium-40	1.4E+01	5.0E+00
	Cobalt-60	4.5E-02	1.9E-01
	Cesium-137	9.0E-02	1.7E-01
	Lead-210	3.8E+00	4.5E+00
	Radium-226	8.7E+00	6.9E+00
	Radium-228	1.2E+00	1.3E+00
	Americium-241	8.4E-03	5.5E-03
	Thorium-228	2.8E-01	2.6E-02
	Thorium-230	6.3E-02	1.3E-02
	Thorium-232	-1.3E-03	1.8E-03
	Uranium-233/234	5.5E-01	5.4E-02
	Uranium-235	1.3E-02	9.2E-03
	Uranium-238	9.4E-02	2.3E-02
	Plutonium-238	4.3E-03	4.9E-03
	Plutonium-239/240	7.2E-04	3.2E-03
	Plutonium-241	-6.6E-01	5.4E-01
	Strontium-90	-5.8E-03	2.3E-02
	Polonium-210	4.1E-02	7.0E-02

APPENDIX A6

BIOTICS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-CT1 Biotic Vegetation Control 1	Potassium-40	2.5E-01	6.5E-02
	Cobalt-60	2.2E-03	2.4E-03
	Cesium-137	-1.7E-03	2.0E-03
	Lead-210	1.1E-01	5.8E-02
	Radium-226	5.3E-03	6.0E-02
	Radium-228	5.7E-03	1.3E-02
	Actinium-228	5.7E-03	1.3E-02
	Americium-241	4.8E-03	1.4E-03
	Thorium-228	-8.9E-05	6.3E-04
	Thorium-230	8.9E-05	3.9E-04
	Thorium-232	2.7E-04	3.0E-04
	Uranium-233/234	2.9E-04	6.9E-04
	Uranium-235	0.0E+00	4.7E-04
	Uranium-238	2.9E-04	5.1E-04
	Plutonium-238	-1.9E-04	4.6E-04
	Plutonium-239/240	-9.5E-05	4.2E-04
	Plutonium-241	-7.9E-02	4.7E-02
	Strontium-90	4.7E-03	1.1E-03
	Polonium-210	1.7E-02	3.3E-03
BV-CT2 Biotic Vegetation Control 2	Potassium-40	2.9E-01	5.3E-02
	Cobalt-60	7.4E-04	1.2E-03
	Cesium-137	4.6e-04	1.1E-03
	Lead-210	7.2E-02	3.3E-02
	Radium-226	3.9E-02	2.6E-02
	Radium-228	7.8E-03	6.3E-03
	Actinium-228	7.8E-03	6.3E-03
	Americium-241	6.7E-03	1.9E-03
	Thorium-228	8.6E-04	6.7E-04
	Thorium-230	1.7E-03	7.9E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-CT2 Biotic Vegetation Control 2 (continued)	Thorium-232	0.0E+00	2.6E-04
	Uranium-233/234	5.7E-04	6.5E-04
	Uranium-235	2.4E-04	3.3E-04
	Uranium-238	8.6E-04	6.2E-04
	Plutonium-238	2.9E-04	3.3E-04
	Plutonium-239/240	9.6E-05	5.0E-04
	Plutonium-241	-9.2E-02	4.8E-02
	Strontium-90	7.1E-03	1.2E-03
	Polonium-210	1.2E-02	2.0E-03
BV-SE1 Biotic Vegetation South East 1	Potassium-40	2.3E-01	5.7E-02
	Cobalt-60	2.5E-03	1.8E-03
	Cesium-137	1.1E-04	1.7E-03
	Lead-210	9.8E-02	5.2E-02
	Radium-226	3.9E-02	3.5E-02
	Radium-228	7.0E-03	1.0E-02
	Actinium-228	7.0E-03	1.0E-02
	Americium-241	6.1E-03	1.6E-03
	Thorium-228	1.1E-03	7.4E-04
	Thorium-230	1.3E-03	6.9E-04
	Thorium-232	8.5E-04	6.7E-04
	Uranium-233/234	4.8E-04	5.0E-04
	Uranium-235	3.6E-04	4.0E-04
	Uranium-238	6.7E-04	7.8E-04
	Plutonium-238	0.0E+00	3.7E-04
	Plutonium-239/240	-9.4E-05	3.2E-04
	Plutonium-241	-5.6E-02	4.8E-02
	Strontium-90	5.3E-03	1.2E-03
	Polonium-210	2.1E-02	2.3E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-NW1 Biotic Vegetation North West 1	Potassium-40	3.2E-01	5.8E-02
	Cobalt-60	2.0E-04	1.3E-03
	Cesium-137	8.3E-04	1.1E-03
	Lead-210	5.9E-02	3.7E-02
	Radium-226	3.8E-02	4.5E-02
	Radium-228	8.9E-03	1.1E-02
	Actinium-228	8.9E-03	1.1E-02
	Americium-241	7.1E-03	1.8E-03
	Thorium-228	9.4E-04	8.3E-04
	Thorium-230	3.4E-03	1.2E-03
	Thorium-232	5.7E-04	5.8E-04
	Uranium-233/234	1.8E-03	9.3E-04
	Uranium-235	2.3E-04	6.5E-04
	Uranium-238	9.5E-04	6.4E-04
	Plutonium-238	3.9E-05	3.8E-04
	Plutonium-239/240	9.7E-05	3.3E-04
	Plutonium-241	-8.3E-02	4.7E-02
	Strontium-90	9.0E-03	1.2E-03
	Polonium-210	1.7E-02	2.2E-03
BV-NW2 Biotic Vegetation North West 2	Potassium-40	3.3e-01	6.0E-02
	Cobalt-60	-5.2E-04	1.4E-03
	Cesium-137	1.1E-03	1.4E-03
	Lead-210	9.0E-02	4.7E-02
	Radium-226	1.6E-02	4.6E-02
	Radium-228	5.0E-03	7.2E-03
	Actinium-228	8.0E-03	7.2E-03
	Americium-241	6.0E-03	1.6E-03
	Thorium-228	6.4E-04	9.0E-04
	Thorium-230	6.2E-03	1.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-NW2 Biotic Vegetation North West 2 (continued)	Thorium-232	9.1E-04	6.2E-04
	Uranium-233/234	3.7E-04	5.2E-04
	Uranium-235	0.0E+00	4.5E-04
	Uranium-238	4.7E-04	4.1E-04
	Plutonium-238	-9.5E-05	3.2E-04
	Plutonium-239/240	0.0E+00	2.6E-04
	Plutonium-241	-6.5E-02	4.8E-02
	Strontium-90	8.6E-03	1.1E-03
	Polonium-210	2.0E-02	2.1E-03
BV-WE1 Biotic Vegetation WIPP East 1	Potassium-40	2.5E-01	4.4E-02
	Cobalt-60	-3.4E-05	1.1E-03
	Cesium-137	5.2E-04	9.1E-04
	Lead-210	3.8E-02	2.8E-02
	Radium-226	1.1E-02	2.9E-02
	Radium-228	3.3E-03	5.5E-03
	Actinium-228	3.3E-03	5.5E-03
	Americium-241	7.0E-03	1.6E-03
	Thorium-228	9.3E-05	7.0E-04
	Thorium-230	1.0E-02	1.9E-03
	Thorium-232	5.6E-04	5.8E-04
	Uranium-233/234	9.3E-05	6.6E-04
	Uranium-235	2.3E-04	6.4E-04
	Uranium-238	3.7E-04	5.8E-04
	Plutonium-238	-1.8E-04	2.5E-04
	Plutonium-239/240	9.1E-05	3.1E-04
	Plutonium-241	-1.7E-02	4.6E-02
	Strontium-90	6.8E-03	1.1E-03
	Polonium-210	2.1E-02	2.1E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-SE2 Biotic Vegetation South East 2	Potassium-40	3.2E-01	6.4E-02
	Cobalt-60	-1.1E-03	1.9E-03
	Cesium-137	1.4E-03	1.7E-03
	Lead-210	9.9E-02	5.0E-02
	Radium-226	2.2E-02	4.6E-02
	Radium-228	8.5E-03	1.2E-02
	Actinium-228	8.5E-03	1.2E-02
	Americium-241	6.4E-03	1.6E-03
	Thorium-228	9.9E-04	8.4E-04
	Thorium-230	2.9E-03	1.1E-03
	Thorium-232	6.3E-04	5.3E-04
	Uranium-233/234	5.0E-04	6.5E-04
	Uranium-235	6.2E-04	5.4E-04
	Uranium-238	3.0E-04	6.5E-04
	Plutonium-238	9.7E-05	3.3E-04
	Plutonium-239/240	4.8E-04	4.2E-04
	Plutonium-241	-8.7E-02	4.8E-02
	Strontium-90	7.6E-03	1.3E-03
	Polonium-210	1.2E-02	2.8E-03
BQ-SAB Biotic Quail Secured Area Boundary	Potassium-40	8.4E-02	3.0E-02
	Cobalt-60	8.1E-04	8.4E-04
	Cesium-137	6.2E-04	9.2E-04
	Lead-210	3.7E-02	1.1E-02
	Radium-226	8.9E-03	1.9E-02
	Radium-228	2.5E-03	3.3E-03
	Americium-241	4.9E-04	3.0E-04
	Thorium-228	3.0E-05	1.6E-04
	Thorium-230	2.9E-03	6.0E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BQ-SAB Biotic Quail Secured Area Boundary (continued)	Thorium-232	9.0E-05	1.3E-04
	Uranium-233/234	1.5E-03	4.5E-04
	Uranium-235	8.4E-05	1.2E-04
	Uranium-238	2.4E-04	2.4E-04
	Plutonium-238	3.6E-05	1.6E-04
	Plutonium-239/240	-3.6E-05	1.6E-04
	Plutonium-241	1.6E-02	3.1E-02
	Strontium-90	1.7E-03	8.7E-04
	Polonium-210	6.0E-04	1.9E-03
BF-BRA Biotic Fish Brantley Lake	Potassium-40	1.1E-01	3.6E-02
	Cobalt-60	4.6E-04	9.5E-04
	Cesium-137	6.9E-04	9.5E-04
	Lead-210	3.6E-03	1.7E-02
	Radium-226	1.9E-02	1.4E-02
	Radium-228	1.3E-03	4.3E-03
	Americium-241	2.3E-04	1.0E-03
	Thorium-228	6.0E-05	1.4E-04
	Thorium-230	4.2E-03	7.0E-04
	Thorium-232	3.0E-05	1.0E-04
	Uranium-233/234	1.6E-03	4.8E-04
	Uranium-235	2.0E-04	2.3E-04
	Uranium-238	6.4E-04	3.1E-04
	Plutonium-238	1.8E-04	1.7E-04
	Plutonium-239/240	-8.8E-05	1.2E-04
	Plutonium-241	2.4E-02	3.8E-02
	Strontium-90	3.6E-04	6.1E-04
	Polonium-210	3.0E-04	1.7E-03
BF-PEC Biotic Fish Pecos River	Potassium-40	9.5E-02	3.1E-02
	Cobalt-60	-7.7E-05	7.7E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BF-PEC Biotic Fish Pecos River (continued)	Cesium-137	-2.0E-04	8.1E-04
	Lead-210	1.3E-02	1.5E-02
	Radium-226	1.9E-02	1.2E-02
	Radium-228	2.1E-03	2.9E-03
	Americium-241	-6.8E-03	3.0E-02
	Thorium-228	-3.5E-05	2.4E-04
	Thorium-230	2.2E-03	5.5E-04
	Thorium-232	1.0E-04	1.2E-04
	Uranium-233/234	2.2E-03	8.1E-04
	Uranium-235	2.5E-04	2.2E-04
	Uranium-238	1.2E-03	4.7E-04
	Plutonium-238	-1.2E-04	1.3E-04
	Plutonium-239/240	7.8E-05	1.5E-04
	Plutonium-241	-1.4E-02	3.1E-02
	Strontium-90	1.1E-04	6.4E-04
	Polonium-210	1.2E-04	1.8E-03
BR-SAR Biotic Rabbit South Access Road	Potassium-40	1.3E-01	4.4E-02
	Cobalt-60	6.0E-04	1.1E-03
	Cesium-137	8.9E-04	1.1E-03
	Lead-210	5.7E-04	1.8E-02
	Radium-226	1.2E-02	2.4E-02
	Radium-228	4.5E-03	4.2E-03
	Americium-241	3.4E-04	2.7E-04
	Thorium-228	-3.4E-05	6.7E-05
	Thorium-230	2.4E-03	5.8E-04
	Thorium-232	1.0E-04	1.5E-04
	Uranium-233/234	1.4E-04	6.5E-05
	Uranium-235	2.1E-05	3.1E-05
	Uranium-238	4.5E-05	3.8E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BR-SAR Biotic Rabbit South Access Road (continued)	Plutonium-238	2.3E-04	2.0E-04
	Plutonium-239/240	0.0E+00	0.0E+00
	Plutonium-241	-1.2E-02	0.0E+00
	Strontium-90	-7.7E-06	6.2E-04
	Polonium-210	-4.9E-05	1.8E-03
BD-SAR Biotic Deer South Access Road Muscle	Potassium-40	9.5E-02	3.2E-02
	Cobalt-60	7.3E-04	8.4E-04
	Cesium-137	-5.8E-05	8.2E-04
	Lead-210	1.4E-03	1.3E-02
	Radium-226	2.2E-02	1.3E-02
	Radium-228	4.0E-03	2.9E-03
	Americium-241	0.0E+00	5.1E-04
	Thorium-228	1.1E-04	5.0E-04
	Thorium-230	1.1E-02	2.3E-03
	Thorium-232	1.1E-04	3.8E-04
	Uranium-233/234	5.4E-03	1.6E-03
	Uranium-235	3.7E-04	5.4E-04
	Uranium-238	1.9E-03	8.9E-04
	Plutonium-238	3.0E-04	4.3E-04
	Plutonium-239/240	2.0E-04	3.9E-04
	Plutonium-241	2.6E-02	8.3E-02
	Strontium-90	-6.6E-04	6.1E-04
	Polonium-210	1.5E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Liver	Potassium-40	7.1E-02	3.1E-02
	Cobalt-60	2.6E-04	8.9E-04
	Cesium-137	-9.7E-04	1.1E-03
	Lead-210	4.6E-02	1.2E-02
	Radium-226	4.7E-03	2.0E-02
	Radium-228	3.9E-03	3.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-SAR Biotic Deer South Access Road Liver (continued)	Americium-241	1.5E-03	5.6E-04
	Thorium-228	4.0E-04	2.9E-04
	Thorium-230	4.6E-03	8.9E-04
	Thorium-232	4.4E-05	1.5E-04
	Uranium-233/234	3.0E-03	7.3E-04
	Uranium-235	-5.1E-05	3.8E-04
	Uranium-238	1.3E-03	5.4E-04
	Plutonium-238	8.5E-05	1.2E-04
	Plutonium-239/240	8.5E-05	1.7E-04
	Plutonium-241	-1.7E-02	3.6E-02
	Strontium-90	1.2E-04	5.3E-04
	Polonium-210	3.4E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Heart	Potassium-40	8.5E-02	3.1E-02
	Cobalt-60	1.3E-03	1.7E-03
	Cesium-137	-1.1E-04	9.6E-04
	Lead-210	8.8E-03	1.6E-02
	Radium-226	6.0E-03	1.9E-02
	Radium-228	3.0E-03	3.5E-03
	Americium-241	1.2E-03	7.0E-04
	Thorium-228	0.0E+00	6.1E-04
	Thorium-230	1.3E-02	2.3E-03
	Thorium-232	0.0E+00	2.8E-04
	Uranium-233/234	2.8E-03	8.7E-04
	Uranium-235	3.6E-04	4.2E-04
	Uranium-238	3.5E-04	3.9E-04
	Plutonium-238	2.4E-04	2.4E-04
	Plutonium-239/240	1.2E-04	1.7E-04
	Plutonium-241	2.0E-02	5.4E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-SAR Biotic Deer South Access Road Heart (continued)	Strontium-90	4.8E-04	7.4E-04
	Polonium-210	2.1E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Muscle	Potassium-40	8.5E-02	2.9E-02
	Cobalt-60	-2.5E-04	6.8E-04
	Cesium-137	1.8E-04	7.9E-04
	Lead-210	1.2E-03	1.2E-02
	Radium-226	1.2e-02	1.0E-02
	Radium-228	3.9E-03	2.7E-03
	Americium-241	1.4E-03	6.3E-04
	Thorium-228	0.0E+00	2.4E-04
	Thorium-230	4.5E-03	9.4E-04
	Thorium-232	9.9E-05	1.9E-04
	Uranium-233/234	2.0E-03	6.9E-04
	Uranium-235	6.0E-05	2.6E-04
	Uranium-238	2.4E-04	3.2E-04
	Plutonium-238	8.7E-05	2.1E-04
	Plutonium-239/240	4.4E-05	8.6E-05
	Plutonium-241	-5.6E-04	3.7E-02
	Strontium-90	-2.5E-04	5.0E-04
	Polonium-210	1.2E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Kidney	Potassium-40	4.0E-02	3.1E-02
	Cobalt-60	1.8E-03	1.4E-03
	Cesium-137	-1.7E-04	1.3E-03
	Lead-210	4.8E-02	1.4E-02
	Radium-226	1.9E-02	3.1E-02
	Radium-228	3.6E-03	4.8E-03
	Americium-241	1.2E-03	7.3E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-SAR Biotic Deer South Access Road Kidney (continued)	Thorium-228	4.5E-04	2.9E-04
	Thorium-230	2.9E-03	6.9E-04
	Thorium-232	8.2E-05	2.5E-04
	Uranium-233/234	1.6E-03	6.9E-04
	Uranium-235	2.1E-04	2.4E-04
	Uranium-238	6.2E-04	4.3E-04
	Plutonium-238	2.1E-04	2.5E-04
	Plutonium-239/240	0.0E+00	1.4E-04
	Plutonium-241	2.1E-02	4.5E-02
	Strontium-90	-3.8E-04	4.6E-04
	Polonium-210	2.0E-03	1.9E-03
BD-SAR Biotic Deer South Access Road Liver	Potassium-40	8.4E-02	2.8E-02
	Cobalt-60	-4.6E-05	7.0E-04
	Cesium-137	-5.2E-04	8.0E-04
	Lead-210	2.9E-02	9.0E-03
	Radium-226	3.5E-04	1.6E-02
	Radium-228	4.6E-03	4.3E-03
	Americium-241	1.0E-03	5.5E-04
	Thorium-228	1.2E-03	5.4E-04
	Thorium-230	4.7E-03	1.0E-03
	Thorium-232	0.0E+00	2.3E-04
	Uranium-233/234	1.4E-03	7.0E-04
	Uranium-235	7.1E-05	3.1E-04
	Uranium-238	4.0E-04	3.7E-04
	Plutonium-238	4.4E-04	3.7E-04
	Plutonium-239/240	6.3E-05	1.2E-04
	Plutonium-241	-2.3E-02	5.3E-02
	Strontium-90	-3.3E-04	6.1E-04
	Polonium-210	5.5E-04	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-NAR Biotic Deer North Access Road Muscle	Potassium-40	7.7E-02	2.5E-02
	Cobalt-60	3.6E-04	5.9E-04
	Cesium-137	3.9E-04	6.9E-04
	Lead-210	2.5E-02	7.2E-03
	Radium-226	8.4E-05	1.2E-02
	Radium-228	2.1E-03	2.2E-03
	Americium-241	7.9E-04	3.7E-04
	Thorium-228	9.3E-05	1.8E-04
	Thorium-230	3.7E-03	8.3E-04
	Thorium-232	0.0E+00	2.8E-04
	Uranium-233/234	1.7E-03	5.5E-04
	Uranium-235	1.9E-04	1.9E-04
	Uranium-238	8.3E-04	3.6E-04
	Plutonium-238	7.7E-05	1.9E-04
	Plutonium-239/240	-7.7E-05	1.1E-04
	Plutonium-241	-1.6E-02	3.2E-02
	Strontium-90	8.4E-04	6.7E-04
	Polonium-210	8.8E-05	1.9E-03

APPENDIX B

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NONRADIOLOGICAL

SOIL ANALYSIS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW1 Terrestrial Surface Non-Radiological North West 1	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	6	mg/kg
	pH	7.5	pH
	Calcium, total	9.0	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	2.2	mg/L
	Sodium, total	3.2	mg/L
	Sodium Absorption Ratio	0.25	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	7	mg/kg
	pH	7.3	pH
	Calcium, total	11	mg/L
	Potassium, total	17	mg/L
	Magnesium, total	2.4	mg/L
	Sodium, total	3.4	mg/L
	Sodium Absorption Ratio	0.24	meq/L
	Saturation Percent	17	% mg/L
	Conductivity	0.14	mmhos/cm
	Chloride	7	mg/kg
	pH	7.3	pH
	Calcium, total	58	mg/L
	Potassium, total	20	mg/L
	Magnesium, total	7.6	mg/L
	Sodium, total	9.0	mg/L
	Sodium Absorption Ratio	0.30	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.070	mmhos/cm
	Chloride	7	mg/kg
	pH	7.4	pH
	Calcium, total	6.3	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW1 Terrestrial Surface Non-Radiological North West 1 (continued)	Potassium, total	8.9	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	2.7	mg/L
	Sodium Absorption Ratio	0.26	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	6	mg/kg
	pH	7.5	pH
	Calcium, total	11	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	2.4	mg/L
	Sodium, total	1.8	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.088	mmhos/cm
	Chloride	6	mg/kg
	pH	7.5	pH
	Calcium, total	8.1	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	2.3	mg/L
	Sodium, total	2.0	mg/L
	Sodium Absorption Ratio	0.16	meq/L
TS-NW2 Terrestrial Surface Non-Radiological North West 2	Saturation Percent	20	% mg/L
	Conductivity	0.043	mmhos/cm
	Chloride	7	mg/kg
	pH	6.6	pH
	Calcium, total	3.4	mg/L
	Potassium, total	8.7	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.16	meq/L
	Saturation Percent	19	% mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW2 Terrestrial Surface Non-Radiological North West 2 (continued)	Conductivity	0.039	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	2.7	mg/L
	Potassium, total	6.1	mg/L
	Magnesium, total	1.7	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.12	meq/L
	Saturation Percent	21	% mg/L
	Conductivity	0.053	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	4.4	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	2.2	mg/L
	Sodium Absorption Ratio	0.24	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.047	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	4.6	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	2.3	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	16	% mg/L
	Conductivity	0.033	mmhos/cm
	Chloride	6	mg/kg
	pH	6.4	pH
	Calcium, total	< 2.5	mg/L
	Potassium, total	6.5	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW2 Terrestrial Surface Non-Radiological North West 2 (continued)	Magnesium, total	1.1	mg/L
	Sodium, total	2.4	mg/L
	Sodium Absorption Ratio	0.49	meq/L
	Saturation Percent	21	% mg/L
	Conductivity	0.047	mmhos/cm
	Chloride	6	mg/kg
	pH	6.5	pH
	Calcium, total	4.5	mg/L
	Potassium, total	8.2	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	1.3	mg/L
	Sodium Absorption Ratio	0.14	meq/L
TS-SE1 Terrestrial Surface Non-Radiological South East 1	Saturation Percent	19	% mg/L
	Conductivity	0.12	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.4	pH
	Calcium, total	13	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	4.2	mg/L
	Sodium, total	1.3	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.071	mmhos/cm
	Chloride	8	mg/kg
	pH	7.7	pH
	Calcium, total	5.8	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	4.5	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.067	mmhos/cm

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-SE1 Terrestrial Surface Non-Radiological South East 1 (continued)	Chloride	7	mg/kg
	pH	6.5	pH
	Calcium, total	6.4	mg/L
	Potassium, total	17	mg/L
	Magnesium, total	2.9	mg/L
	Sodium, total	0.9	mg/L
	Sodium Absorption Ratio	0.07	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.11	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.6	pH
	Calcium, total	10	mg/L
	Potassium, total	11	mg/L
	Magnesium, total	2.7	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	9	mg/kg
	pH	7.3	pH
	Calcium, total	7.9	mg/L
	Potassium, total	17	mg/L
	Magnesium, total	2.4	mg/L
	Sodium, total	1.6	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	17	% mg/L
	Conductivity	0.12	mmhos/cm
	Chloride	31	mg/kg
	pH	7.5	pH
	Calcium, total	9.9	mg/L
	Potassium, total	15	mg/L
	Magnesium, total	3.4	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-SE1 Terrestrial Surface Non-Radiological South East 1 (continued)	Sodium, total	1.1	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
TS-SE2 Terrestrial Surface Non-Radiological South East 2	Saturation Percent	20	% mg/L
	Conductivity	0.055	mmhos/cm
	Chloride	8	mg/kg
	pH	6.9	pH
	Calcium, total	4.8	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	2.1	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.063	mmhos/cm
	Chloride	9	mg/kg
	pH	6.1	pH
	Calcium, total	11	mg/L
	Potassium, total	15	mg/L
	Magnesium, total	2.1	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.07	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.039	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.8	pH
	Calcium, total	2.8	mg/L
	Potassium, total	8.9	mg/L
	Magnesium, total	1.4	mg/L
	Sodium, total	2.0	mg/L
	Sodium Absorption Ratio	0.25	meq/L
	Saturation Percent	22	% mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-SE2 Terrestrial Surface Non-Radiological South East 2 (continued)	Conductivity	0.11	mmhos/cm
	Chloride	12	mg/kg
	pH	6.6	pH
	Calcium, total	14	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	2.7	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.071	mmhos/cm
	Chloride	49	mg/kg
	pH	7.1	pH
	Calcium, total	5.9	mg/L
	Potassium, total	9.1	mg/L
	Magnesium, total	1.1	mg/L
	Sodium, total	1.6	mg/L
	Sodium Absorption Ratio	0.16	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.039	mmhos/cm
	Chloride	6	mg/kg
	pH	6.9	pH
	Calcium, total	2.6	mg/L
	Potassium, total	7.4	mg/L
	Magnesium, total	1.4	mg/L
	Sodium, total	0.9	mg/L
	Sodium Absorption Ratio	0.11	meq/L
TS-CT1 Terrestrial Surface Non-Radiological Control 1	Saturation Percent	19	% mg/L
	Conductivity	0.052	mmhos/cm
	Chloride	17	mg/kg
	pH	6.4	pH
	Calcium, total	3.0	mg/L
	Potassium, total	9.7	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT1 Terrestrial Surface Non-Radiological Control 1 (continued)	Magnesium, total	2.6	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.10	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.030	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.4	pH
	Calcium, total	2.6	mg/L
	Potassium, total	8.3	mg/L
	Magnesium, total	1.4	mg/L
	Sodium, total	0.9	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.046	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.4	pH
	Calcium, total	3.9	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	1.8	mg/L
	Sodium, total	1.5	mg/L
	Sodium Absorption Ratio	0.16	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.038	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.3	pH
	Calcium, total	3.6	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	1.7	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.041	mmhos/cm

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT1 Terrestrial Surface Non-Radiological Control 1 (continued)	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	< 2.5	mg/L
	Potassium, total	7.9	mg/L
	Magnesium, total	1.0	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	0.26	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.052	mmhos/cm
	Chloride	7	mg/kg
	pH	6.5	pH
	Calcium, total	4.2	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	1.5	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.15	meq/L
TS-CT2 Terrestrial Surface Non-Radiological Control 2	Saturation Percent	17	% mg/L
	Conductivity	0.043	mmhos/cm
	Chloride	17	mg/kg
	pH	7.1	pH
	Calcium, total	3.0	mg/L
	Potassium, total	8.8	mg/L
	Magnesium, total	2.5	mg/L
	Sodium, total	0.7	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.032	mmhos/cm
	Chloride	11	mg/kg
	pH	7.3	pH
	Calcium, total	2.5	mg/L
	Potassium, total	8.5	mg/L
	Magnesium, total	1.9	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT2 Terrestrial Surface Non-Radiological Control 2 (continued)	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.041	mmhos/cm
	Chloride	8	mg/kg
	pH	7.2	pH
	Calcium, total	3.8	mg/L
	Potassium, total	8.0	mg/L
	Magnesium, total	2.0	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	22	% mg/L
	Conductivity	0.075	mmhos/cm
	Chloride	9	mg/kg
	pH	7.1	pH
	Calcium, total	9.5	mg/L
	Potassium, total	11	mg/L
	Magnesium, total	2.2	mg/L
	Sodium, total	0.7	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.045	mmhos/cm
	Chloride	9	mg/kg
	pH	6.8	pH
	Calcium, total	2.7	mg/L
	Potassium, total	8.5	mg/L
	Magnesium, total	0.7	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.056	mmhos/cm
	Chloride	11	mg/kg

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT2 Terrestrial Surface Non-Radiological Control 2 (continued)	pH	7.2	pH
	Calcium, total	5.0	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	2.3	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
TS-WE1 Terrestrial Surface Non-Radiological WIPP East 1	Saturation Percent	17	% mg/L
	Conductivity	0.056	mmhos/cm
	Chloride	8	mg/kg
	pH	7.4	pH
	Calcium, total	3.9	mg/L
	Potassium, total	7.9	mg/L
	Magnesium, total	2.1	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	0.12	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.060	mmhos/cm
	Chloride	8	mg/kg
	pH	7.2	pH
	Calcium, total	3.4	mg/L
	Potassium, total	6.1	mg/L
	Magnesium, total	1.2	mg/L
	Sodium, total	1.6	mg/L
	Sodium Absorption Ratio	0.19	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.061	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.1	pH
	Calcium, total	3.6	mg/L
	Potassium, total	8.5	mg/L
	Magnesium, total	1.6	mg/L
	Sodium, total	1.3	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-WE1 Terrestrial Surface Non-Radiological WIPP East 1 (continued)	Sodium Absorption Ratio	0.14	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.049	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.2	pH
	Calcium, total	3.1	mg/L
	Potassium, total	7.0	mg/L
	Magnesium, total	2.0	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	21	% mg/L
	Conductivity	0.087	mmhos/cm
	Chloride	9	mg/kg
	pH	6.8	pH
	Calcium, total	9.3	mg/L
	Potassium, total	14	mg/L
	Magnesium, total	2.5	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.071	mmhos/cm
	Chloride	7	mg/kg
	pH	7.1	pH
	Calcium, total	6.8	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	2.5	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L

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June 14, 1996

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

Volume VIII of VIII

Appendices SUM, SURV, VOC, WAP

APPENDIX SUM

SANDIA REPORT

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Summary of Site-Characterization Studies Conducted From 1983 Through 1987 at the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico

A. R. Lappin

Prepared by
Sandia National Laboratories
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SUMMARY OF SITE-CHARACTERIZATION STUDIES CONDUCTED FROM 1983 THROUGH 1987 AT THE WASTE ISOLATION PILOT PLANT (WIPP) SITE, SOUTHEASTERN NEW MEXICO

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ABSTRACT

The Waste Isolation Pilot Plant (WIPP) is being constructed at a depth of 650 m in bedded halites of the Salado Formation. The geologic setting of the WIPP site has been active for at least 250 million years, and is presently responding to the end of the last pluvial period, within the 10,000-year time scale of regulatory interest. Both construction of the WIPP facility and WIPP site-characterization activities impose additional transient effects, some of which will last until the hydrologic and structural closure of the facility.

The Bell Canyon Formation beneath the WIPP facility contains shales, siltstones, and sandstones. Studies suggest that no channel sandstone is present in the Bell Canyon beneath the WIPP site. Fluid movement would be downward if drilling interconnected the Bell Canyon with the Rustler Formation, the first water-bearing zone above the WIPP facility.

The Salado and Castile Formations contain abundant bedded halites and anhydrites, and deform in response to gravity. Fluids play a major role in this deformation, although the regional permeabilities of both units are extremely low. Pressurized brines may be present within the Castile Formation 200 m or more beneath the WIPP waste-emplacement panels. The hydrologic and structural characteristics of the Salado change within an altered zone extending a few meters from the WIPP underground workings.

The permeability within this altered zone is enhanced, and deformation includes local opening of preexisting fractures in anhydrite and formation of new fractures in halite. Within a few meters of the facility the Salado characteristics become those of the far field, in which permeability is extremely low and deformation is dominated by creep. Brine seepage into the WIPP facility is extremely slow, and involves transient behavior resulting from the combined effects of deformation, low permeability, and ventilation.

At the WIPP site, the hydrology and geochemistry of the Rustler Formation and younger units overlying the Salado are dominated by confined flow within the Culebra dolomite. Rustler karst is not present at the WIPP site, but is present in and near Nash Draw. The combination of modern heads and transmissivities of units other than the Culebra indicates the potential for limited vertical flow within the Rustler, and from the Salado into the Rustler, but is not consistent with infiltration of water from the surface to the Rustler carbonates at the WIPP site. Isotopic studies indicate that surficial water was required for formation of secondary gypsum veins within the Dewey Lake Red Beds overlying the Rustler. The distribution of hydrochemical facies in Culebra groundwaters and the results of stable-isotope, radiocarbon, and uranium-disequilibrium studies are all consistent with the interpretation that there is no modern recharge to the Rustler at the WIPP site, and that a change of flow directions in the Culebra dolomite has occurred over approximately the last 10,000 years.

The transmissivity of the Culebra dolomite varies by approximately 6 orders of magnitude at and near the WIPP site. The transmissivity in the central portion of the site, including the locations of all four WIPP shafts, is low (less than 10^{-6} m^2/s). Higher Culebra transmissivities are found south, northwest, and west of the site, especially in Nash Draw. Fracturing within the Culebra affects local hydrology and contaminant transport, but is not significant in regional-scale behavior at and near the site, at least so long as the present distribution of head potentials is not significantly disturbed.

SUMMARY

The Waste Isolation Pilot Plant (WIPP), which is designed for receipt, handling, storage, and permanent isolation of defense-generated transuranic wastes, is being excavated at a depth of approximately 655 m in bedded halites of the Permian Salado Formation of southeastern New Mexico. Site-characterization activities at the present WIPP site began in 1976. Full construction of the facility began in 1983, after completion of "Site and Preliminary Design Validation" (SPDV) activities and reporting. Site-characterization activities since 1983 have had the objectives of updating or refining the overall conceptual model of the geologic, hydrologic, and structural behavior of the WIPP site and providing data adequate for use in WIPP performance assessment.

This report has four main objectives:

1. Summarize the results of WIPP site-characterization studies carried out since the spring of 1983 as a result of specific agreements between the U.S. Department of Energy and the State of New Mexico.

2. Summarize the results and status of site-characterization and facility-characterization studies carried out since 1983, but not specifically included in mandated agreements.

3. Compile the results of WIPP site-characterization studies into an internally consistent conceptual model for the geologic, hydrologic, geochemical, and structural behavior of the WIPP site. This model includes some consideration of the effects of the WIPP facility and shafts on the local characteristics of the Salado and Rustler Formations.

4. Discuss the present limitations and/or uncertainties in the conceptual geologic model of the WIPP site and facility.

The objectives of this report are limited in scope, and do not include determination of whether or not the WIPP Project will comply with repository-performance criteria developed by the U.S. Environmental Protection Agency (40CFR191). When combined, the results of recent and previous geologic studies of the WIPP site form a conceptual model, summarized below. The model presented is limited to aspects relevant to WIPP site characterization and, ultimately, performance assessment.

The overall geologic and hydrologic setting of the WIPP site area has been transient (not steady-state) since before the beginning of deposition of the Bell Canyon Formation, approximately 250 million years ago, and will continue to be transient after effective closure of the WIPP facility. Some events, such as crystallization of secondary minerals within the Salado Formation approximately 200 million years ago and formation of the Mescalero caliche 400,000 to 500,000 years ago, have taken place on a very long time scale relative to WIPP performance assessment, which must consider only a 10,000-year time frame. Two types of transient response

have occurred or are occurring at and near the WIPP site within the 10,000-year time frame of regulatory interest. These are: a) the continuing natural response of the geologic and hydrologic systems to the end of the last pluvial period (period of decreased temperatures and increased precipitation) in southeast New Mexico; and b) the continuing responses to hydrologic, geochemical, and structural transients resulting from WIPP site characterization and facility construction. The transient responses induced by the presence of the WIPP underground workings will continue until reequilibration following effective structural and hydrologic closure of the facility.

The Bell Canyon Formation, consisting largely of shales, siltstones, and sandstones, contains the first relatively continuous water-bearing zone beneath the WIPP facility. In some parts of the northern Delaware Basin, the unit contains permeable channel sandstones that are targets for hydrocarbon exploration. Recent studies suggest that the upper Bell Canyon at the WIPP site does not contain any major channel sandstone. This decreases the probability of the Bell Canyon serving as a source of fluids for dissolution of overlying evaporites at the WIPP. These same studies indicate that the final direction of fluid flow following interconnection of the Bell Canyon, Salado, and Rustler Formations within a drillhole would be downward into the Bell Canyon, after accounting for density increases in the fluids due to dissolution of halite within the Salado. It is assumed here that the measured hydrologic characteristics of the Bell Canyon Formation are more significant to WIPP performance assessment than those of underlying units. The head distribution within the upper Bell Canyon near the WIPP site indicates flow towards the northeast.

Both regional studies and studies within the WIPP facility indicate that the Castile and Salado Formations, both of which are made up predominantly of layered anhydrites and halites, should be considered as low-permeability units that deform regionally in response to gravity. In general, permeabilities and fluid-flow rates in both units are very low and are insensitive to stratigraphy. Formation permeabilities in the Castile and Salado Formations remote from the WIPP excavations are generally less than 0.1 microdarcy, and the regional water content of Salado halites is up to 2 weight percent. Exceptions include local brine occurrences in Castile anhydrites and gas occurrences in the Salado Formation, both of which are fracture-controlled, can be large in volume, and can be under pressures high enough to cause fluid flow to the surface. No major gas occurrence within the Salado Formation has been encountered at the WIPP site. In fact, where it has been possible to measure far-field brine pressures within the Salado, the pressures, permeabilities, and available brine volumes combine to indicate the potential for only very limited fluid flow upwards into the overlying Rustler Formation. It is not certain that the Castile and Salado Formations are hydrologically saturated regionally.

Pressurized Castile brines have been encountered in Castile anhydrite in hole WIPP-12, approximately 1.5 km north of the center of the WIPP site. Geophysical studies indicate that Castile brines may be present beneath a portion of the WIPP waste-emplacement panels, consistent with earlier assumptions. These brines are stratigraphically 200 m or more below the

WIPP facility horizon and are not of concern except in the case of human-intrusion breach of the facility.

In the western part of the Delaware Basin, extensive halite dissolution has apparently taken place in both the Castile and Salado Formations. However, much of the variability in structure and internal stratigraphic thicknesses within the Castile and Salado Formations results from deformation and original depositional variability, rather than from evaporite dissolution. Regional or far-field deformation of the Castile and Salado Formations involves pressure solution as a major mechanism, due to the presence of intergranular fluids, but occurs too slowly to be of future concern to the WIPP Project. Structures within hole DOE-2 result from deformation rather than dissolution.

The hydrologic and structural characteristics of the Salado Formation in the disturbed zone generated by the presence of the WIPP facility are different than those in the far field. Formation permeability within a couple of meters of the underground workings at the facility horizon increases significantly. Near-field deformation of the Salado Formation involves both the opening of preexisting fractures in anhydrite beneath the facility horizon (Marker Bed 139) and generation of new fractures in halite. Fluid contents in the disturbed zone at the facility horizon decrease in response to facility ventilation and/or deformation. Within a few meters of the underground workings, both hydrologic and structural behavior of the Salado Formation become essentially those of the far field. Brine seepage into the WIPP facility includes a significant transient phase, which will probably last until effective facility closure. The results of preliminary hydrologic testing in the Salado Formation adjacent to the WIPP air-intake shaft indicate extremely low permeabilities, with no apparent stratigraphic variability. The results also indicate that development of a disturbed zone around the WIPP shafts is less extensive than at the facility horizon. The extent, characteristics, and importance of the disturbed-rock zones around the WIPP shafts and at the facility horizon remain to be determined in detail.

At and near the WIPP site, the Rustler Formation should be considered as a layered unit of anhydrites, siltstones, and halites, containing a thin and variably fractured carbonate unit, the Culebra dolomite. The Culebra dolomite is the first continuous water-bearing unit above the WIPP facility and, at the WIPP site, is at least an order of magnitude more permeable than other members of the Rustler Formation, including the Magenta dolomite. The transmissivities of Rustler anhydrites at the WIPP site are too low to measure. As a result, the Culebra dominates fluid flow within the Rustler Formation at the WIPP site and is the most significant pathway to the accessible environment from the WIPP facility, except for direct breach to the surface by human intrusion. The transmissivity of the Culebra varies by approximately six orders of magnitude in the region containing the WIPP site. The Culebra transmissivity in the central portion of the site, including the locations of all four WIPP shafts, is low. Higher Culebra transmissivities are found in areas southeast and northwest of the central part of the site. Fluid flow rates within the Culebra are very low at the site center and in regions to the east, but

relatively high within Nash Draw. Modern flow in the Culebra is confined and largely north-south in the area of the WIPP site.

Fluid flow and geochemistry within the Culebra dolomite and shallower units are in continuing transient response to the marked decrease or cessation of local recharge at approximately the end of the last pluvial period. Both bulk chemistry and isotopic relations within Culebra fluids are inconsistent with modern flow directions if steady-state confined flow is assumed. Because of the relative head potentials within the Rustler Formation at and near the WIPP site, there must be a small amount of vertical fluid flow between its members, even though the permeabilities of Rustler members other than the Culebra dolomite are quite low. Where measured successfully, the modern head potentials within the Rustler prevent fluid flow from the surface downward into the Rustler carbonates. These results do not prohibit either the modern movement of fluids from the underlying Salado Formation upwards into the Rustler Formation or the downward movement of Dewey Lake waters into the Rustler Formation during or even after the cessation of local recharge at the end of the last pluvial period. They do, however, suggest that recharge from the surface to the Rustler Formation is not now occurring at the WIPP site. The results of stable-isotope, radiocarbon, and uranium-disequilibrium studies are also consistent with the interpretation that there is no measurable modern recharge to the Culebra dolomite from the surface at and near the WIPP site. The transient hydrologic response of the Rustler Formation to the end of the last pluvial period has involved at least some change in flow directions in the Culebra dolomite. Although the modern flow is largely north-south, the results of uranium-disequilibrium studies suggest that flow was more easterly during previous recharge.

Within and near Nash Draw, evaporite karst is operative within the Rustler, as evidenced by the continuing development of small caves and sinkholes in near-surface anhydrites and gypsums of the Forty-niner and Tamarisk Members. There is no evidence of karstic hydrology in the Rustler at and near the WIPP site. However fracturing of some portions of the Culebra dolomite is sufficient at the site to strongly affect both hydraulic and transport behavior on the hydropad scale, i.e., over distances of approximately 30 m. Interpretation of multipad interference tests conducted both north and south of the center of the WIPP site indicates that this fracturing need not be incorporated into numerical modeling of the regional-scale hydraulic behavior of the Culebra east of Nash Draw. Similarly, detailed transport calculations indicate that effects due to fracturing are not significant in regional-scale transport within the Culebra dolomite at and near the WIPP site, at least as long as the modern head distribution is not significantly disturbed and the calculated flow directions and transport properties are representative.

The Dewey Lake Red Beds overlying the Rustler Formation consist largely of siltstones and claystones, with subordinate sandstones. In tested locations, the Dewey Lake may be hydrologically unsaturated, but is too low in permeability for successful hydrologic testing. South of the WIPP site, near an area where the unit may be receiving modern recharge, sandstones within the Dewey Lake locally produce potable water. In general, water

levels within the Dewey Lake Red Beds, like those in the underlying Rustler Formation, must be in transient response to the end of the last pluvial period. Isotopic relations suggest that surficial waters have been involved in the formation of secondary gypsum veins within the Dewey Lake, but that the Dewey Lake and Rustler hydrologic systems are largely separate.

The major near-surface units at the WIPP site are the Gatuna Formation and Mescalero caliche. The sandstones and stream-channel conglomerates within the Gatuna indicate that major changes in local climate have occurred over (at least) the last 600,000 years. The widespread preservation of the Mescalero caliche indicates not only the relative structural stability of the Livingston Ridge surface (on which the WIPP surface facilities are sited) over the last 400,000 years, but also that infiltration over this same time period has not been sufficient to dissolve a layer of carbonate 1 to 2 m thick.

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SUMMARY OF SITE-CHARACTERIZATION STUDIES CONDUCTED FROM 1983 THROUGH 1987 AT THE WASTE ISOLATION PILOT PLANT (WIPP) SITE, SOUTHEASTERN NEW MEXICO

1.0 INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico (Figure 1.1) is designed for the receipt, handling, storage, and disposal of defense-generated transuranic (TRU) wastes. The WIPP underground facilities are currently being constructed at a depth of approximately 655 m in bedded halites in the lower portion of the Salado Formation (Table 1.1). First receipt of waste is scheduled for October 1988.

WIPP site-characterization activities began in 1976 with the drilling of hole ERDA-9 near the center of the site (Sandia National Laboratories and United States Geologic Survey, 1983) (Figure 1.2). As used here, the term "WIPP site" specifically refers to the sixteen square miles of T22S, R31E contained within WIPP Zone 3 and shown in Figure 1.2. This terminology is used for internal consistency within the report. Construction of the WIPP facility and monitoring of its underground structural and hydrologic behavior began in 1981, with construction of two shafts and limited underground workings.

WIPP site-characterization and facility-characterization studies through March 1983 are documented in several reports, including: 1) the WIPP Geologic Characterization Report (Powers et al., 1978); 2) the WIPP Final Environmental Impact Statement (FEIS) (U.S. Department of Energy, 1980); and 3) both summary and topical reports completed as part of the WIPP Site and Preliminary Design Validation (SPDV) effort (e.g., Beauheim et al., 1983a; Borns et al., 1983; Lambert, 1983; Popielak et al., 1983; Weart, 1983; Wood et al., 1982).

After the SPDV studies were completed and documented, the U.S. Department of Energy and the State of New Mexico agreed to several additional site-characterization activities, which, with one exception, were scheduled for completion by January 1988. The specific studies are described in Appendices I and II to the "Agreement for Consultation and Cooperation Between [the U.S.] Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant" (1981), and are referred to here as "C&C studies." Some non-C&C studies, such as a major regional-scale interference test of the Culebra dolomite, have also been carried out since 1983. A reactive-tracer experiment in the Culebra dolomite, originally a C&C study, was deleted during 1987, by agreement between DOE and the State of New Mexico. Studies agreed to in lieu of the reactive-tracer experiment should, with a few exceptions, be completed and reported by approximately December 1988.

Thus, formal WIPP site-characterization activities will end approximately December 1988. However, understanding of the geologic, hydrologic, and geochemical behavior of the WIPP facility (and site) will continue to

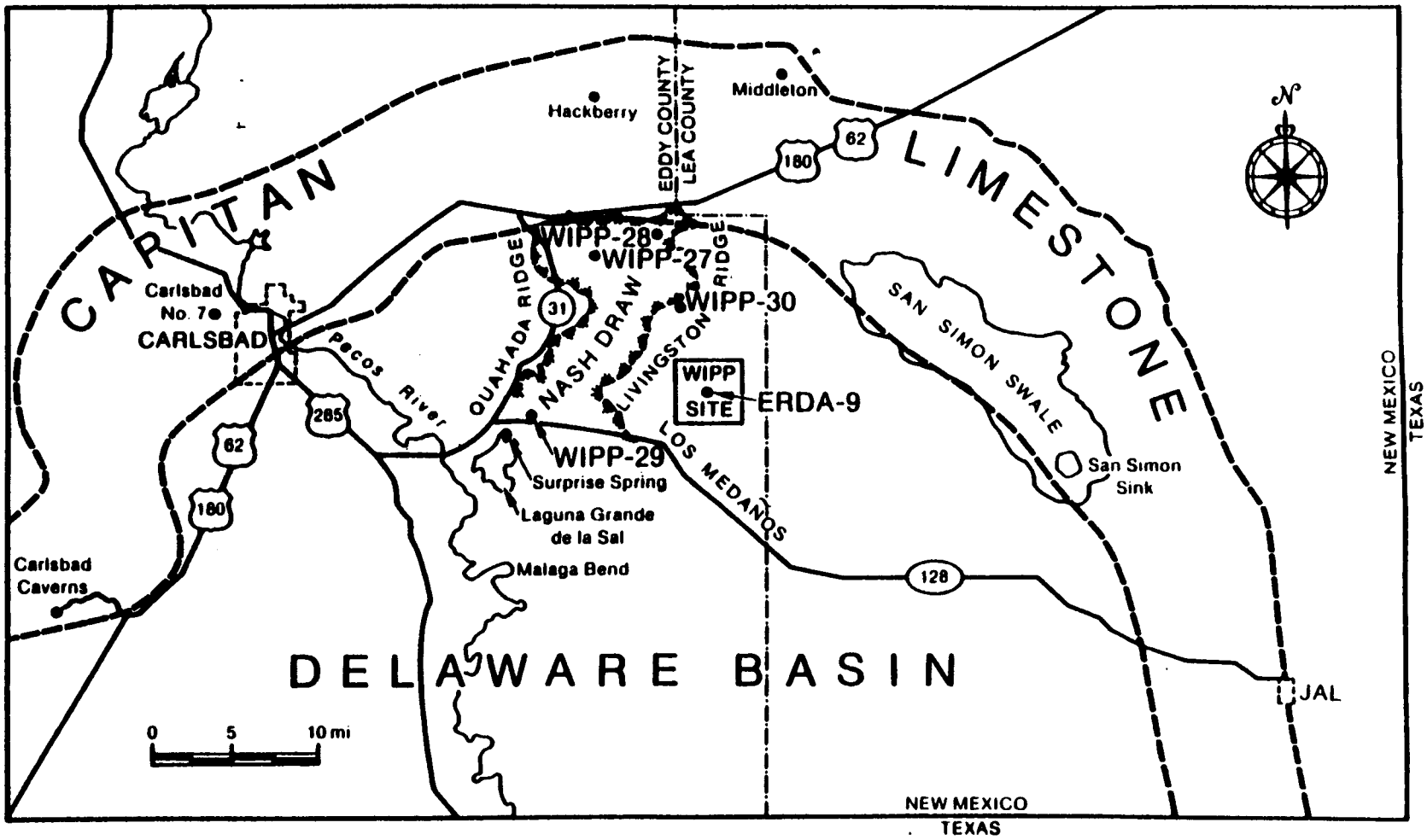


Figure 1.1: Setting of the WIPP site relative to the northern Delaware Basin. Selected geomorphic features and some holes referred to in text but not shown in Figure 1.2 are also included. Modified from Figure VI-1 of Lambert (1983).

Table 1.1: Generalized stratigraphic column of the Delaware Mountain Group and younger sedimentary rocks at and near the WIPP site. Figure 2-1 of Beauheim (1987c).

SYSTEM	SERIES	GROUP	FORMATION	MEMBER
RECENT	RECENT		SURFICIAL DEPOSITS	
QUATERNARY	PLEISTOCENE		MESCALERO CALICHE	
			GATUNA	
TRIASSIC		DOCKUM	UNDIVIDED	
PERMIAN	OCHOAN		DEWEY LAKE RED BEDS	
			RUSTLER	Forty-niner
				Magenta Dolomite
				Tamarisk
				Culebra Dolomite
				unnamed
			SALADO	
			CASTILE	
	GUADALUPIAN	DELAWARE MOUNTAIN	BELL CANYON	
			CHERRY CANYON	
			BRUSHY CANYON	

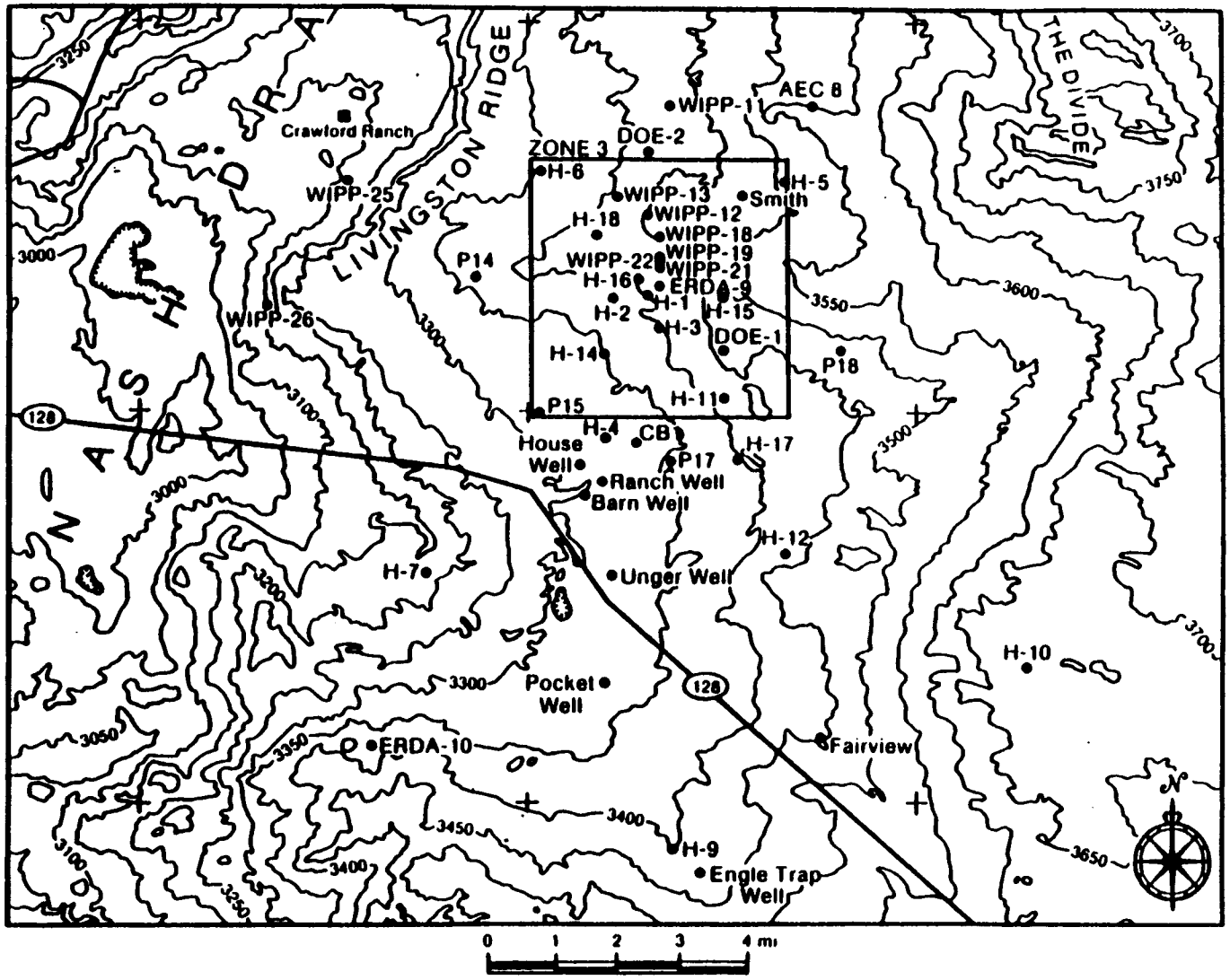


Figure 1.2: Boreholes at and near the WIPP site referred to in text. Holes were drilled as part of the site-characterization of the WIPP, as ranchers' wells, or as potash or hydrocarbon exploration holes. Only exploration holes which have been hydrologically tested are included.

develop after that time. Geotechnical work in and near the WIPP facility will extend into the period of operational demonstration, especially to complete characterization of the hydrologically and structurally disturbed zones around the underground workings and access shafts, in direct support of WIPP performance assessment. Data collected during these studies must support a full evaluation of expected facility performance against criteria developed by the U.S. Environmental Protection Agency (40CFR191) in their present or revised form. The structural, hydrologic, and nuclide-containment behavior of the WIPP facility, including potential far-field paths of nuclide release to the accessible environment, will be monitored throughout the WIPP operational period.

1.1 Report Objectives

This report has four main objectives. These are to:

1. Summarize the results of C&C studies carried out since the Spring of 1983.

2. Summarize the results and/or status of site-characterization and facility-characterization studies carried out since 1983 but not mandated by the C&C Agreement.

3. Compile the results of WIPP site-characterization studies into an internally consistent conceptual model for the geologic, hydrologic, geochemical, and structural behavior of the WIPP site. This model includes preliminary consideration of the local effects of the WIPP facility and shafts on the Salado and Rustler Formations.

4. Discuss the present limitations and/or uncertainties in the conceptual geologic model of the WIPP site and facility.

The objectives of the report are limited in scope and do not include determination of whether or not the WIPP Project will comply with repository-performance criteria developed by the U.S. Environmental Protection Agency (40CFR191). Whether or not the WIPP will comply with 40CFR191 must be demonstrated by the WIPP performance-assessment activity within five years following first emplacement of waste. The objective of this report is to develop as complete a conceptual model as possible for use in the required performance assessment.

1.2 Structure of Report

The remaining parts of this section (1.0) contain:

1. A general discussion of the stratigraphic setting and variability of sedimentary rocks within the northern Delaware Basin that have been of interest during WIPP site characterization (Section 1.3).

2. A general discussion of the technical issues of interest in WIPP site (and facility) characterization (Section 1.4). Emphasis in this discussion is on technical areas of site characterization which have been actively pursued since 1983.

The sections making up the body of the report (2.0 through 4.0) are generally ordered in stratigraphically upward sequence. This structure is a matter of convenience, and is not intended to imply relative priorities of the different issues and units discussed.

Within each technical section, recent studies in the formation(s) of interest are discussed in relation to the topics or issues outlined in Section 1.4. The final section of the report, Section 5.0, attempts to compile the results of the three preceding sections into an internally consistent conceptual model for the geologic, hydrologic, structural, and geochemical behavior of the WIPP site.

1.3 General Stratigraphic Setting of the WIPP Site and Facility

As shown in Figure 1.1, the WIPP site is located in southeastern New Mexico, in the northern portion of the Delaware Basin. The generalized stratigraphy in the vicinity of the WIPP is summarized in Table 1.1. Regional stratigraphic relationships and characteristics are discussed in detail in Powers et al. (1978).

The Delaware Basin became a distinct structure by the late Pennsylvanian Period to early Permian Period, approximately 280 million years ago. Approximately 250 million years ago, the reef now represented by the Capitan limestone began to grow around the margins of the developing basin, and the sandstones, shales, and carbonates now making up the Delaware Mountain Group (DMG) were deposited within the basin. Most of the Capitan limestone is relatively massive. Some portions of the unit are hydrologically active and support local karst hydrology, including the formation of large cavities such as Carlsbad Caverns. The Delaware Mountain Group, which is limited to the basin, contains three major subdivisions, the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations (in ascending stratigraphic order). Only the Bell Canyon Formation is considered here, as it is the first regionally continuous water-bearing formation beneath the WIPP facility. The hydraulic behavior of the Bell Canyon Formation is assumed to be more significant than that of any underlying units in WIPP breach scenarios.

The Bell Canyon Formation is divided into five informal members, the Hays sandstone, Olds sandstone, Ford shale, Ramsey sandstone, and Lamar limestone (in ascending stratigraphic order). The individual members vary in thickness and lithology. As shown in Figure 1.3, the upper Bell Canyon sandstones tend to be elongated and laterally discontinuous, in the nature of "channel sands." Individual sands are separated laterally by stratigraphically equivalent siltstones and/or shales. Near the WIPP site, the Bell Canyon Formation consists of a layered sequence of sandstones, shales/siltstones, and limestone 300 m or more in thickness (Powers et al., 1978).

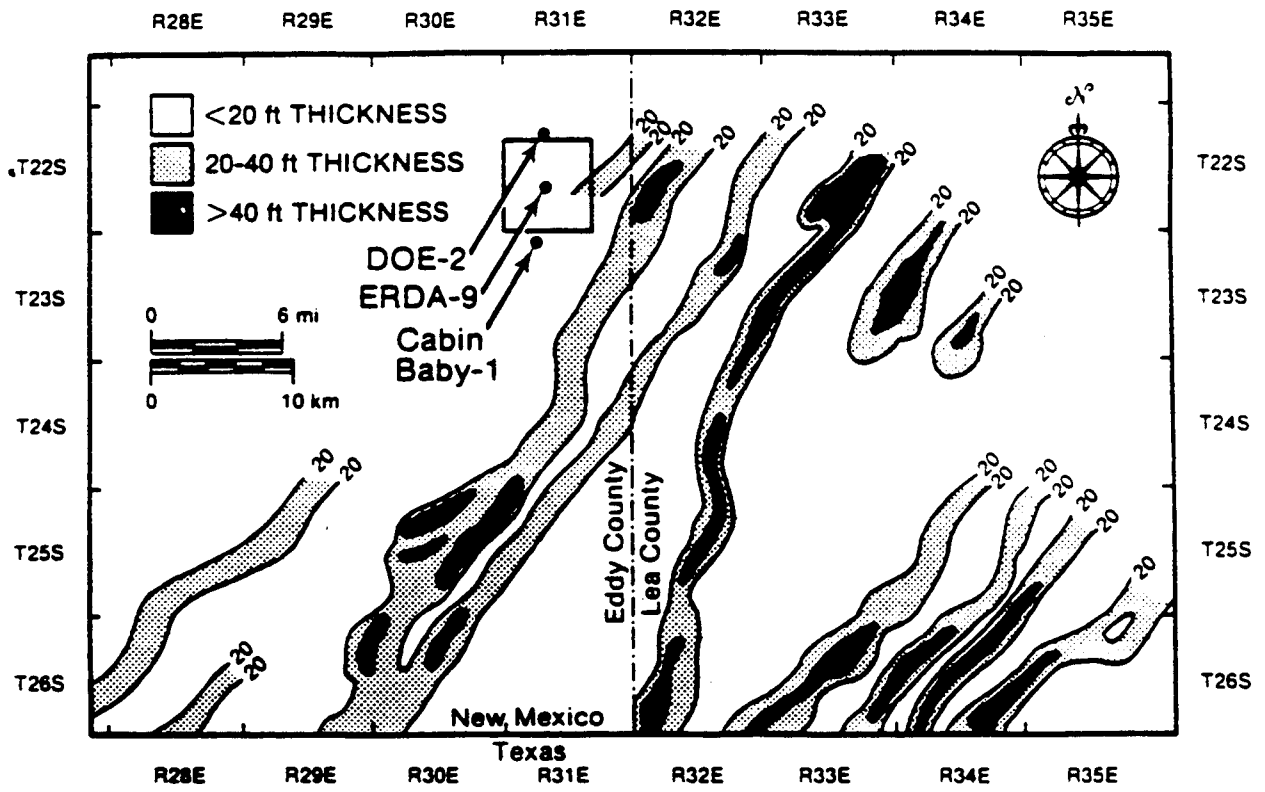


Figure 1.3: Lateral distribution and thicknesses of channel sands in the informal Ramsey member of the Bell Canyon Formation in the northern Delaware Basin, including holes DOE-2 and Cabin Baby-1. Simplified from Figure 2-2 of Davies (1983).

Within the northern Delaware Basin, the sandstones and shales of the Bell Canyon Formation are overlain by the thick-bedded sequence of anhydrites and halites of the Castile Formation, also of Permian age. As shown in Table 1.1, the Castile Formation near the WIPP site normally contains three relatively thick anhydrite/carbonate units and two thick halites. Both anhydrites and halites contain abundant anhydrite and/or carbonate laminae, may be strongly deformed internally, and are variable in local thickness. The thickness of the Castile Formation near the WIPP site is approximately 400 m.

The Salado Formation, of Late Permian (Ochoan) age, is 530 to 610 m thick at and near the WIPP site, and is generally bedded on a scale of 0.1 m to 1 m. It contains 45 numbered "anhydrite" marker beds of variable thickness (MB101 through MB145 with increasing depth). Between marker beds, the Salado consists of layered halites of varying purity and accessory mineralogy; anhydrite ($CaSO_4$), clays, and polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$) are dominant accessory minerals. The WIPP facility horizon is between MB138 and MB139.

The Salado Formation is overlain by the Rustler Formation, also of Ochoan age. As shown in Table 1.2, the Rustler contains five members. Two, the Magenta and Culebra dolomites, are somewhat variable gypsiferous dolomites. The Culebra and Magenta dolomites vary mainly in the concentration of fractures and the local occurrence of silty zones. The other three members of the Rustler (unnamed lower member, Tamarisk Member, and Forty-niner Member in upward succession) consist of varying proportions of anhydrite, siltstone/claystone, and halite. The major mineralogical variability within the Rustler Formation as a whole is in the degree of alteration of anhydrite to gypsum and the presence or absence of halite, both generally interpreted to result from evaporite dissolution. Some of this variability, however, may reflect original depositional patterns. The Rustler ranges from 83 m to 130 m in thickness at the WIPP site, depending on the extent of evaporite dissolution and/or depositional variability.

The Culebra dolomite is the first laterally continuous unit above the WIPP facility to display significant permeability. Barring direct breach to the surface, the Culebra dolomite provides the most direct pathway between the WIPP facility and the accessible environment. The hydrology and fluid geochemistry of the Culebra dolomite are quite complex. The unit displays wide ranges in hydraulic properties, local flow and transport mechanisms, and geochemistry. As a result of these factors, the Culebra has received a great deal of study in WIPP site characterization, both before and since 1983.

The Rustler Formation at the WIPP is overlain by the Dewey Lake Red Beds (the uppermost unit of the Ochoan Series) consisting largely of siltstones and claystones, with subordinate sandstones. The unit is approximately 30 m to 170 m thick at and near the WIPP site, varying at least in part due to post-depositional erosion. Where relatively thick and hydraulically unsaturated, the Dewey Lake Red Beds form a low-permeability buffer zone between the surface and relatively soluble carbonates and/or sulfates in the underlying Rustler Formation. In some areas, however, the unit is

thinned by local erosion and/or is hydraulically saturated. Where sufficiently thin, the Dewey Lake may not present an effective barrier to vertical fluid movement from the surface into the Rustler, depending on the local fluid pressures within and above the Rustler Formation. Where saturated, the Dewey Lake may, in some areas, serve as a source of fluids to the underlying Rustler Formation. The depositional age of the Castile, Salado, and Rustler Formations, as well as the Dewey Lake Red Beds, ranges approximately from 245 million to 230 million years. Over approximately the eastern half of the WIPP site, the Dewey Lake Red Beds are overlain by the (undivided) Dockum Group of sandstones and shales of Triassic age.

Table 1.2: Generalized stratigraphy of the Rustler Formation at and near the WIPP site. Adapted from Snyder (1985).

Age	Member	Approximate Thickness (m)	Generalized Character in "Unaltered" Sections
Permian/ Ochoan	Forty-Niner	45±	Anhydrite Halite and Siltstone Anhydrite
	Magenta Dolomite	6-9	Thinly Laminated Gypsiferous Dolomite; Local Anhydrite
	Tamarisk	65±	Anhydrite Halite and Siltstone Anhydrite
	Culebra Dolomite	6-10	Finely Crystalline, Vuggy, Gypsiferous Dolomite; Local Siltstone
	Unnamed	44±	Alternating Halite, Siltstone, Anhydrite Laminated Siltstone

The shallowest and youngest stratigraphic units at the WIPP site proper, except for recent surficial sands, are the Gatuna Formation, the Mescalero caliche, and the Berino soil. The Gatuna Formation, the upper part of which is approximately 600,000 years in age, consists of siltstones, sands, and stream-laid conglomerates, deposited in a wetter climate than is now present in southeast New Mexico. The Mescalero caliche, 410,000 to 510,000 years in age, is relatively continuous in the vicinity of the WIPP site and supports the Livingston Ridge surface on which the site is located (Figure 1.1). The Berino soil, approximately 250,000 years old, is a thin horizon, and is much less widespread than either the Gatuna or the Mescalero. Together, the Gatuna Formation, Mescalero caliche, and Berino soil indicate

some of the variability of the climate in southeastern New Mexico over the last 600,000 years and the relative structural stability of the Livingston Ridge surface over the last 400,000 to 500,000 years.

Localized gypsite-spring deposits, approximately 25,000 years in age, occur along the eastern flank of Nash Draw, but are not currently active. Around the northwest margin of the Delaware Basin, packrat middens indicate that the climate approximately 10,500 years ago was significantly wetter than that at present. The recent surficial windblown sands at and near the WIPP site are almost all stabilized by vegetation. South of the site, however, there is an area in which surficial dunes appear to be active. It is from these dunes that the area has derived its name, "Los Medanos."

1.4 Technical Issues of Interest in WIPP Site and Facility Characterization

This section contains brief discussions of several technical issues of general interest in site characterization of the WIPP, including some consideration of the WIPP facility itself. The most general issues are discussed first. After that, the approach is generally stratigraphic, in parallel with the structure of the report as a whole. Detailed referencing of individual technical studies is not included here, but is included in Sections 2.0 through 4.0, where appropriate.

1.4.1 Transient Versus Steady-State Geologic, Hydrologic, and Geochemical Setting of the WIPP

In order for the expected behavior of the WIPP facility to be evaluated against the EPA's repository-performance guidelines (40CFR191), it must be demonstrated that the structural, hydrologic, geochemical, and transport behavior of the WIPP facility and environs are adequately understood to provide satisfactory predictions over at least the 10,000-year time frame of regulatory interest. "Structural behavior," as the term is used here, includes both far-field and near-field mechanical deformation of stratigraphic units. Far-field structural behavior is behavior independent of the presence of the WIPP facility, especially the underground workings. Near-field behavior is the behavior of the portions of the Salado and Rustler Formations that have been disturbed by the presence of the WIPP facility. "Hydrologic behavior" includes description of the distribution of hydrologic properties, fluid pressures, and directions of fluid flow. As the term is used here, however, it does not include investigation of chemical equilibrium between fluid and rock. "Geochemical behavior" includes both bulk chemistry and isotopic relations resulting from rock-water interaction, but is largely limited to consideration of natural chemical transport and reactions between rocks and fluids, independent of waste. "Transport behavior" includes consideration of the mechanisms of contaminant transport in Rustler groundwaters and the relative importance of different transport mechanisms; it does not include consideration of any specific radionuclides that will or will not be a part of the WIPP radionuclide inventory.

Two basic assumptions are possible concerning the overall geologic setting of the WIPP site. The simplest assumption, implicitly made in the WIPP FEIS (U.S. Department of Energy, 1980), is that the entire geologic system at the WIPP is at steady state on the time scale of regulatory interest. Under this assumption, the geology, hydrology, and geochemistry of the WIPP site should be constant with (or independent of) time for at least the period of regulatory concern to waste isolation.

However, the overall geologic and hydrologic settings of the WIPP site have been transient (not steady-state) since before the beginning of deposition of the Bell Canyon Formation, approximately 250 million years ago, and will continue to be transient long after effective closure of the WIPP facility. Some events, such as crystallization of secondary minerals within the Salado Formation approximately 200 million years ago and formation of the Mescalero caliche 400,000 to 500,000 years ago, have taken place on a very long time scale. Two types of transient response are occurring at and near the WIPP site within the 10,000-year time frame of regulatory interest. These are: a) the continuing natural response of the geologic and hydrologic systems to the end of the last pluvial period (period of decreased temperatures and increased precipitation) in southeast New Mexico; and b) the responses to man-induced hydrologic, geochemical, and structural transients resulting from site characterization and facility construction.

Thus, there is abundant evidence that the overall setting and behavior of the WIPP site are transient on at least three geologic and two human-induced time scales. The time scales of transient behavior range from at least tens of millions of years in the cases of secondary mineralization and fracture formation within the Salado Formation (independent of the WIPP facility) to tens of years in the case of pressure transients imposed on the Rustler Formation by shaft construction and hydrologic testing. The evidence for transient behavior of the WIPP site comes from a broad range of geologic, hydrologic, geochemical, and structural studies. The WIPP performance-assessment activity will ultimately determine which transient phenomena are significant to the long-term performance of the WIPP facility.

1.4.2 Dissolution of Evaporitic Rocks at and near the WIPP Site

Evaporite dissolution, i.e., dissolution or alteration of halite, anhydrite/gypsum, and/or the sulfatic carbonates of the Rustler, Salado, or Castile Formations by groundwaters, has been an issue of major interest in WIPP site characterization. The fundamental reason for this has been the need to evaluate the possibility that, although the Permian evaporites at the WIPP site have been in existence for approximately 240 million years, they might be regionally or locally dissolved on the 10,000-year time scale of regulatory interest. If this occurred, then evaporite dissolution could play a major role in breach of the WIPP facility, by short-circuiting the transport of radionuclides from the facility to the accessible environment.

There are four settings in which evaporite dissolution is or has been of interest in WIPP site characterization. These include:

1. Regional-scale stratabound dissolution of evaporites, especially halite, within the Castile and Salado Formations. In stratabound dissolution, fluid movement is predominantly parallel to bedding. Stratabound dissolution has probably taken place in the western part of the Delaware Basin, as indicated by the absence of halite from both the Castile and Salado Formations in Figure 1.4. If stratabound dissolution within the Castile reached the WIPP site, mechanical collapse of the overlying Salado Formation would occur, possibly resulting in direct breach of the facility. If stratabound dissolution within the Salado reached the WIPP, direct breach of the facility might result.

The possibility of stratabound dissolution reaching the WIPP site itself on the 10,000-year time scale of interest was evaluated as part of site-characterization activities prior to 1983. There is general agreement that stratabound dissolution of the Castile and/or Salado Formations will not reach the WIPP facility in the 10,000-year time frame of interest. In addition, recent interpretations indicate that much of the variability in the thicknesses of the Castile and Salado Formations is due to deformation and original depositional variability, rather than to evaporite dissolution. This should result in slower estimated dissolution rates.

2. Dissolution of Castile and/or Salado halites by localized upward intrusion of halite-unsaturated fluids from the upper portion of the Bell Canyon Formation into the overlying units. If such dissolution occurred immediately beneath the WIPP site, the resulting mechanical subsidence might directly breach the WIPP facility. If this dissolution mechanism is in fact feasible, the locations at which it might occur in the future are not predictable with the present understanding of hydrology in the northern Delaware Basin.

At the WIPP site, one basinal structure within the Salado Formation was proposed in 1983 as a possible result of subsidence resulting from point-source dissolution of Castile and/or Salado halites. This structure has since been investigated by the drilling, coring, and hydrologic testing of hole DOE-2 (Figure 1.2). No evidence of evaporite dissolution was found in hole DOE-2. The DOE-2 structure is the result of syndepositional and postdepositional deformation of the Castile and Salado Formations, rather than of evaporite dissolution. This conclusion, together with earlier studies indicating that the only proven "breccia pipes" in the northern Delaware Basin result from dissolution within the Capitan limestone and occur only directly above this unit (Snyder and Gard, 1982), indicates that point-source dissolution of Castile and/or Salado evaporites is not operative either within the main part of the basin or at the WIPP site.

3. Dissolution of halite from within the Rustler Formation by stratabound flow. East of the WIPP site, the Rustler Formation contains abundant halite (salt) in the Forty-niner, Tamarisk, and unnamed members. West of the WIPP site, for example in Nash Draw, the Rustler

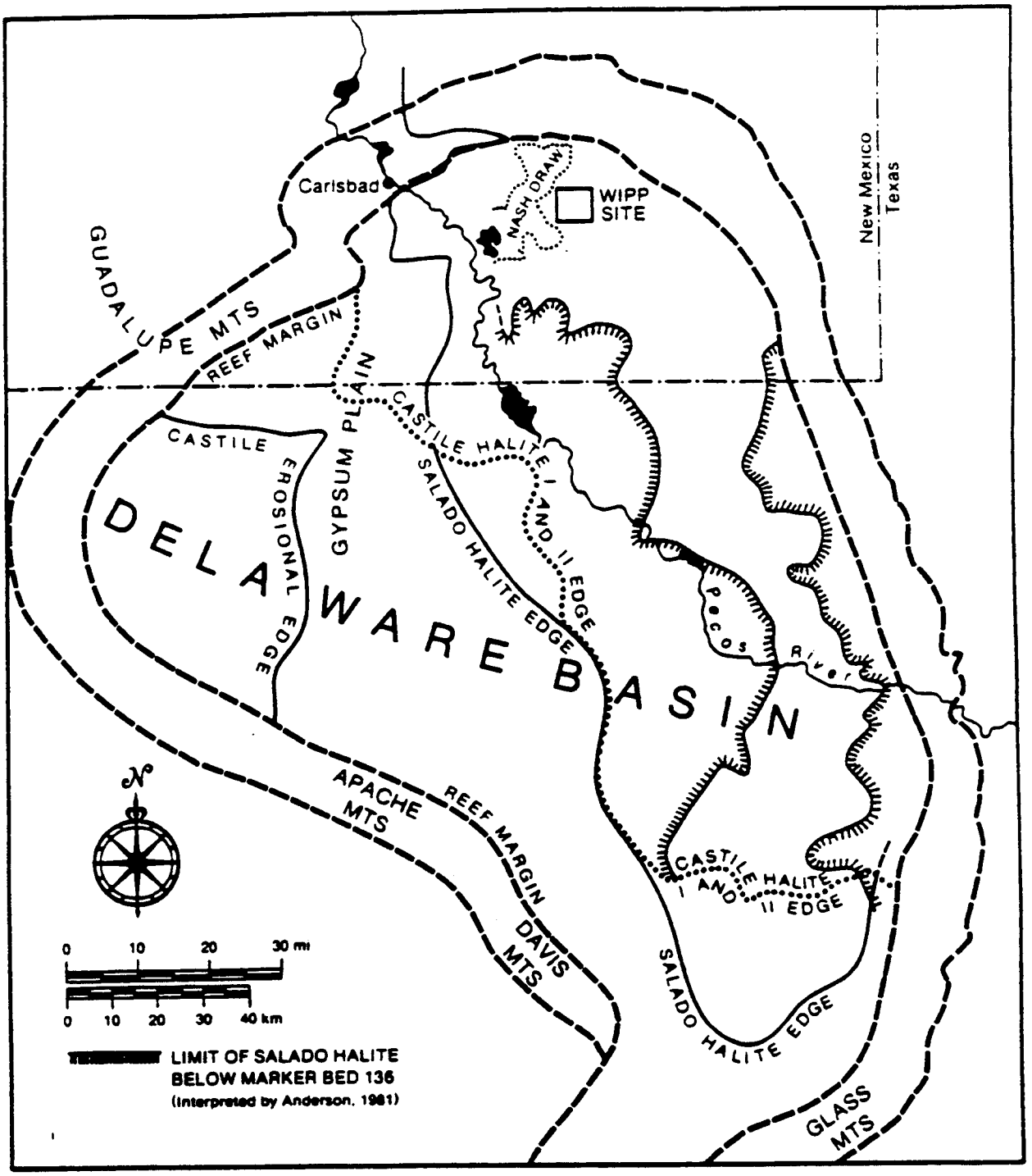


Figure 1.4: Generalized distribution of the Castile and Salado Formations in the Delaware Basin, with emphasis on distribution of halites. Slightly modified from Figure VII-1A of Lambert (1983) and including, in part, the interpretation of Anderson (1981).

Formation is totally devoid of halite (Figure 1.5). If Rustler variability is due to evaporite dissolution and if stratabound dissolution reached the WIPP site within 10,000 years, the overburden at the WIPP would be significantly reduced, perhaps leading to breach.

The variability within the Rustler Formation has conventionally been thought to result from regional-scale stratabound evaporite dissolution, based on the assumption that the distribution of halite was originally uniform. It has also traditionally been assumed that dissolution of Rustler evaporites was a recent phenomenon, linked to the growth of Nash Draw over the last 600,000 years. These two assumptions maximize both the total amount of halite dissolved from the Rustler and the rate at which this dissolution occurs. There is considerable disagreement concerning the uniformity and amount of stratabound evaporite dissolution within the Rustler Formation. However, even with the two "conservative" assumptions outlined above, i.e., assumptions thought to maximize the potential impact to the WIPP, it does not appear feasible for the Nash Draw structure to extend to the WIPP site on the time scale of regulatory interest.

4. Evaporite dissolution within the Rustler Formation as a result of vertical fluid flow. This second potential evaporite-dissolution mechanism involving the Rustler Formation at and near the WIPP site requires local recharge, from the surface to the Rustler Formation, of waters unsaturated in halite and anhydrite/gypsum. If this vertical movement of unsaturated fluids occurs to a significant degree, the resulting local evaporite dissolution within the Rustler might result in local high-permeability channels or pathways within the Rustler Formation. The final result of such dissolution would be the generation of a "karstic" hydrologic system. In such a system, the hydrology and transport behavior would be dominated by relatively narrow high-permeability pathways or channels, even though most of the unit would consist of low-permeability "blocks." The hydrology of at least part of the Rustler Formation within Nash Draw, where the Rustler is exposed at the surface, is known to be karstic, and includes the continuing formation of small caves and sinkholes in anhydrites of the Forty-niner and Tamarisk Members. Such a hydrologic and transport system within the Rustler Formation at the WIPP site itself might provide a means for rapid transport of nuclides from the WIPP facility to the accessible environment.

A comprehensive approach has been taken to the question of Rustler karst at the WIPP site. Field studies have evaluated the surface-geological evidence for and against significant surface infiltration and possible development of karstic cavities below. Hydrologic measurements, including regional-scale pumping tests, have characterized the present distribution of hydraulic properties and relative head potentials within the Rustler at and near the WIPP. Isotopic studies have estimated the isolation or residence times of Rustler waters, estimated the relative importance of vertical and stratabound fluid flow within the Rustler and Dewey Lake, and evaluated the extent to which the entire Rustler hydrologic setting is transient.

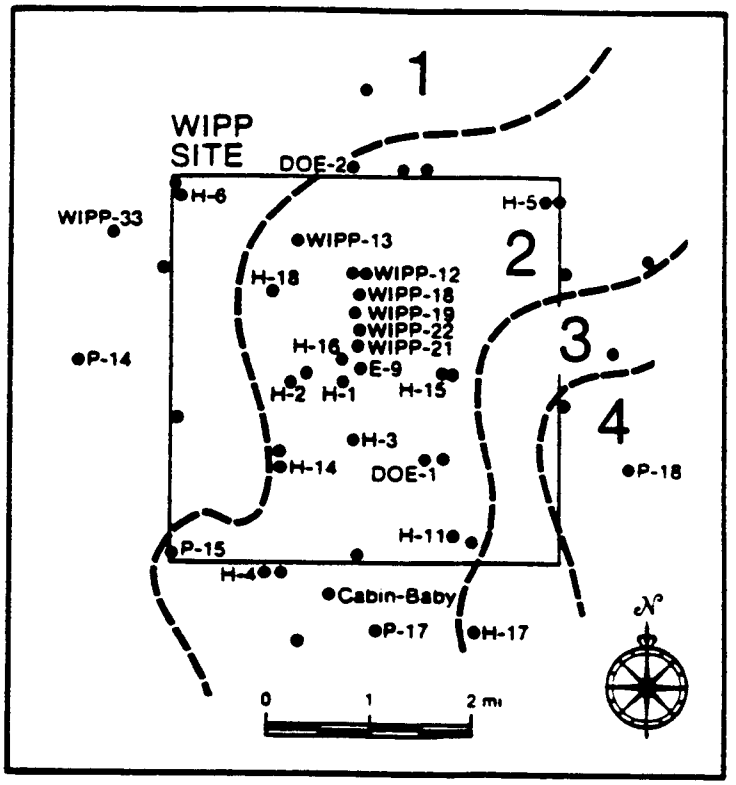


Figure 1.5: Generalized halite distribution within the Rustler Formation at and near the WIPP site. Slightly modified from Figure 9 of Chaturvedi and Channell (1985). Zone 1: no halite present within the Rustler Formation; Zone 2: halite present only below the Culebra Member; Zone 3: halite present between Culebra and Magenta Members; Zone 4: halite present above the Magenta Member.

The combined results of these studies indicate that vertical recharge from the surface to the Rustler is not active at the WIPP site. Where measured successfully, the calculated residence or isolation time of Rustler groundwaters at the WIPP site is greater than 10,000 years. There must have been changes in flow directions within the Culebra dolomite within the last (approximately) 10,000 years. The isotopic results do indicate that some vertical fluid flow has taken place, especially within the Dewey Lake Red Beds. In addition, local development of karstic channels or porosity within Rustler anhydrites does appear to have been a consequence of vertical infiltration of fluids from the surface in the WIPP-33 structure, approximately 1 km west of the western boundary of Zone 3. However, the WIPP-33 structure is unique at and near the WIPP site and is not now significantly active. Regional-scale pumping tests of the Culebra dolomite have not identified any major or dramatic high-transmissivity structures similar to those expected if Rustler karst involving the Culebra were present at the WIPP site.

1.4.3 Directions of Fluid Flow to Be Expected if the Rustler and Bell Canyon Formations Are Interconnected

In the effort to be "conservative," i.e., to not underestimate the impact of breaches of the WIPP facility, it was assumed in the WIPP FEIS (U.S. Department of Energy, 1980) that fluid flow in the event of interconnection of the Rustler and Bell Canyon Formations would be upward into the Rustler. This issue, as well as the distribution of hydrologic properties within the Bell Canyon Formation, has since been investigated in testing of the holes Cabin Baby-1 and DOE-2, near the southern and northern boundaries of the WIPP site, respectively (Figure 1.2).

The results of hydrologic testing in both Cabin Baby-1 and DOE-2 suggest that the WIPP site is not directly underlain by a high-permeability channel sand in the upper part of the Bell Canyon (Figure 1.3). If such a sand is present, it must be more narrow than those shown in Figure 1.3. This decreases the potential, already concluded by Wood et al. (1982) to be negligible, for any significant upward migration of Bell Canyon fluids into overlying evaporites in the absence of a drillhole. In addition, the fluid pressures and brine densities measured in both Cabin Baby-1 and DOE-2 indicate that, in the event of interconnection of the Bell Canyon, Salado, and Rustler Formations within a drillhole, the final direction of fluid flow would be downward into the Bell Canyon Formation. This conclusion assumes that both Bell Canyon and Rustler fluids become saturated as a result of local halite dissolution within the Salado Formation.

1.4.4 Distribution and Origin of Brine Occurrences within Castile Anhydrites

In the northern Delaware Basin, highly pressurized brines have been encountered locally in fractured anhydrites of the Castile Formation during drilling from the surface. The known distribution of these Castile brine occurrences as of 1983 is shown in Figure 1.6. Castile brines have been

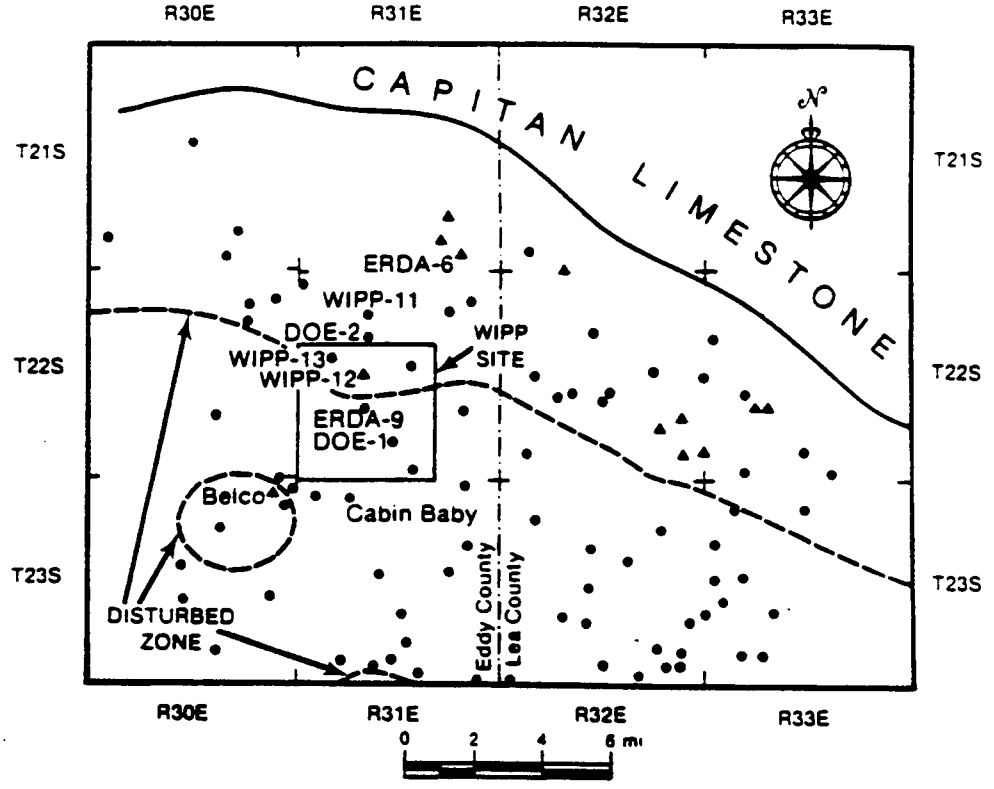


Figure 1.6: Generalized distribution of Castile brine occurrences and approximate extent of the Castile "Disturbed Zone" in the northern Delaware Basin. Distribution of Castile brines is simplified from Figure G-11 of Popielak et al. (1983). Approximate boundaries of Castile "Disturbed Zone" are from Figure 1-1 of Borns et al. (1983). Closed triangles represent holes in which Castile brines have been encountered. ERDA-9 is included for reference, but does not penetrate Castile Anhydrite III completely.

encountered largely in hydrocarbon-exploration drillholes both north and northeast of the WIPP site (i.e., between the WIPP site and the margin of the basin). However, brine was also encountered southwest of the WIPP site, at the Belco well. During WIPP site characterization, Castile brines have been encountered in hole WIPP-12, approximately 1.6 km north of the site center, and in ERDA-6, approximately 8 km northeast of the site center.

Two basic hypotheses have been put forward to explain the origin of Castile brines, namely that the occurrences are due to:

1. Migration of connate Castile fluids from halites into anhydrites fractured as a result of local deformation.

2. Isolation of meteoric waters within the fractured Castile anhydrites, following episodic lateral hydrologic connection of the Castile Formation and the Capitan limestone.

Because of the localized but widely distributed occurrence of Castile brines in the vicinity of the WIPP site, it has previously been assumed for purposes of performance assessment that Castile brine is present beneath the WIPP facility itself. Since the upper Castile anhydrite is stratigraphically 200 m or more beneath the WIPP facility horizon, this brine is of concern only in the event of a drilling intrusion which connects the brine occurrence with the facility. A recent surface-geophysical survey over an area including the WIPP waste-emplacement panels is consistent with the presence of Castile brines beneath a portion of the panels.

1.4.5 Deformation of the Castile and Salado Formations

Borns et al. (1983) define a structurally "Disturbed Zone" (DZ) (Figure 1.6) within the Castile Formation, based largely on the systematic loss of coherent seismic response. The deformation of the Castile Formation within the DZ involves both anhydrites and halites, and is associated with the known occurrences of Castile brines. Although the overall mineralogies of the Salado and Castile Formations are similar, the two units are layered on different scales. Regional deformation of the Salado Formation is largely in response to regional deformation of the underlying Castile Formation.

Recent results indicate that fluids and pressure-solution mechanisms play a major role in far-field deformation of both the Castile and Salado Formations. This has been investigated both theoretically and by examination of core collected in hole DOE-2. The time scale of regional deformation of the Salado and Castile Formations is from thousands to millions of years, too long to be of concern in evaluation of the future performance of the WIPP facility.

Construction of the underground WIPP facility, resulting in generation of a large void space at a depth of 650 m within a stratigraphic section that is predominantly halite, results in a strong local mechanical response within the Salado Formation. The near-field mechanical response of the Salado

Formation around the WIPP facility involves both higher stresses and deformation rates than expected in natural or far-field deformation. At least during early closure, near-field creep deformation appears to involve mechanisms such as dislocation climb. It is presently not known when, or if, pressure solution will become a dominant mechanism in creep closure of the WIPP facility.

Creep, however, is not the only near-field process involved in closure of the WIPP facility. Marker Bed 139 (MB139), approximately 1 m below the WIPP facility horizon, is fractured from pre-excavation processes, i.e., processes not related to excavation of the WIPP facility. The opening of these fractures, in addition to formation of fractures within Salado halites, plays a significant role in the near-field structural response to excavation of the WIPP facility.

Monitoring of these structural "excavation effects" is ongoing, and will continue through the operational phase of the WIPP. The time scale of near-field mechanical effects began with the beginning of construction of the WIPP facility and will continue until structural reequilibration following complete closure of the facility. Therefore, the time of interest may be 100 years or more, depending on both the long-term behavior of the facility and the types and amounts of both waste and backfill that are emplaced.

1.4.6 Fluid Flow within the Salado Formation

Salado halites were assumed to be anhydrous at the time of the WIPP FEIS and SPDV activities, with the exception of small amounts of fluid inclusions and water bound up in hydrous minerals. Fluid flow into the WIPP facility under this assumption would be very small in volume, directly stress-related, and transient. Long-term steady-state fluid flow would be zero.

Recent hydrologic measurements from the surface and within the WIPP facility, combined with geochemical studies within the facility, indicate that grain-boundary fluids are present within the Salado Formation, and that the unit should be considered as a very low-permeability material in which fluid residence times in the far field are on the order of millions of years. There are, however, major increases in both permeability and fluid-pressure gradients within the Salado Formation within a few meters of the WIPP facility at and near the facility horizon. The recent results suggest that, while there are major stress-related transient effects, long-term fluid flow into the facility will reach some very low but non-zero steady-state rate, and will continue until effective hydrologic closure of the facility. On the basis of preliminary hydrologic testing results, the development of an altered or disturbed zone around the WIPP shafts appears to be much more limited than at the facility horizon.

1.4.7 Present-Day Hydrology, Transport Behavior, and Geochemistry of the Rustler Formation

The Culebra Dolomite Member of the Rustler Formation is the first laterally continuous water-bearing zone above the WIPP facility. Transport within the Culebra dolomite constitutes the major transport mechanism from the WIPP facility to the accessible environment, except for direct transport to the surface. Therefore, there is great interest in determining the modern distribution of hydraulic and nuclide-transport properties within the Culebra.

The hydrologic characteristics of the Culebra dolomite are complex. The transmissivity of the unit varies by approximately four orders of magnitude at and near the WIPP site, with relatively high-transmissivity regions both southeast and northwest of the site center. However, the center of the WIPP site, including all four shaft locations, is in a region of low Culebra transmissivity (permeability). The relatively transmissive parts of the Culebra contain fractures that dominate both hydraulic and transport behavior on the scale of individual three-hole hydropads (approximately 30 m between holes). If these fractures were to dominate flow and transport behavior on the "regional" scale considered here, i.e., over the 3.2-kilometer distance between the center of the WIPP site and the boundary of WIPP Zone 3 (Figure 1.2), nuclide-transport times to the accessible environment would be greatly decreased relative to times estimated without considering fractures.

Numerical modeling of Rustler hydrology through 1983 was based on testing only at single holes and individual three-hole hydropads, and ignored possible fracturing. Since 1983, two regional-scale interference tests have been conducted in the Culebra, one centered at the H-3 pad and one at hole WIPP-13 (Figure 1.2). Hydraulic effects of fracturing have been evaluated in detail at the H-3 and H-11 hydropads. The interpretation of the regional-scale multipad interference tests indicates that fracturing need not be included in modeling simulation of Culebra hydrologic behavior at this scale, since test calculations with and without fractures have produced very similar results.

In addition, detailed calculations completed in 1987 indicate that although fracturing plays a major role in local or pad-scale contaminant transport within parts of the Culebra, radionuclide transport to the accessible environment can realistically be modeled using the porous-medium approximation, at least so long as the present pattern of head distributions within the Culebra is not significantly perturbed and the transport properties and flow paths assumed in the calculations are representative. This conclusion may or may not be valid in the case of a breach involving a Castile brine reservoir at high fluid pressures.

Through 1983, numerical modeling of Rustler hydrology also ignored both the geochemical variability of Rustler fluids and possible effects of variable fluid density on directions of fluid flow. Both numerical methods and data bases for evaluation of groundwater flow in the region of the WIPP site have developed significantly since that time. Recent groundwater-flow calculations, which include effects of variable brine density, indicate

that modern fluid flow within the Culebra dolomite is generally north-south in the vicinity of the WIPP site. Flow rates vary greatly, being rapid down the axis of Nash Draw, but extremely slow across the WIPP site proper. While the assumption of hydrologic steady state appears adequate for modeling of head potentials within the Culebra dolomite, groundwater flow across the WIPP site within the Culebra is sufficiently slow to make the assumption of hydrologic steady-state inadequate for detailed modeling of long-term flow directions and rates. However, the changes in flow rates and directions as a function of time appear not to be dramatic at the WIPP site itself. Groundwater flow is quite slow in this area.

As noted, Culebra fluids are quite variable. Recent work indicates that they can be broken into four distinct geochemical facies. The general distribution of fluid compositions is inconsistent with steady-state confined fluid flow in the present flow directions. The mineralogy of the Culebra dolomite is widely variable, but without sharp regional distinctions, since dolomite, clays, and gypsum/anhydrite are all widespread. Halite has not been reliably identified in Culebra core, except for that which may have been introduced during drilling. The analyzed Culebra fluid compositions form a variable but continuous population, all of which reflect exposure to evaporitic rocks.

2.0 BELL CANYON FORMATION

The Delaware Mountain Group is divided into the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations, all of which are predominantly of shales, siltstones, and sandstones. Only the Bell Canyon is considered here, since it is the first regionally continuous water-bearing zone beneath the WIPP facility. The hydraulic behavior of the Bell Canyon is assumed here to be more significant than that of underlying units in WIPP breach scenarios.

There have historically been two reasons for interest in the Bell Canyon Formation in WIPP site characterization. First, the Bell Canyon has been proposed by some as a source of fluids for local or point-source dissolution of halite in the overlying Castile and Salado Formations. This mechanism and general conclusions regarding its validity at the WIPP site are summarized in general terms in Section 2.1, based on work completed through 1983. Second, it must be assumed for purposes of performance assessment that at least one drillhole from the surface will penetrate the WIPP facility. It may then be important to estimate the distribution of permeable zones within the Bell Canyon at the WIPP site and to estimate directions of fluid flow that might result from an open borehole penetration that connected the Bell Canyon with fluid-bearing zones within the Rustler Formation, especially the Culebra dolomite. The character of the Bell Canyon and expected directions of fluid flow between the Culebra and the Bell Canyon at the WIPP site are discussed in Section 2.2.

2.1 Potential for the Bell Canyon Formation to Serve as a Source of Fluids for Dissolution of Evaporites in the Castile and Salado Formations

Anderson (1978, 1981) and Davies (1983) have proposed a major role for the Bell Canyon Formation in point-source dissolution of overlying evaporites. The proposed mechanism involves: 1) recharge of halite-unsaturated fluids to the Bell Canyon Formation from the Capitan limestone; 2) upward movement of these fluids into (at least) the lower halite of the Castile Formation; 3) halite dissolution within the Castile Formation; 4) subsidence and disruption of the Castile and overlying Salado Formations as a result of halite dissolution; 5) downward flow of halite-saturated brines back into the Bell Canyon Formation; and 6) removal of brines through the Bell Canyon Formation. An important characteristic of this hypothesis proposal is that it is not possible to predict localities of future point-source evaporite dissolution.

Wood et al. (1982), as part of the WIPP SPDV studies, addressed the potential for fluids within the upper Bell Canyon Formation to dissolve evaporites within the Castile Formation. For this evaluation, it is assumed that: 1) a permeable sandstone is present at the top of the Bell Canyon Formation, i.e., a Ramsey channel sand (Figure 1.3); 2) the effective thickness of the sandstone is 30 m; and 3) the transmissivity of the sandstone ranges from 1.0×10^{-6} to 2.8×10^{-6} m^2/s. Any decrease in sandstone permeability or shifting of the sandstone to positions below the

top of the Bell Canyon would reduce the potential for dissolution of overlying evaporites.

For the range of hydraulic properties and gradients considered, and assuming the Ramsey sand is at the top of the Bell Canyon, Wood et al. (1982) conclude that:

1. Except at locations adjacent to the Capitan limestone, only diffusional dissolution is possible directly above the Bell Canyon. Salt directly above the top of the Bell Canyon, assuming diffusional processes, is calculated to dissolve at a vertical rate of approximately 0.003 m per 10,000 years. This would have negligible effect on the WIPP facility.

2. Allowing for an order-of-magnitude increase in flow velocities within the Bell Canyon Formation, dissolution would still be too slow to maintain open cavities within Castile halites at depth. Such cavities are required to maintain the high-permeability pathways necessary for dissolution due to the density-flow mechanism outlined above.

3. Even allowing for the maximum potential dissolution rates at the top of the Bell Canyon from both diffusive and convective mechanisms, no significant evaporite dissolution as a result of fluid flow from within the Bell Canyon should be observed at the WIPP facility for at least 10,000 years.

In addition, Lambert (1983) concludes that the Bell Canyon Formation itself shows no evidence of either modern hydraulic connection with a source of halite-unsaturated fluids (such as the Capitan limestone) or any effective path for brines to exit the Delaware Basin. Instead, Lambert interprets the Bell Canyon fluids as having very long residence times and concludes that their compositions reflect extensive rock-water interaction, evolving isotopically and geochemically away from compositions representative of meteoric recharge.

Thus, studies at the end of the WIPP SPDV phase indicated that the Bell Canyon Formation was not dissolving evaporites near the WIPP site. As discussed in Section 3.0, however, this question was later investigated directly by the drilling, coring, and hydrologic testing of hole DOE-2, near the northern boundary of WIPP Zone 3 (Figure 1.2).

2.2 Expected Directions of Fluid Flow Between the Bell Canyon and Rustler Formations

The information on freshwater-equivalent heads in the Rustler and Bell Canyon Formations available through 1983 is summarized in Mercer (1983). At that time, the freshwater head within the Bell Canyon Formation at the center of the WIPP site, approximately 1040 m AMSL, was 120 m greater than the expected freshwater head in the Culebra dolomite at the same location,

approximately 920 m AMSL. (All elevations here are given relative to mean sea level.) This is consistent with the assumption made in the WIPP FEIS (U.S. Department of Energy, 1980) that fluid flow would be upwards into the Rustler if the Bell Canyon and Rustler were interconnected in an open hole. However, this "conservative" assumption, i.e., the assumption with most apparent impact to WIPP performance assessment, neglects: a) the original density of fluids in the Bell Canyon and Culebra; b) possible increases in both Bell Canyon and Culebra fluid densities due to dissolution of halite within the Salado Formation; c) possible effects of fluid potentials within the Salado Formation or elsewhere within the Rustler Formation; and d) possible changes in fluid density as a result of entrainment of waste from within the WIPP facility.

In the event of a drillhole breach interconnecting the Bell Canyon, Castile, Salado, and Rustler Formations, it is reasonable to assume that local dissolution of halite within the Salado Formation would take place, resulting in an average fluid density of approximately 1.2 g/cm^3, the approximate density of saturated NaCl brine. Under this assumption, Bell Canyon brine at the center of the WIPP site would stand to an elevation of approximately 835 m in an open hole, some 445 m above the WIPP facility, but approximately 210 m below land surface, and more than 200 m lower than the Bell Canyon freshwater-equivalent head of approximately 1040 m. Assuming that local halite dissolution within the Rustler or upper portion of the Salado Formations led to a final density of Culebra brine of 1.2 g/cm^3, the Culebra near the center of the WIPP site would support a column of brine to an elevation of approximately 900 m, 20 meters below the freshwater-equivalent head within the Culebra, but some 65 m higher than supported by the underlying Bell Canyon Formation.

Therefore, if brine saturation by halite dissolution is considered, the data available as of 1983 are consistent with the interpretation that interconnection of the Bell Canyon Formation and the Culebra dolomite in an open drillhole through the WIPP facility should result in downward movement of contaminated brine into the Bell Canyon Formation. However, the calculated direction of fluid flow depends on assumed fluid densities. Fluid might move upward until the Bell Canyon and Culebra fluids were saturated with halite, at which time downward flow would begin. In addition, these results depend on the assumption that no significant fluid or gas pressures are generated within the Salado Formation or WIPP facility. As of 1983, however, predicted directions of fluid flow were limited in reliability, because heads and fluid densities in the Culebra dolomite and Bell Canyon Formation had not been measured together in the same hole. Two holes penetrating the Bell Canyon Formation very near the WIPP site have since been drilled and/or hydrologically tested. The results from hole Cabin Baby-1 are discussed in Section 2.2.1, and those from hole DOE-2 in Section 2.2.2.

2.2.1 Results from Hole Cabin Baby-1

Cabin Baby-1, a hydrocarbon exploration hole, was originally drilled through the Castile Formation and the upper 35 m of the Bell Canyon

Formation in 1974 and 1975. At that time, all of the Ramsey and part of the Olds members of the Bell Canyon were penetrated. The hole depth at that time was 1265 m below land surface. As described in Beauheim et al. (1983b), the hole was deepened to a total depth of 1308 m in 1983 to allow hydrologic testing, fluid sampling, and monitoring of Bell Canyon fluid levels. The deepening allowed testing of most of the Hays sandstone member underlying the Olds, in addition to all of the Olds and Ramsey members.

The results of hydrologic testing of the Bell Canyon in Cabin Baby-1 and DOE-2 are summarized in Table 2.1. Only the lowermost "sand" member of the Bell Canyon, the Hays, is significantly permeable in Cabin Baby-1, with an interpreted transmissivity of between 1.7×10^{-7} and 5.1×10^{-7} m^2/s. The description of the Hays member by Beauheim et al. (1983b) indicates that it is siltstone. The estimated transmissivities of the overlying Olds and Ramsey members are less than 10^{-8} m^2/s. Core from the Ramsey member is not available from Cabin Baby-1.

Table 2.1: Summary of hydrologic test results from the Bell Canyon Formation in Cabin Baby-1 and DOE-2. Data from Table 6 of Beauheim et al. (1983b) and Table 7-2 of Beauheim (1986).

Effective Test Interval (m blg)	Unit	K(md)	T(m^2/s)
<u>Cabin Baby</u>			
1230-1246	Lamar	6×10^{-4}	5.7×10^{-11}
1247-1257	Ramsey	2.3×10^{-2} - 8.7×10^{-2}	1.7×10^{-9} - 6.3×10^{-9}
1259-1269	Olds	2.2×10^{-2} - 8.2×10^{-2}	2.1×10^{-9} - 7.9×10^{-9}
1271-1308	Hays	0.57 - 1.7	1.7×10^{-7} - 5.1×10^{-7}
<u>DOE-2</u>			
1263-1272	Ramsey	8.4×10^{-2} - 9.4×10^{-2}	5.8×10^{-9} - 6.5×10^{-9}
1276-1285	Olds	9.8×10^{-2} - 0.11	7.1×10^{-9} - 8.2×10^{-9}
1297-1318	Hays	2.3 - 2.4	5.7×10^{-7} - 6.0×10^{-7}

Fluid samples were successfully collected from the Hays and Olds members of the Bell Canyon in Cabin Baby-1, as was a mixed sample from the entire exposed Bell Canyon. The presence of the tracer added to the drilling

fluid indicates that all of the water samples are slightly contaminated with drilling fluid. Therefore, the reported specific gravity of fluid from the Hays sandstone (1.120 - 1.134) may be slightly too high (Beauheim et al., 1983b).

At the end of operations in 1983, the penetrated portion of the Bell Canyon in Cabin Baby-1 was isolated by a packer emplaced in the lower anhydrite of the Castile Formation, and a monitoring tube was installed to the surface to allow long-term monitoring of a composite Bell Canyon fluid level. As of October 1986, the composite Bell Canyon fluid level in Cabin Baby-1 was stabilized at an elevation of approximately 920 m (Saulnier et al., 1987). Assuming that a specific gravity of 1.12 represents Bell Canyon fluids in the hole, and that the fluid column is supported by the effective pressure at the top of the Hays member at an elevation of -255 m, the calculated pressure at this elevation is 12.81 MPa. This pressure in the Bell Canyon in Cabin Baby-1 would support a column of brine having a density of 1.20 g/cm^3 to an elevation of 842 m.

Culebra fluid pressures and properties in Cabin Baby-1 are contained in LaVenue et al. (1988). These results indicate a Culebra freshwater-equivalent head of approximately 913 m. At the elevation of the base of the Culebra in this hole, approximately 856 m, this requires a fluid pressure of approximately 0.55 MPa. Assuming a final brine density of 1.2 g/cm^3 after halite dissolution, this is equivalent to a brine column supported to an elevation of 903 m.

The expected saturated-brine head in the Culebra in Cabin Baby-1, 903 m, is 61 m higher than the composite saturated-brine head in the Bell Canyon in the same hole, 842 m. Thus, under the assumptions used here and consistent with extrapolations from regional data available as of 1983, the final direction of fluid flow in the event of an open drillhole interconnecting the Bell Canyon and Salado Formations with the Culebra dolomite at Cabin Baby-1 would be downward.

2.2.2 Results from Hole DOE-2

Hole DOE-2, located near the center of the northern boundary of WIPP Zone 3 (Figure 1.2), was drilled in two stages to a total depth of 1318 m, between August 1984 and June 1985 (Mercer et al., 1987). In addition to the shallower units in the hole, the Ramsey, Olds, and Hays "sandstone" members of the Bell Canyon Formation were hydrologically tested (Table 2.1), as described by Beauheim (1986).

The results of testing in DOE-2 are similar to those in Cabin Baby-1, in which the lower "sand," the Hays, is the only unit with appreciable permeability or transmissivity. Estimated transmissivities for the Hays in DOE-2 range from 5.7×10^{-7} to 6.0×10^{-7} m^2/s, similar to the upper estimate of transmissivity for the same zone in Cabin Baby-1. Estimated transmissivities of the Ramsey and Olds members in DOE-2 range only from 5.8×10^{-9} to 8.2×10^{-9} m^2/s, similar to the upper range of estimated transmissivities for the same members in Cabin Baby-1. The lithologic log

contained in Mercer et al. (1987) indicates that all three members are fine-grained sandstones, rather than siltstone.

After hydrologic testing, the Bell Canyon in DOE-2 was isolated for monitoring of a composite fluid level (Beauheim, 1986). As of March 1986, the composite fluid level had "stabilized" at an elevation of approximately 925 m. Assuming that the measured specific gravity of 1.10 (Mercer et al., 1987) is representative for the Bell Canyon fluids, and that the composite Bell Canyon head is controlled by fluid pressures at the top of the Hays member at an elevation of -243 m, this requires a fluid pressure of 12.5 MPa at this elevation. This pressure would support a column of brine having a density of 1.2 g/cm^3 to an elevation of approximately 827 m.

The Culebra freshwater-equivalent head in DOE-2 is approximately 934 m (LaVenue et al., 1988). Using the measured fluid density of 1.04 g/cm^3 (Uhland et al., 1987) for the Culebra in DOE-2, a freshwater-equivalent head of 934 m requires a pressure of 1.47 MPa at the base of the Culebra, at an elevation of 784 m. Assuming a final Culebra brine density of 1.2 g/cm^3 following halite dissolution, the Culebra fluid pressure at DOE-2 would support a brine column of density 1.2 g/cm^3 to an elevation of approximately 909 m, 82 m higher than supported by the composite Bell Canyon head in the same hole. Under the assumptions used here, the final direction of fluid flow in the event of an open hole interconnecting the Bell Canyon, Salado, and Culebra at DOE-2 would be downward.

Wood et al. (1982) estimate that the transmissivities of sandstones within the Bell Canyon Formation normally range from 1.0×10^{-6} to 2.8×10^{-6} m^2/s, although they report a maximum value of 1.7×10^{-5} m^2/s. This range is approximately one order of magnitude greater than the transmissivity of the Hays member in Cabin Baby-1 and DOE-2, and more than two orders of magnitude greater than the transmissivities measured in the Olds and Ramsey members in the same holes. Therefore, the Ramsey member in Cabin Baby-1 and DOE-2 does not appear to be part of one of the channel sands shown in Figure 1.3. Given that Cabin Baby-1 and DOE-2 are the only two holes very near to WIPP Zone 3 that penetrate the Bell Canyon, this result does not guarantee that no channel sandstone is present in the Bell Canyon beneath the WIPP site. Given the general trend of the channel sands shown in Figure 1.3, it does suggest that any channel sand present would have to be at least as narrow as the sand shown at the eastern edge of the WIPP site. Cabin Baby-1 lies along the trend of this sand, however, indicating that this channel is not continuous towards the southwest.

The recent results in both DOE-2 and Cabin Baby-1 are consistent with the conclusion that the final direction of fluid flow resulting from interconnection of the Bell Canyon Formation and the Culebra dolomite at or near the WIPP site would be downwards into the Bell Canyon, contrary to assumptions maintained in the WIPP FEIS. There are some limitations to this conclusion. There might be upward fluid movement until the Bell Canyon and Culebra fluids became essentially saturated with halite, at which time downward flow would begin. In addition, these results depend on the assumption that flow rates within the Bell Canyon and Culebra dominate any fluid pressures generated within the Salado Formation. This assumption appears generally valid, however, given the low fluid-flow rates normally encountered within the Salado Formation (Section 3.0).

3.0 CASTILE AND SALADO FORMATIONS

The major halite-bearing units at and near the WIPP site are the Castile and Salado Formations. Both units contain halites of varying purity and thickness. The two halites within the Castile Formation are normally thick, contain abundant sulfate/carbonate laminae, and are separated by two relatively thick anhydrites. The bedded halites within the Salado Formation contain accessory minerals such as polyhalite, clay, and anhydrite, and are separated by numerous anhydritic marker beds and related clay seams. Locally the middle portion of the Salado Formation contains commercial potash mineralization, at a level some 300 m stratigraphically above the WIPP facility horizon. The underground workings in the WIPP facility are being developed at a depth of approximately 655 m within bedded halites and anhydrites in the lower Salado. The halitic interval containing the WIPP facility horizon is approximately 8 m thick, and is situated between anhydrite marker beds MB138 and MB139. The Castile and Salado Formations are discussed together here, since halite is a major component of both, and many of the processes of interest involve both units.

The Castile Formation overlies the Bell Canyon Formation (Delaware Mountain Group). Near the WIPP site, the Castile normally contains a sequence of three thick anhydrites (Anhydrite I at the bottom and Anhydrite III at the top), separated by two thick halites (Halites I and II). The thickness of the Castile Formation at and near the WIPP site is approximately 400 m. Anderson et al. (1972) provide a general stratigraphic description of the Castile, including the more than 200,000 sulfate/carbonate laminae that occur throughout both halites and anhydrites within the unit. Bedding within Castile anhydrites ranges from massive (approximately 30 m) to laminar (see, for example, Mercer et al., 1987). Individual beds in the Salado are often 1 m thick or less. The unit nominally contains 45 anhydrite marker beds, numbered from Marker Bed 101 (MB101) to MB145 with increasing depth. The Salado Formation is about 600 m thick at the WIPP site.

In some areas, both total thickness and the thickness of stratigraphic intervals within the Castile and Salado Formations are variable. The origin and timing of this variability are discussed in Section 3.1. This variability has played a significant role in WIPP site characterization, since variable halite (and anhydrite) thicknesses could have at least three origins:

1. Initial depositional variability (e.g., Lambert, 1983; Borns and Shaffer, 1985).

2. Gravity-driven deformation, in which dense anhydrites sink into less dense halites, with compensating formation of salt-cored domes or anticlines (Borns et al., 1983; Borns and Shaffer, 1985).

3. Evaporite dissolution, by which halites are preferentially dissolved by contact with unsaturated groundwaters (Anderson, 1978; Davies, 1983).

Significant volumes of fluid are not normally encountered in drilling either the Castile or Salado. There are exceptions, however. Highly pressurized brines have been encountered in the uppermost Castile anhydrite in some hydrocarbon-exploration and stratigraphic test holes near the WIPP site (Figure 1.6). These fluids are under sufficient pressure to flow to the land surface. The origin and distribution of Castile brines at and near the WIPP site is discussed in Section 3.2.

As mentioned previously, the WIPP facility is presently being developed within the bedded halites and anhydrites of the lower Salado Formation. In order to place the WIPP facility within a proper regional perspective, it is necessary to characterize the behavior of the Salado Formation on both the regional scale and adjacent to the WIPP facility itself. The characteristics of the Salado are locally different as a result of "excavation effects" from construction of the WIPP facility. These transient effects demonstrably occur on time scales of interest in performance assessment. Recent studies examining the structural, hydrologic, and geochemical characteristics of the Salado Formation in and near the WIPP facility are discussed in Section 3.3. These studies are progressing, and will play a critical part in monitoring the behavior of the WIPP facility during the operational phase. The discussion of these activities is preliminary.

3.1 Regional and Local Variability, Deformation, and Dissolution of the Castile and Salado Formations

3.1.1 Regional Relationships and Behavior

As mentioned above, both aggregate and internal thicknesses within the Castile and Salado Formations vary locally. The variability near the WIPP site is shown in Figure 3.1. Holes WIPP-12, DOE-2, and WIPP-11 lie within the southern part of the Castile "Disturbed Zone" (DZ) shown in Figure 1.6, while hole Cabin Baby-1 lies outside this zone. Since ERDA-9 penetrates only the upper portion of the Castile Formation, the possible extension of the DZ beneath the WIPP facility has not been determined by drilling. The Castile and Salado Formations in hole Cabin Baby-1 are assumed here to represent the "undisturbed" character of these units near the WIPP site.

In the cross section shown in Figure 3.1, the total thickness of the Castile is known only in holes Cabin Baby-1 and DOE-2. The Castile is 409 m thick in Cabin Baby-1 and 302 m thick in DOE-2. The apparent thickness of Anhydrite I is 72 m in Cabin Baby-1 and 80 m in DOE-2. Therefore, we assume here that the thickness of Anhydrite I is not significantly variable on the scale of the WIPP site, and that, south of DOE-2, Anhydrite I is not strongly involved in structures within the Castile and overlying Salado. Apparent stratigraphic thicknesses from the top of the Castile to the top of Anhydrite I range from 222 m at DOE-2 to 372 m at WIPP-11. The assumed undisturbed thickness, that at Cabin Baby-1, is 337 m.

Much of the variability within the Castile Formation in Figure 3.1 is in halite thickness. For example, the anomalously thick Castile at WIPP-11 includes a thickness of 311 m for Halites I and II, compared with a

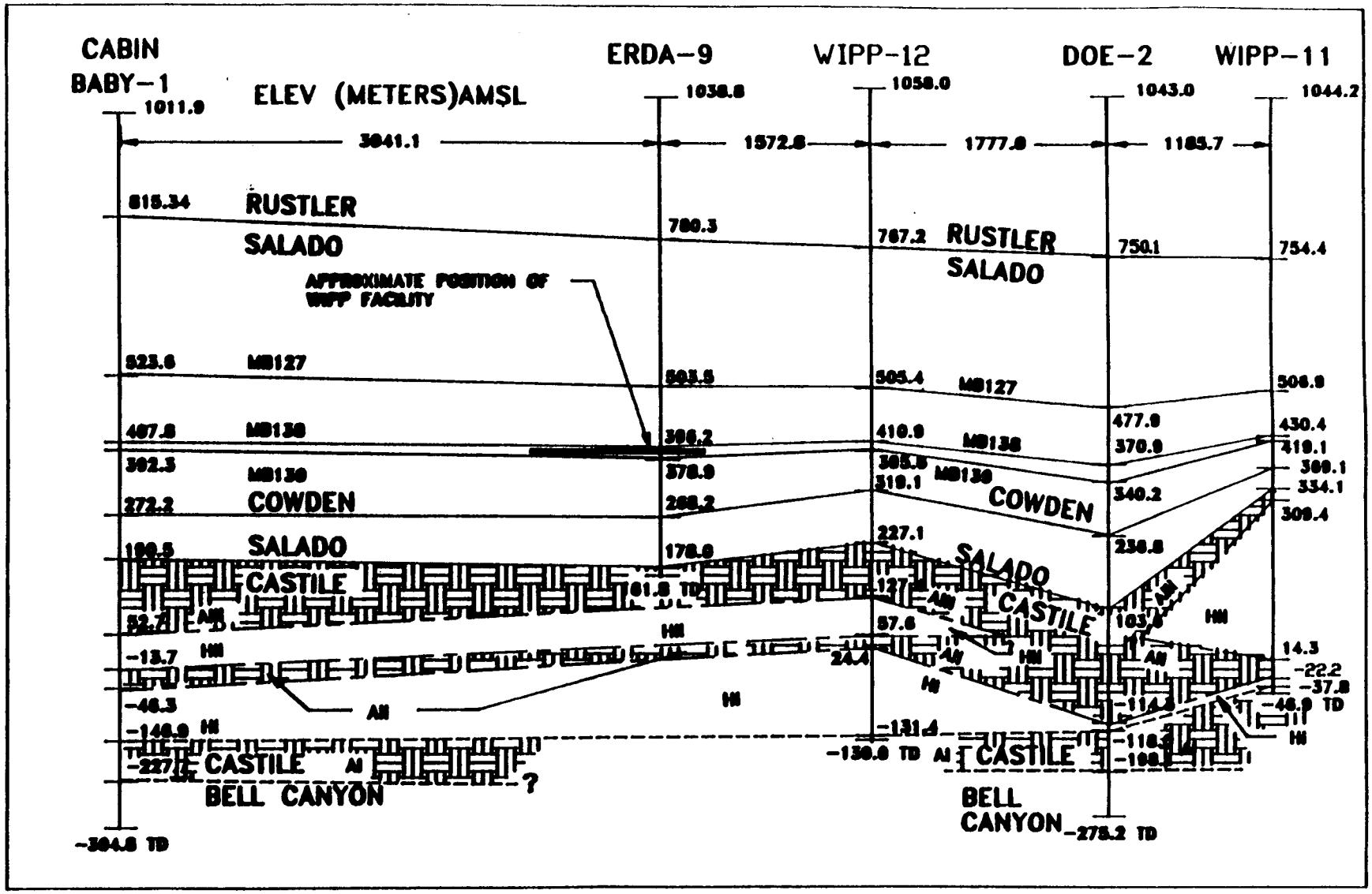


Figure 3.1: Generalized stratigraphic cross section of the Salado and Castile Formations between holes Cabin Baby-1 and WIPP-11. Hole locations used are shown in Figure 3.2. Elevations and hole spacings are in meters.

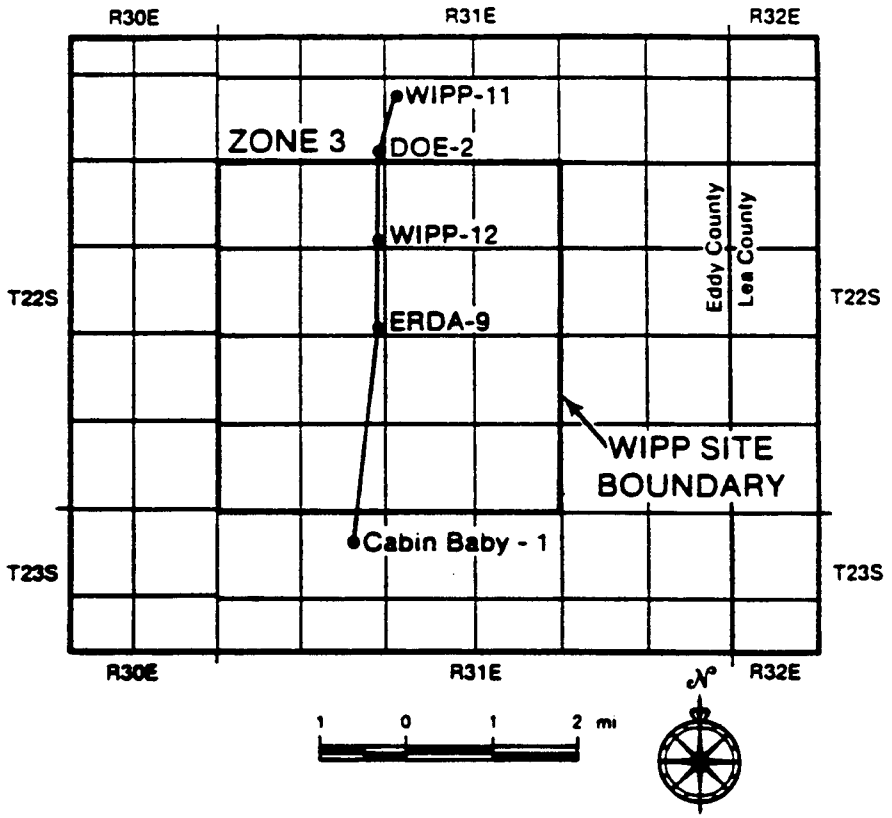


Figure 3.2: Hole locations used in Figure 3.1.

thickness of 167 m for the same units in Cabin Baby-1. At the other extreme, a total of only 2 m of Castile halite is present in DOE-2; Halite II is completely missing.

However, Anhydrites II and III also vary in thickness. Their total apparent thickness (drilled thickness, ignoring dip) in WIPP-11 is 61 m, compared to 219 m in DOE-2. Both values differ significantly from the total thickness of the two units in Cabin Baby-1, 170 m. These relationships indicate that, at least locally, anomalously thick halites within the Castile Formation are combined with anomalously thin anhydrites. Conversely, anomalously thin Castile halite, as in DOE-2, is combined with anomalously thick anhydrite. These results are inconsistent with halite dissolution being the only cause of variability in the thickness of the Castile Formation at the WIPP site.

Locally, the antithetic relations between anhydrite and halite thicknesses within the Castile are consistent with a similar relationship between overall thicknesses of the Salado and Castile Formations. The Salado is 625 m thick at Cabin Baby-1 and 602 m thick in ERDA-9. However, at WIPP-11 and WIPP-12, where the underlying Castile is anomalously thick, the Salado is unusually thin, 420 and 540 m, respectively. On the other hand, the Castile is relatively thin at DOE-2, and the apparent thickness of the Salado at DOE-2 is 647 m, greater than at either Cabin Baby-1 or ERDA-9.

Thus, the variable thicknesses of the combined Salado and Castile Formations at and near the WIPP site appear due to internally compensating variations in thicknesses of both anhydrites and halites. The origin of compensating anhydrite and halite thicknesses may be either depositional, as suggested by Lambert (1983) and Borns and Shaffer (1985), or a consequence of later gravity-driven deformation, as discussed in Borns et al. (1983). The Castile and Salado variability considered here at the WIPP site proper is very similar to that considered by Borns and Shaffer (1985) at the Poker Lake structures well south of the WIPP.

There is considerable evidence for both syndepositional and postdepositional deformation within the Castile Formation, as summarized by Borns et al. (1983) and Borns (1983). These authors distinguish three stages of deformation, listed in the sequence of development:

1. Formation of discontinuous isoclinal folds interpreted to be approximately syndepositional in age, i.e., to have occurred in soft sediments. These structures include displacive crystal growth in both anhydrites and carbonate laminae. Characteristically, the syndepositional structures are confined to a single layer, and may include disruption of the affected layer.

2. Asymmetric folding, including formation of crenulation cleavage, boudinage (separation) of carbonates, and convolute folding of anhydrite stringers within halites. Borns (1983) attributes a widespread subhorizontal fabric within Castile halites to folding at this stage. The axial planes of convolute folds in anhydrite stringers within Halites I and II are also subhorizontal. Borns (1983) interprets these relations to indicate that major deformation within the Castile often involves lateral movement of halite.

3. Late-stage near-vertical fractures and veins, which cross-cut earlier structures. These fractures may be either open, or filled with halite, anhydrite, and/or gypsum.

Syndepositional deformation was probably driven by gravity acting on original depositional slopes, or by responses to density contrasts within still-soft sediments. Borns et al. (1983) attribute later deformation to some combination of direct gravity-driven deformation resulting from deposition of dense anhydrites over less-dense halites and regional tilting of the Delaware Basin. On the large scale, the gravitic driving force for internal deformation of the Castile and overlying Salado Formations is clear. Above Anhydrite I, the Castile includes two thick anhydrites, with densities of approximately 2.95 g/cm^3. Each unit was deposited above thick halite with a density of 2.2 to 2.25 g/cm^3. Modeling discussed in Borns et al. (1983) indicates that, for the relatively thick-bedded Castile, these density contrasts should be sufficient to drive deformation in which the anhydrites effectively sink into underlying halites. Layering within the Salado is too thin to support such deformation; the Salado structures appear essentially to follow those in the underlying Castile as a relatively passive marker.

However, a driving force for deformation can be effective only if there are appropriate deformation mechanisms operating in the rocks involved. There have been three major studies into possible deformation mechanisms within the halites of the Castile and Salado. Munson (1979) assumed that deformation within the units is anhydrous. Munson concludes (Figure 3.3) that deformation under generic conditions for either a high-level-waste or TRU facility in halite would occur by an undefined mechanism, except at relatively high stress levels. At high stress levels, deformation would be dominated by creep mechanisms involving dislocation climb.

In contrast, Borns et al. (1983) associate structures within deformed portions of the Castile and Salado with the presence of fluids, and conclude that pressure solution plays a major role in controlling the regional deformation of both units. During pressure solution, deformation proceeds as a result of the migration of mineral constituents from regions of high stress to regions of low stress by means of diffusion through grain-boundary fluids. In the interpretation of Borns et al. (1983), the participation of fluids during deformation of the Castile and Salado Formations is indicated by veins containing both halite and anhydrite, as well as by anhydrite recrystallization in stress shadows. Recent studies of fluid contents within Salado halites indicate contents of as high as 2 weight percent (see Section 3.3), more than required for pressure solution to be operative (Borns, 1987b).

Borns (1987b) estimates deformation fields for halite, including pressure solution as a deformation mechanism (Figure 3.4). Field "C" in this figure includes the temperature and stress regimes estimated for regional deformation at and near the WIPP site by Borns et al. (1983), while field "B" is an analogous field for natural deformation of halites estimated by Carter and Hansen (1983) and Heard (1972). Pressure solution plays a major role in halite deformation within the conditions of both fields and assumed

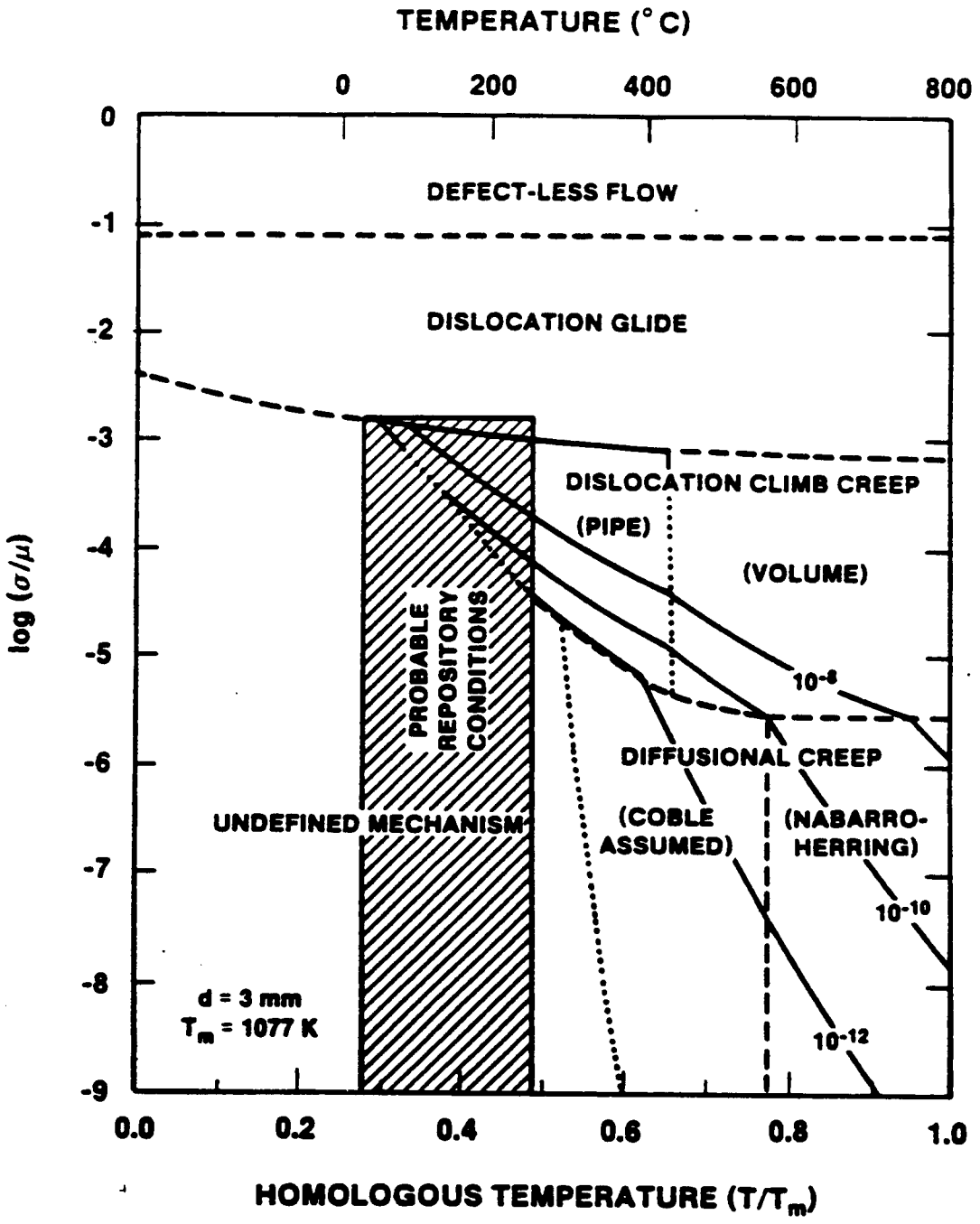


Figure 3.3: Deformation map for halite, assuming all deformation is anhydrous. Figure 2 of Borns (1987b). Homologous temperature (T/T_m) is the ratio between temperature and the dry melting temperature of halite. The stress axis is the log ratio of differential stress to halite shear modulus.

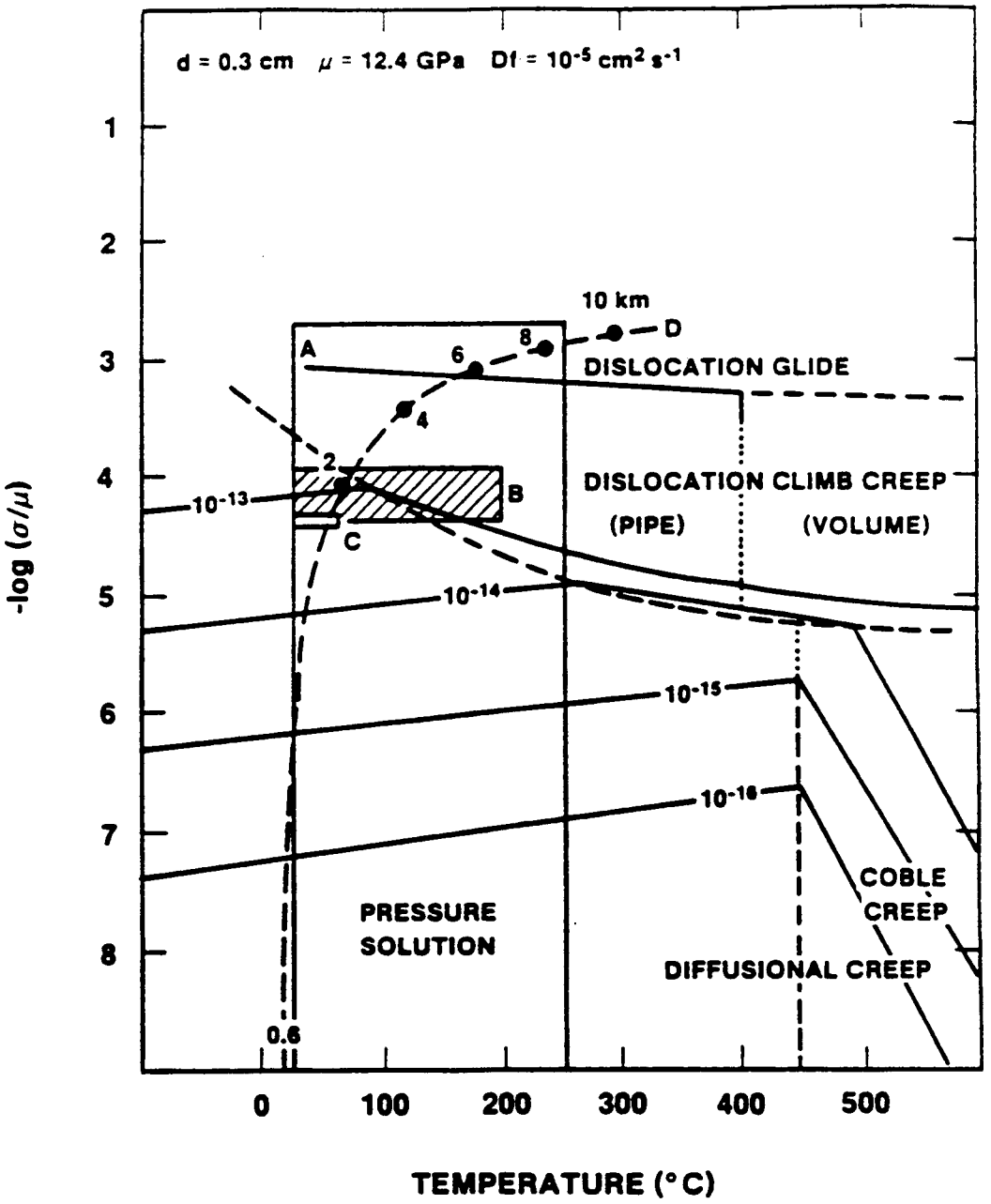


Figure 3.4: Deformation map for halite, assuming fluids present and considering pressure solution as a major deformation mechanism. Figure 4 of Borns (1987b). In this figure, viscous effects on grain boundaries are ignored. Field A is the field of "probable repository conditions" shown in Figure 3.3. Field B is the range of stress and temperature conditions estimated for natural rock-salt deformation (Carter and Hansen, 1983; Heard, 1972). Field C is the range of stress and temperature conditions for gravity-driven deformation at the WIPP site (Borns et al., 1983). Curve D is the estimated stress and temperature path for a Gulf Coast salt dome at the indicated depths (Carter and Heard, 1970).

material properties, so long as the volumetric strain rate is not greater than approximately 10^{-13} s^{-1}. As discussed by Borns (1987b), the maximum strain rates at which pressure solution is a dominant deformation mechanism depend on the character and thickness of the grain-boundary fluids.

The estimated strain rates for far-field deformation at the WIPP site, not including near-field deformation around the WIPP facility itself, are consistent with pressure solution. Based on a range of estimated strain rates of between 3×10^{-14} and 10^{-16} s^{-1}, the range of times calculated for formation of the WIPP-12 anticlinal structure, estimated to have undergone 1% volumetric strain, is 1.1×10^{4} to 10^{6} years (Borns et al., 1983). Near an underground facility such as the WIPP facility, however, early-time strain rates are probably too rapid for pressure solution to be a major deformation mechanism. Reported volumetric strain rates in such a setting are as high as 10^{-11} s^{-1} (Borns, 1987b), and may be even higher during initial transient closure.

In summary, the understanding of far-field deformation within the Castile and Salado Formations is consistent with the interpretations that:

1. Pressure solution, in which deformation results from mineral constituents being transported from high-stress to low-stress domains by means of an intergranular fluid or film, plays a major role in regional deformation of evaporites at and near the WIPP site. Since only approximately 0.2 volume percent (0.1 weight percent) fluid is required for pressure solution to be operative in halite, more than enough fluid is present within the Salado and Castile Formations at and near the WIPP site.

2. Much of the deformation within the DZ may have been effectively syndepositional (i.e., Permian) in age, although this is not the last period of deformation that has taken place.

3. The driving force behind regional-scale evaporite deformation at and near the WIPP is gravitational, due to the depositional emplacement of dense anhydrites over less dense halites. There is, however, a regional overprinting due to Pleistocene tilting of the entire northern Delaware Basin.

4. Deformation such as that known to occur within the DZ, even if it does progress toward the WIPP, is unlikely to reach the WIPP site within 10^{4} years, the minimum estimated time required for formation of the WIPP-12 structure.

5. It is not known whether or when pressure solution will become an important mechanism in closure of the WIPP facility itself. At early times close to the facility, i.e., at relatively high stresses and deformation rates, mechanisms involving dislocation climb (and fracturing) should dominate. At later times and/or at greater distances from the underground workings, i.e., at lower stresses and deformation rates, pressure solution may dominate.

3.1.2 The DOE-2 Structure

The recognition of gravity as a driving force for regional-scale deformation of the Castile and Salado Formations and the probable role of pressure solution in such deformation does not rule out the possibility of halite removal by dissolution. The absence of halite within the Castile in the western part of the Delaware Basin (Figure 1.4) is interpreted as partly due to halite dissolution in response to regional tilting and uplift of the basin. However, as summarized by Neill et al. (1983), there is generally agreement that blanket or stratabound dissolution within the Castile and Salado Formations is not a feasible mechanism for breach of the WIPP facility on the regulatory time frame. Regional-scale evaporite dissolution within the Castile and Salado Formations is not discussed further here.

Both Anderson (1978, 1981) and Davies (1983) proposed that evaporites in the Castile and/or Salado Formations may be locally dissolved by halite-unsaturated fluids moving upwards from the Bell Canyon Formation (see Section 2.0). Subsidence of the overlying evaporites, especially the Salado Formation, would result. Hole DOE-2 was drilled specifically to investigate a depression in MB124 in the middle portion of the Salado Formation (Figure 3.1; see also Figure 2-2 of Mercer et al., 1987). However, the DOE-2 structure is interpreted as being due to lateral and vertical deformation of the Castile and Salado Formations, rather than evaporite dissolution.

The expected position of the top of the Castile Formation (Anhydrite III) in DOE-2 was at an elevation of between 230 and 260 m. However, the top of the Castile in DOE-2 was actually at an elevation of 102 m, more than 120 m lower. The base of the Castile in DOE-2, at an elevation of -199 m, is consistent with regional trends, indicating that the structure does not extend below the top of Anhydrite I.

Laminae within the upper Castile anhydrite in DOE-2 are strongly deformed, with vertical bedding and discontinuous folds at various depths (Mercer et al., 1987; Borns, 1987a). These structures are consistent with syndepositional deformation. Other structures seen in the Salado and Castile Formations in DOE-2, such as pull-apart structures and fibrous vein infillings, are interpreted by Borns as postdepositional. As noted by Borns (1987a), removal of Castile halite from DOE-2 by dissolution should have left in place many of the anhydrite "laminae" originally present in Halites I and II. No such dissolution residues were identified in core collected in hole DOE-2. The very thin Castile halite in DOE-2 (approximately 2 m) is compensated by unusually thick halites within the overlying Salado Formation. As shown in Figure 3.1 and noted in Table 3-3 of Mercer et al. (1987), halites within the informal lower member of the Salado Formation (from MB126 to the top of the Castile) in hole DOE-2 are 96 m thicker than in the same stratigraphic interval in hole WIPP-12, and 204 m thicker than in WIPP-11.

The DOE-2 structure is interpreted as being due to both lateral and vertical deformation of the Castile and Salado Formations, rather than to evaporite dissolution. The structural understanding of the Salado and

Castile does not allow prediction of where such a structure might develop in the future. Drilling and testing of hole DOE-2 indicates that no such structure remains unexamined at and near the WIPP site. Estimated times required for 1% strain in the structure at WIPP-12 indicates, however, that the time required for generation of a significant structure as a result of gravitationally driven deformation probably exceeds the 10,000-year time frame of regulatory interest.

3.2 Occurrence and Origin of Pressurized Brines within Anhydrites of the Castile Formation

Uncertainties about the original thicknesses, rates of gravity-driven deformation, and regional and local dissolution rates of Castile halites relate to natural phenomena affecting the reliability of long-term extrapolations of WIPP performance. One issue, the possible presence of pressurized Castile brines beneath the WIPP facility itself, plays a direct role in evaluation of the possible consequences of human intrusion into the WIPP facility. This is because, when encountered in drillholes, such brines can rise to the land surface; they would be capable of directly transmitting entrained waste to both the Rustler and the land surface. A geophysical survey conducted in 1987 indicates that Castile brines may be present beneath a portion of the WIPP waste-emplacement panels, consistent with previous assumptions made in WIPP performance assessment.

The known occurrences of Castile brines in the northern Delaware Basin as of 1983 (Figure 1.6) are taken from Popielak et al. (1983). Brines have been encountered in fractured Castile anhydrites in several hydrocarbon-exploration drillholes both north and northeast of the WIPP site, between the WIPP site and the margin of the Delaware Basin. In addition, Castile brines were encountered southwest of WIPP in the Belco well, approximately 6.5 km from the center of the site. During WIPP site characterization, pressurized Castile brines have been encountered in holes WIPP-12, approximately 1.6 km north of the site center, and ERDA-6, approximately 8 km northeast of the site center.

Brine volumes in the two occurrences have been estimated on the basis of flow tests and drillstem testing, but remain somewhat uncertain because of limited early flow data and the assumptions necessary concerning both fracture porosity and rock-mass compressibility in the absence of observation holes. Estimated brine volumes in the two occurrences range between 9.5×10^3 and 10^5 barrels for ERDA-6 and between 5×10^6 and 17×10^6 barrels for the WIPP-12 occurrence (Popielak et al., 1983; Neill et al., 1983).

Because of the apparent large volume of the WIPP-12 reservoir, it is reasonable to postulate that this reservoir extends beneath all or part of the WIPP facility. However, geophysical studies prior to 1983 were unsuccessful in determining whether or not Castile brines were present beneath the WIPP facility (Borns et al., 1983). Nonetheless, as a result of the occurrence of Castile brine in WIPP-12, it was assumed through 1983 that these brines were present beneath the WIPP facility (Channell, 1982; Bard, 1982; Case et al., 1982). A geophysical survey using transient

electromagnetic methods was made directly over the WIPP waste-emplacement panels in 1987 (Earth Technology, 1987), to determine the presence or absence of Castile brines beneath the facility. The results contained in Earth Technology (1987) are summarized in Figures 3.5 and 3.6.

As discussed in Section 2.0, the WIPP is underlaid by the Bell Canyon Formation. While the permeability of the upper portion of the Bell Canyon Formation is variable, the entire unit appears to be a good electrical conductor. Therefore, the dominant conductive layer beneath the WIPP facility appears to be the Bell Canyon. However, the apparent variations in depth to the first major conductor appear to exceed the estimated depth uncertainty for the geophysical method used, 75 m (Figure 3.6). At some of the locations, the interpreted depth to the first major conductor lies significantly above the depth of the top of the Bell Canyon Formation, i.e., within the Castile Formation. On the basis of this interpretation, brine may be present within the Castile Formation under part of the area outlined by the WIPP waste-emplacement panels (Earth Technology, 1987).

However, the combination of the depths to the first major conductor indicated in Figure 3.5 and stratigraphic depths indicated in Figure 3.1 suggests that the brine occurrence is limited. The depth to the top of the Bell Canyon is 1230 m in Cabin Baby-1 and approximately 1250 m in ERDA-9 (assuming linear variation between Cabin Baby-1 and DOE-2). Therefore, conductor depths greater than 1300 m in Figure 3.5 almost certainly reflect the Bell Canyon Formation. At the other limit, the depth to the bottom of the Salado is 861 m in ERDA-9 and 821 m in Cabin Baby-1. Since the minimum interpreted depth to the conductor is 988 m, the conductor does not appear to be within the Salado Formation anywhere in the surveyed area. The depth to the bottom of Anhydrite III is 959 m in Cabin Baby-1, and is assumed to be approximately 950 m in ERDA-9. Assuming 75 m vertical uncertainty in the geophysical soundings, this implies that apparent conductor depths of less than approximately 1025 m are consistent with brine occurrence within Anhydrite III. This interpretation suggests that brine is present within Anhydrite III under only the furthest northern and northeastern parts of the waste-emplacement panels. To date, pressurized Castile brines have been found only within fractured portions of the uppermost anhydrite present, Anhydrite II in ERDA-6 and Anhydrite III in WIPP-12.

The results shown in Figure 3.5 are based on one-dimensional modeling. Preliminary attempts at three-dimensional interpretation of the results indicate that the lateral resolution of the interpretation cannot be improved by more complex modeling approaches. Therefore, the "conservative" interpretation is that Castile brines are present beneath at least the northern portion of the WIPP waste-emplacement panels, consistent with both the most recent work and earlier assumptions.

Two basic hypotheses have been put forward to account for the occurrences of Castile brines:

1. Migration of connate Castile fluids into fractured anhydrites as a result of local deformation (Borns et al., 1983; Popielak et al., 1983).

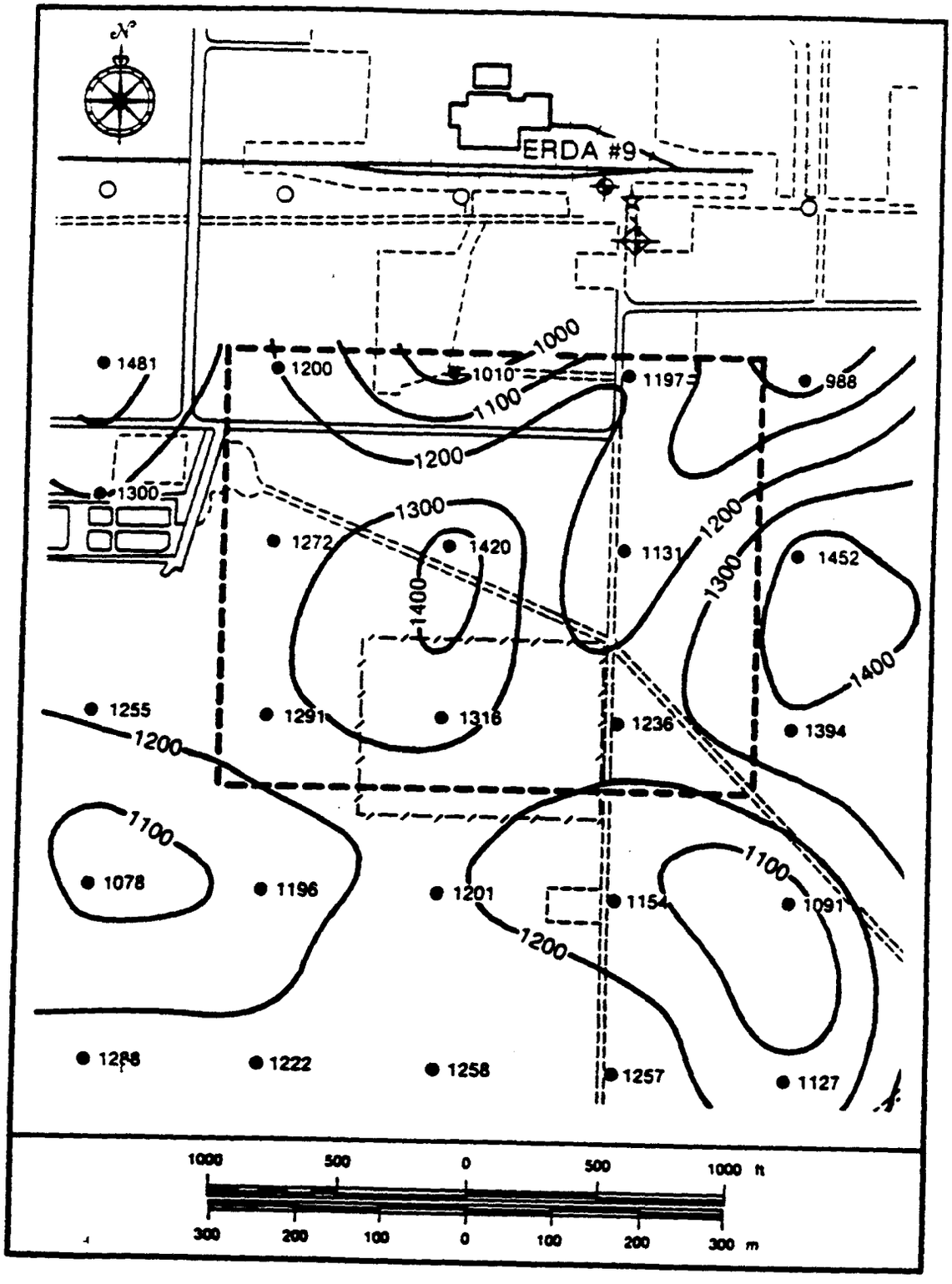


Figure 3.5: Contour map of apparent depth to first major deep conductor in survey including area of WIPP waste-emplacement panels, in meters. The heavily dashed rectangle outlines the surface projection of the WIPP waste-emplacement panels. Simplified from Figure 3-3 of Earth Technology (1987).

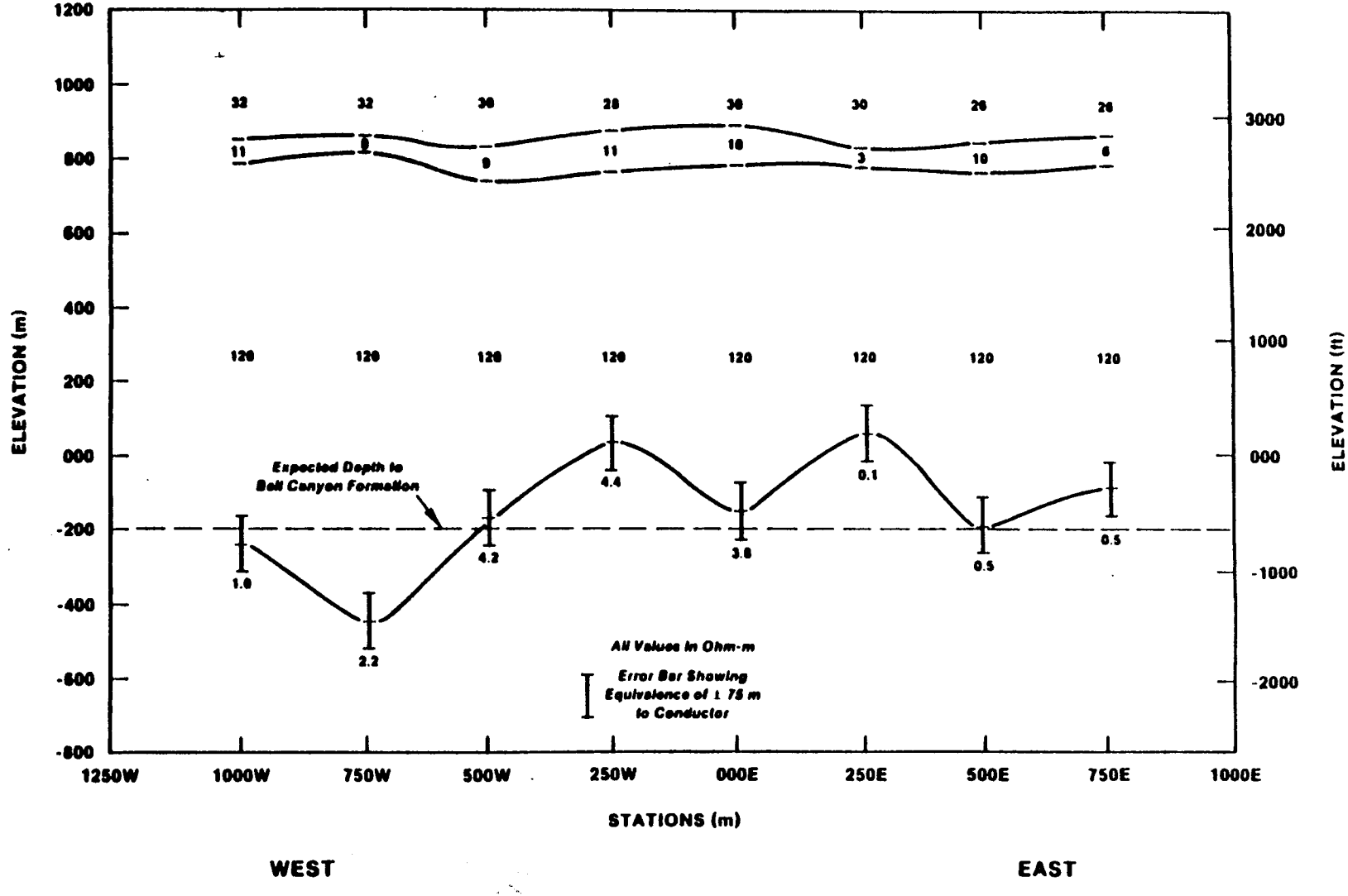


Figure 3.6: Cross section of apparent depth to first major deep conductor, showing brine locally present in both the Bell Canyon and Castile Formations. Line of section is along the north side of the WIPP waste-emplacement panels. Figure 4-11 of Earth Technology (1987).

2. Isolation of meteoric waters within fractured anhydrites following episodic hydrologic connection of the Castile with the Capitan limestone (Lambert and Carter, 1984).

According to the first hypothesis, the brines would be localized by deformation of the Castile Formation. The brines would occur in relatively low-pressure areas, such as the crests of domal or anticlinal structures similar to those encountered at WIPP-12 and ERDA-6. Such brines might continue to be generated by slow gravitationally driven deformation during and after the WIPP operational phase. Borns (1983) estimated that the reduction of porosity of the Castile halites by 0.2% required to generate the volumes of brine encountered in the WIPP-12 domal structure would likely be indistinguishable in bulk-property measurements. As pointed out by Borns (1987b), mechanical displacement and/or fluid movement during gravity-driven deformation need not be continuous. From a mechanical point of view, the emplacement of Castile brines appears consistent with either continuous or episodic deformation, and would result in indistinguishable changes in the properties of surrounding Castile halites. However, as discussed in Section 3.1, regional deformation within the Castile Formation is probably too slow to be of concern in the performance of the WIPP facility.

Lambert and Carter (1984) conclude, on the basis of uranium-disequilibrium studies, that the Castile brine occurrences were neither in-place nor remobilized connate Castile fluids. They conclude that the brine occurrences are the result of isolation of waters resulting from intermittent or episodic lateral hydraulic connection of the Capitan limestone and Castile anhydrites. Local fracturing of the Castile anhydrites is still required. Lambert and Carter (1984) specifically conclude that:

1. The residence or isolation times for the Castile brines at ERDA-6 and WIPP-12 are between 360,000 and 880,000 years.

2. The extent of buildup in $^{234}U/^{238}U$ ratios expected to result from continuous exposure of fresh rock to fluids during gravity-driven deformation is not seen.

3. Therefore, the mode of emplacement of the Castile brines must be episodic in character. The relevant episodic feature of the system is interpreted by Lambert and Carter (1984) to be hydraulic connection between the Castile anhydrites and the Capitan limestone. Any future brine generation, according to this interpretation, would require hydrologic reconnection of the Capitan and Castile.

In summary, recent geophysical studies indicate that brines are probably present within Castile anhydrites under a portion of the WIPP waste-emplacement panels. The brines are 250 m or more stratigraphically below the WIPP facility horizon. Although the detailed distribution of the brines remains unknown, this is not of special concern, since the presence of Castile brines beneath at least a portion of the WIPP facility has been and will continue to be assumed in WIPP performance assessment. The

mechanism(s) giving rise to Castile brine occurrences are not completely known. However, both mechanisms proposed, fluid migration in response to episodic deformation and isolation of fluids resulting from episodic interconnection of the Capitan limestone and Bell Canyon Formation, are unlikely to generate significant additional brine beneath the WIPP facility in the 10,000-year time scale of regulatory interest.

3.3 Recent Hydrologic, Geochemical, and Structural Studies of the Salado Formation

As mentioned above, the WIPP facility is presently being developed within bedded halites and anhydrites of the Salado Formation, at an average depth of approximately 655 m. This section attempts to place the WIPP facility within a proper perspective relative to both local and regional-scale hydrologic and structural behavior of the Salado Formation. Differences in Salado behavior as a result of the presence of the WIPP facility are considered as "excavation effects."

Section 3.3.1 discusses the hydrologic behavior of the Salado Formation as interpreted from testing conducted from the surface and within the WIPP facility. Section 3.3.2 describes the present understanding of the fluid geochemistry and mineralogy of the Salado Formation, based on recent and ongoing studies within the WIPP facility. Section 3.3.3 discusses the interim results of ongoing investigations into the structural behavior of the Salado Formation adjacent to the WIPP facility, with emphasis on Marker Bed 139 (MB139), a relatively thick anhydritic marker bed approximately 1 m below the WIPP facility horizon.

3.3.1 Regional-Scale and Near-Facility Hydrology of the Salado Formation

3.3.1.1 Hydrologic Testing from the Surface and at the Facility Horizon--Unlike the case in the Castile Formation, significant brine flows have not been encountered in hydrologic testing of the Salado Formation from the surface. However, two anomalous phenomena have been encountered in the Salado. First, pressurized gas has been encountered in some holes drilled from the surface and near the mining face in WIPP excavations. In the most dramatic case, nitrogen gas was encountered in the upper portion of the Salado in hole AEC-8, at a depth between 335 m and 391 m, during reworking of the hole approximately one year after original drilling (Table 3.1; Mercer, 1987). The gas pressure was sufficient to partially remove the drillstem from the borehole. A large volume of gas, approximately 6×10^5 m^3, was allowed to flow to the surface without apparent depletion of the reservoir (Mercer, 1987). Gas has also been locally encountered during construction of the WIPP facility, as described in Deal and Case (1987). To date, all gas occurrences within the WIPP facility have been small, although the largest such occurrence did result in a 0.4-m diameter disk being blown out of the face being mined. Second, as shown in Table 3.1, long-term monitoring at some holes penetrating the Salado Formation indicates a slow buildup of fluid pressure. The maximum pressure measured to date is 3.3 MPa (472 psig) at WIPP-12. This pressure is generated within the Salado, since it was measured before the hole was deepened into

Table 3.1: Summary of known Salado gas occurrences and measured wellhead pressures from surface drilling. Gas-occurrence data are modified from Table 2 of Mercer (1987). Fluid-pressure data are from the text of Mercer (1987).

A. Gas Occurrences

Hole	Comments
ERDA-9	At 430 m; trace of H_2S
ERDA-6	At 561 m; blew for 30 min.
AEC-7	At 491 m; blew for 1 hour
AEC-8	At 335-391 m; blew for several months
P-7	Many kicks
P-12	Hole unloaded fluid over weekend
P-20	Slight blow at TD of 608 m

B. Pressures Measured at Surface

Hole	Comments
Cabin Baby	1.4 MPa
WIPP-12	2.94 MPa, before deepening
WIPP-13	2.93 MPa, hole open to Castile and Salado
WIPP-11	0.12 MPa
DOE-2	0
AEC-7	0

the Castile Formation and intersected Castile brines (Section 3.2). The rate at which Salado brine pressures build up is very slow and, as noted by Mercer (1987), the pressures appear to be supported by only very small volumes of fluid. Complete reduction of the 1.6 Mpa (228 psig) pressure at the WIPP-12 wellhead in 1985 was achieved by release of approximately 5 gallons of brine. In some holes, for example DOE-2 and AEC-7, no long-term pressure buildup has been observed.

The published results of "successful" hydrologic tests of the Salado from the surface (Table 3.2) indicate permeabilities from approximately 0.01 microdarcy to a high of 25 microdarcies. Ongoing evaluation indicates that, as a result of instrumentation limitations, testing-time limitations or problems with pressure or flow stabilization, data from the Salado in DOE-2 are the most reliable, indicating a maximum permeability of 0.3 microdarcies. It has not been possible in testing from the surface to identify any discrete sources for this fluid or to determine any stratigraphic effects.

Table 3.2: Summary of Salado hydrologic properties interpreted in hydrologic testing from surface. Modified from Tables 3 through 9 of Mercer (1987). Ongoing interpretation indicates that only results from hole DOE-2 are reliable.

Hole	Comments
AEC-7	550.8-581-3 m; MB 126; gas perm. 3 x 10^{-6} D
AEC-7	672.7-703.2 m; MB 139; gas perm. 12-21 x 10^{-6} D
ERDA-9	436.8-452.9 m; MB 118, 119; perm. 0.1-0.7 x 10^{-6} D
ERDA-9	613.9-638.3 m; MB 136, 137; perm. 0.6-3.2 x 10^{-6} D
ERDA-9	765.7-798 m; Cowden, lower Salado; perm. 1.6-2.2 x 10^{-6} D
ERDA-9	799.5-876 m; lower Salado; perm 0.4-6.5 x 10^{-6} D
ERDA-9	799.5-826.9 m; lower Salado; perm. 0.7-25 x 10^{-6} D
Cabin Baby	230.7-828.2 m; entire Salado; perm. 0.01-0.1 x 10^{-6} D
DOE-2	669-703.8 m; MB 138, 139; perm. $\leq$0.3 x 10^{-6} D

However, there has been only limited "success" in field testing of the Salado from the surface. There appear to be two causes for this. First, the formation permeability appears in many cases to be below the testable minimum for the equipment used, approximately 0.01 to 0.1 microdarcy. For example, testing of all intervals in holes AEC-8, ERDA-10, and WIPP-12 was unsuccessful due to the low permeability and limitations to the test equipment. The most recent results included in Table 3.2, based on testing in Cabin Baby-1 in 1983 and DOE-2 in 1985, suggest an upper permeability

limit of approximately 0.3 microdarcies. As noted by Mercer (1987), it is not clear that any of the successful tests indicate the permeability of undisturbed halite, since the test intervals almost always include one or more interbeds. Second, in the case of hole WIPP-12, hole "ageing" during the seven years between hole completion and attempted testing of the Salado made it extremely difficult to find locations in the borehole that allowed successful setting of packers to isolate intervals for drillstem testing. The tentative interpretation is that this ageing involves loosening of grain boundaries in halites, with a concomitant increase in local permeability around the borehole.

Flow testing of the Salado Formation within the WIPP facility is still in its early stages. Preliminary results indicate that the presence of the WIPP facility has a strong impact on the hydrologic behavior of nearby portions of the Salado Formation. The results of initial gas-flow testing in the WIPP facility are described by Stormont et al. (1987). Interpretation of this testing indicated that apparent gas permeabilities are very low at distances of greater than approximately 2 m from the underground workings, with no distinguishable stratigraphic variability. Stormont et al. (1987) calculate a "far-field" permeability of less than 1 microdarcy for the Salado.

Stormont et al. (1987) identify a zone of markedly increased permeability within approximately 2 m of the underground workings, on the basis of marked increases in gas flow rates at constant injection pressure. The apparent increases in permeability are especially dramatic near room center lines, in both room roofs and floors. In addition, the magnitude of the local increases in permeability appear to be a function of both time and room width. Stormont et al. (1987) note that their measurements are consistent with time-dependent development of a dilatant or "damaged" zone around the underground workings, and that this zone may well be only partially saturated. Finally, Stormont et al. (1987) indicate that the interpretation of their tests was complicated by uncertainties in the degree of saturation of the Salado, pressure-threshold effects inherent in gas-flow testing in either a partially or fully saturated medium, and local flow inhomogeneities due to fracturing in the disturbed or altered zone near the facility.

Recent brine-flow testing within the WIPP facility described by Peterson et al. (1987) has eliminated some of the problems inherent in gas-flow testing. Peterson et al. (1987) describe the results of long-term (240-day) shut-in brine-flow tests in two holes. One hole penetrated "intact" halite and the other "intact" anhydrite in MB139, both at a distance of 8 to 9 m from the underground workings. Assuming complete saturation within the tested zones, the results indicate far-field permeabilities of approximately 0.001 microdarcy for intact halite, and 0.01 microdarcy for MB139. In addition, apparent steady-state "pore" pressures of 8.3 MPa and 10.3 MPa were measured in the two holes. Peterson et al. (1987) note that there is some uncertainty in both estimated permeabilities and fluid pressures, due to the long test times required.

Gas-flow testing of the same two holes prior to brine-flow testing, at a gas-injection injection pressure of 2.1 MPa, indicated halite and marker-bed permeabilities approximately one order of magnitude greater than

indicated in the later brine-flow testing. These higher permeabilities are similar to those reported by Stormont et al. (1987). Gas-flow testing after brine-flow testing indicated effectively zero permeability. The reasons for this complexity are not clear. It may well be that initial gas-flow testing utilized unsaturated flow paths resulting from near-hole dilatancy, and that these flow paths were later saturated during brine-flow testing.

However, it is not clear that the Salado Formation is completely saturated, even in the far-field. For example, the gas "blows" locally encountered in drilling the Salado from the surface (see Table 3.1) indicate that high-pressure gases occur locally within the unit. Unfortunately, it cannot be determined whether the initial pressures in these occurrences represent regional partial saturation or are a result of exsolution of dissolved gases as a result of stress release around drilled holes. The large gas flow in the Salado in hole AEC-8 occurred approximately one year after initial hole completion. Experience during the development of the WIPP facility also indicates the local occurrence of gas within the Salado at high pressure, perhaps approaching the local lithostatic pressure of 16 MPa. Release of gas concentrated along a fracture nearly parallel to the facility working face resulted in a small blowout during mining operations, as described by Deal and Case (1987). Later drilling in front of the same working face encountered gas at a depth of approximately 3 m. However, because gas occurrences within the WIPP facility have all been near faces being actively mined, it cannot be demonstrated that they were at lithostatic pressure before release. They may result from exsolution of dissolved gases during stress release near the excavation. Other observations by Deal and Case, such as the widespread exsolution of gas from brines collected within the WIPP facility and local bubbling of brine seeps on ribs within the facility, further suggest that gas may play a major role in at least the near-field hydrologic behavior of the Salado Formation.

Thus, the results of recent permeability testing within the Salado Formation, both within the WIPP facility and from the surface, are generally consistent with a far-field permeability of approximately 0.001 to 0.1 microdarcy. It is not certain whether the Salado is saturated or partially saturated regionally; in the altered zone near the WIPP facility, it appears to be partially saturated. There are marked near-field increases in Salado permeability near the WIPP facility, resulting from fracturing and possibly matrix dilatancy. The development of a hydrologically altered zone around workings at the WIPP facility horizon appears to depend on both time and geometry. The ultimate extent of this zone and the rate or extent of its elimination or reduction during the final stages of facility closure remain unknown at present, but will be examined carefully during the early operational phase.

3.3.1.2 Hydrologic Testing Adjacent to the WIPP Air-Intake Shaft--Barring a direct breach of the WIPP as a result of human intrusion, the successful long-term performance of the facility largely depends on the success with which the facility shafts are plugged or sealed. Present planning calls for emplacement of shaft seals in both the Salado Formation and the unnamed

lower member of the Rustler Formation. Therefore, it is important to know the distribution of hydrologic properties within both units adjacent to the WIPP shafts. A preliminary series of hydrologic tests was conducted at several levels in the WIPP waste-handling shaft during 1987. Additional testing and monitoring of the hydrologic characteristics of both the Rustler and Salado Formations adjacent to the WIPP air-intake shaft is planned.

The objectives of the preliminary hydrologic testing adjacent to the WIPP waste-handling shaft, results of which are described in Saulnier and Avis (1988), were to:

1. Determine if a significant fractured or altered zone had developed around the concrete shaft liner in the shaft since its completion.

2. Estimate the radial extent of the hydrologic cone of depression resulting from construction of the waste-handling shaft.

3. Determine "far-field" hydrologic properties for previously untested zones in the lower unnamed member of the Rustler Formation and levels in the Salado Formation at which it is anticipated that plugs might be placed at the end of the WIPP operational phase.

Testing in the waste-handling shaft was carried out in subhorizontal drillholes, using three distinct test zones. The detailed experimental instrumentation is described in Stensrud et al. (1988). Zone 1 extended from the hole "bottom" approximately 7.9 m outside the shaft to a depth of some 5.7 m, Zone 2 from approximately 4.8 m to 3.7 m, and Zone 3 from approximately 2.9 to 1.6 m. There was, however, some variability in both test-zone depths and the relationship between Zone 3 and the shaft liner. No shaft liner was present below the 850-foot level. The shaft liner was thin enough in the lower Rustler for Zone 3 to test entirely within the rock mass. At the 850 level, however, the thickened shaft liner in the keyway dictated that Zone 3 in one hole included the interface between rock and shaft liner. (English depth units are used here for consistency with depth records within the shaft).

The results of the preliminary testing in the waste-handling shaft are summarized in Table 3.3 and Figures 3.7 and 3.8. Tested lithologies include mudstone and claystone in the unnamed lower member of the Rustler (at the 782 and 805-foot depths, respectively) and halites, an anhydrite, and a polyhalite within the Salado Formation (850 and 1320-foot depths). All of the tested intervals are extremely low in permeability. Hydraulic conductivities listed in Table 3.3 range only from 10^{-14} to 10^{-13} m/s. This corresponds to an approximate range in permeability of one order of magnitude, from 0.001 to 0.01 microdarcy. There is no consistent increase in conductivity towards the shaft (from Zone 1 to Zone 3) in any of the rock types tested, except at the 850-ft level. In the 850W hole, pressurized fluids flowed into the borehole at the liner/rock interface. The precise origin of these fluids remains to be determined.

Table 3.3: Summary of results of 1987 hydrologic testing in the WIPP waste-handling shaft. From Saulnier and Avis (1988).

Borehole	Lithology	Test Zone Depth Int. (Feet from Shaft Wall)	Test Period	Pressure Pulse (psi)	Hydraulic Conductivity (m/s)	Formation Pressure (psi)
W782W	Silty Mudstone	1) 18.6-26.0	07/18-22/87	113.3	1.0 E-13	90
		2) 12.3-15.9	07/20-22/87	108.3	1.0 E-14	140
		3) 5.4- 9.5	07/21-22/87	99.4	1.0 E-14	140
W805W	Silty Claystone	1) 18.6-26.0	07/11-15/87	94.5	5.0 E-14	225
		2) 12.3-15.9	07/13-15/87	105.1	1.0 E-14	140
		3) 5.4- 9.5	07/14-15/87	97.8	1.0 E-14	110
W805SW	Silty Claystone	1) 18.6-26.5	08/28-31/87	102.9	6.0 E-15	275
		2) 12.3-15.9	Not Tested		1.0 E-14*	90*
		3) 5.4- 9.5	08/29-31/87	92.6	2.0 E-14	70
W850W	Halite	1) 18.6-26.0	07-30/08-03/87	97.6	1.0 E-13	40
		2) 12.3-15.9	08/2-3/87	116.5	1.0 E-13	40
		3) 5.4-9.5	07-31/08-3/87	90.39	Not Analyzable*	
W850SE	Halite	1) 23.2-36.0	08/19-24/87	103.5	3.0 E-14	50
		2) 16.8-20.5	08/21-24/87	103.1	3.0 E-14	30
		3) 10.0-14.1	08/22-24/87	100.7	2.0 E-14	90
W1320E	Halite/ Anhydrite Polyhalite	1) 18.6-41.8	08/11-17/87	173.3	2.0 E-14	550
		2) 12.3-15.9	08/14-17/87	52.6	3.0 E-14	450
		3) 5.4- 9.5	08/15-17/87	53.0	3.0 E-14	100

*Zone 2 analysis from pressure buildup after shut-in, August 28 to 31, 1987.

Physical limitations to the testing system dictated that Zone 3 not extend any closer than approximately 1.6 m from the inside of the shaft. Therefore, even if the one or two holes tested at each level are representative and adequately characterize the permeability at the tested levels, it can only be argued that the results indicate that no damaged zone presently extends more than 2 m into the rock mass. This includes any damage zone resulting from blasting during construction of the shaft. In addition, because of scheduling constraints, all of the testing was relatively short-term. Longer-term testing might identify changes in hydraulic properties near the shaft.

The permeabilities listed in Table 3.3 indicate no significant stratigraphic variability. All of the tests indicate extremely low permeability, roughly one order of magnitude less than estimated from measurements from the surface. One reason for this may be that the holes tested here were nearly horizontal; as a result, at least part of the fluid flow was vertical, perpendicular to layering. The results may imply that vertical

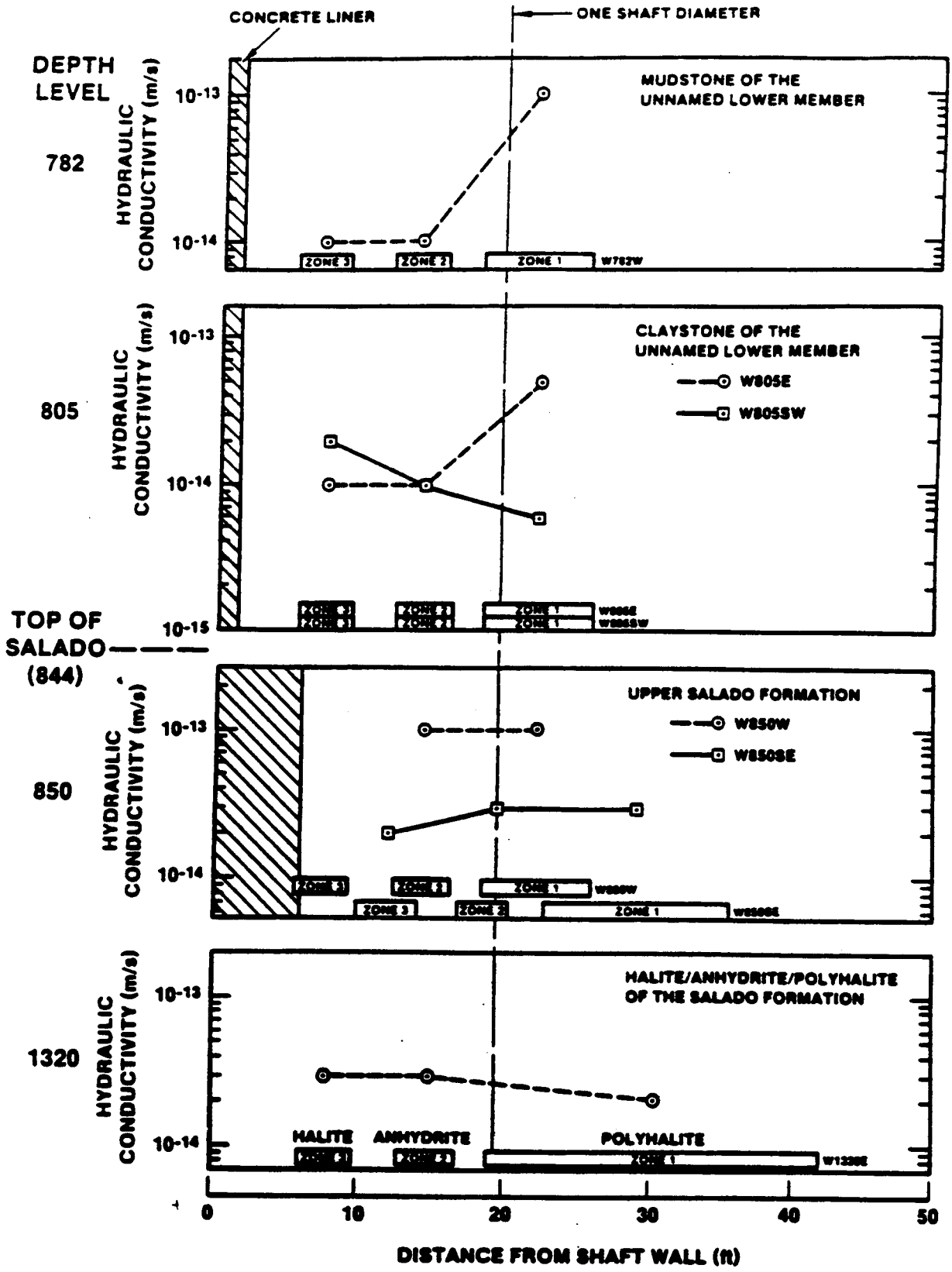


Figure 3.7: Summary of formation conductivities determined in 1987 testing in the WIPP waste-handling shaft. Figure 6.3 of Saulnier and Avis (1988).

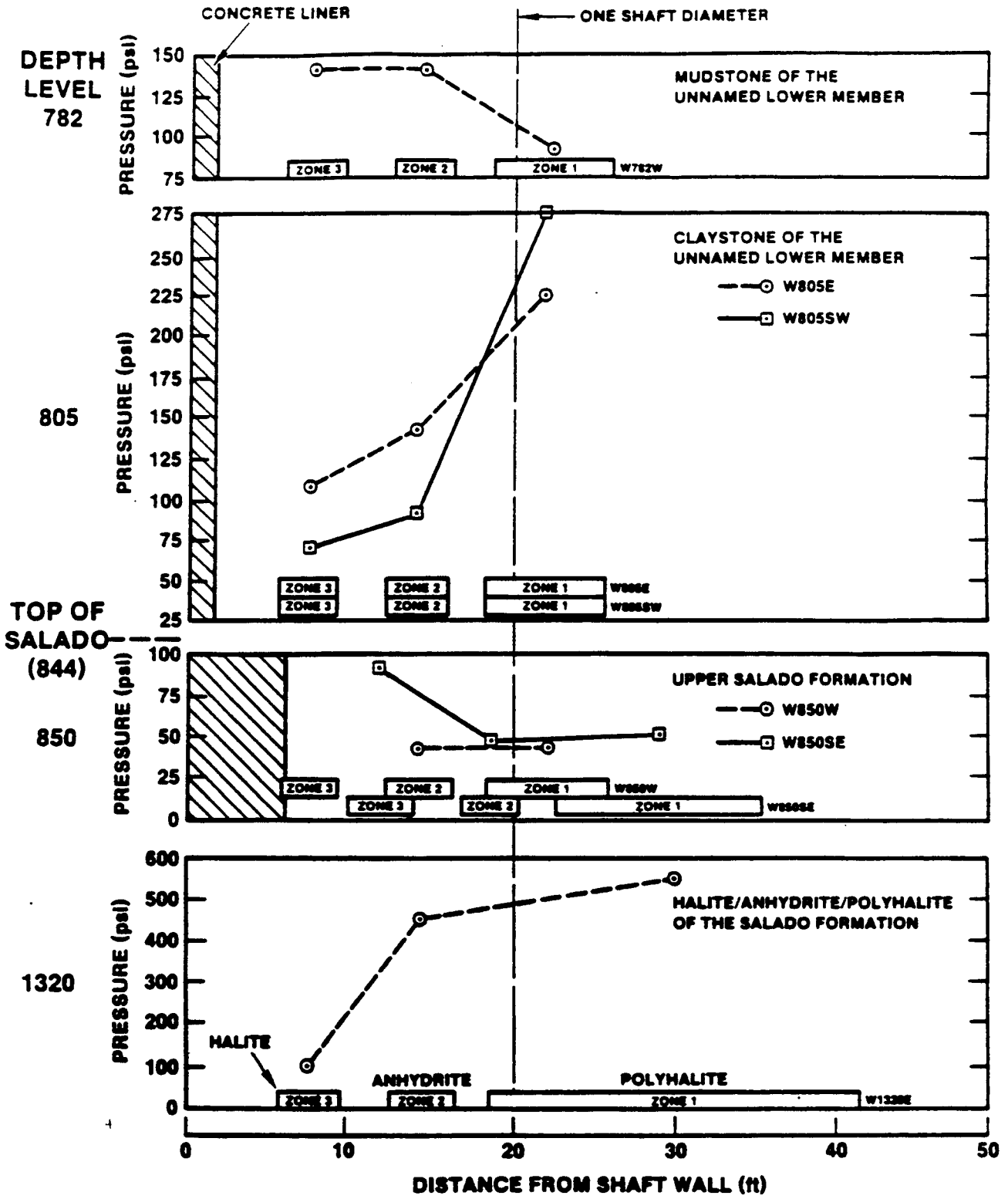


Figure 3.8: Summary of fluid formation pressures determined in 1987 testing in the WIPP waste-handling shaft. Figure 6.1 of Saulnier and Avis (1988).

permeability in both the lower part of the Rustler Formation and the Salado Formation is less than horizontal permeability, consistent with experience in other layered rock types.

Testing adjacent to the waste-handling shaft did indicate a distinct zone of decreased fluid pressures around the shaft at the 805-foot and 1320-foot levels, in claystone and halite/anhydrite/polyhalite, respectively (Figure 3.8). The cone of fluid-pressure depression apparently extends outward to greater than one shaft diameter at these levels. The fluid-pressure profiles at the 782-foot and 850-foot levels may be indeterminate because of effects of equipment compliance (Saulnier and Avis, 1988). The generation of a hydraulic cone of depression around the shaft was expected, consistent with responses noted earlier in the Culebra dolomite to construction of the WIPP exploratory shafts (see Haug et al., 1987). The behavior of this zone outside the Culebra as a function of time remains unknown.

Interpretation or prediction of long-term flow behavior into the shaft would require an observation hole, so that fluid storativities within affected units could be estimated. A nearby observation hole does not exist for the waste-handling shaft. However, hole H-16 was drilled and instrumented in 1987, approximately 17 m from the centerline of the WIPP air-intake shaft, specifically to investigate the near-field hydraulic response of all members of the Rustler Formation to construction of the shaft, and to provide monitoring data adequate for long-term predictions.

The hydrologic testing completed to date adjacent to the waste-handling shaft is preliminary, as is the interpretation of test results. The results to date allow limited fracturing, since only one or two holes was tested at each level. To better determine the presence or absence of fracturing by direct hydrologic measurement, arrays of three or more holes would be needed at each level. The fact that fluids were encountered at the liner/rock interface in one hole at the 850-foot level demonstrates that fluid movement at the shaft-liner/rock interface is possible locally, and that a single drillhole is not sufficient to characterize the source or behavior of these fluids. Non-intrusive geophysical methods similar to those described in Section 3.3.1.3 may aid in characterization of any altered zone around the WIPP shafts.

3.3.1.3 Brine Contents and Brine Seepage into the WIPP Facility--Geophysical studies within the WIPP facility aimed at characterization of the near-field disturbed rock zone are interim, and will continue during the early part of the WIPP operational phase. The presently available results, summarized in Borns and Stormont (1987) and Pfeifer (1987), indicate both that there is near-field variability in the water content and hydrologic properties of the Salado Formation and that water contents of Salado halites in the far-field are approximately twice that estimated at the time of the WIPP SPDV studies.

The results of a series of electrical conductivity measurements within the WIPP underground workings (Pfeifer, 1987) are shown in Figure 3.9. Two

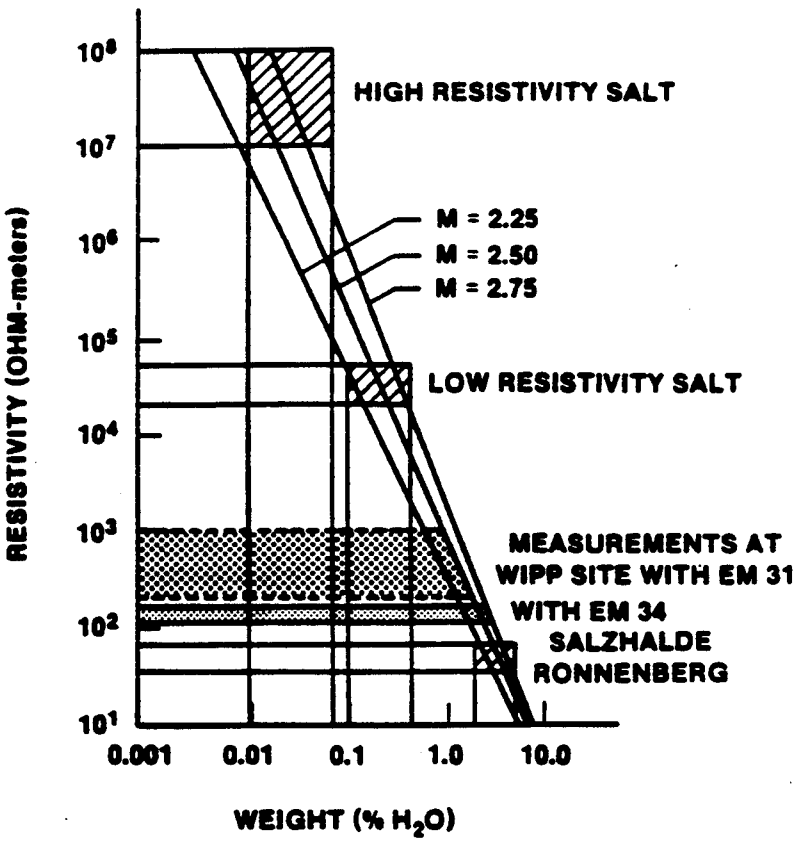


Figure 3.9: Apparent variation in water content of Salado halite at the WIPP facility horizon with depth into the wall. The EM31 survey investigates conductivity up to approximately 2 m depth and the EM34 survey to a depth up to 20 m. Figure 9 of Pfeifer (1987).

different instrumentation systems were used in these measurements. The EM31 system investigates the effective electrical conductivity to a depth of approximately 2 m, the EM34 system to a depth of up to 20 m into the adjacent rock mass. The apparent conductivity near the underground workings, measured with the EM31 system, is lower (resistivity is higher) than that measured at greater depth with the EM34 system. In Figure 3.9 this variation in resistivity is compared with a published correlation between water contents and resistivities of halites. The results are consistent with a water content of approximately 1% (by weight) near the mine opening and 2% or greater in the far field. Recent geophysical moisture and density measurements within the WIPP facility (Hudson, 1987) also are consistent with water contents of approximately 2 weight percent in Salado halite in the far field.

The recent results indicate that far-field water contents within the Salado Formation, estimated to average approximately 2 weight percent, are greater than previously expected. For example, estimated water contents of samples analyzed during SPDV activities ranged from a mean of 0.6 weight percent to a maximum of 1.8 weight percent, compared to mean and maximum values of 0.22 and 1.06 weight percent estimated from measurements on core from hole ERDA-9 (Beauheim et al., 1983a). The earlier estimates were made either on core material or on hand specimens collected during mining.

The combination of significant interconnected fluid contents and non-zero permeabilities within the Salado Formation in both the far-field and near the WIPP facility dictates that there be some fluid flow into the facility until effective hydrologic closure of the facility takes place. Two studies, both in their early stages, investigate the amounts and characteristics of fluid flow into the facility. One study, summarized in Deal and Case (1987), is a long-term study to characterize flow into the WIPP facility (exclusive of shafts) at ambient temperature. The second study, summarized in Nowak and McTigue (1987), is part of an experimental program using electrical heaters to simulate emplacement of defense-generated high-level waste (DHLW). A knowledge of ambient-temperature behavior is required in this study as a baseline for interpretation of later superimposed thermal effects.

Two lines of evidence summarized by Deal and Case (1987) indicate the complexity of ambient-temperature fluid flow into the WIPP facility from the Salado Formation. First, brine "seeps" often form within a few days on mined faces, and are indicated by the development of localized salt crusts or efflorescences on the walls. The seeps often appear to stop flowing after approximately one month. However, investigation of the salt deposits indicates that fluid flow may only decrease rather than ceasing entirely, and that the rate at which mine ventilation removes water locally exceeds the inflow rate at long times. Second, highly variable amounts of both brine and dissolved gas are intersected in drillholes within the WIPP facility. Minimum flow rates are apparently zero. The maximum flow rate was approximately 0.5 liter per day. One hole has produced approximately 235 liters of brine, and produced at a roughly steady-steady rate of 0.2 liters per day (Deal and Case, 1987). However, this hole apparently intersects numerous near-field fractures in MB139 related to the construction of the WIPP facility, and is unusual. Most of the measured

flow rates range from a few hundredths to a few tenths of a liter per day. Deformation near the facility strongly influences fluid flow. Deal and Case (1987) note that fluid flow into most holes within the WIPP facility is initially zero or nearly zero. This phase is normally followed by a relatively rapid rise to some maximum flow rate, after which flow slowly reduces to some relatively steady-state but decreasing value.

Work summarized in Nowak and McTigue (1987) investigates flow into one 0.9-m (36-inch) and three 0.76-m (30-inch) diameter holes emplaced as part of experiments simulating and overtesting emplacement of DHLW. Water was continuously removed from the holes by use of dry nitrogen. A baseline ambient-temperature flow of 5 to 15 grams/day was collected in each hole after an initial transient phase. The average flow of 10 grams per day extrapolates to a steady-state flux of approximately 1.6 $cm^3/day/m^2$ of excavation wall. After the heaters were turned on, there was a rapid increase in flow rate to some peak value, followed by a reduction to near steady-state flow. Apparent steady-state flow rates were 50 to 80 g/day in the two holes containing 1.5 kW heaters, and 8 to 10 g/day in the two holes containing 470 W heaters. The integrated fluid flow into the most strongly heated holes was 36 to 38 kg of fluid after 600 days. This mass is significantly greater than the 0.1 kg collected after two years in similar experiments conducted in domal salts at the Asse Mine, Germany (Nowak and McTigue, 1987). The difference suggests a significant difference between fluid flow in domal salts and in bedded salts, such as those at the WIPP.

Parametric numerical modeling described by Nowak and McTigue (1987) indicates that:

1. Pore-pressure measurements in both the near-field and far-field domains of the Salado Formation are needed to determine far-field and near-field flow behavior, since the observed transient effects resulting from seepage appear at present to be limited to the very near-field domain.

2. The transient stage of flow into the WIPP waste-emplacement rooms will last until connected pore space in both the rooms and any altered zone around the facility is either effectively eliminated or comes to pore-pressure equilibrium with the surrounding Salado. The calculations indicate that transient flow, ignoring closure, might last for more than 5000 years.

3. The rock volume effectively involved in flow within the Salado may be limited, rather than a significant portion of the formation. However, the affected volume must increase with time.

In summary, recent hydrologic results in the Salado Formation indicate that the unit has a far-field permeability of less than 0.1 microdarcy. It has not been possible to determine either stratigraphic effects or the presence of effective fracturing in the far-field environment. The brine content of Salado halites appears to be up to 2 weight percent in the far-field, roughly twice that previously expected. Where it has been possible to measure Salado brine pressures, the calculated heads indicate very limited fluid flow upwards into the overlying Rustler Formation. The permeability

of the Salado locally increases markedly within two meters of excavations at the WIPP facility horizon. The increase in permeability appears to be both time-dependent and geometry-dependent, and to involve significant fracturing. The Salado Formation may be only partially saturated in both the near-field and far-field environments. The low permeability of the Salado Formation, mine ventilation, and rapid mechanical deformation near the WIPP facility result in markedly transient fluid flow into the underground workings. At present, the time-scale of transient flow, volume of the Salado involved in flow, and final fluid volumes to be expected within the WIPP facility remain to be precisely determined.

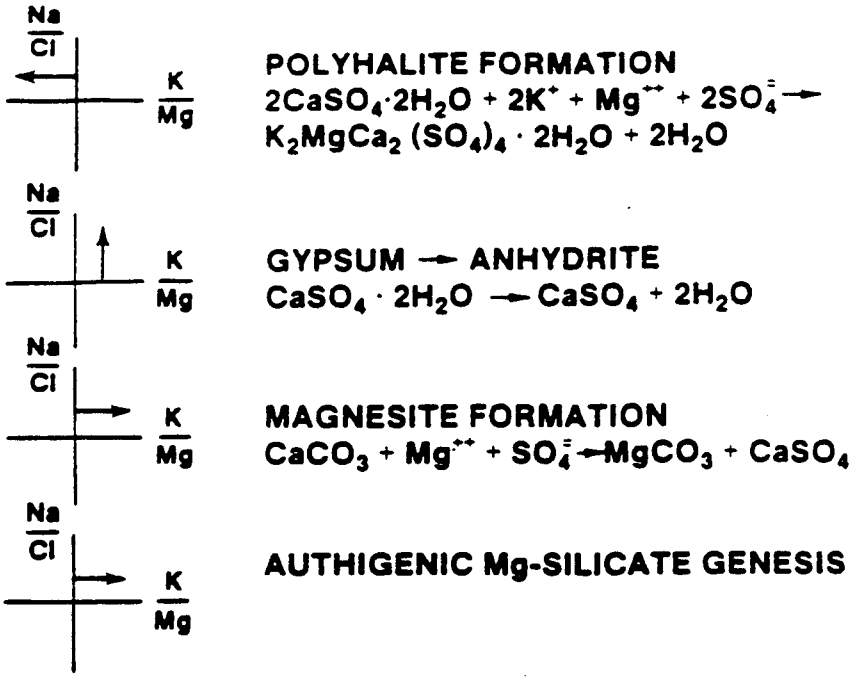
3.3.2 Geochemical and Mineralogical Studies of the Salado Formation Near the Facility Horizon

The mineralogy and stratigraphy of the Salado Formation are somewhat complex. The general mineralogy of the units is summarized by Bodine (1978), and mineralogy near the WIPP facility horizon by Stein (1985). Bodine (1978) noted that Salado clays were unusually depleted in aluminum and enriched in magnesium. The recent work by Stein (1985) does not include detailed clay mineralogy, but does indicate the nearly ubiquitous occurrence of authigenic quartz and magnesite near the WIPP facility horizon, in addition to widespread occurrence of anhydrite, gypsum, and polyhalite as accessory minerals within halites.

As mentioned in Section 3.3.1, it has not been possible to sample Salado fluids during drilling or testing from the surface. However, Salado fluids have been sampled within the WIPP facility, and are continuing to be collected, as described in Deal and Case (1987). The compositional results available to date for Salado fluids collected within the WIPP facility are described in Stein and Krumhansl (1986), and directly address both the character of fluids within the Salado Formation and the validity of assumptions held through 1983 concerning the types of fluids within the unit.

It was assumed through 1983 that Salado halites were anhydrous, with the exception of fluid inclusions and the water of hydration of hydrated minerals such as clays and polyhalites. Both the compositions and ages of fluid inclusions within Salado halites were poorly constrained. The compositional results for Salado fluid inclusions and macroscopic brine occurrences within the WIPP facility, summarized by Stein and Krumhansl (1986), are shown in Figure 3.10. The open and half-open squares in Figure 3.10 represent the compositions of individual fluid inclusions extracted from crystals of halite. The circles and crosses represent the compositions of macroscopic fluids collected from the WIPP facility, respectively from brine "seeps" on the walls and holes in the floor.

The fluid-inclusion compositions and compositions of fluids from seeps and holes form two distinct populations in terms of their respective Na/Cl and K/Mg weight ratios. Therefore, fluids encountered within the WIPP facility cannot primarily arise from the migration of fluid inclusions. Stein and Krumhansl (1986) relate the compositions of fluid-inclusion Groups I (half-open squares in Figure 3.10) and II (open squares) to alteration of brines



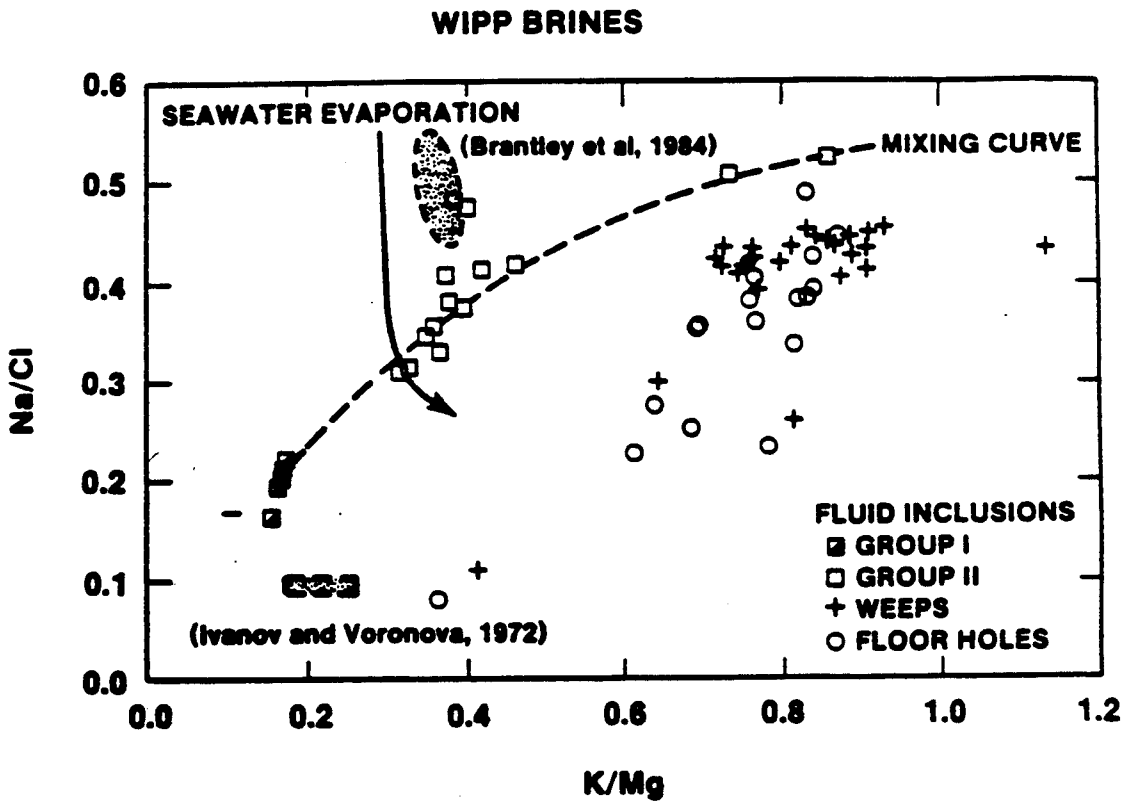


Figure 3.10: Compositional variability of Salado fluids from fluid inclusions and macroscopic brine occurrences in the WIPP facility. Figure 9 of Stein and Krumhansl (1986). Effects of individual reactions on fluid composition are also indicated.

originally resulting from evaporation of seawater. They interpret the controlling mechanisms to be crystallization of polyhalite and magnesite. Polyhalite formation drives fluid compositions to the left of the seawater-evaporation line in K/Mg space (Group I), while formation of magnesite drives fluid compositions to the right (Group II). The compositional effects of these reactions are summarized in the reactions included as part of Figure 3.10.

Both polyhalite and magnesite are widespread accessory minerals within Salado halites (Stein, 1985). Radiometric age dating of polyhalites from the WIPP (Brookins and Lambert, 1987) indicates crystallization ages of from 195 to 216 million years, i.e., from approximately 25 to 45 million years after deposition. The age of magnesite formation is unknown, but is assumed to be similar to that of polyhalite. On this basis, Stein and Krumhansl (1986) conclude that brines contained in fluid inclusions from samples near the WIPP facility horizon are roughly 200 million years old.

The fluids from weeps and seeps in the WIPP facility are enriched in potassium relative to both fluid inclusions and fluids expected from seawater evaporation (Figure 3.10). As discussed by Stein and Krumhansl and noted by Bodine (1978), the Salado clay-mineral assemblage is unusually Mg-rich. Stein and Krumhansl (1986) conclude that the relatively K-rich composition of fluids from weeps and seeps reflects the effects of the growth of these Mg-enriched silicates on grain-boundary fluids. While it is not possible to place a specific age on the grain-boundary fluids, it is known that the kinetics of such reactions are very slow. Therefore, Stein and Krumhansl (1986) conclude that the residence time of grain-boundary fluids within the Salado Formation must be at least several million years. The marked variability of fluids as a function of stratigraphy near the WIPP facility horizon, noted by Stein and Krumhansl, is consistent with there being little or no vertical fluid movement.

There is additional geochemical evidence for both the presence and timing of rock-water interactions involving fluids from the Rustler/Salado contact and deeper evaporite horizons at and near the WIPP. As summarized by Lambert and Harvey (1987), there is a body of consistent radiochronological evidence indicating the absence of any pervasive recrystallization of the evaporite section in approximately the last 200 million years. The internally consistent evidence consists of: a) K-Ar dating of polyhalites ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$); b) Rb/Sr isochrons on sylvites (KCl); and c) both Rb-Sr and K-Ar ages on langbeinite ($K_2Mg_2(SO_4)_3$). Apparent ages on leonite ($K_2Mg(SO_4)_2 \cdot 4H_2O$) are younger than ages on other minerals. Both Rb-Sr and K-Ar ages of clay minerals are significantly greater than the depositional age of the enclosing evaporites, suggesting that secondary reactions involving the clays have not completely altered their compositions. Thus, while the accessory magnesite near the WIPP facility horizon has not been dated, there is abundant radiometric evidence that the last major recrystallization of the Salado Formation occurred approximately 200 million years ago.

Available isotopic evidence for strong rock-water interactions in evaporitic rocks at and below the Rustler/Salado contact is summarized in Figure 3.11. These data and their implications for fluid flow are

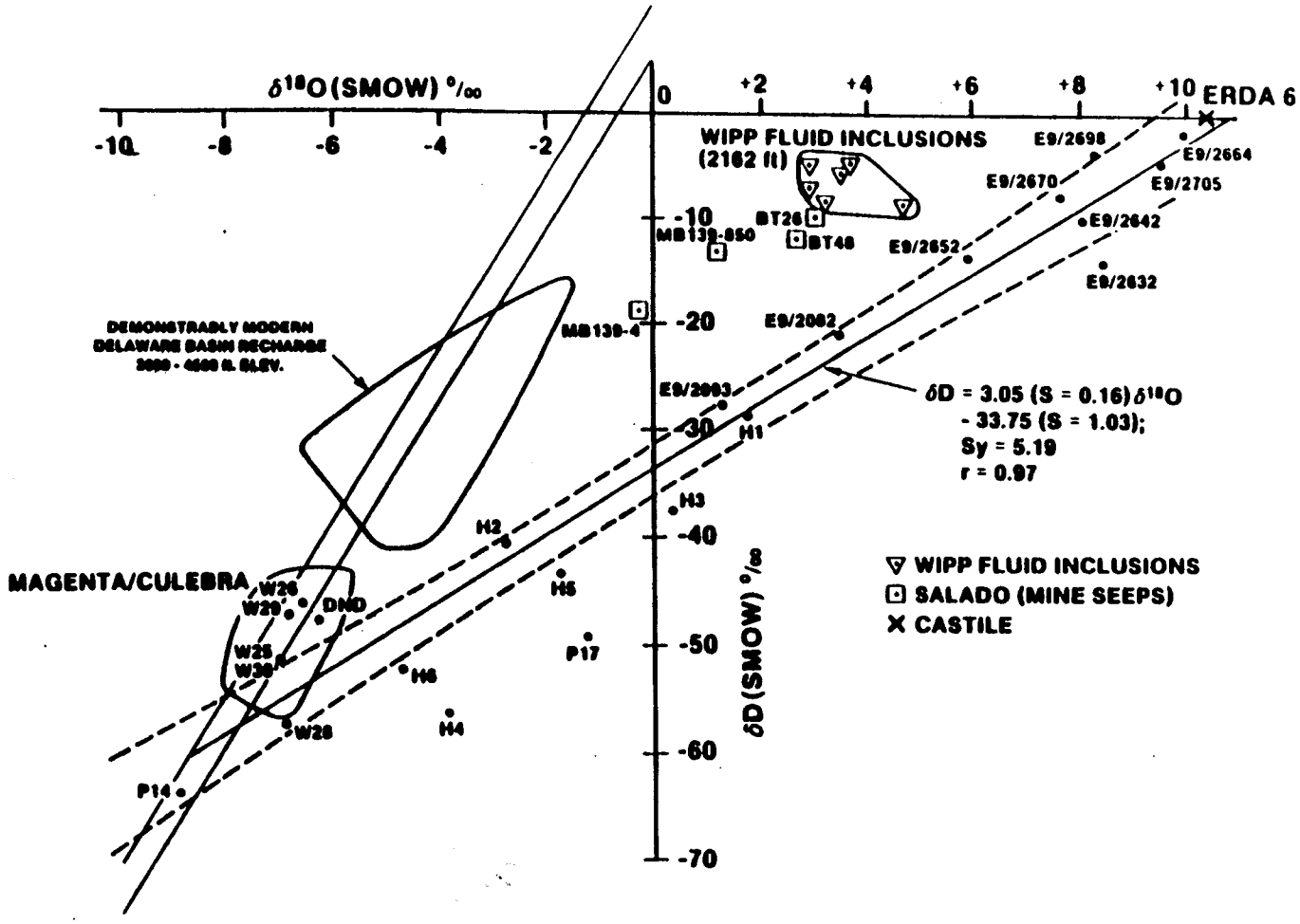


Figure 3.11: Stable-isotope composition of fluids from the Rustler/Salado contact and deeper evaporite zones at the WIPP site. Figure 25 of Lambert and Harvey (1987). Figure includes data from hole ERDA-9 (E9) of O'Neil et al. (1986) and fluid-inclusion data from the WIPP facility horizon (Knauth and Beeunas, 1986), in addition to original data from Lambert and Harvey. Lambert and Harvey data from the Rustler/Salado contact are indicated by hole designations, and those from MB139 by the appropriate prefix. Samples from seeps within the Duval Mine are indicated by the prefix BT (see Lambert and Harvey, 1987, for additional detail).

discussed by Lambert and Harvey (1987) relative to interpretations made by both O'Neil et al. (1986) and Knauth and Beeunas (1986).

O'Neil et al. (1986) consider the linear relationship between the isotopic composition of Castile brines (represented by brines from ERDA-6), fluid inclusions from the lower Salado in hole ERDA-9, and "modern meteoric water" (represented by fluids from Nash Draw and the western part of the WIPP site). They conclude that the trend reflects varying amounts of (vertical) mixing of Castile brines and modern near-surface waters. Lambert and Harvey (1987) conclude that large-scale mixing of fluids should involve major recrystallization of the evaporite section. They conclude, based on the radiometric-dating results discussed above, that such recrystallization has not taken place in the last 200 million years. Since they also concluded that large-scale mixing of fluids within an evaporite section would require recrystallization, the lack of significant recrystallization within the Salado is taken to indicate that there is no significant modern vertical mixing of Castile and surface fluids (Lambert and Harvey, 1987).

Instead, Lambert and Harvey (1987) consider the Castile fluids from ERDA-6, ERDA-9 fluid inclusions, and numerous fluids sampled from the Rustler/Salado contact as a single group (Figure 3.11). They conclude that these fluids form a variable population reflecting a mechanism by which increasing deviation of fluids from the meteoric compositional field results from increasing rock/water ratios, with resulting increasing interaction of fluids with hydrous minerals, especially clays, gypsum, and polyhalite. However, the isotopic character of rock-water reactions involving both gypsum and polyhalite are partially undefined at present.

One group of data shown in Figure 3.11 is not consistent with any single mechanism or trend of rock-water interaction within the Salado Formation. As noted, the trend including data from ERDA-6 brines, ERDA-9 fluid inclusions, and Rustler/Salado fluids appears to be continuous. However, fluids sampled directly in holes penetrating MB139 (samples MB139-850 and MB139-4) and in weeps within the nearby Duval Potash Mine (samples BT26 and BT48) are quite distinct. The isotopic composition of Salado fluid inclusions at the WIPP facility horizon reported by Knauth and Beeaunas (1986) are distinct and different from the character of inclusions from the Salado in ERDA-9. The reasons for the distinctions in fluid-inclusion analyses are not known, but may, as noted by Lambert and Harvey (1987), involve the different fluid-extraction techniques used by the different authors. The reason for the apparently distinct isotopic character of fluids from MB139 is not known at present. The available data indicate only a small isotopic distinction between fluid inclusions and macroscopic fluids collected at the WIPP horizon, in spite of the significant compositional differences between the two types of fluids noted by Stein and Krumhansl (1986).

In summary, the recent geochemical and hydrologic studies of the Salado Formation are generally internally consistent, but are incomplete at the present time. Hydrologic measurements indicate a far-field Salado permeability of less than 0.1 microdarcy. This indicates that, independent of local complications caused by the presence of the WIPP facility itself, fluid flow within the Salado is non-zero but extremely slow. The work by

Stein and Krumhansl indicates that the brine in fluid inclusions within Salado halites is on the order of 200 million years old, and is not the major source of fluid in the WIPP facility. Rather, the variable fluids in the WIPP underground workings appear to be grain-boundary fluids which have residence times within the Salado Formation of at least several million years. The variability in fluid compositions near the WIPP facility horizon is consistent with there being little or no vertical fluid movement. The isotope systematics and radiometric age dating of the Salado brines and minerals, considered together, are not consistent with derivation of Salado brines by modern large-scale vertical mixing of Castile and surficial waters.

3.3.3 Marker Bed 139 and the Structural Behavior of the Salado Formation near the WIPP Facility

Marker Bed 139, an anhydritic marker bed about 1 m in average thickness, occurs approximately 1 m or less below the WIPP facility horizon. Detailed study of MB139 began in 1983, because of concern that undulations on the top of the unit might be the result of deformation at some time after deposition or diagenesis (Jarolimek et al., 1983). If this were true, it is conceivable that such deformation might impact the WIPP facility during either the operational or regulatory time frames. The results of both Jarolimek et al. (1983) and Borns (1985) indicate, however, that the undulations on the upper surface of MB139 are depositional in origin.

Recent interest has focused on the mechanical and hydrologic fluid-flow behavior of MB139 near the WIPP underground workings. Observed behavior in room closure to date, especially in the oldest or "SPDV" rooms, indicates time-dependent opening of fractures in both MB139 and the halitic interval between MB139 and the room floors. It may be necessary to excavate MB139 in some areas before the end of operations, to provide an unaltered locality for emplacement of seals at the facility level. The mineralogy and structure of MB139 also provide information concerning long-term mechanical and fluid behavior within anhydritic portions of the Salado Formation, independent of the WIPP facility. Work examining MB139 and its role in excavation effects near the WIPP facility horizon is progressing; therefore, the discussion here is preliminary.

Borns (1985) investigated the stratigraphy and structure of MB139 in some detail, using core from a five-hole array drilled specifically for this purpose. The general level of internal complexity within MB139 is shown in Figure 3.12. The unit is bounded above and below by irregular contact zones. The lower contact zone (Zone V), often referred to informally as a "clay seam," is clay-rich and locally indicates some erosion and embayment of the top of the underlying polyhalitic halite. The upper contact zone (Zone I) is quite irregular in thickness, and contains structures indicative of shallow water deposition, such as mounds of halite hopper crystals. Borns (1985) concludes that the irregularities on the upper surface of MB139 are primary or depositional in origin, resulting from shallow-water depositional processes such as wave traction. This conclusion is in agreement with conclusions originally reached by Jarolimek et al. (1983).

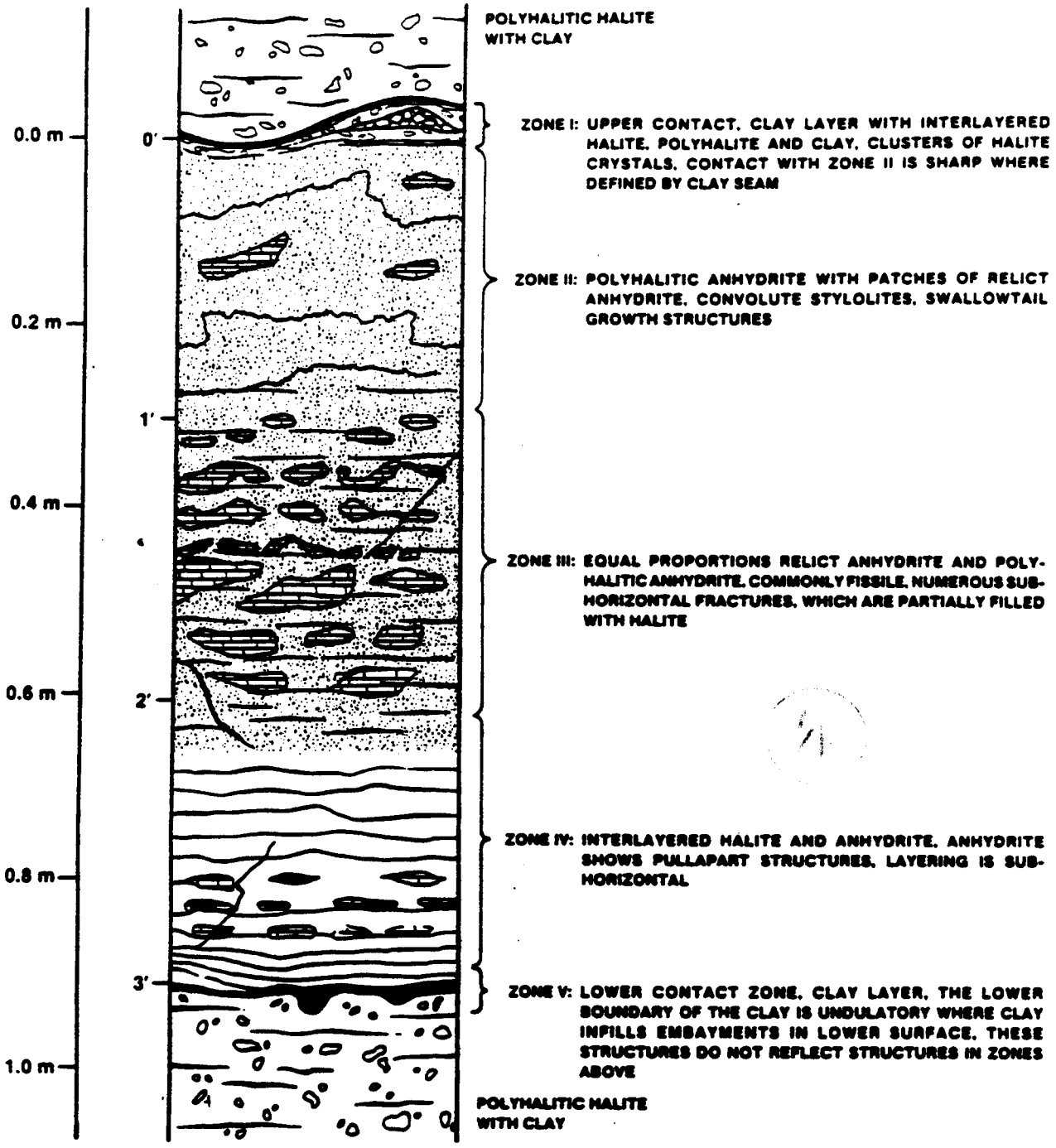


Figure 3.12: Generalized stratigraphic and structural cross section of MB139. The figure demonstrates the internal variability of the unit and the character of both upper and lower contacts. Figure 3 of Borns (1985).

The detailed investigations by Borns also revealed significant internal zonation and variability within the body of MB139. An upper zone within the unit (Zone II) is characterized by extensive replacement of original anhydrite by polyhalite (Figure 3.12), and by the presence of convoluted stylolites. Both features are interpreted to result from fluid movement after deposition. Based on the available radiometric ages on Salado polyhalites (Section 3.3.2), it may be that the formation of polyhalite MB139 occurred as much as 45 million years after deposition. However, polyhalites from within MB139 have not yet been dated. Zone IV, the internal zone directly above the basal contact, contains interlayered halite and anhydrite, with some replacement of anhydrite by later halite, again indicating fluid movement at some time. Anhydritic laminae in this zone show pull-apart structures with horizontal extension.

Within Zone III, the central portion of MB139, replacement of anhydrite by polyhalite is less complete than in Zone II. This zone also contains numerous sub-horizontal fractures, which are partially filled with halite and polyhalite. In some cases, inclined fractures extend from Zone III into or across the overlying Zones I and II. The cores investigated by Borns (1985) were drilled with air; halite was probably not removed from the fractures in Zone III during drilling. On this basis, Borns (1985) concludes that the partially healed subhorizontal fractures in the central part of MB139 predate the construction of the WIPP facility.

The time of formation of the fractures in MB139 is not known in detail. Borns (1985) suggests that they may have formed in response to long-term variations in the overburden pressure at the stratigraphic level of the WIPP facility. Alternatively, as noted by Borns (1985), the fractures may be a response to previous and/or ongoing gravity-driven deformation of the underlying Castile Formation. The horizontal orientation of most of the partially healed fractures favors an origin related to unloading.

An estimate of the variations in overburden pressure at the WIPP facility horizon, extrapolated from estimated variations in overburden at the contact between the Rustler and the Dewey Lake, is shown in Figure 3.13. The overburden pressure at the WIPP facility horizon is estimated to have varied between approximately 16 and 42 MPa since the end of deposition of the Dewey Lake Red Beds. The estimated overburden pressure at the end of the Cretaceous period, 42 MPa, is 2.6 times that at present. Based on stratigraphic interpretations, the reductions in overburden near the ends of the Cretaceous and Tertiary Periods appear to have been relatively sudden. If the interpretations of Borns (1985) are correct, and the sub-horizontal fractures within Zone III of MB139 formed by unloading in response to rapid erosion and removal of overburden, it follows that the formation of the fractures and at least initial movement of the halite-saturated fluids which resulted in their partial healing are probably either early Tertiary or early Pleistocene in age, i.e., that both fracture formation and fluid movement occurred either approximately 60 million or approximately 2 million years ago.

The mineralogical variability of MB139 and the occurrence of partially healed fractures within the central part of the unit have implications for both fluid flow and structural behavior of the unit. The widespread

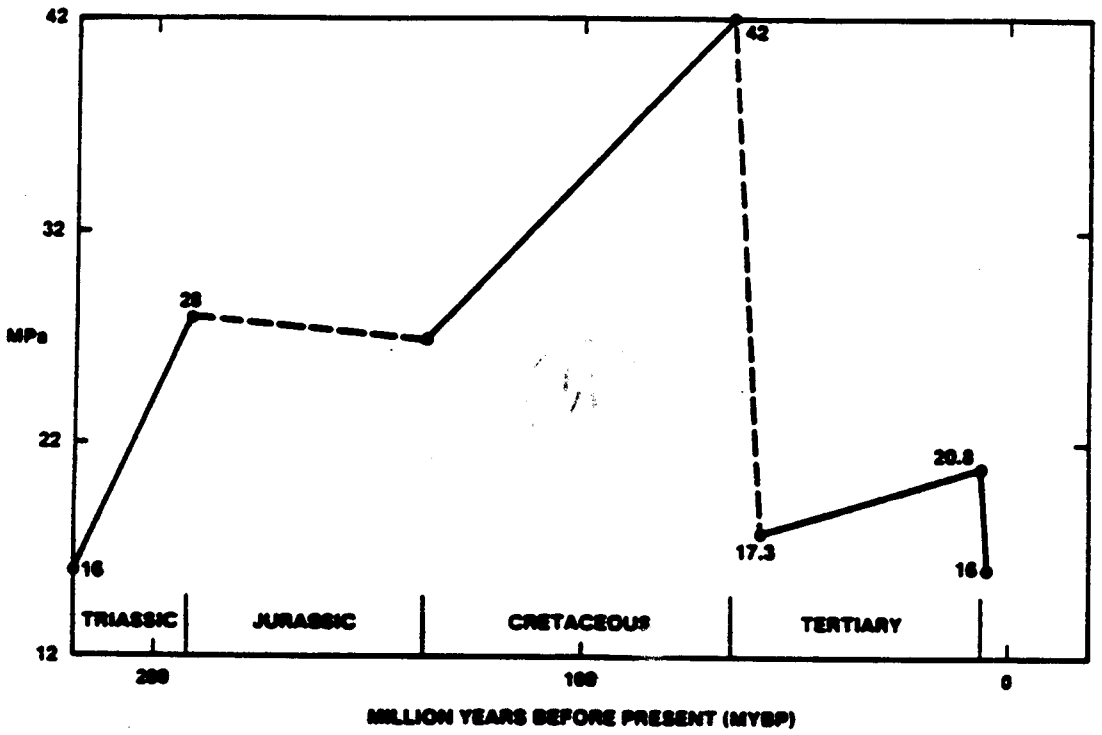


Figure 3.13: Variations in approximate overburden pressure at the WIPP facility horizon as a function of time. Overburden estimates (in MPa, 1 MPa = 145 psi) derived from Figure 10 of Borns (1985) by addition of constant 12 MPa overburden resulting from assumed constant thickness of interval between WIPP facility horizon and Rustler-Dewey Lake contact.

replacement of anhydrite by polyhalite indicates significant fluid movement, possibly some 45 million years after deposition. The replacement of anhydrite and partial healing of fractures by halite may indicate a second period of fluid movement at least 2 million years ago. The available hydrologic information for the Salado Formation at the WIPP site indicates that the far-field permeability within MB139 (and other anhydrite marker beds) is not significantly greater than that of the Salado halites themselves.

Pre-existing fractures within MB139 provide pre-existing planes of weakness that control or influence the near-field mechanical response around the WIPP excavation. Ongoing studies indicate that these fractures open locally in response to excavation. In the near-field altered zone, the resulting permeability is quite high. In the far-field, the permeability of MB139 appears no greater than that of surrounding halites. For confidence in plugging or sealing at the level of the WIPP facility horizon, it must ultimately be demonstrated either that fractures in MB139 will eventually reheal as a result of facility closure, or that damaged portions of the unit have been removed or grouted before seal emplacement. Characterization and delineation of the hydrologically and/or structurally altered zones around the WIPP facility horizon and shafts are ongoing, and will continue into the early operational phase of the facility.

4.0 RUSTLER FORMATION AND YOUNGER UNITS

As noted previously, much effort in WIPP site characterization has been focused on the Culebra Dolomite Member of the Rustler Formation, because this unit is the first laterally continuous water-bearing zone above the WIPP facility. The Culebra has continued to receive attention since 1983. However, work since 1983 has included other members of the Rustler Formation as well as shallower units. Section 4.0 discusses all units above the Salado as a group. Section 4.1 discusses hydrologic testing of the Rustler Formation and Dewey Lake Red Beds, and Section 4.2 discusses both field and numerical studies of the transport properties of the Culebra dolomite. Together, Sections 4.1 and 4.2 constitute a conceptual model of the modern flow and transport behavior within the shallow part of the WIPP stratigraphy, with emphasis on the Culebra dolomite. Section 4.3 discusses geochemical studies addressing both bulk-compositional and isotopic variability within the Rustler Formation and Dewey Lake Red Beds. Section 4.4 discusses studies into the overall geologic behavior of the Rustler and shallower formations at and near the WIPP site. Together, Sections 4.3 and 4.4 summarize available evidence concerning the transient geologic behavior in the region of the WIPP site for units above the Salado Formation.

4.1 Hydrologic Testing of the Rustler Formation and Dewey Lake Red Beds

The Rustler Formation at and near the WIPP site has been hydrologically tested and interpreted at three geometric scales, which are discussed sequentially from the smallest to the largest scale in this section. The smallest-scale of testing is conducted in single holes. Recent single-hole hydrologic testing has provided: 1) local or point transmissivity values for all members of the Rustler Formation except the Tamarisk Member, but with emphasis on the Culebra dolomite; 2) indications of the presence or absence of local hydraulically effective fracturing and wellbore damage within the Culebra; 3) information on relative head potentials within the Rustler; and 4) some indication of the distribution of properties and degree of hydraulic saturation within the Dewey Lake Red Beds. As discussed by Beauheim (1987b), single-hole testing is carried out by means of pumping, drillstem, slug-injection, slug-withdrawal, or pressure-pulse tests, depending on the local permeability or transmissivity. Single-hole testing is interpreted here in terms of transmissivities (in units of m^2/s). Use of this term assumes that the unit being tested is homogeneous across the tested interval. This assumption has been examined directly at hole H-14, in which two separate but overlapping intervals were tested in the Culebra dolomite. The results at H-14 indicate a factor of about 2 in vertical variability in transmissivity within the Culebra within a given hole. Recent single-hole testing of the Rustler Formation and Dewey Lake Red Beds is discussed in Section 4.1.1.

Single-hole tests do not indicate the extent to which either point transmissivity values or fracturing effects can be extrapolated laterally. Hydraulic behavior within the Culebra dolomite is, therefore, also examined at the "hydropad" scale. WIPP hydropads nominally contain three holes, located at the corners of an equilateral triangle 30 m on a side. Hydrologic information at the pad scale is collected by "interference"

testing. During this type of testing, at least two of the three holes on the pad are pumped sequentially in separate tests; the two unpumped holes in each test are used for observation. The objectives of interference hydrologic testing at the pad scale are to collect average or effective hydrologic-property data over distances of some 30 m, and to determine if fracturing effects are significant at this scale.

In the region of the WIPP site, single-pad hydraulic interference tests have been completed at the H-2, H-3, H-4, H-5, H-6, H-7, H-9, and H-11 hydropads. Detailed interpretation including evaluation of the effects of fracturing has been completed only for tests at the H-3 and H-11 hydropads, discussed in Section 4.1.2. Interference testing at the H-3 and H-11 pads has been interpreted using a "dual-porosity" approach, in which the Culebra is assumed to consist of an array of matrix blocks (primary porosity), separated by regularly spaced fractures (secondary porosity).

At some "large" scale, assuming that fracture spacing and properties are not too irregular, the effects of fracturing should become insignificant, i.e., it should become possible to model the flow and/or contaminant-transport behavior of a fractured rock unit such as the Culebra adequately using the porous-medium assumption. The scale at which this simplification is valid, however, may vary significantly with different rock types in different geologic or hydrologic settings. During WIPP site characterization, possible regional hydraulic effects of fracturing have been investigated by "multipad interference testing" of the Culebra dolomite. In this type of testing, one hole is pumped for a relatively long period of time, generally a month or more, while surrounding holes are used to observe hydraulic responses over an area of several square miles. Depending on the distances and extent of fracturing involved, effects due to fracturing may or may not be evident between the pumped hole and some of the observation holes.

Interpretation of multipad interference testing allows estimation of transmissivities and storativities within the tested area, provides information concerning the regional relationship between fluid densities and flow directions, and has allowed investigation of the interaction between WIPP shafts and the Culebra. Two major multipad interference tests, centered at the H-3 hydropad and at hole WIPP-13, have been carried out to date at the WIPP. Additionally, regional hydraulic information has been collected by observing hydrologic responses to WIPP shaft-sinking and shaft-sealing operations. Regional-scale hydrologic interpretation of the Rustler Formation, with emphasis on the Culebra dolomite, is discussed in Section 4.1.3. Interpretation on the regional scale indicates that fracturing need not be incorporated into regional-scale simulation of fluid pressures (head potentials) within the Culebra at and near the WIPP site, because pressure responses are relatively rapid, even on this scale. The assumption of steady state is adequate in modeling the modern Culebra head potentials. However, groundwater flow times are slow enough in the vicinity of the WIPP site to make the assumption of steady-state confined flow within the Culebra inadequate for simulation of long-term flow paths and flow times.

4.1.1 Single-Hole Hydraulic Testing and Interpretation

4.1.1.1 Transmissivity Distribution within Individual Units--Prior to 1985, hydrologic testing at and near the WIPP site was either interpreted using the porous-medium assumption or did not identify significant effects due to fracturing (e.g., Barr et al., 1983). More recently, Beauheim (1986, 1987b) has identified significant fracture effects in hydraulic testing of several holes, using the code INTERPRET. As described in detail by Beauheim (1986, 1987b), INTERPRET utilizes a "pressure-derivative" technique to determine whether or not significant pressure responses due to fracturing are present. In this approach, hydraulically effective fracturing is indicated by a flexure in the plot of dimensionless pressure derivative or drawdown versus dimensionless time (Figure 4.1.1). This flexure reflects a transition from "early" times, in which fluids are effectively produced only from within the fractures, to "late" times, in which fluid is produced from both fractures and matrix, but in which fluid release from the matrix to the fractures is generally the rate-limiting process. The transmissivity interpreted from behavior after this transition is referred to as "system" transmissivity.

At the time of the WIPP FEIS (U.S. Department of Energy, 1980) the suitability of the WIPP site was evaluated largely on the basis of possible releases from the site to Malaga Bend, on the Pecos River approximately 26 km from the WIPP site (Figure 1.1). Requirements for repository performance developed by the Environmental Protection Agency (40CFR191) were released in 1985. Although they may not be in their final form, these requirements place increased emphasis on evaluation of possible releases of radionuclides to the "accessible environment" near the facility. The definition of the accessible environment is not yet final. The WIPP Project has greatly increased the size and reliability of the hydrologic data base for the Rustler Formation since 1985, especially for the Culebra dolomite at and near the WIPP site. Table 4.1 contains the best local estimates of transmissivity used in modeling the hydrology of the Culebra dolomite from 1983 through 1987 and demonstrates the growth in this data base. Table 4.2 summarizes the results of recent single-hole testing in the Culebra dolomite.

Estimated Culebra transmissivities at the WIPP site area and within Nash Draw range over approximately six orders of magnitude, from 2.15 x 10^{-9} m^2/s at P-18 to 1.34 x 10^{-3} m^2/s at WIPP-26 (Tables 4.1 and 4.2). In addition to the growth in the Culebra data base evident in Table 4.1, many of the holes have been retested over the last five years. In some cases recent testing and interpretation have significantly changed earlier estimated transmissivities. However, the more recently estimated Culebra transmissivities are not consistently higher or lower than older values. At H-1 and DOE-2, recent data and interpretation indicate a significantly higher Culebra transmissivity. At H-3 and DOE-1, recent work indicates a lower local transmissivity than estimated earlier. In cases such as P-15, P-17, H-4, and WIPP-30, retesting and/or reinterpretation of earlier results has not resulted in any significant change in estimated Culebra transmissivity. In all cases, however, the more recent data and interpretations are better documented than older work, as a result of the

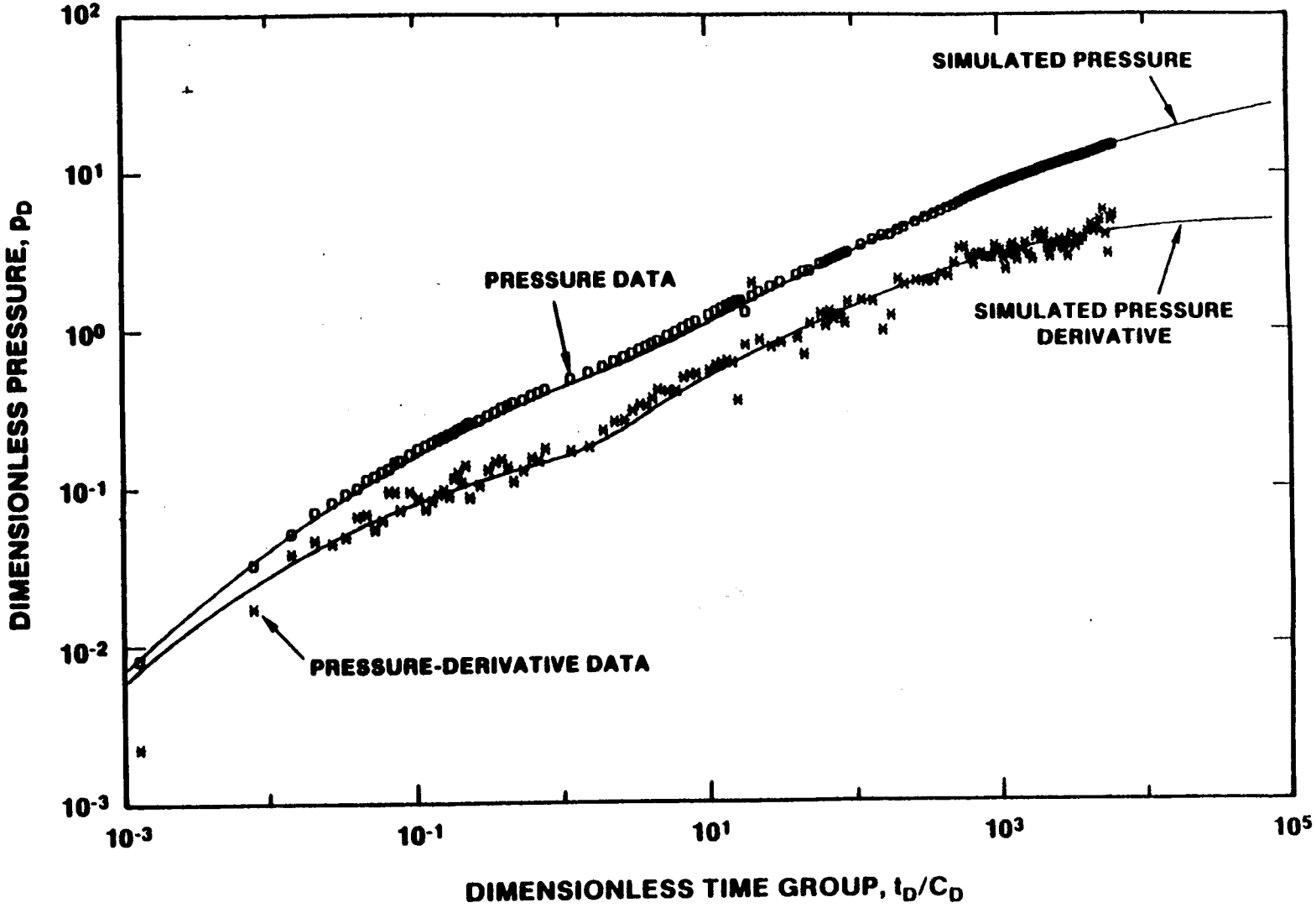


Figure 4.1.1: Measured and simulated response of H-3b1 to pumping of hole H-3b2. The presence of dual-porosity effects due to fracturing is indicated by the inflection in both measured and simulated pressure-derivative curves, in this case at a value of the dimensionless time group of approximately one. Simplified from Figure 6-11 of Beauheim (1987a).

Table 4.1: Transmissivity data bases used in numerical modeling of the Culebra dolomite in Barr et al. (1983), Haug et al. (1987), and LaVenue et al. (1988).

Well	Barr et al. (1983) Transmissivity (ft^2/day)	Haug et al. (1987) Transmissivity (ft^2/day)	LaVenue et al. (1988) Transmissivity (ft^2/day)	Transmissivity (m^2/sec)
H-1	0.07	0.07	0.8	8.60×10^{-7}
H-2	0.4	0.56	0.52	5.59×10^{-7}
H-3	19	3.7	2.3	2.47×10^{-6}
H-4	0.9	1.1	0.95	1.02×10^{-6}
H-5	0.2	0.16	0.14	1.51×10^{-7}
H-6	73	74	74	7.96×19^{-5}
H-7	>1000	1120	1030	1.11×10^{-3}
H-8	16	6.7	8.2	8.82×10^{-6}
H-9	230	170	160	1.72×10^{-4}
H-10	0.07	0.07	0.07	7.53×10^{-8}
H-11	--	10	26	2.80×10^{-5}
H-12	--	0.04	0.18	1.94×10^{-7}
H-14	--	--	0.31	3.33×10^{-7}
H-15	--	--	0.12	1.29×10^{-7}
H-16	--	--	0.7	7.53×10^{-7}
H-17	--	--	0.2	2.15×10^{-7}
H-18	--	--		
WIPP-12	--	--	0.03	3.23×10^{-8}
WIPP-13	--	--	69	7.42×10^{-5}
WIPP-18	--	--	0.3	3.23×10^{-7}
WIPP-19	--	--	0.6	6.45×10^{-7}
WIPP-21	--	--	0.25	2.69×10^{-7}
WIPP-22	--	--	0.37	3.98×10^{-7}
WIPP-25	270	270	270	2.90×10^{-4}
WIPP-26	1250	1250	1250	1.34×10^{-3}
WIPP-27	650	650	650	6.99×10^{-4}
WIPP-28	18	18	18	1.94×10^{-5}
WIPP-29	1000	1000	1000	1.08×10^{-3}
WIPP-30	0.3	0.3	0.3	3.22×10^{-7}
P-14	140	233	214	2.30×10^{-4}
P-15	0.07	0.08	0.09	9.68×10^{-8}
P-17	1	1.7	1.3	1.40×10^{-6}
P-18	0.001	0.002	0.002	2.15×10^{-9}
DOE-1	--	33	11	1.18×10^{-6}
DOE-2	--	36	89	9.57×10^{-6}
ERDA-9	--	--	0.47	5.06×10^{-7}
CABIN BABY	--	--	0.28	3.01×10^{-7}
ENGLE	--	--	43	4.62×10^{-5}
USGS-1	515	515	515	5.54×10^{-4}
	21 Values	25 Values	38 Values	38 Values

Table 4.2: Detailed summary of recent single-well test results in the Culebra dolomite. Slightly modified from Table 5-3 of Beauheim (1987b).

Well	Culebra Interval m (ft)	Interval Tested m (ft)*	Test Type	Transmissivity (ft^2/day)	Transmissivity (m^2/s)	Skin Factor
H-1	206-213.1 (676-699)	205.7-214.3 675-703)	slug #1	1.0	1.1×10^{-6}	--
			slug #2	0.83	8.9×10^{-7}	--
			slug #3	0.83	8.9×10^{-7}	--
			slug #4	0.83	8.9×10^{-7}	--
H-4c	149.4-157.3 (490-516)	150.6-158.5 (494-520)	slug	0.65	7.0×10^{-7}	--
H-8b	179.2-187.1 (588-614)	175.0-190.2 (574-624)	pumping	8.2	8.8×10^{-6}	-7.2
H-12	250.9-259.1 (823-850)	249.9-271.3 (820-890)	slug #1	0.18	1.9×10^{-7}	--
			slug #2	0.18	1.9×10^{-7}	--
H-14	166.1-174.3 (545-572)	162.5-167.9 (533-550.7)	DST/FBU	0.096	1.0×10^{-7}	-0.8
			DST/SFL	0.10	1.1×10^{-7}	--
			DST/SBU	0.10	1.1×10^{-7}	-1.3
H-14	166.1-174.3 (545-572)	162.5-175.0 (533-574)	DST/FBU	0.30	3.2×10^{-7}	-1.1
			DST/SBU	0.31	3.3×10^{-7}	-1.8
			slug	0.30	3.2×10^{-7}	--
H-15	262-4-269.1 (861-883)	260.0-271.3 (853-890)	DST/FBU	0.15	1.6×10^{-7}	2.6
			DST/SBU	0.15	1.6×10^{-7}	2.9
			slug	0.10	1.1×10^{-7}	--
H-16	213.4-221.0 (700-725)	212.4-223.7 (697-734)	DST/FBU	0.85	9.1×10^{-7}	0.0
			DST/SBU	0.85	9.1×10^{-7}	-0.3
			slug	0.69	7.4×10^{-7}	--
H-17	215.2-222.8 (706-731)	214.3-224.0 (703-735)	DST/FBU	0.21	2.3×10^{-7}	-1.5
			DST/SBU	0.22	2.4×10^{-7}	-1.2
			slug	0.22	2.4×10^{-7}	--

Table 4.2: Detailed summary of recent single-well test results in the Culebra dolomite. Slightly modified from Table 5-3 of Beauheim (1987b). (Continued)

Well	Culebra Interval m (ft)	Interval Tested m (ft)*	Test Type	Transmissivity (ft^2/day)	Transmissivity (m^2/s)	Skin Factor
H-18	210.3-217.3 (690-713)	208.8-217.6 (685-714)	DST/FBU	2.2	2.4×10^{-6}	-0.2
			DST/SBU	2.2	2.4×10^{-6}	-1.0
			slug	1.7	1.8×10^{-6}	--
WIPP-12	246.9-254.5 (810-835)	248.4-256.0 (815-840)	slug #1	0.10	1.1×10^{-7}	--
			slug #2	0.097	1.0×10^{-7}	--
WIPP-18	239.9-246-3 (787-808)	239.0-245-7 (784-806)	slug	0.30	3.2×10^{-7}	--
WIPP-19	230.4-237.4 (756-779)	229.8-237.7 (754-780)	slug	0.60	6.5×10^{-7}	--
WIPP-21	222.2-229.5 (729-753)	221.6-228.9 (727-751)	slug	0.25	2.7×10^{-7}	--
WIPP-22	226.2-232.9 (742-764)	228.0-234.7 (748-770)	slug	0.37	4.0×10^{-7}	--
WIPP-30	192.3-199.0 (631-653)	191.7-199.6 (629-655)	slug #1	0.18	1.9×10^{-7}	--
			slug #2	0.17	1.8×10^{-7}	--
P-15	125.9-132.6 (413-435)	125.0-133.5 (410-438)	slug #1	0.090	9.7×10^{-8}	--
			slug #2	0.092	9.9×10^{-8}	--
P-17	170.1-177.7 (558-583)	170.1-178.6 (558-586)	slug #1	1.0	1.1×10^{-6}	--
			slug #2	1.0	1.1×10^{-6}	--
P-18	277.1-285.9 (909-938)	277.1-286.5 (909-940)	slug	4×10^{-3}/7 x 10^{-5}		--
ERDA-9	214.6-221.6 (704-727)	214.9-221.9 (705-728)	slug #1	0.45	4.8×10^{-7}	--
			slug #2	0.47	5.1×10^{-7}	--

Table 4.2: Detailed summary of recent single-well test results in the Culebra dolomite. Slightly modified from Table 5-3 of Beauheim (1987b). (Concluded)

Well	Culebra Interval m (ft)	Interval Tested m (ft)*	Test Type	Transmissivity (ft^2/day)	Transmissivity (m^2/s)	Skin Factor
Cabin baby-1	153.3-161.2 (503-529)	153.3-161.2 (503-529)	slug #1	0.28	3.0×10^{-7}	--
			slug #2	0.28	3.0×10^{-7}	--
DOE-1	250.2-256.9 (821-843)	249.9-256.9 (820-843)	pumping/ drawndown	28	3.0×10^{-5}	-5.1
			recovery	11	1.2×10^{-5}	-6.0
Engle	200.9-207.6 (659-681)	197.5-208.2 (648-683)	pumping	43	4.6×10^{-5}	4.2

*Actual intervals open to the wells.

increase in documentation requirements over the ten-year span of WIPP site characterization. The interpreted test data from recent single-hole testing at and near the WIPP site are included in Beauheim (1987b). Raw data, test histories, and test instrumentation for all hydrologic testing at the WIPP for approximately the last five years are contained in a series of six hydrologic data reports: Hydro Geo Chem (1985); INTERA and Hydro Geo Chem (1985); INTERA (1986); Saulnier et al. (1987); Stensrud et al. (1987); and Stensrud et al. (1988).

Transmissivities listed in Tables 4.1 and 4.2 are not identical in all cases. Transmissivity estimates included in Table 4.1 from three-hole hydropads, such as the H-4 pad, are effective transmissivities. In single-hole tests, this is the same as the measured value. In the case of three-hole hydropads, however, the effective transmissivity is the square root of the product of the estimated maximum and minimum transmissivities on the pad. The calculated effective transmissivity, which is used in regional-scale modeling (Section 4.1.3), generally does not correspond directly to any of the measured single-hole values on the same pad.

As mentioned above, Culebra transmissivities at and near the WIPP site and within Nash Draw range over approximately six orders of magnitude, from more than 10^{-3} m^2/s to less than 10^{-8} m^2/s. However, this variability is not random. A large area of low transmissivities (less than approximately 10^{-6} m^2/s) is present near the center of the WIPP site, extending to the east, southeast, and southwest (Figure 4.1.2). This zone includes holes WIPP-12, 18, 19, 21, and 22; H-1, 2, 4, 5, 10, 12, 14, 15, 16, and 17;

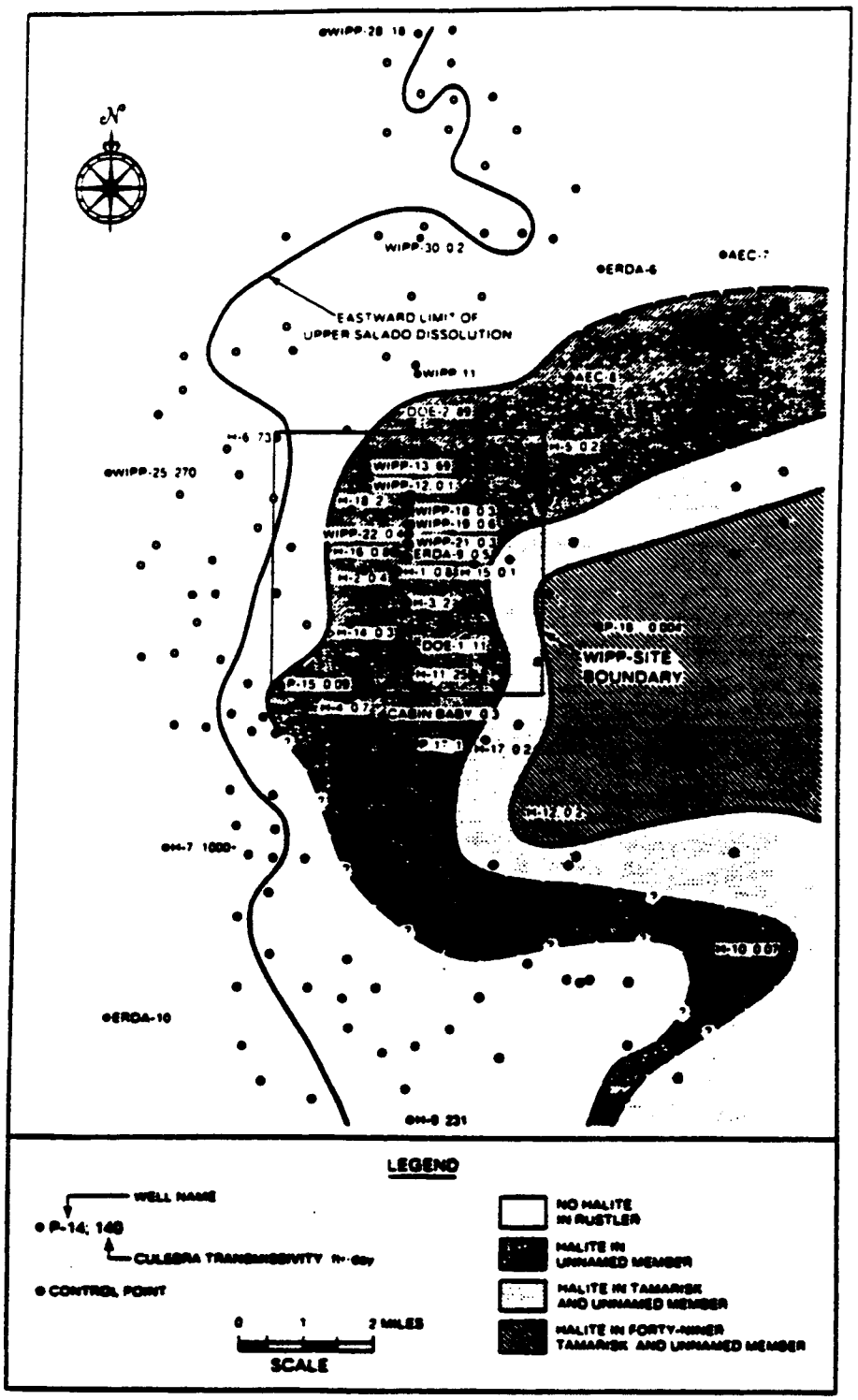


Figure 4.1.2: **Transmissivity of the Culebra dolomite in relation to the distribution of halite within the Rustler Formation. Figure 6-2 of Beauheim (1987b). Halite distribution modified from Snyder (1985). Transmissivities in this figure are given in units of ft^2/day. Multiply by 1.075×10^{-6} to get transmissivities listed in Table 4.1 in m^2/s.**

P-15, 17, and 18; ERDA-9, and Cabin Baby-1 (see also Figure 1.2). Within this low-transmissivity region, relatively high Culebra transmissivities (greater than approximately 10^{-5} m^2/s) have been measured southeast of the site center, in holes DOE-1 and H-11. The transmissivity measured on the H-3 pad (2.0×10^{-6} m^2/s) is transitional between transmissivities at H-11 and DOE-1 and those in the low-transmissivity domain north and southwest of H-3.

A continuous zone of variable but high Culebra transmissivity appears to be present northwest, west, and south of the site center. This zone includes holes H-6, 7, and 9; WIPP-13, 25, 26, 27, 28, and 29; DOE-2 and P-14; and the Engle well (see Figures 1.1 and 1.2). The Culebra transmissivity in hole H-18 (1.8×10^{-6} to 2.4×10^{-6} m^2/s) is transitional between those in adjacent higher-transmissivity and lower-transmissivity domains.

There are some limitations in the Culebra data base, in spite of the fact that Culebra transmissivities have now been estimated at 39 separate localities at and near the WIPP site and within Nash Draw. For example, although the low-transmissivity zone near the site center is interpreted here to be continuous to the southwest, there is no direct measurement of Culebra transmissivity in the interval between holes H-14 and H-2. At present there is also no direct field evidence of connection between the region containing holes DOE-1 and H-11 and the region to the south containing hole H-9. Quantitative integration of point data into a regional transmissivity pattern for the Culebra and evaluation of some of the uncertainties mentioned here are discussed in Section 4.1.3.

Single-hole Culebra tests in which the system transmissivity is less than 10^{-6} m^2/s generally do not show signs of fracturing, while holes with higher transmissivity do. To a first approximation, fracturing within the Culebra (and the Rustler as a whole) appears to be related to the removal of halite. As discussed by Mercer (1983), Snyder (1985), and Beauheim (1987b), there is a general correlation between the distribution of halite within the Rustler Formation (Figures 1.5 and 4.1.2) and transmissivity of Rustler members, especially the Culebra dolomite. The distribution of halite within the Rustler Formation is briefly discussed in Section 4.4.2.

However, the correlation between halite distribution and Culebra transmissivity is neither unique nor completely reliable. With the exception of WIPP-30 and possibly H-10, the Culebra in holes in which there is no halite in the unnamed lower member of the Rustler are highly transmissive. In WIPP-30, there is no halite within the Rustler, and the Culebra transmissivity is quite low. Without exception, the Culebra transmissivity is low if Rustler halite is present above the Culebra. Where there is Rustler halite present only beneath the Culebra, the correlation is not completely reliable, perhaps because of complications involving the response of the Culebra to evaporite dissolution in the upper part of the Salado Formation. For example, holes DOE-2 and WIPP-13, in the western part of the region in which halite is present beneath the Culebra (Figure 4.1.2), are highly transmissive, but hole H-18 is not. In the southeastern part of the WIPP site, holes P-17 and H-3 are relatively low in transmissivity, but the transmissivity at H-11 and DOE-1 is greater than 10^{-5} m^2/s. As discussed by Beauheim (1987b), examination of the detailed

Rustler isopachs summarized in Snyder (1985) does not indicate any consistent reason for the high transmissivities at H-11 and DOE-1.

The significance of the distinction between dual-porosity (fractured) and porous-medium behavior in single-hole hydraulic testing is not completely straightforward. The apparent absence of fracturing in a test does not indicate a total absence of fractures, nor does fracturing in single-hole hydraulic testing indicate that far-field or long-term hydraulic or transport behavior near a given hole is or would be dominated by fracture effects. At one extreme, very local fracturing in a very low-transmissivity test interval may play a role in the very early pressure responses, but may not be evident because of wellbore-storage and fluid-flow surge effects at the beginning of a test. Any low-transmissivity hole listed in Tables 4.1 and 4.2 may contain fractures which are not apparent because of the testing techniques and instrumentation used. However, the effects of these fractures should be extremely localized. At the other extreme, intense fracturing may lead to high transmissivity, but result in such small block sizes that fluid flow from the matrix blocks is "immediately" the rate-limiting step. Dual-porosity effects would not be evident during testing at such a site, and the tested interval would behave hydraulically as an equivalent porous medium. This type of behavior may be applicable, for example, in the highly-transmissive portions of the Culebra within Nash Draw; however, testing results in Nash Draw have not yet been investigated using INTERPRET. The hydraulic behavior of the highly-transmissive Culebra in the Engle well (4.6×10^{-5} m^2/s) does not show dual-porosity effects. However, this behavior is tentatively attributed by Beauheim (1987b) to wellbore and near-wellbore conditions, rather than to extreme fracturing of the test interval.

In addition, the fact that testing at a given hole does not indicate local fracturing does not guarantee that there is not fracturing nearby. Single-hole testing at WIPP-21 indicates a Culebra transmissivity of 2.7×10^{-7} m^2/s, with no dual-porosity effects. This hole responded strongly and rapidly to both the H-3 multipad interference test and activities in both the waste-handling and exhaust shafts. This behavior probably reflects the presence of a "low-storativity" structure, which could be a single fracture or fracture zone connecting the region near WIPP-21 with the two WIPP shafts, but not intersecting WIPP-21 itself.

Single-hole testing may also be strongly affected by drilling-induced near-well effects, which can make the test hole appear either more or less transmissive than the surrounding rock mass. As discussed by Beauheim (1986, 1987b), marked examples of such "skin" effects were found in testing in holes DOE-2 and WIPP-13. In the extreme example of hole DOE-2, the initial estimate of minimum transmissivity was 2.4×10^{-5} m^2/s. The calculated "skin factor" was +31 (Beauheim, 1986). For comparison, a hole so badly damaged that it would not produce fluid at all would have a skin factor of plus infinity. At the WIPP, positive skin factors have, in some cases, been reduced by acid treatment. Treatment of hole DOE-2 with hydrochloric acid removed the near-hole damage effects, and increased the interpreted transmissivity by a factor of 4, from 2.4×10^{-5} m^2/s, to 9.6×10^{-5} m^2/s (Table 4.1). The calculated skin factor at DOE-2 decreased from +31 to -4.7. A skin factor of less than zero indicates good connection of

the physical wellbore with fractures within the rock mass and results in an apparent well radius greater than that of the physical diameter of the hole. The Culebra in several holes listed in Table 4.2 exhibits negative skin factors, indicating good connection of the test hole with the surrounding rock mass.

As mentioned above, the presentation of data in terms of transmissivity explicitly assumes that the tested interval is vertically homogeneous. Data included in Table 4.2 indicate that Culebra transmissivity at H-14 varies with vertical position within the unit. While drilling this hole, it was possible to find a packer seat within the Culebra. Testing of the upper Culebra was then followed by testing of the entire unit. The calculated transmissivity of the upper 1.7 m of the Culebra is 1.1×10^{-7} m^2/s, while that of the entire 8.2 m thickness of the unit is 3.3×10^{-7} m^2/s. This indicates that the transmissivity of the lower 6.5 m of the Culebra in hole H-14 is approximately 2.2×10^{-7} m^2/s. The results at H-14 indicate that the Culebra cannot be assumed to be vertically homogeneous, since the transmissivity of individual zones within the unit vary by a factor of about 2. The results at H-14 are in qualitative agreement with the variability indicated by results of tracer-injection tests at holes H-1, H-2c, H-3, and P-14 (Mercer and Orr, 1979).

Because the Culebra dolomite is generally more permeable than the Magenta dolomite at and near the WIPP site, less testing of the Magenta has been completed at the WIPP. Older transmissivity data for the Magenta dolomite are contained in Mercer (1983) and Gonzalez (1983a). The results of recent testing of the Magenta dolomite in H-14, H-16, and DOE-2 are included in Table 4.3. Overall, reported Magenta transmissivities range from approximately 5.9×10^{-9} m^2/s in hole H-14 to 4.0×10^{-4} m^2/s in WIPP-25. Magenta transmissivities greater than approximately 10^{-6} m^2/s are known only in and near Nash Draw and the small valley south of the WIPP site (Figure 1.2).

As mentioned in Section 1.0, modeling of Rustler hydrology through 1983 assumed that the Culebra and Magenta dolomites were completely confined. This is equivalent to assuming that the unnamed lower, Tamarisk, and Forty-niner members of the Rustler have zero permeability. Indeed, standard hydrologic testing techniques are inapplicable to these units at the WIPP site because of their low permeabilities. Recent advances in testing, data-collection, and interpretation techniques have allowed meaningful examination of these units at three locations: DOE-2, H-14, and H-16 (Table 4.3). Even in the recent testing, however, it has only been possible to test the transmissivities of claystones and siltstones within the non-carbonate members of the Rustler. The claystones and siltstones in the Tamarisk and Forty-niner Members occur near the center of each unit, and are separated from the Magenta or Culebra by a zone of anhydrite/gypsum (Table 1.2). The anhydrites within the Rustler still cannot be tested from the surface, since their in situ transmissivities are less than approximately 10^{-11} m^2/s (Beauheim, 1986; 1987b). In addition, it still has not been possible to measure the transmissivity of the Tamarisk claystone, due to its low transmissivity.

Table 4.3: Summary of available transmissivity information for members of the Rustler Formation in holes H-14, H-16, and DOE-2. Slightly modified from data contained in Tables 5-2 and 5-3 of Beauheim (1987b) and Table 7-2 of Beauheim (1986).

	Zone depth (m)	Test interval (m)	Transmissivity (m^2/s)
H-14			
Forty-niner "claystone"	118.9 - 123.4	116.1 - 124.7	3.2×10^{-8} - 7.6×10^{-8}
Magenta	129.2 - 136.6	128.0 -136.6	5.7×10^{-9} - 6.0×10^{-9}
Culebra	166.1 - 174.3	162.5 - 175.0	3.2×10^{-7} - 3.3×10^{-7}
H-16			
Forty-niner "claystone"	171.6 - 175.0	170.7 - 177.1	2.4×10^{-10} - 6.0×10^{-9}
Magenta	179.8 - 187.8	179.5 - 189.3	2.6×10^{-8} - 3.0×10^{-8}
Culebra	213.4 - 221.0	212.4 - 223.7	7.4×10^{-7} - 9.1×10^{-7}
Unnamed member siltstone	237.1 - 256.6	225.2 - 259.4	2.4×10^{-10} - 2.9×10^{-10}
DOE-2			
Forty-niner "claystone"	204.2 - 207.5	202.4 - 209.1	2.7×10^{-9} - 1.2×10^{-8}
Magenta	213.1 - 220.1	213.4 - 220.1	1.1×10^{-9}
Culebra	251.2 - 257.9	251.2 - 257.9	9.6×10^{-5}

The transmissivity of the Magenta at H-14, H-16, and DOE-2 is 1.1×10^{-9} to 3.0×10^{-8} m^2/s (Table 4.3). The transmissivity of the claystone in the overlying Forty-niner in the same holes is comparable, 5.6×10^{-9} to 1.2×10^{-8} m^2/s. The siltstone within the unnamed lower member of the Rustler has been successfully tested only in hole H-16, in which it has an estimated transmissivity of between 2.4×10^{-10} and 2.9×10^{-10} m^2/s. The transmissivity of the Culebra in DOE-2, H-14, and H-16 ranges from 1.1×10^{-7} to 9.6×10^{-5} m^2/s, at least one order of magnitude greater than that of any of the surrounding units.

The results at H-14, H-16, and DOE-2 indicate that the Culebra is the most significant water-bearing unit within the Rustler at and near the WIPP site, consistent with earlier assumptions, although in some holes (H-10, WIPP-12, P-15) the Culebra transmissivity is similar to the Magenta transmissivities measured at H-14, H-16, and DOE-2. However, the recent results are inconsistent with previous assumptions, in that they suggest that stratabound fluid flow within the portion of the Rustler above the Culebra dolomite may occur as much through the Forty-niner claystone as through the Magenta, except where the Magenta is significantly fractured. At and near the WIPP site, both the Magenta and the Forty-niner claystone are more transmissive than the bounding anhydrites; no data are available concerning the transmissivity of the Tamarisk claystone. There must be a qualitative increase in the transmissivities of the Tamarisk and Forty-niner anhydrites somewhere between the WIPP site and Nash Draw, however, since evaporite karst in and near Nash Draw involves formation of small caverns and sinkholes within the Tamarisk and Forty-niner Members, as briefly discussed in Section 4.4.

4.1.1.2 Head Distribution within the Rustler Formation and between the Rustler, Dewey Lake, and Salado--As mentioned previously, numerical modeling of Rustler hydrology through 1983 assumed the Culebra and Magenta were completely confined, and that the transmissivities of other units within the Rustler were negligible. The results discussed in the preceding section indicate that the transmissivities of claystones or siltstones within the Rustler are locally measurable at the WIPP site, and are similar in magnitude to that of the Magenta dolomite, except where the Magenta is fractured. However, the transmissivity of the Culebra dolomite is normally at least one order of magnitude greater than that of other units within the Rustler at and near the WIPP site, and the transmissivities of Rustler anhydrites at and near the WIPP site are too low to measure. These results suggest that flow within the Culebra dolomite, parallel to layering, is the dominant factor in the hydrology of the Rustler Formation at the WIPP site. However, as discussed briefly in this section, fluid pressures and densities have been measured locally in units both above and below the Culebra.

Therefore, unless the Rustler anhydrites and/or Tamarisk claystone have absolutely zero permeability, there must be some vertical fluid flow within the Rustler. The amount of this flow is not known quantitatively, and cannot be measured directly in the field. At one extreme, vertical fluid flow may be completely negligible relative to stratabound flow within the Culebra dolomite. At the other extreme, "karstic" hydrology might occur within the Rustler Formation at the WIPP site, involving surficial recharge from the surface to the Rustler carbonates and/or anhydrites. In order for fluid flow to take place from the surface to the carbonate members of the Rustler Formation, the head potential within the Forty-niner must be greater than that within the underlying Magenta dolomite, regardless of the head potential or state of saturation within the Dewey Lake Red Beds. The relationships among the effective hydraulic heads of the various members of the Rustler Formation, the Salado, and the Dewey Lake in the central portion of the WIPP site are shown in Figure 4.1.3. The flow directions indicated include the expected effects due to variable brine densities.

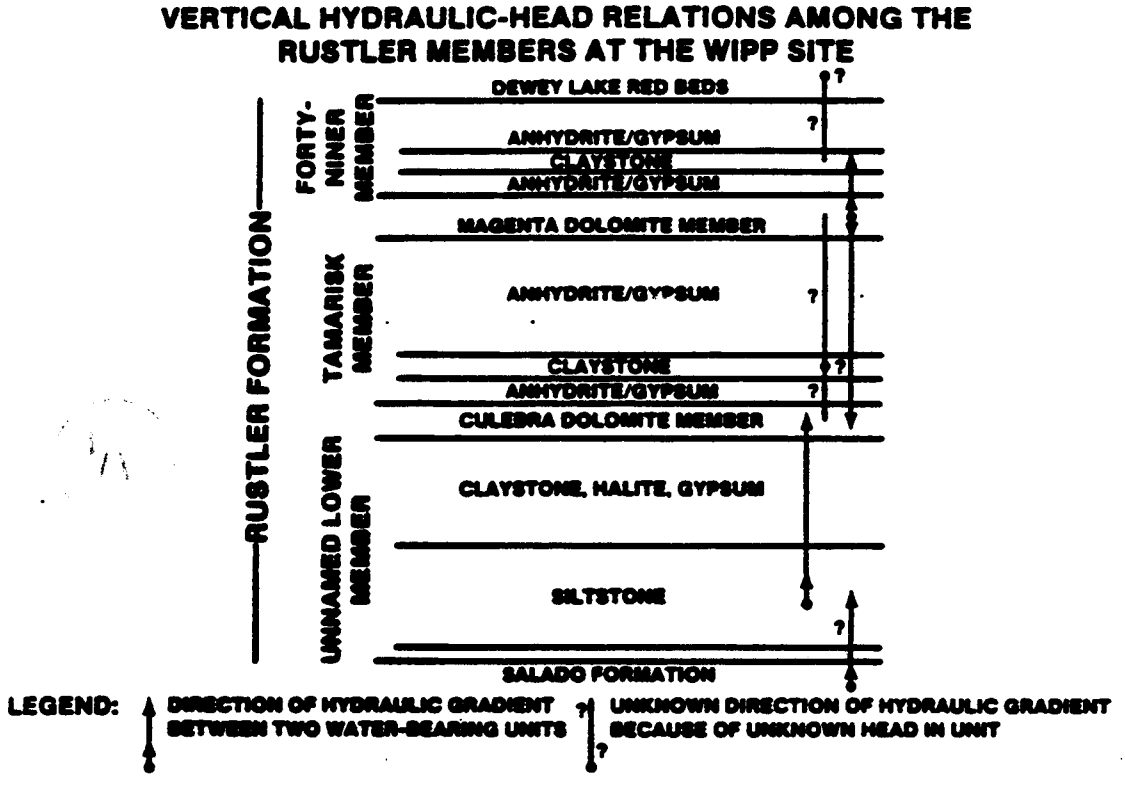


Figure 4.1.3: Head relations among units in the Rustler Formation and between the Rustler, Dewey Lake Red Beds, and Salado at the WIPP site. Figure 6-3 of Beauheim (1987b).

Figure 4.1.3 is based, in part, on testing of the Rustler and lower Dewey Lake Red Beds at H-14, H-16, and DOE-2. The transmissivity of the lower Dewey Lake was too low for successful testing, i.e., less than approximately 10^{-11} m^2/s. In fact, testing was unable to determine whether the Dewey Lake is hydraulically saturated. The regional pattern of hydrologic saturation within the Dewey Lake is not well known (Mercer, 1983); only very limited evidence has been found for local saturation at the WIPP site. South of the WIPP site, water is locally produced from the Dewey Lake, perhaps from lenticular sands within the unit (Mercer, 1983). Wells probably producing from within the Dewey Lake include the Pocket, Fairview, and Ranch wells indicated in Figure 1.2. As noted by Mercer (1983) the region east of the Ranch well includes thick active dune sands, and may serve as a location for local recharge to the Dewey Lake (see also Section 4.3.2).

In holes H-14 and H-16, consistent with the relationships shown in Figure 4.1.3, the Magenta head is greater than the head in the Forty-niner claystone (Beauheim, 1987b). Therefore, modern fluid flow between these two members is upward, rather than downward. Since water at these two holes is not moving from the top of the Rustler downwards into the Magenta, it cannot be moving from the surface down into the Magenta dolomite.

The Dewey Lake Red Beds at H-14 and H-16 may not be saturated. If not, fluid flow from the surface to the Forty-niner claystone is not likely. Given the uncertainty in regional saturation and head potentials within the Dewey Lake Red Beds the results at H-14 and H-16 do not rule out fluid movement from the surface downward into the Forty-niner claystone or the upper anhydrite in the Forty-niner and/or into the Magenta dolomite in some areas; i.e., where the Dewey Lake is saturated. Also, these results do not eliminate the possibility of flow between the Dewey Lake Red Beds and the Rustler carbonates in the past, if heads within the Dewey Lake Red Beds and Forty-niner were higher at that time relative to heads within the Magenta.

Magenta heads near the center of the WIPP site are greater than Culebra heads (Figure 4.1.3), consistent with downward flow between these two units. As indicated in Figures 17 and 18 of Mercer (1983), the difference in heads between the two units tends to increase towards the east and decrease towards the west, primarily due to a general east-to-west decrease in Magenta heads. Within and near Nash Draw, the heads within the two units are similar; in some places in and near Nash Draw, (H-7a, WIPP-26, WIPP-28), the Magenta is unsaturated (Mercer, 1983).

Vertical flow from the Magenta to the Culebra has been considered in regional-scale modeling of Culebra hydrology (Section 4.1.3.1). However, as noted above and indicated in Figure 4.1.3, it has not been possible to measure either transmissivities or head potentials within either the claystone or anhydrites in the Tamarisk at or near the WIPP site. Vertical flow between the Magenta and Culebra is discussed further by Mercer (1983) and Beauheim (1987b). The possible consequences of such flow, as considered in numerical modeling of Culebra hydrology (Haug et al., 1987), are briefly considered in Section 4.1.3.1.

As noted by Mercer (1983) and Beauheim (1987b), the head potentials in the silty portion of the unnamed lower member of the Rustler are greater than within the Culebra over much of the area of the WIPP site. Thus, fluid flow into the Culebra from the underlying unnamed member and possibly the Salado Formation is possible at both of these locations. However, as indicated in Figure 4.1.3, it has not been possible to measure either transmissivities or head potentials within the claystone, halite, or gypsum/anhydrite in the upper part of the unnamed lower member. The possible implications of vertical fluid flow from the unnamed member into the Culebra in numerical modeling of Culebra hydrology are briefly discussed in Section 4.1.3.1.

4.1.2 Single-Pad Interference Testing

Interference testing at the scale of a single hydropad is designed to provide data concerning the hydrologic effects of both fracturing and "anisotropy" at a geometric scale of some 30 m. If the test interval behaves as a porous medium at the hydropad scale, interference testing yields an "anisotropy tensor," which indicates local directions of maximum and minimum transmissivities. If, however, the porous-medium assumption is not valid at this scale, i.e., if fracturing effects are significant, testing at this scale normally provides average system transmissivities and storativities along the independent pairs of flow paths. Section 4.1.2.1 describes the detailed results of single-pad interference testing at the H-3 hydropad, and Section 4.1.2.2 the detailed results of testing at the H-11 pad. Detailed interpretation of pad-scale interference testing has only been completed to date for these two locations. Interpretation of results obtained at the H-2, H-4, H-5, H-6, H-7, and H-9 pads is ongoing.

4.1.2.1 Interference Testing at the H-3 Hydropad--Beauheim (1987a) interprets hydraulic data collected at the H-3 hydropad (Figure 4.1.4) during single-hydropad testing in 1984 and the H-3 multipad interference test conducted in 1985 and 1986. Hole H-3b3 was the pumped hole during the 1984 test, and H-3b2 the pumped hole during the H-3 multipad test.

The characteristic drawdown response in both pumped and observation holes at the H-3 pad is shown in Figure 4.1.1. As noted in Section 4.1.1, the inflection in dimensionless pressure at early dimensionless times indicates fracturing at H-3. In fact, the responses of observation holes on the H-3 pad to the beginning of pumping during both single-pad and multi-pad testing tests were practically instantaneous. Observation holes H-3b1 and H-3b3 responded within five seconds to the beginning of pumping in H-3b2 during the multipad test. The peak drawdowns in the observation holes were 90% or more of the drawdown in the pumped hole, even in the relatively short 1984 test. As a result, it was necessary to interpret the responses of observation holes on the H-3 pad as if these holes were a part of the pumped hole. This conclusion is supported by the fact that the calculated effective hydraulic radius of the pumped well in the 1984 testing (H-3b3) is approximately 146 m (Beauheim, 1987a). This interpretation, however, makes it impossible to determine storativities along the flow paths at the H-3 pad.

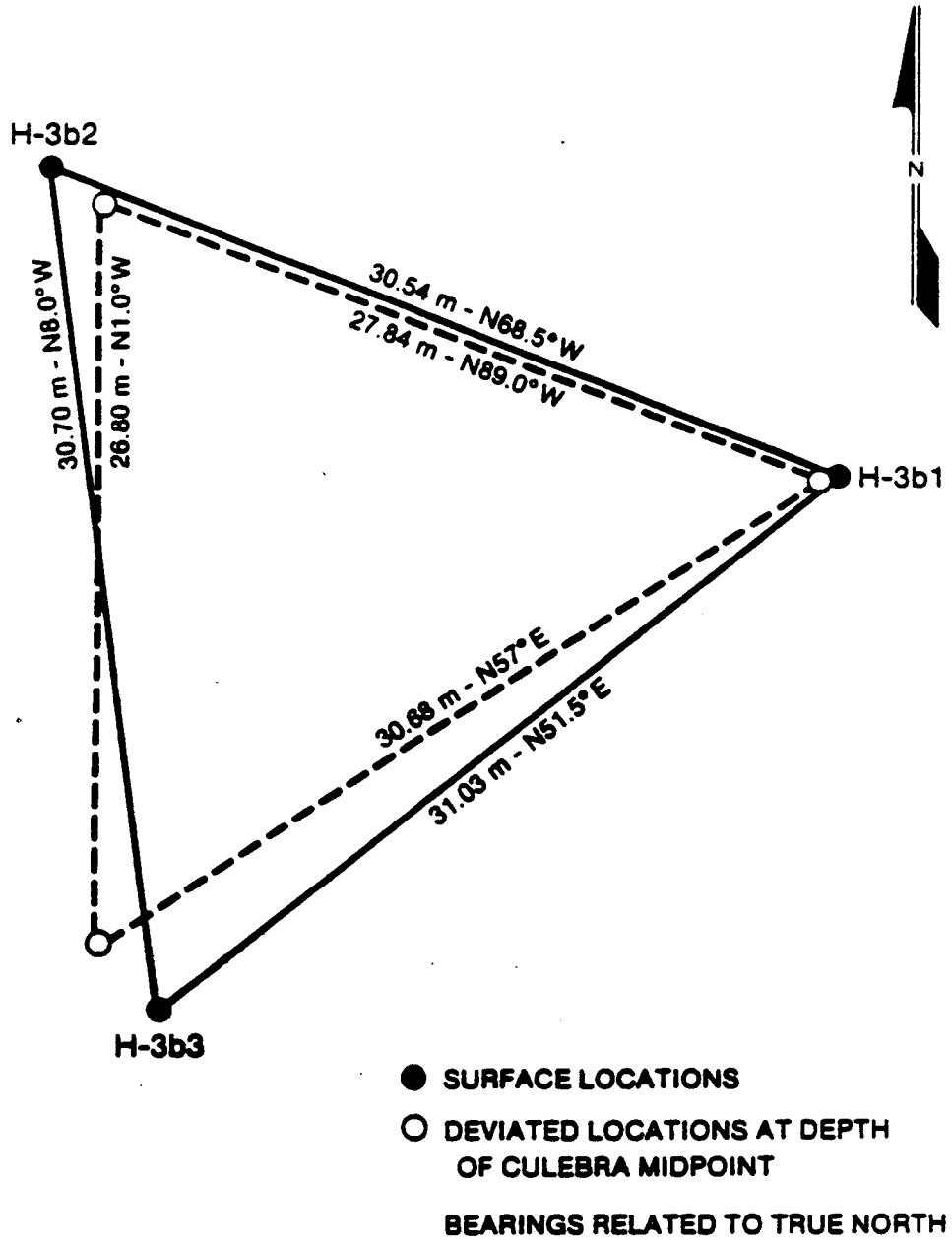


Figure 4.1.4: Physical layout of the H-3 hydropad. The figure is a plan view, showing positions and distances between wells both at the surface and where penetrating the Culebra dolomite. Figure 4.1 of Kelley and Pickens (1986).

The results of interference testing on the H-3 pad are summarized in Table 4.4. There is no significant difference between the interpreted transmissivities of the three holes on the H-3 pad, since the range in values is only from 3.1 to 3.2 x 10^{-6} m^2/s for the 1984 testing and 1.8 to 1.9 x 10^{-6} m^2/s for the multipad test. Therefore, there is no apparent anisotropy in the hydraulic properties at H-3. There is, however, a decrease of approximately 50% between the average transmissivity at H-3 interpreted from the 1984 testing, in which the pumping phase lasted 14 days at an average pumping rate of 4.0 gpm, and that interpreted from the H-3 multipad interference test, in which the pumping phase lasted 62 days, at an average rate of 4.8 gpm. Beauheim (1987a) attributes this difference to either a real difference in transmissivity between holes H-3b3 and H-3b2, the specific wells pumped in the two tests, and/or to the fact that the average transmissivity of the relatively large volume investigated during the long-term H-3 multipad test is lower than the average transmissivity of the volume investigated in the shorter-term 1984 testing. Consistent with this latter interpretation, the original H-3(b1) transmissivity of 2.0 x 10^{-5} m^2/s reported by Mercer (1983) is based on a combination of bailing/recovery and slug tests, both of short duration.

Table 4.4 includes estimates of both "skin factor" and the "storativity ratio" for individual holes on the H-3 pad. Calculated skin factors range from -7.3 to -8.1. As discussed by Beauheim (1987a), the strongly negative skin factors indicate direct connection of all three wellbores with fractures, consistent with the interpreted effective radius of 146 m for hole H-3b3. Although the storativities of the observation holes on the H-3 pad could not be calculated, Beauheim (1987a) does calculate "storativity ratios" (omegas), the ratio of fluid storativity within the fractures (secondary porosity) to that of the entire system of matrix plus fractures (primary plus secondary porosity). The calculated values range from 0.03 to 0.25. As noted by Saulnier (1987), most fractured-rock systems have a storativity ratio less than 0.1. The storativity ratios at the H-3 pad indicate unusually high storage within fractures, perhaps due to the vugginess of the Culebra.

4.1.2.2 Interference Testing at the H-11 Hydropad and Comparison with Results at the H-3 Pad--Saulnier (1987) summarizes the interpretation of pad-scale interference testing carried out at the H-11 hydropad (Figure 4.1.5) in 1984 and 1985. During 1984, holes H-11b1, H-11b2, and H-11b3 were each pumped in individual tests lasting from 12 to 21 hours. The 1985 test, in which H-11b3 was the pumped hole, lasted for 32 days. However, complications with instrumentation during the 1985 testing resulted in four distinct pumping and recovery periods. The resulting superposition of effects complicates interpretation of the 1985 results.

The results of interference testing at H-11 are included in Table 4.4. The interpreted transmissivities for pumped holes and for flow paths between pumped and observation holes on the H-11 pad range from 1.2 x 10^{-5} to 3.0 x 10^{-5} m^2/s. With the exception of the interpreted transmissivity of H-11b1 during 1984 pumping the range is only 2.5 x 10^{-5} to 3.0 x 10^{-5} m^2/s.

Table 4.4: Summary of single-pad interference testing results for the Culebra dolomite at the H-3 and H-11 hydropads. Slightly modified from data contained in Tables 6-1 and 6-3 of Beauheim (1987a) and Table 6.1 of Saulnier (1987).

	Transmissivity (m^2/s)	Skin Factor	Storativity	Storativity Ratio (ω)	Flow Ratio(λ)
H-3(1)					
H-3b3 (1984) pump	3.1×10^{-6}	-7.8	-	0.07	-
H-3b1 (obs.)	3.2×10^{-6}	-7.3	-	0.25	-
H-3b2 (obs.)	3.2×10^{-6}	-7.6	-	0.04	-
H-3b2 (1986) pump	1.8×10^{-6}	-8.1	-	0.03	-
H-3b1 (obs.)	1.9×10^{-6}	-7.7	-	0.25	-
H-3b3 (obs.)	1.9×10^{-6}	-8.0	-	0.10	-
H-11(2)					
H-11b1 (1984) pump	1.2×10^{-5}	-3.3	-	0.01	1.3×10^{-9}
H-11b2 (obs.)	2.5×10^{-5}	-	8×10^{-4}	0.35	2.0×10^{-6}
H-11b3 (obs.)	2.8×10^{-5}	-	5.5×10^{-4}	0.35	1.3×10^{-6}
H-11b2 (1984) pump	-	-	-	-	-
H-11b1 (obs.)	2.7×10^{-5}	-	6.1×10^{-4}	0.43	2.0×10^{-6}
H-11b3 (obs.)	2.6×10^{-5}	-	4.5×10^{-4}	0.40	3.8×10^{-6}
H-11b3 (1984) pump	2.8×10^{-5}	-4.4	-	0.01	2.3×10^{-6}
H-11b1 (obs.)	2.7×10^{-5}	-	6.3×10^{-4}	0.30	1.3×10^{-6}
H-11b2 (obs.)	2.6×10^{-5}	-	7.2×10^{-4}	0.30	1.3×10^{-6}
H-11b3 (1985) pump	3.0×10^{-5}	-4.6	-	0.01	3.7×10^{-7}
H-11b1 (obs.)	2.7×10^{-5}	-	2.9×10^{-3}	0.07	5.0×10^{-6}
H-11b2 (obs.)	2.8×10^{-5}	-	2.6×10^{-3}	0.07	5.8×10^{-6}

(1) All holes H-3 pad interpreted as part of pumped hole; therefore, storativities not available, but skin factors and point transmissivities available for all holes.

(2) Observation holes on H-11 pad well-behaved; therefore, transmissivities, except for pumped hole, are averages between observation and pumped hole.

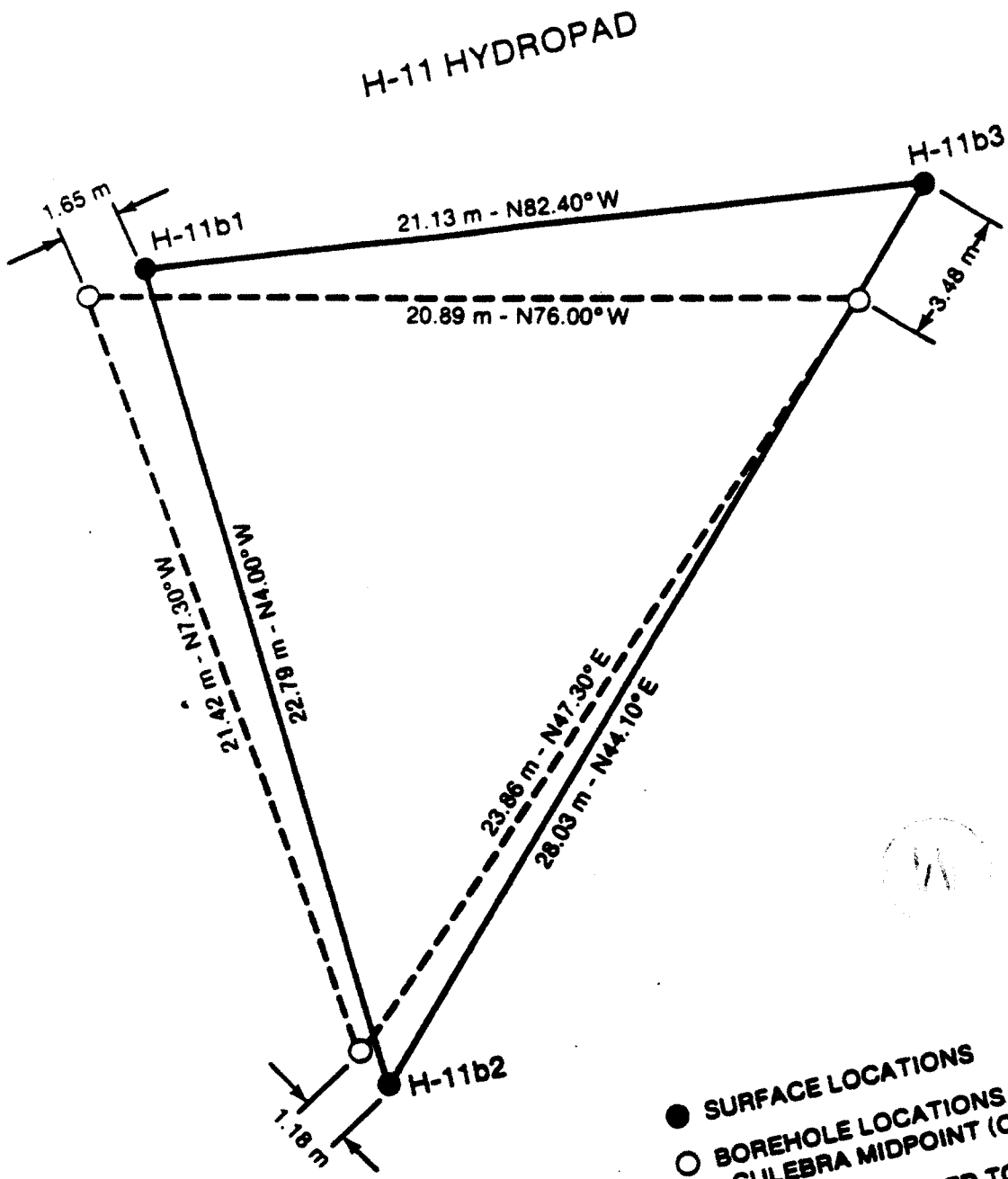


Figure 4.1.5: Physical layout of the H-11 hydropad. The figure is a plan view, showing positions and distances between wells both at the surface and where penetrating the Culebra dolomite. Modified from Figure 3.1 of Saulnier (1987).

The behavior of observation holes on the H-11 pad is consistently different than that observed on the H-3 pad. Although the observation holes on the H-11 pad displayed dual-porosity behavior, their response to the beginning and ending of pumping was sufficiently delayed to allow interpretation as observation holes, rather than as part of the pumped well. The calculated effective hydraulic radius of H-11b3, consistent with the behavior of the observation holes, is 4.9 m (Saulnier, 1987), as compared to an effective radius of 146 m at the H-3 pad (Beauheim, 1987a).

Comparison of the hydrologic behaviors at the H-3 and H-11 pads indicates that the hydraulic effectiveness of fracturing at a given site need not be proportional to the transmissivity. The interpreted transmissivity of H-11b3 during pumping of this hole in 1984 is 2.8×10^{-5} m^2/s, as compared to a transmissivity of 3.1×10^{-6} m^2/s for hole H-3b3 in 1984 testing at the H-3 pad. However, the effective radius of H-3b3 is 146 m, while that of H-11b3 is 5 m. In addition, the observation holes at the H-3 pad had to be treated as part of the pumped well, while observation holes at the H-11 pad behaved properly as observation wells. As shown in Table 4.3, the calculated skin factors at the H-3 pad, which range from -7.3 to -8.1, are consistently more negative than those at the H-11 pad, which range from -3.3 to -4.6.

Interpretation of behavior along the assumed radial flow paths between observation and pumped wells on the H-11 pads indicates average hydraulic storativities between 4.5×10^{-4} and 2.9×10^{-3}, with the higher values interpreted from testing in 1985. These storativities are higher than regional storativities calculated by Beauheim (1987a) from multipad testing at the H-3 pad (7.4×10^{-6} to 3.0×10^{-5}, see Table 4.6). As at the H-3 pad, calculated storativity ratios at H-11 range from 0.01 to 0.43, higher than normal for fractured media.

Calculated interporosity-flow parameters (lambdas) at H-11 range from 1.3×10^{-9} to 5.8×10^{-6} (Table 4.4). As noted by Saulnier (1987), the definition of the parameter lambda includes the ratio of the matrix permeability (permeability of the primary-porosity system) to permeability of the fractures (secondary-porosity system). Therefore, the calculated results indicate that there is a strong contrast between matrix and fracture permeabilities at the H-11 pad. As also indicated by Saulnier (1987), interpretation of the calculated lambda values at the H-11 pad is consistent with effective block or slab dimensions of 0.3 to 1.0 m. The available information on the effective block size in fractured portions of the Culebra dolomite is discussed further in Section 4.2, based on the results of testing with conservative tracers at the H-3 hydropad.

Using the system transmissivities interpreted from 1984 testing and an average storativity of 6.3×10^{-4}, Saulnier (1987) estimates the extent and orientation of hydraulic "anisotropy" at H-11. The calculated maximum transmissivity vector of 3.3×10^{-5} m^2/s is oriented 5.8 degrees north of east, and the calculated minimum transmissivity vector of 2.1×10^{-5} m^2/s 5.8 degrees west of north (Table 4.5). The calculated ratio of 1.6:1 between maximum and minimum transmissivities at H-11 indicates only a small degree of anisotropy. However, the presence of fractures at this site indicates that these results are only qualitative; because of the

fractures, directional variations in properties are almost certainly not continuous. Also, since the indicated directions of maximum and minimum transmissivity do not coincide with any direct flow paths on the H-11 pad, there is no guarantee that either the maximum or minimum values are reliable.

Table 4.5: Summary of apparent hydraulic anisotropy of the Culebra dolomite. Compiled from results contained in Saulnier (1987) and Gonzalez (1983b).

	T_{MAX} (m^2/s)	T_{MIN} (m^2/s)	T_{MAX}/T_{MIN}	Orientation of T_{MAX}
Site				
H-4(1)	2.9×10^{-6}	1.1×10^{-6}	2.6	N76W
H-5	2.4×10^{-7}	9.7×10^{-8}	2.5	N25W
H-6	1.1×10^{-4}	5.2×10^{-5}	2.1	N29W
H-11(2)	3.3×10^{-5}	2.1×10^{-5}	1.6	N84E

(1) Data for H-4, H-5, and H-6 from Gonzales (1983b).
(2) Data for H-11 from Saulnier (1987).

The available interpretations of anisotropy within the Culebra dolomite are summarized in Table 4.5. Earlier interpretations at the H-4, H-5, and H-6 pads all explicitly make the porous-medium assumption (Gonzalez, 1983b). The interpretation of Saulnier (1987) is based on the calculated system transmissivities. The available interpretations indicate transmissivity ratios between 1.6:1 and 2.6:1, with a direction of between N84E and N76W for the major transmissivity vector. For calculated major Culebra transmissivities between 2.4×10^{-7} m^2/s and 1.1×10^{-4} m^2/s and minor transmissivities between 9.7×10^{-8} and 5.2×10^{-5} m^2/s there appears to be less than a factor of three hydraulic anisotropy. The available results indicate that there is no consistent orientation of maximum Culebra transmissivity.

4.1.3 Multipad Interference Testing

As noted in the introduction to Section 4.0, the best method of estimating the regional distribution of properties within a variable hydrologic unit is by regional-scale testing and interpretation. At the WIPP site, two regional-scale multipad interference tests of the Culebra dolomite have been completed, centered at the H-3 hydropad and at hole WIPP-13. The H-3

multipad interference test and related analytical interpretation and regional-scale modeling of Culebra hydrology are discussed in Section 4.1.3.1. The WIPP-13 test and related interpretative and modeling studies are discussed in Section 4.1.3.2.

4.1.3.1 The H-3 Multipad Interference Test and the Regional Culebra Model of Haug et al. (1987)--The pumping phase of the H-3 multipad interference test (Figure 4.1.6) extended from October 15, 1985, to December 16, 1985. Recovery monitoring continued until April 16, 1986, when the data-acquisition system at the H-3 pad was turned off. Raw data from the test are included in INTERA (1986). Analytical interpretations of both detailed results at the H-3 pad and average or apparent transmissivities and storativities between H-3b2 (the pumped hole) and the numerous observation holes are reported by Beauheim (1987a). Analytical interpretation of regional flow patterns generated in response to the test, with emphasis on evaluation of a linear-flow regime at holes H-3, H-11, and DOE-1, is reported by Tomasko and Jensen (1987). Numerical calculation or simulation of Culebra transmissivities, heads, and fluid densities on the regional scale are reported by Haug et al. (1987), as well as modeling of the transient pressure responses to the H-3 multipad test.

Beauheim (1987a) describes the analytical (as opposed to numerical) interpretation of hydraulic data collected during the H-3 multipad interference test. Results on the H-3 pad itself are discussed in Section 4.1.2. The regional distribution of Culebra properties, based on Beauheim's analytical interpretation, is summarized in Table 4.6. The analytical approach used to interpret responses at observation holes necessarily assumes both radial flow into the pumped hole and homogeneous or average properties between pumped hole and individual observation holes (Beauheim, 1987a). Therefore, transmissivity values listed in Table 4.6 are apparent average values for an assumed radial flow path between H-3b2 and the listed observation hole. Beauheim (1987a) found it necessary to correct both pre-test and post-test heads for the relatively long-term transient behavior of some water levels at and near the WIPP site (Table 4.6). This transient behavior is in response to some combination of hydrologic testing, shaft sinking and sealing operations, and a possible regional transient.

Observation-hole responses to the H-3 multipad test fall into three general categories. First, on the H-3 pad itself, hydraulic fracturing was sufficient to require that Observation holes H-3b1 and H-3b3 be considered as part of the pumped hole (Section 4.1.2). Second, Observation holes DOE-1 and H-11b1, respectively 1606 and 2423 m southeast of H-3b2 (Figure 4.1.6), responded rapidly to both the beginning and ending of pumping. Drawdown in DOE-1 began 48 hours into the test, and that in H-11b1 only three hours later (Table 4.6). The average transmissivities interpreted along flow paths between H-3b2 and DOE-1 and H-11b1 are 5.9×10^{-6} m^2/s between DOE-1 and H-3b2 and 7.3×10^{-6} m^2/s between H-11b1 and H-3b2. Calculated apparent storativities along the same flow paths are 1.0×10^{-5} and 7.4×10^{-6}, respectively. Beauheim (1987a) concludes that the rapid responses at DOE-1 and H-11b1 and relatively high calculated transmissivities along flow paths between these holes and H-3b2 indicate a

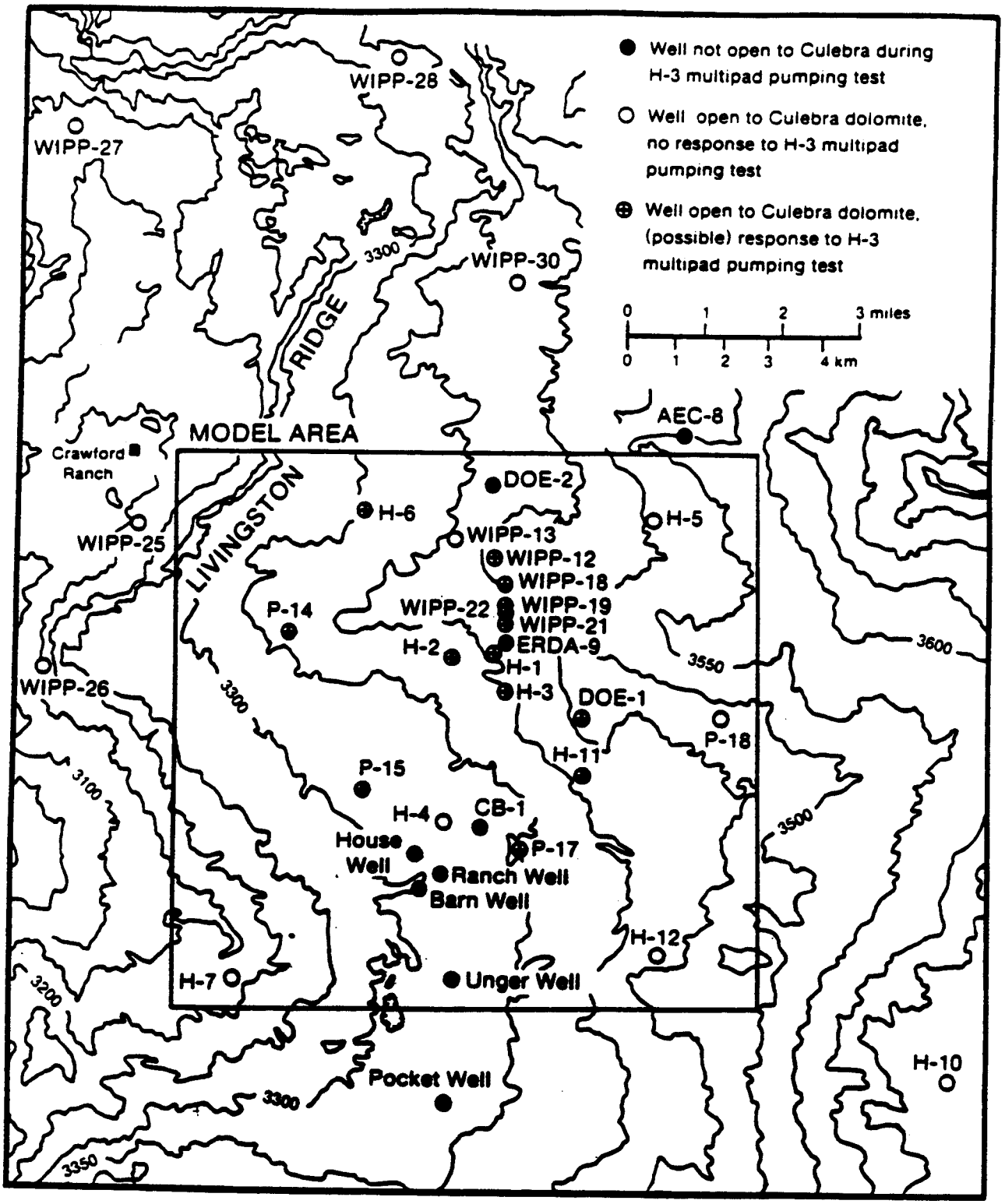


Figure 4.1.6: Pumping and observation wells for the H-3 multipad interference test. Figure 3.2 of Haug et al. (1987).

Table 4.6: Summary of results of analytical interpretation of H-3 multipad interference test. Slightly modified from data contained in Tables 3-1, 5-1, and 6-4 of Beauheim (1987a).

Well	Distance(m)[1]	Direction	First Obs.[2] Drawdown (hrs)	Delay in Max. Drawdown (hr)	Unmodified Interpretation		Modified Interpretation		
					T(m^2/s)[3]	S	T(m^2/s)	S	Head Modification (m/day)
H-11b1	2423	S42E	79	51	1.4×10^{-5}	6.6×10^{-6}	7.3×10^{-6}	7.4×10^{-6}	8.6×10^{-3}
DOE-1	1606	S68E	57	48	9.9×10^{-6}	9.2×10^{-6}	5.9×10^{-6}	1.0×10^{-5}	5.5×10^{-3}
H-1	815	N19W	488	1423	8.9×10^{-7}	3.9×10^{-5}	4.9×10^{-7}	2.7×10^{-5}	2.64×10^{-2}
H-2b2	1270	N54W	433	1393	2.7×10^{-6}	4.5×10^{-5}	1.3×10^{-6}	3.0×10^{-5}	1.16×10^{-2}
WIPP-19	1875	N2E	1207	1855	3.1×10^{-6}	2.9×10^{-5}	-	-	-
WIPP-21	1437	N3E	437	678	1.2×10^{-6}	9.0×10^{-6}	-	-	-
WIPP-22	1739	N2E	990	727	1.7×10^{-6}	1.7×10^{-5}	-	-	-

(1) Distances and directions measured from H-3b2 to the indicated well.
(2) First drawdown and delay in maximum drawdown are given relative to times at which pump was turned on and off, respectively.
(3) Unmodified and modified transmissivities (T) and storativities (S) are apparent average values between H-3b2 and indicated well, assuming radial flow to H-3b2.

preferential connection between the H-3 pad and the southeast portion of the WIPP site. He further concludes, consistent with single-pad interference testing at both H-3 and H-11 (see Section 4.1.2), that this connection is related to fractures. Third, holes north and northwest of H-3b2 were much slower to respond to the H-3 multipad test, indicating relatively poor and variable hydraulic connection in this direction. Hole H-1, 815 m from H-3b2, did not respond to pumping until approximately 488 hours into the test. The best estimate of the average transmissivity between H-3b2 and H-1 is 4.9×10^{-7} m^2/s. H-2b2, slightly further from H-3b2 than hole H-1, responded earlier (433 hours). The slightly higher apparent transmissivity between H-2b2 and H-3b2 (1.3×10^{-6} m^2/s) than between H-1 and H-3b2 indicates local variability within the Culebra dolomite, even in the low-transmissivity domain containing H-1, H-2, and H-3. In contrast to behavior at and southeast of the H-3 pad, there is no indication that regional-scale flow or pressure response between H-3 and either H-2b2 or H-1 involved fractures. Holes WIPP-19, 21, and 22 are north of the WIPP facility (Figure 4.1.6). Therefore, their response to any pumping test at H-3 will be influenced by the intervening WIPP shafts, unless the sealing of these shafts is perfect. There was, in fact, considerable uncertainty about the rates of leakage from the Culebra into the WIPP exhaust and waste-handling shafts during the H-3 test. As a result, interpreted transmissivities for flow paths extending north of the center of the WIPP site, i.e., between H-3b2 and holes WIPP-19, 21, and 22, may be inaccurate (Beauheim, 1987a).

Several observation holes did not respond measurably during the H-3 multipad test, including H-4, P-14, P-15, and P-17. Therefore, only minimal transmissivities could be calculated for areas south and southwest of H-3, based on the lack of response. Beauheim (1987a) estimates that the average transmissivity between H-4 and H-3b2 would need to be less than 1.0×10^{-6} m^2/s. As indicated in Table 4.2, drilling and testing of hole H-14 has since yielded results consistent with this bounding interpretation.

Tomasko and Jensen (1987) note a strikingly linear relationship between the observed drawdowns and the square root of time in holes H-3b2, H-11b1, and DOE-1 during the H-3 multipad test, and conclude from this that much of the response to the test in this area was a result of "linear flow," in which flow is largely confined to a linear high-transmissivity structure between less-permeable boundaries. Their interpretation is a second line of evidence for a high-transmissivity structure in the southeastern part of WIPP Zone 3. Figure 4.1.7 shows the nearly linear response of H-3b2 versus the square root of time during the pumping phase of the H-3 multipad test. Tomasko and Jensen (1987) interpret the limited curvature shown in Figure 4.1.7 to reflect the fact that the high-transmissivity structure containing H-3b2 is finite in width.

Figure 4.1.8 compares observed drawdowns and recoveries at H-11 and DOE-1 with those calculated assuming linear flow in a high-transmissivity structure oriented N29W. There is good agreement during the pumped phase, even with a model that used a simplified transmissivity distribution. Although calculated drawdowns exceed those measured, the shape of both drawdown and recovery curves agree well. This linear-flow approach yielded average transmissivities of 2.2×10^{-6}, 9.7×10^{-6}, and 2.0×10^{-5} m^2/s for

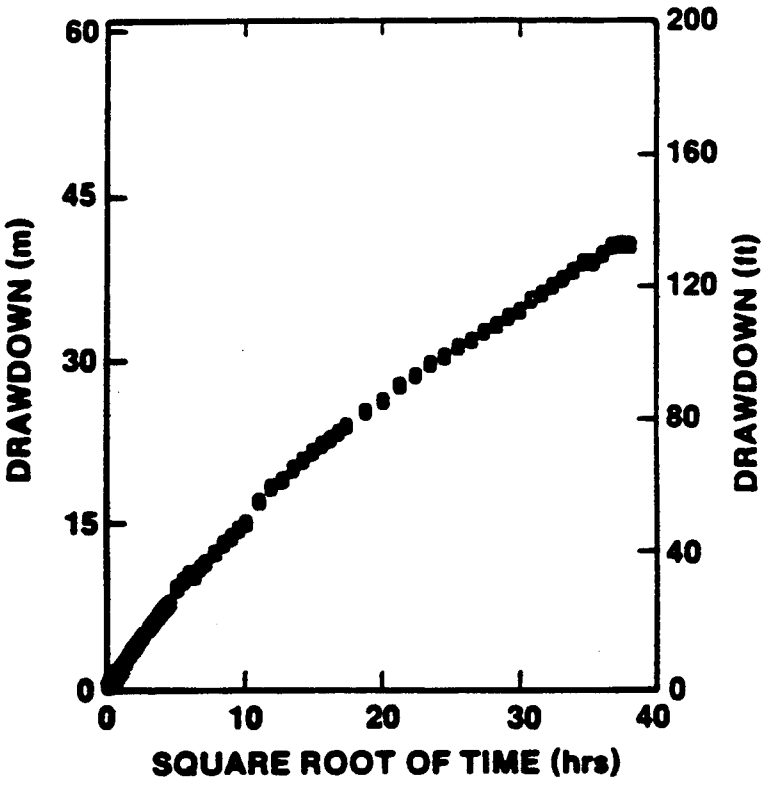


Figure 4.1.7: Observed drawdown versus the square root of time in hole H-3b2 during the H-3 multipad interference test. Slightly modified from Figure 15 of Tomasko and Jensen (1987).

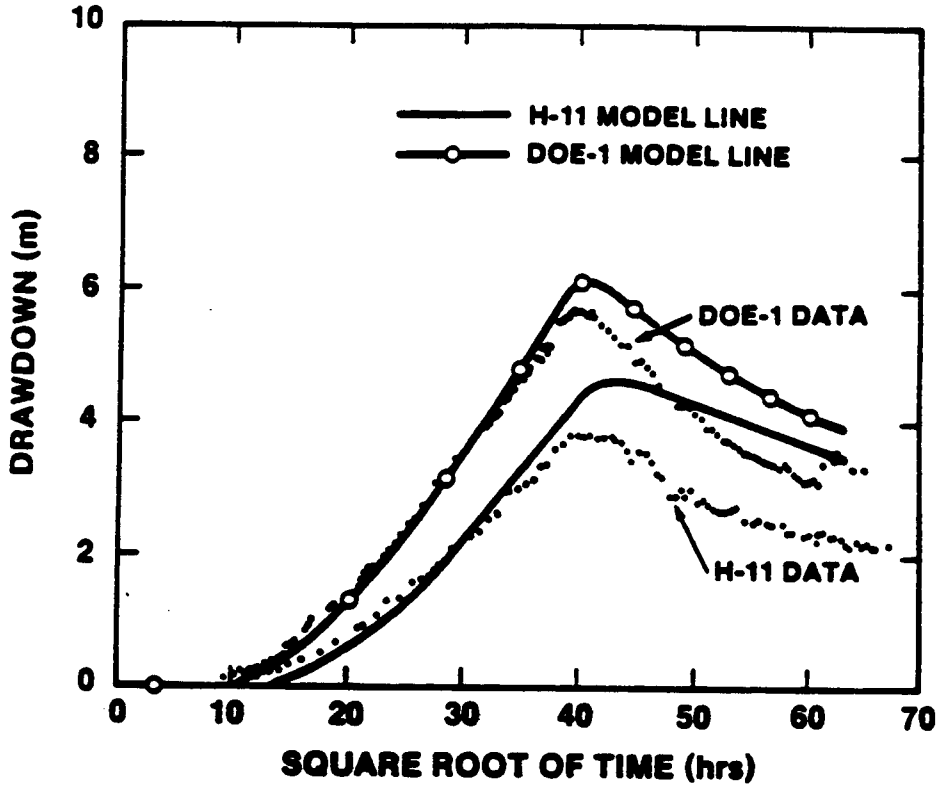


Figure 4.1.8: Comparison of measured and simulated responses at H-11 and DOE-1 during the H-3 multipad interference test, assuming perfectly linear flow. Figure 25 of Tomasko and Jensen (1987).

the H-3 pad and between H-3 and DOE-1 and H-11, respectively. These results are in qualitative agreement with the results of Beauheim (1987a) discussed above (2.0×10^{-6}, 5.9×10^{-6}, 7.3×10^{-6} m^2/s, respectively).

The analytical approaches discussed thus far involve specific assumptions, some of which pose real limitations in interpretation of testing on this geometric scale within a unit as complex as the Culebra dolomite. These include:

1. Regional-scale flow is assumed to be either perfectly radial or perfectly linear.

2. Transmissivities are either assumed uniform between pumped hole and observation hole, or a simplified transmissivity distribution is assumed.

3. Constant fluid density is assumed.

4. The Culebra dolomite is assumed to be completely confined.

In contrast, the approach taken by Haug et al. (1987), using the code SWIFT II (Reeves et al., 1986a; Reeves et al., 1986b), is fully numerical, and includes consideration of: a) a more complex pattern of regional flow, based on calculation of transmissivities between measurement points; b) variable fluid densities; and c) vertical fluid flux into or out of the Culebra. The modeling approach of Haug et al. (1987) assumes steady-state boundary conditions.

The results of non-directional kriging of the April 1986 Culebra-transmissivity data base (Figures 4.1.9 and 4.1.10) provide a quantitative indication of the statistical reliability of the data base at that time, independent of geologic and hydrologic judgement. The limited size of the data base resulted in the kriged transmissivity pattern consisting largely of "circles" around measured data points (Figure 4.1.9). The roughly circular areas within which the uncertainty in transmissivity (defined here as one standard deviation) was less than one order of magnitude were centered on individual hydro holes and approximately one kilometer in diameter (Figure 4.1.10). The only regions in which the areas of one-order-of-magnitude uncertainty overlapped was in the regions H-1 - H-2 - H-3 and H-11 - DOE-1. This finding provided strong impetus for testing of additional holes within WIPP Zone 3, as indicated by the large number of holes in Table 4.1 for which data have been collected or revised since April 1986.

One major emphasis of Haug et al. (1987) is consideration of the regional hydrologic behavior of the Culebra, independent of transient effects imposed by the WIPP facility. This required estimation of Culebra head potentials as they existed prior to the sinking of the WIPP shafts (Figure 4.1.11). Figure 4.1.12 shows the simulated or calculated Culebra transmissivity distribution resulting from calibration of downhole pressures within the Culebra against the "measured" pre-shaft freshwater-equivalent head potentials shown in Figure 4.1.11. The calibration effort

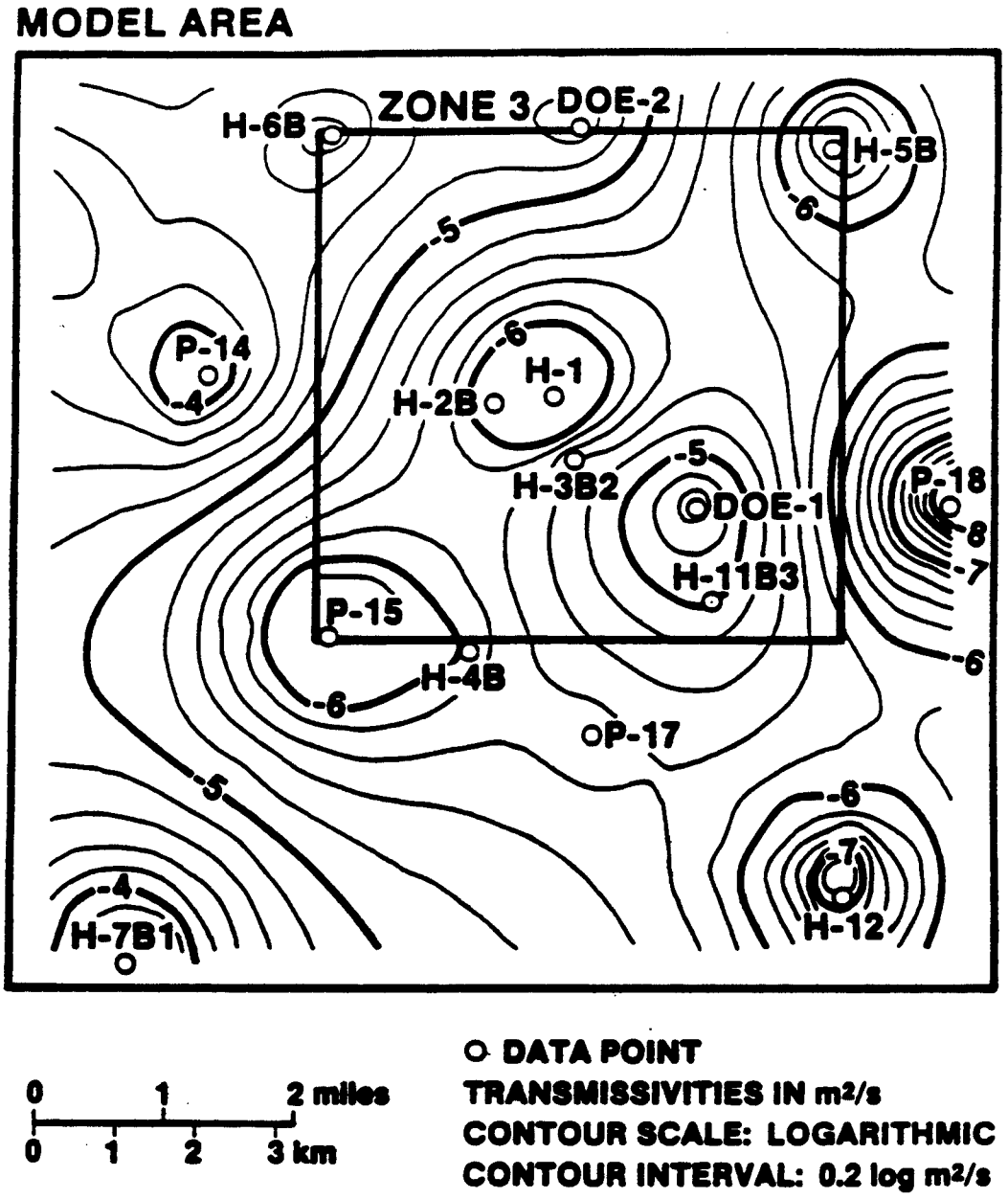


Figure 4.1.9: Initial kriged Culebra transmissivities, based on data available as of April 1986. Slightly modified from Figure 3.7 of Haug et al. (1987).

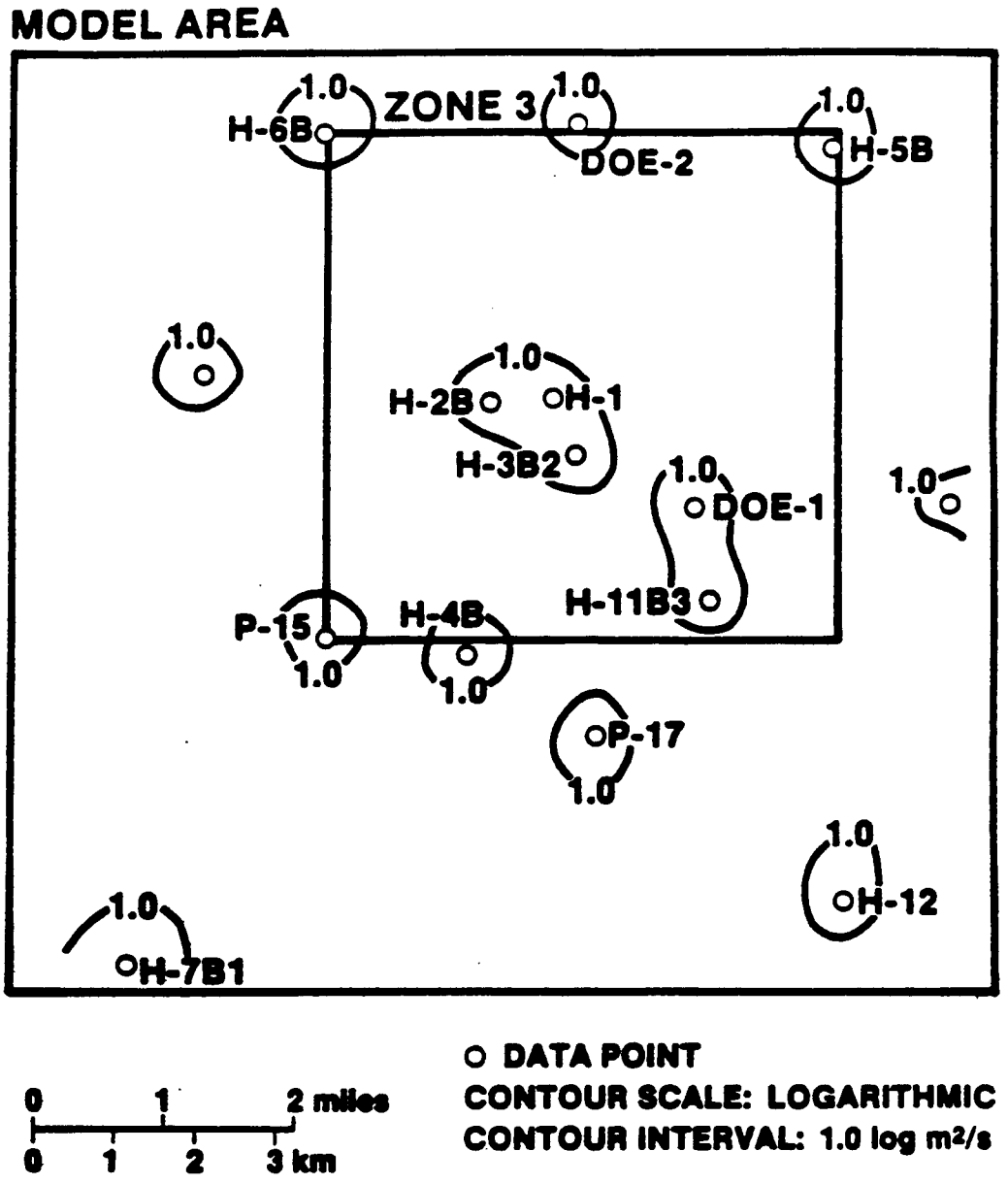


Figure 4.1.10: Estimation error in initial kriged Culebra transmissivities, based on data available as of April 1986. Slightly modified from Figure 3.8 of Haug et al. (1987).

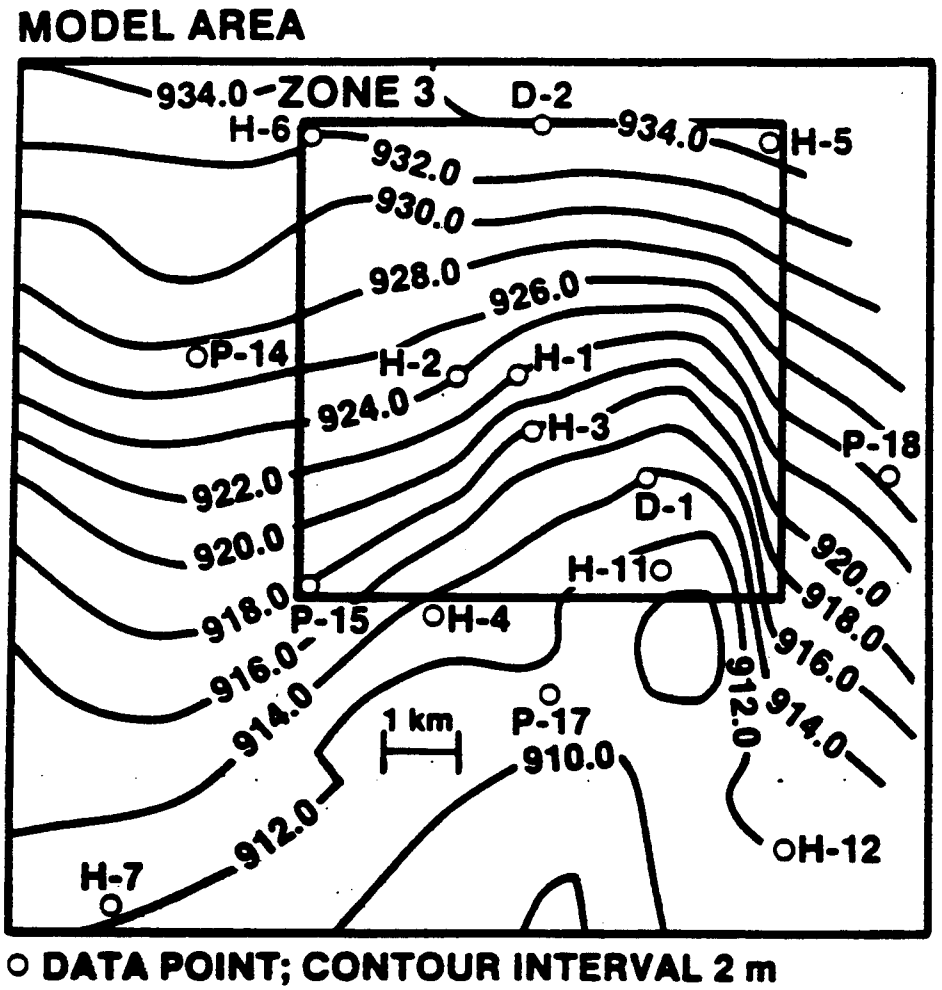


Figure 4.1.11: Best estimate of pre-shaft Culebra freshwater equivalent heads, based on data available as of April 1986. Slightly modified from Figure 3.9 of Haug et al. (1987).

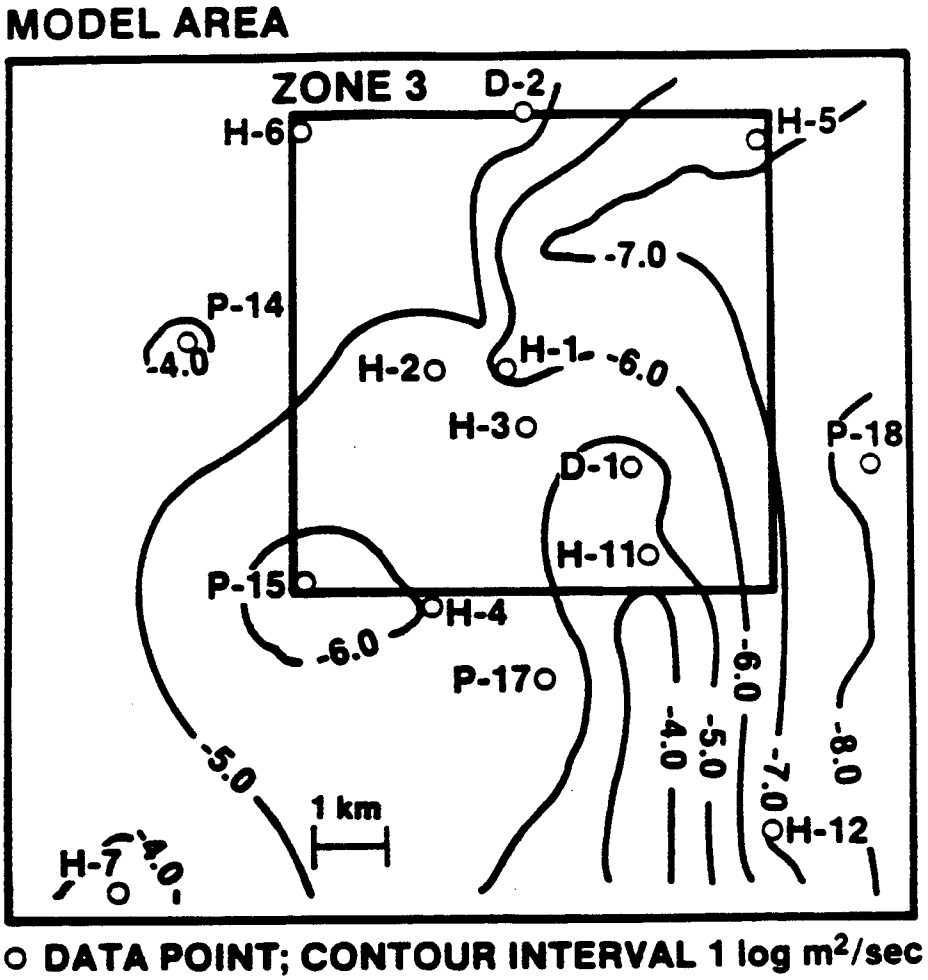


Figure 4.1.12: Best calculated distribution of Culebra transmissivities, based on pressure calibration to head distribution shown in Figure 4.1.11. Slightly modified from Figure 4.4 of Haug et al. (1987).

involved use of "pilot points" in some locations between measured data. At the pilot points, transmissivities were assigned, consistent with the uncertainty in initial kriged values. Evaluation of the statistical properties of the expanded data base including the pilot-point transmissivities indicated that the statistical properties of this data base were consistent with those of the measured data.

The transmissivity distribution in Figure 4.1.12 is marked by four main features:

1. A large and apparently continuous zone of relatively low transmissivity ($T<10^{-6}$ m^2/s) including the site center, the locations of the WIPP shafts, and extending to the east and northeast.

2. An apparently isolated region of low transmissivity in and near the southeastern portion of the site, in the region P-15 - H-4 - P-17. As noted in Section 4.1.1, it is not clear from existing point data whether or not this zone is connected to the low-transmissivity zone closer to the site center.

3. A narrow high-transmissivity zone ($T>10^{-5}$ m^2/s) in the region containing H-11 and DOE-1, and extending to the south. This zone was largely required in the model to account for the relatively low heads observed at H-11 and DOE-1 (Figure 4.1.11).

The central portion of the high-transmissivity zone is defined in Haug et al. (1987) only by several pilot points, since no data from within the zone were available as of April 1986. The zone is consistent with results of both Beauheim (1987a) and Tomasko and Jensen (1987). Model transmissivities in the central part of the zone, approximately 3.0×10^{-4} m^2/s, are similar to the transmissivities at H-9b (1.7×10^{-4} m^2/s) and P-14 (2.3×10^{-4} m^2/s), but lower than the transmissivity at H-7b (1.1×10^{-3} m^2/s) (Table 4.1). The assigned value was chosen in the effort to be reasonably "conservative," i.e., to have the zone contain as high a transmissivity as was reasonable.

4. A relatively large and apparently continuous high-transmissivity zone in the western part of the modeled area. As of April 1986, the high-transmissivity zone included measured data only at holes H-6, DOE-2, P-14, and H-7. The need to define the relationship of this high-transmissivity zone to the low-transmissivity zone containing the center of the WIPP site was a major driving force behind multipad interference testing at WIPP-13 (Section 4.1.3.2).

The calculated transmissivity distribution (Figure 4.1.12) served as a basis for further model calibration (Haug et al., 1987). The distribution of Culebra fluid densities measured as of April 1986 is shown in Figure 4.1.13. Culebra fluids in the vicinity of the WIPP site range in density from approximately 1.00 to greater than 1.10 g/cm^3 (see Section 4.1.3.2). Two main features of Figure 4.1.13 are of note:

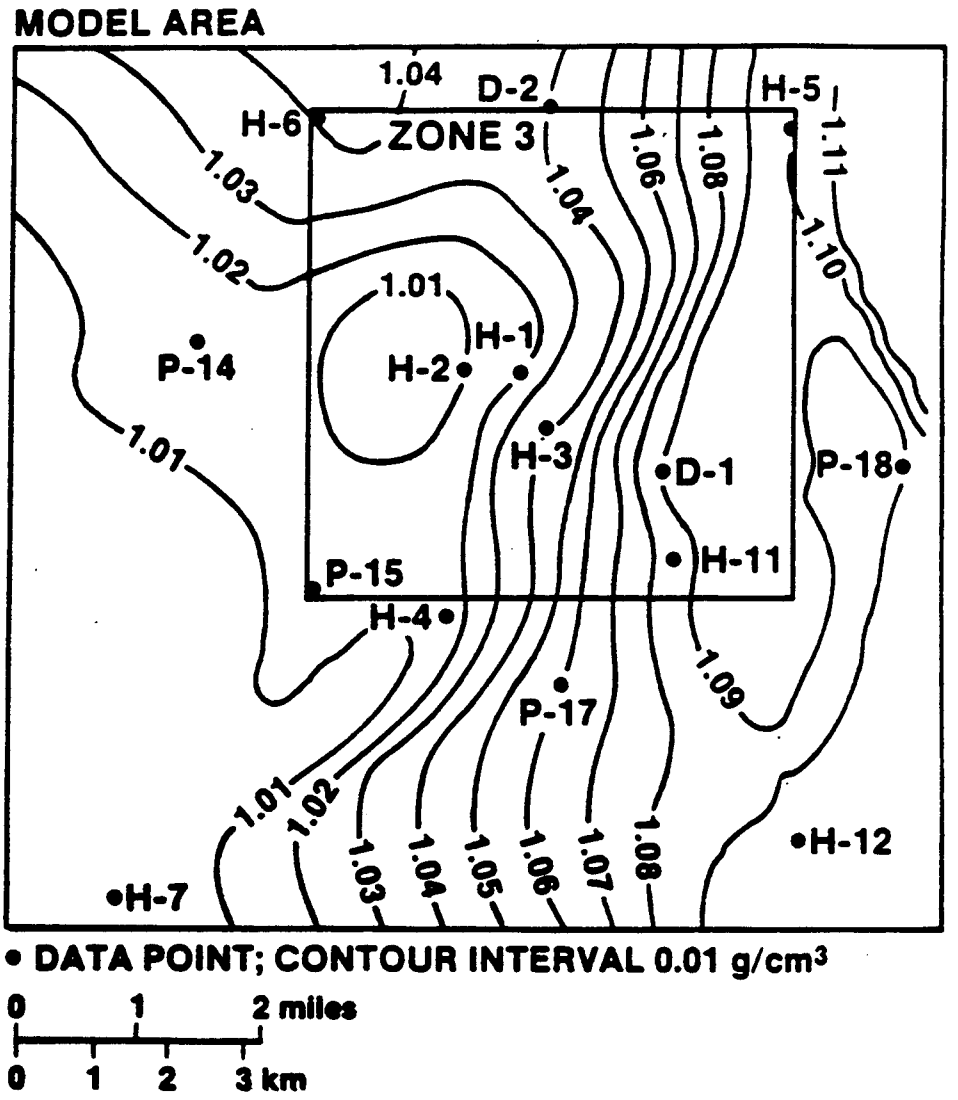


Figure 4.1.13: Best estimate of density distribution of Culebra fluids, based on information available as of April 1986. Figure 3.10 of Haug et al. (1987).

1. A linear zone of steep gradient in fluid density separates a large area of high fluid density (1.08 g/cm^3 or greater) east of the site center from an analogous area of relatively low fluid density (1.04 g/cm^3 or less) west of the site center.

2. Major curvature in the lines of fluid densities 1.01 through 1.04 g/cm^3 in the northwest part of the modeled area. As of April 1986, only measured density data from H-6, DOE-2, H-2, and P-14 provided control for this curvature.

During calibration of Culebra transmissivities against fluid densities, the interpolated brine densities near the boundaries of Figure 4.1.13 were first used as initial boundary conditions in simulation of assumed variable-density steady-state confined flow within the Culebra (Haug et al., 1987). The results of this approach were not satisfactory (Figures 4.1.14 and 4.1.15). Calculated brine densities at steady state are too low in the eastern portion of the model. The density contrasts in the eastern portion of the model (with the exception of the region near P-17) were adjusted successfully by slightly increasing the transmissivity in the northeastern portion of the model, without significantly changing fluid densities assigned at the boundaries. Over the western portion of the model, the problem was more severe. At steady state, a large area, including holes H-1, H-2, P-17, P-15, and P-14, was calculated to have fluid densities between 1.04 and 1.05 g/cm^3, compared to measured densities of 1.06 g/cm^3 at P-17 and less than 1.03 g/cm^3 at the other holes. The high calculated brine densities over the western portion of the site reflect the southward movement of the relatively dense brines at H-6 and DOE-2 required by steady-state confined flow (Haug et al., 1987).

These results are taken by Haug et al. (1987) to be consistent with at least three possibilities:

1. The interpolated brine densities along the northern boundary of the model are incorrect, except for the measured value at H-6. This possibility is considered in detail by Haug et al. (1987). Because of the recent increase in brine-density data in the northwest portion of the modeled area, the possibility is not considered further here (see Section 4.1.3.2).

2. There is enough vertical fluid leakage into and/or out of the Culebra to significantly affect fluid densities within the unit. This possibility is considered further by Haug et al. (1987), and is discussed below (see also Section 4.1.1).

3. The Culebra hydrologic regime is not at steady state on the time scale required for water flow across the modeled area. Transient boundary conditions for the hydrology of the Rustler Formation are consistent with recent geologic and isotopic results discussed in Sections 4.3 and 4.4, but have not yet been modeled directly, and are not considered further here.

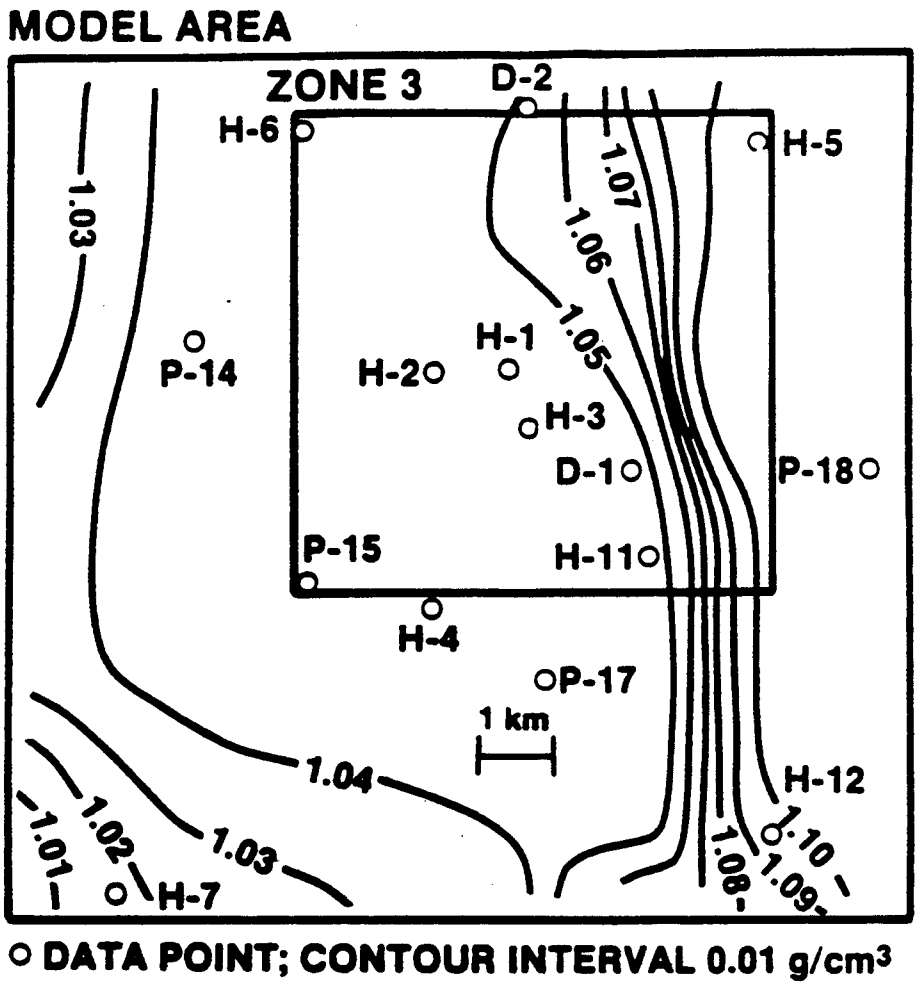


Figure 4.1.14: Calculated steady-state, brine-density distribution within the Culebra dolomite, based on data available as of April 1986. Slightly modified from Figure 4.7 of Haug et al. (1987).

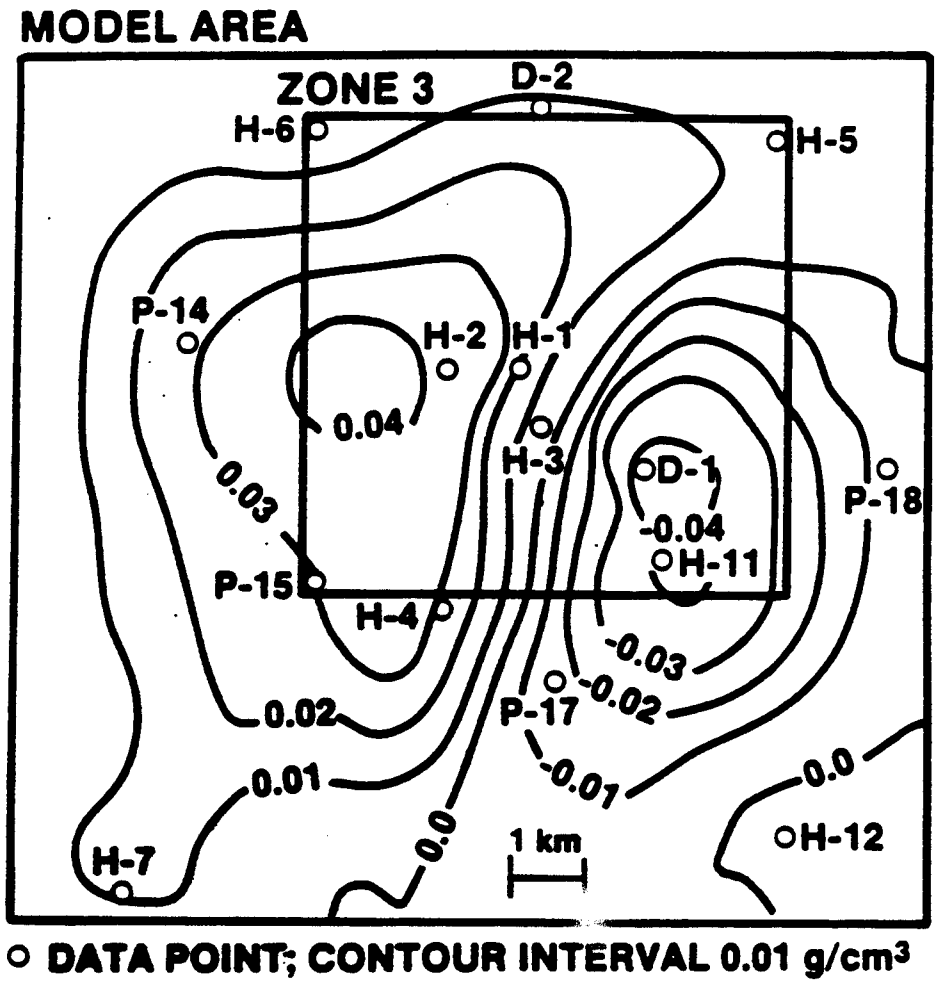


Figure 4.1.15: Difference between calculated steady-state brine density distribution within the Culebra (Figure 4.1.14) and the measured estimated distribution shown in Figure 4.1.13. Slightly modified from Figure 4.8 of Haug et al. (1987).

Haug et al. (1987) initially addressed the density contrast over the western portion of the modeled area by assuming that brine densities along the northern boundary of the model were incorrect; therefore, calibration against fluid density did not change interpolated transmissivities in this area. In the vicinity of hole P-17, however, better agreement between calculated and measured fluid densities was obtained by shifting the location of the southern high-transmissivity zone in Figure 4.1.12 closer to P-17.

Haug et al. (1987) then considered the possibility of vertical fluid flow into and/or out of the Culebra dolomite in two areas:

1. At and near P-17, where measured brine densities were 0.04 g/cm^3 higher than those calculated. Upward flow of relatively dense brine from the Rustler/Salado contact zone, through the unnamed lower member of the Rustler, into the Culebra dolomite was considered at this location, consistent with known head relationships (see Section 4.1.1).

2. Over the western and southwestern part of the modeled area, in which measured fluid densities are significantly less than modeled densities. Uniform downward flow of relatively fresh (low-density) fluids from the Magenta into the Culebra was considered in this area.

Assuming a brine density of 1.19 g/cm^3 for the Rustler/Salado contact zone and/or unnamed lower member of the Rustler in the region near P-17, Haug et al. (1987) estimate that a vertical flux of 10^{-12} m^3/m^2s would be sufficient to result in a calculated brine density within the Culebra of 1.06 g/cm^3, the measured value. Given the approximate vertical gradient of 0.18 m/m at this location, based on head relations shown in Mercer (1983), this flux would require a vertical hydraulic conductivity of 5.7 x 10^{-12} m/s in the unnamed member. This is within the range thought reasonable (Haug et al., 1987), but slightly higher than recently measured adjacent to the WIPP waste-handling shaft (Section 3.3.1.2). Thus, a very small upward flux into the Culebra in the vicinity of P-17 appears to be largely consistent with known data, and improves agreement between measured and calculated brine densities in the area. However, it is not feasible to measure the small flux in a reasonable time in the field.

In considering fluid flow from the Magenta dolomite downward into the Culebra over the western portion of the modeled area, Haug et al. (1987) assumed a brine density of 1.00 g/cm^3 for the Magenta. Addition of a small but constant vertical flux of 5 x 10^{-12} m^3/m^2s over the western portion of the model led to two qualitatively different responses:

1. In areas of low Culebra transmissivity, the resulting freshwater-equivalent heads were increased significantly, causing unacceptable disagreement between calculated and observed heads. In these areas, however, the assumed flux did significantly decrease the calculated brine densities within the Culebra.

2. In areas of high Culebra transmissivity, addition of the vertical flux did not significantly harm the agreement between calculated and

measured freshwater heads, nor did it significantly improve the agreement between measured and calculated brine densities within the Culebra.

Vertical flux from the Magenta downward into the Culebra dolomite over the western portion of the modeled area is consistent with known head and fluid-density relationships in some areas (Section 4.1.1.2). However, the flux, if real, must be laterally variable rather than constant, and the vertical conductivity of the Tamarisk claystone and anhydrites between the Magenta and Culebra may simply be too low at and near the site. The modeling results of Haug et al. (1987) suggest that vertical flow rates must be higher in regions in which the Culebra is more transmissive, and lower in regions where it is less transmissive. This amount of coupling of Culebra transmissivity with that of the overlying Tamarisk and Magenta members has not been identified in the regional variations in transmissivities of the different members of the Rustler at and near the WIPP site. For example, the transmissivity of the Tamarisk claystone, between the Magenta and Culebra, is too low for measurement at and near the site; the transmissivity of the Tamarisk anhydrites may be even lower. Given enough modeling time and effort, it appears that excellent agreement between measured and calculated brine densities within the Culebra dolomite could be obtained by calibration against both transmissivity distribution in the Magenta, Tamarisk, and Culebra and vertical flux, assuming steady-state boundary conditions. However, this agreement would not in any way be unique, and might not be consistent with the inability to measure properties within the Tamarisk. This is not to say that vertical flow is not occurring within the Rustler Formation (see Sections 4.1.1 and 4.4), simply that data are not adequate to model it precisely. The extremely low transmissivity of the Tamarisk claystone and anhydrites, relatively high transmissivity of the Culebra, and geochemical relationships within the Rustler (Section 4.4) suggest that transient confined flow within the Culebra dominates Rustler hydrology at and near the WIPP site.

In summary, model calibration to the Culebra pre-shaft head distribution by Haug et al. (1987) largely met with success, but also indicated uncertainties in the understanding of Culebra and Rustler hydrology. Calibration to the freshwater head distribution was successful to within one meter of measured values. Assuming steady-state confined flow, however, the resulting Culebra transmissivity distribution was not successful in simulating the measured brine-density distribution. In the eastern portion of the model, the required adjustment in transmissivity was minor. Over the western portion of the model, the results of Haug et al. (1987) indicated that: 1) the April 1986 understanding of brine densities may be qualitatively incorrect; 2) there may be regional-scale vertical flow within the Rustler Formation; and/or 3) the hydrologic setting of the Rustler Formation may be transient on the time scale required for groundwater flow across the modeled area.

The next step in model calibration by Haug et al. (1987) was simulation of transient stresses within the modeled area, assuming steady-state boundary conditions. Several transient activities were simulated, including: 1) sinking and grouting of the three existing WIPP shafts; 2) three pumping

tests and slug tests at H-2; 3) convergent-flow tracer testing at H-3; 4) a step-drawdown hydraulic test at H-3; and 5) the multipad interference test at H-3.

Responses to shaft sinking and grouting (both occurring before the H-3 multipad test) were well simulated using the density-calibrated transmissivity distribution estimated by calibration to the pre-shaft head distribution. From this, Haug et al. (1987) concluded that the transmissivity distribution in the region containing H-1, H-2, H-3, DOE-1, and H-11 was approximately correct.

Responses in the WIPP shafts and in holes WIPP-19, 21, and 22 during and after the H-3 multipad test could not be simulated closely unless additional leakage in the shafts was assumed to have occurred during the test. This conclusion, while coincidental, is supported by the fact that the hydraulic responses to sinking and initial grouting of the shafts were well simulated using the "steady-state" transmissivity distribution, while the later H-3 test itself was not.

The final calculated Culebra transmissivity distribution and fluid-flow velocities estimated on the basis of data available as of April 1986 and including adjustment for fluid-density effects in the eastern half of the model are shown in Figure 4.1.16. Four features are of note in this figure:

1. Fluid flow (presented as Darcy velocities) is extremely slow in the area H-12 - H-5 - WIPP-12. Calculated Darcy velocities in this area are 10^{-9} m/s or less.

2. Fluid flow in the southeastern portion of the model is strongly dominated by the high-transmissivity zone in the area H-11 - DOE-1 - P-17. Flow in this area is largely north-south, with Darcy velocities of approximately 10^{-8} m/s.

3. Flow in the northwest and western portions of the modeled area is rapid and largely north-south. Darcy velocities in this area range approximately from 5×10^{-9} to 1×10^{-8} m/s.

4. The region near the center of the WIPP site (WIPP-12 - P-15 - P-17) has relatively low Darcy velocities, approximately 1×10^{-9} to 3×10^{-9} m/s. The high-transmissivity zone to the southeast forces fluid flow in the region between H-4 and the center of the site to be northwest-southeast, in effect connecting the two high-transmissivity zones southeast and northwest of the site center. The control for this flow at the time of the H-3 multipad test was limited, since hole H-14 did not exist at that time.

As discussed in Section 4.1.2, interference testing at the H-3 and H-11 hydropads indicates the strong local influence of fracturing on hydraulic response. Haug et al. (1987) investigate whether or not a dual-porosity formalism is required to model regional-scale responses within the Culebra dolomite by examining times required for pressure equilibration between matrix blocks and fractures.

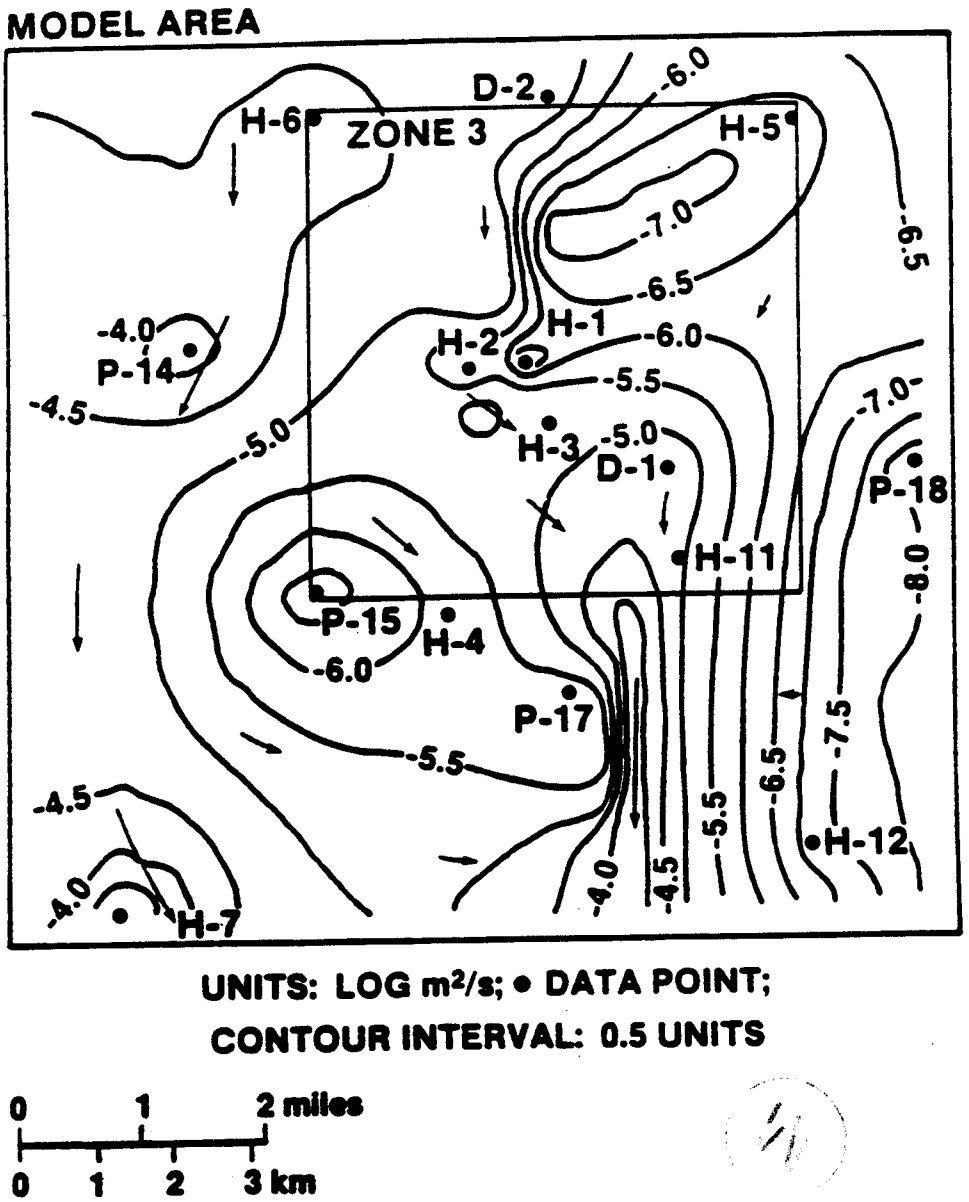


Figure 4.1.16: Final calculated Culebra transmissivities and flow directions, based on data available as of April 1986. Slightly modified from Figure 4.11 of Haug et al. (1987).

The time required for pressures in the fracture and matrix in a fractured medium to equilibrate to within 1% is proportional to the square of matrix block size and linearly proportional to the fluid diffusivity within the matrix. For a range of Culebra matrix block sizes (fracture spacings) between 1 and 8 m and a representative range of matrix compressibilities, matrix porosities, and matrix conductivities, Haug et al. (1987) calculate a maximum pressure-response time of 26 days. For the base-case properties interpreted from conservative-tracer testing at the H-3 pad (Section 4.2) the calculated pressure response time is only six hours. Based on these preliminary calculations, Haug et al. (1987) conclude that a dual-porosity formalism is not needed in modeling the regional-scale hydraulic responses within the Culebra dolomite at and near the WIPP site. Haug et al. (1987) modeled the transient hydraulic responses at the H-3 hydropad to both shaft sinking and sealing and the H-3 multipad interference test using both dual-porosity and porous-medium formalisms to examine this conclusion further. Consistent with their conclusion that use of the dual-porosity formalism is not needed at a regional scale, the maximum difference between the transient freshwater heads calculated using the two approaches is 0.02 m.

However, the validity of this conclusion is somewhat limited by the range of fracture spacings considered. The correlation between fracturing and transmissivity within the Culebra discussed in Section 4.1.1 indicates that fracturing is significant in areas of transmissivity greater than approximately 10^{-6} m^2/s. The approximate fracture spacing at the H-3 pad, with a transmissivity of 2×10^{-6} m^2/s, is 0.25 to 1 m (Section 4.2). Zones of higher transmissivity presumably have smaller effective block sizes. The preliminary calculations of Haug et al. (1987) indicate that it is in zones of otherwise low transmissivity, in which fracturing is not evident in single-hole testing, and in which fracture spacings may significantly exceed the thickness of the Culebra, that hydraulic behavior on something approaching the regional scale might be controlled by fracturing. However, there is no evidence of any discrete fracture structures within low-transmissivity portions of the Culebra dolomite at or near the WIPP site.

In summary, fielding and interpretation of the H-3 multipad interference greatly increased the understanding of the hydrology of the Culebra Dolomite Member of the Rustler Formation. It emphasized the role of fracturing and lack of hydraulic anisotropy within the H-3 hydropad. The analytical interpretation by Beauheim (1987a) indicated the presence of a high-transmissivity region in the vicinity of H-11 and DOE-1, suggested strong directional dependence of responses to the test, and suggested that transmissivities between H-3 and H-4 were probably less than 10^{-6} m^2/s, an interpretation later confirmed by drilling and testing of hole H-14. The interpretation of Tomasko and Jensen (1987) indicated that regional-scale flow in the southeastern portion of the WIPP site was probably controlled by a linear high-transmissivity zone. Numerical modeling of the site area by Haug et al. (1987) yielded a more complete estimate of the lateral distribution of Culebra transmissivities, qualitatively consistent with the interpretations of Beauheim (1987a) and Tomasko and Jensen (1987). A high-transmissivity region in the vicinity of H-11 and DOE-1 was interpreted to be present, in addition to a largely separate high-transmissivity zone west and northwest of the site center. Large areas northeast, east, and

southwest of the site center appeared to have low transmissivity. The interpretation of Haug et al. (1987) indicated both that fluid flow on the WIPP site proper was largely controlled by the high-transmissivity zone containing holes H-11 and DOE-1, and that the effects of this zone included northwest to southeast flow across the area including H-4 and the site center itself. Consideration of discrete fractures or inclusion of dual-porosity formalism appears not to be required to model the regional-scale hydrologic behavior of the Culebra dolomite at and near the WIPP site.

Limitations to interpretation of the H-3 multipad test strongly influenced hydrologic field activities in 1986 and 1987. On a regional scale, the information gained through the H-3 test supported fielding and interpretation of a test centered at WIPP-13, which is discussed in the next section. In preparation for this test, updated and more-reliable data on the Culebra were collected at DOE-2, and a series of WIPP holes (13, 18, 19, 21, and 22). The paucity of reliable data in the southern half of Zone 3 led to the drilling and testing of H-14 and H-15, as well as to reentry and testing of the Culebra in P-17, H-4c, P-14, P-15, Cabin Baby-1, and ERDA-9. The scarcity of head-potential and hydraulic-property data from members of the Rustler other than the Culebra led to testing of all members in holes H-14, and H-16. H-16 itself was sited primarily to address the problem of linkage between all five members of the Rustler Formation and the WIPP air-intake shaft.

4.1.3.2 The WIPP-13 Multipad Interference Test and the Regional Culebra Model of LaVenue et al. (1988)--The second regional-scale or multipad interference test of the Culebra dolomite was centered at hole WIPP-13 (Figures 1.2 and 4.1.17). The pumping phase of the WIPP-13 test lasted from January 12, 1987, to February 17, 1987. Water levels were monitored continuously in 17 surrounding wells, at distances ranging from 1280 to 6248 m. Analytical interpretation of the WIPP-13 multipad test is discussed by Beauheim (1987c). Numerical simulation of Culebra transmissivities and pre-shaft heads in an area including that examined in the WIPP-13 test is the primary focus of LaVenue et al. (1988). This effort includes evaluation of long-term transient hydrologic data at and near the WIPP site. Detailed modeling of transient effects of the WIPP-13 multipad test will be combined during 1988 with calibration of the transient effects of a planned multipad interference test at the H-11 hydropad and emplacement of the WIPP air-intake shaft.

The effects of dual-porosity behavior were quite strong in WIPP-13 during the pumping phase of the WIPP-13 test (Figure 4.1.18). The Culebra in WIPP-13 has an estimated transmissivity of 7.4×10^{-5} m^2/s (Beauheim, 1987c). The Culebra in and near WIPP-13 is best thought of as a double-porosity medium with unrestricted interporosity flow (Beauheim, 1987c).

The analytical interpretation by Beauheim (1987c) indicates that WIPP-13 lies within a relatively homogeneous fractured region, which includes WIPP-13 and DOE-2, as well as the H-6 hydropad (both H-6a and H-6b were monitored during the WIPP-13 test). DOE-2, at a distance of 1475 m from WIPP-13, responded within one hour to the beginning of pumping, while H-6b, at a distance of 2188 m, responded within 8 hours (Table 4.7). The

LOCATIONS OF THE WIPP SITE AND OBSERVATION WELLS

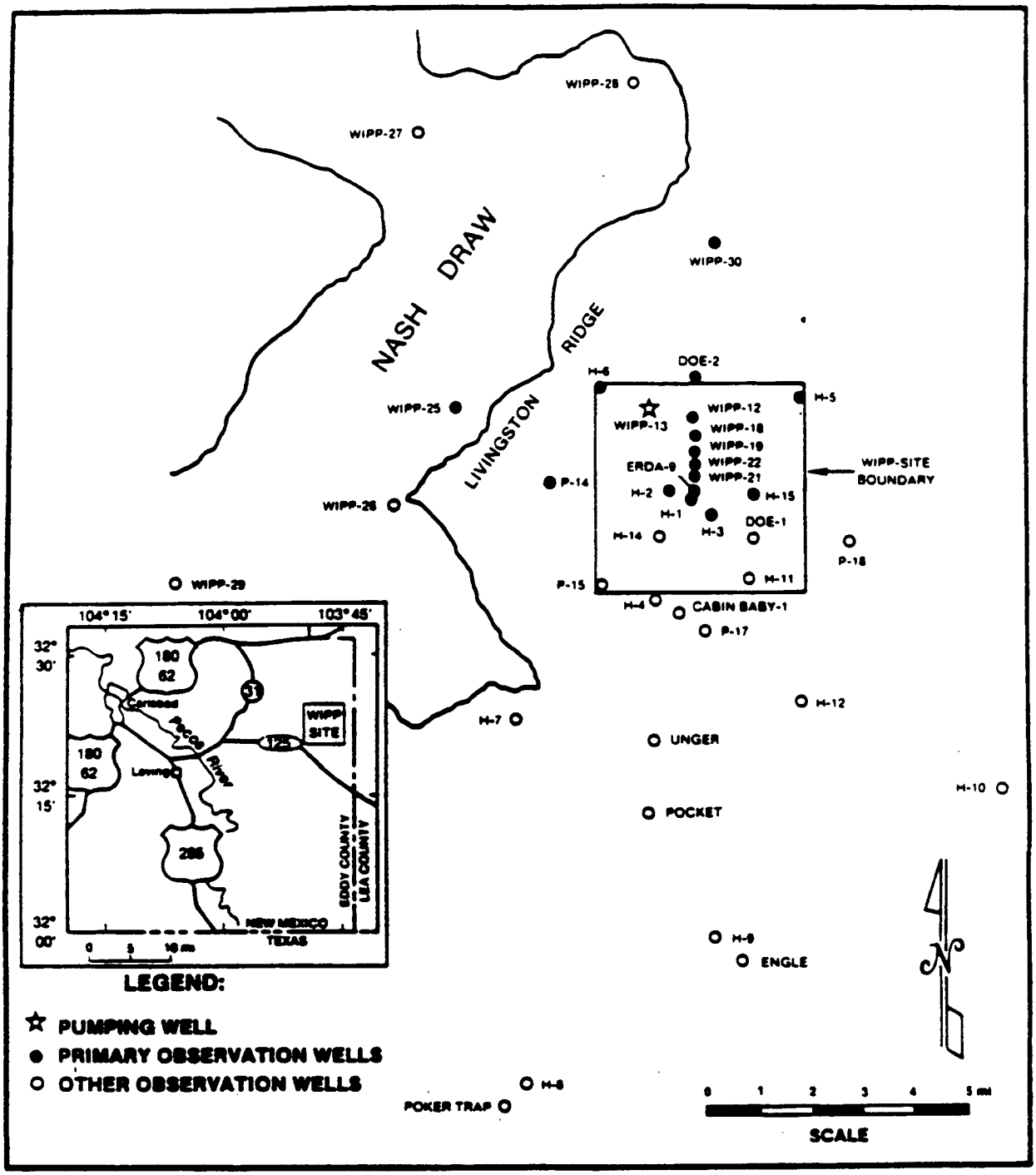


Figure 4.1.17: Pumped and observation wells for the WIPP-13 multipad interference test. Figure 1-1 of Beauheim (1987c).

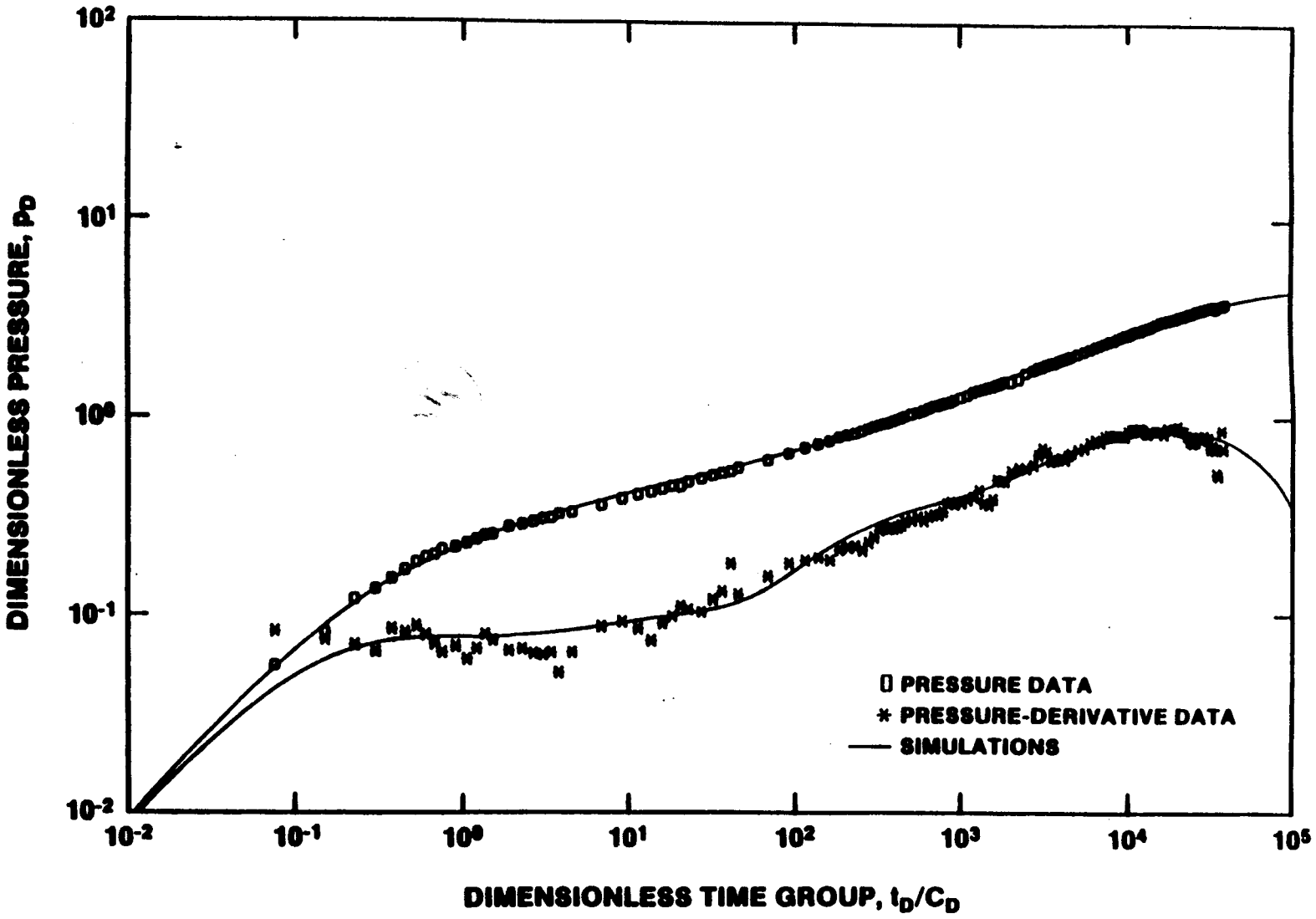


Figure 4.1.18: Measured and simulated hydrologic response of WIPP-13 during the pumping phase of the WIPP-13 multipad interference test. Slightly simplified from Figure 6-1 of Beauheim (1987c).

Table 4.7: Summary of analytical interpretation of results of the WIPP-13 multipad interference test. Slightly modified from data conatined in Tables 3-1, 5-1, and 6-1 of Beauheim (1987c).

Well	Distance(m)[1]	Direction	First [2] Drawdown (hrs)	Delay in Max. Drawdown (hr)	Maximum Drawdown (Psi)	T(m^2/s)[3]	S	Water-Level Modification (m/day)
WIPP-13	0	-	0	0		7.4×10^{-5}	-	-
DOE-2	1475	N45E	1	1	17.3	6.1×10^{-5}	5.1×10^{-6}	-
H-6a	2192	N20W	8	5	7.7	7.6×10^{-5}	8.2×10^{-6}	-
H-6b	2189	N20W	8	5	7.9	7.4×10^{-5}	7.9×10^{-6}	-
WIPP-30	5587	N12E	61	136	4.9	3.0×10^{-5}	5.6×10^{-6}	5.3×10^{-3}
WIPP-12	1283	S55E	74	186	11.9	8.5×10^{-6}	3.6×10^{-5}	4.5×10^{-3}
WIPP-18	1521	S45E	74	86	9.3	2.5×10^{-5}	4.0×10^{-5}	3.6×10^{-3}
WIPP-19	1823	S37E	102	186	7.2	2.6×10^{-5}	4.0×10^{-5}	7.6×10^{-3}
WIPP-21	2216	S29E	133	396	3.6	2.4×10^{-5}	5.3×10^{-5}	1.7×10^{-2}
WIPP-22	1933	S34E	102	286	5.7	2.0×10^{-5}	4.7×10^{-5}	8.2×10^{-3}
H-1	2676	S16E	600	2086(?)	1.1	2.2×10^{-5}	1.3×10^{-4}	1.4×10^{-2}
H-2b2	2597	S0W	445	986	1.4	1.7×10^{-5}	7.3×10^{-5}	6.0×10^{-3}
ERDA-9	2518	S24E	550	396	2.0	2.4×10^{-5}	5.4×10^{-5}	1.6×10^{-2}
Exhaust shaft	2414	S26E	400	336	3	3.0×10^{-5}	5.5×10^{-5}	2.9×10^{-2}
P-14	4228	S58W	71	56	0.8	2.8×10^{-4}	5.2×10^{-5}	-
WIPP-25	6264	S88W	76	26	0.3	7.0×10^{-4}	6.4×10^{-5}	-

(1) Distance and direction from WIPP-13.
(2) Time relative to beginning and ending of pumping phase.
(3) Apparent and effective transmissivity (T) and storativity (S) assume homogenous properties between WIPP-13 and given well, as well as radial flow into WIPP-13.

apparent average transmissivities between WIPP-13 and holes DOE-2 and H-6b are 6.1×10^{-5} m^2/s and 7.4×10^{-5} m^2/s, respectively. The rapid responses at DOE-2 and H-6b and the low apparent storativities between these holes and WIPP-13, 5.1×10^{-6} and 7.9×10^{-6}, respectively, suggest that the hydraulic response in this region is strongly affected by fracturing (Beauheim, 1987c).

The boundaries of the zone containing WIPP-13, DOE-2, and H-6 are complex. To the north, the zone appears to extend nearly to hole WIPP-30 (Beauheim, 1987c). This interpretation is based largely on the fact that WIPP-30, with a reported transmissivity of only 3.2×10^{-7} m^2/s (Beauheim, 1987b; Mercer, 1983) and at a distance of 5587 m from WIPP-13, responded within 61 hours to the beginning of pumping. In addition, the apparent average storativity between WIPP-13 and WIPP-30, 5.6×10^{-6}, is similar to that calculated between WIPP-13 and both DOE-2 and H-6b. Analytical interpretation of the response of DOE-2 to pumping of WIPP-13 requires addition of a low-permeability boundary; i.e., the response at DOE-2 shows the effects of a low-permeability region nearby. A change from high to low Culebra transmissivities must occur somewhere between DOE-2 and WIPP-12, as well as between DOE-2 and H-5.

Results contained in Beauheim (1987b) indicate a Culebra transmissivity of approximately 1.0×10^{-7} m^2/s in WIPP-12 (Table 4.2). The apparent average transmissivity between WIPP-13 and WIPP-12 is 8.5×10^{-6} m^2/s (Beauheim, 1987c). WIPP-12, only 1283 m from WIPP-13, did not respond to pumping of WIPP-13 until 74 hours into the test. Thus, by analogy with arguments concerning the response of WIPP-30, the boundary between the high-transmissivity zone containing WIPP-13 and the low-transmissivity zone containing WIPP-12 must lie relatively close to WIPP-13.

South of WIPP-12, the boundary between high-transmissivity and low-transmissivity domains probably lies further away from WIPP-13. Holes WIPP-18, 19, 21, 22; H-1, 2; and ERDA-9 all have estimated Culebra transmissivities of 1.0×10^{-6} m^2/s or less (Table 4.1). The apparent effective average transmissivities between WIPP-13 and these holes range from 1.7×10^{-5} to 2.6×10^{-5} m^2/s (Table 4.7), while that between WIPP-13 and the WIPP exhaust shaft is 3.0×10^{-5} m^2/s. Times required for the first response to pumping of WIPP-13 range from 74 to 600 hours, including the exhaust shaft. The high-transmissivity zone containing WIPP-13 is consistently represented as a high-permeability boundary in interpretation of the response of these observation holes (Beauheim, 1987c). The apparent behavior between WIPP-13 and the WIPP exhaust shaft is consistent with that between WIPP-13 and nearby observation holes. Beauheim (1987c) notes that the responses in both ERDA-9 and the exhaust shaft appear to be complicated by activities within the shaft.

The relatively homogeneous zone containing WIPP-13, DOE-2, and H-6 appears to be bounded on the west by a zone of higher transmissivity extending into the main portion of Nash Draw (Beauheim, 1987c). Apparent transmissivities between WIPP-13 and holes P-14 and WIPP-25 are 2.8×10^{-4} and 7.0×10^{-4} m^2/s, respectively. Hole WIPP-25, at a distance of 6264 m from WIPP-13, was the most distant monitoring hole used in the test (Figure 4.1.17).

The presence of both higher-transmissivity and lower-transmissivity domains outside the WIPP-13 - DOE-2 - H-6 region is consistent with the fact the analytical interpretation of the hydrologic behavior at WIPP-13 required the addition of both low-permeability and high-permeability boundaries (Beauheim, 1987c). In addition, a linear-flow interpretation of the flow near WIPP-13 analogous to that completed for the H-3 multipad test by Tomasko and Jensen (1987) was not successful.

The numerical simulation of Culebra hydrology over a large area, including the region stressed in the WIPP-13 test, is discussed and summarized in LaVenue et al. (1988). The emphasis in LaVenue et al. (1988) is on simulation of the Culebra hydrology as it existed before construction of the WIPP shafts, i.e., prior to 1981. Detailed numerical interpretation of the transient hydrologic stresses imposed by the WIPP-13 multipad test, sinking of the WIPP air-intake shaft, and a combined multipad interference test and conservative-tracer test at the H-11 pad will be conducted in 1988.

As noted in Section 4.1.1, there has been a significant increase in the Culebra transmissivity, head, and fluid-density data base since April 1986. In addition, as evident in Figure 4.1.19, the area included in modeling described in LaVenue et al. (1988), 24 x 25 km, is significantly larger than that included in Haug et al. (1987) (see Figure 4.1.6). As a result, the total data base considered in LaVenue et al. (1988) is much larger than that considered only 1.5 years earlier. Culebra transmissivity data from 38 individual wells or hydropads are considered in the 1988 report, as opposed to 24 locations in the 1987 report (Table 4.1). Compilation of the data base used by LaVenue et al. (1988) was significantly more complex for the data base used by Haug et al. (1987), both because of the increased number of holes and because of the increased awareness and concern about transient phenomena in Rustler hydrology. For example, development of the baseline water-level data required consideration of long-term transients, even in holes not directly affected by hydraulic testing at and near the WIPP site. In addition, some well locations were resurveyed (LaVenue et al., 1988); most Culebra fluid densities were revised as a result of recent sampling (Uhland et al., 1987), and were evaluated by detailed pressure-density surveys (Crawley, 1987).

The initial kriged Culebra transmissivities of LaVenue et al. (1988) are shown in Figure 4.1.19, based on data available as of November 1987. The general pattern is different from that indicated in Haug et al. (1987) (Figure 4.1.9). The increase in the available data base results in the initial kriged distribution in Figure 4.1.19 varying smoothly across much of the site area. The kriged transmissivities tend to be higher towards the west and lower towards the east, with an isolated zone of higher transmissivities at H-11 and DOE-1. In Figure 4.1.9, with the exception of the hole pairs H-1 - H-2 and H-11 - DOE-1, each data point tends to define a separate transmissivity zone.

The effects of the increased number of measurements on the Culebra transmissivity data base are demonstrated more clearly by comparison of Figure 4.1.10 with Figures 4.1.20 and 4.1.21. Kriging of the transmissivity data base available as of April 1986 (Figure 4.1.10) indicated that regions of

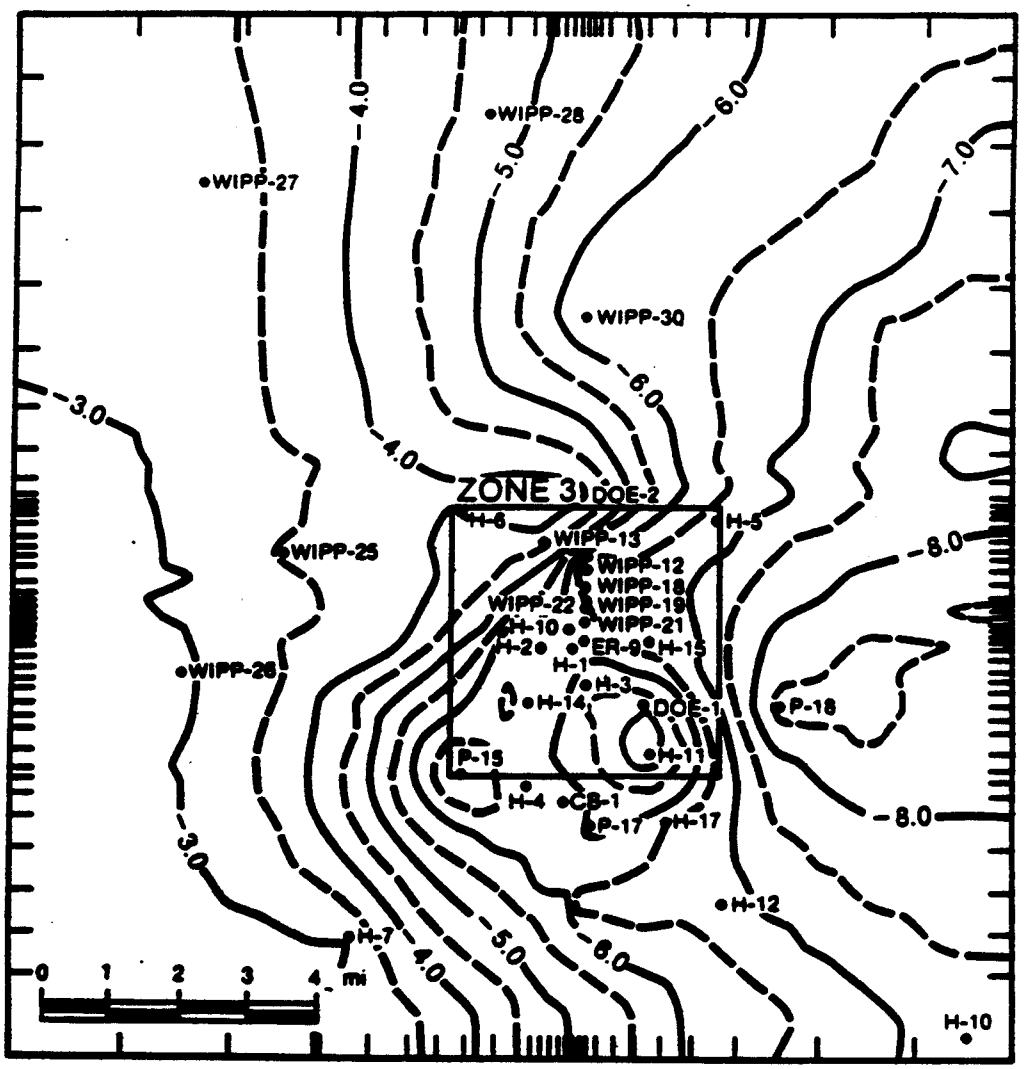


Figure 4.1.19: Initial kriged Culebra transmissivities, based on data available as of November, 1987. Values kriged with code AKRIP. Figure 3.12A of LaVenue et al. (1988).

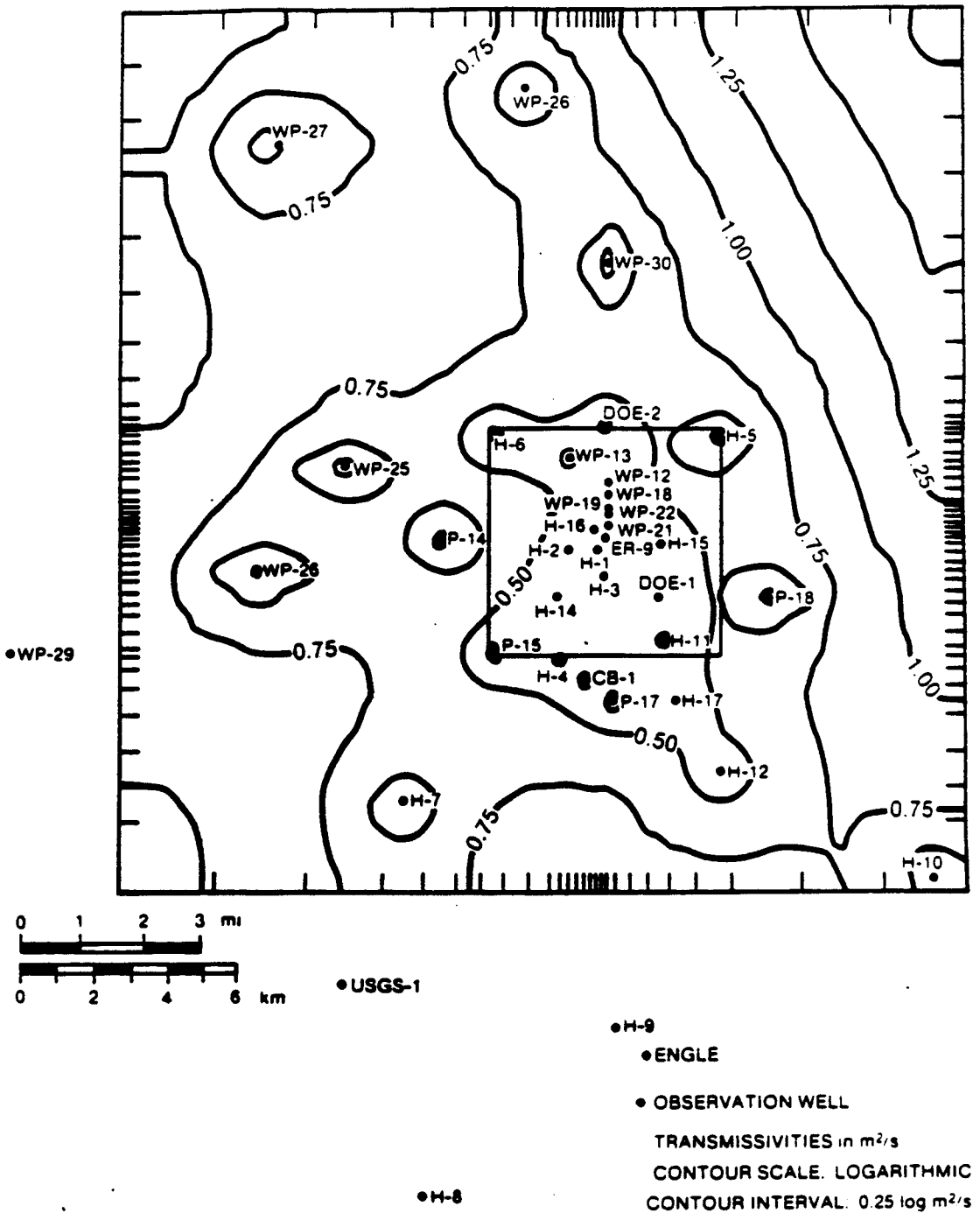


Figure 4.1.20: Estimation error in initial kriged Culebra transmissivities (one standard deviation), based on data available as of November 1987, assuming no uncertainty in individual measurements. Values kriged using code AKRIP. Figure 3.12B of LaVenue et al. (1988).

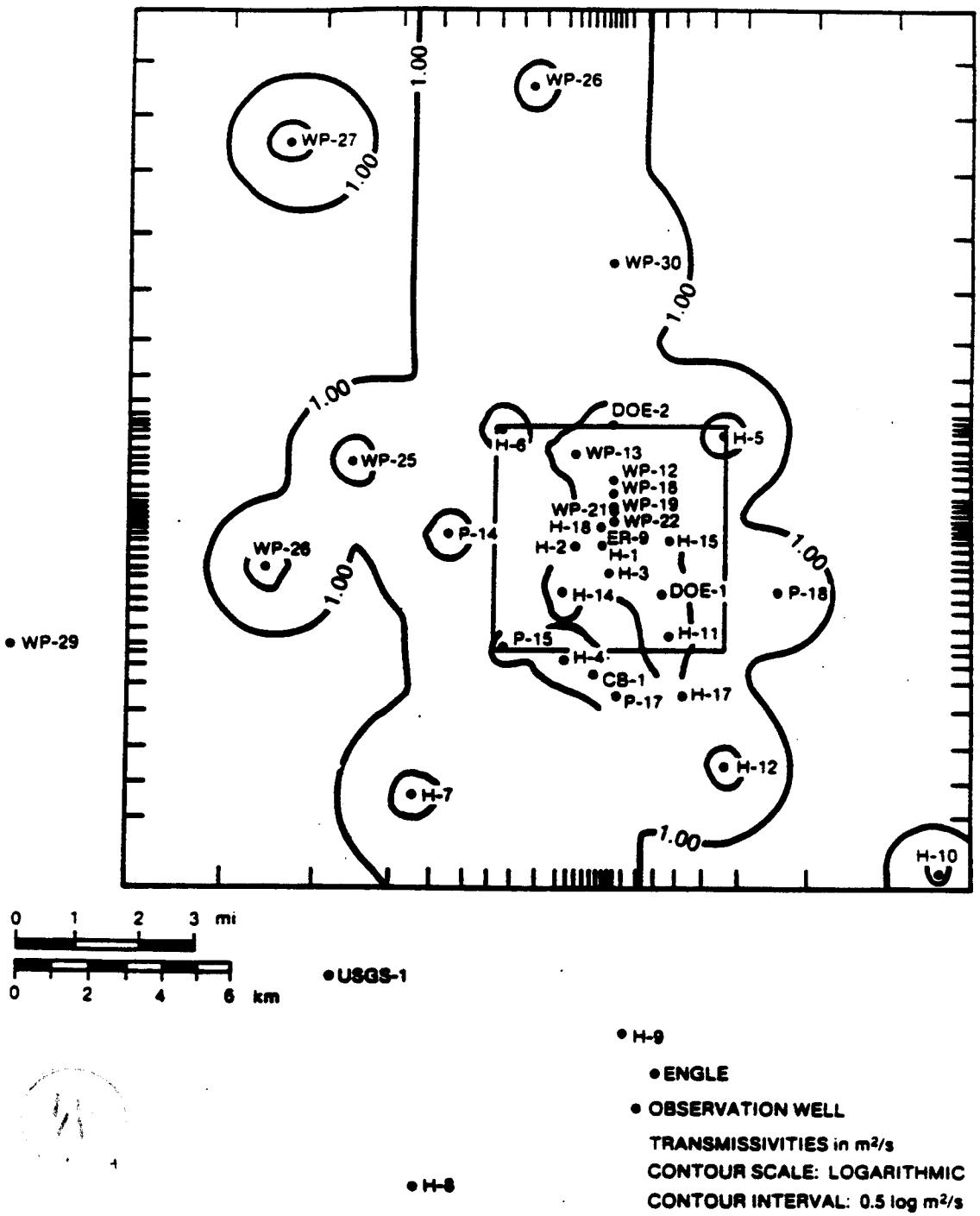


Figure 4.1.21: Estimation error in initial kriged Culebra transmissivities (one standard deviation), including estimated uncertainty in individual measurements. Values kriged using code K603. Figure 3.11B of LaVenue et al. (1988).

one order of magnitude uncertainty (defined at one standard deviation) did not overlap, except in very limited areas. Because of the limited data base available at that time, it was not possible for Haug et al. (1987) to consider either an underlying regional trend in the data or uncertainty in the measured data.

LaVenue et al. (1988) apply two kriging techniques to the Culebra transmissivity data in order to consider both the regional west-to-east decrease in transmissivities (Figure 4.1.19) and uncertainties in the measured data. Kriging of the enlarged data base using the AKRIP code, which fits a polynomial surface to the regional trend, but does not consider uncertainty in the measured data (LaVenue et al., 1988), indicates that the uncertainty in Culebra transmissivities over a large area, including most of Zone 3, should be less than 0.5 log unit at one standard deviation and less than one order of magnitude (1.0 log unit) at two standard deviations (Figure 4.1.20). Within the smaller area including both the center of the WIPP site and the locations the WIPP shafts, the uncertainty at two standard deviations is 0.5 log units or less; i.e., Culebra transmissivities should be estimated to within a factor of approximately three in this region, if it is assumed that field measurements are precise.

Results analogous to those in Figure 4.1.20, calculated by LaVenue et al. (1988) using the K603 code, which applies a linear trend surface to regional data, but allows consideration of uncertainty in measured data, are shown in Figure 4.1.21. LaVenue et al. (1988) estimate the uncertainty in measurements of Culebra transmissivities to be 0.25 log unit when transmissivity is estimated from pumping tests and 0.5 log units when estimated from other tests. Inclusion of these estimated uncertainties in individual measurements, combined with a simplified regional trend surface, suggests (Figure 4.1.21) an estimation error (one standard deviation) of 0.5 log unit or less within most of Zone 3. These results indicate that the uncertainty in Culebra transmissivities at two standard deviations within much of Zone 3, i.e., in a region extending from DOE-2 in the north to beyond H-11 in the south, is less than an order of magnitude, even including the estimated uncertainties in field measurements.

Such statistical approaches must not be overinterpreted, because they include no direct consideration of geologic processes. However, comparison of Figures 4.1.20 and 4.1.21 with Figure 4.1.10 provides a direct impression of the qualitative increase in both the size and reliability of the Culebra data base since April 1986.

The present distribution of measured Culebra fluid densities (LaVenue et al., 1988) is shown in Figure 4.1.22. Although the overall pattern is similar to that estimated on the basis of data available in April 1986 (Figure 4.1.13), with a general west-to-east increase in density, there are two significant differences. The density distribution in the west half of Zone 3 in Figure 4.1.13 is strongly non-linear, due to relatively high densities at H-6 and/or DOE-2. The variation in fluid densities in the region H-1 - DOE-2 - H-6 - P-14, based on data available as of November 1987 (Figure 4.1.22), is less irregular, and the regional trend is more consistent with the general west-to-east increase in density. Fluid

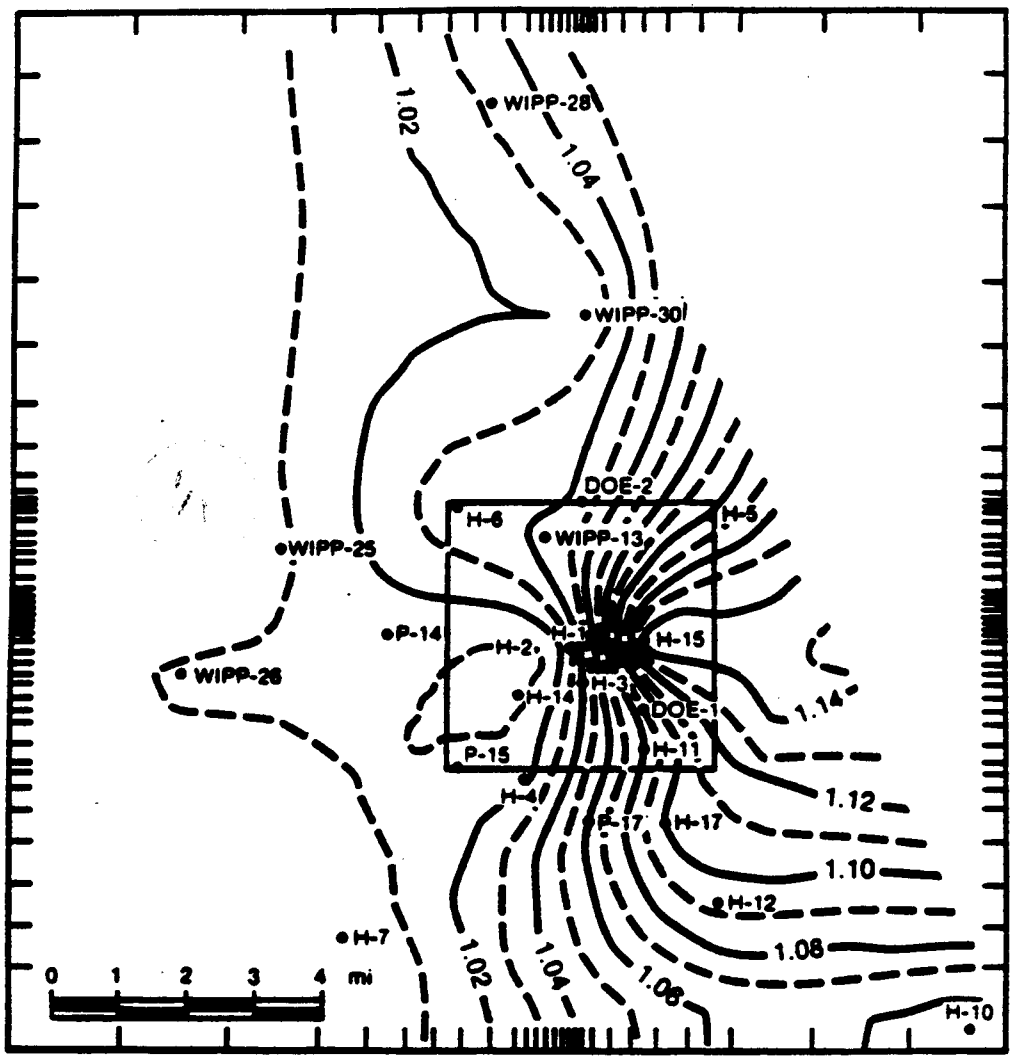


Figure 4.1.22: Measured density distribution of Culebra fluids, based on information available as of November 1987. Figure 3.15 of LaVenue et al. (1988).

densities in the region H-14 - H-2 - P-14 still appear to be anomalously low. The brine density distribution in the eastern part of Zone 3 (Figure 4.1.22) is also somewhat different than in Figure 4.1.13. In Figure 4.1.13, a general north-south trend of constant-density lines extends largely across the WIPP site west of holes DOE-1 and H-11. The distribution is more complex east of these holes. In Figure 4.1.22, the estimated brine density of approximately 1.14 g/cm^3 at hole H-15 causes significant curvature in the density distribution in the eastern portion of Zone 3. Nonetheless, the overall pattern of the distribution of Culebra brine densities based on data available as of November 1987 is simpler than previously estimated.

The present understanding of the distribution of pre-shaft freshwater-equivalent heads within the Culebra dolomite is shown in Figure 4.1.23. The general pattern is similar to that estimated by Haug et al. (1987), with a north-south head gradient of approximately 10^{-3} m/m across the area of the WIPP site. Gradients within the Culebra both south and north of the site are lower, approximately 10^{-4} m/m.

There is, however, one significant difference between the head distributions shown in Figures 4.1.23 and 4.1.11. Head contours form a sharp embayment in the southeastern portion of Zone 3 in Figure 4.1.11, extending at least as far north as the east-center of the site. Interpretation of water-level and fluid-density data available to November 1987 indicates (Figure 4.1.23) that there is little evidence of an embayment in Culebra freshwater-equivalent heads within WIPP Zone 3, except for the 913-m contour in the extreme southern part of the zone. Within the modeled area, head contours up to 919 m elevation do define a broad embayment south and east of the WIPP site. Expansion and improvement of the data base for calculation of Culebra freshwater-equivalent heads during 1986 and 1987 has resulted in significant smoothing of the estimated head distribution, especially within Zone 3.

In calibration efforts by Haug et al. (1987), it was assumed that Culebra fluid pressures and fluid densities were at steady state before construction of the WIPP shafts. As discussed in Section 4.1.3.1, assumption of steady state is adequate for simulation of pre-shaft Culebra heads or fluid pressures. The results in Haug et al. (1987), however, indicated problems with the assumption of steady-state confined flow in simulation of Culebra brine densities. The calibration approach taken by LaVenue et al. (1988) differed from that taken earlier. LaVenue et al. (1988) assumed that the fluid-density distribution remains fixed on the time scale required for pressure equilibration, and no calibration against the brine-density distribution was attempted. The calculations do take account of the variable fluid density at each point within the Culebra; they assume that effects of variable brine density on the modern flow directions can be estimated reliably fixing the modern fluid-density distribution in place. The results of calibration of Culebra transmissivities against the freshwater-equivalent head distribution shown in Figure 4.1.23, assuming that the fluid-density distribution shown in Figure 4.1.22 remains fixed (LaVenue et al., 1988), are shown in Figure 4.1.24.

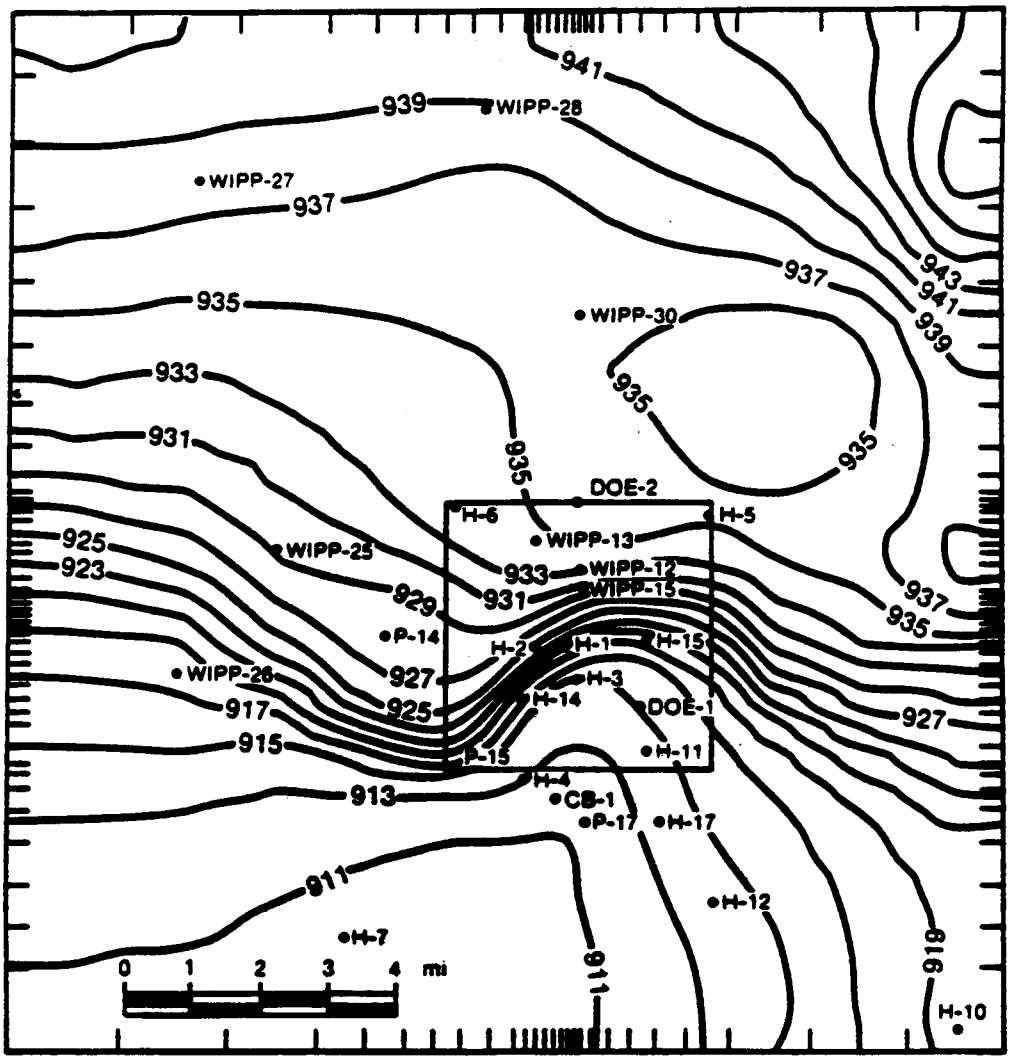


Figure 4.1.23: Estimate of pre-shaft, freshwater-equivalent heads in the Culebra dolomite, based on data available as of November 1987. Figure 3.14 of LaVenue et al. (1988).

The overall distribution of calibrated transmissivities (Figure 4.1.24) is not greatly different from the initial kriged distribution (Figure 4.1.19). The general trend of decreasing transmissivities from west to east is preserved. During calibration, transmissivities west of WIPP-30 and WIPP-28 were increased. Transmissivities in the area containing H-6, P-14, and WIPP-25 were generally decreased slightly, while those in the southern part of Nash Draw were increased. The low-transmissivity domain in WIPP Zone 3 ($T < 10^{-6}$ m^2/s) is expanded in the more recent interpretation (Figure 4.1.24). This region, including the center of the WIPP site, is now expected to be continuous from H-5 in the northeast to P-15, H-4, and Cabin Baby-1 to the southwest.

Calibration in the region between holes H-17, H-11, P-17, and extending to the south, required significant adjustment to the kriged distribution. Transmissivities in this region were increased from kriged values, similar to changes required during calibration by Haug et al. (1987). In order to simulate the low heads at H-11 and DOE-1 and the sharp head embayment in the southern part of Zone 3 expected on the basis of April 1986 data (Figure 4.1.11), Haug et al. (1987) included a narrow high-transmissivity zone east of P-17 (Figure 4.1.16). During calibration by Haug et al., a maximum transmissivity of approximately 3×10^{-4} m^2/s was assigned in this zone. The calibrated transmissivity distribution of LaVenue et al. (1988) in this region does not include as marked a high-transmissivity structure (Figure 4.1.24). Relatively high transmissivities are still required in the area, because of both the relatively low heads at H-11 and DOE-1 and the low gradients south of the WIPP site. However, the maximum transmissivity assigned at the pilot points shown in Figure 4.1.24 is approximately 5×10^{-5} m^2/s, only a factor of two greater than the effective transmissivity of 2.8×10^{-5} m^2/s calculated at the H-11 pad (Table 4.1).

LaVenue et al. (1988) investigate the need for the high-transmissivity zone by making calibration runs in which the increase in transmissivities south of H-11 was not incorporated, as well as runs in which the assigned heads along the southwestern part of the model were increased slightly. In all cases, the fit between calculated and estimated heads was worse than when increased transmissivities south of H-11 were included. Thus, a region of relatively high transmissivities is still expected to be present south of H-11. Transmissivities within this zone may be approximately twice as great as those measured at H-11. Both the lateral extent of the zone and the contrast between the high-transmissivity zone and surrounding regions are expected to be smaller than estimated in Haug et al. (1987). The zone is still expected to connect with the high-transmissivity region further to the south.

The changes in estimated transmissivities within and near the WIPP site are a direct result of the increase in the Culebra data base since April 1986 (Table 4.1). For example, hole H-14 was drilled and tested in 1986, specifically to examine transmissivities southwest of the site center (Section 4.1.1). Holes P-15, H-4, H-15, H-16, P-17, Cabin Baby-1, ERDA-9, and WIPP-12 have all been tested or retested since April 1986 (Table 4.2). Hole H-17 was drilled and tested specifically to evaluate the high-transmissivity zone east of P-17. Transmissivities at both DOE-1 and H-11 have been interpreted in detail since 1986, as discussed in Section 4.1.1.

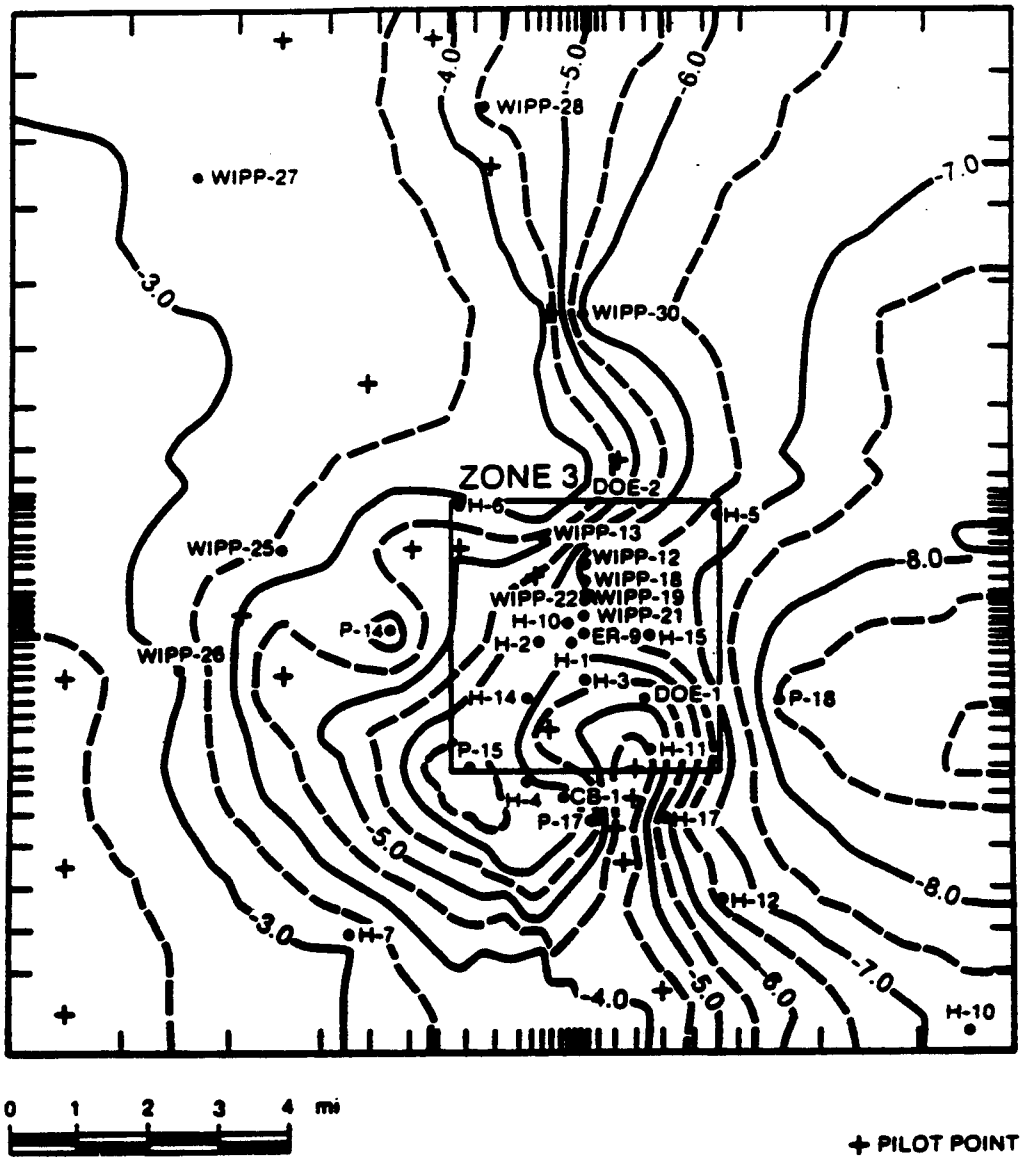


Figure 4.1.24: Calculated Culebra transmissivities at and near the WIPP site, based on steady-state calibration against freshwater-equivalent head distribution shown in Figure 4.1.23, fixing in place the fluid-density distribution shown in Figure 4.1.22. Figure 4.3 of LaVenue et al. (1988).

The distribution of Culebra pre-shaft head potentials calculated using the calibrated transmissivity distribution shown in Figure 4.1.24, is shown in Figure 4.1.25. Differences between calculated heads and those estimated on the basis of field data (Figure 4.1.23) are shown in Figure 4.1.26. The agreement is excellent, generally to within 1 m. This is less than the estimated uncertainty in freshwater-equivalent heads at individual wells, approximately 2 meters (LaVenue et al., 1988).

The modern flow directions and Darcy velocities within the Culebra dolomite at and near the WIPP site calculated by LaVenue et al. (1988) are shown in Figure 4.1.27. Darcy velocities do not include consideration of effective porosity; therefore, they do not represent actual groundwater particle velocities. Flow within the Culebra at and near the WIPP site is largely north-south, except in relatively low-transmissivity areas directly affected by either the high-transmissivity zone south of H-11 or by Nash Draw. Calculated Darcy velocities vary by six orders of magnitude, from 10^{-12} m/s (m^3/m^2s) east of the WIPP site to as high as 10^{-6} m/s along the axis of Nash Draw. In the region between WIPP-12 and the WIPP shafts, calculated Darcy velocities range from 2.5 to 7.5 x 10^{-10} m/s, and flow is north-south. LaVenue et al. (1988) note that calculated flow directions in the vicinity of DOE-2 appear unreliable due to local irregularities in the structure of the Culebra. As a result of the high-transmissivity zone south of H-11, flow in the vicinity of H-14 is towards the southeast, with a Darcy velocity of less than 10^{-9} m/s. Flow within the zone south of H-11 is to the south, with a Darcy velocity of approximately 2.5 x 10^{-9} m/s. The Darcy velocities shown in Figure 4.1.27 assume completely confined flow within the Culebra, and also assume steady-state heads and fixed brine-density distribution (LaVenue et al., 1988). They provide a realistic indication of modern flow directions.

Particle flowpaths and flowtimes calculated within the modelled area, assuming that the effective porosity of the Culebra is uniform at 16% are shown in Figure 4.1.28. As noted in Section 4.2, measured porosities within the Culebra range from 0.07 to 0.30. The effective in situ porosity is not known, but must be variable. It is not clear that assumption of confined flow within Nash Draw is valid. In addition, as discussed in Sections 4.3 and 4.4, Culebra hydrology is not at steady state, and there has probably been at least some change in flow directions within the Culebra within the last 10,000 years; the magnitude of the change remains uncertain. The travel times shown in Figure 4.1.28 must be taken only as an indication of the effects of relative variability in estimated particle flow rates.

Calculated particle velocities within Nash Draw are quite high, and calculated flow times across the entire modeled area are quite short in this region. Calculated travel times along paths A, B, and C (Figure 4.1.28) increase from west to east, from a low of 450 years to a high of 2800 years. Changes in Rustler water levels within Nash Draw since the beginning of potash mining approximately 50 years ago, described by Hunter (1985), indicate that the steady-state assumption is not realistic in this region, even on this relatively short time scale. At the other extreme, flow of a groundwater particle from H-5 to the southern boundary of the modeled area of LaVenue et al. (1988) is calculated to take more than one

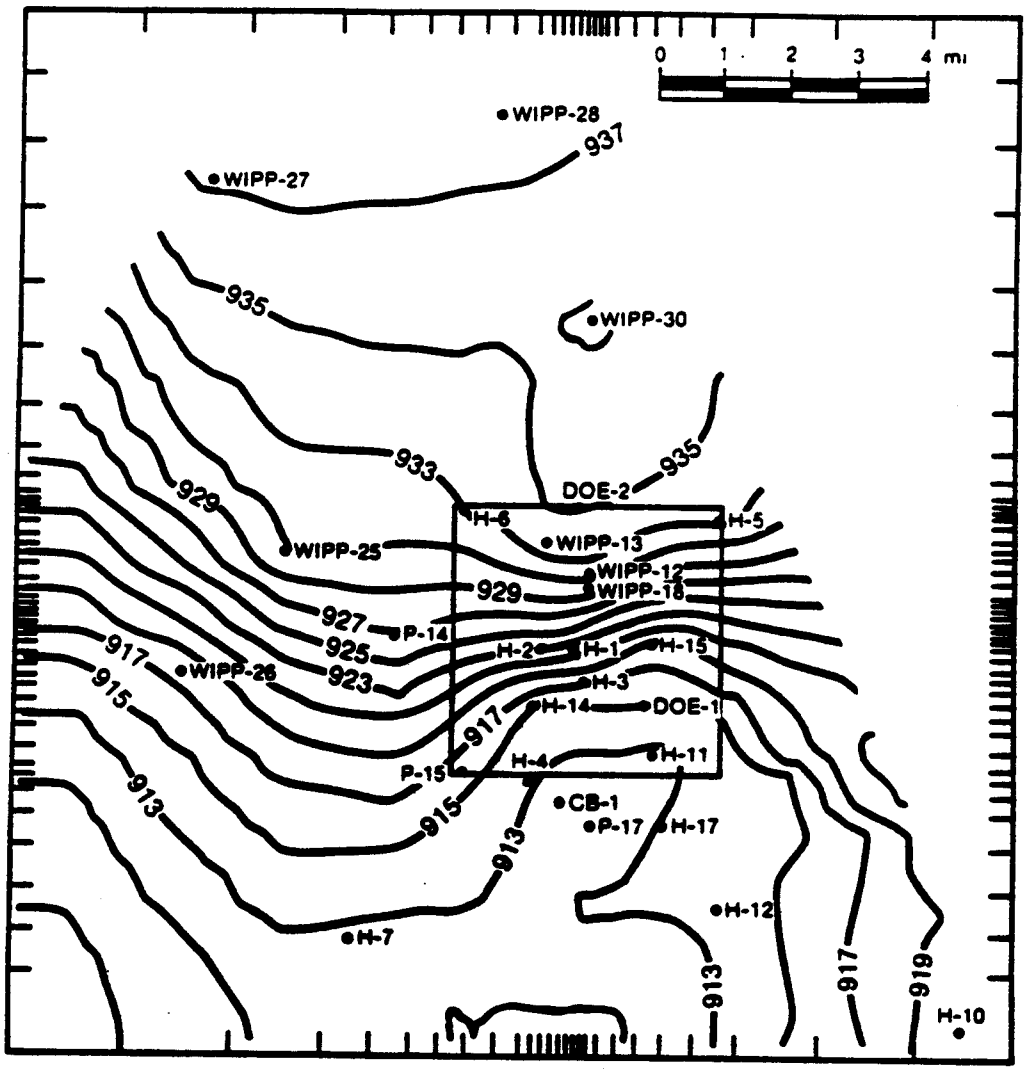


Figure 4.1.25: Calculated pre-shaft, freshwater-equivalent head distribution in the Culebra dolomite, based on calibrated transmissivity distribution shown in Figure 4.1.24. Figure 4.5A of LaVenue et al. (1988).

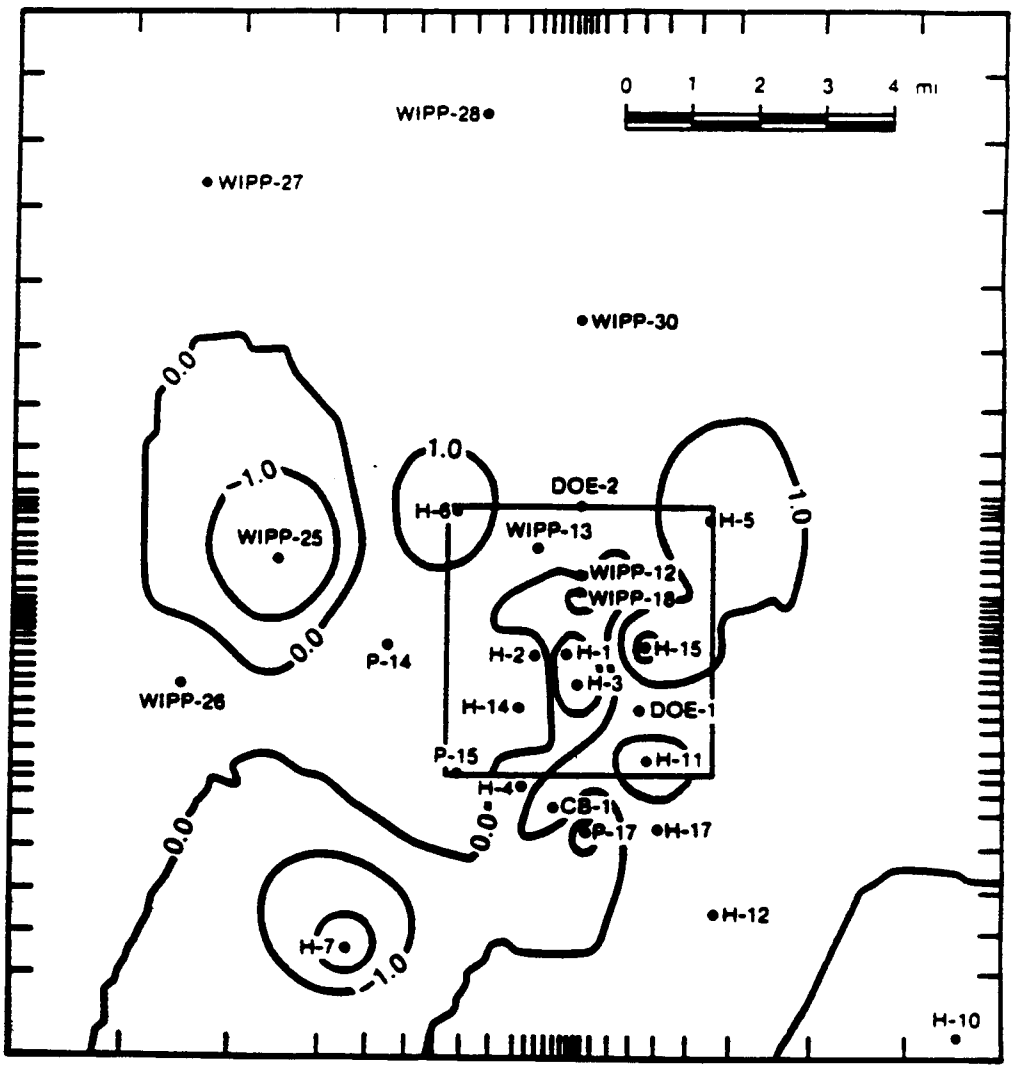


Figure 4.1.26: Difference between calculated Culebra head distribution (Figure 4.1.25) and measured pre-shaft head distribution (Figure 4.1.23). Figure 4.6 of LaVenue et al. (1988).

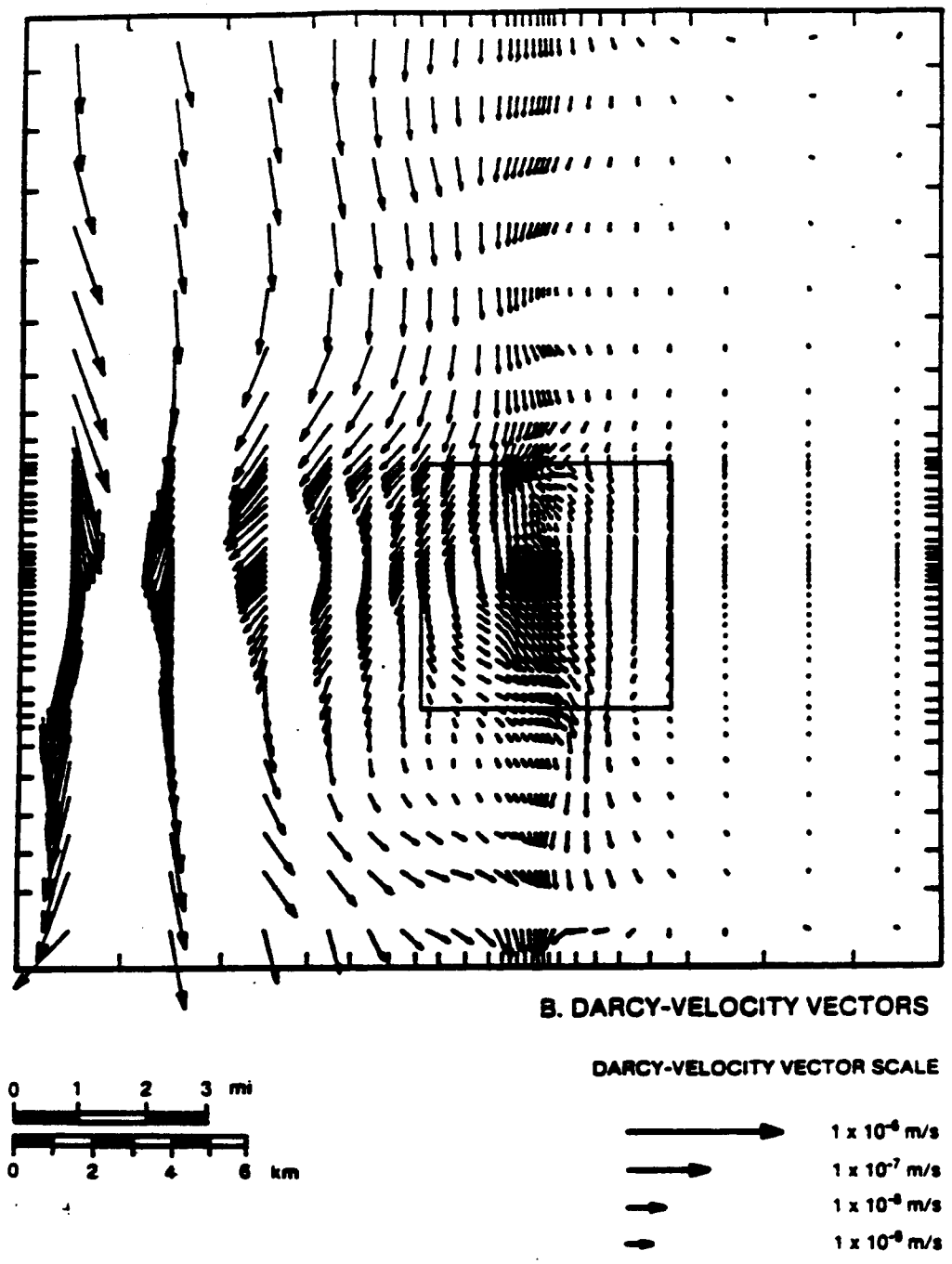


Figure 4.1.27: Calculated Darcy-velocity vectors in the Culebra dolomite, assuming the transmissivity distribution shown in Figure 4.1.24 and head distribution shown in Figure 4.1.25. Figure 4.5B of LaVenue et al. (1988).

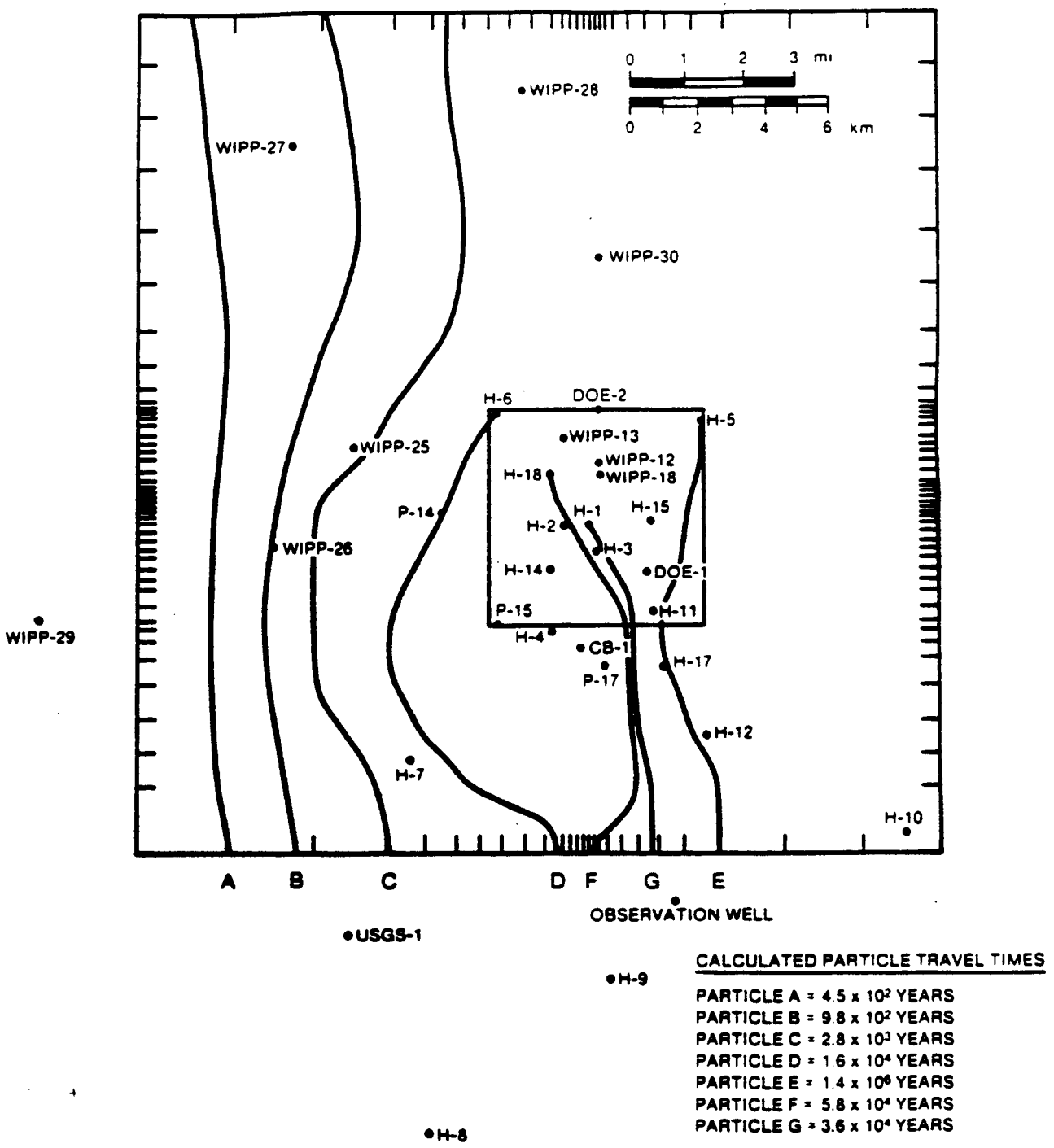


Figure 4.1.28: Calculated particle flowpaths and flow times within the Culebra dolomite, assuming steady-state and the transmissivity and head distributions shown in Figures 4.1.24 and 4.1.25. Figure 4.17 of LaVenue at al. (1988).

million years. Given that Culebra hydrology is in transient response to the end of the last pluvial period, it is not realistic to expect steady-state flow within the unit on a time scale of 106 years (LaVenue et al., 1988). The result indicates, however, that groundwater flow within the Culebra on the eastern part of the WIPP site is extremely slow.

Figure 4.1.28 also demonstrates an important consequence of the recent changes in the understanding of the distribution of Culebra transmissivities. Path G represents assumed steady-state flow from a position above the center of the WIPP waste-emplacement panels, analogous to the flowpath used in the detailed generic transport calculations contained in Reeves et al. (1987) (Section 4.2). Reeves et al. (1987) used the Culebra transmissivity distribution calculated by Haug et al. (1987), which included higher transmissivities south of H-11 than estimated by LaVenue et al. (1988) (Figure 4.1.24). The groundwater travel time calculated by LaVenue et al. (1988) for flow from directly above the center of the waste-emplacement panels to the southern boundary of the model shown in Figure 4.1.24 is 36,000 years. The calculated flow time from the release point of path G to the southern boundary of the WIPP site (Zone 3) is approximately 13,000 years, roughly 2.5 times that estimated by Reeves et al. (1987) along an analogous flowpath, but assuming the transmissivity distribution shown in Figure 4.1.16. The changes in interpreted Culebra transmissivities and head potentials since April 1986 have significantly increased expected groundwater flow times across the WIPP site within the Culebra dolomite. However, given the uncertainties in effective porosities, flowpaths, and transmissivities within the Culebra dolomite, the recent results must be considered approximate.

4.2 Pad-Scale and Regional-Scale Studies of Contaminant Transport within the Culebra Dolomite

For purposes of WIPP performance assessment, contaminant (radionuclide) transport within the Culebra dolomite is of concern in two general types of breach scenario. Section 4.2 discusses contaminant-transport results at both the hydropad and regional scale, under "low-pressure," relatively undisturbed conditions. Low-pressure conditions correspond to a release of fluids from the WIPP facility that does not disturb the pre-existing head distribution in the Culebra. "High-pressure" conditions, for which studies have not yet been completed, represent a breach involving effective connection of the Culebra dolomite with a pressurized brine in the Castile Formation beneath the WIPP facility (see Section 3.2) for a long enough period of time to significantly change the head gradients within the Culebra.

Detailed field testing of transport properties in the Culebra dolomite has been carried out only at the hydropad scale and is discussed in Section 4.2.1. Recent interpretation of conservative-tracer testing at the H-3 hydropad indicates that fracturing plays a major role in pad-scale contaminant transport in the transmissive (fractured) portions of the Culebra. In low-transmissivity areas, such as at the H-4 pad, pad-scale transport within the Culebra is best modelled using the equivalent-porous-medium assumption.

For purposes of performance assessment, however, the critical scale for transport within the Culebra dolomite is not the hydropad, but rather the distance between the point of breach into the Culebra and the boundary to the accessible environment. For purposes of consistency within this report, the boundary of WIPP Zone 3 is assumed to represent the boundary to the accessible environment. Contaminant transport over the 3.2 km from the center of the WIPP site to the boundary of Zone 3 is not amenable to field testing on a reasonable time scale. It is thus necessary to estimate the "regional-scale" transport behavior within the Culebra by numerical modeling. Section 4.2.2 discusses the regional-scale transport behavior of the Culebra dolomite at and near the WIPP site. The results in Section 4.2.2 indicate that, at least as long as the Culebra heads are not significantly disturbed and the assumed flow paths and material properties within the Culebra are reasonably representative, numerical simulation of regional-scale transport within the Culebra at and near the WIPP site need not include effects due to fracturing.

4.2.1 Hydropad-Scale Transport of Conservative Tracers at the H-3 and H-4 Hydropads

Convergent-flow tracer tests operated at the H-3 hydropad in May and June 1984 and at the H-4 hydropad between October 1982 and October 1984 are interpreted by Kelley and Pickens (1986). The interpretations are summarized here, with the objectives of examining the relative importance of dual-porosity or fracture-flow effects on the hydropad scale at two separate locations and discussing the ranges of transport parameters at the two locations.

The first stage of a convergent-flow tracer test is to establish approximate steady-state gradients between the observation holes and the pumped well. Tracers are then injected into the observation wells and their transport to the pumped well monitored. The fluorinated organic tracers meta-trifluoromethylbenzoate (m-TFMB) and pentafluorobenzoate (PFB) were used in testing at the H-3 pad. These same tracers were used at the H-4 pad, in addition to para-fluorobenzoate (p-FB) and thiocyanate (SCN). It is generally assumed that the tracers are chemically stable throughout a test, and that they do not interact with the surrounding rock mass except by diffusion (Kelley and Pickens, 1986).

The interpretation of the H-3 and H-4 tracer tests was done using the code SWIFT II (Reeves et al., 1986a; 1986b). SWIFT II handles the hydraulic and transport behavior of fractured media by means of a "dual-porosity" formalism, in which the composite medium is assumed to consist of an array of porous matrix blocks (primary porosity) and regularly spaced fractures (secondary porosity). The fractures and matrix are allowed to interact. The matrix-block geometry is idealized as either uniform slabs (parallel non-intersecting fractures) or cubes (three orthogonal fracture sets). In interpretation, radial flow towards the pumped hole was assumed.

Interpretation assuming the presence of three orthogonal sets of fractures and the assumption of radial flow are both equivalent to the assumption of isotropy. As mentioned in Section 4.1.2, however, interpretation of

hydraulic interference testing at the H-4, H-5, H-6, and H-11 hydropads indicates some directional dependence of Culebra hydraulic properties. In contrast, interpretation of the hydraulic behavior on the H-3 pad (Beauheim, 1987a) indicates effectively isotropic behavior. The results contained in Kelley and Pickens (1986) must be considered approximate.

4.2.1.1 Conservative-Tracer Tests at the H-3 Hydropad--The observed tracer behavior during convergent-flow testing at H-3 is shown in Figure 4.2.1, and is summarized in Table 4.8. Hole H-3b3 was the pumped hole in this test. Meta-trifluoromethylbenzoate (m-TFMB) injected in hole H-3b1 was first detected in hole H-3b3 ("breakthrough") approximately 0.92 days (22 hrs) after injection, and reached a well-defined peak concentration approximately 2.6 days (62.4 hrs) after injection. After this time, tracer concentration decreased rapidly towards a relatively steady-state value. In contrast, the pentafluorobenzoate (PFB) injected into hole H-3b2 travelled to the sampling hole much more slowly, was first detected approximately 3.76 days (90.2 hrs) after injection, reaching a very broadly defined peak concentration (if any) after approximately 23 days (552 hrs).

Thus, there is a marked difference between the apparent directional dependence of hydraulic behavior and transport behavior at the H-3 pad. Hydraulic anisotropy at the H-3 pad is negligible. However, m-TFMB breakthrough along the H-3b1 - H-3b3 path was four times more rapid than PFB breakthrough along the H-3b2 - H-3b3 path. The preliminary interpretation of a convergent-flow conservative-tracer test at the H-6 pad (Gonzalez, 1983b) also indicates a discrepancy between the directional dependence of hydraulic and transport behavior within the Culebra. In testing at H-6, PFB injected into H-6b arrived at H-6c 16 times more rapidly than did m-TFMB injected into H-6a (Gonzalez, 1983b). These results suggest that the apparent difference between the behaviors of m-TFMB and PFB at the H-3 pad reflects differences in transport behavior along the two flow paths, rather than inherent differences in the behavior of the two tracers.

Parameters resulting from calibration to the observed behavior of the H-3 test are shown in Table 4.9. In calibration, varying input parameters are used to simulate the observed tracer behavior until satisfactory agreement is reached. Because these same parameters were used in regional-scale transport calculations (Section 4.2.2), it is important to understand the character of the parameters listed in Table 4.9.

Three parameters, solute free-water diffusion coefficient, matrix tortuosity, and longitudinal dispersivity, were taken by Kelley and Pickens (1986) from ranges of published values, not based on WIPP-specific information. Specifically, values of 0.15 and 0.45 for matrix tortuosity were used as variable input to calculations. The matrix porosity value shown in Table 4.9 (0.20) is the approximate average of a series of six helium-pycnometer measurements made on Culebra core from holes H-3b2 and H-3b3.

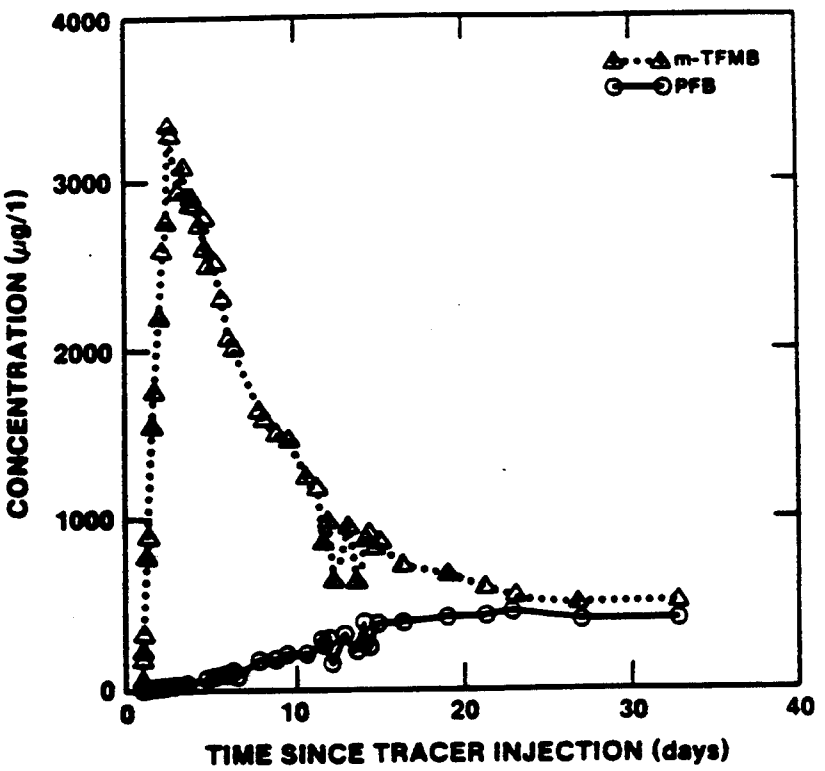


Figure 4.2.1: Observed tracer behavior during the convergent-flow test at the H-3 hydropad. Figure 4.5 of Kelley and Pickens (1986).

Table 4.8: Summary of observed tracer behavior during the convergent-flow test at the H-3 hydropad. Slightly modified from Table 4.2 of Kelley and Pickens (1986).

Parameter	Tracer	
	m-TFMB	PFB
1. Flow path	H-3b1 to H-3b3	H3b2 to H-3b3
2. First detection (days)	0.92	3.76
3. First reported concentration (mg/ℓ)	56	20
4. Time of peak concentration (days)	2.59	23.04
5. Peak concentration (mg/ℓ)	3379	444
6. Relative Peak Concentration (m/m_o)	3.3×10^{-6}	4.3×10^{-7}
7. Total tracer mass recovered (m/m_o)	0.53	0.15
8. Apparent fracture porosity	0.0019	0.019

Fracture porosity and matrix block length are specific outputs of the calculations, for the specific input values of other variables. Thus, in extrapolation of H-3 transport properties to other locations, only matrix block lengths and fracture porosities are based on the results of the H-3 tracer test; other values were input to interpretation of the H-3 testing based on either literature review or laboratory measurements.

The calculated fracture porosity of 0.19% along the H-3b1 - H-3b3 flow path (Table 4.9) was estimated directly from the relationship among pumping rate, H-3b1 - H-3b3 path length assuming direct radial flow, Culebra thickness, and time required for m-TFMB to reach peak concentration (22 hrs). Similar analysis along the H-3b2 - H-3b3 path yields an estimated fracture porosity of 1.9%. A fracture porosity of .19% was used in sensitivity studies, and was assumed to be applicable along both flowpaths on the H-3 pad (Kelley and Pickens, 1986).

Figures 4.2.2 and 4.2.3 show the best-fit simulations of transport behavior along the H-3b1 - H-3b3 flow path as a function of the specified input parameters. There is excellent agreement between measured and simulated results, with two different effective block sizes (1.2 and 2.1 m) being

Table 4.9: Input and best-fit calibration parameters from interpretation of the conservative-tracer test at the H-3 hydropad. Slightly modified from Table 4.3 of Kelley and Pickens (1986).

	Tracer	
	m-TFMB	PFB
Flow path	H-3b1 to H-3b3	H-3b2 to H-3b3
Input Parameters		
1. Diffusion coefficient for solute-free water (m^2/s)	7.4×10^{-10}	7.4×10^{-10}
2. Matrix tortuosity	0.15, 0.45	0.15, 0.45
3. Longitudinal disporsivity (m)	3.0	1.5
4. Matrix porosity	0.20	0.20
5. Fracture porosity	-	1.9×10^{-3}
Output Parameters		
1. Fracture porosity	1.9×10^{-3}	(1.9×10^{-2})
2. Matrix-block length (m)	1.2, 2.1	0.25, 0.44

calculated as a function of two different input matrix tortuosities (0.15 and 0.45, respectively). Figure 4.2.4 shows the analogous best-fit simulation for the H-3b2 - H-3b3 flowpath, assuming a matrix tortuosity of 0.15. The calculated effective block size along the H-3b2 - H-3b3 flowpath, 0.25 to 0.44 m, is smaller than along the path H-3b1 - H-3b3. As mentioned earlier, the calculated block sizes are only qualitative although, as noted by Kelley and Pickens (1986) they are consistent with observation of both Culebra core and exposures within the WIPP shafts. Thus, conservative-tracer testing at the H-3 pad indicates both the strong role of fracturing in transport at this scale (at least in some directions) and the strong directional dependence of estimated transport parameters such as effective block size.

The role of both matrix and fractures in pad-scale contaminant transport of conservative (non-sorbing) trace contaminants in the Culebra dolomite at the H-3 pad is emphasized in Figures 4.2.5 and 4.2.6. If dual-porosity and single-porosity simulations are both adjusted to match the time of peak

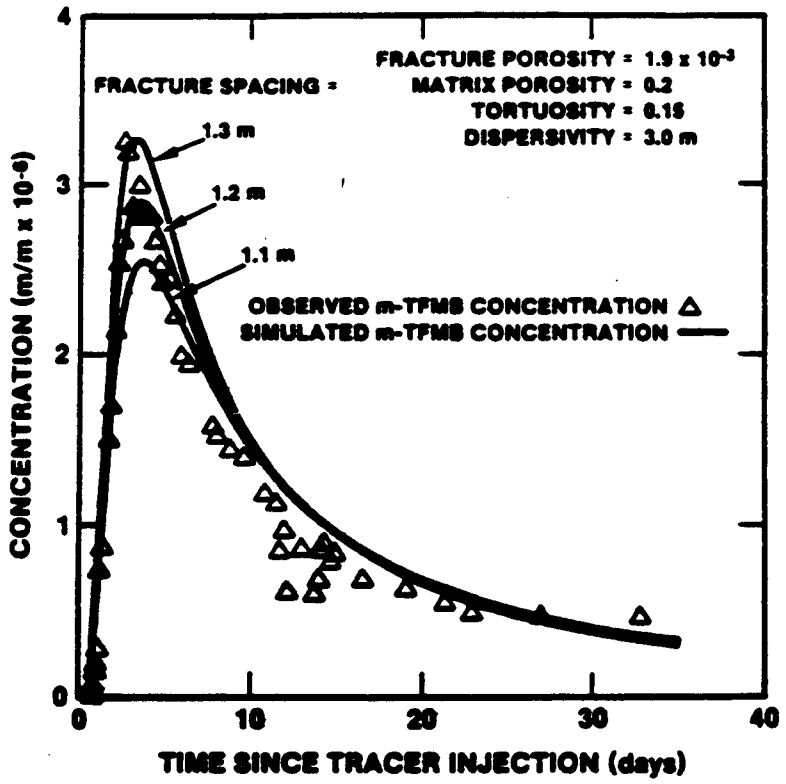


Figure 4.2.2: Best-fit simulation of measured transport behavior along the H-3b1 - H-3b3 flow path, assuming matrix tortuosity of 0.15. It is assumed that 1 kg of m-TFMB was successfully injected, and remained stable throughout the test. Figure 4.10a of Kelley and Pickens (1986).

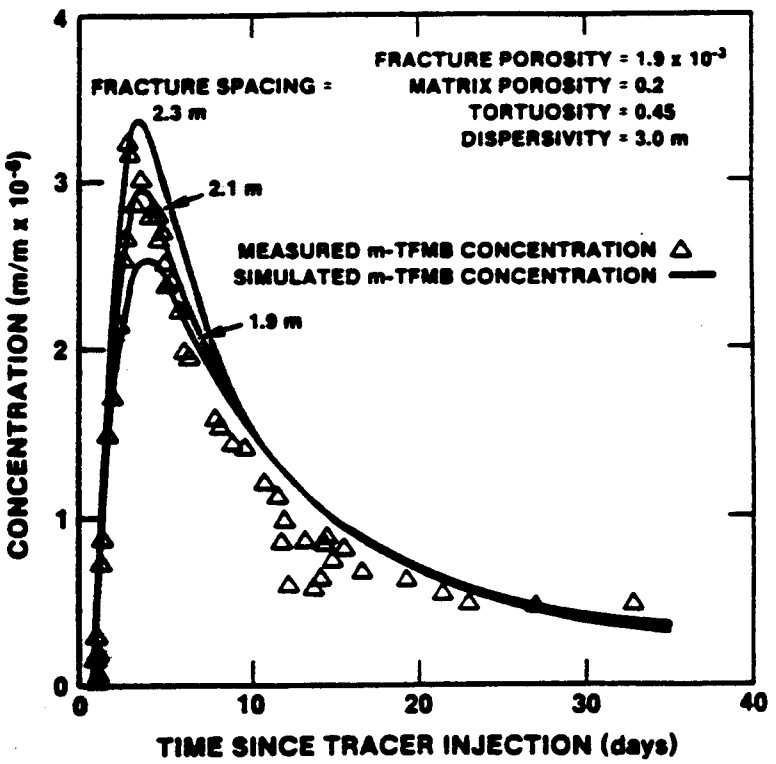


Figure 4.2.3: Best-fit simulation of measured transport behavior along the H-3b1 - H-3b3 flow path, assuming matrix tortuosity of 0.45. Figure 4.10b of Kelley and Pickens (1986).

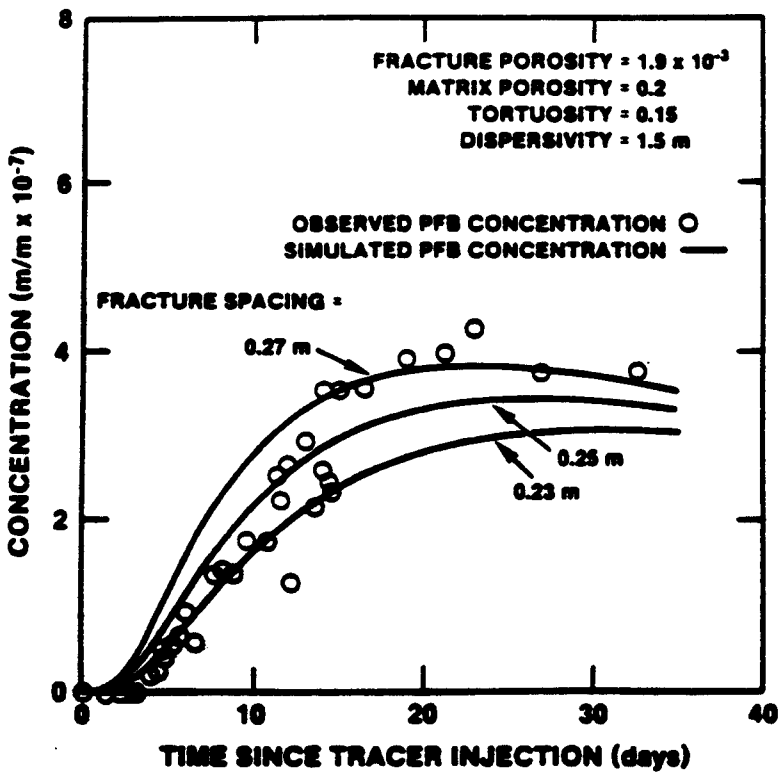


Figure 4.2.4: Best-fit simulation of measured transport behavior along the H-3b2 - H-3b3 flow path, assuming matrix tortuosity of 0.15. Fracture porosity is assumed to be the same as calculated for the flow path H-3b1 to H-3b3. Figure 4.11a of Kelley and Pickens (1986).

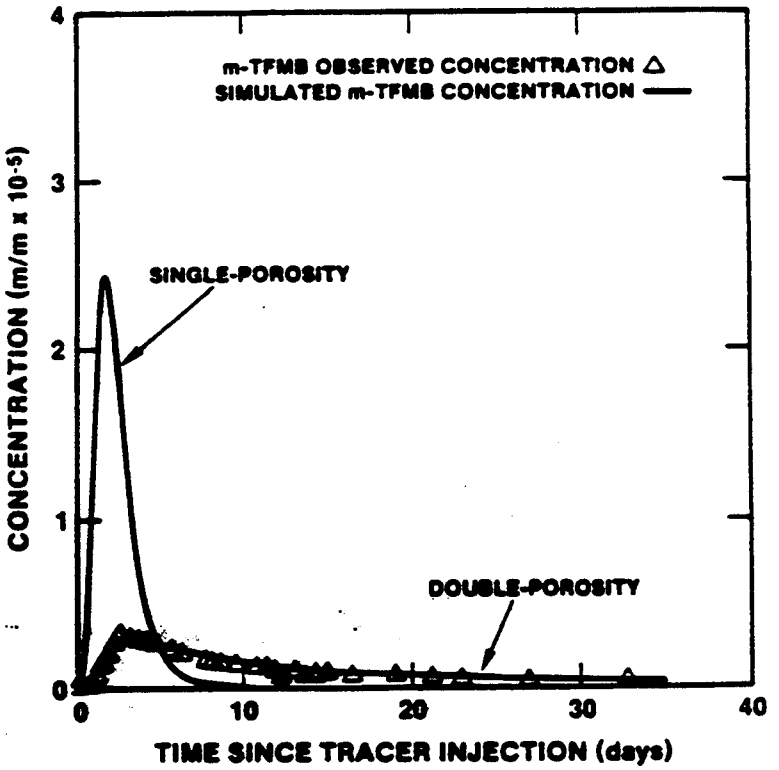


Figure 4.2.5: Best-fit single-porosity and dual-porosity simulations of tracer behavior along the H-3b1 - H-3b3 flow path when both simulations are forced to match the time of peak concentration. Figure 4.12 of Kelley and Pickens (1986).

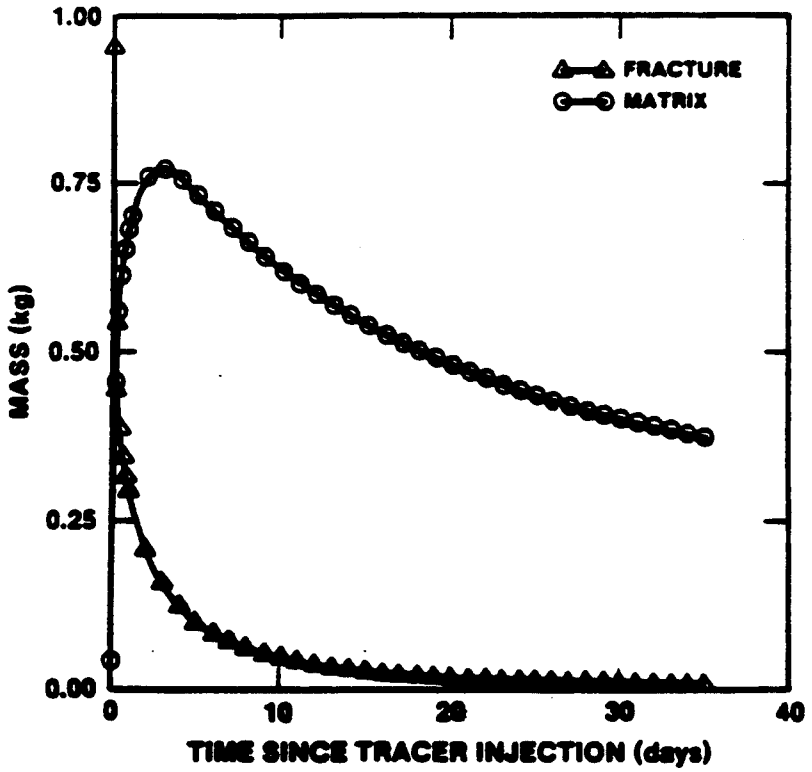


Figure 4.2.6: Calculated total masses of tracer m-TFMB in matrix and fractures as a function of time after injection. The fact that the total mass is less than 1 kg after approximately 2.5 days into the test reflects removal of tracer at the sampling hole, H-3b3. Figure 4.13 of Kelley and Pickens (1986).

concentration for m-TFMB transport along the path H-3b1 - H-3b3 (Figure 4.2.5), the post-peak behavior of the two simulations is qualitatively different. In the single-porosity simulation, the effective rock-mass porosity required to match the time of peak concentration is 0.0019, equivalent to the estimated fracture porosity in the dual-porosity simulation. The single-porosity simulation is thus equivalent to assuming no interaction between fractures and matrix, i.e., it is a "discrete-fracture" simulation, in which interaction between fractures and matrix is negligible. The peak concentration in the single-porosity simulation, which is overestimated by a factor of approximately eight, drops off very quickly, approaching zero, eight days after tracer injection. In contrast, the best-fit dual-porosity simulation matches both the time and magnitude of the tracer peak concentration well. In addition, both the observed tracer concentrations and those calculated with the best-fit dual-porosity parameters are above the detection limit more than 30 days after injection.

The conclusion by Kelley and Pickens (1986) that both the short-term and long-term transport behavior at the H-3 pad are affected by interaction of fractures and matrix is also supported by Figure 4.1.26. This figure indicates the total masses of m-TFMB calculated to be present in the matrix and fractures as a function of time since tracer injection. Initially, all of the injected tracer is contained in the fractures, and the total tracer mass in the matrix is zero. After approximately 0.5 days, however, tracer storage within the matrix blocks dominates as a result of diffusion from the fractures. At early times, storage within the matrix decreases both the concentration and the total mass of tracer in the fractures, consistent with the lower peak concentration calculated using the dual-porosity formalism (Figure 4.2.5). At longer times, the concentration of material within the matrix is greater than that within the fractures. Therefore, material diffuses from the matrix into the fractures, effectively keeping the concentration within the fractures from rapidly decreasing to zero as it does in the single-porosity simulation.

Interpretation of the H-3 conservative-tracer experiment provided the first estimates of Culebra transport parameters (fracture porosity and effective matrix block size) in fractured portions of the Culebra dolomite. There are unavoidable uncertainties in these estimates, however, due to both the need to assume radial flow in the interpretation and uncertainties in parameters such as effective matrix porosity. Regardless of these limitations, the conservative-tracer test at the H-3 pad provides direct evidence of the role of matrix diffusion in contaminant transport in fractured portions of the Culebra dolomite. This evidence is critical in supporting assumptions made in calculation of regional-scale transport within the Culebra (Section 4.2.2).

4.2.1.2 Conservative-Tracer Tests at the H-4 Hydropad--Conservative-tracer testing at H-3 investigated pad-scale contaminant transport where the Culebra is known to be effectively fractured (transmissivity approximately 2×10^{-6} m^2/s). At the H-4 pad, however, the transmissivity is lower (10^{-6} m^2/s or less; Tables 4.1 and 4.2), and there is no evidence of dual-porosity behavior in hydraulic testing.

The physical layout of the H-4 hydropad is shown in Figure 4.2.7. During steady-state, convergent-flow tracer testing at the pad between October 27, 1982, and October 15, 1984, H-4c was the pumped hole (at nominal rates of 1.66×10^{-2} and 3.33×10^{-2} l/s), and tracers were injected into holes H-4a and H-4b. Due to the very long test time at the H-4 pad, detailed interpretation of tracer behavior is hampered by pumping-rate fluctuations and pump breakdowns, as well as by questionable tracer stability (Kelley and Pickens, 1986).

The observed tracer behavior during testing at H-4 is summarized in Table 4.10. The first tracer detected in H-4c was m-TFMB travelling along the path H-4b to H-4c. However, the tracer was not detected until 262 days after injection. Tracer recovery was very limited during the test, the greatest being 37% of the total mass of m-TFMB injected. Because of the limited tracer recovery, the emphasis here is on m-TFMB behavior.

The calculated effective matrix or fracture porosities controlling first arrival of m-TFMB and PFB (Table 4.9), analyzed in the same method as in testing at the H-3 pad, are 0.033 and 0.053, respectively. Lab-measured total porosity for samples from the H-2, H-3, H-4, and H-6 pads range from 0.07 to 0.30, with an average value of 0.16 (Reeves et al., 1987). The two Culebra samples from hole H-4b have reported total porosities of 0.20 and 0.30. Therefore, the apparent porosities calculated from peak-concentration behavior in the H-4 tracer test may indicate that the hydraulically effective porosity of the Culebra at H-4 is significantly less than total porosity, that the tracers used did not remain stable and non-reactive for the two-year duration of the test, and/or that the Culebra core samples from H-4 are not representative.

Kelley and Pickens (1986) applied three different interpretative models to the behavior of m-TFMB at the H-4 pad: 1) a single-porosity model; 2) a dual-porosity model; and 3) a layered porous-medium model. The first two models are analogous to those used in interpretation of conservative-tracer testing at the H-3 pad. The third model is different in that it assumes that the Culebra consists of a specified number of parallel high-permeability and low-permeability porous layers. In this approach, unlike the dual-porosity approach, the total surface area available for diffusive transport between high-permeability and low-permeability zones is fixed by the specified number of high-permeability zones.

The simulation of m-TFMB behavior shown in Figure 4.2.8 assumes specified numbers of high-permeability zones and stability of 1 kg of tracer for the duration of the test. The time of peak concentration (388 days) is matched with an effective porosity of 0.04. However, the peak concentration is overestimated by a factor of approximately two if the Culebra is assumed to be uniform (one high-permeability zone). Kelley and Pickens (1986) note that improved agreement between observed and calculated behavior resulted if it was assumed that only 0.5 kg of tracer was effectively injected, rather than the nominal 1.0 kg.

A dual-permeability formalism was also used by Kelley and Pickens (1986), assuming that both low-permeability and high-permeability zones had an

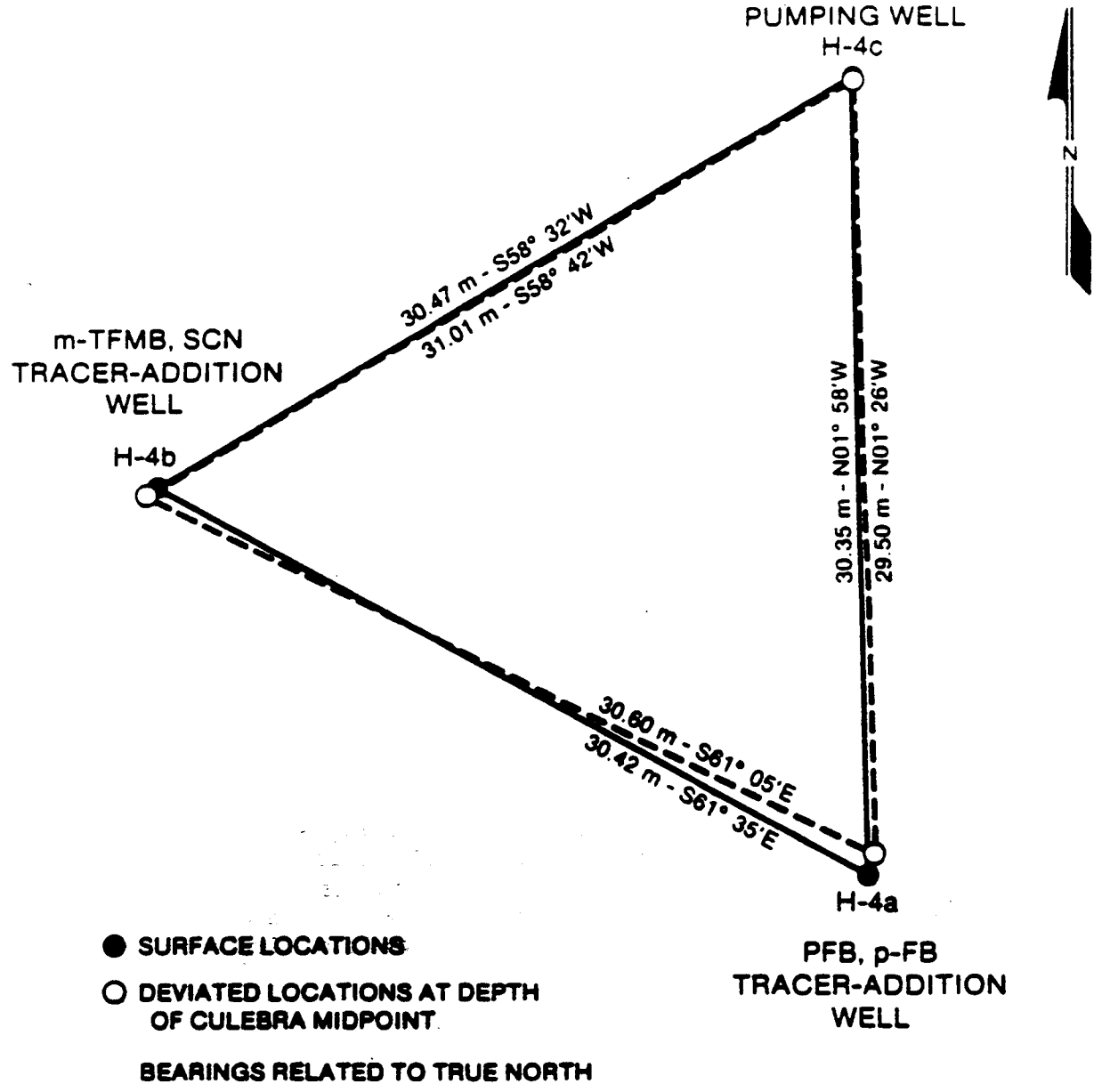


Figure 4.2.7: Physical layout of the H-4 hydropad. The figure includes orientations and spacings between holes, both at the surface and at the depth of the Culebra dolomite. Figure 6.1 of Kelley and Pickens (1986).

Table 4.10: Summary of observed tracer behavior during the convergent-flow, conservative-tracer test at the H-4 hydropad. Slightly modified from Table 6.2 of Kelley and Reeves (1986).

Parameter	Tracer	
	m-TFMB	PFB
1. Flow path	H-4b to H-4c	H-4a to H-4c
2. First detection (days)	262.2	501.1
3. First reported concentration (mg/ℓ)	78	48
4. Time of peak concentration (days)	388.2	507
5. Peak concentration (mg/ℓ)	723	54
6. Relative peak concentration (m/m_o)	7.1×10^{-7}	5.3×10^{-8}
7. Tracer Mass recovered (m/m_o)	0.37	0.022
8. Apparent fracture porosity from peak concentration	0.033	0.053(1)

(1) Apparent porosities for SCN = 0.024; p-FB = 0.064.

effective porosity of 0.20. The number of high-permeability zones was allowed to vary. It was assumed that 1.0 kg of m-TFMB remained stable throughout the test. The presence of increasing numbers of interfaces between high-permeability zones and "matrix" zones, in which only diffusive transport is allowed, effectively decreases the simulated peak concentration (Figure 4.2.8). The best fit was obtained for five or six high-permeability zones, although none of the fits were satisfactory (Kelley and Pickens, 1986), in part because they overestimate tracer concentrations at longer times. In order to improve the long-term fit, it would have to be assumed that there was some tracer degradation at longer times.

In summary, interpretation of the conservative-tracer test at the H-4 pad, while not successful in developing detailed estimates of transport parameters in unfractured portions of the Culebra, does indicate important considerations in both tracer testing at the pad scale and interpretation of regional-scale modeling of transport behavior. Both tracer and hydraulic behavior during the test are consistent with porous-medium behavior, indicating that fracturing need not be considered in evaluation of pad-scale or regional-scale transport in areas of relatively low Culebra

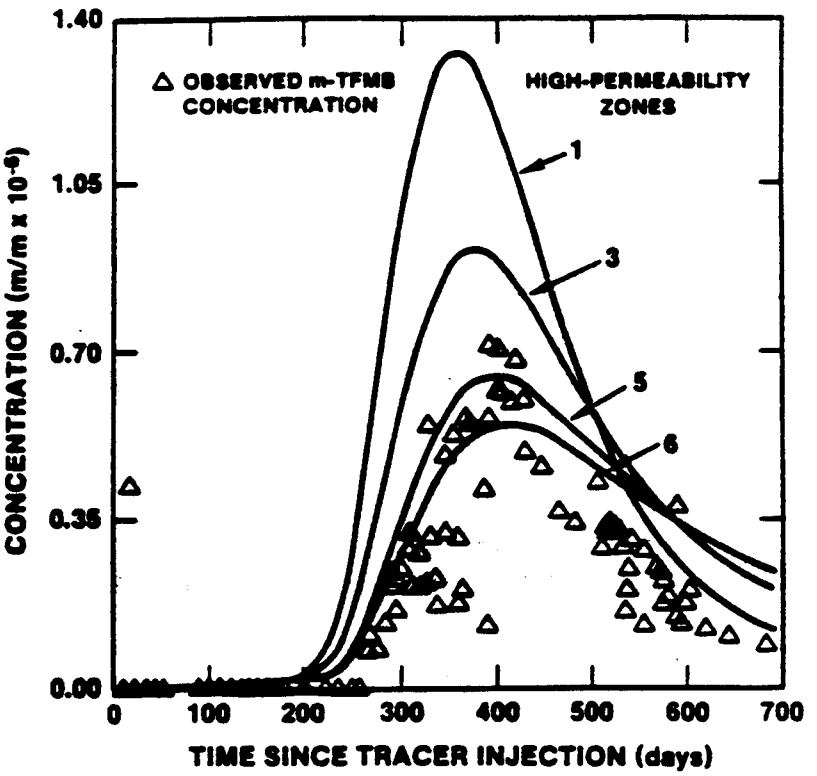


Figure 4.2.8: Best-fit simulation of m-TFMB behavior during testing at the H-4 hydropad, assuming effective injection and stability of 1 kg of tracer and control of behavior by the specified numbers of multiple high-permeability zones. Figure 6.11 of Kelley and Pickens (1986).

transmissivity ($T \leq$ approximately 10^{-6} m^2/s). If it is assumed that the Culebra at H-4 is vertically homogeneous and that the tracers used were stable and non-reactive for the duration of the test, then the hydraulically effective matrix porosity of the Culebra may be significantly less than the total porosity. Given the long duration of the H-4 test, however, it is probable that the tracers degraded during the test.

4.2.2 Regional-Scale Contaminant Transport in the Culebra Dolomite under Low-Pressure Conditions

Regional-scale contaminant transport within the Culebra dolomite under the low-pressure type of breach scenario, i.e., under conditions which do not disturb the head distribution within the Culebra, has been examined by Reeves et al. (1987). Significant transport under these conditions might be expected in the event of failure of the WIPP shaft seals in the absence of human intrusion, or in the event of an imperfectly plugged human-intrusion breach involving a high-pressure brine source within the Castile Formation. Calculations are ongoing to investigate behavior following a second type of breach, in which fluids are assumed to be injected at high pressures into the Culebra for long enough to dominate the local head potentials and flow rates.

The calculations in Reeves et al. (1987) investigate: 1) the significance of the interactions between matrix and fractures seen in tracer and hydraulic testing at the H-3 pad in regional-scale transport within fractured portions of the Culebra dolomite; and 2) the relative importance of several transport and material parameters of the Culebra in regional transport within fractured portions of the Culebra. The calculations in Reeves et al. (1987) were made using the following approach and/or assumptions:

1. Contaminants were assumed to be continuously injected into the Culebra dolomite at points directly above the WIPP waste-emplacement panels at a constant rate after time zero. The injection was slow enough not to disturb the "natural" (pre-WIPP-shaft) gradient or transmissivity distribution.

2. The boundary of WIPP Zone 3 was assumed to represent the boundary of the accessible environment.

3. Effects of radioactive decay and lateral dispersion were assumed negligible, and were not included. If lateral dispersion were included in the calculations, it would effectively slow down transport. The effects of lateral dispersivity on total integrated release to the accessible environment have not been quantified.

4. Material properties and flow velocity were assumed homogeneous between the point of entry into the Culebra and the accessible environment. The analysis was done in terms of an average Darcy velocity yielding groundwater travel times equivalent to those calculated from the flow model described in Haug et al. (1987). Fluid

flow and contaminant transport were controlled by the transmissivity and head distributions estimated by Haug et al. (1987), and were calculated along the flow paths shown in Figure 4.2.9.

5. As a result of the strong interactions between fractures and matrix observed in the conservative-tracer test conducted at the H-3 hydropad (Section 4.2.1), the double-porosity formalism was initially assumed to be appropriate for modeling of transport within fractured portions of the Culebra. However, a major objective of the report was to examine the consequences of both the "discrete-fracture" and "equivalent-porous-medium" end-member behaviors in regional transport.

6. The base-case values and ranges of properties shown in Table 4.11 were assumed to be representative for fractured portions of the Culebra dolomite. The Culebra transport properties estimated in conservative-tracer testing at the H-3 pad were taken as the base-case properties.

7. "Breakthrough," defined by Reeves et al. (1987) as the time at which the calculated contaminant concentration at the boundary to WIPP Zone 3 equaled 10% of the injected concentration, was assumed to provide a meaningful measure of transport behavior. Conclusions in the report are specifically evaluated on the basis of this assumption.

8. It was assumed that retardation effects within the Culebra dolomite can be realistically modeled as a linear process, i.e., that chemical reactions are "fast" relative to flow times within fractures, are reversible, and reflect local equilibrium within the matrix. Thus, it was assumed that chemical retardation within the matrix of the Culebra dolomite can be represented realistically by using an appropriate "matrix distribution coefficient," k_d.

9. The possible presence of mineralogical "skins" on matrix blocks was ignored, as were advective transport within the matrix and sorption on fracture surfaces. These assumptions appear to be generally "conservative," i.e., they should bias the calculations towards greater fracture flow, except for the case of mineralogical skins inhibiting diffusion into the matrix.

Figure 4.2.10 compares the average calculated travel times for a conservative contaminant from positions above the WIPP facility to the southern boundary of WIPP Zone 3, along the flow paths shown in Figure 4.2.9, according to three different assumptions. Using the dual-porosity formalism and assuming uniform distribution of the base-case material properties estimated at the H-3 pad, the time predicted for "breakthrough" of a conservative (non-sorbing) contaminant at the boundary of WIPP Zone 3 is 3490 years after the beginning of continuous injection. This is approximately 90% of the 3730 years predicted by single-porosity calculations in which the porosity is set equal to the sum of the base-case matrix and fracture porosities, 16.2%. In the absence of chemical retardation of the contaminant, the role of the matrix in transport is largely one of storage due to diffusion from fractures into/out of matrix blocks (Section 4.2.1).

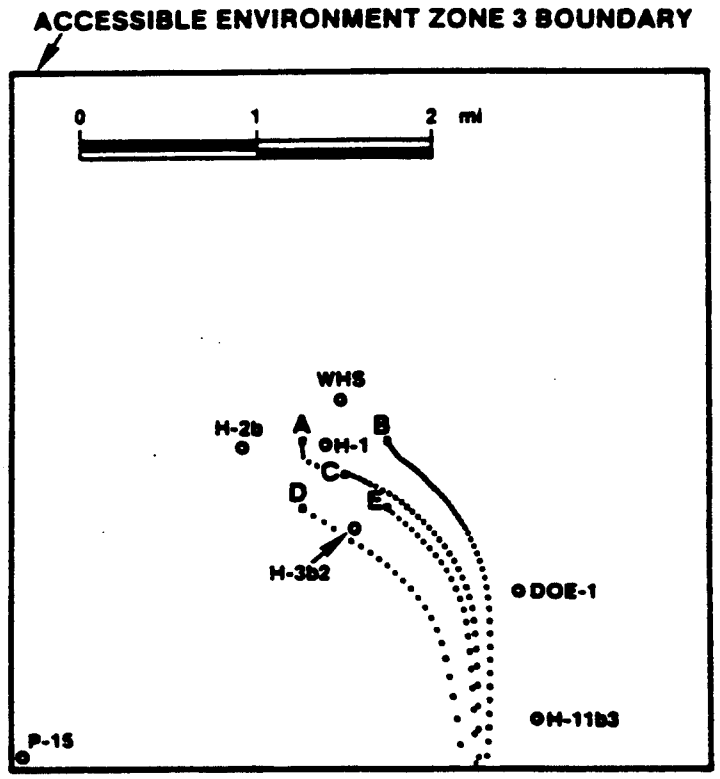


Figure 4.2.9: Release points into the Culebra dolomite and flow paths to the accessible environment considered by Reeves et al. (1987). Points A-E are vertical projections of the corners and center of the WIPP waste-emplacement panels upwards onto the Culebra dolomite. The small crosses extending from points A-E to the southern boundary of Zone 3 are equal-time marks along the flow paths. Slightly modified from Figure 1.7 of Reeves et al. (1987).

Table 4.11: Base-case Culebra transport properties and ranges of properties considered in regional-scale transport within Culebra dolomite. Slightly modified from Table 2.2 of Reeves et al. (1987).

Parameter	Units	Symbol	Base-Case	Range in Values	Relative Range (2)
1. Free-water diffusivity	cm^2/s	D'	2×10^{-5}	4×10^{-6} to 9×10^{-5}	4.30
2. Matrix tortuosity	-	θ'	0.15	0.05 to 0.50	3.00
3. Matrix-block length	2L'	m	2.4	0.25 to 7.0	2.81
4. Matrix porosity	-	ϕ'	0.16	0.07 to 0.30	1.44
5. Fracture porosity	-	ϕ	2×10^{-3}	2×10^{-4} to 2×10^{-2}	9.90
6. Longitudinal dispersivity	m	α	100	50 to 300	2.50
7. Specific matrix flux	m^3/m^2s	u	3.2×10^{-9}	2.2×10^{-9} to 4.7×10^{-9}	0.78
8. Matrix distribution coefficient	$m\ell/g$	k_d	(1)	(1)	-
9. Fraction distribution coefficient	$m\ell/g$	k_d	0	0	-

(1) Calculations done with fixed values of k_d = 0.0, 10, 10^2, 10^4 $m\ell/g$.
(2) Range divided by base-case value.

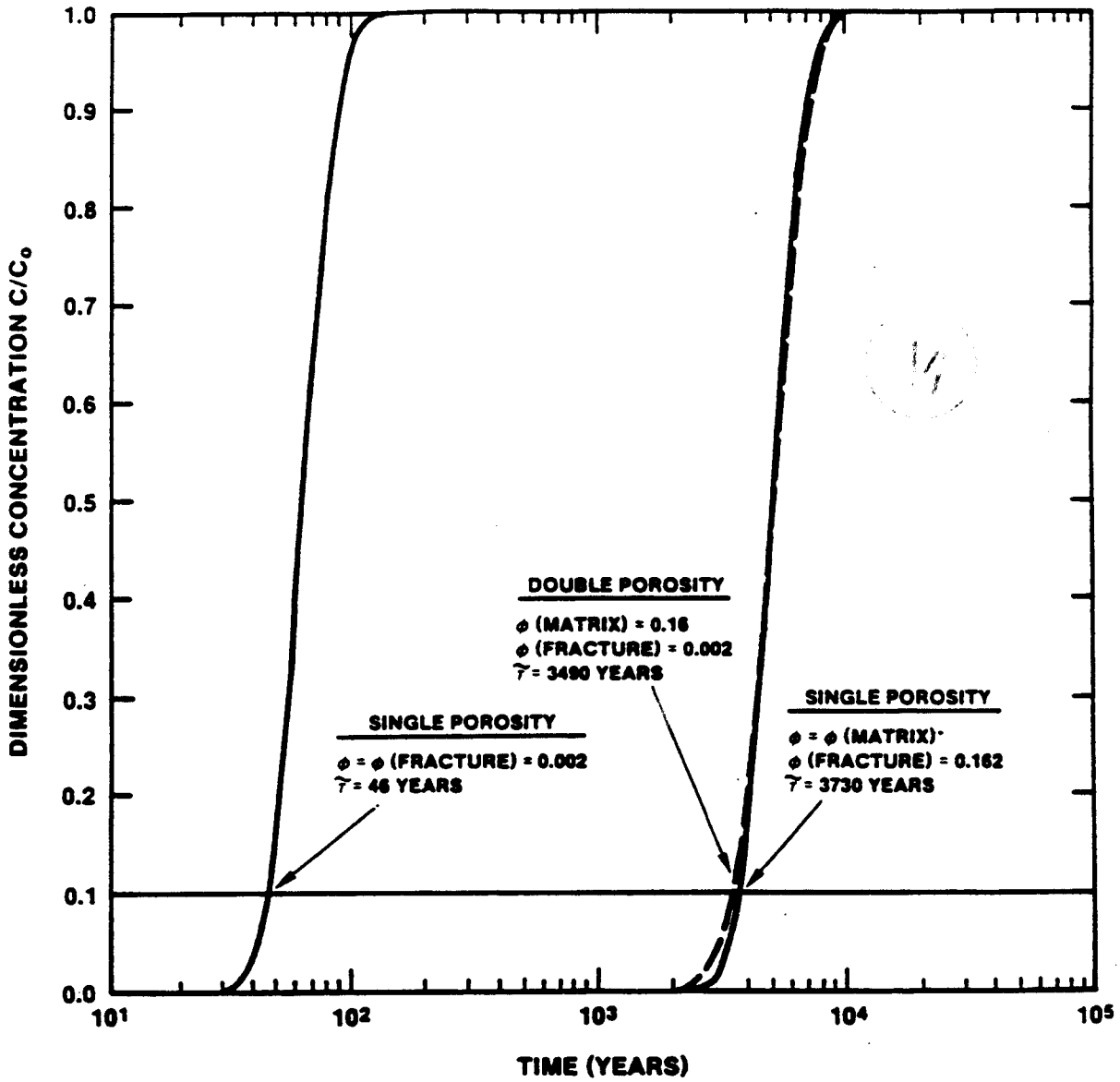


Figure 4.2.10: Comparison of base-case, regional-scale transport behavior of a conservative contaminant in the Culebra dolomite under discrete-fracture, dual-porosity, and porous-medium assumptions. Breakthrough is defined here as the time at which the concentration at the boundary of WIPP Zone 3 equals 10% of the injected concentration. Figure 5.1 of Reeves et al. (1987).

In effect, the single-porosity curve on the right-hand side of Figure 4.2.10 assumes instantaneous diffusion into and equilibration with the matrix.

At the other extreme, diffusion time into the matrix is infinite in fracture flow if it is assumed that fractures and matrix do not interact. The breakthrough time calculated (Figure 4.2.10) assuming that transport occurs only within fractures, assuming a fracture porosity of 0.2%, is 46 years (Reeves et al., 1987).

The experimental results at the H-3 hydropad (Section 4.2.1.1) and the calculated variations in breakthrough time at the boundary of WIPP Zone 3 shown in Figure 4.2.11 indicate the importance of matrix diffusion in both pad-scale and regional-scale transport in the Culebra dolomite. As described by Reeves et al. (1987), a diffusion time means that 1000 years is required for contaminant concentration in the center of matrix blocks to reach approximately 68% of the concentration at fracture surfaces. The base-case diffusion time (Figure 4.2.11) is 152 years. Even for diffusion times significantly greater than the base case value, a large benefit is gained from diffusion of non-sorbing contaminants into matrix blocks (Figure 4.2.11). Base-case transport properties were assumed in the calculations summarized in Figure 4.2.11, except for diffusion into matrix blocks.

Thus, the effective transport behavior within the Culebra dolomite for transport between any breach point directly above the WIPP emplacement panels and the boundary of Zone 3, assuming the breach does not disturb the head distribution within the Culebra, appears to be nearly that of an equivalent porous medium having a porosity equal to the sum of matrix plus fracture porosities. Inclusion of the dual-porosity formalism at this scale, given the assumed properties and flow paths, does not change calculated travel times by more than approximately 10%.

The conclusions supported by results shown in Figures 4.2.10 and 4.2.11 only apply directly to calculations assuming the base-case transport and material properties for the Culebra, which are based largely on interpretation of the conservative-tracer test at the H-3 pad (Section 4.2.1.1). Therefore, Reeves et al. (1987) examined the sensitivity of the results to variations in parameters. The relative importance of several transport parameters in regional-scale transport in the Culebra estimated by Reeves et al. (1987) is summarized in Table 4.12. Reeves et al. (1987) define importance in terms of both the sensitivity of calculated behavior to uncertainty in a given parameter and the estimated range of uncertainty of that parameter in the Culebra dolomite at and near the WIPP site. Thus, a highly sensitive parameter that was known with perfect precision would have zero importance. In contrast, a relatively insensitive parameter could be very important if its range of uncertainty was large.

Reeves at al. (1987) conclude that five parameters are most important in controlling "breakthrough" time to the southern boundary of WIPP Zone 3 in the Culebra dolomite. These are: 1) the matrix retardation (K'), where K' is proportional to $(1 + k_d)$ and k_d is the matrix distribution

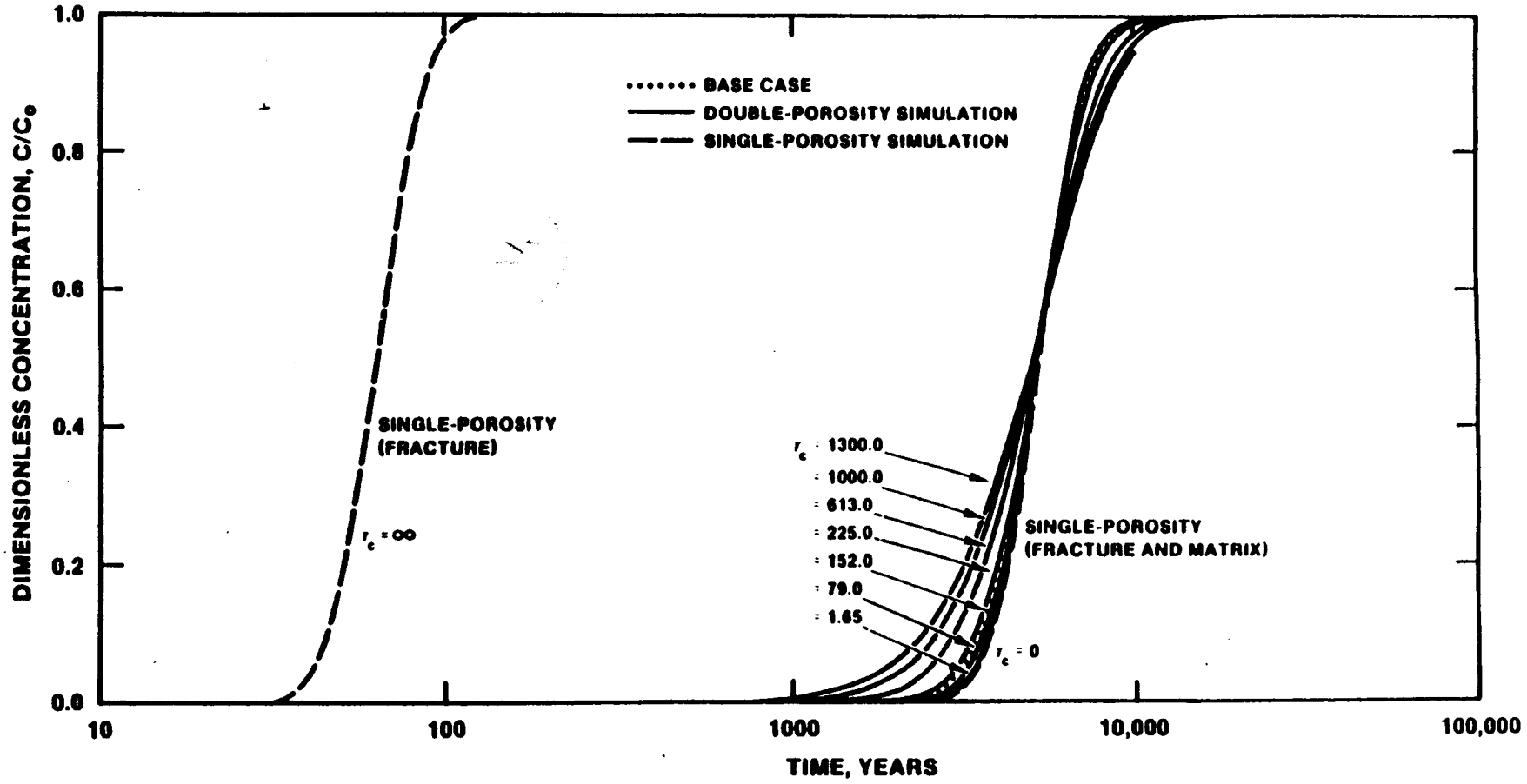


Figure 4.2.11: Estimated effect of variations in diffusion time on breakthrough, otherwise assuming base-case Culebra properties. The diffusion time is the time required for contaminant concentration at the center of matrix blocks to equal approximately 68% of the concentration in fractures. Modified from Figure 4.3 of Reeves et al. (1987).

Table 4.12: Estimated importance of different parameters in regional-scale contaminant transport within the Culebra dolomite. Table 4.5 of Reeves et al. (1987).

Parameter	Symbol	Sensitivity[a]	Importance Coefficient[a]	Importance Ranking
Free water diffusivity	D'	0.064	0.28	5
Matrix tortuosity	θ'	0.064	0.19	6
Matrix-block length	$2L'$	-0.13	0.36	4
Matrix porosity	ϕ'	1.1	1.58	1
Fracture porosity	ϕ	0.013[b]	0.13	7
Fracture dispersivity	α	-0.17	0.43	3
Fracture flux	u	-1.1	0.86	2

(a) Results are valid for retardations $K' = 1$, 1.50×10^2, 1.49×10^3, and 1.49×10^5.
(b) Upper-bound estimate.

coefficient; 2) the effective matrix porosity; 3) the Darcy flux within the fractures (defined as a specific flux m^3/m^2s); 4) the dispersivity in the fractures; and 5) the effective matrix-block size. Reeves et al. (1987) conclude that four parameters are relatively unimportant in controlling regional transport within the Culebra. These include: 1) free-water diffusivity; 2) matrix tortuosity; 3) fracture porosity; and 4) retardation in the fractures (not shown in Table 4.12).

The linear dependence of calculated breakthrough time on matrix retardation (K') is indicated in Figure 4.2.12. This behavior also indicates the effective porous-medium behavior on the regional scale, since for an ideal porous medium the dependence of breakthrough time on retardation is strictly linear. Breakthrough to the southern boundary of Zone 3 should not occur within 10,000 years after release for any matrix distribution coefficient (k_d) greater than approximately 0.2 mL/g for the assumed base-case Culebra material properties.

Valid use or extrapolation of the results contained in Reeves at al. (1987) depends on the assumptions listed at the beginning of this section, especially the representative character of the base-case transport properties and range of properties used in the calculations. The validity of the results is also dependent on the validity of the transmissivity and head distribution within the Culebra dolomite between the calculated

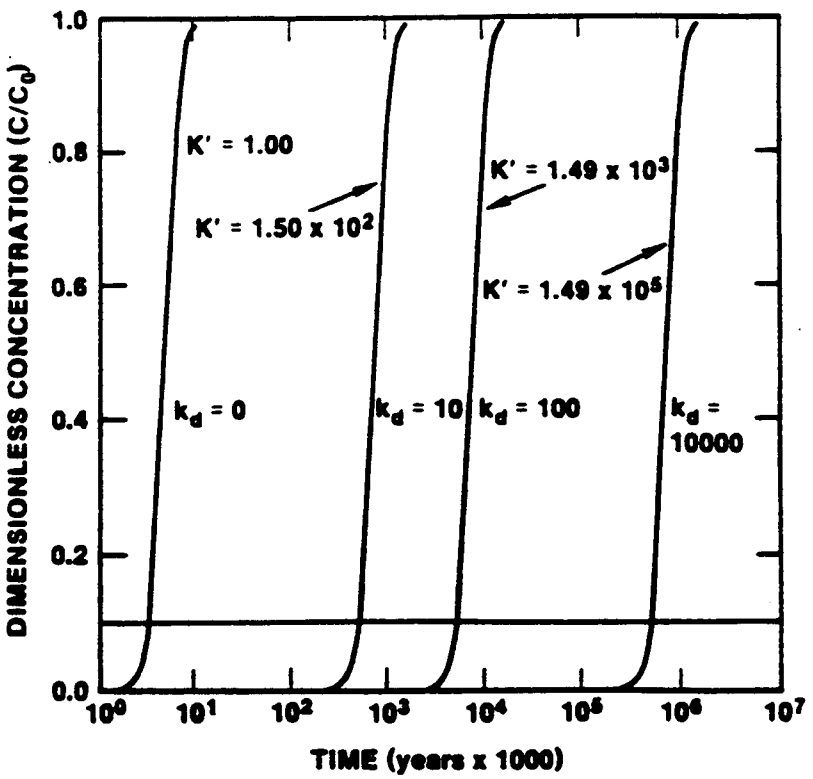


Figure 4.2.12: Variations in calculated breakthrough times to the boundary of WIPP zone 3 as a function of assumed matrix retardation, otherwise assuming base-case material properties. Matrix retardation (K') is proportional to $1 + k_d'$. Therefore, for a matrix distribution coefficient (k_d') of 0, K'=1.0. Slightly modified from Figure 4.1 of Reeves et al. (1987).

release points and the southern boundary of Zone 3. The results of LaVenue et al. (1988) discussed in Section 4.1.3.2 indicate that groundwater and contaminant travel times in the southern part of WIPP Zone 3 may be even slower than calculated by Reeves et al. (1988), so long as flow directions and rates within the Culebra are not affected too greatly by the continuing transient response of the Culebra to the end of the last pluvial period.

Effective matrix diffusion within fractured portions of the Culebra may be possible only because of the relatively slow flow velocities calculated assuming an undisturbed Culebra head distribution. In the event of a brine-reservoir breach of the WIPP facility, the volumes of brine injected from the Castile Formation into the Culebra dolomite might be sufficient to redefine the head distribution within the Culebra, greatly increase hydraulic gradients, and decrease flow times to the accessible environment. Calculations are underway to determine if the dual-porosity formalism is required to evaluate transport within the Culebra under these conditions.

4.3 Geochemical Studies in the Rustler Formation and Shallower Units

The hydrologic studies discussed in Section 4.1 and transport studies discussed in Section 4.2 largely ignore both geochemical behavior within the Rustler Formation and the overall geologic behavior of the WIPP site, except for interaction between the Culebra dolomite and trace contaminants. The status and present conclusions of geochemical studies within the Rustler Formation and shallower units are discussed in this section. The results of these studies, summarized by Siegel et al. (1988a), help place constraints on the relationship between the modern geochemistry and flow directions within both the Culebra dolomite and the Rustler Formation as a whole.

Section 4.3.1 describes the status of geochemical studies of major and minor solutes, in which Culebra groundwaters have been divided into four hydrochemical facies that may be diagnostic of natural interactions between Culebra waters and the matrix of the Culebra dolomite. The results, when compared with modern flow directions within the Culebra, indicate that the geochemistry of Culebra fluids is inconsistent with steady-state confined flow.

Section 4.3.2 discusses the expansion of the stable-isotope results and interpretations contained in Lambert (1983) to interpretations contained in Lambert (1987b) and Lambert and Harvey (1987). Stable-isotope studies themselves do not provide any information concerning the absolute ages of groundwaters. The studies can, in some cases, indicate whether different bodies of water were recharged under similar or different climatic conditions. The results of the recent stable-isotope studies indicate that the isotopic composition of Rustler groundwaters at and near the WIPP site is distinct from that of modern meteoric precipitation at similar elevations in the northern Delaware Basin.

Section 4.3.3 summarizes studies examining the lengths of time groundwaters in the Rustler/Salado contact zone, Rustler Formation, and Dewey Lake Red

Beds in the region of the WIPP site may have been isolated from contact with atmospherically derived components such as radiocarbon, tritium, and chlorine-36 (Lambert, 1987a). At the WIPP site, the applicability of such "environmental isotopes," which occur in ultratrace amounts, is unavoidably limited by the variability of the rock types present, as well as by the ages of both rocks and groundwaters. Specifically, no detectable ^{36}Cl above background has been detected in Rustler fluids, because of the large chlorine background inherent in fluids which have been involved in dissolution of halite from within the Rustler Formation. Nor have tritium levels significantly above background been identified in Rustler fluids, except in hole WIPP-29, interpreted on other grounds to be contaminated by potash mining. Radiocarbon studies met with only limited success, because the normal techniques used in drilling hydrocarbon-exploration and hydrologic test holes at and near the WIPP have resulted, in many cases, in some contamination with organic materials. The limited number of minimally contaminated radiocarbon results, however, indicate that the Culebra dolomite and part of the Dewey Lake Red Beds at the WIPP site have been isolated from atmospheric carbon sources for at least 12,000 years.

Section 4.3.4 discusses fluid-flow directions and rates within the Culebra dolomite, as interpreted from uranium-disequilibrium studies (Lambert and Carter, 1987). The results provide an effectively independent check of conceptual models derived from other studies. Although the present uranium-disequilibrium data base is limited, allowing considerable uncertainty in flow directions, the results indicate that there must have been a significant change in flow directions within the Culebra dolomite, on a time scale generally consistent with the end of local recharge indicated by radiocarbon studies.

4.3.1 Solute Geochemistry and Delineation of Hydrochemical Facies within the Culebra Dolomite

This section summarizes the currently available data and hypotheses (Siegel et al., 1988a) concerning the origin and compositions of waters in the Culebra dolomite. These authors delineate Culebra fluids into various hydrochemical facies, consider the compatibility of these facies with modern flow patterns derived from stratigraphic and hydrologic studies, and examine the interactions of Culebra solutes and host-rock mineralogies. Although Siegel et al. (1988a) emphasize the Culebra, relevant preliminary results of work on fluids from the Magenta dolomite, Rustler/Salado contact zone, and Dewey Lake Red Beds are included. One section of Siegel et al. (1988a), Bodine et al. (1988), was prepared as a summary interpretation of a separate study (Bodine and Jones, 1988), based on an independent data base. Data used in estimation of oxidation potentials (Eh) (Myers et al., 1988) were collected as part of the WIPP Water-Quality Sampling Program.

4.3.1.1 Hydrochemical Facies--The analytical ranges of compositions of Culebra waters and compositions used in calculations contained in Siegel et al. (1988a) are included in Table 4.13; major solutes are listed in Table 4.13a, minor and trace solutes in Table 4.13b. Individual data sets

Table 4.13a: Major solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b).

Well(s)	Collection Date[1]	Lab[2]	Total Dissolved Solids (mg/L)[7]	Ionic Strength (molal)[8]	Bromide (mg/L as Br)	Fluoride (mg/L as F)	Iodide (mg/L as I)	Boron (mg/L as B)	Lithium (mg/L as Li)	Strontium (mg/L as Sr)	Silica (mg/L as SiO_2)	Iron (mg/L as Fe)	Manganese (mg/L as Mn)
Culebra													
DOE-1	4/85	UNC	131200	2.53	56	-	-	37	0.64	26	8.4	0.28	-
DOE-1	(2)	avg			60	1.2	-	36	0.64	21	-	-	-
DOE-1	(2)	rng			56-64	1.0-1.7	-	35-37	(1)	16-26	8-24	-	-
DOE-2	3/85	UNC	60400	1.19	34	1.7	0.22	16	0.47	38	17	0.036	0.30
DOE-2	(2)	avg			35	1.6	0.22	18	0.47	29	-	-	-
DOE-2	(2)	rng			34-36	1.2-2.2	(1)	14-24	(1)	22-38	17-24	-	-
H-2A	4/86	UNC	12900	0.27	5.6	2.2	0.081	10	0.22	9.5	13	1.1	0.055
H-3B3	6/84	UNC	55000	1.08	29	2.1	0.13	30	0.53	23	9.8	0.57	0.13
H-3B3	2/85	UNC	55800	1.08	26	1.9	0.14	26	0.40	30	11	0.20	0.12
H-3B2, H3B3	(4)	avg			31	1.8	0.14	28	0.41	25	-	-	-
H-3B2, H3B3	(4)	rng			26-39	1.5-2.1	0.13-0.14	21-34	0.30-0.53	23-30	9-20	-	-
H-4B	5/81	UNC	21700	0.46	42	-	-	18	0.39	14	11	-	-
H-4C	8/84	UNC	21200	0.45	48	2.1	0.23	20	0.49	18	13	2.2	0.20
H-4B	7/85	UNC	20200	0.42	43	2.7	-	14	0.40	14	14	0.32	0.11
H-4B, H-4C	(4)	avg			44	2.2	0.23	18	0.42	15	-	-	-
H-4B, H-4C	(4)	rng			43-48	1.7-2.7	(1)	14-23	0.39-0.49	13-18	11-30	-	-
H-5B	6/81	UNC	154400	2.99	62	-	-	33	0.77	32	6.2	-	-
H-5C	10/81	UNC	154500	3.00	64	-	-	35	0.77	31	5.8	-	-
H-5B	8/85	UNC	152600	2.97	49	2.0	0.19	34	0.81	29	7.1	2.9	0.29
H-5B, H-5C	(4)	avg			58	1.3	0.19	33	0.78	31	-	-	-
H-5B, H-5C	(4)	rng			49-64	0.8-2.0	(1)	29-35	0.77-0.81	29-32	5-36	-	-
H-6B	5/81	UNC	59300	1.18	34	-	-	11	0.44	32	20	-	-
H-6B	9/85	UNC	57400	1.13	34	1.9	0.096	10	0.45	30	18	0.094	0.13
H-6B	(3)	avg			34	1.6	0.096	9.5	0.44	28	-	-	-
H-6B	(3)	rng			34-35	1.3-1.9	(1)	7-11	0.44-0.45	24-32	18-43	-	-

Table 4.13a: Major solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b). (Continued)

Well(s)	Collection Date[1]	Lab[2]	Total Dissolved Solids (mg/L)[7]	Ionic Strength (molal)[8]	Bromide (mg/L as Br)	Fluoride (mg/L as F)	Iodide (mg/L as I)	Boron (mg/L as B)	Lithium (mg/L as Li)	Strontium (mg/L as Sr)	Silica (mg/L as SiO_2)	Iron (mg/L as Fe)	Manganese (mg/L as Mn)
H-7B1	3/86	UNC	3220	0.089	0.57	1.5	0.052	0.76	0.10	8.5	47	0.056	0.050
H-7B1	(3)	avg			0.57	1.4	0.052	0.77	0.11	7.7	-	-	-
H-7B1	(3)	rng			(1)	1.2-1.5	(1)	0.34-0.80	0.10-0.12	5.8-8.7	47-92	-	-
H-8B	1/86	UNC	2830	0.083	0.085	2.5	0.14	0.48	0.12	6.9	29	0.036	0.021
H-8B	(2)	avg			0.085	2.4	0.14	0.49	0.12	6.7	-	-	-
H-8B	(2)	rng			(1)	2.1-2.5	(1)	0.48-0.50	0.12	5.9-7.4	29-56	-	-
H-9B	11/85	UNC	3080	0.087	0.24	3.3	0.11	0.63	0.18	7.5	27	0.032	0.015
H-9B	(2)	avg			0.24	3.0	0.11	0.66	0.18	7.2	-	-	-
H-9B	(2)	rng			(1)	2.6-3.3	(1)	0.63-0.70	0.17-0.18	7.0-7.5	27-39	-	-
H-10B	3/80	GS	65700	1?	-	1.3	-	13	-	-	1.5	-	-
H-11B3	6/85	UNC	117400	2.23	47	-	-	32	0.62	25	-	0.14	0.22
H-11B3	(2)	avg			48	1.3	-	31	0.50	20	-	-	-
H-11B3	(2)	rng			47-48	1.0-1.6	-	30-32	0.38-0.62	18-25	25-32	-	-
H-12	8/85	UNC	140500	2.72	76	-	-	39	1.2	31	7.2	0.22	0.087
H-12	(2)	avg			76	1.5	-	38	0.85	29	-	-	-
H-12	(2)	rng			76-77	1.1-2.3	-	35-39	0.61-1.2	18-38	7-96	-	-
P-14	2/86	UNC	24900	0.58	72	1.7	0.42	0.72	0.28	51	30	2.0	0.18
P-14	(2)	avg			72	1.5	0.42	0.72	0.28	50	-	-	-
P-14	(2)	rng			(1)	1.2-1.7	(1)	(1)	(1)	48-51	30-69	-	-
P-17	3/86	UNC	86500	1.67	72	1.9	0.18	38	0.87	29	8.5	4.0	0.87
P-17	(2)	avg			70	1.6	0.18	35	0.87	31	-	-	-
P-17	(2)	rng			69-72	1.2-1.9	(1)	32-38	(1)	28-36	0-8.5	-	-
P-18	10/77	GS	118300	2.5?	-	1.2	-	100	-	-	1.0	-	-

Table 4.13a: Major solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b). (Continued)

Well(s)	Collection Date[1]	Lab[2]	Total Dissolved Solids (mg/L)[7]	Ionic Strength (molal)[8]	Bromide (mg/L as Br)	Fluoride (mg/L as F)	Iodide (mg/L as I)	Boron (mg/L as B)	Lithium (mg/L as Li)	Strontium (mg/L as Sr)	Silica (mg/L as SiO_2)	Iron (mg/L as Fe)	Manganese (mg/L as Mn)
WIPP-13	2/87	avg	-	-	39	1.4	-	11	0.35	25	-	-	-
WIPP-25	8/80	UNC	12100	0.26	2.6	-	-	1.5	0.20	12	34	-	-
WIPP-25	8/80	avg			2.6	-	-	1.5	0.20	12	-	-	-
WIPP-25	8/80	rng			(2)	-	-	(1)	(1)	(1)	(1)	-	-
WIPP-25	2/86	UNC	13600	-	3.4	1.7	0.042	1.7	0.22	17	33	0.50	0.11
WIPP-25	2/86	avg			3.8	1.6	0.042	1.7	0.22	17	-	-	-
WIPP-25	2/86	rng			3.4-4.2	1.6-1.7	(1)	1.7	(1)	(1)	33-67	-	-
WIPP-26	8/80	UNC	15100	0.33	3.2	-	-	1.4	0.24	17	33	-	-
WIPP-26	8/80	avg			3.2	-	-	1.4	0.24	17	-	-	-
WIPP-26	8/80	rng			(1)	-	-	(1)	(1)	(1)	(1)	-	-
WIPP-26	11/85	UNC	17600	0.37	3.9	1.7	0.070	1.6	0.23	20	35	0.026	<0.01
WIPP-26	11/85	avg			3.9	1.5	0.070	1.6	0.23	18	-	-	-
WIPP-26	11/85	rng			(1)	1.3-1.7	(1)	(1)	(1)	17-20	35-65	-	-
WIPP-27	9/80	UNC	134700	2.57	28	-	-	2.3	0.33	51	23	-	-
WIPP-27	(2)	avg			28	-	-	2.1	0.33	51	-	-	-
WIPP-27	(2)	rng			(1)	-	-	1.9-2.3	(1)	(1)	13-23	-	-
WIPP-28	9/80	UNC	46600	0.90	7.2	-	-	5.8	0.30	16	36	-	-
WIPP-28	9/80	avg			7.2	-	-	5.8	0.30	16	-	-	-
WIPP-28		rng			(1)	-	-	(1)	(1)	(1)	(1)	-	-
WIPP-29	8/80	UNC	245400	4.91	45	-	-	4.4	0.78	29	22	-	-
WIPP-29	8/80	avg			45	-	-	4.4	0.78	29	-	-	-
WIPP-29	8/80	rng			(1)			(1)	(1)	(1)	(1)	-	-
WIPP-29	12/85	UNC	324100	6.57	61	4.6	0.38	5.2	0.70	13	15	1.1	1.7
WIPP-29	12/85	avg			61	-	0.38	5.5	0.70	11	-	-	-
WIPP-29	12/85	rng			(1)	0.9-4.6	(1)	5.2-5.8	(1)	9-13	15-110	-	-
WIPP-30	9/80	UNC	29100	0.58	10	-	-	6.1	0.27	18	6.5	-	-
WIPP-30	9/80	avg			10	-	-	6.1	0.27	18	-	-	-
WIPP-30	9/80	rng			(1)			(1)	(1)	(1)	(1)	-	-

Table 4.13a: Major solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b). (Concluded)

Well(s)	Collection Date[1]	Lab[2]	Total Dissolved Solids (mg/L)[7]	Ionic Strength (molal)[8]	Bromide (mg/L as Br)	Fluoride (mg/L as F)	Iodide (mg/L as I)	Boron (mg/L as B)	Lithium (mg/L as Li)	Strontium (mg/L as Sr)	Silica (mg/L as SiO_2)	Iron (mg/L as Fe)	Manganese (mg/L as Mn)
Engle	3/85	UNC	3270	0.09	0.27	2.8	0.12	0.97	0.17	8.4	29	0.59	0.060
Engle	3/85	avg			0.27	2.8	0.12	0.87	0.17	7.7	-	-	-
Engle	3/85	rng			(1)	2.8-2.9	(1)	0.77-0.97	(1)	7.0-8.4	29-54	-	-
Magenta													
H-3B1	7/85	UNC	8560	-	5.8	2.4	1.2	2.0	0.32	17	10	0.11	0.028
H-3B1	(3)	rng			5.8-6.0	1.8-2.6	1.2-2.0	2.0-4.5	0.32	13-18	10-26	-	-
H-4C	11/86	UNC	23900	-	5.9	2.4	0.31	12	0.46	12	9.1	0.71	0.29
H-4C	(2)	rng			5.9-7.5	2.2-2.6	(1)	11-12	0.41-0.46	12-14	9-26	-	-
H-5C	10/86	UNC	6980	-	0.93	2.5	0.31	11	0.20	10	11	1.5	0.020
H-5C	10/86	rng			(1)	2.5	(1)	10-11	0.20	8-10	11-26	-	-
H-6C	10/86	UNC	4540	-	2.3	1.5	0.086	2.2	0.21	9.8	11	0.26	0.010
H-6C	10/86	rng			1.0-2.3	1.5-1.7	(1)	2.2-2.4	0.19-0.21	7.1-9.8	11-28	-	-
Dewey Lake Red Beds													
Ranch	6/86	UNC	2520	-	2.3	0.82	0.13	0.10	0.12	5.9	52	0.024	<0.01
Ranch	6/86	rng			2.3	0.8-1.0	(1)	0.10-0.19	(1)	3.2-5.9	52-86	-	-
Twin-Pasture	1/86	UNC	401	-	0.17	0.58	<0.01	0.13	<0.05	1.1	47	<0.01	<0.01
Twin-Pasture	1/86	rng			(1)	0.5-1.4	(1)	0.13-0.16	(1)	0.6-1.1	47-90	-	-
Bell Canyon Fm.													
DOE-2	7/85	UNC	149500	-	250	1.1	6.4	54	5.8	150	2.5	11	28
DOE-2	7/85	rng			(1)	0.4-1.4	6.4-7.9	54-61	2.8-5.8	150-300	2-30	-	-

Table 4.13b: Minor and trace solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b).

Well(s)	Collection Date[1]	Lab[2]	Zone[3]	Sodium (mg/L as Na)	Potassium (mg/L as K)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Chloride (mg/L as Cl)	Sulfate (mg/L as SO_4)	Bicarbonate (mg/L as HCO_3)[4]	pCO_2[5]	pH[4]
Culebra												
DOE-1	4/85	UNC	A	45800	1100	1730	1610	73600	7350	45	-2.60	7.1
DOE-1	(2)	avg	A	46000	1100	1700	1600	75000	7400	-		-
DOE-1	(2)	rng	A	45000-46000	(1)	(1)	(1)	73000-77000	(1)	45-46		7.1
DOE-2	3/85	UNC	C	18400	410	1960	1060	34600	3950	67	-2.33	7.0
DOE-2	(2)	avg	C	18000	420	1900	1000	33000	3700	-		-
DOE-2	(2)	rng	C	17000-19000	410-420	1900-2000	900-1100	32000-35000	3400-4000	(1)		(1)
H-2A	4/86	UNC	C	3570	93.5	743	167	5310	2980	57	-3.38	8.0
H-3B3	6/84	UNC	C	17400	495	1550	829	29500	5130	-	-2.83	7.4
H-3B3	2/85	UNC	C	18000	425	1470	783	30300	4820	52	-2.86	7.4
H-3B2, H-3B3	(4)	avg	C	18000	440	1400	760	29000	4800	-		-
H-3B2, H-3B3	(4)	rng	C	17000-19000	360-500	1200-1600	690-830	27000-31000	4600-5200	50-52		7.4
H-4B	5/81	UNC	C	6080	215	700	455	7980	6230	71	-3.35	8.0
H-4C	8/84	UNC	C	6150	222	698	505	7950	5700	75	-3.11	7.8
H-4B	7/85	UNC	C	5850	210	691	427	7480	5520	69	-3.04	7.7
H-4B, H-4C	(4)	avg	C	6000	220	690	450	7700	5700	-		-
H-4B, H-4C	(4)	rng	C	5800-6200	180-260	690-700	400-510	7400-8000	5500-6300	68-75		7.6-8.0
H-5B	6/81	UNC	A	52400	1290	1710	2140	89500	7360	80	-3.21	7.9
H-5C	10/81	UNC	A	52300	1300	1720	2150	89500	7570	86	-3.17	7.9
H-5B	8/85	UNC	A	54100	1350	1700	2170	85400	7840	50	-2.86	7.4
H-5B, H-5C	(4)	avg	A	53000	1300	1700	2200	87000	7600	-		-
H-5B, H-5C	(4)	rng	A	52000-55000	1200-1400	1700-1800	2100-2200	84000-90000	7300-7900	-		-
H-6B	5/81	UNC	C	18600	450	2150	1080	33000	3980	96	-2.16	7.0
H-6B	9/85	UNC	C	18000	375	2040	1040	32300	3570	94	-2.07	6.9
H-6B	(3)	avg	C	18000	420	2000	1100	33000	3600	-		-
H-6B	(3)	rng	C	17000-19000	370-450	1900-2200	1000-1200	32000-34000	3300-4000	90-96		6.9-7.2

Table 4.13b: Minor and trace solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b). (Continued)

Well(s)	Collection Date[1]	Lab[2]	Zone[3]	Sodium (mg/L as Na)	Potassium (mg/L as K)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Chloride (mg/L as Cl)	Sulfate (mg/L as SO_4)	Bicarbonate (mg/L as HCO^3)[4]	pCO_2[5]	pH[4]
H-7B1	3/86	UNC	B	207	7.0	587	130	320	1850	120	-2.20	7.
H-7B1	(3)	avg	B	210	7.0	570	130	320	1800	-		-
H-7B1	(3)	rng	B	200-210	7.0	540-590	130	300-350	1700-1900	120		7.3-7.4
H-8B	1/86	UNC	B	55.1	3.83	548	157	30.5	1950	96	-2.70	7.3
H-8B	(2)	avg	B	54	3.9	540	170	32	1800	-		-
H-8B	(2)	rng	B	51-56	3.7-4.1	520-550	150-180	30-33	1600-2000	93-96		7.2-7.3
H-9B	11/85	UNC	B	146	6.85	590	137	194	1900	110	-2.43	7.4
H-9B	(2)	avg	B	150	7.2	580	150	190	1800	-		-
H-9B	(2)	rng	B	140-150	6.8-7.6	560-620	130-170	170-200	1700-1900	110		7.3-7.4
H-10B	3/80	GS	C	21000	520	1600	1000	36000	5600	45	-	8.3
H-11B3	6/85	UNC	A	40400	943	1700	1320	65900	7180	54	-2.63	7.2
H-11B3	(2)	avg	A	39000	940	1600	1300	66000	7200	-		-
H-11B3	(2)	rng	A	37000-41000	(1)	1500-1700	1300-1400	65000-67000	(1)	54-55		7.2-7.3
H-12	8/85	UNC	A	49200	1270	1760	1980	79000	7210	53	-2.61	7.2
H-12	(2)	avg	A	50000	1300	1800	2000	80000	7200	-		-
H-12	(2)	rng	A	49000-51000	(1)	1700-1900	1900-2000	78000-80000	(1)	53-62		7.2
P-14	2/86	UNC	C	4360	37.9	3520	840	14500	1590	110	-1.81	6.8
P-14	(2)	avg	C	4100	41	3700	800	14000	1600	-		-
P-14	(2)	rng	C	3700-4400	37-45	3500-3900	760-840	13000-15000	1500-1700	100-110		6.8-6.9
P-17	3/86	UNC	C	28300	782	1620	1460	48200	6020	64	-2.90	7.5
P-17	(2)	avg	C	28000	820	1600	1500	49000	6000	-		-
P-17	(2)	rng	C	28000-29000	780-880	1500-1700	1400-1600	48000-51000	5900-6100	61-64		7.5
P-18	10/77	GS	A	9200	6200	5600	16000	80000	980	310	-	7.2

Table 4.13b: Minor and trace solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b). (Continued)

Well(s)	Collection Date[1]	Lab[2]	Zone[3]	Sodium (mg/L as Na)	Potassium (mg/L as K)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Chloride (mg/L as Cl)	Sulfate (mg/L as SO_4)	Bicarbonate (mg/L as HCO_3)[4]	pCO_2[5]	pH[4]
WIPP-13	2/87	avg	C	19000	340	-	-	36000	4500	~120	-	~6.6
WIPP-25	8/80	UNC	C	3160	73.5	905	260	5250	2500	210	-1.69	6.9
WIPP-25	8/80	avg	C	3200	74	900	260	5200	2500	-		-
WIPP-25	8/80	rng	C	(1)	(1)	(1)	(1)	5200-5300	(1)	(1)		(1)
WIPP-25	2/86	UNC	C	3180	102	1140	315	6320	2380	130	-	7.2
WIPP-25	2/86	avg	C	3300	100	1100	330	6200	2400	-		-
WIPP-25	2/86	rng	C	3100-3400	100-110	1100-1200	310-340	6200-6400	2300-2400	(1)		(1)
WIPP-26	8/80	UNC	C	3620	170	1240	355	7200	2480	140	-1.86	6.9
WIPP-26	8/80	avg	C	3600	170	1200	360	7000	2500	-		-
WIPP-26	8/80	rng	C	(1)	(1)	(1)	(1)	6900-	(1)	(1)		6.9
WIPP-26	11/85	UNC	C	4220	343	1340	380	8770	2420	120	-2.14	7.1
WIPP-26	11/85	avg	C	4100	350	1300	390	8600	2400	-		-
WIPP-26	11/85	rng	C	3800-4300	340-360	1200-1400	370-430	8400-8800	2300-2500	(1)		(1)
WIPP-27	9/80	UNC	D	39200	8060	3210	1900	78500	3830	120	-1.33	6.4
WIPP-27	(2)	avg	D	39000	8100	3200	2000	78000	3900	-		-
WIPP-27	(2)	rng	D	39000-40000	(1)	3100-3300	1900-2000	77000-79000	3800-3900	(1)		6.4
WIPP-28	9/80	UNC	C	15200	485	1180	555	24800	4380	-	-0.76	6.5
WIPP-28	9/80	avg	C	15000	480	1200	560	24000	4400	-		-
WIPP-28	9/80	rng	C	(1)	(1)	(1)	(1)	24000-25000	(1)	-		-
WIPP-29	8/80	UNC	D	71400	15600	950	5480	138000	14000	210	-0.87	6.1
WIPP-29	8/80	avg	D	71000	16000	880	5600	140000	14000	-		-
WIPP-29	8/80	rng	D	(1)	(1)	810-950	5400-5700	130000-140000	13000-14000	(1)		6.1
WIPP-29	12/85	UNC	D	94900	23300	413	6500	179000	20000	160	-0.75	5.9
WIPP-29	12/85	avg	D	92000	22000	410	6400	180000	18000	-		-
WIPP-29	12/85	rng	D	90000-95000	20000-24000	(1)	6300-6500	179000-180000	17000-20000	(1)		(1)

Table 4.13b: Minor and trace solutes and other parameters in analyzed groundwaters from the Culebra, Magenta, Dewey Lake, and Bell Canyon. From Siegel et al. (1988b). (Concluded)

Well(s)	Collection Date[1]	Lab[2]	Zone[3]	Sodium (mg/L as Na)	Potassium (mg/L as K)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Chloride (mg/L as Cl)	Sulfate (mg/L as So_4)	Bicarbonate (mg/L as HCO^3)[4]	pCO_2[5]	pH[4]
WIPP-30	9/80	UNC	C	8570	255	1140	460	14600	4120	40 HCO_3	-4.41	8.8
WIPP-30	9/80	avg	C	8600	260	1100	460	15000	4100	17 CO_3		-
WIPP-30	9/80	rng	C	(1)	(1)	(1)	(1)	14000-15000	(1)	(1)		(1)
Engle	3/85	UNC	B	200	5.60	588	152	231	1990	110	-2.44	7.4
Engle	3/85	avg	B	190	5.5	580	140	230	1900	-		-
Engle	3/85	rng	B	180-200	5.4-5.6	570-590	130-160	220-240	1800-2000	(1)		(1)
Magenta												
H-3B1	7/85	UNC	Mag	1520	34.5	1000	292	3360	2310	47	-	8.0
H-3B1	(3)	rng	Mag	1500-1600	34-36	1000	270-300	3300-3400	2200-2400	45-47		7.7-8.0
H-4C	11/86	UNC	Mag	7110	85.1	651	411	8460	7100	70	-	8.4
H-4C	(2)	rng	Mag	7100-7300	85-99	610-660	390-420	8400-8500	(1)	70-85		8.1-8.4
H-5C	10/86	UNC	Mag	1480	33.6	550	173	1070	3620	56	-	8.0
H-5C	10/86	rng	Mag	1400-1500	(1)	(1)	170-190	1000-1100	(1)	(1)		(1)
H-6C	10/86	UNC	Mag	642	16.6	546	160	428	2700	51	-	7.7
H-6C	10/86	rng	Mag	(1)	(1)	(1)	160-170	420-430	2400-2700	(1)		(1)
Ranch	6/86	UNC	DL	200	4.0	420	202	418	1100	220	-	7.0
Ranch	6/86	rng	DL	180-200	3.6-4.0	(1)	190-210	390-420	920-1100	(1)		(1)
Dewey Lake Red Beds												
Twin-Pasture	1/86	UNC	DL	25.4	3.85	80.4	22.5	44.1	75.1	230	-	7.8
Twin-Pasture	1/86	rng	DL	24-26	3.7-4.3	80-81	22-25	44-47	70-76	(1)		(1)
Bell Canyon												
DOE-2	7/85	UNC	BC	49600	885	5910	1330	89700	2020	48	-	6.8
DOE-2	7/85	rng	BC	(1)	(1)	(1)	(1)	89000-90000	(1)	(lab)		(1)

Footnotes for Tables 4.13a and 4.13b

*Solute values from various labs have been rounded as follows:

-Na, K, Ca, Mg, CL, SO_4 from UNC	: 3 significant figures
-all others from UNC	: 2 sig. figs
-all solutes from GS	: 2 sig. figs
-all "avg" values	: 2 sig. figs
-all minimum 'rng' values	: down to 2 sig. figs
-all maximum 'rng' values	: up to 2 sig. figs
-all total dissolved solids (TDS)	: to nearest 100 mg/L or to 3 sig. figs (for TDS<10000)
-all bicarbonate values	: to 2 sig. figs
-all pH values	: to 0.1 pH unit
-all pCO_2 values	: to 0.01 unit
-all ionic strength values	: to 0.01 molal

(1) Collection date: a number in parentheses indicates that values in that row are averages or ranges of data for up to that number of samples

(2) avg - average of one or more values from one or more laboratories; used to calculate element ratios and generate contour plots (Siegel and others, 1988)
rng - range of values from one or more laboratories; gives a crude estimate of the uncertainties associated with the data. A single value in the range row means that all values were indentical. A "(1)" in the range row means that only one reliable value was available
GS - USGS Central labs
UNC - UNC Geotech (before Oct. 1, 1986, Bendix Field Engineering Corp.), Grand Junction, Co.

(3) zone - hydrochemical facies zone described by Siegel and others (1988). Applies only to Culebra.

(4) Bicarbonate and pH values were measured in the field when the samples were collected. (Exception: HCO_3 in the DOE-2 Bell Canyon sample was measured in the lab)

(5) pCO_2 - calculated using PHRQPITZ (Siegel and others, 1988)

(6) Stratigraphic horizon: BC - Bell Canyon Formation
DL - Dewey Lake Red Beds
Mag - Magenta Dolomite

(7) Total dissolved solids - calculated by summing the major solutes

(8) Ionic strength - calculated using PHRQPITZ (Siegel and others, 1988)

evaluated in compiling the table and methods for evaluating the data are discussed in Robinson (1988), Lambert and Harvey (1987), and Siegel et al. (1988b). The data in Tables 4.13a and 4.13b were used by Siegel et al. (1988a) in facies assignments of Culebra fluids, saturation-index calculations, and factor analyses, as well as in plotting of element-ratio contours.

On the basis of the available major-solute analyses (Table 4.13a), Culebra waters can be combined into four hydrochemical facies (Figure 4.3.1). These include:

1. Zone A (H-5, H-11, H-12; DOE-1, P-17, P-18(?)), containing saline NaCl brines (about 2 to 3 molal) with a Ca/Mg weight ratio near unity. These waters are found in the eastern third of the WIPP site and further east, in a region roughly coincident with the region of lowest Culebra transmissivity. In the western part of Zone A, halite is present only in the unnamed lower member (Figure 1.5); in the eastern part of the zone, halite is present throughout the Rustler.

2. Zone B (H-7, H-8, H-9, Engle), containing relatively fresh waters (<0.1 molal) in which Ca^{++} and $SO_4^{=}$ are the dominant solutes. These waters are found only south of the WIPP site. No Rustler halite is present in this zone. Data from the South and Indian wells (Bodine and Jones, 1988) suggest that these wells should also be classified as part of Zone B.

3. Zone C, containing waters of variable compositions, low to moderate ionic strength (about 0.3 to 1.1 molal), and Ca/Mg weight ratios greater than 1.5:1. These waters extend from the central part of the WIPP site to the eastern part of Nash Draw, in regions of low to high Culebra transmissivity. In the eastern part of the zone, halite is present in the unnamed lower member; on the western side of the zone, Rustler halite is absent. In general, the most saline brines in Zone C are found in the eastern part of the zone.

4. Zone D, containing waters of anomalously high salinities (about 3 to 7 molal) and K/Na mole ratios (about 0.2) relative to other sampled fluids (3 molal or less; K/Na mole ratios of 0.01 to 0.09) This zone is apparently confined to western Nash Draw, and contains only holes WIPP-27 and WIPP-29. Fluid compositions at WIPP-29 have have changed over the course of seven years of monitoring, probably in response to nearby potash refining operations.

The chemical characteristics of the defined Culebra fluid facies can be summarized graphically in a Piper (trilinear) diagram (Figure 4.3.2). This plot generalizes the relationships between several major solutes, i.e., those in the Na-K-Mg-Ca-Cl-SO_4-CO_3 system. Relative proportions of cations and anions are shown in the triangular plots in the bottom half of the figure, relative ratios of divalent to monovalent cations and chloride to (sulfate plus carbonate) in the parallelogram portion of the figure.

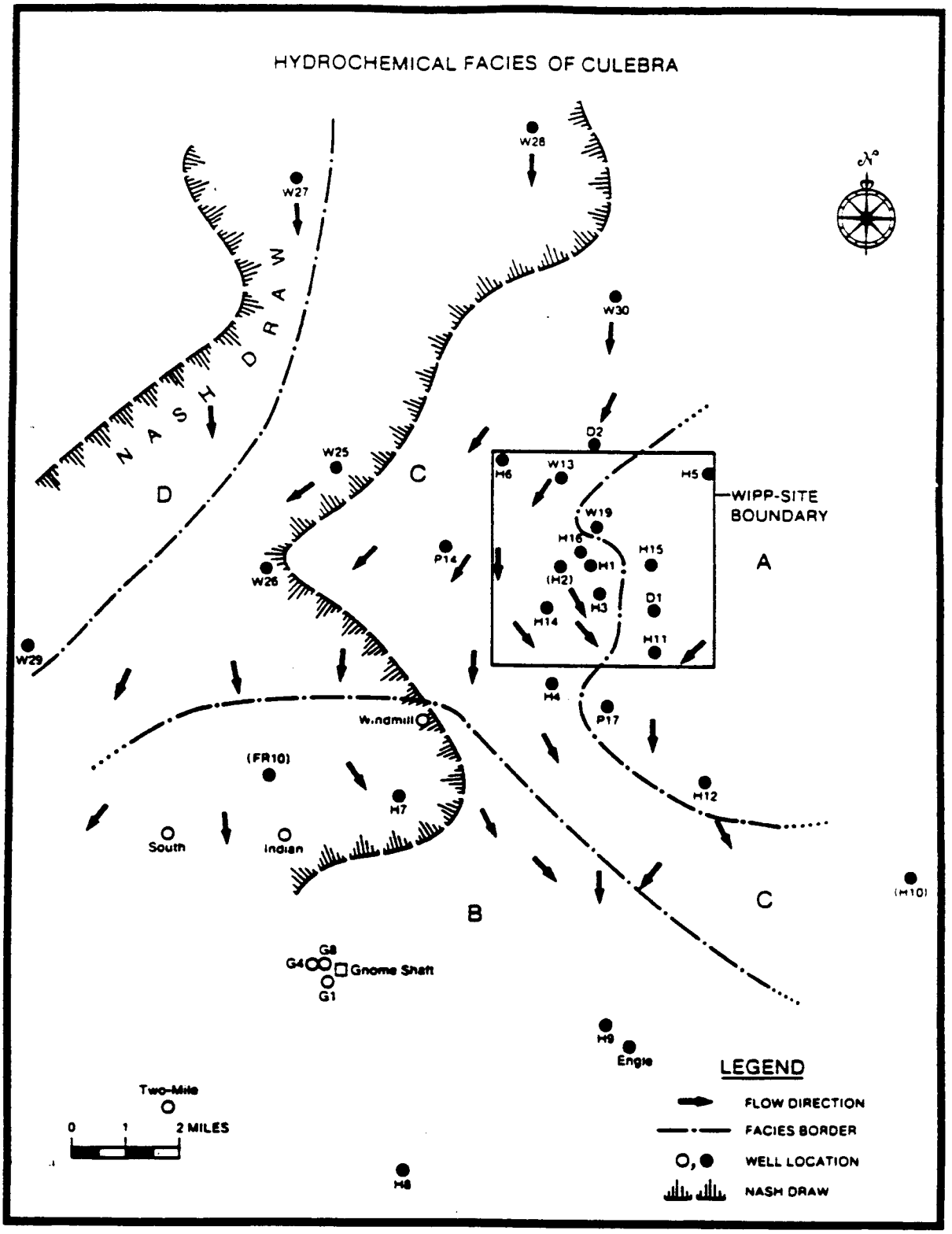


Figure 4.3.1: Summary of hydrochemical facies and local flow directions in the Culebra dolomite. Facies boundaries from Siegel et al. (1988a); modern flow directions from Figure 4.5B of LaVenue et al. (1988).

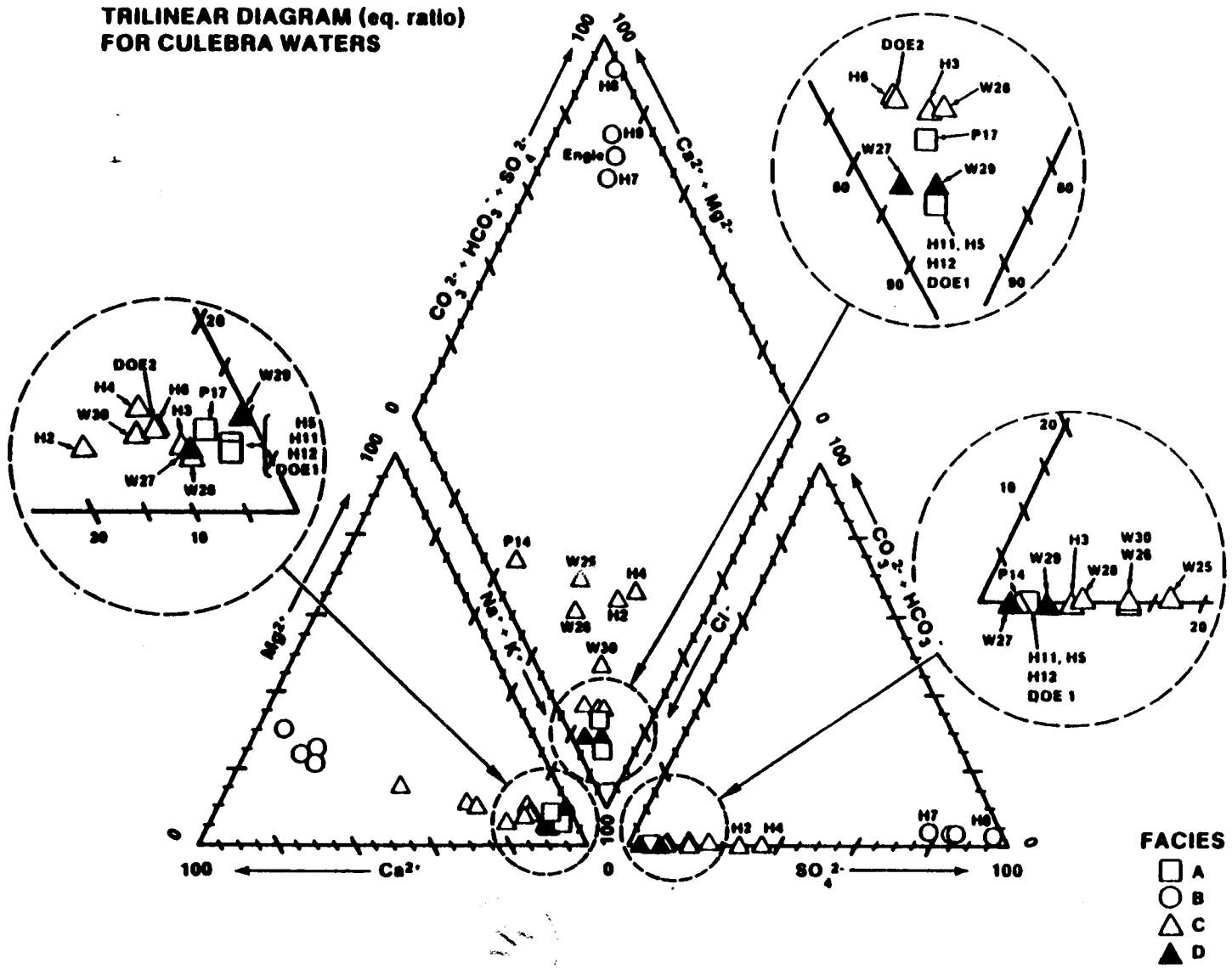


Figure 4.3.2: Piper (trilinear) diagram for analyzed Culebra fluids. Analyses are represented in terms of equivalents per liter. From Siegel et al. (1988b).

The analyses from Zone A have nearly identical ionic proportions (Figure 4.3.2), and plot very near the Na-Cl corner in both parts of the figure. In contrast, the analyses of the dilute fluids from Zone B all plot near the Ca-Mg-SO_4 corner in the upper part of the figure. Analyses from Zone C are variable, and those groundwaters closer to the Na-Cl corner of the plot are similar to waters from Zone A. Zones A and C are distinguished primarily on the basis of Ca/Mg ratio and ionic strength. Waters from Zone D have similar ionic ratios as fluids from Zone A except for K/Na; Zone D is distinguished primarily on the basis of its high K/Na ratios.

The overall interpretation of the facies distribution (Siegel et al., 1988a), assuming that the Culebra is relatively confined, is that flow directions within the Culebra must be transient. The inconsistency of Culebra fluid densities and steady-state confined flow was noted in Section 4.1, based on numerical modeling studies of Haug et al. (1987) and LaVenue et al. (1988). Ramey (1985) noted that modern flow directions within the Culebra do not appear consistent with the modern salinity distribution. This inconsistency is also evident in Figure 4.3.1, which is based on a larger and more reliable data base than considered by Ramey (1985). The most striking evidence is that fluids in Zone B, a facies with low salinity, lie down-gradient from more saline waters in Zone C. It is difficult to explain the origin of fluids presently in Zone B by steady-state confined flow through Zone C (Figure 4.3.1). One alternative to steady-state flow, based on isotopic studies (Sections 4.3.2, 4.3.3, and 4.3.4), is that there has been a significant change in flow directions within the Culebra dolomite in the last (approximately) 12,000 years. This is consistent with geologic evidence indicating the transient geologic and hydrologic setting of the WIPP site (Section 4.4).

4.3.1.2 Normative Salt Assemblages of Rustler Waters--The chemical variability of Culebra fluids has also been evaluated on the basis of normative salt assemblages, as summarized by Bodine et al. (1988). The normative salt assemblage (salt norm) of a given water is the equilibrium assemblage of salts that would precipitate from the water if it were evaporated to dryness under standard conditions (25 degrees C, 1 atmosphere pressure). In this interpretation, the SNORM code (Bodine and Jones, 1986) was applied by Bodine et al. (1988) to a different data base than that shown in Table 4.13.

The interpretations of the derivation of Culebra fluids based on hydrochemical facies, isotopic data, and physical hydrology are not in all cases consistent with those based on interpretation of salt norms. Siegel and Lambert (1988) conclude that the overall hydrologic setting of the Culebra is transient. Bodine et al. (1988) conclude that the present distribution of salt norms within the Rustler Formation is, when considered alone, generally consistent with the modern Culebra flow field. These authors relax the vertical confinement of the Rustler. On the basis of solutes alone, their interpretation cannot exclude dilution of primitive-diagenetic brines at P-14 and in the low-permeability, halite-rich zones of the Culebra east of WIPP Zone 3 (for example at P-18) by water that has infiltrated from the surface and dissolved both halite and anhydrite or gypsum. With increasing distances from P-18 and P-14, increasing amounts

of solutes from recharge are interpreted to have mixed with primitive-connate Culebra solutes.

Based on salt-norm calculations, Bodine et al. (1988) suggest four end-member fluid compositions from evaporitic rocks at the WIPP site. These are:

1. Brines containing alkaline earth (Ca, Mg, Ba, Sr, etc) chloride salts in their normative assemblages, combined with relatively low Cl/Br weight ratios (<300). These brines could arise as primitive-diagenetic fluids, for example when connate waters are involved in dolomitization. The data base supporting this end member is limited.

2. Dilute alkali-bearing carbonate waters, produced during recharge by carbonic-acid dissolution of detrital silicates in the zone of infiltration.

3. Dilute sulfate-rich waters, produced when meteoric waters dissolve anhydrite and/or gypsum, but little else.

4. Variably saline halite-rich fluids or brines, produced when meteoric waters dissolve both anhydrite/gypsum and halite in the Rustler and upper Salado Formations.

Bodine et al. (1988) conclude that the solutes in most waters in the Rustler Formation can be produced by mixing of these four end members. Water produced by dewatering of gypsum is not precluded by the solute assemblages. However, the stable-isotope compositions of confined Culebra and Magenta waters (Section 4.3.2) are characteristically meteoric, indicating that gypsum dewatering has not played an identifiable role in their derivation. Bodine et al. (1988) conclude that, if analyzed solutes from the Culebra at P-18 are representative, the Culebra water from P-18 has the highest proportion of apparent primitive-diagenetic brine. They also suggest that some components of the water from P-14 may be primitive, if it is assumed that there has been no mixing or contamination. Waters from the Rustler-Salado contact zone at H-5 and H-6 contain the highest proportion of the primitive-connate solutes. According to Bodine et al (1988), the relative proportion of recharge-type solutes to primitive-diagenetic solutes within the Culebra increases from the WIPP site towards the north, west, and south.

The interpretative model of Bodine et al. (1988) relies heavily on the compositions of Culebra fluids at P-18 and P-14. As noted by Siegel et al. (1988b), the representative character of samples of Culebra fluids from P-18 is suspect, i.e., the analyses appear reliable, but may not represent actual Culebra fluids at this location. Hydrologic considerations also weigh against the reliability of these data. The Culebra transmissivity at P-18 (7.5×10^{-11} to 4.3×10^{-9} m^2/s, Table 4.2) is the lowest yet measured at or near the WIPP site. Therefore, while the Culebra at P-18 intuitively seems likely to contain connate brine, consistent with the norm-based interpretation of Bodine et al. (1988), the very fact that the Culebra is

so low in transmissivity at P-18 permeability makes it extremely difficult if not impossible to collect a meaningful fluid sample from the hole. In P-14, the situation is reversed. The Culebra in P-14 is extremely transmissive (2.3×10^{-4} m^2/s, Table 4.1). The preservation of original connate or diagenetic fluids in such a permeable region does not seem possible or consistent with expected rates of fluid flow in the vicinity (Figure 4.1.28). In addition (Section 4.3.2), the stable-isotope composition of Culebra waters from P-14 is meteoric, suggesting that P-14 fluids have not been involved in extensive diagenetic reactions. However, the analyses of Culebra waters from P-14 do appear reliable. The cause of the apparent primitive-diagenetic component in these fluids is not known.

The salt-norm interpretation also relies heavily on vertical recharge from the surface to provide fluids for dilution of the interpreted primitive-diagenetic signature of Culebra fluids, especially south of the WIPP site. However, the isotopic evidence, discussed in later parts of Section 4.3 and in Section 4.4, as well as the measured head and transmissivity distributions within the Rustler, discussed in Section 4.1, suggest that vertical recharge to the Culebra from the surface is not currently active at and near the WIPP site. The Culebra dolomite is confined at and south of the site, while the Dewey Lake Red Beds, where tested, are effectively impermeable. Finally, as discussed in Section 4.4, the preservation of large amounts of anhydrite in the Tamarisk Member overlying the Culebra, suggests that vertical infiltration of dilute solutions through the Tamarisk has been minimal. These relationships do not indicate that there has been no vertical fluid movement within the Rustler Formation or between the Dewey Lake and the Rustler, but that such movement is limited, and does not currently extend from the surface down to the Culebra.

4.3.1.3 Saturation Indices and Factor Analysis of Culebra Waters--Saturation indices of several evaporite minerals in analyzed Culebra waters have been calculated using the code PHRQPITZ (Plummer et al., 1988), and are summarized in Siegel et al. (1988a). The variation in halite saturation index as a function of ionic strength is shown in Figure 4.3.3. All fluids are undersaturated with respect to halite and Na and Cl concentrations vary widely. There is a consistent increase in halite saturation index with increasing ionic strength.

The variations in calculated gypsum and anhydrite saturation indices with ionic strength are shown in Figure 4.3.4. The data are internally consistent and indicate both a general saturation with respect to gypsum and an increase in anhydrite saturation with increasing ionic strength. However, with the exception of WIPP-29 (Zone D) all samples are undersaturated with respect to anhydrite. As a result, almost all Culebra waters are capable of converting into gypsum any anhydrite with which they might come into contact.

Most calculated dolomite saturation indices for Culebra fluids indicate saturation or apparent supersaturation (Figure 4.3.5). The relationships between saturation indices, pH, and calculated pCO_2 suggest, as discussed in Siegel et al. (1988b), that loss of CO_2 during sample collection may be

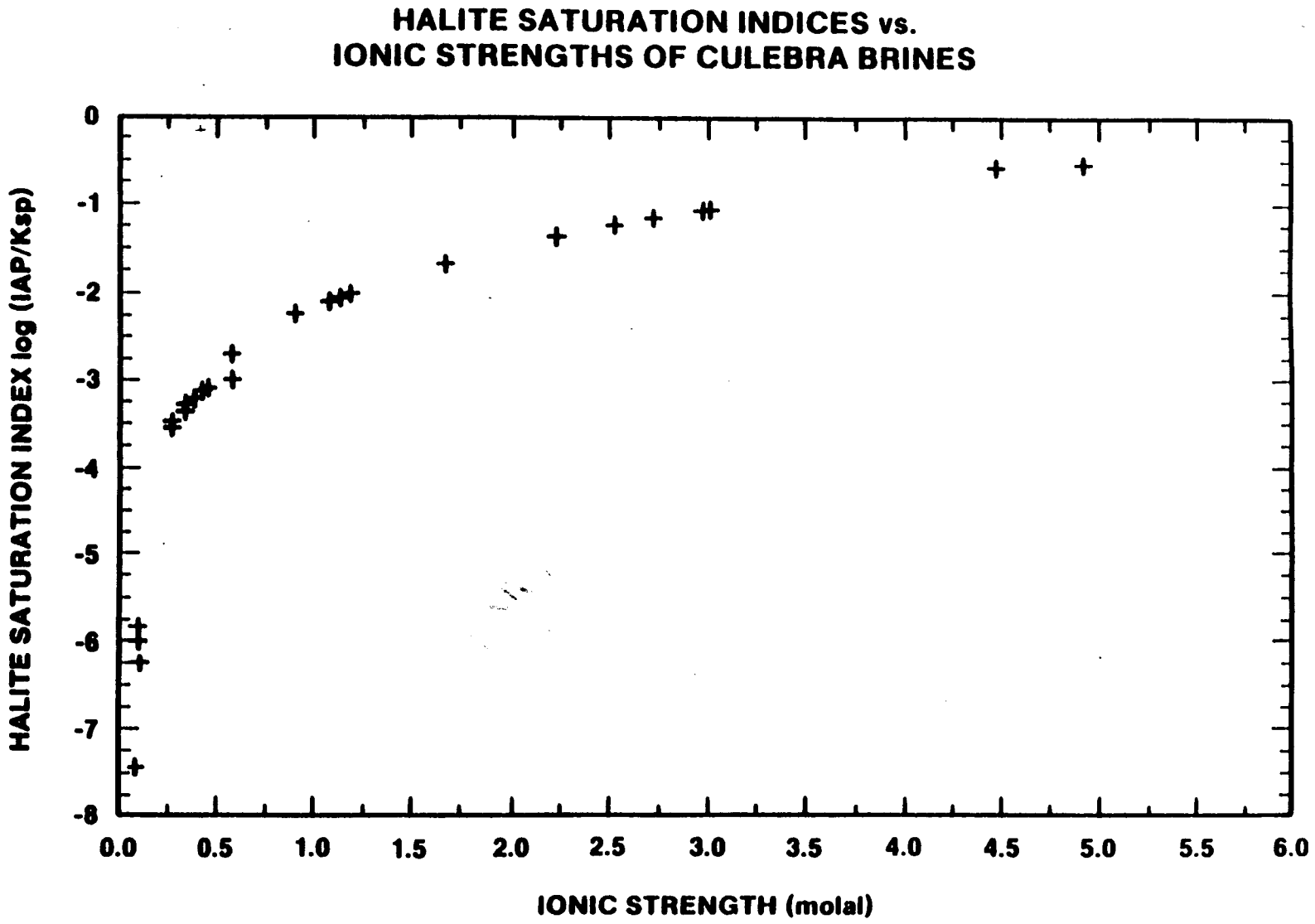


Figure 4.3.3: Variation in calculated halite saturation indices of Culebra waters as a function of ionic strength. From Siegel et al. (1988b).

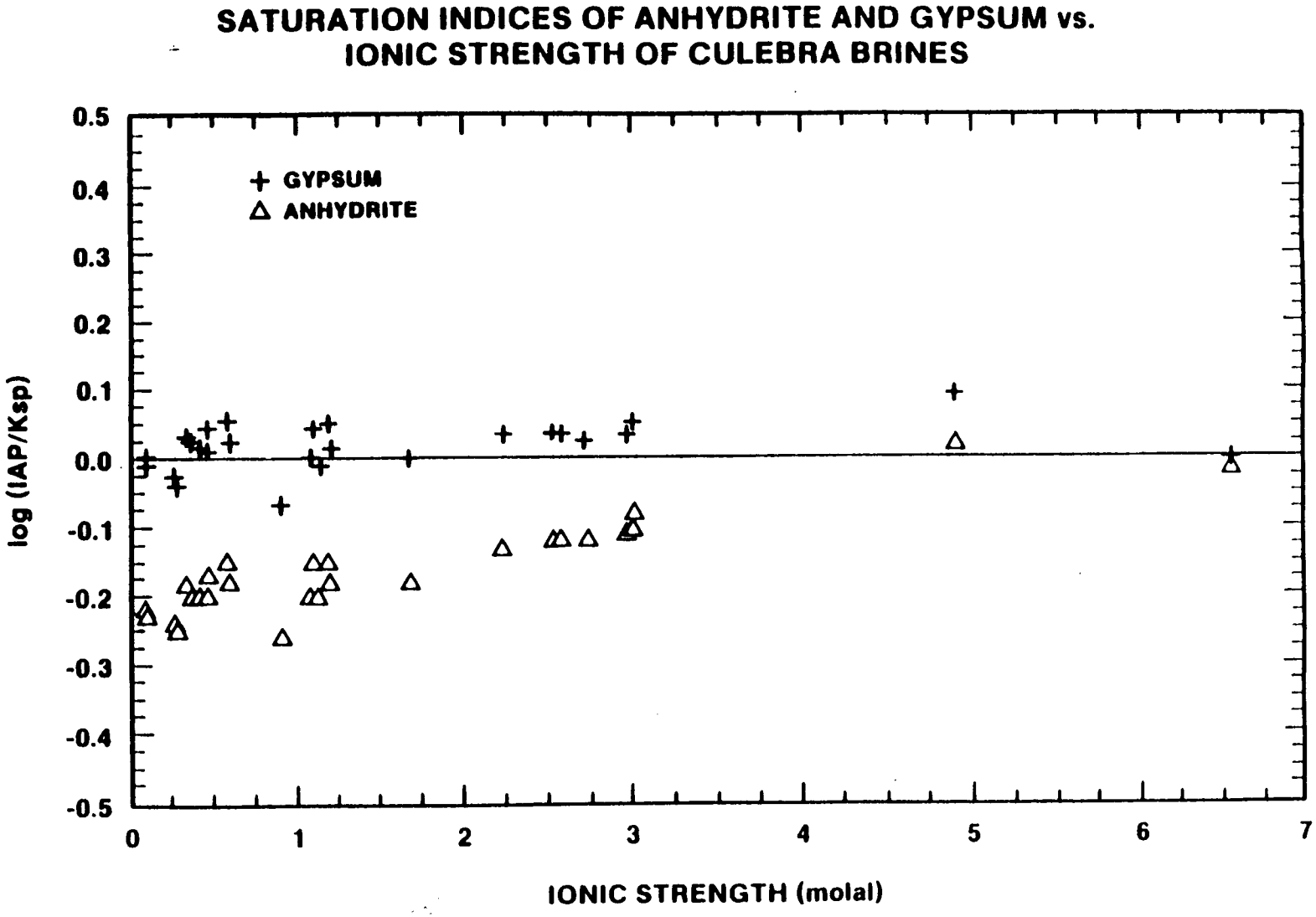


Figure 4.3.4: Variation in calculated gypsum and anhydrite saturation indices of Culebra waters as a function of ionic strength. From Siegel et al. (1988b).

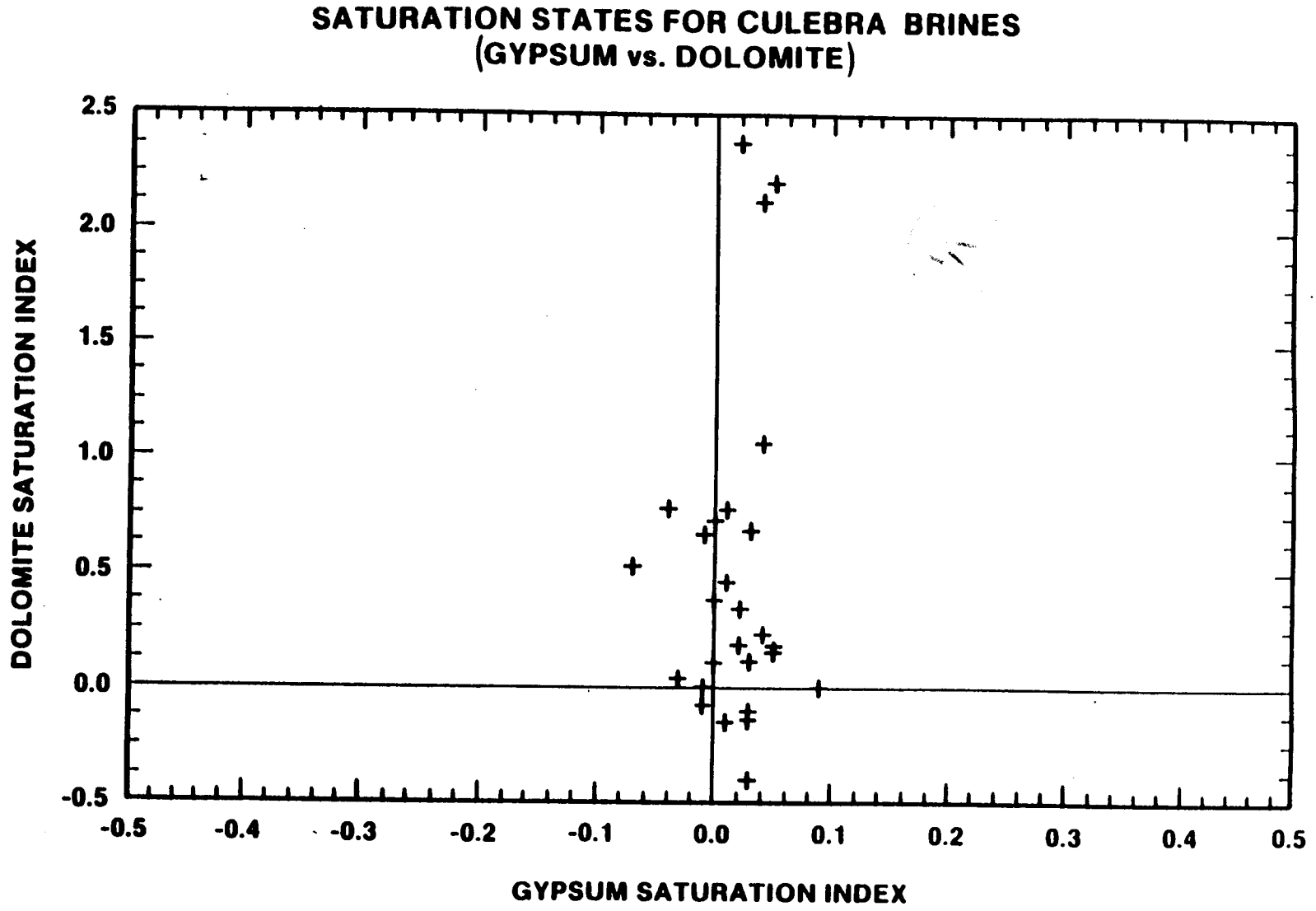


Figure 4.3.5: Variations in calculated dolomite saturation indices of Culebra waters as a function of calculated gypsum indices (Figure 4.3.4). From Siegel et al. (1988b).

responsible for the apparent supersaturation; other potential sources of error include use of an inappropriate free energy for dolomite and analytical error. The wide scatter in dolomite saturation indices gives some indication of the apparent effect of degassing on calculations involving dolomite. The origins of the high original pCO_2 in Culebra waters is not known, but may include carbonate dissolution and/or microbial action (see Section 4.3.3).

In addition to the major solutes used in defining hydrochemical facies and in calculating saturation indices considered thus far, there are consistent trends in both major-element (Ca, Mg, Na, K, Cl, and SO_4) and minor-element (Br, I, Sr) ratios in Culebra fluids. These trends, which are discussed in more detail in Siegel et al. (1988b) include the following:

1. The Na/Cl ratios of fluids south of the WIPP site are higher than would be produced by simple dissolution of halite, suggesting the importance of dissolution of Na-silicates at some time in the derivation of fluids in this area. This is consistent with the norm-based end member of dilute meteoric alkali-bearing carbonate waters discussed in Section 4.3.1.1.

2. At WIPP-27 and WIPP-29, the K/Na ratios and Na, K, Mg, Cl, and SO_4 concentrations are significantly higher than at other wells in Nash Draw or west of the site, suggesting that potash refining operations have significantly contaminated these locations. This is consistent with the definition of hydrochemical facies "D" in Section 4.3.1.1.

3. Both ratios and concentrations of several elements are anomalous in samples collected from P-14, compared to surrounding wells. For example, concentrations of Ca, Sr, and I are anomalously high at P-14, and K and SO_4, low. The Na/Cl, K/Na. and Mg/Ca ratios are somewhat low, and the Cl/Br ratio distinctly low at this well. The "primitive-diagenetic" salt norm at P-14 is anomalous (Section 4.3.1.1).

4. Regionally, the Cl/Br weight ratios are highest in Nash Draw, intermediate through the center of the WIPP site and to the south, and lowest at P-14 and H-4.

Examination of the relations between element ratios discussed above indicate that correlations between elements are not simply linear. For this reason, the data in Table 4.13 were also examined using Principal Component Analysis (PCA). The technique is described in detail in Siegel et al. (1988b). The purposes of PCA are to determine if the fluids come from a single or continuously variable population, and to delineate the different independent ways (factors) by which major and minor elements are correlated.

The preliminary results of factor analysis of Culebra fluids indicate that, on a regional scale, the samples are all drawn from a single chemical population; i.e., their chemistry is controlled by a consistent set of components. The most important component shown by R-mode PCA is dominated

by Na, K, Mg, Br, and Cl. All solutes except SiO_2, alkalinity, and pH exhibit positive correlation with this factor. The second major factor also includes Na and Cl, but is dominated by Ca, HCO_3, and Sr. Overall, the data are interpreted to suggest that the two fluid-compositional factors describing the variability of Culebra waters represent addition of solutes by dissolution of halite, gypsum/anhydrite, and carbonates (Siegel et al., 1988b).

However, because the amount of solute added by halite dissolution is so large relative to that added by other reactions, i.e., because halite solubility is much greater than that of other minerals considered, other chemical correlations may be masked. For this reason, a second set of PCA was carried out by Siegel et al. (1988b), using a method designed to be independent of total dissolved solids and hence halite dissolution. The primary component determined in this analysis contains two groups of elements that are inversely correlated. One group contains Mg, bicarbonate alkalinity, and SiO_2; the other group contains Na, pH, B, and Li. This pattern of element association is tentatively interpreted by Siegel et al. (1988b) to reflect clay diagenesis or silicate hydrolysis. The apparent uniformity of the compositional factors describing the variability of Culebra waters does not identify a discrete mechanistic or mineralogical delineation between the hydrochemical facies defined in Section 4.3.1.1.

4.3.1.4 Estimated Oxidation-Reduction Potentials of Culebra Waters--Many of the transuranic elements to be emplaced in the WIPP facility have multiple valence states. Therefore, given the possible role of the Culebra dolomite in transport to the accessible environment, it is important to estimate oxidation potentials (redox potentials, Eh) within the unit. Available measurements of redox potentials in Culebra waters are described in detail by Myers et al. (1988), and are summarized in Figure 4.3.6. Myers et al. (1988) conclude that the calculated potentials summarized in Figure 4.3.6, based on the data from Pt electrodes and redox pairs involving N, I, As, and Se, are fairly insensitive to assumptions concerning activity-concentration relationships, reasonable uncertainties in analytical data, and errors introduced by uncertainty in field pH. Absolute potential measurements made with Pt electrodes are not generally considered highly reliable; they are included here only for purposes of inter-well comparison. Nonetheless, many of the data are internally inconsistent.

The internally consistent values, indicated in Figure 4.3.6 by the vertical shaded bars, are interpreted by Myers et al. (1988) to bracket the redox potentials for the wells in Zone B (H-7, H-8, H-9, and Engle) between +330 and +630 mv (or higher). A similar range is indicated for WIPP-26 (Zone C) in the eastern part of Nash Draw. Data for the nitrogen couple in hydrochemical facies A and C (Figure 4.3.1), except for WIPP-26, indicate less oxidizing conditions, with an estimated Eh of less than approximately +330 mv.

Quantitative data are not available from within most of Nash Draw. The internally consistent data from WIPP-26 indicate a similar range of redox potential to that at H-7, H-8, and H-9. The platinum-electrode

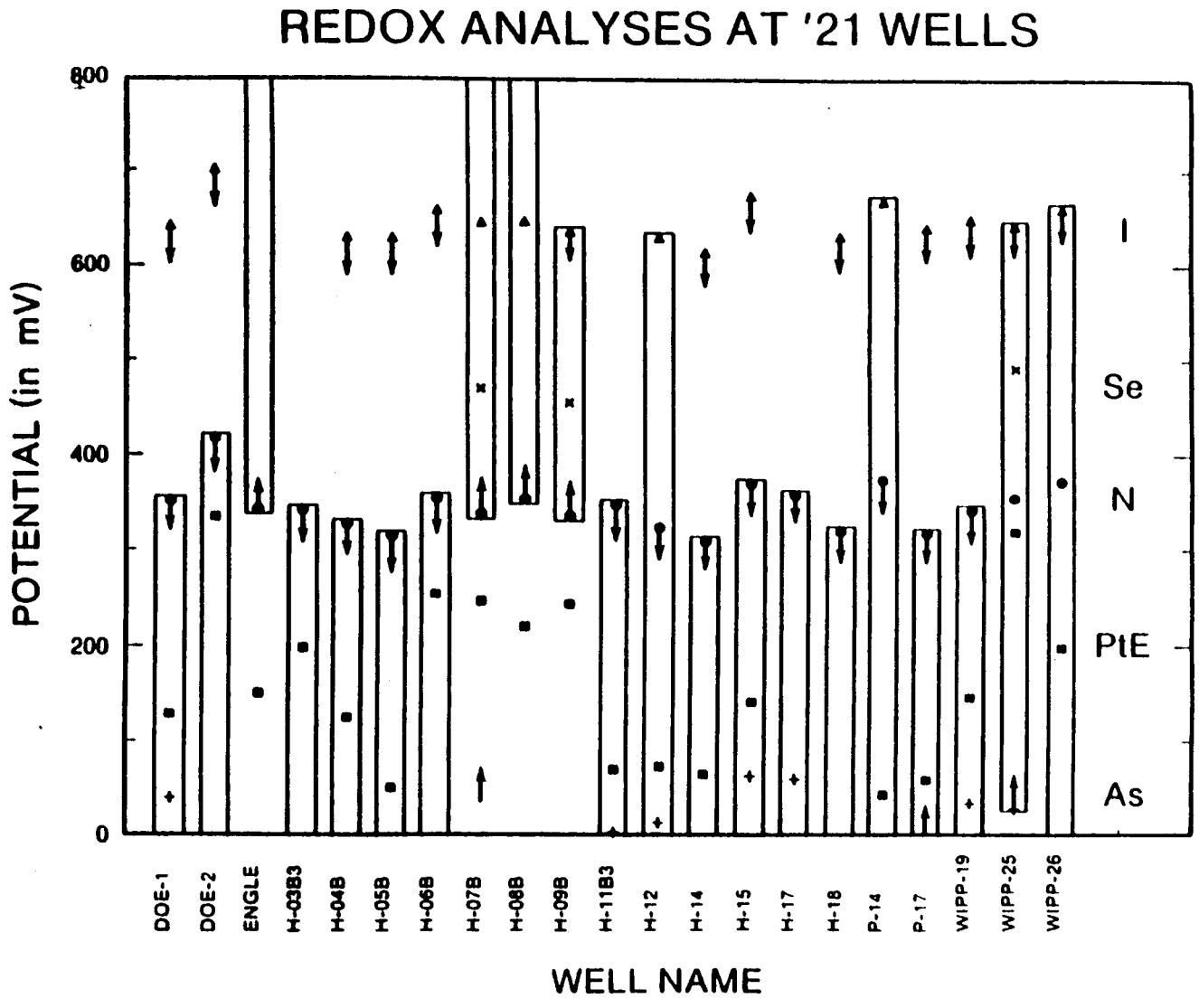


Figure 4.3.6: Variability in approximate redox potential of waters from several Culebra wells. Symbols: + = AsIII/AsV; □ = platinum electrode; o = NH_3/NO_3^-; x = SeIV/SeVI; ▲ = I^-/IO_3^-. Arrows indicate upper or lower limits resulting from one member of pair being present at levels below the detection limit. From Siegel et al. (1988b).

measurements in H-7, H-8, H-9 and WIPP-26 (Figure 4.3.6) are higher than those at most other locations. The apparent range of consistent potentials in WIPP-25 is large. Lambert and Robinson (1984) note, however, that WIPP-25 evolved H_2S during fluid sampling, suggesting that these results are suspect. Relative measurements with Pt electrodes (Lambert and Robinson, 1984), also indicate that redox potentials in the Culebra in Nash Draw are higher than those in the underlying Rustler/Salado contact zone.

Thus, there appear to be consistent variations in redox potential within the Culebra dolomite, with more reducing conditions to the northeast and more oxidizing conditions toward the southwest. This regional variation in the modern oxidation potential plays a significant role in interpretation of uranium-disequilibrium studies discussed in Section 4.3.4.

4.3.1.5 Mineralogy of the Culebra Dolomite--It has already been noted that both the composition and density of Culebra fluids vary considerably at and near the WIPP site. One objective of studies summarized in Siegel et al. (1988a) was to determine whether or not variations in Culebra mineralogy correlate with variations in Culebra fluid compositions. Accordingly, detailed mineralogical studies of Culebra samples from ten different locations along three east-west traverses have been conducted, and are described by Sewards et al. (1988).

Figure 4.3.7 shows a mineralogical cross section of the Culebra dolomite from Nash Draw towards the east, south of the WIPP site proper, as interpreted from sampled core (Sewards et al., 1988). As in any core study, especially in a locally fractured unit such as the Culebra, it cannot be demonstrated that the sampled core has been in contact with flowing groundwater. Mineralogical contents estimated by Lambert (1988) during preparation of rubbled material selected for isotopic analysis of Culebra matrix and veins (Section 4.4.2) differ somewhat from analyses summarized in Figure 4.3.7. The mineralogy at H-7 and H-10 (Figure 4.3.7) is probably representative of intact core samples at the WIPP. The dominant mineral in the selected cores is fairly pure dolomite, comprising about 85% of the bulk rock (by weight). Minor amounts of gypsum, calcite, and clay are observed throughout the sampled cores, but their distribution is heterogeneous both vertically and laterally. Fractures, which are present in most cores, are most commonly lined with clay and gypsum. Gypsum ($CaSO_4 \cdot 2H_2O$) occurs as both fracture and vug fillings. Available analyses indicate that it is nearly pure. Both the composition and textural features suggest that it is secondary in origin. Calcite from the upper portion of the Culebra in WIPP-29 is also interpreted to be secondary. Minor amounts of pyrite, magnesite, quartz, and authigenic feldspar have been observed in some cores. Finally, a dark optically-amorphous and X-ray-amorphous material is present in some abundance in Culebra samples examined, and has been tentatively identified as organic matter. It is generally associated with clays, and often occurs in algal structures or haloes surrounding vugs, the origin of which is attributed to biological activity.

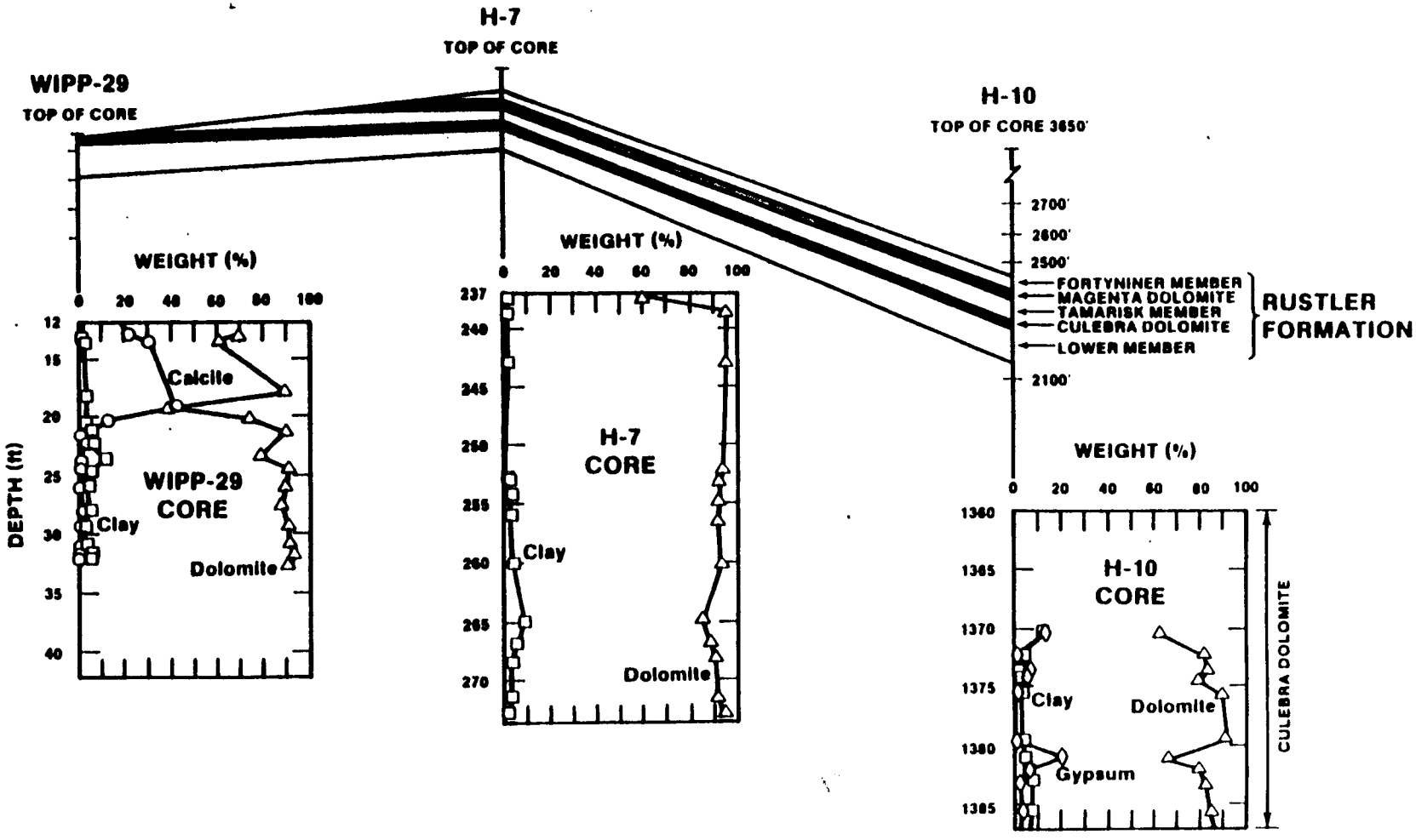


Figure 4.3.7: Fence diagram of variations in bulk mineralogy of core samples of the Culebra dolomite along the east-west section including holes WIPP-29, H-7, and H-10. From Siegel et al. (1988a).

In the intact cores examined by Sewards et al. (1988), corrensite, an ordered mixed-layer illite-smectite clay, is the second most abundant mineral within the Culebra after dolomite. In addition to occurring along fractures, clays are also present in the matrix of all Culebra samples, and commonly make up 3 to 5 weight percent of the bulk sample. The dominant clay minerals are corrensite, illite, chlorite, and a serpentine-like mineral, tentatively identified as amesite.

The recent mineralogical studies in the Culebra indicate that the unit is vertically and laterally heterogeneous. The dominant variation in Culebra fluids, variation in Na and Cl (Section 4.3.1.1), is not reflected in the presence or absence of halite in Culebra core. Dolomite, clays, and gypsum are ubiquitous, and calcite local in occurrence. Table 4.14 summarizes potential rock/water reactions that may influence the chemistry of Culebra waters. With the exception of halite, all of the minerals involved in reactions listed in Table 4.14 occur in the Culebra throughout the area at and near the WIPP site. Halite that has definitely not been introduced during drilling has not been reliably identified in any Culebra core. With the exception of halite dissolution, any of the reactions indicated in Table 4.14 can occur in any of the Culebra hydrochemical facies zones defined. Examination of potential rock/water reactions affecting fluids within the Culebra has not yet identified unique or discontinuous relationships between matrix mineralogy and fluid composition that can be used to place additional constraints on either present or past directions of fluid flow.

In summary, the highly variable fluids within the Culebra dolomite can be divided into four facies. The distribution of these facies is not consistent with modern regional flow directions estimated from hydrologic measurements, if steady-state confined flow is assumed. Zone B, containing lower-salinity fluids lies down-gradient from Zone C, which contains more saline waters. An internally consistent interpretation of the variability of Rustler fluids is possible on the basis of salt norms if large-scale vertical recharge is assumed in some areas. However, some of the analyses used in this interpretation do not appear to be representative, and both isotopic and hydrologic evidence suggest that such vertical fluid movement is not now operative at and near the WIPP site. The mineralogy of core samples from the Culebra dolomite is consistent only in its variability. It cannot be demonstrated that sampled fluids at a given well have been in contact with a given piece of core; therefore it cannot be directly demonstrated that rock/water interactions identified on the basis of a given core sample control or affect the local fluid composition. The available data cannot identify any unique relations between Culebra matrix mineralogy and major-solute or minor-solute compositions of Culebra waters that can themselves be used to place constraints on either past or present flow directions within either the Culebra or the Rustler Formation as a whole. As discussed in Section 4.4.2, however, the isotopic compositions of some minerals within the Rustler, especially gypsums, can be used to place constraints on vertical fluid flow.

Table 4.14: Summary of possible rock-water reactions affecting compositions of Culebra fluids. From Siegel et al. (1988a).

Chemical Process	Potential Effect on Culebra Water
Halite Dissolution	increase Na, Cl, Br, Li; decrease Cl/Br; increase solubility of carbonates and sulfates up to 3 molal NaCl and then decrease solubility causing changes in Ca, Mg, SO_4, CO_3
Precipitation/dissolution of gypsum	decrease/increase Ca, SO_4
Precipitation/dissolution of calcite and dolomite	decrease/increase Ca, Mg, CO_3
Dolomitization: calcite + Mg -> dolomite + Ca	decrease Mg/Ca
Dedolomitization: dissolution of gypsum and dolomite with concurrent precipitation of calcite.	decrease pH, alkalinity/SO_4; maintain Mg/Ca molar ration < 1
Ion exchange involving Mg, K-rich clays in NaCl brines	loss of Na, gain of Mg, K by solution
Mixing of connate hypersaline formation water with recharge water that has dissolved gypsum,	increase Mg, Ca, K, Na, Cl; decrease SO_4, Cl/Br
Incongruent dissolution of polyhalite	increase Mg, K, SO_4; decrease Ca, Cl/Br

4.3.2 Recent Stable-Isotope Studies of Groundwaters from the Rustler Formation and Younger Units

4.3.2.1 The Character of Modern Recharge in the Northern Delaware Basin--As mentioned above, stable-isotope studies do not provide direct information concerning the age of groundwater. Rather, they may indicate whether or not two or more bodies of water were recharged under similar climatic conditions and whether or not one of the bodies of water is modern. At the WIPP site, the approach requires both determination of the isotopic character of modern recharge in the region and determination of

whether or not the isotopic character of groundwaters in the Rustler Formation and younger units is consistent with that of modern precipitation. Recent stable-isotope studies of groundwaters in the northern Delaware Basin conducted as part of WIPP site-characterization activities are summarized by Lambert and Harvey (1987).

The present stable-isotope data base for waters from Carlsbad Caverns (Lambert and Harvey, 1987), is summarized in Figure 4.3.8. Samples were collected from active drips or pools in portions of the cavern system well above the modern water table. Depending on assumptions concerning seasonal averaging of fluid compositions during infiltration and possible evaporation within the caverns, these waters may or may not be representative of modern meteoric recharge in the northern Delaware Basin at elevations similar to that of the surface of the WIPP site.

Lambert and Harvey (1987) conclude that, with one possible exception (sample "GS"), evaporation and rock-water interaction do not play a significant role in derivation of the waters shown in Figure 4.3.8. This is because the waters fall in or near the "meteoric field," defined by the compositional space between the statistical world-wide precipitation trends calculated by Craig (1961) and by Epstein et al. (1965, 1970). Therefore, the isotopic character of the waters (Figure 4.3.8) is interpreted as consistent with that of modern meteoric recharge in the northern Delaware Basin.

The character of modern precipitation in the northern Delaware Basin also rests on other analyses. In 1983, waters from Carlsbad Caverns were essentially the only waters interpreted to represent this recharge. As shown in Figure 4.3.9, most of the more recent measurements on surficial waters and some on shallow groundwaters in the vicinity of the WIPP site and at similar elevations are consistent with measurements on unconfined waters from the Capitan limestone. Samples from a local storm (August 26, 1980) fall within the Carlsbad Caverns field, as do samples from the Dewey Lake Red Beds at the James Ranch and Quaternary alluvium at WIPP-15. The character of the water from the Dewey Lake Red Beds in the James Ranch well is consistent with the interpretation that the Dewey Lake is experiencing modern recharge at this location. The well at the James Ranch (identified as "ranch well" in Figure 1.2) is close to a locally active dune field south of the WIPP site; WIPP-15 was drilled specifically to investigate San Simon Sink (Figure 1.1), an active collapse feature over the Capitan limestone. The measured deuterium/hydrogen ratios of nine water-table samples from the Ogallala Formation in southeastern New Mexico are consistent with the lighter end of the Carlsbad Caverns field in Figure 4.3.9. Heavier Ogallala samples also high in tritium, discussed by Lambert (1988), are consistent with this field. Thus, Lambert and Harvey (1987) base the isotopic composition range of their field of "demonstrably modern precipitation" used in discussions below and in later figures in this section on measurements at several localities, and in several different geologic units. Additional information, especially concerning both the deuterium and tritium characteristics of groundwaters in the High Plains of Texas and the northern Delaware Basin of New Mexico is contained in Lambert (1988).

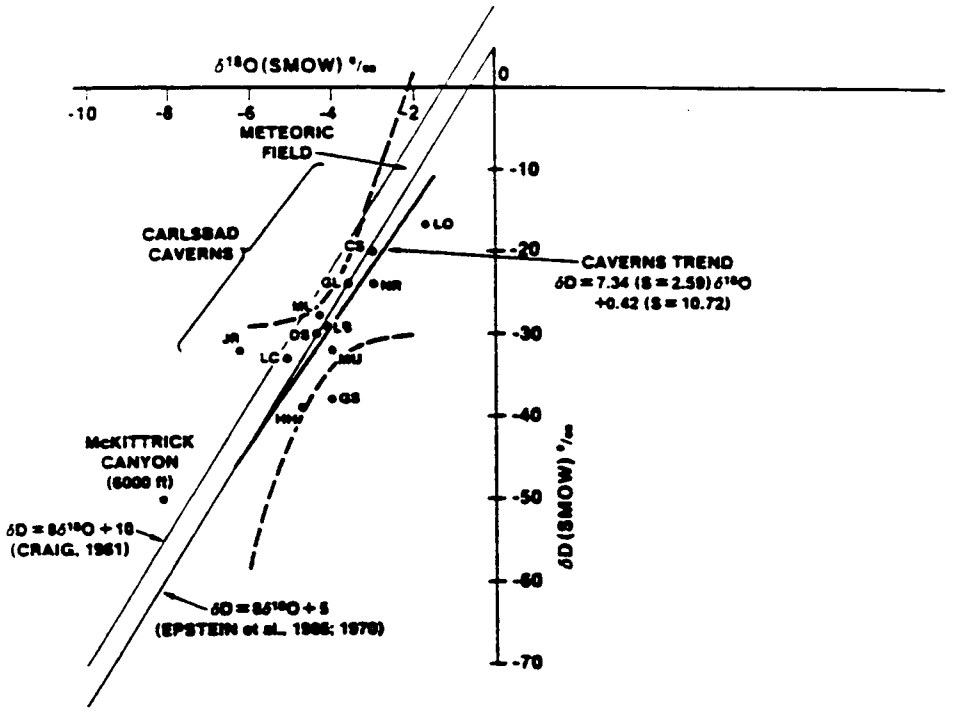


Figure 4.3.8: Available stable-isotope analyses of waters from the unconfined portion of the Capitan limestone in Carlsbad Caverns, New Mexico. The two-letter identification of individual samples is fully explained in Table 3 of Lambert and Harvey (1987). The meteoric field is defined as the area between the statistical correlation lines of Craig (1961) and Epstein et al. (1965, 1970). Slightly modified from Figure 6 of Lambert and Harvey (1987).

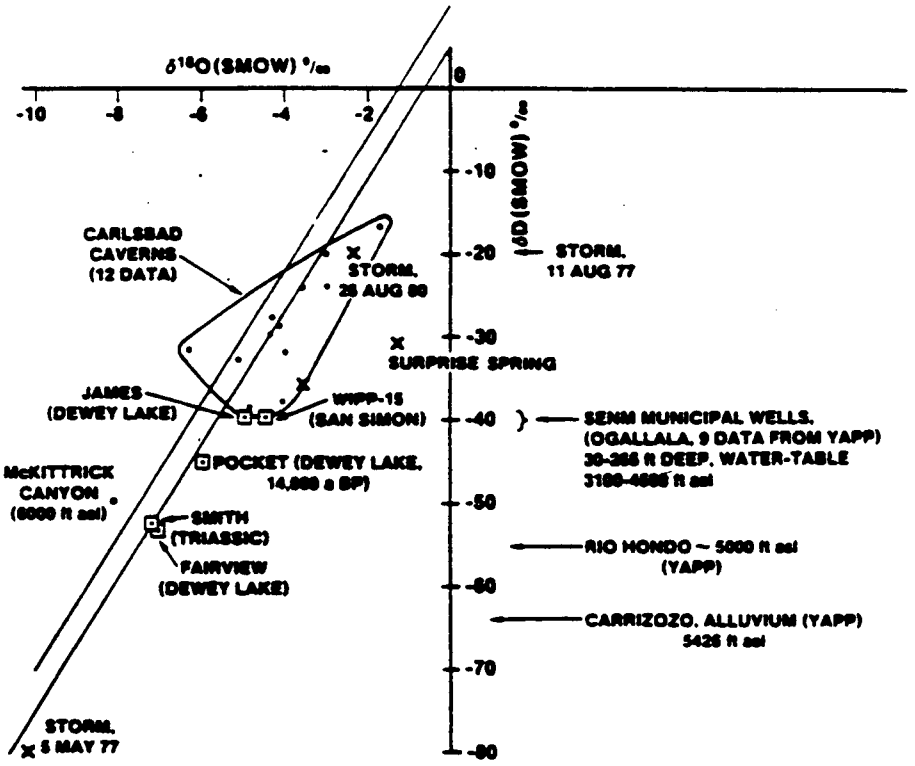


Figure 4.3.9: Recent stable-isotope analyses of surficial and near-surface waters in the northern Delaware Basin. Slightly modified from Figure 9 of Lambert and Harvey (1987).

Stable-isotope data from both the travertine deposit in McKittrick Canyon and a local storm (May 5, 1977) are much lighter than the Carlsbad Caverns field shown in Figure 4.3.9. The isotopic character of these samples is interpreted by Lambert and Harvey (1987) to be due to local elevation effects and point-data variability of individual storms. A similar elevation-dependent argument is made concerning the deuterium data available for Rio Hondo and at Carrizozo (see Lambert and Harvey, 1987 for discussion and detailed sample locations).

Not all data from stratigraphic units above the Rustler fall in the Carlsbad Caverns field in Figure 4.3.9. Water from the Dewey Lake Red Beds at the Pocket well is relatively light. This water has a calculated minimum radiocarbon age of 14,000 years (Section 4.3.3). The ages or isolation times of the relatively light waters from the Smith and Fairview wells are not known. The available stable-isotope results indicate complexity within the Dewey Lake Red Beds. The James Ranch well appears to contain "modern" water, and is located near an active dune field. The Pocket and Fairview wells, which both contain water isotopically distinct from the Carlsbad Caverns field in Figure 4.3.9, are both located near the southwestern lobe of Nash Draw.

4.3.2.2 The Hydrology of the WIPP Site and Vicinity Relative to Modern Recharge--Figure 4.3.10 summarizes the available stable-isotope data for groundwaters from the Magenta and Culebra dolomites at and near the WIPP site. In this figure, the isotopic character of these waters is contrasted with the Lambert and Harvey (1987) estimate of "demonstrably modern Delaware Basin recharge at 3,000 - 4,500 feet elevation," discussed above. The compositionally distinct waters from WIPP-29 and Surprise Spring, both of which are distinct from the meteoric field (Figure 4.3.8) are discussed separately below.

There is no overlap between the Culebra/Magenta data near the meteoric field and the interpreted compositional field representing modern recharge (Figure 4.3.10). On the basis of the consistent compositional distinctions shown in Figure 4.3.10, Lambert and Harvey (1987) conclude that: 1) the stable-isotope compositions of Culebra and Magenta groundwaters do not reflect modern meteoric recharge of the Rustler Formation; 2) there is no significant modern recharge to the Magenta and Culebra dolomites at and near the WIPP site; and 3) the waters presently contained within the Magenta and Culebra at and near the WIPP site were recharged under different climatic conditions than those at present. Therefore, at least some aspects of the hydrology of the Rustler Formation must be transient on some time scale.

The Rustler Formation is not the only unit in the northern Delaware Basin that contains older water. There is also significant variability in the isotopic character of fluids within the Capitan limestone (Figure 4.3.11). The heavier samples defining the "Carlsbad Caverns" compositional field in this figure, which is almost identical to the modern recharge field in Figure 4.3.10, are from the unconfined and partially saturated hydrologic system within Carlsbad Caverns. The lighter samples are from wells drilled

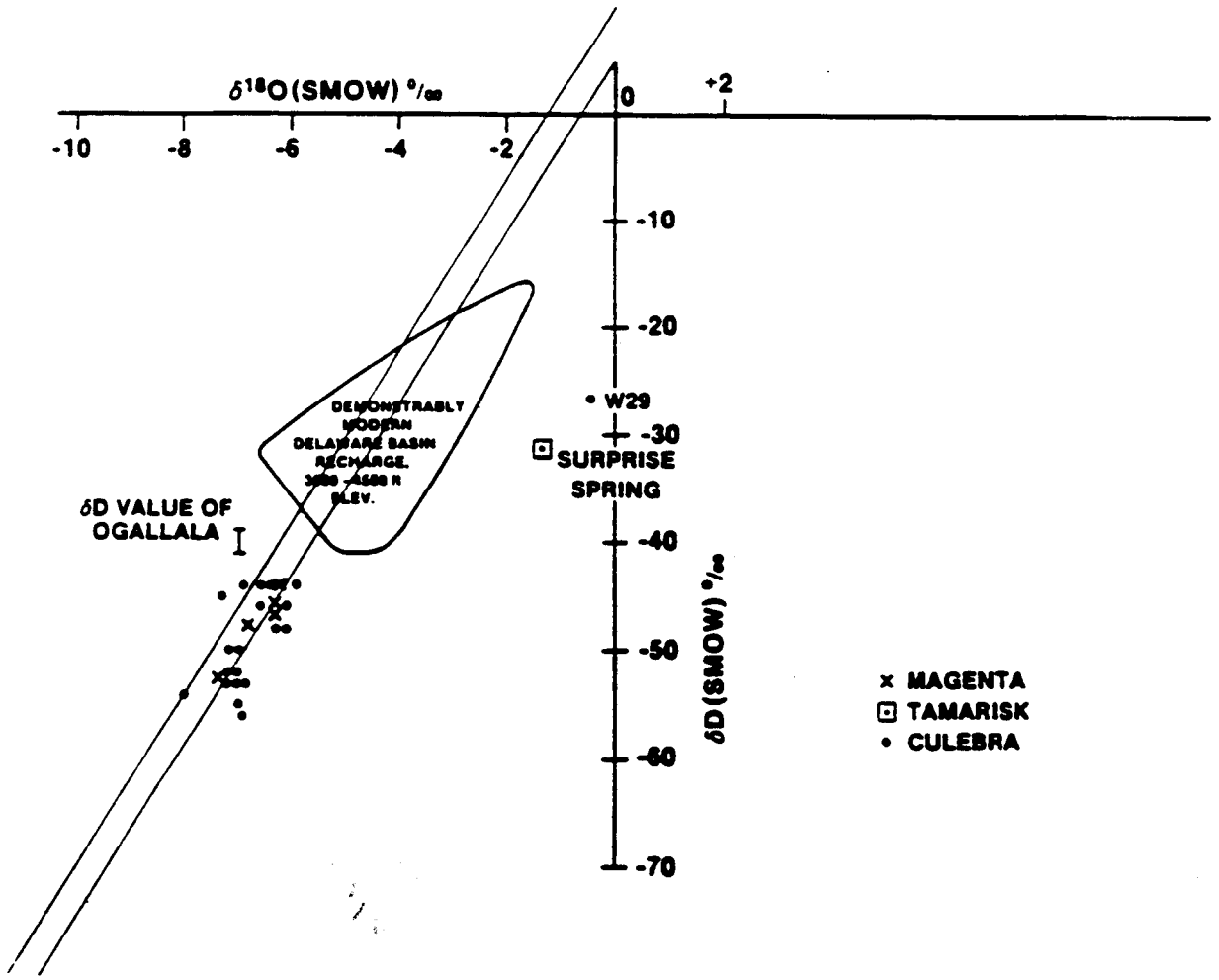


Figure 4.3.10: Stable-isotope compositions of waters from the Culebra and Magenta dolomites at and near the WIPP site. The "modern recharge" field is defined by the Carlsbad Caverns field and other consistent data contained in Figures 4.3.8 and 4.3.9. Note the anomalous character of samples from WIPP-29 and Surprise Spring. Slightly modified from Figure 14 of Lambert and Harvey (1987).

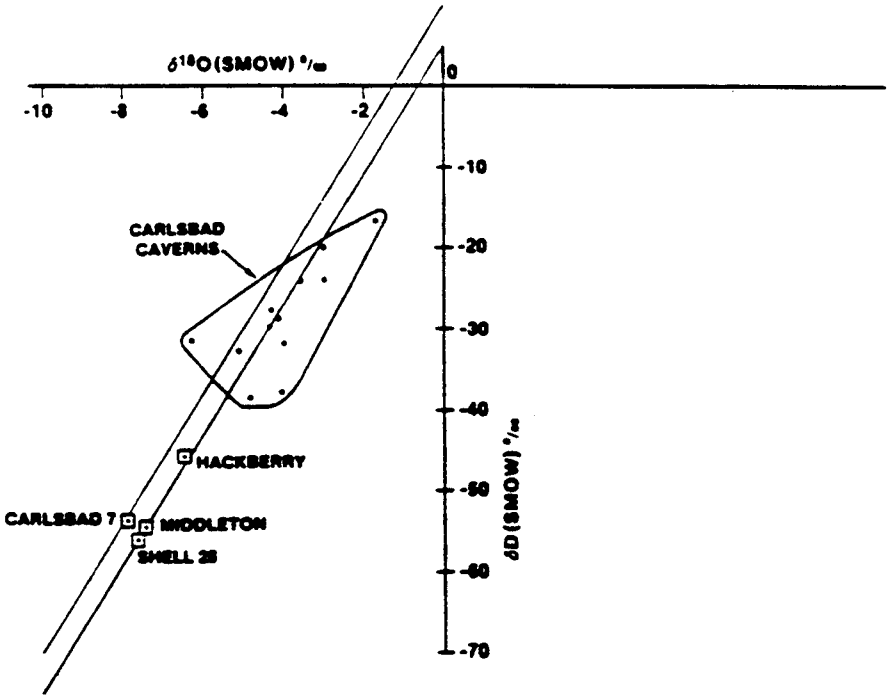


Figure 4.3.11: Comparison of stable-isotope character of waters from unconfined and confined portions of the Capitan limestone. Slightly modified from Figure 10 of Lambert and Harvey (1987).

into confined regions of the Capitan. The signatures of samples from confined portions of the Capitan limestone fall within the same compositional field as most Rustler fluids. Based on uranium-disequilibrium studies, Barr et al. (1983) estimate the isolation times for the Capitan waters from the Middleton and Hackberry wells (Figure 1.1) as 5.8×10^5 and 1.05×10^6 years, respectively.

Thus, stable-isotope measurements in the Rustler Formation, Dewey Lake Red Beds, and Capitan limestone are consistent with the conclusion that the hydrology of the northern Delaware Basin is transient. The fundamental conclusions of Lambert and Harvey (1987) and Lambert (1988) concerning the hydrologic setting of the northern Delaware Basin are:

1. The isotopic compositions of waters from unconfined portions of the Capitan limestone, the Ogallala Formation, and several other unconfined sampling locations at elevations similar to that of the WIPP site are representative of modern meteoric recharge within the northern Delaware Basin.

2. The general isotopic composition of samples from the Culebra and Magenta dolomites of the Rustler Formation at and near the WIPP site, as well as of samples from confined portions of the Capitan limestone, is distinct from that of modern meteoric precipitation within the northern Delaware Basin.

3. The Culebra and Magenta dolomites at and near the WIPP site, in addition to part of the Dewey Lake Red Beds and confined portions of the Capitan limestone, were recharged under climatic conditions different from those effective at the present time.

4. Therefore, the hydrology of the northern Delaware Basin is transient on some time scale. The stable-isotope technique itself provides no information concerning the possible times or time gaps between two interpreted recharge intervals or events, nor does it necessarily provide information concerning where recharge might have taken or be taking place. In the specific case of the Rustler Formation, however, the stable-isotope technique does indicate that significant modern meteoric recharge to the Culebra or Magenta is not taking place at any of the sampled localities.

One site-specific focus of Lambert and Harvey (1987) is the determination of whether or not southeastern Nash Draw, specifically the area including hole WIPP-29 and Surprise Spring (Figure 1.1), is a major point of discharge for Rustler fluids flowing across the WIPP site. Lambert and Harvey (1987) evaluate the question by comparison of the solute and isotopic characteristics of fluids from hole WIPP-29 and Surprise Spring with those of other Rustler fluids. As shown in Figure 4.3.10, the isotopic signatures of fluids from both WIPP-29 and Surprise Spring are quite distinct from the meteoric field. Lambert and Harvey (1987) conclude that the solute characters of WIPP-29 and Surprise Spring waters are also distinct.

In general, the modern flow directions within the Culebra in Nash Draw are roughly parallel to the axis of Nash Draw (Section 4.1). This suggests that, if Surprise Spring is to be a major point of Culebra discharge, fluids must first flow through the region of hole WIPP-29. Rustler groundwaters have been sampled at both Surprise Spring and WIPP-29. It is essentially impossible to derive Surprise Spring waters from evaporation of WIPP-29 Culebra waters, since the lower chloride content at Surprise Spring (Figure 4.3.1) indicates major dilution relative to WIPP-29. The same argument applies to derivation of Surprise Spring waters from Culebra waters at both H-5 and H-6 at the WIPP site, and at many holes within Nash Draw itself. Further, as noted by Lambert and Harvey (1987), Surprise Spring appears to discharge from the Tamarisk Member of the Rustler, rather than from either the Culebra or Magenta.

In addition, the Cl/K (weight) ratios for fluids from holes WIPP-27 and WIPP-29 are distinctly lower than those of other Rustler fluids both in and outside Nash Draw, including Surprise Spring (Section 4.3.1.1). Culebra groundwaters from WIPP-27 and WIPP-29 have Cl/K ratios of ten and nine, respectively, compared to ratios generally from 38 to 73 in holes outside Nash Draw, and a value of 52 at Surprise Spring. Hole WIPP-27 is downslope from the tailings ponds of Mississippi Chemical Corporation's potash refinery in Nash Draw, while WIPP-29 is downslope from the tailings ponds of the International Minerals and Chemicals refinery (Lambert and Harvey, 1987).

Lambert and Harvey (1987) interpret these relationships and the fact that the isotopic compositions of waters from WIPP-29 and Surprise Spring are both distinct from the meteoric field to indicate that:

1. The hydrology of Surprise Spring is essentially isolated and independent from that of the Culebra at WIPP-29, and is not dominated by confined Rustler groundwaters from elsewhere. Surprise Spring discharges from the Tamarisk Member of the Rustler. Nearby exposures of the Tamarisk serve as a likely recharge area for Tamarisk discharge at Surprise Spring, and may or may not be contaminated by local potash-refining operations. The isotopic compositions of groundwaters at both WIPP-29 and Surprise Spring appear to have been derived from surface-type water by partial evaporation.

2. Surprise Spring is not at present a significant point of discharge for Culebra and/or Magenta fluids flowing across the WIPP site.

3. As indicated by the relatively low Cl/K weight ratios in fluids from WIPP-27 and WIPP-29, local potash refining has a major impact on Rustler geochemistry and hydrology within Nash Draw (Section 4.3.1.1).

Lambert and Harvey (1987) conclude that the isotopic character of fluids collected from the Rustler/Salado contact zone (Figure 4.3.13) is strongly affected by rock-water interaction (isotope shift). The extent of this effect generally increases with increasing distance from Nash Draw, paralleling a general decrease in permeability (Section 4.1) and increase in rock-water ratios.

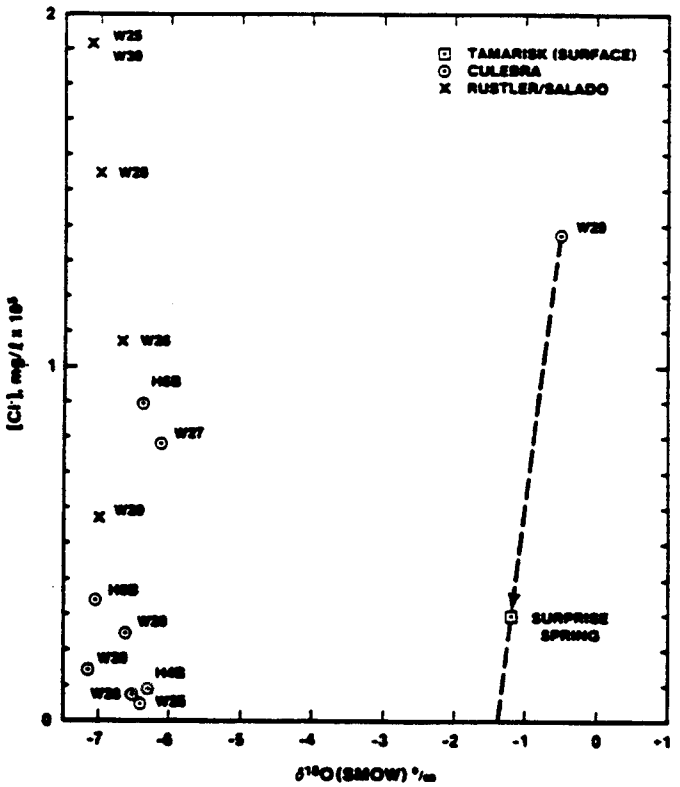


Figure 4.3.12: Relationship between oxygen fractionation and chloride content for analyzed fluids from the Culebra, Magenta, and Rustler/Salado contact. Figure 21 of Lambert and Harvey (1987).

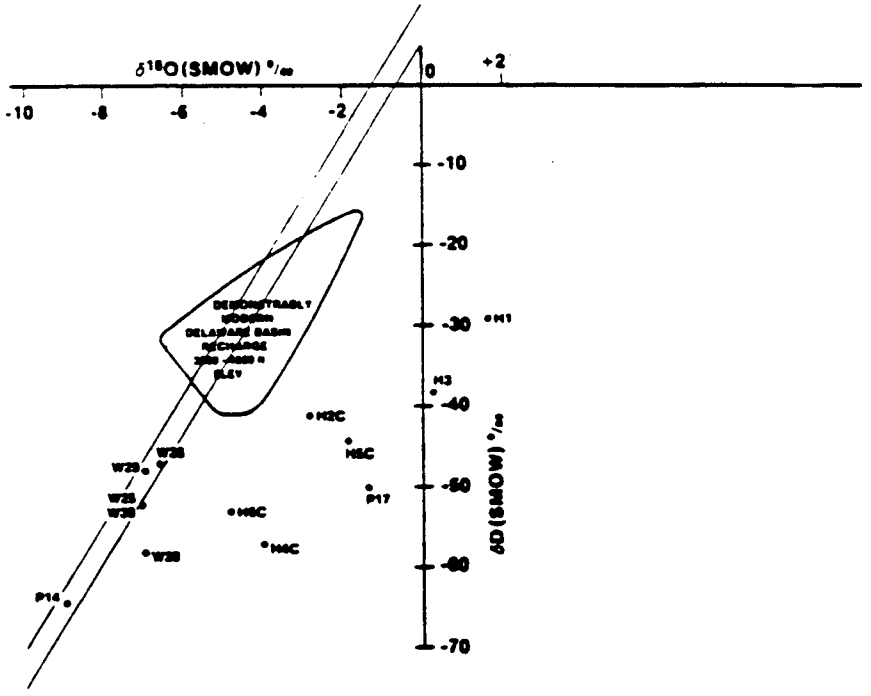
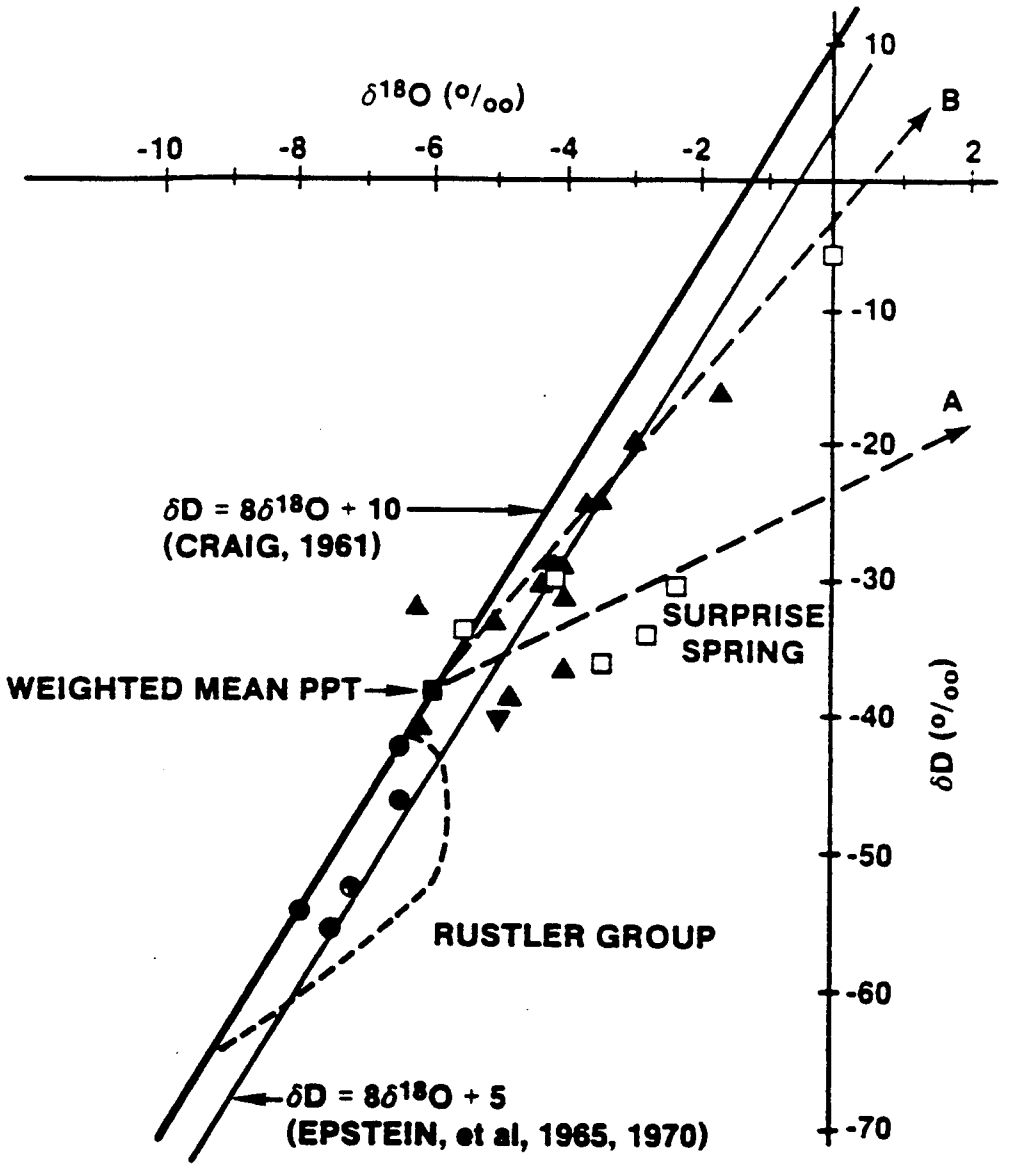


Figure 4.3.13: Stable-isotope character of waters from the Rustler/Salado contact, compared with modern precipitation in the northern Delaware Basin. The "modern recharge" field is defined as in Figure 4.3.10. Figure 15 of Lambert and Harvey (1987).

The interpretations of Lambert and Harvey (1987) and Lambert (1987b) are not consistent with some conclusions contained in Chapman (1986), which is based on review of much of the data contained in the two later reports. The fundamental disagreement lies in interpretation of the distinctions between waters from unconfined portions of the Capitan limestone, modern precipitation, and Rustler waters from at and near the WIPP site. The logic behind a portion of the disagreement is shown in Figure 4.3.14. Chapman (1986) concludes that the isotopic character of modern meteoric recharge in both the northern Delaware Basin and the Roswell Basin is represented by the weighted mean precipitation for the town of Roswell, calculated by Hoy and Gross (1982) (Figure 4.3.14), and that meteoric variability in both areas is closely represented by the trend line of Craig (1961). If these assumptions are valid, then it is possible to derive most of the isotopic compositions of unconfined waters collected within Carlsbad Caverns by "high-humidity" evaporation (line B in Figure 4.3.14) of water representing the calculated Roswell-weighted mean precipitation. Under this interpretation, the unconfined waters from Carlsbad Caverns would be secondary, and would not represent modern meteoric precipitation. As shown, the weighted mean precipitation used by Chapman to derive unconfined Capitan waters is also distinct from the compositional field defined by most Rustler, Dewey Lake, and confined Capitan waters. Chapman (1986) attributes this difference to a "seasonal or amount effect."

Chapman (1986) also notes that, if only stable-isotope relationships are considered, the isotopic character of waters from Surprise Spring can be derived by partial near-surface evaporation of Rustler groundwaters (Line A in Figure 4.3.14); i.e., that Surprise Spring could be a major point of discharge for Rustler waters at and near the WIPP site. While this appears to be theoretically possible on the basis of stable-isotope relationships alone, the solute-composition relationships described in Lambert and Harvey (1987) and summarized above preclude this possibility.

The disagreement between the interpretations contained in Lambert and Harvey (1987) and Chapman (1986) concerning the overall nature of the hydrology in southeastern New Mexico is fundamental, and cannot be resolved by stable-isotope studies alone. However, these studies do clarify the differences in opinion. Chapman (1986), in effect assumes that the hydrology of southeastern New Mexico is at steady state (or, alternatively, that its response to changing climatic conditions is effectively instantaneous). She assumes that the weighted mean precipitation for Roswell and the statistical correlation of Craig (1961) are significant by themselves, and demonstrates that it is possible, based on these assumptions, to generate unconfined waters from Carlsbad Caverns by evaporation. By Chapman's interpretation, the unconfined Capitan waters do not represent modern recharge. However, the field of demonstrably modern Delaware Basin recharge defined by Lambert and Harvey (1987) includes or is consistent with analyses from several other locations in addition to Carlsbad Caverns. The weighted mean precipitation used by Chapman to derive unconfined Capitan waters by evaporation is also distinct from the compositional field defined by most Rustler, Dewey Lake, and confined Capitan waters. Chapman (1986) attributes this difference to a "seasonal or amount effect." The



A: TREND FOR "LOW-HUMIDITY" EVAPORATION
B: TREND FOR "HIGH-HUMIDITY" EVAPORATION

- ● CAPITAN AQUIFER
- ▼ SHALLOW AQUIFERS: SANTA ROSA, DEWEY LAKE
- □ SURFACE WATER
- ▲ CARLSBAD CAVERNS
- ■ WEIGHTED MEAN PPT

Figure 4.3.14: Possible derivation of Carlsbad Caverns waters from modern precipitation. Modified from Figures 13 and 14 of Chapman (1986), by addition of the statistical correlation line for meteoric precipitation of Epstein et al. (1965, 1970) and deletion of waters from the Roswell Basin.

operation of this effect on Rustler, Dewey Lake, and confined Capitan waters, as well as Ogallala water from the High Plains is not explained.

Lambert and Harvey (1987) do not assume that the hydrology of southeastern New Mexico is at steady state. They do assume that significant departure in isotopic signature from the meteoric field defined by the compositional space between the statistical correlations of Craig (1961) and Epstein et al. (1965, 1970) is required before any recourse to evaporation is justified. Unconfined Capitan waters (and others, such as Ogallala fluids and samples from alluvium at WIPP-15) are interpreted by Lambert and Harvey (1987) to represent modern meteoric recharge in the northern Delaware Basin. The demonstrably different isotopic character of most Rustler, Dewey Lake, and confined Capitan waters from the field they interpret to represent modern recharge in the northern Delaware Basin is taken to reflect recharge under conditions distinctly different from those controlling modern recharge. Since steady state is not assumed, no single weighted mean precipitation is either defined or deemed relevant. The conclusions of isotopic studies discussed in Sections 4.3.3, 4.3.4, and 4.4.2 are consistent with the interpretation of a transient hydrologic setting of the Rustler Formation and shallower units at and near the WIPP site.

4.3.3 Recent Isotopic Studies with Emphasis on Radiocarbon

Studies investigating the applicability of several environmental isotopes (isotopes generated primarily within the atmosphere), especially radiocarbon, to the shallow stratigraphic units at the WIPP are summarized by Lambert (1987a, 1988). Although the emphasis in these studies was on radiocarbon, tritium, and chlorine-36 were briefly evaluated. No ^{36}Cl above background could be identified, nor could tritium values significantly above background be identified except in hole WIPP-27. The high chlorine background is to be expected in fluids in a halite-bearing evaporite section. The tritium at WIPP-27, consistent with the major-solute composition of Culebra groundwaters from WIPP-27 (Section 4.3.1.1), is interpreted to be due to contamination by potash-refining operations. Radiocarbon studies indicate that many of the sampled wells have been contaminated by organic materials during drilling, casing, and/or hydrologic testing. The successful radiocarbon measurements indicate isolation times of at least 12,000 to 16,000 years for three Culebra waters and one Dewey Lake water. Two of the four measurement points lie on nearly opposite sides of the WIPP site.

The relationship between calculated "percent modern carbon" (PMC) and the bicarbonate content of most of the fluids analyzed to date, including three samples from the Rustler/Salado contact zone, is summarized in Figure 4.3.15. PMC is carbon counts relative to 1950 wood. As shown in Figure 4.3.15, there is a strongly linear relationship between PMC and bicarbonate. The apparent end members are: a) a 0-PMC fluid with a bicarbonate content of approximately 60 mg/l, i.e., groundwater in equilibrium with carbonate, assuming bicarbonate is equal to total carbonate; and b) a 100-PMC fluid with a bicarbonate content of approximately 300 mg/l.

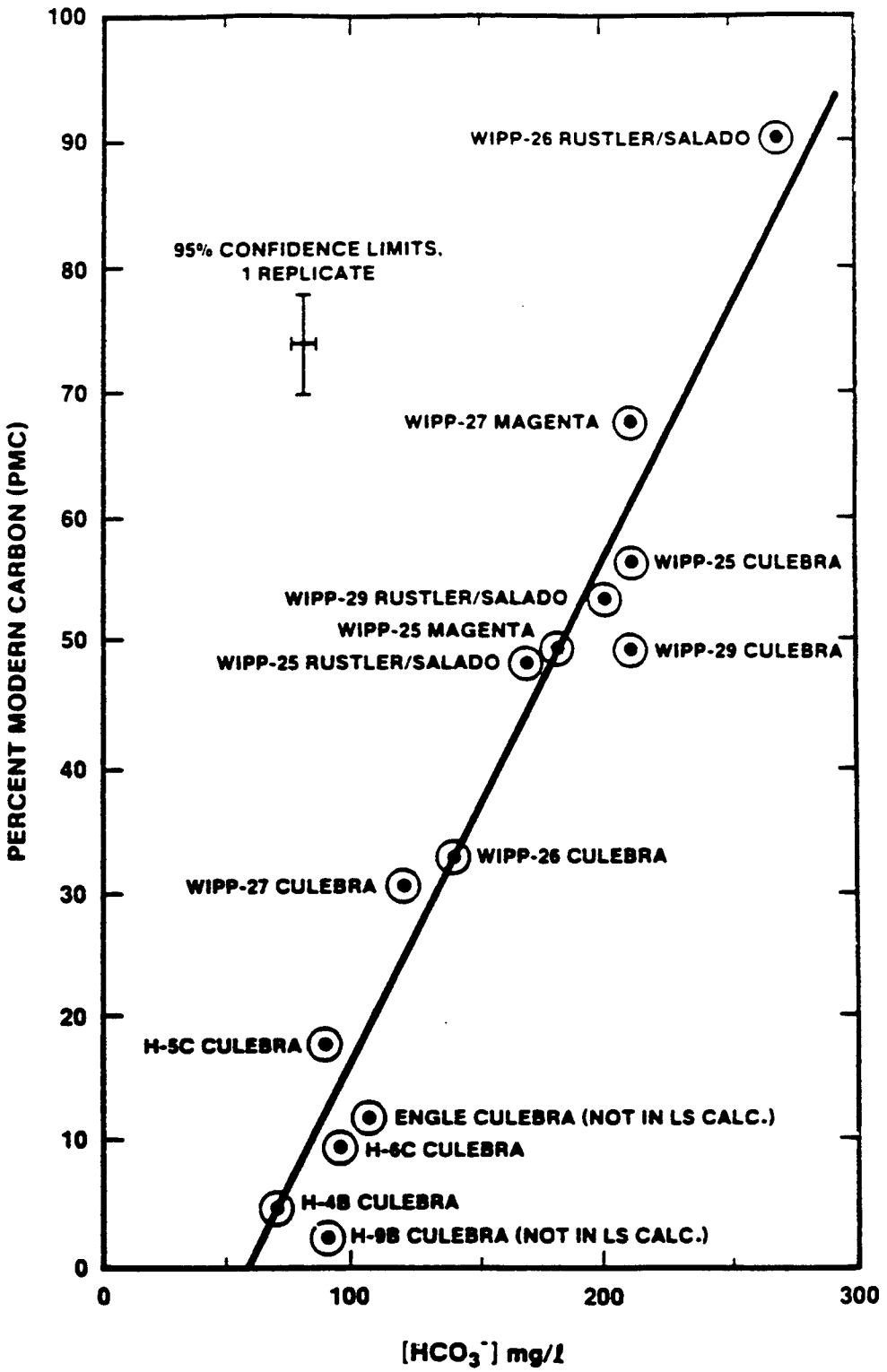


Figure 4.3.15: Relationship between calculated percent modern carbon (PMC) and bicarbonate in analyzed fluids. Figure 3 of Lambert (1987a).

If, as is commonly the case in radiocarbon studies, it is assumed that recharge groundwaters initially containing small amounts of atmospherically derived CO_2 (PMC near 100) equilibrate fairly quickly with carbonate minerals underground, it is difficult to explain waters in Figure 4.3.15 having greater than approximately 60 mg/l bicarbonate. In other words, one would expect the slope in Figure 4.3.15 to be negative rather than positive if this slope reflected increasing equilibration with underground carbonates with increasing time (decreasing PMC) (Lambert, 1987a). By this logic, the high-PMC samples in Figure 4.3.15 do not represent modern infiltration.

Regardless of the origin of high-PMC contents, a linear relationship should result from evaluation of any two compositional variables for the same fluids, if the data distribution in Figure 4.3.15 is a result of linear mixing of two fluid components. This is not the case for the analyzed fluids since the relationship between ^{13}C fractionation and bicarbonate (Figure 4.3.16) is statistically random. This result suggests that at least three fluid components may be involved in mixing to develop the indicated 13_C distribution. In such mixing, unique delineation of the mixing relationships and the ages or isolation times of the specific groundwater components involved is most likely impossible (Lambert, 1987a).

The relation between percent modern carbon (PMC) and ^{13}C fractionation for the samples on which adequate data are presently available is shown in Figure 4.3.17. The sampled fluids fall into two relatively distinct groups: a) a small group containing samples with less than approximately 10 PMC; and b) a larger group with from 10 to greater than 90 PMC. Data from H-5c and Engle could be included with the low-PMC group shown in Figure 4.53, though, as noted by Lambert (1987a), the statistical correlations within both data groupings are stronger if the four low-PMC samples (H-4b, H-6c, H-9b, and Pocket) are considered as a separate group. Of the four low-PMC samples, all but that from the Pocket well are for fluids from the Culebra dolomite; the Pocket sample is from the Dewey Lake Red Beds.

The definition of two distinct data groupings (Figure 4.3.17) leads to identification of three carbon-isotopic compositional components apparently involved in mixing within Rustler, Dewey Lake, and Rustler/Salado fluids. These are:

1. Dissolved carbon from Permian marine carbonates. Because the Permian carbonates are more than 200 million years old, this carbon is no longer measureably radioactive.

2. CO_2 derived from modern organic materials injected in variable amounts into the sampled holes during drilling and/or casing activities. Lambert (1987a) found it pointless to attempt dating of almost all of these contaminated samples, as discussed below.

3. CO_2 derived from Pleistocene and older organics during recharge. The location of this recharge cannot be specified on the basis of these studies. Because of the possible contamination of all these samples by small amounts of CO_2 from the modern reservoir, calculated PMC values

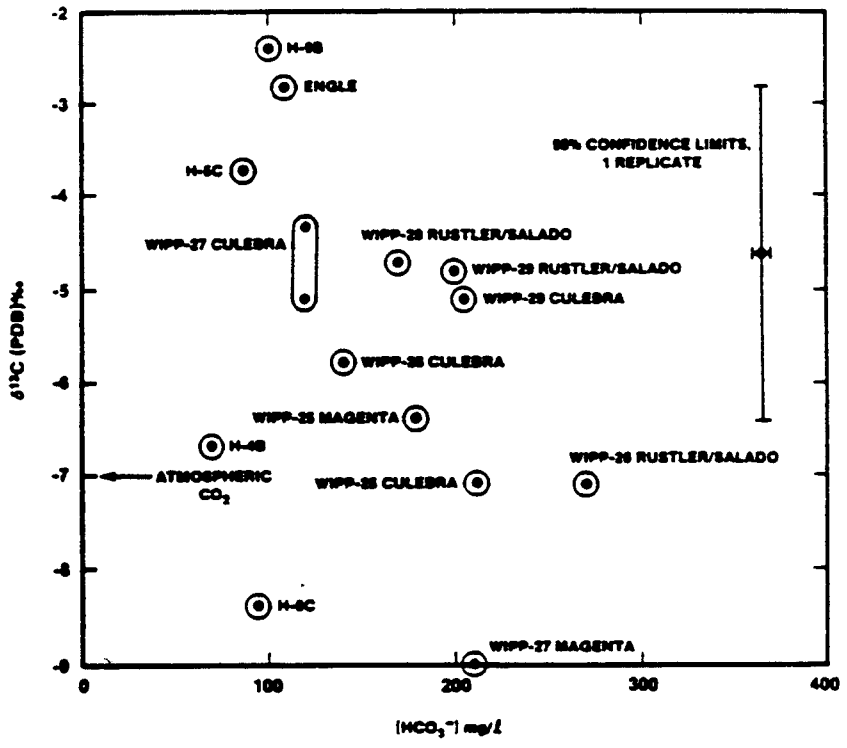


Figure 4.3.16: Relationship between ^{13}C fractionation and bicarbonate for analyzed fluids. Figure 4 of Lambert (1987a).

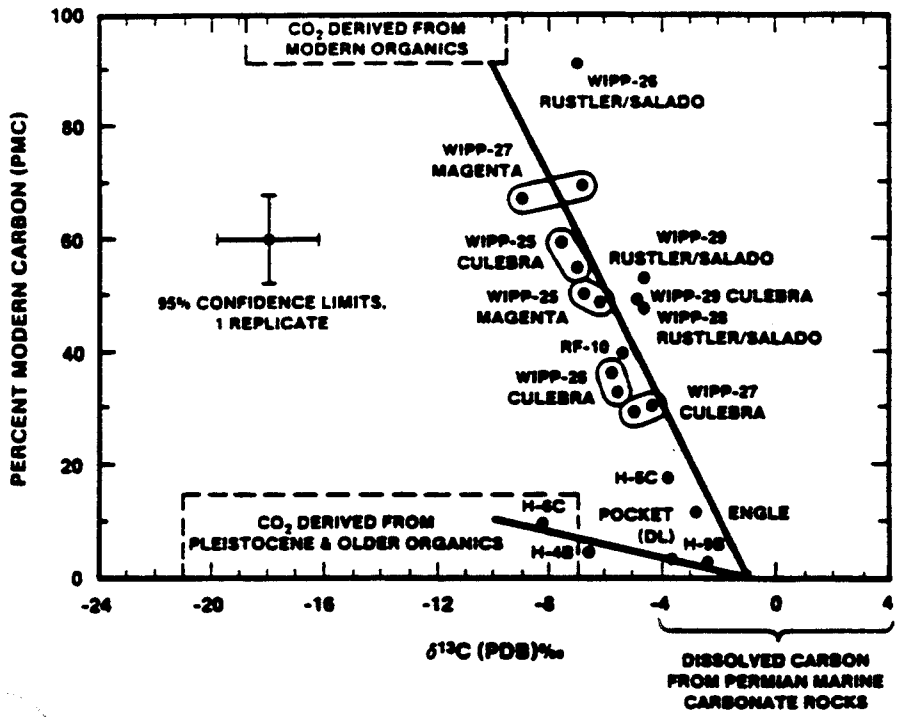


Figure 4.3.17: Relationship between percent modern carbon and ^{13}C fractionation for analyzed fluids. Three-component mixing is a plausible explanation for carbon-isotope characteristics of sampled Rustler and Dewey Lake fluids. In addition to "dead" carbon resulting from interaction with Permian carbonates, all samples may contain both CO_2 derived from Pleistocene and older organics and an unresolved component of CO_2 derived from modern organics. Figure 9 of Lambert (1987a).

in the four low-PMC samples shown in Figure 4.3.17 must be upper limits. Conversely, calculated ages or residence times for the fluids must be lower limits.

Lambert (1987a) applied several different numerical models to the analyzed groundwaters. The results, summarized in Table 4.15, indicate calculated isolation times of the sampled waters from any significant component of atmospherically derived carbon. The ages do not indicate that the fluids have been in their present location for the indicated time, simply that they have been isolated from a near-surface environment for approximately the time indicated. For the samples on which application of the models of Tamers (1975), Pearson and Swarzenki (1974), Mook (1976), and Evans et al. (1979) were generally successful, i.e., the four low-PMC samples (H-4 Culebra, H-6 Culebra, H-9 Culebra, and Pocket Dewey Lake), the results indicate isolation times of between 10,600 and 25,700 years, depending on both sample and model used. The different models used vary in the correction mechanisms assumed to effect fluid interaction with the rock. Lambert (1988) notes that it is not possible to reliably separate the effects of natural isotope evolution from effects of contamination for any data lying off the two-component mixing lines in Figure 4.3.17, i.e., within the three-component mixing triangle.

- Because of the method it uses in correcting for equilibration between groundwater and carbonates, and because it involves only a limited number of empirically-derived inputs, Lambert (1987a) concludes that the model of Evans et al. (1979) is the available model most applicable in the WIPP environment. One conclusion arising from the presence of Permian marine carbonates in the Rustler and use of the model of Evans et al. (1979) is that any groundwater sample with greater then 50 PMC must either be contaminated, or must be assumed to have had very limited exposure to the carbonates present. Application of the model of Evans et al. (1979) to the entire data set results in: a) calculated isolation times of 12,100 to 16,100 years for the four low-PMC samples identified in Figure 4.3.17; and b) physically impossible negative model ages for all samples on and near the trend including modern organics in Figure 4.3.17, with the exception of samples from H-5c (Culebra) and Engle (Culebra). These two samples yield model ages of 714 and 2,410 years, respectively, but lie within the three-component mixing triangle shown in Figure 4.3.17.

Based on radiocarbon studies, Lambert (1987a) concludes that:

1. The four interpretable radiocarbon ages on Rustler and Dewey Lake fluids, i.e., those calculated on minimally contaminated samples using the model of Evans et al. (1979), indicate that some Culebra and Dewey Lake fluids present in the vicinity of the WIPP site were isolated from atmospheric radiocarbon at least 12,000 to 16,000 years ago. The relatively tight cluster of ages may suggest some type of recharge episode, rather than a gradient resulting from continuous recharge.

2. Because of there being no consistent directional age gradient in calculated ages in such old groundwaters, the radiocarbon technique provides no information concerning directions or rates of fluid flow within either the Rustler Formation or the Dewey Lake Red Beds in applications to date on WIPP groundwaters.

Table 4.15: Results of application of different interpretative models to available radiocarbon analyses, including corrections involving dolomite. Part of Table 4 of Lambert (1987a).

Locality	PMC	$\delta^{13}C$	Tamers (1975)	Pearson and Swarzenki (1974)	Mook (1976)	Evans et al. (1979)
H-4	4.82	-6.7	19300	17300	12000	16100
H-6	9.7	-8.4	13600	12600	10600	12100
H-9	2.22	-2.4	25700	20200	indet.	14900
Pocket	3.67	-3.8	21600	17400	indet.	14000

3. To date, most radiocarbon measurements on Rustler fluids collected in hydrologic drillholes are invalidated by unknown amounts and types of organic contamination occurring during and after drilling. Most fluids have a carbon-isotopic signature apparently reflecting nonresolvable three-component mixing among inorganic carbon, organic carbon from a past period of surficial recharge, and modern organic contamination introduced during drilling. All samples collected may be contaminated at some level; therefore, most calculated groundwater ages are lower limits.

4. Application of several models to calculate radiocarbon ages indicates that the best useable model is that of Evans et al. (1979), which accounts for both congruent dissolution of carbonates and possible continuing exhange of radiocarbon between the diluted groundwater solution and the surrounding country rock.

While the radiocarbon studies described by Lambert (1987a; 1988) were partially successful and indicate lower-limit isolation times for sampled fluids at four specific locations, extrapolation of the results must be done carefully. The results do not: a) mean that the sampled fluids have been in residence at the sampling sites for the indicated lengths of time; b) provide any information about where major recharge occurred when it did take place; or c) rule out small but indeterminate amounts of modern vertical recharge to the Rustler and Dewey Lake at the WIPP site. The available radiocarbon data can be interpreted consistently to mean that "steady-state" recharge of the Rustler and Dewey Lake is an actively ongoing process only at locations removed from the WIPP site, and that flow times from the point(s) of recharge to the sample localities are at least 12,000 to 16,000 years. However, the results mean that surficial recharge at the WIPP site, if significant at some time in the past, effectively stopped at the sampled localities at least 12,000 to 16,000 years ago. Two of the sampling localities, H-4 and H-6 lie close to and on nearly opposite sides of WIPP Zone 3.

Lambert (1987a) also concludes that measured ^{36}Cl and tritium contents on minimally contaminated Rustler fluids at and near the WIPP site cannot be discriminated from background values. Because of the high chlorine background in fluids that have been in contact with halite present in the Rustler and/or in surficial deposits in southeast New Mexico, no measurable ^{36}Cl was detected. No tritium content greater than 0.2 tritium units (TU) was found in any fluid that was demonstrably minimally contaminated, in contrast to a reasonable "background" level of 3 - 7 TU. The highest measured tritium content in Culebra water is 6.9 TU from WIPP-27 (Lambert, 1987a). However (Section 4.3.1.1) the Culebra at WIPP-27 is interpreted to be contaminated by potash-refining operations, on the ground of major-solute chemistry. Therefore, Lambert (1987a) concludes that there is no advantage in pursuing either technique further in the Rustler Formation at the WIPP site.

4.3.4 Uranium-Disequilibrium Studies in the Culebra Dolomite

The radiocarbon studies summarized in Section 4.3.3 indicate that the recharge age of groundwaters presently in the Culebra dolomite and part of the Dewey Lake Red Beds at and near the WIPP site is at least 12,000 to 16,000 years. While these results indicate that, independent of flow path, travel times from recharge to their present location are long, they indicate nothing about the flow directions or distances involved. The uranium-disequilibrium technique discussed in this section addresses some questions which cannot be addressed by radiocarbon or stable-isotope techniques, such as apparent directions of fluid flow. The basic principles of the uranium-disequilibrium method are discussed in both Lambert and Carter (1984) and Lambert and Carter (1987).

Interpretations of uranium-disequilibrium data can only be as reliable as the number and quality of the samples from which the data are derived, and are also limited by the applicability of the principles involved in the interpretations. There are two specific constraints to interpretation of uranium-disequilibrium data at and near the WIPP site. First, data east of Nash Draw are extremely limited in number, since values are known at only four locations, H-4, H-5, H-6, and WIPP-30. As a result, there is considerable uncertainty in both contouring of results and inferred flow directions east of Nash Draw. Second, as noted by Lambert and Carter (1987), there is no known trace component of Rustler fluids which reliably indicates whether or not any sampled groundwater is representative with respect to either total uranium content or uranium-disequilibrium "activity ratio" (A.R.). The activity ratio considered here is in terms of relative decay rates of the ^{234}U and ^{238}U isotopes, not the ratio of chemical activities. Two measurement trends have been noted which help evaluate the extent of approach to steady-state fluid composition during serial sampling and/or indicate the direction from which the sampled fluid may approach or bound a representative state for groundwater at the sampling locality. Uranium is a trace contaminant, at concentrations greater than normal for evaporitic rocks, in drilling and sampling apparatus, especially casing. Therefore, total uranium in the sampled fluid generally decreases with increasing pumping rate and/or total pumping time (Lambert and Carter, 1984), as the amount of contamination is reduced. Measured total uranium

contents in Culebra waters should represent upper bounds. The measured $^{234}U/^{238}U$ activity ratio in sampled fluids generally increases with total pumping volume and rate; i.e., with decreasing contamination from the casing and/or sampling apparatus (Lambert and Carter, 1984). This is presumably because the contamination present in sampling apparatus and casing has an Activity Ratio (A.R.) very near 1.0. Any measured A.R. in a sampled fluid should thus represent lower bounds.

As noted in Lambert and Carter (1987), interpretation of uranium-disequilibrium studies involves additional assumptions. During recharge, an initial A.R. equal to or not much greater than 1.0 (generally 1 - 3) is assumed to be fixed at the edge of the oxidation zone. There are several generalized sequences of behavior that can follow infiltration. The conceptual and numerical model used is essentially that of Osmond and Cowart (1976). The variability can be simplified by considering the relationship between A.R. and total uranium in the analyzed fluid. Under reducing conditions, the total uranium content of the fluids remains low, and the A.R. normally increases along the direction of fluid flow. This increase is a result of the preferential leachability of the ^{234}Th resulting from the alpha decay of ^{238}U within the country rock, relative to the leachability of ^{238}U (Lambert and Carter, 1984; 1987). Thus, the combination of low total uranium content and elevated A.R. is interpreted to reflect flow along a flow path under relatively reducing conditions or locally "stagnant" flow conditions, both occurring on a time scale for which the technique is applicable, approximately 2,000,000 years (Lambert and Carter, 1984). In contrast, a measured groundwater A.R. near 1.0 is taken to indicate one of three things: 1) approach to secular equilibrium after a lengthy period of radioactive decay; 2) sampling of fluids soon after recharge; and/or 3) possible "swamping" of a higher A.R. by dissolution of rock uranium having an A.R. very near 1.0. A strong correlation of increasing total uranium content of sampled fluids with decreasing fluid A.R. along an inferred flow path favors the third interpretation. This can only occur under relatively oxidizing conditions under which the congruent solubility of uranium is enhanced.

The available data for the $^{234}U/^{238}U$ A.R.s in Culebra fluids at and near the WIPP site are summarized in Figure 4.3.18. The figure shows a general eastward or southeastward increase in A.R.s east of Nash Draw. Contour lines shown in Figure 4.3.18 are based on the assumption that variations in A.R. are approximately linear between data points. From the resulting contours, it was inferred by Lambert and Carter (1987) that the most likely region of recharge for Culebra groundwaters is in or near the upturned edge of the Rustler units within Nash Draw. This interpretation reflects a major easterly or southeasterly component of flow from a recharge region within Nash Draw, assuming that high A.R.s such as measured in the WIPP site area at H-4, WIPP-30, and H-5 are generated by downgradient flow under relatively reducing conditions.

The flow directions implied by the contouring in Figure 4.3.18 are not unique, because of both the limited data east of Nash Draw and uncertain relationships between flow directions and directions in which A.R.s increase. All that is certain is that, unless no reaction is taking place, fluid flow must be at some angle to the lines of constant A.R., but need

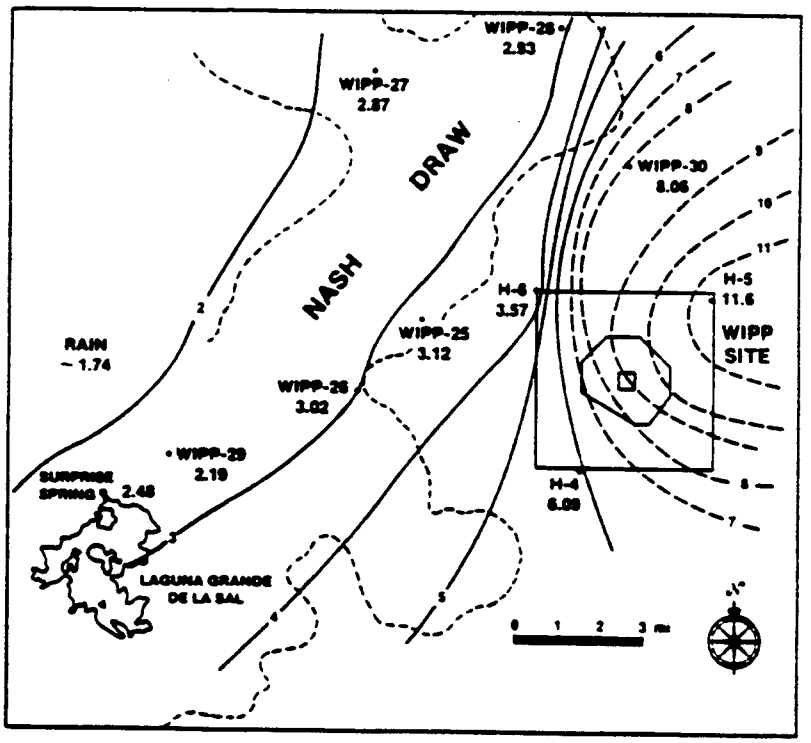


Figure 4.3.18: $^{234}U/^{238}U$ activity ratios in analyzed Culebra fluids. Figure 3 of Lambert and Carter (1987).

not be perpendicular to these lines. By analogy, groundwater flow in a fractured or anisotropic medium need not be perpendicular to potentiometric contours. If fluid flow is assumed to be perpendicular to the A.R. contours in Figure 4.3.18, flow is required to have taken place from regions of (present) high permeability in Nash Draw towards regions of (present) low permeability east of Nash Draw, such as the vicinity of H-5.

In addition, there is considerable freedom in the contouring of A.R. values themselves. An indication of this is shown in Figure 4.3.19. In the interpretation shown in Figure 4.3.19, the assumption of roughly linear variation in A.R. between data points is relaxed, and contours are rotated into a more north-south position. Under this interpretation, since the flow direction must be inclined to A.R. contours, the present A.R. distribution would be consistent with flow towards the south or southeast following recharge, i.e., at a lower angle to both the axis of Nash Draw and the very loose regional zonation of permeability within the Culebra (Section 4.1) than implied in Figure 4.3.18. However, flow towards the axis of Nash Draw is not consistent with the data.

While the uranium-disequilibrium method is not always capable of identifying the recharge area, it is capable, unlike radiocarbon applied to Rustler groundwaters, of estimating flow directions following recharge. The higher-permeability areas within the Rustler Formation in Nash Draw seem a more likely paleorecharge area than either the surface of the WIPP site area or the low-permeability areas east of WIPP-30. Therefore, flow within the Culebra following recharge probably had at least some easterly component.

Regardless of the estimated fluid-flow directions following recharge, the flow times estimated for the buildup to measured A.R.s east of Nash Draw depend on both the measured or assumed original uranium content of the host rock and the measured or assumed total uranium content of the groundwater fluid immediately after recharge. This buildup is a result of a combination of differential leachability of ^{234}Th and ^{238}U under reducing conditions and radioactive decay. In general, estimated flow times towards a measured high A.R. are inversely proportional to the initial uranium content of the groundwater and proportional to the estimated uranium content of the country rock. For example, Lambert and Carter (1987) found it impossible to generate calculated A.R.s greater than 3.4 using the mean present-day U concentration in Culebra core (0.9×10^{-6} g/g) and the lowest measured U concentration in Culebra fluid (0.134×10^{-9} g/g) as input. They interpret this inability to indicate that: (a) the present uranium concentration of the available Culebra core samples is probably not representative of the rock controlling A.R. buildup; and (b) the lowest measured uranium concentration in the fluid phase has been increased by at least some congruent dissolution.

Lambert and Carter (1987) estimated flow times to H-5, assuming that the original U content of Culebra fluids was the same as the lower value measured in fluid from the Rustler/Salado contact in hole WIPP-30 (0.024×10^{-9} g/g). Calculated travel times are approximately 550,000 and 30,000 years, for an assumed low-uranium and high-uranium Culebra matrix, respectively. The low-uranium matrix was taken as the average value

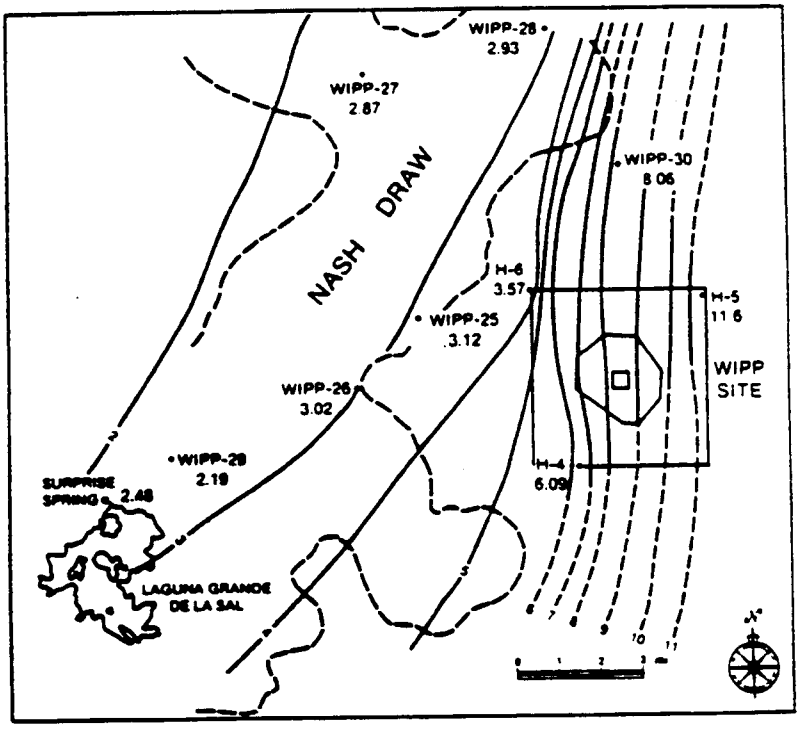


Figure 4.3.19: Contours of $^{234}U/^{238}U$ activity ratios in analyzed fluids, relaxing constraint of linear variation between data points. Modified from Figure 3 of Lambert and Carter (1987).

measured on core (0.9×10^{-6} g/g), and the high-uranium matrix (9.0×10^{-6} g/g) was assumed. The assumed value is similar to that measured in a silty zone found within a Permian limestone in Carlsbad Caverns. In the WIPP site area, local high U contents within Culebra are supported by a known (but uncored) occurrence of a silty zone in hole P-15, indicated by geophysical logging to be rich in (uranium + thorium + potassium). A final A.R.-evolution path, assuming the initial uranium content in the fluid was the same as that measured in Carlsbad rain, 0.01×10^{-9} g/g, yields estimated flow times to H-5 of 140,000 and 12,000 years, respectively for the low-uranium and high-uranium Culebra matrices.

Thus, the minimum estimated times required for ingrowth of ^{234}U to give the measured high A.R.s at H-5, assuming a uranium-rich Culebra matrix, are qualitatively consistent with the estimated minimum recharge ages based on radiocarbon studies reported in Lambert (1987a). Analyzed Culebra core has a lower uranium content than assumed in these calculations. Therefore, flow times from the position of recharge to H-5 were almost certainly much greater. The measured A.R. of greater than 11.0 at H-5 is inconsistent with any significant modern recharge in this area. A minimum flow time of at least several thousand years is required under reducing conditions to generate such an A.R., regardless of assumptions concerning initial fluid and rock-matrix properties, location of recharge, and directions of fluid flow.

The ingrowth of A.R.s cannot be considered independently of the total dissolved uranium in the fluid phase. Figure 4.3.20 indicates a westerly or northwesterly increase in the amount of uranium in Culebra waters, from the WIPP site towards Nash Draw. Although there is uncertainty in the contouring of total uranium contents, the general direction of increase correlates with a general decrease in A.R. in a similar direction (Figure 4.3.18 or 4.3.19).

It is difficult to explain how any easterly flow of oxidized fluids involved in significant evaporite dissolution could maintain both high A.R.s and low total uranium contents measured east of Nash Draw, as would be required by any interpretation involving steady-state flow directions consistent with A.R. contouring in either Figure 4.3.18 or 4.3.19. During such flow, uranium would have to be precipitated within the Culebra dolomite. No evidence for elevated uranium concentrations has been found within the Culebra, except in hole P-15; the P-15 occurrence may in fact be a detrital accumulation. Measured uranium contents of bulk Culebra core are too low to account for the measured A.R.s.

A logical explanation of the combination of measured A.R.s and total uranium contents of Culebra groundwaters at and near the WIPP site involves a change of flow directions, after development or ingrowth of the elevated A.R.s measured east of Nash Draw (Lambert and Carter, 1987). In this interpretation, an early flow system with at least some component of easterly flow under reducing conditions, would later be changed, resulting in some component of westerly flow. The magnitude of the required change in flow directions within the Culebra is not well defined at present. Combination of the contours in Figure 4.3.19 and 4.3.20 requires something like a 60-degree change, assuming recharge occurred in the northern part of

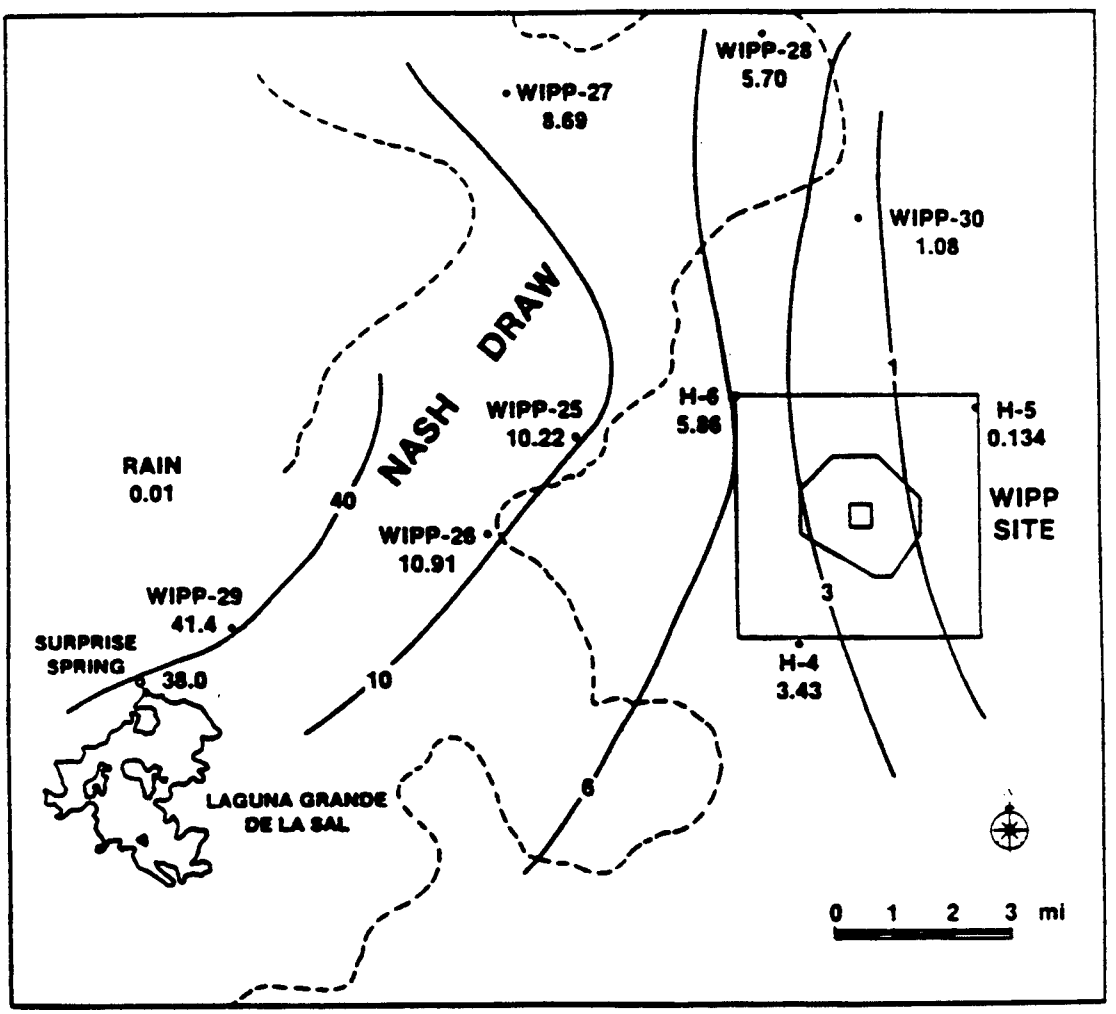


Figure 4.3.20: Total dissolved uranium content of analyzed fluids. Figure 2 of Lambert and Carter (1987).

Nash Draw. Combination of the contours in Figure 4.3.18 and Figure 4.3.20, assuming recharge within the main part of Nash Draw, implies a more marked "reversal" of flow directions.

Because of the general westward increase in total uranium in the Culebra groundwaters, the process resulting in a change in flow directions within the Culebra must include a general westward increase in oxidation potential, with resulting increase in uranium solubility. The mechanism for such an increase in oxidation potential, while not well defined at present, would presumably be related to the continuing exhumation of the Rustler Formation within Nash Draw (Lambert and Carter, 1987). Consistent with this interpretation, the redox measurements discussed in Section 4.3.1.4 generally indicate more oxidizing conditions within the Culebra south of the WIPP site and within at least part of Nash Draw than at the WIPP site.

Regardless of the detailed interpretation of transient flow directions within the Culebra, the uranium-disequilibrium studies of Lambert and Carter (1987) place strong constraints on some aspects of Culebra hydrology at and near the WIPP. These include the three constraints that:

1. Culebra fluid residence times at or flow times to sampling localities east of Nash Draw (H-4, H-5, H-6, and WIPP-30) are at least several thousand years. The shortest calculated residence or flow times are consistent with minimum groundwater isolation times estimated in radiocarbon studies (Section 4.3.3).

2. Regardless of the high Culebra head potentials in the area (Figure 4.1.23), no significant recharge is occurring in the vicinity of H-5. This conclusion is indicated by the high A.R. and low total fluid uranium in this area.

3. A significant amount of evaporite dissolution, under relatively oxidizing conditions appears to have taken place in and near Nash Draw, as indicated by the relatively high dissolved uranium contents in this area.

4.4 Recent Studies Addressing Near-Surface Geology and Hydrology at and near the WIPP Site

Considerable emphasis since 1983 has been given to evaluation of near-surface processes at the WIPP site. The primary objective of this effort has been evaluation of the potential for evaporite dissolution within the Rustler Formation. Regardless of conclusions concerning evaporite dissolution within the Rustler, studies of near-surface processes and stratigraphy at the WIPP demonstrate the transient nature of the climate and near-surface hydrologic setting in southeastern New Mexico. Section 4.4.1 summarizes recent studies of the near-surface stratigraphy and general geologic and hydrologic setting of southeastern New Mexico. Section 4.4.2 briefly summarizes recent studies concerning the extent of rock/water interactions and evaporite dissolution within the Rustler Formation.

4.4.1 Recent Studies of Near-Surface Stratigraphy at and near the WIPP Site

Recent studies of the near-surface stratigraphy at and near the WIPP site summarized in Bachman (1985) were conducted as part of the evaluation of possible near-surface evaporite dissolution. The present distribution of the Gatuna Formation at and near the WIPP site is shown in Figure 4.4.1. An ash bed relatively high in the Gatuna is between 500,000 and 600,000 years in age (Bachman, 1980). Since the Gatuna is overlain by the Mescalero caliche, which began to form approximately 500,000 years ago (Bachman, 1980), Bachman (1985) concludes that the Gatuna is ". . . at least as old as Middle Pleistocene and may contain some much older deposits." While preparing the isopachs shown in Figure 4.4.1, Bachman determined that the Gatuna along Livingston Ridge, on the east side of Nash Draw (Figure 1.1), contains cross-bedded channel deposits and conglomerates deposited by westward-flowing streams. The Bachman (1985) interpretation of the probable courses of streams at and near the WIPP site during Gatuna time is shown in Figure 4.4.2. Areas near the WIPP site presently overlain by Gatuna gravels were occupied approximately 600,000 years ago by moderate-energy stream channels. Based on comparison of the isopach maps for the Gatuna (Figure 4.4.1), Triassic rocks (Figure 4.4.3), and the Dewey Lake Red Beds (Figure 4.4.4), Bachman (1985) concludes that the Gatuna streams flowed across and eroded both Triassic and Dewey Lake Red Beds strata. In contrast, the present climate and surface-hydrologic setting at the WIPP site does not support any moderate-energy streams.

The Mescalero caliche, which overlies the Gatuna, is interpreted by Bachman (1985) as reflecting a slow process of soil formation on a stable geomorphic surface. The caliche is well-developed, and, in locations where the ". . . laminar horizon and the dense plugged horizons within the caliche are at the surface," contributes to ". . . rapid runoff and even to flooding during periods of heavy rainfall" (Bachman, 1985). Radiometric measurements indicate that the basal and upper portions of the Mescalero caliche began to form approximately 510,000 and 410,000 years ago, respectively (Bachman, 1980). The Mescalero surface on which the Mescalero caliche formed, encompasses the Livingston Ridge surface at and near the WIPP site (Figure 1.1). The widespread occurrence of the Mescalero caliche indicates relative structural stability of the Livingston Ridge surface over at least the last 400,000 years.

The Berino soil, a locally distributed paleosol up to approximately 1 m thick, is interpreted by Bachman (1985) as a remnant soil sequence that originally included the older Mescalero caliche. Local survival of the Berino, which began to form approximately 350,000 years ago, is interpreted to require ". . . a long period of tectonic and geomorphic stability within a limited climatic regime" (Bachman, 1985).

There is widespread evidence that the hydrologic setting of the vicinity of the WIPP site has changed at least once over the last 600,000 years. The Gatuna Formation, including moderate-energy stream gravels and conglomerates, was deposited at least 600,000 years ago in a setting which included actively eroding streams. Since approximately 350,000 years ago, the Livingston Ridge surface developed on the Mescalero caliche has remained

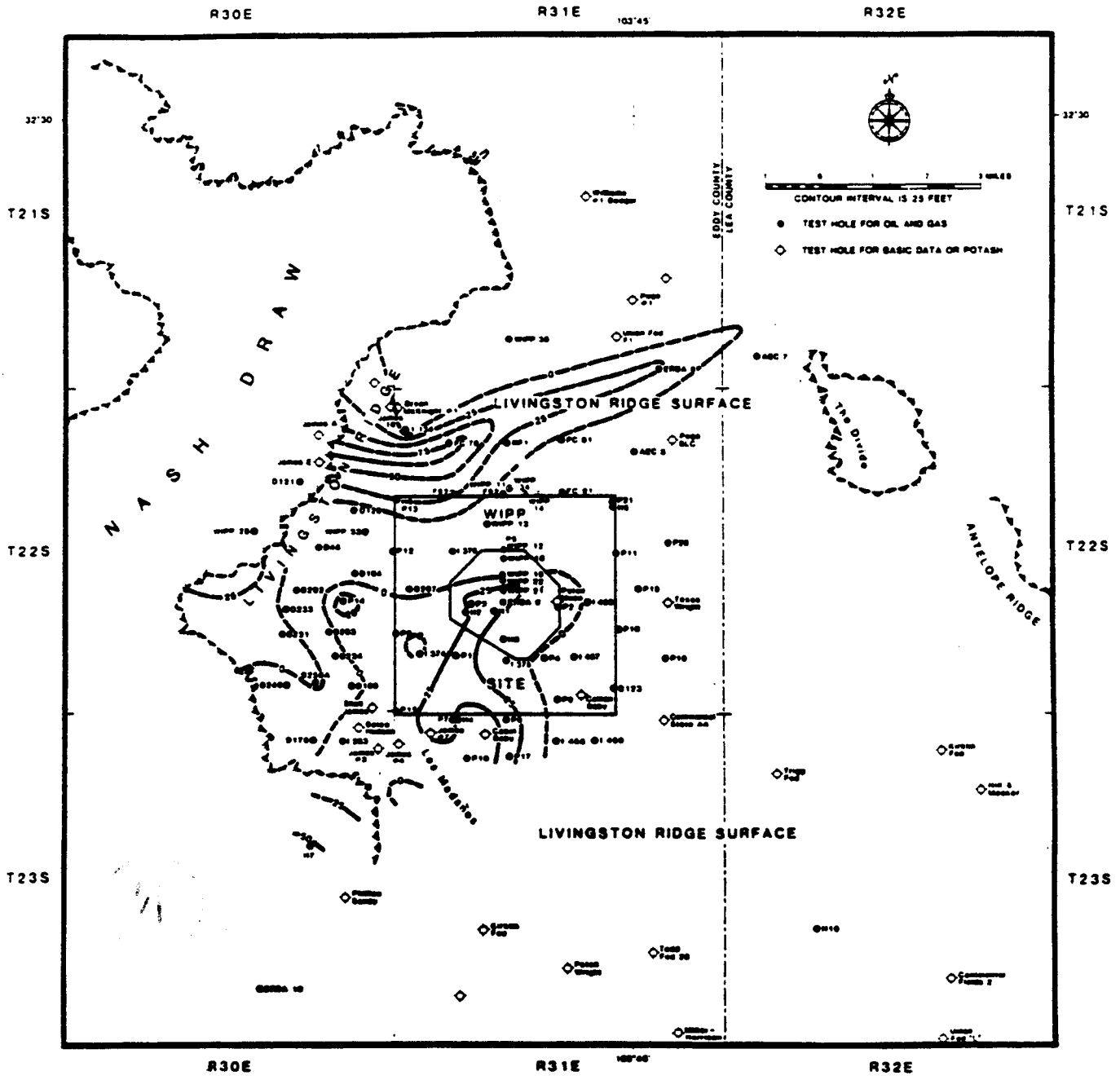


Figure 4.4.1: Distribution and thickness of the Gatuna Formation at and near the WIPP site. Figure 4 of Bachman (1985).

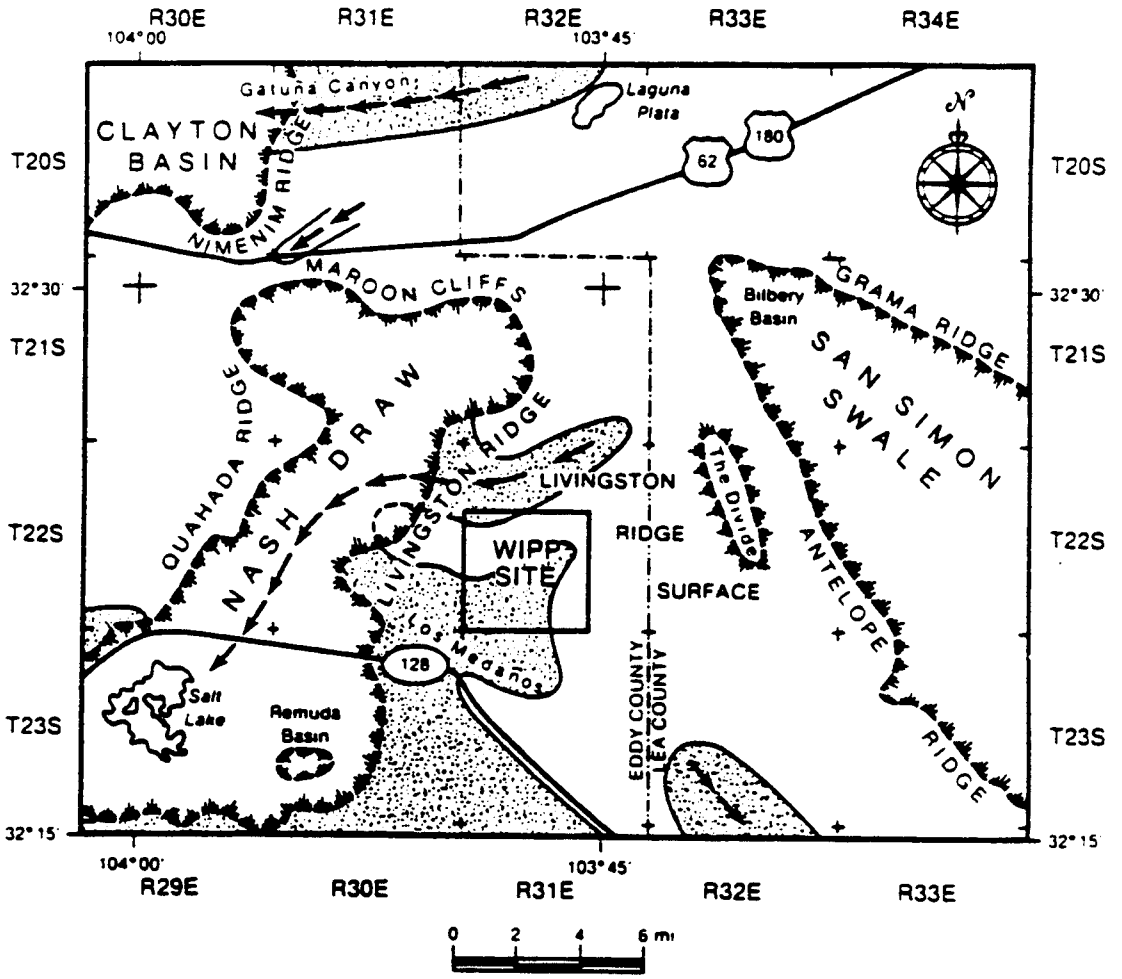


Figure 4.4.2: Probable distribution of stream channels and flow directions at and near the WIPP site during Gatuna time. Figure 11 of Bachman (1985). The present distribution of the Gatuna Formation is indicated by the stippled pattern.

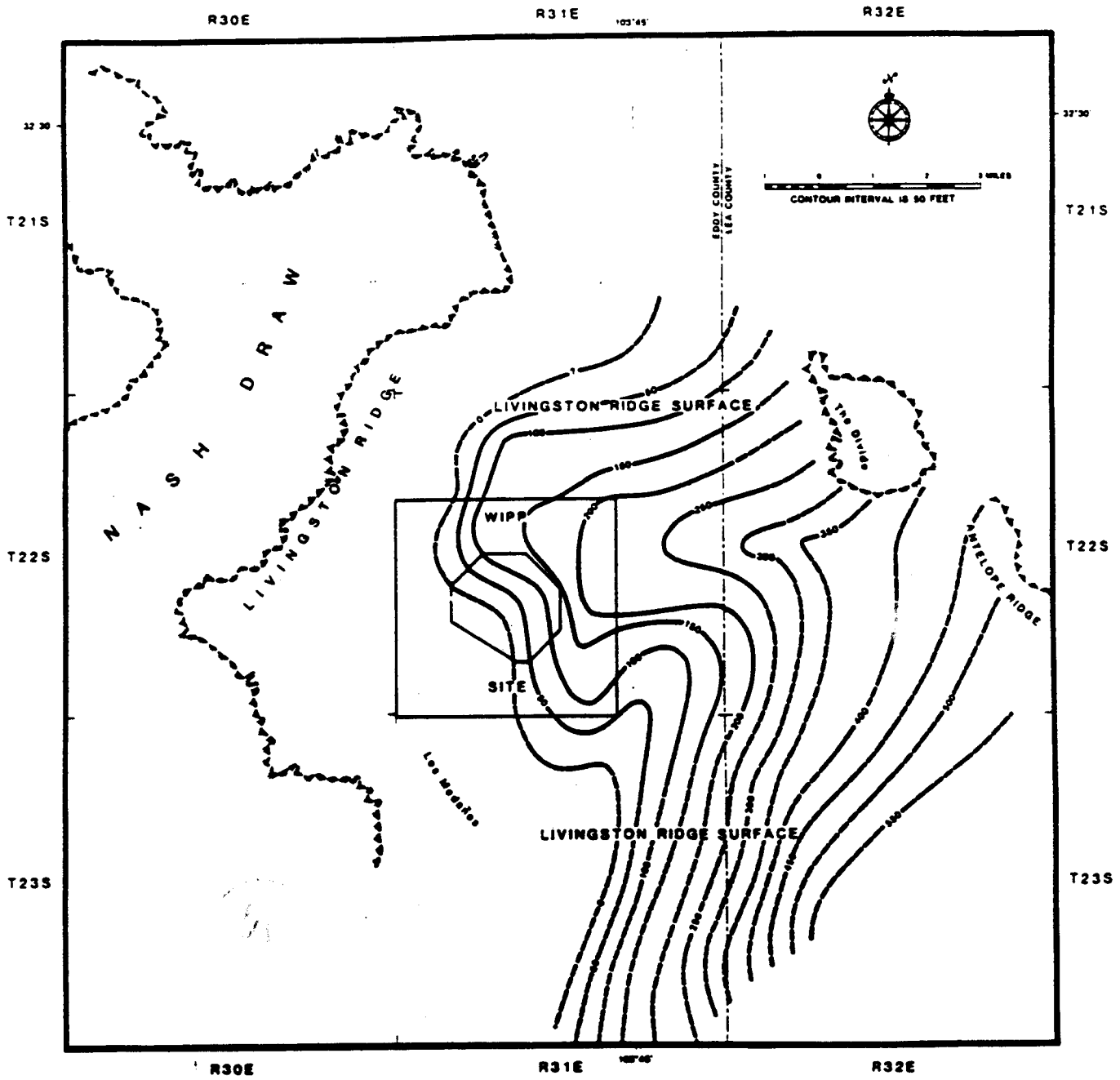


Figure 4.4.3: Distribution and thickness of Triassic rocks at and near the WIPP site. Figure 5 of Bachman (1985).

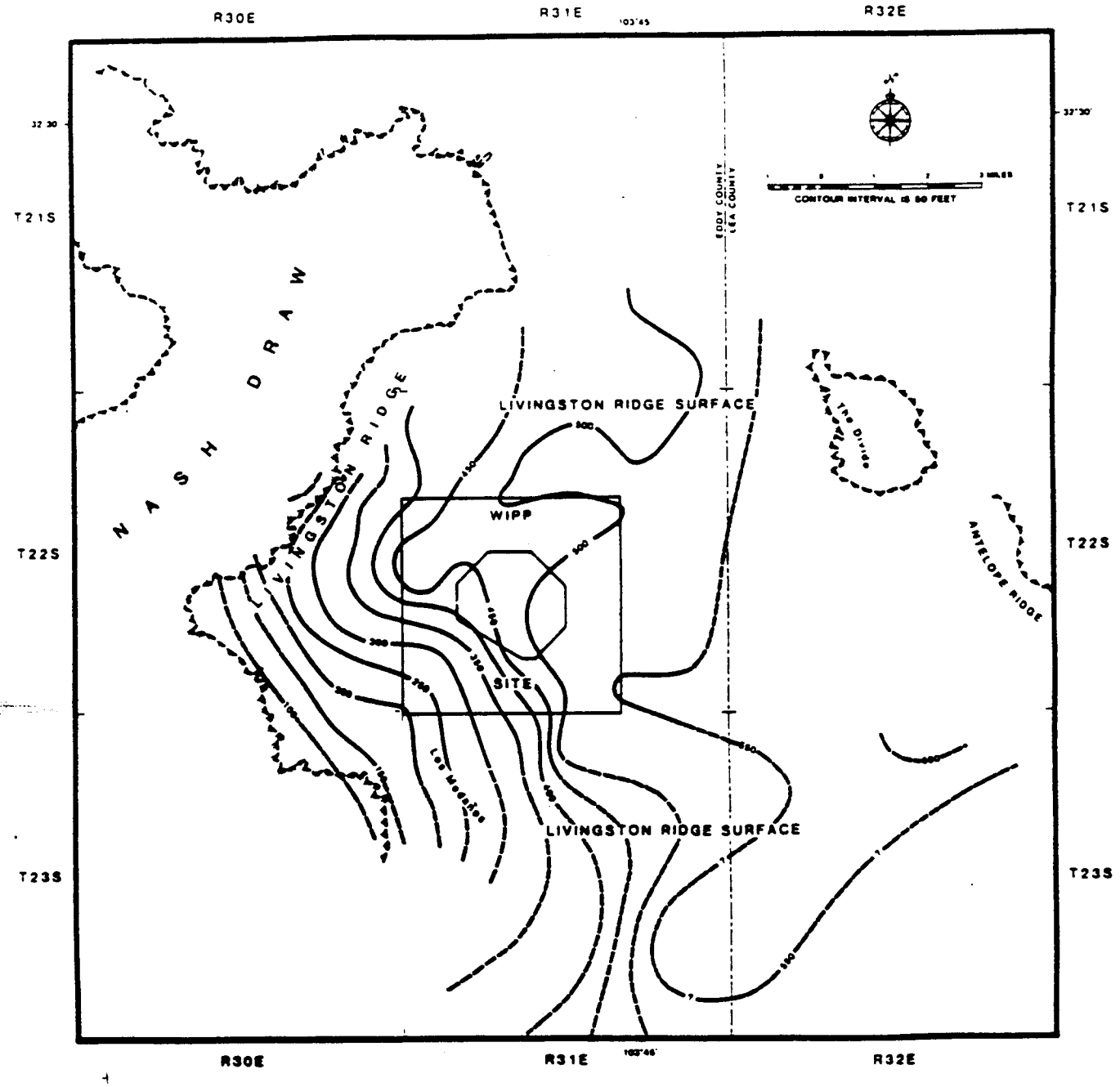


Figure 4.4.4: Distribution and thickness of the Dewey Lake Red Beds at and near the WIPP site. Figure 6 of Bachman (1985).

relatively stable; i.e., stable enough for local survival of the thin, 350,000-year-old Berino soil. The time scale of the climatic change between the Gatuna and Mescalero, however, is more than an order of magnitude greater than most groundwater residence, flow, and/or recharge times discussed in Section 4.3.

There is, however, evidence of local surface-water activity near the WIPP site, ending some 25,000 years ago (Bachman, 1980; 1985). This evidence consists of gypsite (calcium sulfate) spring deposits along the east side of Nash Draw. The fact that these springs are no longer active is interpreted by Bachman (1985) to indicate that ". . . the groundwater regime originally responsible for dissolving underground beds of gypsum and depositing spring deposits is no longer active." Bachman (1985) interprets the spring activity as ". . . part of a paleokarst system resulting from a much different [wetter] climatic regime" than the present regime in southeastern New Mexico.

There is limited evidence of regional climatic variability in southeastern New Mexico on approximately the same time scale as the gypsite springs in Nash Draw. As noted by Lambert (1987a), ". . . additional evidence for [a] wetter local climate is given by VanDevender (1980). From studying packrat middens in Rocky Arroyo, northwest of Carlsbad, New Mexico (about 35 miles northwest of the [present] study area . . . he determined that a juniper-oak community was present in the early Holocene (10,500 to 10,000 radiocarbon years ago), where now desert scrub communities exist." The presence of these middens is taken by Lambert and Harvey (1987) to indicate that ". . . in the immediate vicinity of the Delaware Basin, a wetter climate prevailed more than 10,000 years ago; the present desert scrub-plant communities have been stable in the last 4,000 years." Unfortunately, the data presented by VanDevender (1980) provide no information concerning variations in the climate in the area between approximately 10,000 and 4,000 years ago.

There is strong evidence for both climatic and hydrologic changes having occurred since at least 600,000 years ago in the vicinity of the WIPP site, and limited evidence for a "wetter" climate than present approximately 10,000 years ago. Unfortunately, there are broad time gaps in the regional information that is available. For example, no deposits are known at or near the WIPP site that are intermediate in age between the Berino soil and the gypsite springs in Nash Draw (Lambert, 1988).

The stratigraphic and paleoclimatic studies discussed in this section are not alone in indicating a transient hydrologic setting for the WIPP site and vicinity. Fluid-density and flow-time relations discussed in Sections 4.1.3.1 and 4.1.3.2, as well as hydrochemical facies discussed in Section 4.3.1 are all inconsistent with steady-state confined flow. The isotopic studies discussed in Sections 4.3.2, 4.3.3, and 4.3.4 indicate a transient hydrologic setting for the Rustler. The time scale of transience is generally consistent to within less than an order of magnitude with the time scale of the climatic change indicated by the gypsite springs in Nash Draw (Bachman, 1980; 1985) and the packrat-midden studies of Van Devender (1980).

4.4.2 Recent Studies of Evaporite Dissolution and/or Vertical Fluid Movement within the Rustler and Younger Formations

4.4.2.1 General Geologic Studies--As mentioned above, the Mescalero caliche is relatively continuous at and near the WIPP site. Where continuous, it plays a major role in limiting modern infiltration of precipitation. As noted by Bachman (1973), however, the unit is not completely continuous, since it is locally pierced by conical structures, roughly 1 m or less in diameter, resulting from localized caliche dissolution by humic acid released by plant roots. The structures generally do not completely penetrate the caliche (Bachman, 1973). Where these structures do completely penetrate, local infiltration through the Mescalero caliche may occur, at least to the depth of plant roots. The widespread presence of the Mescalero caliche on the Livingston Ridge surface must be taken to indicate structural stability of the surface, not to indicate the impossibility of localized infiltration. The widespread preservation of the caliche does indicate that not enough infiltration on a regional scale has taken place since its formation to result in its wholesale dissolution.

As discussed in Section 4.1.1 and 4.1.3, the measured head relations and relative transmissivities of members of the Rustler indicate only limited vertical fluid flow within the Rustler Formation. While there is limited vertical movement, stratabound or confined flow within the Culebra dolomite dominates the hydrology of the Rustler Formation at and near the WIPP site. If, however, vertical flow were to extend from the surface to the Rustler, through both the Mescalero caliche and the Dewey Lake Red Beds, the hydrologic setting of the Rustler Formation at and near the WIPP site might be "karstic." In such a system, vertical fluid movement both from the surface to the Rustler and within the Rustler might result in formation of solution channels or cavities. If karstic hydrology dominated within the Rustler at and near the WIPP site, transport rates to the accessible environment would be significantly increased (e.g., Chaturvedi and Channell, 1985). The presence of karstic cavities within the Rustler at the WIPP site has been proposed by Barrows et al. (1983) to explain apparent gravity patterns in the vicinity of holes WIPP-14 and WIPP-34 (Figure 4.4.1). Two additional structures have been interpreted by some to indicate the extension of the evaporite-karst behavior within Nash Draw over the WIPP site itself (see Neill et al., 1983). The first, a depression and related breach of the Mescalero caliche at hole WIPP-33, is interpreted (e.g., Bachman, 1985) as having originated by downward infiltration from the surface to sulfatic portions of the Forty-niner and Tamarisk Members of the Rustler immediately above and below the Magenta dolomite. The second is a relatively large but shallow depression in the SW1/4, SW1/4, Sec.29, T22S, R31E (see Figure 3.2 for general location), examined directly by Bachman. Bachman (1985) concludes that this structure is a result of wind erosion.

One approach used in arguing in favor of karstic hydrology in the Rustler at and near the WIPP (e.g., Barrows, 1982) is based on the assumption of an idealized water budget or water balance, independent of the presence or absence of specific structures indicating infiltration of surface recharge to the required depths. In such an approach, values of variables such as

infiltration, precipitation, and evapotranspiration are assumed to be known with high precision and accuracy. Any excess of estimated precipitation over estimated evapotranspiration is then attributed to vertical recharge from the surface to the Rustler, i.e., to karstic hydrology. As shown by Hunter (1985), however, the uncertainties in precipitation, infiltration, evapotranspiration and Rustler-discharge data at and near the WIPP site are so large that water-budget techniques cannot be used either to determine the amount of recharge or to determine that recharge is occurring. The detailed water budget described by Hunter (1985) is, in fact, not inconsistent with the conclusion (Sections 4.3.2, 4.3.3, 4.3.4) that no recharge is now occurring at and near the WIPP site. The evaluation of the potential for karst hydrology within the Rustler at and near the WIPP site must be by means of hydrologic and geochemical studies (see Sections 4.1, 4.3, and 4.4.2), rather than by an idealized water budget. The recent hydrologic and isotopic studies discussed in Sections 4.1, 4.3, and 4.4.2 place serious constraints on the plausibility of karstic recharge presently being active at the WIPP site.

If surface waters are to infiltrate to the level of the Rustler Formation, they must penetrate the Dewey Lake, after having penetrated both surficial sands and the Mescalero caliche. The presence of local structures penetrating the Mescalero indicates that localized infiltration is possible, although these structures generally do not completely penetrate the caliche and contain secondary laminar deposits resulting from infilling. Extensive studies of local surface depressions at and near the WIPP site led Bachman (1985) to conclude that:

1. Breaches of the Mescalero significantly larger than those represented by the structures resulting from dissolution by humic acid are required for more than extremely localized infiltration, i.e., for development of karstic structures or hydrology in underlying units. The Mescalero caliche continues underneath the depression in the SW1/4, SW1/4, Sec.29, T22S, R31E examined at the specific request of the New Mexico Environmental Evaluation Group (Neill et al., 1983). Therefore, Bachman (1985) concludes that the depression is a surface structure resulting from wind erosion.

2. The relatively large breach of the Mescalero beneath the surficial depression examined by drilling of hole WIPP-33 (Figure 4.4.1) in 1979 (Snyder and McIntyre, 1981) is a result of infiltration, but is unique at and near the WIPP site. The vicinity of WIPP-33 is the only region near the WIPP site in which vertical infiltration from the surface to the Rustler and resulting development of karstic hydrology and structures in the Rustler is reasonable.

Bachman (1985) does suggest that the gypsite springs along the east side of Nash Draw are the result of removal of anhydrite/gypsum from within the Rustler and development of a local flow system connecting WIPP-33 with the eastern side of Nash Draw. Either cavernous porosity or very soft clay-rich debris was encountered in Forty-niner and Tamarisk anhydrites directly above and below the Magenta dolomite in WIPP-33, but not in either the Magenta or Culebra dolomites. The depth of burial of the Forty-niner anhydrite in WIPP-33 is approximately 120 m.

The apparent WIPP-33 structure within the Rustler is consistent with interpretations that:

1. Rustler dolomites are nearly the last rock type to be significantly affected by evaporite dissolution (Snyder, 1985).

2. Because of the relative mechanical weakness of gypsum, the maintenance of open karstic structures within gypsum is possible only at relatively shallow depths. Bachman (1987) examines the regional distribution and impact of the dissolution of anhydrite and gypsum at relatively shallow depths. Certainly, sulfate dissolution has taken and is taking place within the Rustler Formation in Nash Draw, as evidenced by the continuing formation of small caves and sinkholes in the gypsums/anhydrites of the Tamarisk and Forty-niner Members.

3. The only Rustler carbonate from a water-bearing zone in the region to have recrystallized in response to input of meteoric water is at WIPP-33 (Lambert, 1988).

There is no consensus concerning the amount of evaporite dissolution within the Rustler east of Nash Draw. Two schools of thought exist. One approach, most recently summarized by Snyder (1985) and Lowenstein (1987), basically assumes an original laterally homogeneous halite distribution within the Rustler. By this assumption, lateral variability within the Rustler, especially the presence or absence of halite within the claystone portions of the unnamed lower member, Tamarisk, and Forty-niner Members, is due to halite dissolution. A simplified representation of halite distribution within the Rustler is shown in Figure 1.5. A representative cross section showing the variations in thicknesses and lithologies of individual members of the Rustler is shown in Figure 4.4.5.

As shown in Figure 4.4.5, the progressive east-to-west decrease in halite in successively lower members of the Rustler is reflected largely in decreasing thickness of the affected member. The thickness of the Culebra and Magenta dolomites varies only slightly across the area of the WIPP site. In fact, as shown by changes in Rustler thickness between holes WIPP-25 and BLM-1 (Figure 4.4.6), advanced stages of evaporite dissolution within the Rustler involve alteration/dissolution of anhydrite and gypsum rather than dolomites. The interpretations contained in Snyder (1985) and Lowenstein (1987) maximize both the total amount of halite originally present within the Rustler Formation and the amount of later dissolution. The conclusion in the WIPP FEIS (1980) that evaporite dissolution within the Rustler Formation was not of concern to the WIPP Project was based largely on extrapolation of vertical dissolution rates required to generate the depth of Nash Draw in the approximately 600,000 years since deposition of the Gatuna Formation (Bachman, 1974).

In contrast, Holt and Powers (1984; 1987) conclude on the basis of sedimentological arguments and structures that many structures within the Rustler Formation interpreted by authors such as Snyder (1985) and Lowenstein (1987) as resulting from halite dissolution are a result of primary depositional variability. By this interpretation, the amount of

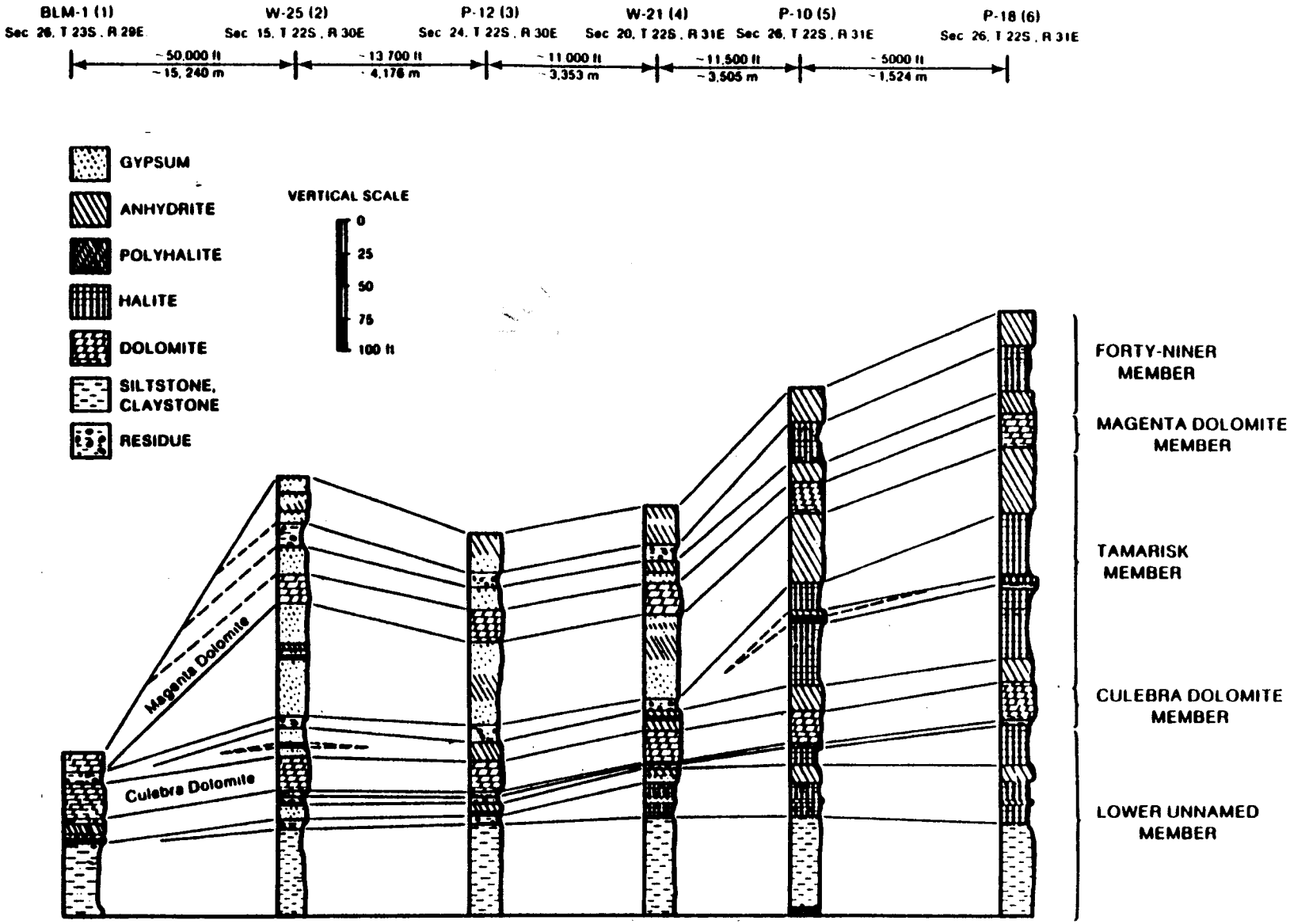


Figure 4.4.5: Columnar cross section across the WIPP site, showing lithologic correlations and variability of units in the Rustler Formation. Figure 2 of Snyder (1985).

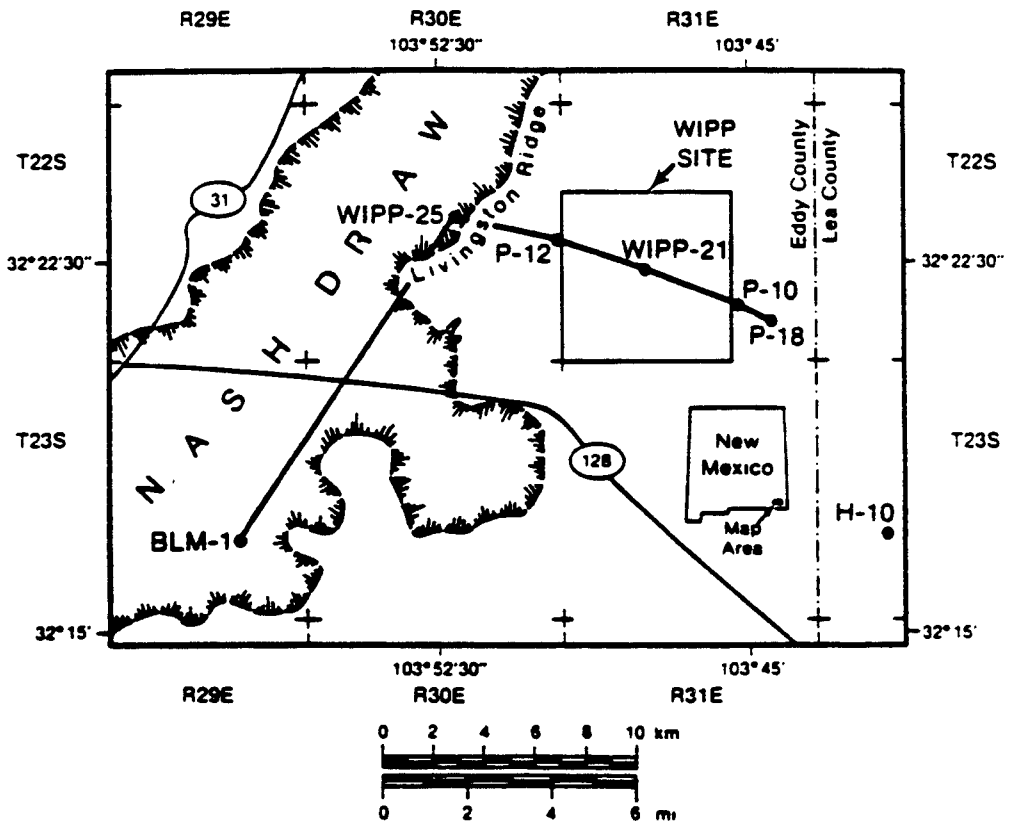


Figure 4.4.6: Hole locations used in Figure 4.4.5. Figure 1 of Snyder (1985).

halite later removed from the Rustler by evaporite dissolution is reduced. Since extrapolation of the estimated rates of dissolution within Nash Draw (Bachman, 1974) indicate that there is no need for concern at the WIPP site over the next 10,000 years, the differing interpretations do not directly affect the expected reliability of the WIPP facility. However, as discussed in Beauheim (1987b), primary depositional variability within the Rustler weakens the present understanding of the correlation between halite distribution within the Rustler, fracturing, and the transmissivity of the Culebra dolomite.

The conclusion that some of the gypsum observed within the Rustler is primary, rather than being due to alteration of preexisting anhydrite, is part of the interpretation by Holt and Powers (1984; 1987). Thus, little movement of water outside the Culebra or Magenta members might be required to account for gypsum observed in the Forty-niner or Tamarisk Members. At the other extreme, the assumption that infiltration from the surface to the Rustler is presently operative at the WIPP site, i.e., that karstic hydrology is important in the Rustler Formation east of Nash Draw or WIPP-33, requires that alteration within the Rustler and overlying formations involves surficial waters. At least localized flow through the anhydritic portions of the Forty-niner and Tamarisk Members is required by this assumption. Recent isotopic studies summarized by Lambert (1988) place constraints on the extent to which waters and hydrated minerals within the Rustler and Dewey Lake Red Beds reflect connate fluids, fluids resulting from stratabound movement, and fluids involved in vertical infiltration.

4.4.2.2 Isotopic Studies--Figure 4.4.7 summarizes $^{87}Sr/^{86}Sr$ measurements (Brookins and Lambert, 1988) on sulfates (anhydrites and gypsum) and carbonates from several evaporitic zones at the WIPP, as well as the Dewey Lake Red Beds. The isotopic signatures of samples from both the Nash Draw gypsite springs and the Mescalero caliche (see Section 4.4.1) are interpreted to represent surficial components; i.e., high $^{87}Sr/^{86}Sr$ ratios resulting from surficial weathering. At the other extreme, the markedly different and internally homogeneous isotopic signature of the anhydrites from throughout the Castile and Salado Formations is interpreted to imply that there has been no distinguishable input of surficial components to these rocks. Anhydrites and gypsums from the unnamed lower member, Tamarisk, and Forty-niner indicate only a very limited input of surficial material, presumably by solute transport by either vertical or stratabound flow.

The Magenta dolomite, which is significantly less permeable than the Culebra in most areas (see Section 4.1.1) is also more similar in $^{87}Sr/^{86}Sr$ character to the surrounding anhydrites and gypsums than is the Culebra. This implies, consistent with conclusions reached in Sections 4.1 and 4.3, dominantly stratabound fluid flow within the Rustler, with the Culebra dolomite being predominant. If the apparent surficial component of the Culebra were a result of vertical infiltration, rather than stratabound flow of originally surficial waters, the infiltration would be expected to alter the overlying portions of the Rustler. Instead, there is much less overlap between $^{87}Sr/^{87}Sr$ ratios measured in the Magenta, Tamarisk, and

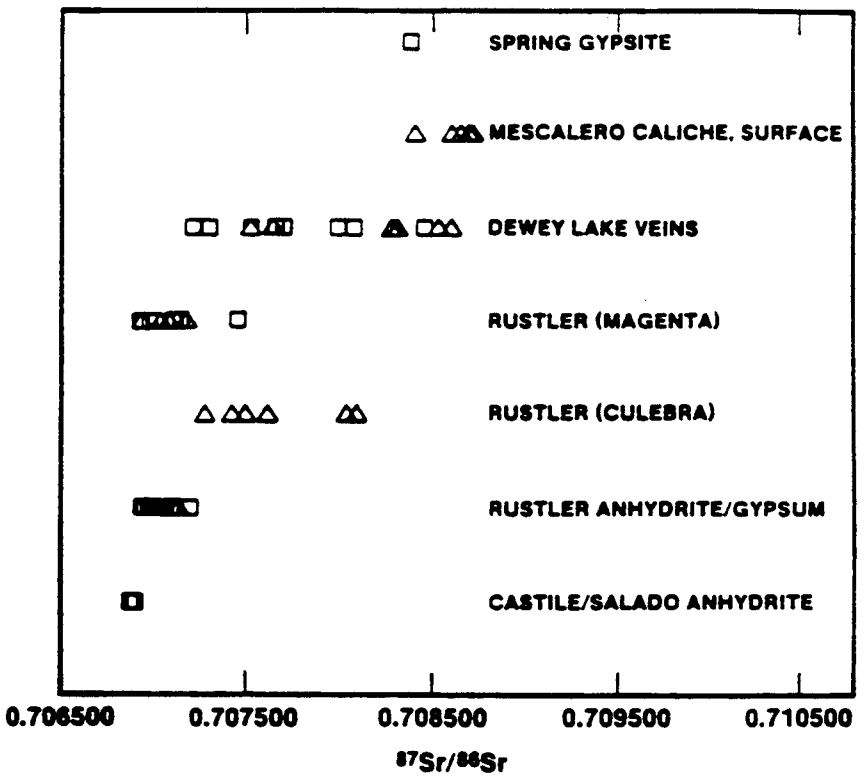


Figure 4.4.7: $^{87}Sr/^{86}Sr$ in Ochoan and related rocks at and near the WIPP site. Squares are anhydrites or gypsums; triangles are carbonates. All samples from the Dewey Lake are from veins. Samples from other units include both matrix and veins. Figure 17 of Lambert (1988).

Forty-niner Members with those measured in the Dewey Lake Red Beds than between the ratios measured in the Culebra and in the Dewey Lake.

Results contained in Figure 4.4.8 indicate further that the hydrologic system in the Dewey Lake Red Beds is significantly distinct from that of underlying units. With the exception of the Dewey Lake Red Beds, this figure summarizes the $^{87}Sr/^{86}Sr$ relationships between coexisting mineral pairs in evaporitic host rocks and in gypsum and/or calcite veins in the same unit. The question is whether these veins are locally derived or result from fluid movement over relatively long-distances. The matrix of the Dewey Lake Red Beds, however, is made up of silicic siltstones and sandstones. Therefore, carbonates and sulfates are rare in the matrix and analyses of Dewey Lake matrix materials are not included in Figure 4.4.8. The gypsum veins within the Dewey Lake probably cannot be locally derived. The strontium-isotopic character of the Dewey Lake gypsum veins (Figure 4.4.8) spans the range from surficial values represented by caliche and spring deposits in Figure 4.4.7 to isotopic values from underlying units. Since effectively none of the Dewey Lake veins can be locally derived, the range in their isotopic character indicates varying degrees of mixing of surficial waters and waters driven upward from the underlying evaporitic zones, consistent with modern head relationships discussed in Section 4.1.1.

Without exception, the strontium-isotope characters of coexisting mineral pairs from veins and host rock in units beneath the Dewey Lake are statistically identical to each other (Figure 4.4.8), indicating that the isotopic character of the vein material is controlled by that of the accompanying host rock, and not by a pervasive hydrologic system interconnected with veins in the Dewey Lake. This is even true for the one sample pair from the Culebra. These results indicate that there is little or no input of surficial material transported by groundwater below the Dewey Lake Red Beds, even into veins. All units below the Dewey Lake Red Beds considered here are evaporitic, i.e., they contain significant carbonates and/or sulfates in their matrix. Therefore, the local derivation of vein carbonates or sulfates is internally consistent.

Figures 4.4.9 and 4.4.10 indicate some constraints in rock-water ratios during gypsum crystallization or recrystallization in the Rustler and Dewey Lake. The dashed lines in Figures 4.4.9 and 4.4.10 represent the ranges in deuterium/hydrogen characteristics of Rustler water and modern surface-meteoric waters identified by Lambert and Harvey (1987) and Lambert (1988). At a sufficiently high rock/water ratio, i.e., when all of the available water is consumed in gypsum formation, for example during alteration of preexisting anhydrite, the deuterium characteristics of the resulting gypsum water, of crystallization are constrained to be the same as that of the water added to the system. Therefore, the dashed fields in Figures 4.4.9 and 4.4.10 also represent the expected isotopic character of secondary gypsums formed under conditions involving very high rock/water ratios (Lambert, 1988). At equilibrium with a large excess of water, the deuterium/hydrogen ratio in gypsum is approximately 20 parts per thousand less than that of the coexisting water (Lambert, 1988). Therefore, the fields outlined by solid lines in Figures 4.4.9 and 4.4.10 are decreased from the fields outlined by dashed lines by 20 per mil and represent the

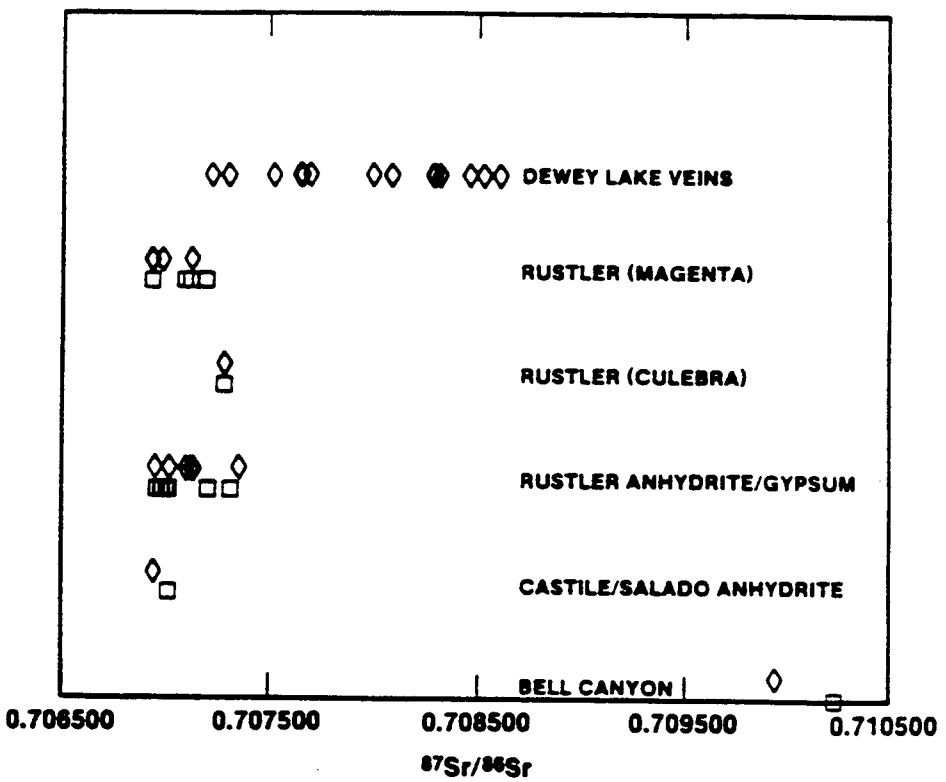


Figure 4.4.8: $^{87}Sr/^{86}Sr$ in coexisting mineral pairs from veins and Ochoan host rocks at and near the WIPP site. Squares are host rocks; diamonds are veins. Figure 18 of Lambert (1988).

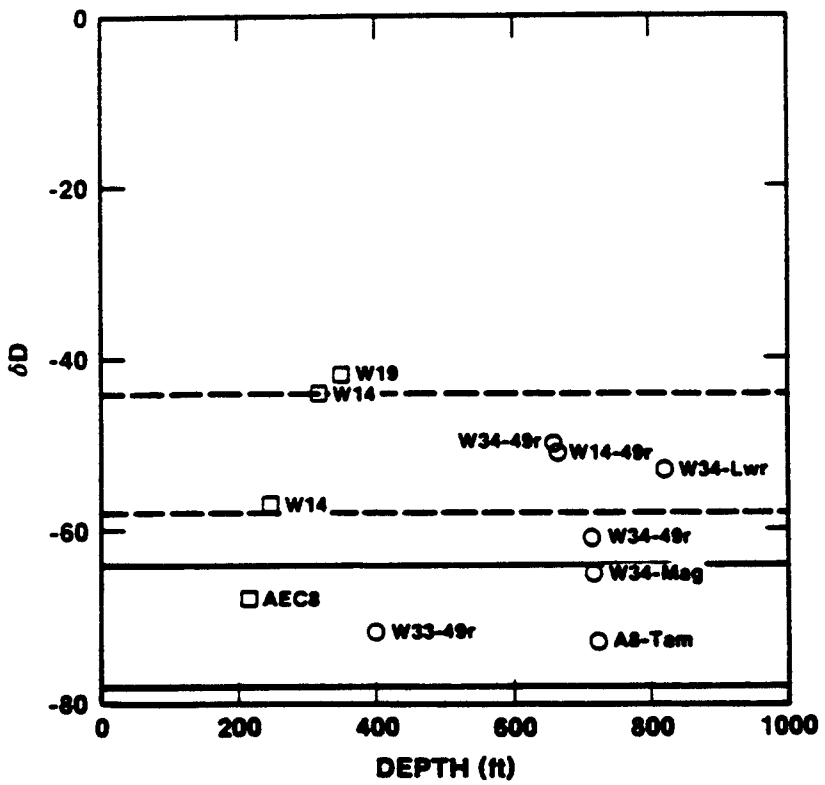


Figure 4.4.9: Deuterium distribution of the waters of crystallization of gypsums from the Dewey Lake Red Beds (squares) and Rustler Formation (circles) at and near the WIPP site, as a function of variations in rock/water ratio involving only Rustler-type water, the range in deuterium content of which is taken from Figure 4.3.10. Solid lines are for crystallization in the presence of a large amount of water, dashed lines for crystallization under conditions involving a very high rock/water ratio, in which all of the water is consumed in gypsum formation. Figure 19A of Lambert (1988).

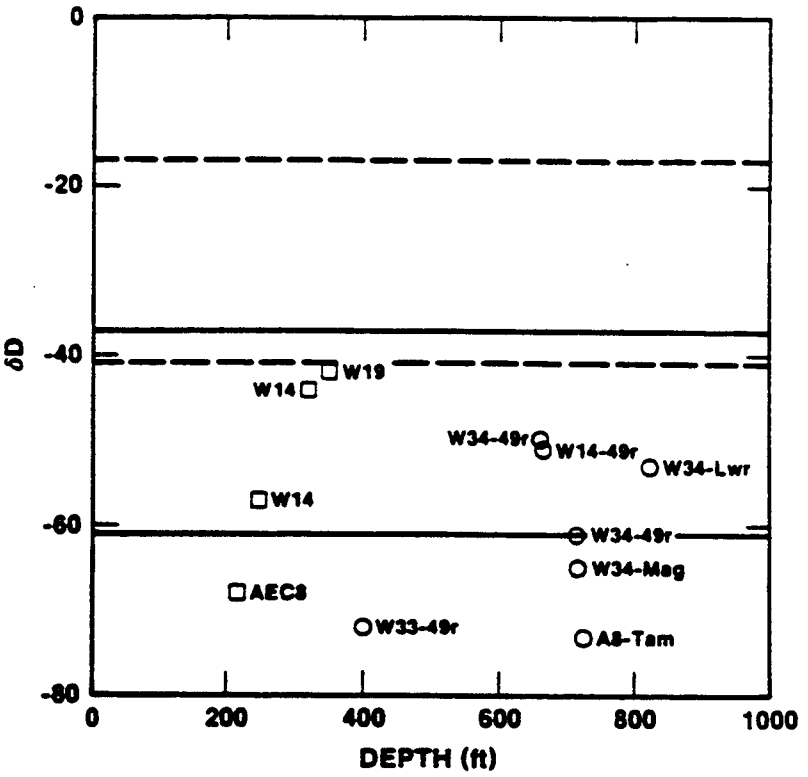


Figure 4.4.10: Deuterium distribution of the waters of crystallization of gypsums from the Dewey Lake Red Beds (squares) and Rustler Formation (circles) at and near the WIPP site, as a function of variations in rock/water ratio involving only surface-type water, the range in deuterium content of which is taken from consistent data in Figures 4.3.8 and 4.3.9. Solid lines are for crystallization in the presence of a large amount of water, dashed lines for crystallization under conditions involving a very high rock/water ratio, in which all of the water is consumed in gypsum formation. Figure 19B of Lambert (1988).

expected hydrogen-isotopic character of gypsums crystallized in the presence of excess amounts of Rustler-type and modern surface-meteoric waters, respectively.

The relationships shown in Figure 4.4.9 are consistent with crystallization of all of the analyzed gypsums with varying amounts of Rustler-type water, with the possible exception of vein material from the Dewey Lake in WIPP-19. Formation of the Dewey Lake gypsum veins in WIPP-19 apparently required infiltration of waters with the same isotopic character as those interpreted by Lambert and Harvey (1987) to represent modern meteoric precipitation. The character of the gypsum from WIPP-33 indicates crystallization in the presence of a large excess of Rustler-type water, but is not consistent with crystallization in the presence of any amount of modern-type water (Figure 4.4.10). [If it is assumed that the Magenta dolomite is more porous (permeable) than surrounding zones within the Rustler at this location, the isotopic variations in the vein gypsums from hole WIPP-34 are consistent with gypsum crystallization under varying ratios of rock to Rustler-type water.] The isotopic relationships (Figure 4.4.9) are consistent with crystallization of gypsums within the unnamed lower and Forty-niner members in response to vertical fluid flow upwards and downwards from the Magenta, assuming increasing effective rock/water ratio with increasing distance from the Magenta. This interpretation is also consistent with modern Rustler head relationships shown in Figure 4.1.3.

While results shown in Figure 4.4.9 are generally consistent with gypsum crystallization in equilibrium with varying amounts of Rustler-type waters, the results in Figure 4.4.10 indicate that this need not be the case for all samples. In Figure 4.4.10, the dashed field represents expected gypsum compositions for crystallization using modern surface-meteoric water, at a very high rock/water ratio, the solid field crystallization in the presence of greatly excess water. The hydrogen-isotopic relations indicate that it is impossible to form the gypsum from the Forty-niner Member at WIPP-33 with modern surface-meteoric water. This conclusion is consistent with the interpretations of Bachman (1980) that the gypsite springs in Nash Draw, which he believes to be the discharge for the WIPP-33 structure, are not presently active. The relations shown in Figure 4.4.10 also indicate that it is not possible to form the gypsum from the Magenta dolomite in WIPP-34 with surface-meteoric waters. The internally consistent interpretation of vertical variations in rock/water ratios within the Rustler Formation in WIPP-34, evident in Figure 4.4.9, breaks down if surface-meteoric waters are assumed to be involved.

The isotopic results summarized by Lambert (1988) indicate that there has been significant involvement of surficial waters in formation of gypsum veins within the Dewey Lake Red Beds. These same results indicate that the hydrologic behavior of the Dewey Lake is largely distinct from that of the underlying units and that there has been some upward movement of fluids into the Dewey Lake from the underlying Rustler Formation, consistent with the modern head relationships discussed in Section 4.1. Isotopic relations within secondary gypsums in the Rustler and Dewey Lake are somewhat ambiguous. In many cases, a given gypsum may have crystallized in equilibrium with either Rustler-type or modern surficial-meteoric waters,

depending on the rock/water ratio that is assumed to have been effective at the time of crystallization. The isotopic variability of gypsums from hole WIPP-34 is, however, best explained by local vertical movement of Rustler-type waters out of the Magenta dolomite, without the vertical karst channel system proposed for this locality by Barrows et al. (1983). It appears impossible to have crystallized secondary gypsum veins from the Dewey Lake at hole WIPP-19 without input of modern surface-meteoric waters. At WIPP-33, where the best physical evidence exists for vertical fluid movement from the surface downwards to the Rustler at depth, the isotopic character of analyzed vein gypsum from the Forty-niner indicates that this movement and related gypsum crystallization does not involve modern surface-meteoric water, i.e., that the WIPP-33 structure is essentially no longer active.

5.0 SUMMARY OF WIPP SITE-CHARACTERIZATION ACTIVITIES, 1983 THROUGH 1987

This section summarizes the present understanding of major aspects of WIPP site characterization, including some effort to place the WIPP facility in a regional hydrologic, structural, and geochemical prespective. A general conceptual model for the geologic behavior of the WIPP site and facility vicinity is presented in Section 5.1. Later sections describe more specific inclusions and briefly discuss remaining uncertainties or limitations. It must not be assumed either that any uncertainty discussed is significant to performance of the WIPP facility, or that any given uncertainty could be significantly reduced by further work. It is ultimately the role of the WIPP performance-assessment activity to determine which uncertainties are expected to be significant in evaluation of the short-term and long-term performance of the WIPP facility. The effort here is to provide as complete a conceptual model as possible for these decisions.

5.1 General Conceptual Model for the Geologic Behavior of the WIPP Site and Facility

The overall geologic and hydrologic setting of the WIPP site area has been transient (not steady-state) since before the beginning of deposition of the Bell Canyon Formation, approximately 250 million years ago, and will continue to be transient long after effective closure of the WIPP facility. Some events, such as crystallization of secondary minerals within the Salado Formation approximately 200 million years ago and formation of the Mescalero caliche 400,000 to 500,000 years ago, have taken place on a very long time scale relative to WIPP performance assessment, which must consider only a 10,000-year time frame. Two types of transient response have occurred or are occurring at and near the WIPP site within the 10,000-year time frame of regulatory interest. These are: a) the continuing natural response of the geologic and hydrologic systems to the end of the last pluvial period (period of decreased temperatures and increased precipitation) in southeast New Mexico; and b) the continuing responses to hydrologic, geochemical, and structural transients resulting from WIPP site characterization and facility construction. The transient responses induced by the presence of the WIPP underground workings will continue until reequilibration following effective structural and hydrologic closure of the facility.

The Bell Canyon Formation, consisting largely of shales, siltstones, and sandstones, contains the first relatively continuous water-bearing zone beneath the WIPP facility. In some parts of the northern Delaware Basin, the unit contains permeable channel sandstones that are targets for hydrocarbon exploration. Recent studies suggest that the upper Bell Canyon at the WIPP site does not contain any major channel sandstone. This decreases the probability of the Bell Canyon serving as a source of fluids for dissolution of overlying evaporites at the WIPP. These same studies indicate that the final direction of fluid flow following interconnection of the Bell Canyon, Salado, and Rustler Formations within a drillhole would be downward into the Bell Canyon, after accounting for density increases in the fluids due to dissolution of halite within the Salado. It is assumed

here that the measured hydrologic characteristics of the Bell Canyon Formation are more significant to WIPP performance assessment than those of underlying units. The head distribution within the upper Bell Canyon near the WIPP site indicates flow towards the northeast.

Both regional studies and studies within the WIPP facility indicate that the Castile and Salado Formations, both of which are made up predominantly of layered anhydrites and halites, should be considered as low-permeability units that deform regionally in response to gravity. In general, permeabilities and fluid-flow rates in both units are very low and insensitive to stratigraphy. Formation permeabilities in the Castile and Salado Formations remote from the WIPP excavations are generally 0.1 microdarcy or less, and the regional water content of Salado halites is up to 2 weight percent. Exceptions include local brine occurrences in Castile anhydrites and gas occurrences in the Salado Formation, both of which are fracture-controlled, can be large in volume, and can be under pressures high enough to cause fluid flow to the surface. No major gas occurrence within the Salado Formation has been encountered at the WIPP site. In fact, where it has been possible to measure far-field brine pressures within the Salado, the pressures, permeabilities, and available brine volumes combine to indicate the potential for only very limited fluid flow upwards into the overlying Rustler Formation. It is not certain that the Castile and Salado Formations are hydrologically saturated regionally.

Pressurized Castile brines have been encountered in Castile anhydrite in hole WIPP-12, approximately 1.5 km north of the center of the WIPP site. Geophysical studies indicate that Castile brines probably are present beneath a portion of the WIPP waste-emplacement panels, consistent with earlier assumptions. These brines are stratigraphically 200 m or more below the WIPP facility horizon and are not of concern except in the case of human-intrusion breach of the facility.

In the western part of the Delaware Basin, extensive halite dissolution has apparently taken place in both the Castile and Salado Formations. However, much of the variability in structure and internal stratigraphic thicknesses within the Castile and Salado Formations results from deformation and original depositional variability, rather than from evaporite dissolution. Regional or far-field deformation of the Castile and Salado Formations involves pressure solution as a major mechanism, due to the presence of intergranular fluids, but occurs too slowly to be of future concern to the WIPP Project. Structures within hole DOE-2 result from deformation rather than dissolution.

The hydrologic and structural characteristics of the Salado Formation in the disturbed zone generated by the presence of the WIPP facility are different than those in the far field. Formation permeability within a couple of meters of the underground workings at the facility horizon increases significantly. Near-field deformation of the Salado Formation involves both the opening of preexisting fractures in anhydrite beneath the facility horizon (Marker Bed 139) and generation of new fractures in halite. Fluid contents in the disturbed zone at the facility horizon decrease in response to facility ventilation and/or deformation. Within a few meters of the underground workings, both hydrologic and structural

behavior of the Salado Formation become essentially those of the far field. Brine seepage into the WIPP facility includes a significant transient phase, which will probably last until effective facility closure. The results of preliminary hydrologic testing in the Salado Formation adjacent to the WIPP air-intake shaft indicate extremely low permeabilities, with no apparent stratigraphic variability. The results also indicate that development of a disturbed zone around the WIPP shafts is less extensive than at the facility horizon. The extent, characteristics, and importance of the disturbed-rock zones around the WIPP shafts and at the facility horizon remain to be determined in detail.

Where not extensively altered, the Rustler Formation should be considered as a layered unit of anhydrites, siltstones, and halites, containing an important and variably fractured carbonate unit, the Culebra dolomite. The Culebra dolomite is the first continuous water-bearing unit above the WIPP facility and, at the WIPP site, is at least an order of magnitude more permeable than other members of the Rustler Formation, including the Magenta dolomite. The transmissivities of Rustler anhydrites at the WIPP site are too low to measure. As a result, the Culebra dominates fluid flow within the Rustler Formation at the WIPP site and is the most significant pathway to the accessible environment from the WIPP facility, except for direct breach to the surface by human intrusion. The transmissivity of the Culebra varies by approximately six orders of magnitude in the region containing the WIPP site. The Culebra transmissivity in the central portion of the site, including the locations of all four WIPP shafts, is low. Higher Culebra transmissivities are found in areas southeast and northwest of the central part of the site. Fluid flow rates within the Culebra are very low at the site center and in regions to the east, but relatively high within Nash Draw. Modern flow in the Culebra is confined and largely north-south in the area of the WIPP site.

Fluid flow and geochemistry within the Culebra dolomite and shallower units are in continuing transient response to the marked decrease or cessation of local recharge at approximately the end of the last pluvial period. Both bulk chemistry and isotopic relations within Culebra fluids are inconsistent with modern flow directions if steady-state confined flow is assumed. Because of the relative head potentials within the Rustler Formation at and near the WIPP site, there must be a small amount of vertical fluid flow between its members, even though the permeabilities of Rustler members other than the Culebra dolomite are quite low. Where measured successfully, the modern head potentials within the Rustler prevent fluid flow from the surface downward into the Rustler carbonates. These results do not prohibit either the modern movement of fluids from the underlying Salado Formation upwards into the Rustler Formation or the downward movement of Dewey Lake waters into the Rustler Formation during or even after the cessation of local recharge at the end of the last pluvial period. They do, however, suggest that recharge from the surface to the Rustler Formation is not now occurring at the WIPP site. The results of stable-isotope, radiocarbon, and uranium-disequilibrium studies are also consistent with the interpretation that there is no measurable modern recharge to the Culebra dolomite from the surface at and near the WIPP site. The transient hydrologic response of the Rustler Formation to the end of the last pluvial period has involved at least some change in flow

directions in the Culebra dolomite. Although the modern flow is largely north-south, the results of uranium-disequilibrium studies suggest that flow was more easterly during previous recharge.

Within and near Nash Draw, evaporite karst is operative within the Rustler, as evidenced by the continuing development of small caves and sinkholes in near-surface anhydrites and gypsums of the Forty-niner and Tamarisk Members. There is no evidence of karstic hydrology in the Rustler at and near the WIPP site. However fracturing of some portions of the Culebra dolomite is sufficient at the site to strongly affect both hydraulic and transport behavior on the hydropad scale, i.e., over distances of approximately 30 m. Interpretation of multipad interference tests conducted both north and south of the center of the WIPP site indicates that this fracturing need not be incorporated into numerical modeling of the regional-scale hydraulic behavior of the Culebra east of Nash Draw. Similarly, detailed transport calculations indicate that effects due to fracturing are not significant in regional-scale transport within the Culebra dolomite at and near the WIPP site, at least as long as the modern head distribution is not significantly disturbed and the calculated flow directions and transport properties are representative.

The Dewey Lake Red Beds overlying the Rustler Formation consist largely of siltstones and claystones, with subordinate sandstones. In tested locations, the Dewey Lake may be hydrologically unsaturated, but is too low in permeability for successful hydrologic testing. South of the WIPP site, near an area where the unit may be receiving modern recharge, sandstones within the Dewey Lake locally produce potable water. In general, water levels within the Dewey Lake Red Beds, like those in the underlying Rustler Formation, must be in transient response to the end of the last pluvial period. Isotopic relations suggest that surficial waters have been involved in the formation of secondary gypsum veins within the Dewey Lake, but that the Dewey Lake and Rustler hydrologic systems are largely separate.

The major near-surface units at the WIPP site are the Gatuna Formation and Mescalero caliche. The sandstones and stream-channel conglomerates within the Gatuna indicate that major changes in local climate have occurred over (at least) the last 600,000 years. The widespread preservation of the Mescalero caliche indicates not only the relative structural stability of the Livingston Ridge surface (on which the WIPP surface facilities are sited) over the last 400,000 years, but also that infiltration over this same time period has not been sufficient to dissolve a layer of carbonate 1 to 2 m thick.

5.2 Individual Conclusions and Discussions

This Section contains descriptions and discussions of more specific conclusions concerning geologic chracterization of the WIPP site and vicinity. In each case, the description of the conclusion is followed by a brief discussion.

5.2.1 Conclusions Concerning the Overall Geologic and Hydrologic Setting of the WIPP Site and Vicinity

1. Conclusion: The overall geologic behavior at the WIPP site has been transient since before the beginning of deposition of the Bell Canyon Formation approximately 250 million years ago. Radiometric age dating indicates that secondary polyhalites in the Salado Formation near the WIPP facility horizon crystallized approximately 200 million years ago, some 40 million years after deposition of the Salado. Fractures within MB139, which are now partially healed, probably formed in response to rapid unloading at the end of the Cretaceous or in the Tertiary, i.e., more than approximately 2 million years ago. The hydrologic setting of the WIPP site appears to be in transient response to the end of the last pluvial period.

Discussion: Not all of the secondary minerals in the Salado have been dated. The age of magnesite, which appears to play a large role in controlling the composition of fluid inclusions, has not been determined. The age of fracturing in MB139 has not been determined directly. However, given that estimated ages of secondary mineralization and fracturing within MB139 appear large relative to the regulatory time frame of 10,000 years, the present estimates are adequate. Understanding of the hydrology of the WIPP site, especially the Rustler Formation, has been a major focus of site-characterization activities (see below).

2. Conclusion: There is abundant evidence for climatic and hydrologic transients at the WIPP site over the time interval of approximately 600,000 to 300,000 years before the present, as well as for long-term structural stability of the Livingston Ridge surface, on which the WIPP surface facilities are sited. The Gatuna Formation indicates a much wetter climate approximately 600,000 years ago, resulting in the presence of relatively high-energy streams on what is now the Livingston Ridge surface. The formation of the Mescalero caliche and Berino soil indicate a relatively drier climate approximately 500,000 and 300,000 years ago. The widespread preservation of the Mescalero indicates structural stability of the Livingston Ridge surface for approximately 300,000 years. In addition to structural stability, the preservation of the Mescalero caliche indicates that the regional infiltration over approximately the last 500,000 years has been insufficient to dissolve the existing caliche.

Discussion: The available geologic data do not provide a continuous time-stratigraphic record over the last 600,000 years. For example, only the upper portion of the Gatuna Formation has been dated; the age of lower portions of the unit is unknown. No dated deposits younger than the Berino soil are present at the WIPP site. Regional preservation of the Mescalero caliche does not mean that there is no local infiltration of surficial waters, since local dissolution of caliche due to the action of plant roots is known; in some places, the resulting structures completely pierce the Mescalero.

3. Conclusion: There is localized evidence for climatic and hydrologic changes near the WIPP site on the time scale of 25,000 to 10,500 years ago. Gypsite springs along the east side of Nash Draw appear to have been inactive for approximately 25,000 years. Packrat middens northwest of Carlsbad indicate a climate approximately 10,000 years ago significantly cooler and wetter than that approximately 4,000 years ago.

Discussion: Neither gypsite springs nor packrat middens have been found at the WIPP site proper. The radiometric age-dating of the gypsite spring deposits is not internally consistent, although the faunal assemblage in the deposits is definitely Late Pleistocene in age. The gypsite springs and packrat middens provide only a qualitative indication of change in climate and precipitation. Therefore, they cannot be used as direct input for transient boundary conditions in numerical modeling of hydrology at the WIPP site. Little information is available concerning the climate and hydrology of the northern Delaware Basin between approximately 10,000 and 4,000 years ago.

4. Conclusion: There is abundant evidence that the natural fluid flow and geochemistry of the Rustler are dominated by confined flow within the Culebra dolomite at and near the WIPP site, and that flow within the Culebra is transient on a time scale of approximately 10,000 years or longer.

   The hydrology and geochemistry of the Rustler, and therefore those of all other units as well, are recovering from the most recent pluvial interval in southeastern New Mexico. Factors indicating the overall transient setting of Rustler hydrology at and near the WIPP site include: a) the inconsistency between modern flow directions and present brine-density distribution within the Culebra dolomite if steady-state confined flow is assumed; b) the inconsistency between present hydrochemical facies within Culebra fluids and modern flow directions if steady-state confined flow is assumed; c) the inconsistency between the isotopic characteristics of Rustler fluids and both modern flow directions and surficial recharge to the Rustler at and near the WIPP site; and d) geologic, isotopic, and hydrologic studies indicating that vertical fluid movement into and out of the Rustler Formation is limited.

   Because the transmissivities of non-carbonate units within the Rustler are not zero and different hydraulic heads are known in different Rustler members, there must be limited vertical fluid flow within the Rustler Formation. However, the transmissivities of Rustler anhydrites and the Tamarisk claystone at and near the WIPP site are too low to measure; therefore vertical fluid flow must be extremely limited.

Discussion: The present isotopic data bases are limited in size. Therefore, the presence of small structures inconsistent with regional interpretations is possible. In addition, because of the limited data base, directions of flow interpreted from uranium-disequilibrium studies include considerable uncertainty. The available results indicate that,

although stratabound flow within the Culebra dolomite dominates at and near the WIPP site, this is not necessarily true within Nash Draw. Because of the existence of small caves and sinkholes within Tamarisk and Forty-niner anhydrites in Nash Draw, there must be a qualitative increase in the transmissivity of these members somewhere between the WIPP site and Nash Draw. Avaliable evidence suggests that this change does not take place east of WIPP-33.

5. Conclusion: At least three types of man-induced transients at the WIPP site are known or can be expected. The transients include hydrologic, geochemical, and structural effects, independent of the emplacement of waste.

   The hydrology of the Rustler Formation at and near the WIPP has been and will continue to be affected by both hydrologic testing in the area and the construction and sealing of the WIPP shafts. The hydrologic behavior of the Salado Formation, both in the WIPP facility itself and adjacent to the access shafts, has been altered by construction of the WIPP facility and shafts. This alteration includes development of a local altered or disturbed rock zone, within which permeability is significantly increased and a zone of partial saturation has probably developed. The altered zone, however, is probably less extensive around lined shafts than at the facility horizon.

   In the Rustler Formation, the use of lost-circulation materials during the drilling of hydrocarbon-exploration holes and hydrologic test holes not drilled with air has resulted in development of at least local geochemical transients of unknown magnitude, lateral extent, and duration. Any far-field radionuclide migration outside the WIPP facility in the Rustler may be superimposed on these transients. Possible geochemical alteration within the Salado Formation due to the presence of the WIPP facility remains to be examined in detail, with the exception of effects due to emplacement of TRU wastes. For example, the long-term geochemical stability of grouting materials used in both the Rustler and Salado is not yet known.

   The construction of the WIPP facility imposes a transient near-field structural effect on at least nearby portions of the Salado Formation. At the facility horizon, this effect includes both local opening of preexisting fractures in MB139 and formation of fractures in halite. Transient structural behavior around the WIPP shafts will include the Rustler Formation and extend to the land surface. However, the limited information available to date suggests that structural effects around the WIPP shafts will be less than those at the facility horizon.

Discussion: The effective time scales of the man-induced transients in and near the WIPP facility are not well known. Transients directly resulting from the construction of the WIPP facility will last until reequilibration following the effective hydrologic and structural closure of the facility. The time scale of hydrologic transients within the Rustler induced by hydrologic testing is short, maybe decades. The time scale of induced geochemical transients within the Rustler is not known. Only those

transients which might affect the performance of the WIPP facility need be determined in any more detail than indicated here. Determination of which transients need be considered is part of the WIPP Performance Assessment activity.

5.2.2 Conclusions Concerning the Bell Canyon Formation

1. Conclusion: Calculations completed as part of the WIPP SPDV effort indicate that the Bell Canyon does not have sufficient brine-carrying capacity to dissolve halite rapidly enough for halite dissolution within the Castile and/or Salado Formations as a result of brine-density flow. Therefore, in regions of the Castile and Salado reasonably removed from concern regarding stratabound dissolution, such as the WIPP site, only halite dissolution as a result of diffusional processes need be considered. Such diffusion proceeds at a rate too slow to be of concern to the WIPP Project.

Discussion: The conclusions are dependent upon the assumed gradients within the Bell Canyon and range of Bell Canyon hydraulic properties, both of which are somewhat uncertain. The SPDV calculations did not result in total agreement that point-source dissolution was not a feasible mechanism at the WIPP site. However, the structure specifically proposed as a result of point-source dissolution was directly examined by drilling and testing of hole DOE-2, and was found to result from deformation within the Castile and Salado Formations, rather than from halite dissolution.

2. Conclusion: Investigations in holes Cabin Baby-1 and DOE-2 suggest indicate that the upper Bell Canyon Formation beneath the WIPP site is not significantly permeable. Therefore, regardless of the relative heads, the volumes of fluid flow between the Culebra dolomite and the upper Bell Canyon would be minor if the two units were interconnected as a result of drilling. These same studies indicate that the final direction of fluid flow would be downward into the Bell Canyon.

Discussion: Although Cabin Baby-1 and DOE-2 lie directly south and north of the WIPP site center, they provide only two data points. Given the regional trends of the Ramsey channel sands in the upper Bell Canyon, it is possible that a narrow sand crosses the center of the site from northeast to southwest, without having been intersected by either drill hole. The conclusion concerning directions of fluid flow pertains only to the final direction of flow, assuming halite saturation of both Bell Canyon and Culebra fluids as a result of dissolution of Salado halite. The conclusion does not describe either directions or rates of fluid flow prior to such saturation. In addition, the conclusion assumes that the fluid-carrying capacity of the Bell Canyon is sufficient to completely overwhelm any potential heads within the Salado Formation. This assumption appears reasonable, given the extremely small volumes of Salado flow intersected in hydrologic test holes at the WIPP site.

5.2.3 Conclusions Concerning the Castile and Salado Formations

1. Conclusion: Regional-scale deformation of the Castile and Salado Formations may well be ongoing at and near the WIPP site in response to gravity. However, estimation of the time required for formation of the WIPP-12 anticline indicates that such deformation probably occurs at a rate too slow to be of concern to the behavior of the WIPP facility. Fluids play a major role in regional-scale deformation of the Castile and Salado Formations, especially in deformation of halites and anhydrite stringers or laminae. Both estimated deformation rates and mechanistic considerations are consistent with pressure solution being a major deformation mechanism on the regional scale. This conclusion is consistent with greater deformation rates at lower differential stresses than would be the case for strictly anhydrous deformation. Inclusion of pressure solution as a deformation mechanism results in predicted strain rates at the WIPP site which are consistent with estimated rates elsewhere.

Discussion: Regional-scale deformation in response to gravity is not constrained to occur at a constant rate. Therefore, deformation rates averaged over long periods of time may be exceeded during shorter intervals. For pressure solution to be active, there must be a relatively continuous fluid film along grain boundaries. While textural evidence of pressure solution has been noted in core from the WIPP site, the presence of the required grain-boundary film has not been demonstrated directly. Although the role of pressure solution in regional-scale deformation is probable, it is not clear if or when the same mechanism will become dominant in near-field deformation around the WIPP facility. If it did become active, it would help accelerate mechanical closure of the facility by increasing deformation at relatively low differential stresses.

2. Conclusion: Much of the variability in both total and interval stratigraphic thicknesses of the Castile and Salado Formations at and near the WIPP site is due to syndepositional and postdepositional deformation, rather than to evaporite dissolution. Therefore, any interpretation of the thicknesses of these units must be done on a vertical scale involving as much of the Salado and Castile as possible, rather than on the scale of a single stratigraphic interval. Similarly, the interpretation must be done on as large a geographic scale as possible, since horizontal movement, especially of halites, is involved. Apparent one-hole anomalies are especially suspect.

Discussion: On the regional scale, especially in the western portion of the Delaware Basin, regional dissolution has apparently removed the halite from both the Castile and Salado Formations, and the original thickness of halite is unknown. At the local scale, as demonstrated in hole DOE-2, dissolution cannot be ruled out without interpretation on a broad stratigraphic and geographic scale.

3. Conclusion: The basinal structure in hole DOE-2, near the northern boundary of WIPP Zone 3, extends downwards from MB124 in the Salado to the top of Castile Anhydrite I. However, the DOE-2 structure resulted

from syndepositional and postdepositional deformation, rather than from halite dissolution. Deformation involved in formation of the DOE-2 structure resulted in displacement of all but 2 m of halite from the Castile Formation. However, both the Castile anhydrites and the entire Salado Formation (especially halites) are unusually thick in this hole. No evidence of dissolution was identified in DOE-2 core.

Discussion: The present understanding of the hydrology and structural behavior of the Castile and Salado Formations indicates that point-source dissolution of evaporites requires connection with a major source of unsaturated water, such as the Capitan limestone. This is not known to have occurrd within the body of the Delaware Basin, with the possible exception of the emplacement of Castile brines. While the present hydrologic and structural understanding does not allow prediction of where either point-source dissolution or a gravitational structure such as that at DOE-2 might form in the future, the drilling, coring, and hydrologic testing of DOE-2 demonstrates that no such structure presently exists within WIPP Zone 3. Calculations indicate that rates of gravitationally driven deformation are too slow to be of concern to the WIPP facility on the regulatory time scale.

4. Conclusion: The average far-field permeability of the Salado Formation, based on testing both from the surface and near the WIPP facility horizon, is 0.1 microdarcy or less, except where fractures locally contain small or large volumes of gas at elevated pressures. The stratigraphic variability of far-field permeability within the Salado is presently unknown, but appears negligible.

Discussion: It is not known for sure that the Salado is hydraulically saturated in the far-field. Known gas occurrences in drilling from the surface and within the WIPP facility indicate that partial saturation may be present in both the near-field and far-field, at relatively high confining pressures. The distribution of fracture systems, range of possible initial gas pressures, and effective fracture permeabilities in the far-field Salado remain unknown.

5. Conclusion: Where it has been possible to measure Salado fluid pressures, calculated heads indicate the potential for limited fluid flow upwards into the overlying Rustler Formation. Measurements to date indicate, however, that the amount of fluid available from the Salado is extremely limited. At least in the case of WIPP-12, the Salado fluid pressures and calculated heads exceed those in the underlying Castile brine reservoir. It has not been possible to determine any discrete source of fluid flow within the Salado Formation in testing from the surface.

Discussion: The measured Salado fluid pressures indicate only the possible directions of modern fluid flow. The measured pressures may be relict, developed under different geologic conditions than those at present, e.g., they may have been developed during the last pluvial period. The time scale on which such pressures or heads might change as part of the transient overall response of the WIPP hydrologic setting to the end of the

last pluvial period is not known, but must be long, given the low regional permeability of the Salado.

6. Conclusion: Water contents of Salado halites in the far-field appear to be as much as 2 weight percent, based on geophysical logging, greater than previously estimated. This does not have any direct impact on expected fluid flow into the WIPP facility, other than indicating that fluid volumes available to support long-term fluid flow may be greater than previously expected.

Discussion: To date, the interpretation of far-field water contents is based only on geophysical studies. Measurements on core are ongoing.

7. Conclusion: Consistent with assumptions maintained since brine was encountered in Castile Anhydrite III in WIPP-12, recent geophysical studies indicate that Castile brine may be present beneath a portion of the WIPP waste-emplacement panels. Brine is most likely present beneath the northern and northeastern portion of the waste-emplacement panels, and probably comes close to the southwestern and southeastern corners of the panels. However, the brines, if present, are 200 m or more below the WIPP facility horizon, and are not of concern except in the event of drilling-induced breach connecting a brine occurrence with the WIPP facility.

Discussion: Because of the dominant effect of the underlying Bell Canyon Formation, it is possible that the interpreted brine occurrences within the Castile are not real. Three-dimensional modeling of the results does not appear promising in defining the lateral distribution of Castile brines more accurately. Because of the vertical uncertainty inherent in the measurements, it is not possible to distinguish between brine occurrence within Anhydrite III and within Anhydrite II. However, where Castile brines have been encountered, it has always been present in the uppermost anhydrite.

8. Conclusion: Both uranium-disequilibrium studies and structural calculations appear consistent with emplacement of brines into fractured Castile anhydrites as a result of an episodic process. The process may involve either local brine movement during deformation and fracturing of anhydrite in low-pressure locations such as anticlinal crests, or long-distance fluid movement into preexisting fractures as a result of episodic hydrologic connection of the Capitan limestone and Castile Formation.

Discussion: It is not agreed that deformation or hydrologic connection of the Capitan limestone and Castile is the relevant episodic process involved in generation and/or emplacement of Castile brines. Structural studies indicate that deformation of the Castile Formation is episodic, with resultant episodic generation and emplacement of brines. Under these assumptions, generation of fractures and migration of brines into anhydrites may occur during the next 10,000 years, but probably at too low

a rate to be of concern to the WIPP Project. Isotopic studies are interpreted to indicate a residence time for Castile brines sampled at ERDA-6 and WIPP-12 of more than 100,000 years. While this interpretation indicates prior hydraulic connection of the Castile anhydrites and the Capitan limestone, it also indicates that this connection has not been operative for more than 100,000 years.

9. Conclusion: Both fluid-inclusion and grain-boundary fluids are present within the Salado Formation, in addition to loosely-held waters of hydration in hydrated minerals. The composition of Salado fluid inclusions is apparently controlled by the crystallization of polyhalite and magnesite. Radiometric age dating of polyhalites indicates that they are approximately 200 million years old. Therefore, the Salado fluid inclusions appear to be approximately 200 million years old. Fluids encountered within macroscopic flows into the WIPP facility appear to be dominantly grain-boundary fluids rather than fluids from fluid inclusions. The composition of grain boundary fluids within the Salado is apparently controlled by diagenetic reactions involving crystallization of Mg-rich layer silicates. Because the kinetics of these reactions are slow, it is concluded that the residence time of grain-boundary fluids within the Salado is at least several million years. The marked vertical variability of fluids near the WIPP facility horizon indicates very limited vertical fluid flow within the Salado.

Discussion: Crystallization of magnesite appears to have a major affect on fluid-inclusion compositions. However, magnesite from samples at the WIPP has not been dated. It has not been possible to estimate the residence time of Salado grain-boundary fluids directly. Radiometric measurements indicating ages for clay minerals greater than the Permian indicate that diagenetic or secondary reactions involving Mg have not involved complete recrystallization.

10. Conclusion: In the Salado Formation near the WIPP facility, there is strong coupling of deformation and hydraulic behavior. Within approximately 2 m of the underground rooms and entryways, fracturing and probable matrix dilation have led to a marked increase in permeability, and quite possibly to development of a zone of partial saturation. The increase in permeability appears to be both time-dependent and geometry-dependent. Within a few meters of the underground workings, however, the hydrologic properties of the Salado essentially become the same as regional properties.

    The time scale on which the WIPP facility will affect the local hydrology of the Salado Formation, while undetermined at present, is likely to be extensive, continuing until reequilibration after effective mechanical closure of the facility. Within the facility, there is a three-stage generalized flow behavior. Holes are normally dry when first drilled. Fluid flow then normally rises rapidly to a maximum flow rate, after which it more slowly decreases to something approximating steady-state flow, though probably still decreasing. Porous-medium calculations based on the estimated far-field permeability indicate that steady-state fluid flow might not be

reached for more than 5000 years, because of the extremely low permeabilities; these calculations do not yet include consideration of facility closure. The observed "steady-state" flow is qualitatively consistent with measured far-field permeabilities. Both measurement and calculations to date indicate that effective pore pressures within the Salado have been affected by the presence of the WIPP facility only within a few meters of the facility.

Discussion: Within the altered zone around the WIPP facility, the porous-medium approximation may not be adequate for either flow or transport modeling. The distances from the underground workings at which this simplifying assumption becomes valid remain to be determined. At present, there is not an adequate characterization of the fracturing adjacent to the WIPP facility to allow realistic modeling of flow and transport behavior within the altered zone, nor do adequate models exist. The long-term extent of the altered (fractured) zone around both underground workings and shafts remains unknown. However, the zone should be larger around underground workings than around lined shafts. Both the total long-term brine seepage to be expected from the Salado and the total volume of the Salado affected by fluid flow depend on the available porosity as a function of time within the WIPP facility and any altered zone that may be present. The effects of stress relief around the WIPP facility on both near-field and far-field hydrology will be examined in detail during the WIPP operational-demonstration period.

11. Conclusion: **Preliminary hydrologic testing adjacent to the WIPP waste-handling shaft indicates that all of the tested intervals, which include claystone and siltstone in the unnamed lower member of the Rustler and both halites and anhydrites within the Salado, are extremely low in permeability. While there was evidence of a hydraulic cone of depression around the shaft, there was no evidence of fracturing or alteration, except at the 850-ft level. At this level, pressurized fluids were encountered at the liner/rock interface and flowed into the test hole. Testing extended from approximately 2 m outside the shaft liner to a depth of some 10 m. The results are consistent with the interpretation that damage effects due to either blasting of the shaft or deformation around the shaft do not presently extend more than two meters into the surrounding rock mass.**

Discussion: **Due to scheduling constraints, only one or two holes was/were tested at each level. Therefore, these results do not indicate a complete absence of fracturing, merely that fractures were not intersected by the one or two holes at each level, except the 850-foot level. To better determine the presence or absence of fracturing by direct measurement, arrays of three or more holes would be needed at each level. The results do not indicate a potential altered zone within 2 m of the liner. Finally, the waste-handling shaft has been at its present diameter for approximately four years. The operational phase of the WIPP is expected to extend approximately 25 years, after which shaft seals must be emplaced successfully. The extrapolation of the present results to 25 years may not be reliable.**

12. Conclusion: Anhydrite Marker Bed 139, approximately 1 to 2 m beneath the WIPP facility horizon, contains partially healed and filled fractures which predate construction of the WIPP facility and play a significant role in both mechanical deformation near the WIPP facility and the near-field enhancement in permeability. The estimated age of the fractures is at least two million years. However, the far-field permeability of MB139 is not significantly greater than that of the surrounding halites.

Discussion: Development of any altered zone around the WIPP facility will be time dependent. Therefore, the boundary between the hydrologic near-field and far-field regimes will also be time dependent. The rate and extent to which the fracture porosity and permeability of MB139 in the altered zone near the WIPP facility horizon will be reduced during closure of the WIPP facility has not yet been demonstrated.

5.2.4 Conclusions Concerning the Rustler Formation and Younger Units

1. Conclusion: The available transmissivity data base at and near the WIPP site suggests that: a) the Culebra dolomite is at least one order of magnitude more transmissive than other members of the Rustler at most locations; and b) except where it is fractured in or near Nash Draw, the transmissivity of the Magenta dolomite is the same order of magnitude as that of other members of the Rustler. Consequently, confined flow within the Culebra dominates the hydrology of the Rustler at and near the WIPP site, and Rustler karst is not present.

Discussion: The Magenta data base is significantly smaller than that of the Culebra. Transmissivities of Rustler claystone/siltstones are very low but measurable at the Site, except for the Tamarisk claystone, which has not been successfully tested due to its low transmissivity. The transmissivity of Rustler anhydrites at the Site are too low to measure successfully. Somewhere between the WIPP site and Nash Draw (including WIPP-33), there must be a marked increase in the local permeability of Rustler anhydrites/gypsums. Where they are exposed or relatively near the surface, i.e., in Nash Draw and at WIPP-33, Rustler anhydrites are capable of supporting open cavernous porosity. The character and location of this transition in behavior of the Rustler anhydrites are not known in detail, but apparently involve decreasing overburden pressure (allowing the gypsums to maintain open porosity) and specific structures at the locations of both recharge and discharge.

The WIPP-33 structure is unique at and near the WIPP site, since it includes the three components necessary but not sufficient for karstic geology within the Rustler: 1) a sufficiently large breach in the Mescalero caliche and relatively thin Dewey Lake Red Beds; 2) shallow enough depth to gypsums within the Forty-niner and Tamarisk Members to allow maintenance of open porosity in gypsums above and below the Magenta; and 3) a probable local base level at the time the structure was mainly active, namely the gypsite springs on the east side of Nash Draw. Both the deuterium/hydrogen ratios of secondary gypsum from WIPP-33 and approximate dating of the gypsite springs within Nash Draw suggest that the WIPP-33 structure is largely inactive at present.

2. Conclusion: Measurements of relative heads within the Rustler Formation at the WIPP site are not consistent with modern infiltration from the surface to the Magenta, let alone from the surface to the Culebra. Therefore, at least at the measured locations, there is no modern infiltration of surficial waters to Rustler carbonates.

Discussion: The holes on which this conclusion is based provide only limited geographic coverage, and do not include any locations at which the Dewey Lake Red Beds are known to be hydraulically saturated. Where tested, the Dewey Lake was too tight for hydraulic testing, and may be either completely or partially saturated. No head or transmissivity information is available from the Tamarisk Member of the Rustler, due to its exceedingly low transmissivity. These results do not rule out vertical movement of water from either the surface or the Dewey Lake into the Rustler in areas in which the Dewey Lake is saturated directly above the Rustler, or in any area in the past if heads in the Dewey Lake were higher at that time.

3. Conclusion: Culebra transmissivity varies by approximately six orders of magnitude in the region of the WIPP site and Nash Draw. Transmissivities generally decrease from west to east across the site area. For purposes of generalization, the distribution can be divided into broad areas of relatively low Culebra transmissivity ($\leq 10^{-6}$ m^2/s), in which the porous-medium assumption appears adequate to describe local hydraulic and transport behavior, and areas of relatively high transmissivity ($\geq 10^{-5}$ m^2/s), in which a dual-porosity formalism appears adequate to describe local hydraulic and transport behavior. Both of these zones are represented by several wells. Two wells (H-3 and H-18) penetrate an apparently thin transition zone, in which transmissivity varies between 10^{-6} and 10^{-5} m^2/s.

The central portion of the WIPP site, including all four WIPP shafts, lies within an apparently continuous area of low transmissivity. This area extends well east of the site, and includes the holes H-1, 2, 4, 5, 10, 12, 14, 15, 16, and 17; WIPP-12, 18, 19, 21, and 22; ERDA-9; Cabin Baby-1; P-15, 17, and 18, in addition to the WIPP shafts. North of the WIPP site, measurements at WIPP-30 indicate the presence of a northern zone of low transmissivity, which may or may not be continuous with the zone near the site center.

There is a zone of relatively high Culebra transmissivity southeast of the center of the Site, which is indicated both by point measurements at H-11 and DOE-1 and by the presence of very low hydraulic gradients south of WIPP Zone 3. Northwest of the site center, there is a relatively uniform high-transmissivity zone containing holes WIPP-13, DOE-2, and H-6. This zone is bounded by low-transmissivity domains to the north, east, and southeast, and by an even higher-transmissivity domain to the southwest and west. Within both Nash Draw and the valley south of the WIPP site containing H-7 and H-9, Culebra transmissivity is both high and variable.

Discussion: There are some exceptions to the generalizations listed above. WIPP-21, which has a low transmissivity, responds quite rapidly to activities in the WIPP shafts, indicating that the region containing WIPP-21 is connected to the shafts by a low-storativity structure, which may involve fractures. Tests at individual low-transmissivity wells examine only a very small area. Neither analytical nor numerical modeling is capable of identifying a small, discrete high-transmissivity structure embedded in a low-transmissivity domain, unless it is close to measured data points. No evidence for such a discrete structure is known at the WIPP site. On the other hand, the hydraulic behavior of the Engle well, which has a high transmissivity, shows no dual-porosity effects. Test results from the Culebra in Nash Draw have not been examined for dual-porosity behavior; fracturing may be extensive enough in Nash Draw to make a dual-porosity formalism unnecessary.

The boundaries of the low-transmissivity zone including WIPP-30 remain unknown. The interpretation based on the rapid and large response of this hole to the WIPP-13 pumping test suggests that the high-transmissivity domain including WIPP-13, DOE-2 and H-6 extends close to WIPP-30.

The boundaries of the high-transmissivity zone south of H-11 and DOE-1 and the connection of this zone with the larger high-transmissivity region containing H-7, H-8, and H-9 have not been determined directly, nor has the maximum transmissivity within the zone. The presence of the zone south of H-11 and DOE-1 is indicated by both analytical and numerical modeling of the H-3 multipad interference test, as well as by more recent calibration of Culebra transmissivities against calculated pre-shaft heads. This zone will be investigated during 1988 by a multipad interference test to be conducted at the H-11 pad. The reason for the relatively high transmissivities at H-11 and DOE-1 remains unknown.

4. Conclusion: The estimation error for Culebra transmissivities over most of the WIPP site (in terms of m^2/s) is less than one log unit at two standard deviations, including estimated uncertainties in field measurements. The estimation error is generally larger outside Zone 3.

Discussion: The statistical treatment of Culebra transmissivities should not be overinterpreted, since it does not include specific consideration of geologic processes. In addition, this treatment assumes vertical homogeneity within the Culebra. Testing at H-14 indicates that transmissivity may vary by a factor of about 2 across the Culebra at a given locality.

5. Conclusion: Groundwater flow rates within the Culebra vary greatly. Flow within Nash Draw is relatively rapid; flow in the central portion of the WIPP site and in regions further east is extremely slow. The estimated flow time from a position above the center of the WIPP waste-emplacement panels to the southern boundary of Zone 3, assuming steady-state distribution of the present heads and transmissivities within the Culebra, is approximately 13,000 years.

Discussion: Calculated particle-flow rates and integrated travel times are approximate. The head distribution and flow directions within the Culebra are not at steady state. The similar Culebra and Magenta heads within Nash Draw suggest that assumption of confined flow within the Culebra may not be realistic in this region. In addition, the calculations assume a uniform effective porosity of 16%. The effective Culebra porosity probably varies laterally, suggesting that both flow rates times and flow paths are more variable than calculated.

6. Conclusion: Single-pad interference testing at the H-3 and H-11 hydropads indicates a complex role of fracturing within the Culebra. At H-3, the system transmissivity is approximately 2×10^{-6} m^2/s, and no significant directional dependence of hydraulic response has been measured. However, the data from observation holes on the H-3 pad had to be interpreted as if the radius of the pumped well extended beyond the observation holes; i.e., the response of the observation holes to the beginning and end of pumping was practically instantaneous. At the H-11 pad, the transmissivity is 1.2 to 3.0×10^{-5} m^2/s. However, the observation holes on the H-11 pad responded more slowly during testing than those on the H-3 pad. The extent or effectiveness of fracturing is not a simple function of transmissivity.

Discussion: The available data are only sufficient for detailed interpretation of interference testing using a dual-porosity formalism, i.e., assuming uniform fracture spacing. This limitation is irreduceable, however, given the limited core recovery within the Culebra. Detailed interpretation of interference testing has been completed only for testing at the H-3 and H-11 hydropads. Interpretation of interference testing at the H-2, H-4, H-5, H-6, H-7, and H-9 hydropads will be completed in the next year.

7. Conclusion: Regional-scale simulations indicate that it is not necessary to incorporate a dual-porosity formalism into regional-scale modeling of Culebra head distributions. This is because the time scale for pressure equilibration between fracture and matrix for matrix-block sizes up to the thickness of the Culebra is very short relative to the time scale required for regional groundwater flow.

Discussion: The pressure effects of a discrete or narrow high-transmissivity structure embedded within a low-transmissivity domain remain to be determined in detail. It cannot be claimed that any reasonable amount of drilling or hydrologic testing will completely eliminate the possibility of a small high-transmissivity structure being present within the Culebra dolomite. However, no such structure is known to exist at or near the WIPP site.

8. Conclusion: Both fractures and matrix play a major role in pad-scale transport of contaminants within fractured portions of the Culebra dolomite. At the H-3 pad, the first detected arrival of conservative (non-reacting) tracers in a convergent-flow test was strongly

controlled by fracturing, while tracer behavior both at and after the time of peak concentration showed evidence of strong interaction between fractures and matrix. Storage within the matrix served to decrease peak concentrations, but also resulted in greater concentrations at longer times than expected for fracture transport alone. The results indicate that matrix storage should play a major role in regional-scale transport of even conservative contaminants, so long as these contaminants have a reasonable diffusion coefficient into the matrix.

In addition, the results of the conservative-tracer test at the H-3 pad indicate that the relationship between hydraulic properties and transport properties can be complex. At H-3, no directional dependence of hydraulic behavior has been measured. In contrast, the time interval before first detected arrivals of tracers along the two flow paths investigated differed by a factor of about four.

Discussion: Detailed interpretation of dual-porosity effects in contaminant transport within the Culebra is presently completed only for testing at the H-3 pad. An additional conservative-tracer test will be conducted during 1988 at the H-11 hydropad, along the apparent regional flow path from the center of the WIPP site to the southern boundary of Zone 3. Any significant role of the matrix in contaminant transport within fractured portions of the Culebra requires that conservative contaminants be able to diffuse into matrix blocks. Interpretation to date of the H-3 test involves superposition of two radial-flow solutions; calculations are ongoing to investigate the possible effects of matrix anisotropy on transport behavior.

9. Conclusion: Calculations indicate that regional-scale contaminant transport within the Culebra Dolomite can be modeled realistically using the porous-medium assumption, so long as the Culebra transport properties and flowpaths used in these calculations are representative, and at least so long as the existing distribution of head potentials within the Culebra is not significantly disturbed. Calculated times required for contaminants to break through to the southern boundary of WIPP Zone 3 following release at any point directly above the WIPP waste-emplacement panels are only approximately 10% lower if a dual-porosity formalism is used than if the same release is modeled using the porous-medium assumption. The completed regional-scale calculations assume a transmissivity distribution which probably assigns too high a transmissivity to the region including holes H-11 and DOE-1.

Discussion: Calculations are presently ongoing to investigate the utility validity of the porous-medium approximation in modeling transport within the Culebra in the event of a breach involving a Castile brine occurrence. The assumption that there is effective diffusion from fractures into the adjacent Culebra matrix is explicit in conclusions based on calculations completed to date. Results of interference testing support the conclusion that fluid flow is unrestricted between matrix blocks and fractures, i.e., that there are no significant or continuous low-permeability skins on

matrix blocks. This has been demonstrated in the conservative-tracer experiment at the H-3 pad. Effective matrix retardation within the Culebra has not yet been demonstrated for some radionuclides making up the WIPP inventory, but will be demonstrated experimentally in the laboratory during the WIPP operational-demonstration phase.

10. Conclusion: The variability in compositions of Culebra groundwaters allows their subdivision into four hydrochemical facies. Zone A, east of the WIPP site, contains saline Na-Cl brines. Zone B, south of the site, contains relatively fresh waters in which Ca and SO_4 are the main solutes. Zone C, which includes the WIPP site and the eastern part of Nash Draw, contains quite variable fluids. Zone D, within Nash Draw, shows evidence of contamination from potash refining operations. The modern distribution of hydrochemical facies within the Culebra is not consistent with steady-state confined flow within the Culebra. Therefore, the solute geochemistry of Culebra fluids is not at steady-state, nor is the overall hydrology of the Culebra.

Discussion: This conclusion assumes the dominance of confined flow within the Rustler in the vicinity of the WIPP site, consistent with both isotopic studies and measurements of the modern relative head potentials and transmissivities of the several members of the Rustler.

Interpretation of normative salts within Rustler fluids is partially consistent with steady-state flow, if extensive vertical mixing is allowed. The measured head relationships within the Rustler are inconsistent with infiltration from the surface. The composition of Culebra waters at P-18 and P-14 play a major role in normative interpretation Culebra waters. The representative character of groundwater samples from the Culebra from P-14 and P-18 is suspect.

11. Conclusion: Analyzed Culebra fluids are all undersaturated with respect to halite, but approximately saturated with respect to gypsum and carbonate (dolomite). All fluids except that from hole WIPP-29 are undersaturated with respect to anhydrite. Therefore, almost all Culebra waters are capable of converting into gypsum any anhydrite they may contact. Carbonates, sulfates, and clay minerals are ubiquitous in Culebra core. Halite not introduced during coring has not been identified reliably. With the exception of halite, all analyzed Culebra fluids appear to be in approximate equilibrium with the host rock. Studies to date have not identified any discrete variations in Culebra mineralogy that can be used to bound hydrochemical facies.

Discussion: The dominant reactions controlling the variability of Culebra fluids appear to be the dissolution of halite and reactions between fluids and a ubiquitous but variable clay-mineral phase. Both the compositions of clays and the detailed reactions between clays and Culebra remain to be determined in detail. It cannot be demonstrated that the mineralogy of intact core specimens is representative of portions of the Culebra that have been in significant contact with groundwater.

12. Conclusion: There appear to be significant lateral variations in the oxidation state of Culebra waters. Fluids from hydrochemical facies Zone B, south of the site, appear to be more oxidized than those within Zones A and C, which include the WIPP site. The available information from within Nash Draw indicates that the redox potential at WIPP-26 is similar to that within Zone B. Results at WIPP-25 appear to be problematical, due to evolution of H_2S during sampling. The results indicate generally more oxidizing conditions south and southwest of the WIPP site than at the site itself.

Discussion: Oxidation states of Culebra fluids are not known in detail, and are generally bracketed by the occurrence of one member of a redox couple at too low a concentration for analysis. The possible effects of contamination have been evaluated only in hole WIPP-25.

13. Conclusion: Recent stable-isotope studies indicate that the bulk of the Rustler Formation and part of the Dewey Lake Red Beds at and near the WIPP site were last recharged under climatic conditions significantly different than those of today. This is consistent with the interpretations that the overall hydrology of the Rustler Formation is in transient response to the end of the last pluvial period in southeastern New Mexico, and that there is no modern meteoric recharge to the Rustler Formation at and near the WIPP.

Discussion: The data base on which the interpreted isotopic range of modern meteoric recharge is based includes measurements from several different rock types and locations, including the Capitan limestone in Carlsbad Caverns, alluvium at WIPP-15, the Ogallala Formation in both southeastern New Mexico and on the High Plains of Texas, and the Dewey Lake Red Beds near an active dune field. The Dewey Lake, however, appears to include both modern and older waters. The stable-isotopic signature of all analyzed waters from confined portions of the Culebra and Magenta dolomites are distinct from the defined meteoric field.

The stable-isotope results do not provide any direct information about the timing of recharge, only about different conditions of recharge. In addition, the results do not rule out modern recharge to the Rustler at some location removed from the WIPP site itself. However, the results do indicate that measurable amounts of recharge are not now occurring at the WIPP site.

14. Conclusion: Both stable-isotope and compositional characteristics of Rustler waters at Surprise Spring, in the southwestern portion of Nash Draw, are dominated by near-surface recharge and discharge, including partial evaporation. Major dilution would be required to derive the solute chemistry at Surprise Spring from Culebra waters at WIPP-29, which is nearby. In addition, Surprise Spring apparently discharges from the Tamarisk Member of the Rustler, rather than the Culebra. Therefore, Surprise Spring, does not appear to be a discharge point for Culebra or Magenta waters crossing the WIPP site.

Discussion: It is possible that some Rustler waters from the area of the WIPP site discharge in southern Nash Draw, including Surprise Spring. The results summarized here, however, suggest that the hydrology and solute chemistry at Surprise Spring are dominated by local processes and groundwaters, and that any input of waters from the area of the WIPP site would not be identifiable, even if present.

15. Conclusion: Use of lost-circulation materials in hydrocarbon-exploration hole and hydrologic test holes (except those drilled with air) and metabolism of these materials by introduced and/or natural organisms within the Rustler makes meaningful radiocarbon measurements on Rustler fluids difficult. All Rustler and Dewey Lake holes may be contaminated to some degree. Therefore, estimated periods for which Rustler or Dewey Lake waters have been isolated from atmospheric carbon should represent lower bounds.

16. Conclusion: Available radiocarbon measurements indicate isolation times of three Culebra and one Dewey Lake water from input of atmospherically generated nuclides for at least 12,000 years. This is consistent with paleoclimatic studies indicating a wetter climate in the northern Delaware basin approximately 10,000 years ago. The results are taken to imply that there has not been significant (i.e., detectable) vertical recharge to the Culebra and at least part of the Dewey Lake near the WIPP site in at least 12,000 years. The results also indicate, because of the relatively tight clustering of ages, that recharge may have been a pulse event rather than continuous. At any rate, the available radiocarbon results do not indicate any consistent age gradient for waters within the Culebra, and cannot be used to indicate paleoflow directions.

Discussion: The data base of successful radiocarbon measurements is extremely limited in size. Extrapolation of these results to the confined Culebra over the entire Site area may be tenuous, but is consistent with both the fact that the Culebra is regionally confined and the results of both stable-isotope uranium-disequilibrium studies. Additional radiocarbon measurements will be made over the next (approximately) two years.

17. Conclusion: Available uranium-disequilibrium results for Culebra rocks and groundwaters indicate that there must have been a significant distinct change in flow directions within the Culebra on the time scale of approximately 10,000 years. The paleoflow direction involved at least some component of easterly flow, in contrast to the modern flow directions within the Culebra, which are essentially north-south in the Site area. The change in flow directions has apparently occurred as a result of the end of Culebra recharge at or near the end of the last pluvial period. The estimated flow time to the vicinity of H-5 is at least several thousand years, and flow has occurred under reducing conditions, regardless of where recharge is interpreted to have taken place. Therefore, modern recharge is not occurring at H-5, regardless of the relatively high Culebra heads in the region. The

current distribution of total dissolved uranium in analyzed Culebra groundwaters is qualitatively consistent with regional variations in the oxidation potential within the unit, with more reducing conditions in the area at the WIPP site than south of the site and in at least part of Nash Draw. The interpretation based on uranium-disequilibrium studies is consistent with the distribution of Culebra hydrochemical facies, stable-isotope studies, and radiocarbon studies in indicating that the overall hydrologic and geochemical setting of the Rustler is transient on a time scale of approximately 10,000 years, and is recovering from the last pluvial period in southeastern New Mexico.

Discussion: The present uranium-disequilibrium data base is extremely limited in size, especially south of the WIPP site. Therefore, significant uncertainty remains concerning the constraints imposed by these studies on both paleo and modern flow directions. However, some change in flow directions within the Culebra is required by the data.

18. Conclusion: $^{87}Sr/^{86}Sr$ studies on both matrix minerals and coexisting mineral pairs from matrix and veins in the evaporitic units below the Dewey Lake Red Beds, and on veins and/or matrix materials from the Dewey Lake, Mescalero caliche, and gypsite springs in Nash Draw indicate distinct variations in the amounts of high-$^{87}Sr/^{86}Sr$ material derived from surficial weathering that are involved in the different units. The measured strontium-isotopic character of the gypsite springs and the Mescalero caliche indicate derivation from surficial components. The character of both matrix minerals and coexisting mineral pairs from matrix and veins in the Castile and Salado Formations, as well as in Rustler anhydrites and the Magenta dolomite indicate little or no input of surficial components. The isotopic compositions of coexisting mineral pairs from veins and matrices are statistically identical, indicating that the components of the veins were locally derived in all units but the Dewey Lake.

There is a broad range of strontium-isotopic character of vein minerals from the Dewey Lake, from surficial values to values similar to those from underlying anhydrites and the Magenta dolomite. Since sulfates and carbonates are very rare in the matrix of the Dewey Lake, the broad range in strontium-isotopic character of Dewey Lake vein gypsums is taken to indicate a mix of surface-type components and components from the underlying Rustler. Upward flow from the Rustler Formation is consistent with measured head relationship. The strontium-isotopic character of analyzed carbonate minerals from the Culebra shows more overlap with that of vein material from the Dewey Lake than does the character of either the intervening Rustler anhydrites or the Magenta dolomite. This is taken to imply that surficial components in the Culebra probably result from confined flow following recharge at some location removed from the WIPP site. If the Culebra near the WIPP site were presently receiving surficial components by vertical recharge, this recharge would be expected to have altered the isotopic character of Rustler zones above the Culebra.

Discussion: The isotopic data base for veins and host-rock minerals in the Rustler and Dewey Lake is limited in size. It has not yet been possible to date any of the secondary minerals directly. Therefore the strontium-isotopic results, while indicating the types of waters involved, do not provide any direct information concerning the ages of these waters.

19. Conclusion: The study of deuterium/hydrogen ratios in vein gypsums in the Dewey Lake and Rustler indicate that all of the gypsums, with the possible exception of vein gypsum from the Dewey Lake in WIPP-19, may have crystallized in the presence of varying amounts of Rustler-type water, rather than in the presence of water representing modern meteoric recharge in the region. The hydrogen-isotope character of secondary Rustler gypsums in hole WIPP-34 is consistently explained by Rustler-type fluids moving both upwards and downwards from the Magenta dolomite into surrounding members, with increasing rock/water ratios corresponding to increasing distance from the Magenta. This internal consistency is lost if crystallization of gypsums from WIPP-34 is assumed to have taken place in the presence of modern meteoric waters.

In fact, it does not appear possible to have crystallized vein gypsums from either the Magenta and Tamarisk in WIPP-34 or from the Forty-niner in WIPP-33 in the presence of any amount of water representing modern meteoric recharge. Both WIPP-33 and WIPP-34 were drilled to investigate either geophysical anomalies or structures that might be the result of Rustler karst. There is no indication of anomalous structure at WIPP-34. The WIPP-33 structure is interpreted to be the result of karst hydrology, but is apparently unique at and near the WIPP site. The isotopic results suggest, consistent with geologic interpretations, that the WIPP-33 structure is no longer significantly active.

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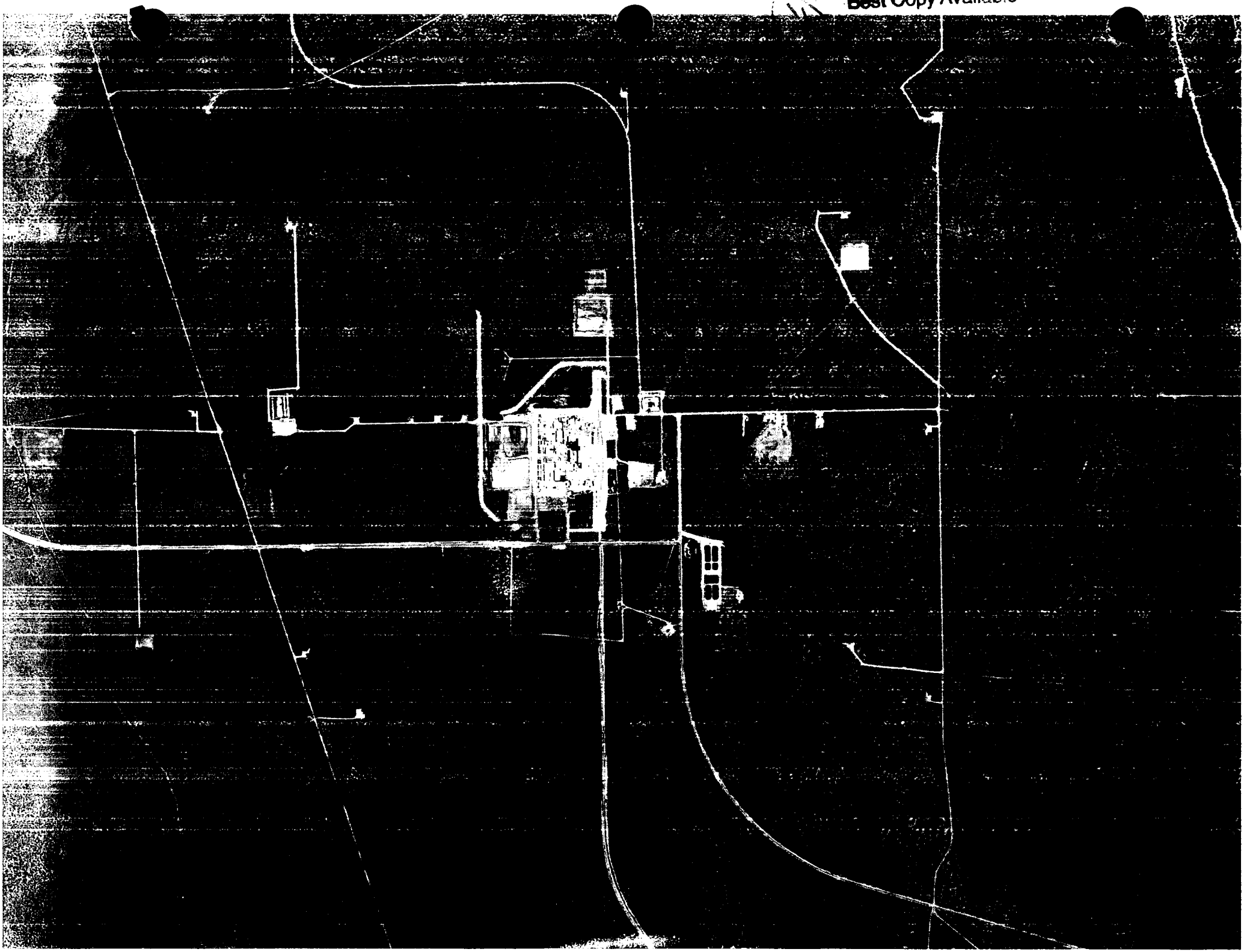

APPENDIX VOC

VOC SCREENING METHODOLOGY

APPENDIX D13

VOC SCREENING METHODOLOGY

(From the WIPP RCRA Part B Permit Application, Rev. 6)

APPENDIX D13
VOC SCREENING METHODOLOGY

Screening the volatile organic compounds (VOCs) for inclusion in the exposure assessment was a two-step process. The first step was determining that only those VOCs listed in both Appendix VIII of Title 40 of the Code of Federal Regulations (CFR) Part 261 and in the Waste Isolation Pilot Plant (WIPP) Quality Assurance Program Plan (QAPP) were eligible for inclusion in the demonstration. The second step was to score the VOCs based on the concentration-toxicity screening technique presented by the U.S. Environmental Protection Agency (EPA) in the *Risk Assessment Guidance for Superfund* (EPA 1989, p. 5-23). The scoring was performed using the weighted average VOC concentrations reported in the Idaho National Engineering Laboratory (INEL) and Rocky Flats Environmental Technology Site (RFETS) headspace sampling (Appendix C2, Table C2-1). The methodology used in calculating the average VOC headspace concentrations is described in Appendix C2.

The listing in Appendix VIII and/or the QAPP was used as a rough screening. VOCs that were to be analyzed on a site-specific basis (i.e., formaldehyde and hydrazine) were also screened out. VOCs listed in these sources are presented in Table D13-1; VOCs selected from this listing are as follows:

- Benzene
- Bromoform
- Carbon disulfide*
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- 1,2-Dichloroethane
- (cis)-1,2-Dichloroethylene
- 1,1-Dichloroethylene
- Isobutanol*
- Methyl ethyl ketone
- Methylene chloride
- 1,1,2,2-Tetrachloroethane
- Tetrachloroethylene
- Toluene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane*
- Trichloroethylene
- Trichlorofluoromethane*
- Vinyl chloride*

* No headspace data available

TABLE D13-1
Chemicals in 40 CFR Part 261 Appendix VIII and WIPP QAPP

Compound	Synonyms	CAS Number	Appendix VIII Constituent	QAPP
Acetone	2-Propanone	67-64-1		+
Antimony		7440-36-0		+
Arsenic		7440-38-2	+	+
Barium		7440-39-3	+	+
Benzene		71-43-2	+	+
Beryllium		7440-41-7	+	+
Bromoform	Tribromomethane	75-25-2	+	+
n-Butyl alcohol	Butanol, 1-Butanol	71-36-3		+
Cadmium		7440-43-9	+	+
Carbon disulfide	Carbon bisulfide	75-15-0	+	+
Carbon tetrachloride		56-23-5	+	+
Chlorobenzene		108-90-7	+	+
Chloroform		67-66-3	+	+
Chromium		7440-47-3	+	+
Cresol	Cresylic acid	1319-77-3	+	+
Cyclohexane		110-87-7		+
1,4-Dichlorobenzene	p-Dichlorobenzene	106-46-7	+	+
ortho-Dichlorobenzene	1,2-Dichlorobenzene	95-50-1	+	+
1,1-Dichloroethane	Ethylidene chloride	75-34-3		+
1,2-Dichloroethane	Ethylene dichloride	107-06-2	+	+
(cis)-1,2-Dichloroethylene	(cis)-1,2-Dichloroethene, sym-Dichloroethylene	540-59-0	+	+
1,1-Dichloroethylene	1,1-Dichloroethene, Vinylidene chloride	75-35-4	+	+
2,4 Dinitrophenol		51-28-5	+	+
2,4-Dinitrotoluene		121-14-2	+	+
Ethyl benzene		100-41-4		+
Ethyl ether	Diethyl ether, Ether	60-29-7		+
Formaldehyde		50-00-0	+	SS
Hexachlorobenzene		118-74-1	+	+
Hexachloroethane		67-72-1	+	+
Hydrazine		302-01-2	+	SS
Isobutanol	Isobutyl alcohol	78-83-1	+	+
Lead		7439-92-1	+	+
Mercury		7439-97-6	+	+
Methanol	Methyl alcohol	67-56-1		+
Methyl ethyl ketone	2-Butanone	78-93-3	+	+
Methyl isobutyl ketone	4-Methyl-2-pentanone	108-10-1		+
Methylene chloride	Dichloromethane	75-09-2	+	+
Nickel		7440-02-0	+	+
Nitrobenzene		98-95-3	+	+
Pentachlorophenol		87-86-5	+	+
Polychlorinated Biphenyls (PCBs)		1336-36-3	+	+
Pyridine		110-86-1	+	+
Selenium		7782-49-2	+	+
Silver		7440-22-4	+	+
1,1,2,2-Tetrachloroethane		79-34-5	+	+
Tetrachloroethylene	Tetrachloroethene, Perchloroethylene	127-18-4	+	+
Thallium		7440-28-0	+	+
Toluene		108-88-3	+	+
1,1,1-Trichloroethane	Methyl chloroform	71-55-6	+	+
1,1,2-Trichloroethane		79-00-5	+	+
Trichloroethylene	Trichloroethene	79-01-6	+	+
Trichlorofluoromethane	Freon-11	75-69-4	+	+
1,1,2-Trichloro-1,2,2-trifluoroethane	Freon-113	76-13-1		+
1,2,4-Trimethylbenzene	Pseudocumene	95-63-6		+
1,3,5-Trimethylbenzene	Mesitylene	108-67-8		+
Vanadium Pentoxide	Vanadium Oxide	1314-62-1	+	+
Vinyl chloride	Chloroethylene	75-01-4	+	+
m-Xylene	1,3-Dimethylbenzene	108-38-3		+
o-Xylene	1,2-Dimethylbenzene	95-47-6		+
p-Xylene	1,4-Dimethylbenzene	106-42-3		+
Zinc		7440-66-0		+

SS=Site Specific

The VOCs listed were further screened using the scoring technique outlined by EPA (EPA, 1989). First, the headspace concentration in parts per million by volume was converted to a concentration in micrograms per cubic meter for carcinogens and milligrams per cubic meter for noncarcinogens. Several VOCs did not have sample quantitation limits (SQLs) reported by the laboratories providing the headspace sampling data; for these VOCs (carbon disulfide, isobutanol, 1,1,2-trichloroethane, trichlorofluoromethane, and vinyl chloride), SQLs were calculated (Appendix C2), and one-half the calculated SQL (rounded to two decimal places) was used for the headspace concentration in the scoring process.

A risk factor was calculated for each VOC from the weighted average headspace concentration and the toxicity value. The risk factors for all VOCs were summed to yield a total risk factor. The contribution of each VOC to this risk factor was then calculated by dividing the individual risk factor by the total risk factor. The chemicals cumulatively responsible for approximately 99 percent of the total risk factor were selected for use in the assessments.

The conversion of headspace VOC concentration in parts per million per volume to micrograms per cubic meter (for carcinogens) was performed using the following equation:

$$HS_c = (HS)(10^{-6}\ mol\ fraction/ppmv)\left(\frac{P \times MW}{R \times T}\right)(10^{6}\ \mu g/g)(10^{3}\ L/m^{3}) \qquad \text{(D13-1)}$$

where

HS_c = weighted average headspace concentration for carcinogens, $\mu g/m^3$
P = pressure, 1 atm
MW = molecular weight, g/mol
R = ideal gas constant, 0.082057 L atm/mol K
T = temperature, 298 K
HS = weighted average headspace concentration, ppmv.

The conversion of headspace VOC concentration in parts per million per volume to milligrams per cubic meter (for noncarcinogens) was performed using the following equation:

$$HS_n = (HS)(10^{-6}\ mol\ fraction/ppmv)\left(\frac{P \times MW}{R \times T}\right)(10^{3}\ mg/g)(10^{3}\ L/m^{3}) \qquad \text{(D13-2)}$$

where

HS_n = weighted average headspace concentration for noncarcinogens, mg/m^3.

The equation used to calculate the individual risk factors for carcinogens was:

(D13-3)

$$R_{ci} = HS_c \times UR$$

where
R_{ci} = risk factor for carcinogenic VOC *i*
UR = unit risk factor for VOC *i*, $(\mu g/m^3)^{-1}$.

The equation used to calculate the individual risk factors for noncarcinogens was:

(D13-4)

$$R_{ni} = \frac{HS_n}{RfC}$$

where
R_{ni} = risk factor for noncarcinogenic VOC *i*
RfC = reference concentration for VOC *i*, mg/m^3.

The total risk factor was calculated using the equation:

(D13-5)

$$R_t = R_1 + R_2 + R_3 + \ldots + R_i$$

where
R_t = total risk factor
$R_1 + \ldots + R_i$ = risk factors for VOCs 1 through *i*.

Separate values of R_t were calculated for carcinogens and noncarcinogens. Finally, the ratio of the individual risk to the total risk (R_{ci}/R_t or R_{ni}/R_t) was calculated for each VOC. Based on this ratio, the VOCs responsible for approximately 99 percent of the total risk factor were selected for inclusion in the assessments.

Table D13-2 presents the VOC screening results using the headspace concentrations of the VOCs. The following chemicals were selected to be included in the no-migration demonstration:

- Carcinogens
  - Carbon tetrachloride
  - Chloroform
  - 1,1-Dichloroethylene
  - Methylene chloride
  - 1,1,2,2-Tetrachloroethane

- Noncarcinogens
  - Carbon disulfide
  - Chlorobenzene
  - Methyl ethyl ketone
  - Toluene.

TABLE D13-2
Results of the VOC Screening Using Headspace Concentrations

Carcinogen	Molecular Weight (grams per mole)	Headspace Concentration (parts per million by volume)		Headspace Concentration (micrograms per cubic meter)	Chemical Class	UR (cubic meters per microgram)		Calculated Score	Absolute Score	Percent of total	
Benzene	78.11	9.25	a	2.95e+04	A	8.30e-06	c	0.245241838	0.245241838	0.0033066001	
Bromoform	252.77	9.38	a	9.70e+04	B2	1.10e-06	c	0.106656948	0.106656948	0.0014380576	
Carbon tetrachloride	153.84	375.5	a	2.36e+06	B2	1.50e-05	c	35.43550059	35.43550059	0.4777774952	*
Chloroform	119.39	25.33	a	1.24e+05	B2	2.30e-05	c	2.844455073	2.844455073	0.0383518392	*
Methylene chloride	84.94	368.5	a	1.28e+06	B2	4.70e-07	c	0.601610915	0.601610915	0.0081115309	*
1,1-Dichloroethylene	96.95	11.46	a	4.54e+04	C	5.00e-05	c	2.271802306	2.271802306	0.0306307516	*
1,2-Dichloroethane	98.96	9.07	a	3.67e+04	B2	2.60e-05	c	0.954351636	0.954351636	0.0128675404	*
1,1,2,2-Tetrachloroethane	167.86	9.35	a	6.42e+04	C	5.80e-05	c	3.722673296	3.722673296	0.0501928714	*
Tetrachloroethylene	165.85	9.4	a	6.38e+04	C-B2	5.80e-07	c	0.036977659	0.036977659	0.0004985705	
1,1,1-Trichloroethane	133.4	317.1	b	1.73e+06	C	1.60e-05	c	27.67834734	27.67834734	0.3731876576	*
1,1,2-Trichloroethane	133.42	0.07	b	3.82e+02	C	1.60e-05	c	0.006110926	0.006110926	0.0000823937	
Trichloroethylene	131.4	25.1	a	1.35e+05	C-B2	1.70e-06	c	0.229290525	0.229290525	0.0030915283	
Vinyl chloride	62.5	0.16	b	4.09e+02	A	8.40e-05	d	0.034351633	0.034351633	0.0004631637	
								Total=	46.3959077	1.00000	

*VOCs account for approximately 99 percent of total score.

Noncarcinogen	Molecular Weight (grams per mole)	Headspace Concentration (parts per million by volume)		Headspace Concentration (milligrams per cubic meter)	Chemical Class	RfC (milligrams per cubic meter)		Calculated Score	Absolute Score	Percent of total	
Carbon disulfide	76.14	0.13	b	4.05e-01	ND	7.00e-01	d	0.578264172	0.578264172	0.0001886173	
Chlorobenzene	112.56	12.52	a	5.76e+01	D	2.00e-02	d	2881.552379	2881.552379	0.9399003669	*
(cis)-1,2-Dichloroethylene	96.95	8.97	a	3.56e+01	D	ND		—	0	0	
Isobutanol	74.12	0.13	b	3.94e-01	ND	ND		—	0	0	
Methyl ethyl ketone	72.1	63.66	a	3.83e+01	D	1.00e+00	c	0.383306971	0.383306971	0.0001250265	
Toluene	92.13	19.4	a	7.31e+01	D	4.00e-01	c	182.7304444	182.7304444	0.0596027381	*
Trichlorofluoromethane	137.38	0.07	b	3.93e-01	ND	7.00e-01	d	0.561812778	0.561812778	0.0001832512	
								Total=	2136.94983	1.00000	

*VOCs account for approximately 99 percent of total score.

[a]Measure data from INEL and RFETS sampling.
[b]One-half the calculated sample quantitation limit.
ND = No data available.
[c]Toxicity data from *Integrated Risk Information System.*
[d]Toxicity data from *Health Effects Assessment Summary Tables, Annual Update.*

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APPENDIX WAP

WASTE ANALYSIS PLAN

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CHAPTER C

WASTE ANALYSIS PLAN

(From the WIPP RCRA Part B Permit Application, Rev. 6)

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CHAPTER C
WASTE ANALYSIS PLAN

Introduction

This waste analysis plan (WAP) has been prepared for disposal activities to be conducted at the Waste Isolation Pilot Plant (WIPP) facility to meet requirements set forth in Title 20 of the New Mexico Administrative Code, Chapter 4, Part I (20 NMAC 4.1), Subpart V, §264.13. Guidance in the most recent U.S. Environmental Protection Agency (EPA) manual on waste analysis has been incorporated into the preparation of this WAP (EPA, 1994). Accordingly, this chapter includes a facility description; information on the waste to be managed; a discussion of parameters, rationale, and test methods; details of planned waste sampling and analysis; a description of the waste shipment screening and verification process; and a description of the quality assurance (QA)/quality control (QC) program.

When using this WAP, the term "WIPP," when used in the context of requiring a duty or responsibility, means the U.S. Department of Energy (DOE) as the facility owner and operator and the Westinghouse Waste Isolation Division (WID) as the co-operator, as set forth in the WIPP Resource Conservation and Recovery Act (RCRA) Permit Application certification (Chapter M of this permit application). This WAP establishes waste characterization requirements for DOE waste generators at other sites. Waste characterization requirements are implemented in lower-tier documents, including the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP)[1] and quality assurance project plans (QAPjP) for individual generator sites and analytical laboratories.

The mission of the WIPP Project, as established by the U.S. Congress in 1979 (Public Law 96-164), is to provide a research and development facility to demonstrate the safe disposal of transuranic (TRU) mixed waste generated as a result of United States defense activities. This permit application and this WAP are for the management of TRU mixed waste to be disposed of at the WIPP facility.

TRU mixed waste contains both TRU radioactive and hazardous components, as defined in 20 NMAC 4.1, Subpart VIII, §268.35(d), and in the Federal Facility Compliance Act, Public Law 102- 386, Title 1, §3021(d). It is designated and separately packaged as either contact-handled (CH) or remote-handled (RH), based on the radiological dose rate at the surface of the waste

[1]The Transuranic Waste Characterization Quality Assurance Program Plan, DOE/CAO 94-1010 (April, 1995), utilizes a performance-based approach to allow individual sites to have the flexibility to employ analytical and examination methods that meet the quality assurance objectives specified in this WAP. The DOE will conduct waste characterization activities at each generator site planning to ship waste to the WIPP facility to obtain the requisite data. TRU mixed waste characterization described in the QAPP includes: 1) radiography, 2) headspace gas sampling and analysis, 3) solidified waste sampling and analysis, and 4) visual examination.

container. Both CH TRU and RH TRU mixed wastes will be received and disposed of at the WIPP facility.

The hazardous components of the TRU mixed waste to be managed at the WIPP facility are designated in the WIPP facility's RCRA Part A permit application. This WAP describes the measures that will be taken to assure that the wastes received at the WIPP facility are within the scope of the RCRA Part A permit application as established by 20 NMAC 4.1, Subpart V, §264.13, and that they comply with unit-specific requirements of 20 NMAC 4.1, Subpart V, Miscellaneous Units.

Both CH TRU and RH TRU mixed waste at the WIPP facility will be managed using containers that meet or exceed the requirements of the U.S. Department of Transportation (DOT) for Type A containers. The use of the term "container" when referring to waste characterization activities refers to a drum, canister, or Standard Waste Box (SWB) unit. Section D-1a(1) provides details regarding the design and use of these waste containers.

The WIPP facility requires TRU waste characterization programs to adhere to the requirements specified in this WAP, and enumerated in the WIPP Waste Acceptance Criteria (WAC), and the Transuranic Waste Characterization QAPP (DOE, 1995a). All waste characterization activities discussed in Section C-4 will be carried out at generator sites in accordance with this WAP. WIPP management will audit site waste characterization programs and activities as described in Section C-5. This WAP describes the relationship of the waste characterization data and information to the regulatory requirements of 20 NMAC 4.1. The waste characterization program for wastes to be received at the WIPP facility for disposal has been designed to utilize sampling and analysis. In addition, acceptable knowledge of waste generation processes may be used for those wastes for which no practical characterization techniques exist (such as debris waste).

Some TRU mixed waste is retrievably stored at the DOE generator sites. Additional waste will be generated and packaged into containers at these sites in the future. TRU mixed waste will be retrieved from storage areas at a DOE site. Retrievably stored waste is defined as waste generated after 1970 and before implementation of the QAPP characterization requirements. Newly generated waste is defined as waste generated after implementation of QAPP characterization requirements. Stored TRU waste will be characterized on an ongoing basis, as the waste is retrieved. Newly generated TRU waste will be characterized as it is generated. Waste characterization requirements for stored and newly generated wastes differ due to the QAPP requirements, as discussed in Sections C-3a and C-3b.

Characterization requirements for individual containers of waste are specified on a waste stream basis. A waste stream is defined as waste material generated from a single process or from an activity that is similar in material, physical form, isotopic make-up, and hazardous constituents. Waste streams are grouped by Waste Matrix Code Groups related to the physical and chemical properties of the waste. Generator/storage sites must use the characterization techniques described in this WAP to assign appropriate Waste Matrix Code Groups for WIPP disposal. The

Waste Matrix Code Groups are solidified inorganics, solidified organics, salt waste, soils, lead/cadmium metal, inorganic nonmetal waste, combustible waste, graphite, filters, heterogeneous debris waste, and uncategorized metal.

Wastes are initially categorized into three broad Summary Category Groups that are related to the final physical form of the wastes. Waste characterization requirements for these groups are specified separately in Section C-2 of this WAP. These groups include Homogeneous Solids (Summary Category S3000), Soil/Gravel (Summary Category S4000), and Debris Wastes (Summary Category S5000).

The WIPP waste characterization program carried out by generators will be controlled under this WAP and implemented by the requirements of the QAPP and the WAC Certification Program (DOE, 1991). Waste characterization activities at the generator sites include the following, although not all these techniques will be used on each container, as discussed in Section C-2:

- Radiography, which is an x-ray technique to determine physical contents of containers
- Visual examination of opened containers as an alternative way to determine their physical contents or to verify Radiography results
- Headspace-gas sampling to determine volatile organic compound (VOC) content of gases in the void volume of the containers
- Sampling and analysis of waste forms that are homogeneous and can be representatively sampled to determine concentrations of hazardous waste constituents and toxicity characteristic contaminants of waste in containers
- Compilation of documented acceptable knowledge into an auditable record

The DOE's objective is to operate and maintain the WIPP facility free of both chemical and radiological contamination. Therefore, as allowed by 20 NMAC 4.1, Subpart V, §264.13, and consistent with joint EPA and U.S. Nuclear Regulatory Commission (NRC) guidance, all waste sampling and analyses will be conducted by the DOE generator sites in accordance with the requirements of this WAP. The WAP specifies required characterization activities that the generator must complete in order to be able to provide the information needed to send TRU waste to the WIPP facility for disposal. In accordance with this WAP, the generator sites will conduct the required waste characterization activities. Once the sufficient waste characterization is complete, the generator will complete a Waste Stream Profile Form documenting the results of their characterization activities (see Section C-1b). Generators will perform specific waste analyses according to the Transuranic Waste Characterization Sampling and Analysis Methods Manual (hereinafter referred to as the Methods Manual), which prescribes appropriate EPA-specified analytical methods modified as needed due to the presence of TRU waste

contaminants (DOE, 1995b). Since the DOE has determined that the waste analysis parameters (Section C-2a) are the same for CH and RH TRU mixed waste, RH TRU waste will be characterized using the same techniques as are used for CH TRU waste, with the exception of visual examination. Most RH TRU waste will be inspected using radiographic examination, but the DOE decided that visual examination will not be used to verify radiographic examination for RH TRU waste due to the added radiological exposure, cost, and waste generation associated with visual examination. The sampling and analytical methods that are used for CH waste characterization will not change except for that they will be performed remotely in shielded facilities for most RH waste characterization. The remote manipulations used for waste characterization (i.e., shaking and pouring) are common and will not require additional operator training. If at some point in time more effective waste characterization methods are developed for CH TRU or RH TRU waste, they will be submitted for inclusion in the Methods Manual per the DOE/Carlsbad Area Office (CAO) procedure discussed in Appendix C7. The data reports and the Waste Stream Profile Forms (see Section C-1b) resulting from waste characterization activities will be transmitted to the WIPP, reviewed for completeness, and screened for acceptance prior to loading any waste into the Transuranic Package Transporter (TRUPACT-II) or RH TRU mixed waste shielded road cask at the generator facility, as described in Section C-5. Only waste that has been characterized in accordance with this WAP and that meets the WAC, will be accepted for disposal at the WIPP facility.

C-1 Facility Description

C-1a Description of Processes and Activities at the WIPP

General descriptions of the WIPP facility waste handling processes are provided below. Detailed process descriptions are provided in Chapter D, Section D-10a(3), of this permit application.

CH TRU Mixed Waste Handling Process Overview

Waste from DOE TRU mixed waste generator/storage sites identified by the DOE as meeting the WAC will be disposed of at the WIPP facility. The ten major generator/storage sites anticipated to send the majority of waste for disposal at the WIPP are:

- Argonne National Laboratories (East)
- Idaho National Engineering Laboratory
- Los Alamos National Laboratory
- Lawrence Livermore National Laboratory
- Mound Facility
- Nevada Test Site
- Oak Ridge National Laboratory
- Richland (Hanford) Site
- Rocky Flats Environmental Technology Site
- Savannah River Site

Figure C-3 shows the geographic location of these sites. There are several small generator/storage sites that will either ship their waste to the WIPP facility for disposal or to one of the major generator/storage sites for waste characterization and certification to the WIPP requirements. Those sites will be identified to the New Mexico Environment Department (NMED) as they are certified and prior to initiating any shipments from these sites to the WIPP facility.

CH TRU mixed waste will arrive at the WIPP facility in a DOT Type B transportation package (i.e., a TRUPACT-II or other approved package). Each TRUPACT-II is capable of carrying up to two DOT Type A SWBs, two seven-packs of DOT Type 7A 55-gallon (gal) drums, or one DOT Type 7A Ten-drum Overpack (TDOP).

When the TRUPACT-IIs arrive at the WIPP facility, radiological surveys, security checks, and shipping documentation reviews will be performed. Upon completion of these checks, the hazardous waste manifest will be signed to release the driver. Should radiological surveys (i.e., surface dose rate, contamination) exceed acceptable levels, the TRUPACT-IIs and transport trailer will be placed outside the Waste Handling Building (WHB) in the parking area container storage unit or in the WHB itself. Factors such as weather conditions, time of receipt, and space availability will determine the actual location for placement of the TRUPACT-IIs and transport trailer. Once the location is established, the appropriate radiological boundaries (i.e., ropes, placards, etc.) will be erected around the affected TRUPACT-IIs and transport trailer. In the event that fixed and/or removable contamination is detected on the external surface of TRUPACT-IIs in excess of WIPP free release limits, Waste Operations, in conjunction with Operational Health Physics, would assess the situation and formulate a plan of recovery to decontaminate the shipping container(s).

The TRUPACT-IIs will be removed from the transport trailer and taken inside the WHB. Inside the WHB, the TRUPACT-IIs will be opened and the waste containers removed. As the containers are being removed, radiological surveys will be conducted. If contamination is detected on the waste containers, a determination will be made as to whether small area "spot" decontamination activities will be performed or to replace the waste containers, reseal the TRUPACT-II, and prepare a new hazardous waste manifest to ship the payload back to the generator/storage facility. Should small area decontamination be conducted, the resulting waste will be managed as "derived" waste. Derived waste management is discussed in detail in Section D-10a(3)(a).

When the containers are removed from the TRUPACT-II, additional checks will be conducted to verify that the waste containers are the same as those described on the hazardous waste manifest and the WIPP Waste Information System (WWIS) database (described in Section C-5a). When all identification checks have been completed, the generator's copy of the manifest will be returned to them (within 30 days of waste receipt). If there are any discrepancies, the generator will be contacted for resolution. Discrepancies that are not resolved within 15 days of waste receipt will be reported to the NMED as required by 20 NMAC 4.1, Subpart V, §264.72. If a resolution is not reached within 30 days of waste receipt, the waste will be returned to the site

which shipped the containers. A more detailed discussion on discrepancy resolution is provided in Section C-5b of this chapter.

The waste containers will be loaded onto a facility pallet, which will be transferred to a conveyance loading car. The conveyance loading car will move the loaded facility pallet into the waste hoist cage, which will be lowered to the underground waste receiving station through the Waste Shaft. At the underground waste receiving station, the pallet will be transferred to an underground waste transporter, which will move the loaded facility pallet to an underground hazardous waste management unit (HWMU). At the HWMU, the waste containers will be removed from the facility pallet and will be emplaced in a waste emplacement room. Bags of backfill material will be placed around and on top of the stacked waste containers. Section D-10a(3)(b) of this permit application provides a more complete description of the facility and the CH waste management activities.

RH TRU Mixed Waste Handling Process Overview

RH TRU mixed waste will arrive at the WIPP facility in a shielded road cask. Upon arrival, radiological surveys, security checks, and shipping documentation reviews will be performed. Upon completion of these checks, the hazardous waste manifest will be signed to release the driver. Should radiological surveys (i.e., surface dose rate, contamination) exceed acceptable levels, the road cask and transport trailer will be placed outside the WHB in the controlled area or in the WHB itself. Factors such as weather conditions, time of receipt, and space availability will determine the actual location for placement of the road cask and transport trailer. Once the location is established, the appropriate radiological boundaries (i.e., ropes, placards, etc.) will be erected around the road cask and transport trailer. In the event that fixed and/or removable contamination is detected on the external surface of the road cask in excess of WIPP free release limits, Waste Operations, in conjunction with Operational Health Physics, would assess the situation and formulate a plan of recovery to decontaminate the road cask.

The RH TRU mixed waste canister will be removed from the shielded road cask in the WHB hot-cell complex, where it will be checked against the identity on the hazardous waste manifest and the WWIS to verify that the canister is suitable for emplacement. The generator's copy of the manifest is then returned to the generator. If there are any discrepancies, the generator will be contacted for resolution. Discrepancies that are not resolved within 15 days of waste receipt will be reported to the NMED, as required by 20 NMAC 4.1, Subpart V, §264.72. If a resolution is not reached within 30 days of receipt of the waste, the canister will be returned to the site that shipped the canister.

The RH canister will be checked for external surface contamination in the hot-cell complex. If an unacceptable condition is identified, the canister will be overpacked. The overpacked canister will then reenter the normal waste management process line. The canister will then be placed into a facility cask for transport to an HWMU. The facility cask will be placed onto the facility

cask transfer car and will be loaded onto the waste hoist and lowered to the underground waste receiving station.

At the underground waste receiving station, the facility cask transfer car will move the facility cask, loaded with the RH TRU mixed waste canister, from the waste hoist cage, and a forklift will transport it to an HWMU. The emplacement machine will be positioned in front of a predrilled horizontal hole bored into the room wall, and the facility cask will be placed on the machine assembly. The emplacement machine will then insert the waste canister into the hole. A shield plug will be inserted into the hole to provide radiation protection.

The amount of RH TRU mixed waste disposed in each panel is limited, based on thermal and geomechanical considerations. A nominal spacing of 8 feet (ft) (2.4 meters [m]) between centers for RH TRU mixed waste canisters is planned. Section D-10a(3)(c) of this permit application provides a more complete description of the facility and the RH waste management activities.

C-1b Identification of TRU Mixed Waste Managed at the WIPP Facility

Waste Stream Identification

Waste destined for disposal at WIPP is characterized on a waste stream basis. A waste stream is defined as waste material generated from a single process or activity that is similar in material, physical form, isotopic make-up, and hazardous constituents. Waste may be generated as either process or process batch waste streams. A process is defined as a system or series of continuous or regularly occurring actions taking place in a predetermined manner over extended periods of time, resulting in waste that is substantially uniform. A process batch is defined as an amount of material subject to a particular unit chemical process, unit physical mixing process, or another short-term operation, resulting in waste that is substantially uniform. Sites delineate waste streams using acceptable knowledge. Acceptable knowledge is fully described in Section C-4b and Appendix C9.

There are various identifiers used for waste streams, all developed for specific purposes. Table C-1 is a cross correlation table that shows the interrelation between all of these identifiers.

The Summary Category Group (Matrix Parameter Summary Category) description is the broadest grouping. The Summary Category Groups are assigned to each waste stream identified by generators to facilitate RCRA waste characterization and reflect the physical form of the waste.

The Waste Matrix Codes (or Matrix Parameter Categories) were developed by the DOE, in response to the Federal Facilities Compliance Act, as a methodology to aid in classifying mixed waste streams within the DOE system. These codes represent different physical and chemical matrices. The Waste Matrix Code Group (or Final Waste Form) is a grouping of the Waste Matrix Codes that have similar physical and chemical properties.

A Waste Stream WIPP Identifier (ID) is assigned to each specific waste stream at a specific generator site. Similarities in the IDs do not necessarily correlate to similarities between waste streams. The Waste Stream Name is linked to the ID.

Waste stream descriptions may also be associated with TRUPACT-II content (TRUCON) codes. TRUCON content codes were originally developed as a type of shorthand representation of the chemical content and physical waste form of generator waste streams for use in the TRUPACT-II transportation safety analysis. Each waste stream was reviewed and a TRUCON code was assigned. Newly identified waste streams eligible for WIPP disposal will be assigned TRUCON codes, which will be approved by the NRC prior to shipment of the waste streams.

The Item Description Code is a site-specific numerical code applied to individual waste streams to identify their source. These codes represent the local identifiers, used by the generator sites to specify the waste stream type and/or generation area of TRU and TRU mixed waste, and are used at most DOE facilities that generate TRU and TRU mixed waste.

The Waste Type is a numerical designator ranging from one to four that indicates if the waste is a solidified inorganic, solid inorganic, solid organic, or solidified organic. This description is used in the shipment of the waste.

Waste Categories are included in Table C-1 for the purposes of linking this information to the compatibility study presented in Appendix C1.

Waste stream information has been provided by the generator/storage sites and is documented in the WIPP Transuranic Waste Baseline Inventory Report (WTWBIR) (see Table C-2). The information provided by the generator/storage sites in the WTWBIR is not the result of waste characterization. It is an estimate of waste stream constituents. Therefore, one WTWBIR waste stream may relate to numerous waste streams for the purpose of waste characterization. The WTWBIR information was compiled in order to estimate waste volumes and properties for long-term performance assessment. All waste characterization activities must still be conducted and each waste stream submitted to the WIPP facility on a Waste Stream Profile Form for approval. Waste stream descriptions will be finalized over the course of waste characterization at the sites. Changes that have been made to the WTWBIR in recent revisions to this document do not affect this permit application.

Currently, the majority of existing retrievably stored waste to be disposed at WIPP is in earthen-covered storage or other storage which is not readily accessible. Because of this, all of the waste within a waste stream may not be available for sampling and analysis at one time. In these instances, sites will divide waste streams into waste stream lots based on staging, transportation, or handling issues. Characterization activities are then undertaken on a waste stream lot basis. Sites initially delineate and describe waste streams using acceptable knowledge. As waste characterization activities proceed, waste stream descriptions may change based on the results of sampling and analysis. Results from waste characterization are used to confirm acceptable knowledge, including the assignment of EPA hazardous waste codes to waste streams, as appropriate.

The quantity of waste reported in the WIPP RCRA Part A application was determined using reported generator information on waste generating processes, and waste constituents and characteristics. If it was suspected, based on knowledge of a waste generating process, that a RCRA-regulated hazardous constituent may be contained in the waste, the waste was assumed to contain that constituent. The waste volume associated with each reported EPA code was assumed to equal the volume of the waste stream. Therefore, it appears that receipt of the total annual waste volumes reported in the Part A application over WIPP's projected 25 year waste-emplacement period would exceed the 6.2 million cubic feet (ft^3) (175,600 cubic meters (m^3)) allowable waste capacity specified in the Land Withdrawal Act of 1992. This is because many waste streams with multiple EPA codes were counted as multiple volumes. A biennial report, in accordance with 20 NMAC 4.1, Subpart V, §264.75, will provide information on actual volume and waste descriptions received for disposal during the time period covered by the report.

Waste Summary Categories Accepted at the WIPP Facility

Once a waste stream has been delineated, sites assign a Waste Matrix Code to the waste stream based on the physical form of the waste. Waste streams are assigned to one of three broad Summary Category Groups; S3000-homogeneous solids, S4000-soils/gravel, and S5000-debris wastes. These Summary Category Groups are used to determine further characterization requirements.

S3000—Homogeneous Solids

Solid process residues are defined as solid materials, excluding soil, that do not meet the NMED criteria for classification as debris (20 NMAC 4.1, Subpart VIII, §268.2[g] and [h]). Included in the series of solid process residues are inorganic process residues, inorganic sludges, salt waste, and pyrochemical salt waste. Other waste streams are included in this Summary Category Group based on the specific waste stream types and final waste form. Each waste stream designated as a 3000 solid process residue is identified in Table C-2 with the EPA hazardous waste codes that are associated with that waste stream. This Summary Category Group is expected to contain toxic metals and spent solvents. This category includes wastes that are at least 50 percent by volume solid process residues.

S4000—Soils/Gravel

This Summary Category Group includes waste streams that are at least 50 percent by volume soil as identified in Table C-2 with the EPA hazardous waste codes that are associated with that waste stream. This Summary Category Group is expected to contain toxic metals. Soils are further categorized by the amount of debris included in the matrix.

S5000—Debris Wastes

This Summary Category Group includes waste that is at least 50 percent by volume materials that meet the NMAC criteria for classification as debris (20 NMAC 4.1, Subpart VIII, §268.2) as follows:

> Debris means solid material exceeding a 2.36 inch (in.) (60 millimeter) particle size that is intended for disposal and that is:
>
> 1. a manufactured object, or
> 2. plant or animal matter, or
> 3. natural geologic material.
>
> However, the following materials are not debris:
>
> 1. any material for which a specific treatment standard is provided in 20 NMAC 4.1, Subpart VIII, 268 Subpart D;
>
> 2. process residuals such as smelter slag and residues from the treatment of waste, wastewater, sludges, or air emission residues; and
>
> 3. intact containers of hazardous waste that are not ruptured and that retain at least 75 percent of their original volume.

However, for the purposes of this WAP, all heterogeneous materials, or waste materials whose physical form does not lend itself to sampling and analysis, are considered to be in the Summary Category Group regardless of the size of the waste materials. That is, this Summary Category Group includes heterogeneous waste materials that are less than 2.36 in.

A mixture of debris (that has not been treated to the standards provided by 20 NMAC 4.1, Subpart VIII, §268.45), and other material is subject to regulation as debris if the mixture is comprised primarily of debris, by volume, based on visual inspection (20 NMAC 4.1, Subpart VIII, §268.2[g]). Due to the presence of radioactive contaminants in the waste and the safety hazards involved in opening waste containers, the DOE has opted to use radiography as a form of nondestructive examination of the waste form in place of visual examination of the waste form. For these reasons, radiography will be used on 100 percent of stored waste containers and most RH TRU waste containers to determine the physical composition of debris mixtures. The percentage of debris materials in mixtures in newly generated CH TRU waste will be determined by visual examination during packaging.

"Hazardous debris" means debris that contains a hazardous waste listed in 20 NMAC 4.1, Subpart II, 261 Appendix VIII, or that exhibits a characteristic of hazardous waste identified in 20 NMAC 4.1, Subpart II, §261, Subpart C.

Included in the S5000 series are metal debris, lead containing metal debris, inorganic nonmetal debris, asbestos debris, combustible debris, graphite debris, heterogeneous debris, and composite filters, as well as other minor waste streams, as identified in Table C-2. This Summary Category Group is expected to contain toxic metals and spent solvents. The EPA hazardous waste codes associated with the debris waste streams are included in Table C-2.

Examples of waste that might be included in the S5000 series are asbestos-containing gloves, fire hoses, aprons, flooring tiles, pipe insulation, boiler jackets, and laboratory tabletops. Also included are combustible debris constructed of plastic, rubber, wood, paper, cloth, and graphite and biological materials. Examples of graphite waste that would be included in this series are crucibles, graphite components, and pure graphite.

Chemical Properties of the Waste

This section of the WAP provides an overview of the chemical properties of the waste and the waste source. Hazardous constituents and target analytes for waste to be disposed of at the WIPP facility are shown in Table C-3.

The most common hazardous constituents in the TRU mixed waste to be managed in the WIPP facility consist of the following:

Metals

Some of the TRU mixed waste to be emplaced in the WIPP facility contains metals for which 20 NMAC 4.1, Subpart II, §261.24, toxicity characteristics were established (EPA hazardous waste codes D004 through D011). These materials are known to be present based on acceptable knowledge of waste-generating processes and various analytical results used to verify acceptable knowledge. Cadmium, chromium, lead, mercury, selenium, and silver are present in discarded tools and equipment, solidified sludges, cemented laboratory liquids, and waste from decontamination and decommissioning activities. A large percentage of the waste consists of lead-lined gloveboxes, leaded rubber gloves and aprons, lead bricks and piping, lead tape, and other lead items. Lead, because of its radiation-shielding applications, is the most prevalent toxicity-characteristic metal present.

Halogenated Volatile Organic Compounds

Some of the mixed waste to be emplaced in the WIPP facility contains spent halogenated organic solvents identified in 20 NMAC 4.1, Subpart II, §261.31 (EPA hazardous waste numbers F001 through F005). The presence of these compounds is confirmed by analytical results from headspace gas sampling of TRU mixed waste. Tetrachloroethylene; trichloroethylene; methylene chloride; carbon tetrachloride; 1,1,1-trichloroethane; and 1,1,2-trichloro-1,2,2-trifluoroethane (EPA hazardous waste codes F001 and F002) are the most prevalent halogenated organic compounds identified in TRU mixed waste that may be managed at the WIPP facility during the Disposal Phase. These compounds are commonly used to clean metal surfaces prior to plating, polishing, or fabrication; to dissolve other compounds; or as coolants. Because they are highly volatile, only very small amounts typically remain on equipment after cleaning or, in the case of treated wastewaters, in the sludges after clarification and flocculation.

Nonhalogenated Volatile Organic Compounds

Xylene, methanol, and n-butanol are the most prevalent nonhalogenated VOCs in TRU mixed waste that may be managed at the WIPP facility during the Disposal Phase. These compounds occur in TRU mixed waste materials in much smaller quantities than halogenated VOCs. Like the halogenated VOCs, they are used as degreasers and solvents and are similarly volatile. The same analytical methods that are used for halogenated VOCs are used to detect the presence of nonhalogenated VOCs.

Waste Not Accepted at the WIPP Facility

The DOE has established WIPP WAC to specify the chemical and physical forms of TRU mixed waste that will be accepted at the WIPP facility. These criteria include those required to ensure occupational safety and protection of human health and the environment.

The following waste is unacceptable for management at the WIPP facility:

- Ignitable, reactive, and corrosive waste, as defined under 20 NMAC 4.1, Subpart II, Characteristics of Hazardous Waste
- Liquid wastes, (all waste must meet the WAC criteria regarding liquid content)
- Compressed gases

- Incompatible waste, as defined under 20 NMAC 4.1, Subpart V, Appendix V (waste must be compatible with backfill, seal and panel closure materials, container, cask, and TRUPACT-II materials as well as with other waste)

- Headspace-gas VOC concentrations resulting in average annual emissions not protective of human health and the environment (Table C-5 lists target maximum average headspace concentrations)

- Wastes with EPA codes not listed on RCRA Part A permit application

- Waste with equal to or more than 50 parts per million (ppm) (50 milligrams per liter [L]) polychlorinated biphenyls (PCB)

The WIPP facility will not accept waste that exhibits the characteristics of ignitability, reactivity, or corrosivity. The DOE ensures through administrative and operational procedures at the generator sites that TRU mixed waste received at the WIPP facility does not exhibit these characteristics. These characteristics are generally associated with liquid wastes or specific waste forms that may react violently. This WAP and the WAC, therefore, prohibit liquid waste, explosives, compressed gases, oxidizers, and pyrophorics. The absence of these wastes is confirmed by radiography, visual examination, and headspace analysis.

The TRU mixed waste received at the WIPP facility will not be aqueous or liquid, will not contain WAC-prohibited materials, and will be capable of being handled at standard temperatures and pressures without reaction to oxygen or water (see Table C-4). The WAC specifies that liquid waste is not acceptable at the WIPP. The WIPP facility will not accept containers holding waste that would be considered a liquid waste as defined in 20 NMAC 4.1, Subpart I, §260.10. Every container holding waste with less than 2 L of liquid for a 55-gal drum or 8 L in a SWB must contain as little residual liquid as is reasonably achievable, and all internal containers (e.g., bottles and cans) must contain less than one in. (2.5 centimeters) of liquid at the bottom of the container.

Additionally, TRU mixed waste cannot contain explosives, compressed gases, oxidizers, or nonradionuclide pyrophoric materials. (Waste generators have submitted information on waste streams based on known waste generation processes that indicate certain waste streams may have the potential for reactivity, ignitability, or corrosivity.) These characteristics must be eliminated prior to waste acceptance for disposal at the WIPP.

Before accepting a container holding TRU mixed waste, WIPP personnel will examine the radiography data records to verify that the container holds no unvented compressed gas containers and no greater than one percent by volume of residual liquid. If discrepancies or inconsistencies are detected during the radiography data record review, WIPP personnel may review the radiography video tape to verify that the observed physical form of the waste is consistent with the waste stream description provided by the generator and to ensure that no

WAC-prohibited materials are present in the waste. Section C-5 includes a description of the waste verification process that the DOE intends to conduct prior to receiving a shipment at the WIPP.

The WIPP will manage TRU mixed waste in a manner that mitigates the buildup of explosive or flammable gases within the waste. Containers are vented through individual carbon composite particulate filters, allowing any gases that are generated by radiolytic and microbial processes within a waste container to escape; to prevent over pressurization. Gas generation is discussed in detail in Chapter I, Section I-1e(4).

The WIPP facility is designed to manage only compatible waste. Therefore, a compatibility analysis was performed to identify potential incompatibilities for all defense generated TRU mixed waste reported in the WTWBIR. Wastes were screened for incompatibilities based on their chemical content and physical waste form by comparing information presented in 20 NMAC 4.1, Subpart V, Appendix V, and the EPA document "*A Method for Determining the Compatibility of Hazardous Wastes*," (Hatayama et al., 1980). The compatibility analysis also took into account waste compatibility with various aspects of the repository such as shaft, seal, and panel closure materials, backfill, and fire suppressant materials. Appendix C1 provides additional details and results of this analysis.

To ensure the integrity of the WIPP facility, waste streams identified to contain incompatible materials or materials incompatible with waste containers cannot be shipped to WIPP unless they are treated to remove the incompatibility. Only those waste streams that are compatible or have been treated to remove incompatibilities will be shipped to WIPP.

As described in Chapter D, Section D-9b(4), the potential risks to human health and the environment are due to emissions of VOCs from the waste containers into the air pathway. The most stringent environmental performance standard of 20 NMAC 4.1, Subpart V, §264.601(b) is the acceptable excess risk levels for residential (chronic) exposure to carcinogens (10^{-6} for Class A and B carcinogens and 10^{-5} for Class C carcinogens). In addition, the risk assessment in Chapter D examined occupational exposures and compared them to Occupational Safety and Health Administration risk standards. WAC have been developed to limit the VOC concentrations in the headspace of waste containers to those which when averaged will ensure compliance with the performance standards. These limits are presented in Table C-5 as VOC headspace concentration limits. In reality, these are maximum <u>average</u> headspace concentrations. This means that some containers can exceed these values as long as averages in a disposal room do not. For a generator to ship waste that exceeds any of these values, a WAC exception must be requested at which time WIPP personnel will evaluate the impact on the average concentrations in the disposal room.

The DOE will only allow generators to ship those waste streams with EPA Hazardous Waste Codes listed on Part A of this application. Characterization of all waste streams will be performed as required by this WAP. If during the characterization process, new hazardous

waste codes are identified, those wastes cannot be accepted for disposal at the WIPP facility until a permit modification has been submitted and approved. Similar waste streams at other generator sites will be examined more closely to ensure that the newly identified code does not apply. If other waste streams also require a new hazardous waste code, shipment of these waste streams will also cease until a permit modification has been submitted and approved. Approval will be based on the physical and chemical properties of the waste.

Transformer oils containing PCBs have been identified in a limited number of waste streams included in the Waste Matrix Code corresponding to organic sludges. Because the WIPP facility is not seeking permission to manage PCB waste, these waste streams are required to be screened to assure PCB levels are below 50 ppm.

Control of Waste Acceptance

The waste acceptance program is defined in the WAC (DOE, 1991 or current revision). This document provides a list of criteria that must be met for waste to be shipped to the WIPP facility for management. The WAC requires the generator to prepare a waste certification program that lists the methods and techniques used to determine compliance with the WAC and the QA/QC criteria that are applied to the generator's waste certification program. One of the criteria that the generator is required to meet is compliance with the applicable portions of this WAP. The WAC certification programs result in controlled and consistent waste properties and final packaging.

A Waste Stream Profile Form will describe a CH TRU or RH TRU mixed-waste stream destined for shipment to and disposal at the WIPP facility. The Waste Stream Profile Form summarizes important information about a particular waste stream. Examples of information contained in a Waste Stream Profile Form are:

- The generator's site name
- Original generator of waste stream
- A description of the waste stream
- The date of WAC certification by the DOE/CAO and the certification document title and date
- The Waste Stream WIPP Identification Number
- The designated Summary Category Group
- A listing of acceptable knowledge documentation used to identify the waste stream

- The waste-characterization procedures used and the reference and date of the procedure
- The data packages supporting the characterization
- The EPA hazardous waste codes
- Waste Stream Profile Form Certification statement signed by the manager of the generator site

These data will be provided for each waste stream prior to its acceptance for disposal at the WIPP. The Waste Stream Profile Form data will be transmitted once for each waste stream from a facility.

For waste streams that are continually generated, a Waste Stream Profile Form may be submitted once the waste stream has been characterized per the QAPP based on the variability of the waste stream (as shown in Appendix C6). Characterization activities will continue in order to verify consistency with the initial characterization and Waste Stream Profile Form (Section C-3a). If there are discrepancies, the waste will be redefined to a separate waste stream, and a new Waste Stream Profile Form will be submitted.

The WIPP Waste Operations Manager will be responsible for the review of Waste Stream Profile Forms (see Section C-1c and Figure C-4) and data records to verify compliance with the restrictions on TRU mixed wastes for WIPP disposal. The Waste Stream Profile Form includes a section requiring the waste generator to provide the data and documentation of WAC certification for the TRU mixed waste stream described on the form. The WIPP Waste Operations Manager will also be responsible for the review of shipping records (see Section C-5b) to verify that each container has been prepared under a WAC-certified program and in accordance with this WAP. Waste characterization data must indicate the absence of unacceptable materials.

Generator site waste stream characterization will be subject to the Generator/Storage Site Waste Screening and Certification Audit Program (Appendix C11) for compliance with this WAP. Section C-5 further discusses WIPP facility waste screening activities.

C-1c Waste-Generating Processes

Waste-Generating Processes At DOE Generator Facilities

TRU mixed waste generated at DOE sites results from specific processes and activities that are well-defined and well-controlled, enabling the DOE to characterize waste streams on the basis of knowledge of the process and the raw materials used. Examples of the major types of operations that generate TRU mixed waste include:

- Production of Nuclear Products—Production of nuclear products includes reactor operation, radionuclide separation/finishing, and weapons fabrication and manufacturing. The majority of the TRU mixed waste was generated by weapons fabrication and radionuclide separation/finishing processes. More specifically, wastes consist of residues from chemical processes, air and liquid filtration, casting, machining, cleaning, product quality sampling, analytical activities, and maintenance and refurbishment of equipment and facilities.

- Plutonium Recovery—Plutonium recovery wastes are residues from the recovery of valuable plutonium-contaminated molds, metals, glass, plastics, rags, salts used in electrorefining, precipitates, firebrick, soot, and filters.

- Research and Development (R&D)—R&D projects include a variety of hot cell or glovebox activities that often simulate full-scale operations described above, producing similar TRU mixed wastes. Other types of R&D projects include metallurgical research, actinide separations, process demonstrations, and chemical and physical properties determinations.

- Decontamination and Decommissioning—Facilities and equipment that are no longer needed or usable are decontaminated and decommissioned, resulting in TRU mixed wastes consisting of scrap materials, cleaning agents, tools, piping, filters, Plexiglas™, gloveboxes, concrete rubble, asphalt, cinder blocks, and other building materials. This is expected to be the largest category by volume of TRU mixed waste to be generated in the future.

Waste-Generating Processes at the WIPP Facility

Nonradioactive hazardous waste generated at the WIPP facility is characterized, placed in containers, and temporarily stored, in accordance with 40 CFR §262.34, until it is transported off site for treatment and/or disposal at a permitted facility. This waste generation and accumulation activity, which is performed in compliance with 20 NMAC 4.1, Subpart III, is not subject to RCRA permitting requirements and, as such, is not addressed in this permit application.

Administrative practices that direct normal operations at the WIPP facility will be implemented to minimize the possibility of generating new TRU mixed waste. For this reason, any TRU mixed waste generated through normal waste handling operations will be derived from the waste received from the off-site generator. Throughout this application, site-generated waste that is derived from waste generated at an off-site facility is referred to as *derived waste*. Because derived wastes can contain only those RCRA-regulated materials present in the waste from which they were derived, no additional characterization of the derived waste is proposed for disposal purposes. In other words, the generator's characterization data and knowledge of the

processes at the WIPP facility will be used to identify and characterize containers of derived waste. The management of derived waste is addressed in Section D-10a(3)(a).

Hazardous constituents within the waste containers are known and have been determined to be acceptable for disposal at the WIPP facility. Therefore if a spill, breach, or other type of release of TRU mixed waste from a container occurs, the waste generated during cleanup would be managed as derived waste. Anticipated sources of derived waste during the Disposal Phase include:

- Swipes used to detect external radioactive contamination during receipt inspection and other radiological checks

- Any TRU mixed waste generated through nonroutine events, such as the cleanup of spills

C-1d Description of HWMUs

The underground HWMUs (defined as waste panels) are 2,150 ft (655 m) beneath the surface, in the WIPP underground and are designated as Panels 1 through 10. Each waste panel, designated as Panels 1 through 8, consists of seven parallel rooms and two access drifts. Each room is approximately 300 ft (91 m) long, 33 ft (10 m) wide, and 13 ft (4 m) high. Access drifts connect the rooms and have the same cross section. Panels 9 and 10 are the disposal area access drifts which may be used by the DOE for waste disposal in the future. The DOE intends to operate the WIPP facility in a manner that minimizes the number of underground HWMUs that are open at any one time, as discussed in Section B-1b.

The underground HWMUs provide room for 6.2 million ft^3 (175,600 m^3) of TRU mixed waste, of which no more than 250,000 ft^3 (7,080 m^3) may be for RH TRU mixed waste. The remainder will be for CH TRU mixed waste. RH TRU mixed waste canisters will be inserted into horizontal holes bored into the walls of the HWMUs. The CH TRU mixed waste packages will fill the remaining HWMU space exclusive of the panel closures.

The surface HWMUs are inside the WHB and the parking area south of the WHB. The WHB is the surface facility where waste handling activities will take place (Figure D-1). The WHB has a total area of approximately 84,000 square ft (ft^2) (7,803 square m (m^2) of which 33,175 ft^2 (3,083 m^2) are designated for the waste handling and storage of CH TRU mixed waste and 21,318 ft^2 (1,981 m^2) are designated for the waste handling and storage of RH TRU mixed waste, as shown in Figure D-1. These combined areas are being permitted as a container storage unit. The CH side of the WHB will store up to 2718.2 ft^3 (77.02 m^3) and the RH side up to 377 ft^3 (10.7 m^3), under normal conditions of operations. The concrete floors are sealed with an impermeable coating that has excellent resistance to the chemicals in TRU mixed waste and, consequently, provide secondary containment for TRU mixed waste.

The parking area HWMU (Figure D-2) south of the WHB will be used for storage of waste in sealed shipping containers awaiting unloading, having a surface area of 272,500 ft^2 (25,315 m^2). This area is also being permitted as a container storage unit for 1536 ft^3 (43.5 m^3) of CH and 126 ft^3 (3.6 m^3) of RH waste. The sealed shipping containers provide secondary containment in this HWMU. System descriptions for the WHB HWMU and TRU mixed waste handling systems and a description of the impermeable coating are provided in Sections D-10a(2)(b), D-10a(2)(c), and D-10a(3).

C-2 Waste Parameters

This section discusses the parameters of interest for waste characterization purposes, and the rationale for their selection.

C-2a Selecting Waste Analysis Parameters

The following analytes were selected as parameters of interest:

- Toxicity characteristic contaminants listed in 20 NMAC 4.1, Subpart II, §261.24, Table 1 (excluding pesticides)
- F-listed solvents (F001, F002, F003, F004, F005) found in 20 NMAC 4.1, Subpart I, §261.31, and known to be used at DOE sites
- Hazardous constituents included in 20 NMAC 4.1, Subpart II, §261 Appendix VIII, and reported to be present in waste generated by DOE TRU waste generator/storage sites

Table C-3 summarizes the parameters of interest and the rationale for including each parameter in this WAP. The next sections provide a description of the acceptable methods to evaluate these parameters for each waste Summary Category Group.

C-2b Criteria and Rationale for Parameter Selection

Parameters were selected for characterization based on data needed to address regulatory requirements for accepting TRU mixed waste at the WIPP miscellaneous-unit disposal facility.

Radiography will be used to examine containerized waste to ascertain its physical form. This technique can detect liquid wastes and containerized gases, which are prohibited for WIPP disposal. Prohibiting liquids and containerized gases prevents the shipment of corrosives, ignitable waste, or reactive waste. Radiography will also be able to confirm that the physical form of the waste matches its waste stream description (i.e. Homogeneous Solids, Soil/Gravel, or Debris Waste [including uncategorized metals]). If the physical form does not match the waste stream description, the waste will be designated as another waste stream and assigned

the preliminary hazardous waste codes that are inherent to the new waste stream assignment. If radiography indicates that the waste does not match the waste stream description, a non-conformance report will be completed and the inconsistency will be resolved per Section C8-13 of Appendix C8. The proper waste stream assignment will be determined, the correct hazardous waste codes will be assigned, and the resolution will be documented.

Headspace-gas samples are used to determine the types and concentrations of VOCs in the void volume of waste containers. Averages of measured headspace VOC concentrations in waste containers received at the WIPP site will be compared routinely with those used in this permit application's environmental pathway analysis demonstration to ensure that on an annual basis there are no associated adverse worker or public-health impacts. Average concentrations of VOCs in headspace gas have been used in this permit application's environmental pathway analysis to demonstrate that average annual concentrations of VOCs emitted from containers emplaced at the WIPP will be well below health-based limits (headspace gas analytical data used to determine average concentrations is provided in Appendix C-2).

For wastes that can be representatively sampled (Homogeneous Solids and Soil/Gravel Wastes), the total concentrations of PCBs, VOCs, semivolatile organic compounds (SVOC), and metals will be determined analytically. A representative sample is defined in 20 NMAC 4.1, §260.10 as "a sample of a universe or whole (e.g., waste pile, lagoon, groundwater) which can be expected to exhibit the average properties of the universe or whole."

Data on total concentration will be used to quantify the types and quantities of RCRA-regulated listed hazardous constituents, and to determine whether the waste exhibits a toxicity characteristic under 20 NMAC 4.1, Subpart II. Toxicity characteristic will be determined using total extraction analysis rather than the toxicity characteristic leaching procedure (TCLP), because total concentrations are more useful for repository compliance demonstrations[2] and result in more conservative estimates of toxicity characteristics. (Appendix C3 discusses comparability of the results of these two methods.)

Documented acceptable knowledge will be used to determine the types and quantities of listed and toxicity characteristic waste that cannot be directly sampled for total metals or total organics. Debris waste is heterogeneous, having waste forms that cannot be representatively sampled (e.g. personal protective equipment, leaded rubber gloves, manufactured goods, and natural geologic material). In these types of wastes, acceptable knowledge is used to make a hazardous waste determination. Radiography, visual examination, and headspace gas sampling will be

[2]According to 20 NMAC 4.1, Subpart IX, §270.14(b)(2), the information needed regarding the chemical and physical properties is "...all the information which must be known to treat, store, or dispose of the wastes properly in accordance with Part 264 [Subpart V]." For a mined geological repository such as the WIPP, totals analyses provides such information needed to model the solubility and transport of waste and waste constituents over the long-term. For this reason the DOE has opted to require totals analyses of representative samples of homogeneous waste.

used to verify the acceptable knowledge used. (Appendix C9 details the use of acceptable knowledge).

Table C-6 summarizes the parameters, methods, and rationales for stored and newly generated CH TRU wastes according to their waste forms, and Table C-7 is a parallel table for RH TRU wastes.

C-3 Characterization Techniques and Frequency

Generator/storage sites will characterize waste on a waste stream basis using a variety of techniques. Characterization techniques include: acceptable knowledge, radiography, headspace-gas sampling and analysis, and homogeneous solids and soils/gravel sampling and analysis.

Acceptable knowledge refers to applying knowledge of the hazardous nature of the waste based on the materials or processes used to generate the waste. This may include accompanying records; administrative, procurement and quality controls associated with the processes generating the waste; past sampling and analytical data; material inputs to the waste-generating process; and the time during which the waste was generated (certain waste-generating processes are associated with specific historical time periods). Information required for characterizing waste using acceptable knowledge includes the physical form of the waste and documented changes to the process or material inputs. Appendix C9 outlines the minimum set of requirements which must be met by the generator sites in order to use acceptable knowledge. In addition, verification of acceptable knowledge through sampling and analysis and the generator-site audit program is described in the appendix.

Acceptable knowledge is used in three ways: 1) to delineate waste streams, 2) to make hazardous waste determinations for debris waste, and 3) to determine if homogeneous solids and soil/gravel are RCRA-listed wastes. Used for these purposes, acceptable knowledge balances the requirements for providing definitive chemical and physical characterization of waste streams when it is difficult to obtain a representative sample because of the physical waste form and/or composition of the waste (e.g., metal, glass, and combustibles). This use of acceptable knowledge is outlined in *Waste Analysis: EPA Guidance Manual for Facilities That Generate, Treat, Store and Dispose of Hazardous Waste,* (EPA, 1994), where EPA has specifically referred to the characterization of mixed waste as a situation where the use of acceptable knowledge is appropriate.

Generator sites will use acceptable knowledge to sort waste containers into waste streams for the purposes of grouping waste for further characterization. Since the waste is characterized on a waste stream basis, minimal variability of hazardous constituents between waste containers in a waste stream will provide a more representative characterization of the waste stream. The analyses performed will not differ based on the waste stream, only on the physical form of the waste (i.e., debris waste cannot be sampled for totals analyses). Both stored and newly

generated wastes will be separated in this fashion, though the types of acceptable knowledge used may differ. Section C-4b discusses the use of acceptable knowledge, sampling, and analysis in more detail. Acceptable knowledge is discussed more completely in Appendix C9.

Radiography is used to verify the physical form of retrievably stored CH TRU waste and most RH TRU waste. Based on this physical form (ie, Homogeneous Solids/Soils/Gravel or Debris) it is determined whether a representative sample can be collected and totals analyses performed on the waste. For newly generated waste, physical form will be verified during packaging. Radiography is also used in conjunction with acceptable knowledge to characterize debris wastes. Radiography and the associated information compiled from acceptable knowledge (e.g., age of the waste, generating process) will be used to determine the RCRA-regulated constituents present in the waste.

All waste containers are sampled and analyzed for VOCs in the headspace gas. A statistically selected portion of homogeneous solids and soil/gravel is sampled and analyzed for RCRA-regulated total VOCs, SVOCs, and metals. Sampling and analytical methods used for waste characterization are discussed in Section C-4a.

In the process of performing organic analyses, nontarget compounds may be identified. These compounds will be reported as tentatively identified compounds (TIC). The specific procedures for positive TIC identification are implemented by the QAPP. Positively identified TICs listed in 20 NMAC 4.1, Subpart V, 264, Appendix IX,[3] will be added to the target analyte list if they are detected in 25 percent of all samples from a given waste stream as implemented in the QAPP. The DOE will add these compounds to the list of hazardous constituents for the waste stream (and additional EPA hazardous waste codes, if appropriate), and a permit modification will be submitted adding these constituents, if necessary.

Waste characterization sampling and analysis activities will differ for retrievably stored waste and newly generated waste. The waste characterization data collection design for each type of waste is described in the following sections. Figures C-1 and C-2 summarize the waste characterization data collection design for newly generated and retrievably stored waste, respectively. Table C-8 provides a summary of hazardous waste characterization requirements for all TRU mixed waste by waste characterization parameters.

C-3a Newly Generated Waste

The RCRA-regulated constituents in newly generated wastes will be documented and verified at the time of generation to provide acceptable knowledge for the waste stream. Newly generated mixed waste characterization will begin with verification that processes generating the waste have operated within established written procedures. Waste containers will be classified

[3]Appendix IX of 264 was chosen because analytical methods have been established for all analytes listed.

into waste streams using acceptable knowledge. Verification that the physical form of the waste (Summary Category Group) corresponds to the physical form of the assigned waste stream is accomplished during packaging. This process consists of the operator confirming that the waste is assigned to a waste stream that has the correct Summary Category Group for the waste being packaged. If a confirmation cannot be made, corrective actions will be taken per Section C8-13 of Appendix C8. A second operator, who is equally trained to the requirements of the WAC and QAPP (See Appendix C4, Section C4-3b for training requirements), will provide additional verification by reviewing the contents of the waste container to ensure correct reporting. If the second operator cannot provide concurrence, corrective actions will be taken per Section C8-13 of Appendix C8. The subsequent waste characterization activities depend on the assigned Summary Category Group since waste within the homogeneous solids and soils/gravel summary category groups will be characterized using different techniques than the waste in the debris waste summary category group.

All newly generated waste containers will undergo headspace-gas analysis for VOC concentrations. If the DOE believes the frequency can be reduced in the future based on trends in analytical results, it may provide technical arguments for such a reduction and request a permit modification. The headspace-gas sampling method is provided in Appendix C4, Section C4-1.

Newly generated waste streams of homogeneous solids and soils/gravel wastes will be randomly sampled a minimum of once per year for total VOCs, SVOCs and metals. Sampling frequency of once per year is only allowed if a process has operated within established bounds without any significant process changes or fluctuations. Otherwise, the waste must be considered as process batches. Significant process changes and process fluctuations can be determined using statistical process control charting techniques; these techniques require historical data for determining limits for indicator species and subsequent periodic sampling to assess process behavior relative to historical limits. If the limits are exceeded, the waste stream must be recharacterized, and the characterization must be performed according to procedures required in the QAPP for retrievably stored waste. The process behind this control charting technique is described in Appendix C6, Section C6-5.

Also, as another control of waste generated from a particular process, the bounds for a waste generating process will be established by the specific written procedures for that process. Examples of parameter bounds that could affect a waste generated by a process are volumes of input material, change in the input material, and any other changes that would change the output of that process.

To ensure that the generator site procedures for waste generating processes contain the proper controls of the waste stream, generator site waste generating process procedures must contain sections containing the following information:

- Scope

- Purpose
- Responsible organizations for implementing the requirements of the procedure
- Administrative process controls
- Material inputs
- Waste Streams Generated
- Process controls and range of operation that affect final hazardous waste determinations
- Rate and quantity of hazardous waste generated
- List of applicable operating procedures relevant to the hazardous waste determination
- Nonconformance reporting
- Process knowledge verification sampling
- Reporting and records management

Events where procedurally established bounds are exceeded or any condition of normal operation not being met are events that could trigger an increased sampling frequency of a waste stream. As long as a process does not change within a year, the waste generated by that process will have the same characteristics, and therefore, one sample could verify the lack of variability of that waste stream. Compliance with process procedures and the maintenance of the parameters specified by those procedures will be verified by WIPP during the Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C11).

The records generated by the process procedures will be examined for indications of process changes or limits being exceeded that would change the output of that process. If these changes are apparent, WIPP will verify that a follow-up sample of process waste was collected and analyzed. Records of that analysis will be available for examination by the auditors. If records of the analysis are not available, the waste stream will not be acceptable at the WIPP facility for disposal and the site may lose certification authority. If a generator site changes a process but determines that increased sampling is not required because the change will not affect waste generated by that process, the DOE/CAO must be notified in the form of a memorandum to the CAO Waste Characterization Manager. The DOE/CAO must concur with

the decision to not increase the sampling frequency before any additional waste from that process is shipped.

The toxicity characteristics of homogeneous solids and soils/gravel waste streams will be determined using total analysis of toxicity characteristic contaminants, rather than the TCLP. The sampling methods for homogeneous solids and soil/gravel wastes is provided in Appendix C4, Section C4-2.

Acceptable knowledge, examination during packaging, and headspace-gas sampling and analysis are used to characterize debris waste. When waste is being generated by processes that are driven by written procedures, the waste generated by that process can be characterized by acceptable knowledge. Other documentation besides written procedures provide useful information that can be used for acceptable knowledge. Examples of documentation used for waste characterization by acceptable knowledge practices are described in Appendix C9. RCRA-regulated metals present in debris wastes are associated with specific waste materials (i.e., lead in leaded rubber gloves, leaded glass, or lead shielding). Knowledge of the materials and operations that generated these waste streams is used to determine if they contain RCRA-regulated metals. Acceptable knowledge is further explained in Section C-4b and Appendix C9.

C-3b Retrievably Stored Waste

All retrievably stored waste containers will be examined using radiography to confirm the physical waste form (Summary Category Group), to verify the absence of prohibited items, and to determine the waste characterization techniques to be used based on the Summary Category Groups (i.e., S3000, S4000, S5000). Repackaged retrievably stored waste may be handled as newly generated waste to confirm the Summary Category Group. The applicability of Real-Time Radiography (RTR) as an example for this purpose is detailed in Appendix C5.

To confirm the results of radiography, a statistically selected number of the CH waste container population will be visually examined by opening containers to inspect waste contents to verify radiography results. Appendix C6, Section C6-1 contains the approach used to statistically select the number of drums to be visually examined.

All retrievably stored containers will undergo headspace gas analysis for VOC concentrations. The headspace gas sampling method is provided in Appendix C4, Section C4-1.

A statistically selected portion of homogeneous solids and soil/gravel wastes will be sampled and analyzed for total VOCs, SVOCs, and metals. The approach used to statistically select drums for homogeneous solids and soil/gravel wastes is different than the method used to select waste containers for visual examination. This method is also included in Appendix C6, Section C6-2. The sampling methods for these wastes are provided in Appendix C4, Section C4-2.

The toxicity characteristic of homogeneous solids and soil/gravel wastes will be determined using total analysis of toxicity characteristic parameters, rather than the TCLP. Appendix C3 discusses comparability of these analytical results to those of the TCLP method.

Representativeness of containers selected for visual examination and waste subjected to homogeneous solids and soil/gravel sampling and analysis will be validated via examination of documentation that shows that true random samples were collected. (Because representativeness is a quality characteristic that expresses the degree to which a sample or group of samples represent the population being studied, the random sampling of waste streams ensures representativeness.)

Acceptable knowledge, along with radiography and headspace-gas sampling and analysis, is used to characterize debris waste. RCRA-regulated metals present in debris wastes are associated with specific waste materials (i.e., lead in leaded rubber gloves, leaded glass, or lead shielding). Knowledge of the materials and operations that generated these waste streams is used to determine if they contain RCRA-regulated metals. Acceptable knowledge is further explained in Section C-4b and Appendix C9.

Specific waste analysis methods are documented in the Methods Manual. Alternative methods will also be approved by the DOE/CAO Manager and accepted by the NMED. The procedure for this method of submittal and approval is provided in Appendix C7. Appendix C8 discusses required analytical method quality assurance objectives (QAO) and analytical procedures. Site-specific sampling and analysis activities will be documented in the QAPjP prepared by the generator sites, and approved by the WIPP facility personnel.

C-4 Characterization Methods

The characterization techniques used by sites include acceptable knowledge, headspace-gas sampling and analysis, radiography, and solidified waste sampling and analysis. All characterization activities are performed in accordance with the QAPP and the Methods Manual. Table C-8 provides a summary of the characterization requirements for TRU mixed waste.

As part of characterization efforts, waste containers will be tested in testing batches. A testing batch is a suite of waste containers undergoing radiography using the same testing equipment. A testing batch can be up to 20 waste containers without regard to waste matrix. Samples will be collected in sampling batches. A sampling batch is a suite of samples of similar matrix (i.e., gas or solid) collected consecutively, using the same sampling equipment within a specific time period. A sampling batch can be up to 20 samples (excluding field QC samples), all of which must be collected within 14 days of the first sample in the batch. Samples will be analyzed in analytical batches. An analytical batch is a suite of samples of similar matrix (i.e., gas or solid) processed as a unit, using the same analytical method within a specific time period. An analytical batch can be up to 20 samples (excluding laboratory QC samples), all of which must be received by the laboratory within 14 days of the validated time of sample receipt of the first sample in the batch. For on-line integrated headspace-gas sampling/analytical systems, samples

sample in the batch. For on-line integrated headspace-gas sampling/analytical systems, samples will be collected and analyzed in on-line batches. An on-line batch is the number of headspace gas samples that are collected and analyzed within a 12-hour period using the same on-line integrated sampling/analysis system.

C-4a Sampling and Analytical Methods

Headspace Gas Sampling and Analysis

All TRU waste will be sampled and analyzed to determine the concentrations of VOCs (presented in Table C-9) in headspace gases. Sampling protocols, equipment, and QA/QC methods for headspace-gas sampling are provided in Appendix C4, Section C4-1. In accordance with EPA convention, identification of compounds detected by gas chromatography/mass spectrometry methods that are not on the list of target analytes must be reported. These compounds are reported as tentatively identified compounds in the waste data package and must be added to the target analyte list if detected in 25 percent of all samples from a given waste stream and if they appear in the 20 NMAC 4.1, Subpart II, 264, Appendix IX list as implemented in the QAPP. The headspace gas analysis method QAOs are specified in Appendix C8.

Homogeneous and Soil/Gravel Sampling and Analysis

The goal of sampling of homogeneous and soil/gravel wastes is to collect a sample that is representative of the waste stream. This is accomplished through core sampling, which is described in Appendix C4, Section C4-2. The waste containers for sampling and analysis are selected randomly from the population of containers for the waste stream. The random selection methodology is specified in Appendix C6.

Totals analyses for VOCs, SVOCs, and RCRA-regulated metals are used instead of the TCLP to determine waste parameters that may be important to the performance within the disposal system (Tables C-10 and C-11). If sample preparation and/or cleanup methods are required, the analyst must use the procedures specified in the Methods Manual. Alternate sample preparation or cleanup methods must be submitted for review and approval in accordance with the DOE/CAO procedure contained in Appendix C7. The generator may use the results from these analyses to determine if a waste exhibits a toxicity characteristic. The mean concentration of toxicity characteristic contaminants are calculated for each waste stream such that it can be reported with an upper 90 percent confidence limit (UCL_{90}). The UCL_{90} values for the mean measured contaminant concentrations in a waste stream will be compared to the specified regulatory levels in 20 NMAC 4.1, Subpart II, expressed as total values, to determine if the waste stream exhibits a toxicity characteristic. A comparison of total analyses and TCLP analyses is presented in Appendix C3, and a discussion of the UCL_{90} is included in Appendix C6, Section C6-3.

Laboratory Selection

The DOE will conduct analyses using laboratories that are qualified through participation in the Performance Demonstration Program (DOE, 1995c, d) and in accordance with the QAPP. These laboratories will use methods presented in SW-846, *"Test Methods for Evaluating Solid Waste, Physical/Chemical Methods"*, (EPA, 1986). In the event that the SW-846 method cannot meet program specific QAO due to the properties of TRU waste, an alternate method may be submitted to CAO for approval. Since the original method is not acceptable for use due to inability to meet QAOs, the alternative method would have to be more sensitive and stable. The methods submitted as alternatives would be more restrictive, as far as data acceptability, than SW-846 methods. Appendix C7 contains the DOE/CAO procedure for submittal and approval of alternative analytical methods. The DOE specified analytical protocols and procedures for waste characterization are published in the Methods Manual.[4] The Methods Manual acts as a unified source of information on the sampling and analytical techniques used to comply with the requirements of the QAPP. Many of the procedures found in the Methods Manual are based on analytical methods found in SW-846. In these instances, the analyst is referred directly to the SW-846 method for the requirements of the procedure. Only information unique to the waste characterization program (e.g., target analytes, QAOs, QC requirements) is included in the Methods Manual. The differences between SW-846 methods and the methods contained in the Methods Manual are presented in Appendix C12.

A performance-based approach to analytical method selection also allows individual sites the flexibility to adapt methods to meet the specified analytical method QAOs in Appendix C8. In addition, methods and supporting performance data demonstrating QAO compliance must be submitted to the CAO for review and approval in accordance with Appendix C7. Once approved, the methods will be incorporated into the Methods Manual.

Analytical methods used by the laboratories must: 1) satisfy all of the appropriate QAOs as implemented in the QAPP, and 2) be implemented through laboratory-documented standard operating procedures. These methods fulfill all of the WAP requirements. Alternative methods must demonstrate equivalency, showing that the performance characteristics of the method (e.g., detection limit, accuracy, and precision and completeness for the waste matrix in question) meet or exceed the WAP requirements and objectives. These analytical QAOs are discussed in detail in Appendix C8.

[4]Analytical procedures that have been evaluated by the DOE and shown to produce acceptable results in terms of data quality are implemented by the generator sites.

C-4b Acceptable Knowledge

RCRA regulations codified in 40 CFR Parts 260 through 265, 268, and 270, and New Mexico Hazardous Waste Management Regulations in 20 NMAC 4.1, Subparts I through Subpart VI, Subpart VIII, and Subpart IX, authorize the use of acceptable knowledge as a method which can be used in appropriate circumstances by waste generators, or treatment, storage, or disposal facilities to make hazardous waste determinations. Acceptable knowledge is defined in *Waste Analysis: EPA Guidance Manual for Facilities That Generate, Treat, Store and Dispose of Hazardous Waste* (EPA 1994) to include process knowledge, waste analysis data, and facility records of analysis performed before the effective date of RCRA regulations. Acceptable knowledge, as an alternative to sampling and analysis, can be used to meet all or part of the waste characterization requirements under RCRA (EPA 1994).

Acceptable knowledge is one of a number of techniques used to characterize TRU waste. It is used in conjunction with radiography, headspace gas sampling and analysis, and solidified waste sampling and analysis to meet the requirements of the WAP. Acceptable knowledge is used in TRU waste characterization activities in three ways:

- To delineate TRU waste streams
- To determine if TRU debris wastes exhibit a toxicity characteristic (40 CFR §261.24)
- To determine if TRU wastes are listed (40 CFR §261.31)

Acceptable knowledge is discussed in detail in Appendix C9, which outlines the minimum set of requirements which must be met by the generator sites in order to use acceptable knowledge. In addition, this appendix describes the verification of acceptable knowledge through sampling and analysis and the Generator/Storage Site Waste Screening and Acceptance Audit Program.

C-4c Radiography

Radiography is a nondestructive qualitative and quantitative technique that involves X-ray scanning of waste containers to identify and verify waste container contents. Since the system required for conducting radiography examination is fairly expensive, smaller generator sites reserve the right to conduct visual examination of waste containers in lieu of radiography. For sites that choose to use visual examination in lieu of radiography, the detection of liquid waste in non-transparent inner containers, detected from shaking the container, will be handled by assuming that any liquid that is detected is over WAC limits and the item will be rejected and/or repackaged to exclude the unacceptable characteristic. When radiography is used, or visual examination of transparent containers is performed, the same assumption will be used if the volume of liquid in inner containers is questionable. Radiography, or the equivalent, will be used on the existing/stored waste containers to verify the physical characteristics of the TRU mixed

waste correspond with its waste-stream identification/waste-stream Waste Matrix Code. This is used to determine that the sampling parameter and analysis requirements for that waste form are met. The results of radiography are verified through visual examination of a statistically selected subpopulation of CH TRU waste containers in each CH TRU waste stream. Radiographic examination protocols and QA/QC methods are provided in Appendix C4, Section C4-3.

The applicability of RTR is presented as an example of radiography in Appendix C5. However, the DOE is exploring other methods for the radiographic examination of TRU waste like digital radiography and computer tomography, which have the potential to increase the resolution of radiometric images and increase the discrimination of various waste items. These methods are being developed by DOE and private industry. Several prototype systems exist that are in the process of being validated as qualified radiographic examination methods. When these systems are completely operational and approved, per the procedure outlined in Appendix C7, they will be included in future revisions of the Methods Manual. The quality assurance, quality control and training requirements established for radiography will also apply to newly developed radiographic methods.

C-4d Quality Assurance Sampling and Analysis Requirements

The WIPP facility will assure adequate waste characterization by generator sites sending TRU mixed waste to the WIPP for disposal through appropriate data validation and usability and reporting controls. These steps will be taken at three program levels: 1) the data generation level, 2) the site project level, and 3) the WIPP facility level. These levels are shown in Figure C-5 and the validation process at each level is described in Appendix C8, Sections C8-10 and C8-11. These controls are implemented by the QAPP, by the site-prepared QAPjPs, and by site-specific SOPs. The sampling and analysis program data validation and compliance to data quality objectives (DQO) and QAOs make up the first level of control. The following general requirements must be met by the generator characterization programs:

- Raw data must be reported accurately in a pre-approved format, must be maintained in permanent files, and must be traceable.

- All data must receive a technical review by another qualified analyst, the technical supervisor, and the laboratory QA officer.

- All raw data must have the signatures of a technical supervisor and a QA officer before release.

Generator sites will be responsible for data validation and verification of waste characterization for each container and the data must be documented by release signatures from the Site Project Manager, Site Data Validation Officer, and the Site Data QA Officer. This is the second level of verification.

The DOE operates a QA/QC program to ensure and maintain the integrity of data, documents, and information associated with the management of TRU mixed waste. The following waste characterization activities are described within this subsection: QA/QC control procedures, DQOs, QAOs, data generation, data transmittal, data verification, and records management.

The WIPP will also institute QA/QC control over the waste characterization program through the Generator/Storage Site Waste Screening and Acceptance Audit Program. This audit program is discussed in Section C-5 of this chapter and Appendix C11.

QA/QC Control Practices

Waste characterization QA/QC ensures that the characterization data obtained at generator sites are suitable for regulatory compliance purposes. The WIPP facility implements stringent QA/QC over the generation, transmittal, and verification of data from waste characterization determinations. In addition, the WIPP facility extends QA/QC practices to the management of all records associated with waste shipment screening determinations.

Data Quality Objectives

As previously described, the waste characterization data obtained through this WAP implementation will be used to ensure that the WIPP facility meets regulatory requirements with regard to both regulatory compliance and to ensure that all wastes are properly managed during the Disposal Phase. The DQOs established for this plan are implemented by the QAPP. They are designed to address the specific waste characterization parameters that will be evaluated. To satisfy the RCRA regulatory compliance requirements, the following DQOs are established by this WAP and have been incorporated into the QAPP (DOE, 1995a):

- Headspace-Gas Sampling and Analysis
  - To quantify the concentrations of VOC constituents in the total waste inventory to ensure compliance with the environmental performance standards of 20 NMAC 4.1, Subpart V, §264.601(b).
- Total Analysis of Homogeneous solids and soil/gravel
  - To compare UCL_{90} values for the mean measured contaminant concentrations in a waste stream with specified toxicity characteristic levels in 20 NMAC 4.1.
  - To report the average concentration of hazardous constituents in a waste stream, as specified in 20 NMAC 2.1, Subpart II, 261, Appendix VIII, with a 90 percent confidence interval.

- Radiography

  – To verify the TRU waste streams by Waste Matrix Code for purposes of physical waste form identification and determination of sampling and analytical requirements.

- Visual Examination

  – To verify the TRU waste streams by Waste Matrix Code for purposes of physical waste form identification and determination of sampling and analytical requirements.

  - To provide a process check on a sample basis by verifying the information determined by radiography.

Reconciliation of these DQOs by the Generator/Storage Site Project Manager is addressed in Appendix C8, Section C8-11.

Quality Assurance Objectives

Each characterization method described in the QAPP has a corresponding set of QAOs that are intended to provide assurance that the data generated by that method is of known quality. The generator sites must demonstrate compliance with each QAO associated with the various characterization methods as described in the QAPP. Site Project Managers are further required to perform a reconciliation at the project level of the data sets submitted by the various organizations at the site with the DQOs established in this WAP and implemented in the QAPP. The Site Project Manager must determine that all of the DQOs have been met for the characterization of the waste stream prior to submitting a Waste Stream Profile Form to WIPP for approval (Appendix C8, Section C8-11). The following QAO elements must be considered for each technique as a minimum:

- Precision

  - Precision is a measure of the mutual agreement among multiple measurements.

- Accuracy

  - Accuracy is the degree of agreement between a measurement result and the true or known value.

- Completeness

  - Completeness is a measure of the amount of valid data obtained from a method compared to the total amount of data obtained that is expressed as a percentage.

- Comparability

  - Comparability is the degree to which one data set can be compared to another.

A more detailed discussion of the QAOs, including a mathematical representation, where appropriate, can be found in Appendix C8, which describes the QAOs associated with each method of analysis.

Sample Control

The sites will implement a sample handling and control program that will include the maintenance of field documentation records, proper labeling, and a chain of custody (COC) record. The site QAPjP will document this program and include COC forms to control the sample from the point of origin to the final analysis result reporting. WIPP will review and approve the QAPjP, including the determination that the sample control program is adequate. Details of this sample control program are provided in Appendix C4 and are summarized below to include:

- Field Documentation of samples including: point of origin, date of sample, container ID, sample type, analysis requested, and COC number.

- Proper Labeling and/or tagging including: proper sample numbering, sample ID, sample date, sampling conditions, and analysis requested.

- Chain-of-Custody control including: name of sample relinquisher, sample receiver, and the date and time of the sample transfer.

- Proper sample handling and preservation.

Data Generation

The DOE's waste characterization program implements the programmatic QA requirements in Chapter 1.0 of SW-846 (EPA, 1986), and the DOE/CAO verifies these requirements through QAPjP review and approval. The generator site QAPjPs are controlled by the QAPP. The QAPP identifies the specific requirements for all QAPjPs including: DQOs; QAOs; sampling procedures; sample custody procedures; calibration procedures and frequencies; analytical procedures; data reduction, validation, and reporting requirements; internal QC checks and frequencies;

performance and system audits and frequencies; preventive maintenance; procedures for assessing data quality; and procedures for corrective actions.

A pre-approved format will be used by each generator site for reporting waste characterization data. This form will be defined by the generator site QAPjP. The data reporting format will include all of the elements required by this WAP and implemented through the QAPP for data reports (Appendix C8, Section C8-12). The generator site must prepare data packages to meet the requirements of QAPjPs. All generator site QAPjPs are reviewed and approved by the DOE/CAO (See Appendix C10).

The DOE/CAO will perform audits of the generator site waste characterization programs to verify that site sampling, data collection, data validation, and reporting practices, as implemented by the site QAPjPs, will meet DQOs in this WAP (Generator/Storage Site Waste Screening and Acceptance Audit Program). The primary functions of these audits are to review data packages prepared by the generator sites that demonstrate adherence to the requirements of this WAP and assure adherence to the written, approved characterization program (as required by their QAPjPs). These audits ensure that implementation of the QAPjPs are consistent with the intent of the requirements of this WAP as implemented by the QAPP. Section C-5 and Appendix C11 provide additional information on the audits of the generator sites performed by the DOE/CAO.

The DOE/CAO further requires all analytical laboratories analyzing WIPP waste characterization samples for the generator sites to have established, documented QA/QC programs. The DOE/CAO annually evaluates these laboratories and their QA/QC programs as part of their participation in the laboratory performance program. The audits cover the requirements of the lab's QA/QC program as well as compliance with the method parameters specified in the Methods Manual, this WAP, and the QAPP. Continued compliance with these parameters will be verified by ongoing CAO audits. The laboratory's QA/QC program must include the following:

- Facility organization
- A list of equipment/instrumentation
- Operating Procedures
- Laboratory QA/QC Procedures
- Quality Assurance Review
- Laboratory Records Management

Data Transmittal

The DOE/CAO, through the QAPP and generator site QAPjPs, controls aspects of the waste-characterization data transmittal process. Data reports document the analytical results from the required characterization analyses and contain the characterization data plus documentation of required QA/QC activities associated with the sampling and analyses. The QAPP implements the WAP requirements for maintaining the integrity of the data in data reports by requiring data validation at both the data-generation level and the generator-site project level before the data are transmitted to the WIPP facility. Section C8-10 of Appendix C8 discusses the data validation process in more detail.

Data will be transmitted by hard copy from the data generation level to the generator site TRU mixed waste characterization project level. Transmitted data will include testing, sampling, and analytical data reports and data review checklists on forms approved under the generator sites QAPjP. Testing, sampling, and analytical data will be reported for each waste container. These data will also be input electronically into the WWIS. Data will be entered into the WWIS in the exact format required by the database (see Section C-5a for WWIS data requirements and Appendix C13 for the WWIS data dictionary). Summarized characterization information will be reported on a waste stream basis and transmitted by hard copy to the WIPP Waste Operations when requested. Hard copy data packages will include site name, program identification, waste container numbers, release signatures from the generator Site Project Manager and Site Project QA Officer, and a concise narrative summarizing the results of the site project-level review. Section C8-12 of Appendix C8 provides the format requirements for generator/storage site data reports; both hard copy and electronic. The report will briefly describe any problems or noteworthy observations (e.g., nonconformance reports, operational variances).

Once a waste stream is fully characterized, the site project manager will also submit to the WIPP facility a summary of the waste stream information and reconciliation with DQOs (Section C8-11 of Appendix C8). Based on this summary, the generator site project manager will complete a Waste Stream Profile Form (Figure C-4). This will be used as the basis for acceptance of waste characterization information on wastes to be disposed of at the WIPP.

Data Verification

The first level of data verification by the generator site will confirm that the waste characterization data are properly reported for the characterized waste containers that will be shipped to the WIPP. Data review, validation, and verification procedures used by the generator sites are required by the QAPP to assure that 100 percent of the data reported has received an independent technical review to assure that data generation and reduction were conducted in a technically correct manner, calculations have been verified correct, and all variances from accepted analytical methods (appropriate to the waste type being analyzed) have been documented and approved. Data packages will be reviewed for completeness to verify that they include field sampling records, raw analytical data, calculation records, COC documentation,

calibration records, QA sample results, and that sample holding times and preservation methods were met or exceptions documented. Completed data must be signed by the technical supervisor. At the second level of verification, the Site Project Manager, the Site Data Validation Officer, and the Site Data QA Officer will also ensure that a repeat of this review is performed for at least one randomly chosen container quarterly. Finally, a check for the data package elements required by the QAPP will be performed by the WIPP Waste Operations section as the third level of verification for data packages to assure that data packages are complete. Figure C-5 shows the components of each level of data verification. Data verification is discussed in more detail in Appendix C8, Section C8-10.

Records Management

Records related to waste characterization sampling and analysis activities at the generator sites will be maintained in the testing, sampling, or analytical facility files or site project files for those facilities located on sites. Contract waste analytical facilities will forward testing, sampling, and analytical QA documentation along with testing, sampling, and analytical batch data reports to the site project office for inclusion in site central files.

All waste characterization data and related QA/QC records in the site project files for waste to be shipped to the WIPP facility are designated according to NQA-1, Supplement 17S-1, as either Lifetime Records or Non-Permanent Records. Records designated as Lifetime Records shall be maintained for the life of the waste characterization program at a participating site plus six years then offered to the DOE/CAO. Waste characterization records designated as Non-Permanent Records shall be maintained for five years from the date of (record) generation and then discarded. Table C-13 provides a listing of records designated as Lifetime Records and Non-Permanent Records. Records, both Lifetime and Non-Permanent, shall also be maintained during the course of any enforcement action for which they are relevant. An appropriate records inventory and disposition schedule shall be prepared and approved by appropriate site personnel. Site personnel responsible for all aspects of records management shall be identified in the QAPjPs.

All waste characterization data and related records sent to the DOE/CAO are designated as Permanent by the WIPP facility. These records shall be maintained by DOE/CAO or WID for the active life of the WIPP facility plus two years. The active life of the WIPP facility is defined as the Disposal Phase and the Decommissioning Phase. These records shall also be maintained during the course of any enforcement action for which they are relevant. At the time of records disposition, the records shall be sent to the Federal Records Center. These records will then be transferred to the National Archives after an additional 30 years. However, this disposition requirement does not preclude the inclusion of these records in the permanent marker system or other requirements for institutional control.

Raw data obtained by testing, sampling, and analyzing TRU waste in support of this WAP will be identifiable, legible, and provide documentary evidence of quality. The reporting requirements

are different for each technique used, but the forms for data reporting will be pre-approved forms, provided in site-specific documentation

C-5 Verification for TRU Mixed Waste

The third level of data verification, which is performed at the WIPP facility, involves screening and verification of waste stream data and waste shipments. Documentation on waste streams will be screened and verified to ensure that the waste is acceptable for disposal at the WIPP facility according to applicable RCRA requirements. Quality controls related to waste labeling, identification, transport, and screening will ensure that the waste packages arriving at the WIPP facility are the same as those transported from the generator sites and are correctly identified on the EPA Hazardous Waste Manifest.

WIPP waste screening is a two-phased process. Phase I will occur prior to transporting the waste to the WIPP facility. Phase II will occur after the waste shipment arrives but before it is emplaced. Figure C-6 presents the waste shipment screening process.

C-5a Phase I Waste Stream Screening and Verification

The first phase of the waste screening and verification process will occur before waste is shipped to the WIPP site. Before WIPP will begin the process of accepting waste from a generator site, an initial audit of that site will be conducted as part of the Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C11). The RCRA portion of the generator site audit program will provide on-site verification of characterization procedures, data package preparation, and recordkeeping. The secondary verification step is the waste-characterization data package completeness/accuracy review and acceptance by the WIPP as part of the Waste Stream Profile Form approval process. At the WIPP facility, screening includes verification that all of the required elements of a data package are present (Appendix C8, Section C8-12) and that the waste characterization data meet acceptance criteria required for compliance with the WAP.

Once a generator site has prepared a QAPjP in accordance with the QAPP, it is submitted to the DOE/CAO for review and approval (See Appendix C10). The generator site will implement the specific parameters of the QAPjP once it is approved. The initial site RCRA audit will be performed at some point after this implementation has taken place and before a Waste Stream Profile Form has been submitted to the WIPP for approval. The checklists used in this audit will be based on each site's QAPjP. Additional audits, focusing on results of waste characterization, will be performed at least annually. The WIPP has the right to conduct unannounced audits and to examine any records that are related to the scope of the audit. More detail about this audit program is provided later in this section and in Appendix C11.

When the required waste stream characterization data have been collected by a generator and the initial site audit has been successfully completed, the generator Site Project Manager can

verify that waste stream characterization meets the WAP requirements as a part of the Level 2 data verification required by the QAPP (Appendix C8, Section C8-11). If the waste characterization does not meet the requirements of the WAP, the waste stream cannot be sent to the WIPP until those requirements are met. The generator will complete a Waste Stream Profile Form and submit it to Waste Operations, along with the accompanying waste characterization documentation for that waste stream. This provides notification that the generator considers that the waste stream (identified by the waste stream identification number) has been adequately characterized for disposal according to the WIPP facility approved QAPjP and QAPP DQOs.

The Waste Stream Profile Form is provided as Figure C-4. It includes information on the generator site name and EPA identification number, the technical contact for information on that waste stream, the WIPP ID, Summary Category Group, listing of acceptable knowledge documentation used, and waste characterization data package identification numbers associated with that waste stream. The form also requires the date of the WAC certification for that waste stream, procedures used for characterization, and EPA Hazardous Waste Code designations. Upon WIPP facility approval of the waste stream for disposal through the use of the Waste Stream Profile Form, the generator may begin shipping waste containers from that waste stream.

As part of the waste characterization data submittal, the generator site will also transmit the data on a container basis via the WWIS database. This data submittal can occur at any time as the data are being collected. The system will conduct internal limit checks as the data are entered, and the data will be available to WIPP personnel for review as supporting information for Waste Stream Profile Form review.

If discrepancies arise as a result of this review, the generator sites will be contacted by WIPP Waste Operations and required to provide the necessary additional information to resolve the discrepancy before that waste stream is approved for disposal at the WIPP facility. If the discrepancy is not resolved, the waste stream will not be approved.

WIPP WWIS Description

The WWIS is an electronic database that contains information and data related to the characterization, certification, and the shipment of waste destined for WIPP. The database design contains different modules for waste characterization data (as required by the QAPP and RCRA), waste certification data (as required by the WAC), and transportation data (as required by the TRUPACT-II Authorized Methods for Payload Control (TRAMPAC). The database contains edit, limit, and other data check functions to ensure that data supplied meet the requirements and the limits of the QAPP, RCRA, the WAC, and the TRAMPAC. All TRU waste sites planning to ship waste to WIPP will supply the required data to the WWIS. The WWIS will verify that all of the supplied data meet the edit and limit checks prior to the shipment of any waste to WIPP. The WWIS database will notify the generator site if any of the supplied data fails to meet the requirements of the edit and limit checks via an appropriate error message. The generator site

will be required to correct the discrepancy with the waste or the waste data and re-transmit the corrected data prior to acceptance of the data by the WWIS. WIPP facility personnel will review data reported for each container of each shipment prior to providing notification to the shipping site that the shipment is acceptable. Table C-12 gives a partial listing of the data fields contained in the WWIS.

The WWIS will generate the following:

- Container Emplacement Report

  This report will be added to the operating record as an indication of the quantities of waste, date of emplacement, and location in the repository. This report will be generated on a shipment basis. Reports that are included as part of the operating record will be retained at the site, for the life of the facility.

- Shipment Summary Report

  This report will contain the container IDs of every container in the shipment, listed by TRUPACT-II number and by assembly number (for seven packs), for every assembly in the TRUPACT-II. This report is used by Waste Operations to verify containers in a shipment and will be generated on a shipment basis.

- Characterization Data Report

  This report will be generated on a waste stream basis and will be used by the WIPP in the Waste Stream Profile Form review and approval process. This report will contain the data listed in the Waste Characterization Data Module on Table C-12. This report will be generated and attached to the Waste Stream Profile Form for inclusion in the facility operating record and will be kept for the life of the facility.

- Reports of Change Log

  This will consist of a short report that lists the user ID and the fields changed. The report will also include a reason for the change. A longer report will list the information provided on the short report and include a before and after image of the record for each change, a before-record for each deletion, and the new information for added records. These reports provide an auditable trail for the data in the database.

Access to the WWIS will be controlled by a Data Administrator (DA) of the Waste Operations section who will control the WWIS users based on approval from management personnel. Integrity of the WWIS data will be maintained by strict access control to the database. The WWIS system is located in a limited access area within the WIPP site. Access to the computer room area where the WWIS system will reside is controlled through a cipher lock door system whose combination is only granted to authorized personnel. This computer room also houses the systems that provide the WIPP local and wide area networks, and is staffed by experienced computer operators on a 24 hour basis.

The WWIS will be included in the contingency planning performed by the Information Technology Resources (ITR) Section at the WIPP site. This section operates the computer room. This planning includes dual storage (other than the computer room) of software backup tapes that will permit rapid restart of the system.

The computer room is provided with power by a uninterruptible power supply system that can provide clean, harmonic filtered power for 30 minutes after the loss of the primary power supply. This will provide for an orderly shutdown of the database.

Nightly backups of the WWIS system will occur as part of the overall backup program for all of the systems. The database can be restarted, if for whatever reason, a catastrophic failure occurs using the previous day's backup copy. In addition to the nightly backup procedure, the database will be archived quarterly and annually. The archived copies will be included in the operating record and retained for the life of the facility.

The WWIS system hardware and application software is constructed using client-server architecture. The client software will provide the user interface and communication to the server. This limits user access only to those database functions approved by the WIPP, such as allowing the small quantity generator sites to populate a defined data structure established on the system for them by the WIPP. Onsite terminals are located within controlled access areas designated for use by authorized WWIS users. Offsite access will be by direct log in through multi-layer password/user ID methodology. The first layer of control will provide authorized access to the WIPP network, the second layer will provide authorized users access to the WWIS system, and the third layer defines the specific functions of the WWIS that each user has been assigned. Access to the various WWIS functions is controlled by the WWIS DA. All access attempts will be logged by the system. Waste Operations and ITR personnel will routinely review the logs for the purpose of identifying and investigating unauthorized access attempts.

The TRU waste generator sites will only have access to data that they have supplied, and only until the data have been formally accepted by the WIPP. After the data have been accepted, the data will be protected from indiscriminate change and can only be changed by a qualified DA.

The database has a Data Change Log that will require a reason for the change from the DA prior to accepting the change. The data change information, the user ID of the qualified DA making the change, and the date of the change will be recorded in the data change log automatically. The data change log cannot be revised by any user, including the DA. The data change log will be subject to internal and external audits and will provide an auditable trail for all changes made to previously approved data.

Examination of the Waste Stream Profile Form

Members of the Waste Operations section will be responsible for the verification of completeness and accuracy of the Waste Stream Profile Form. This verification will consist of a review of the Waste Stream Profile Form by the Environmental Compliance and Support section and the Quality Assurance department. These groups will review the Waste Stream Profile Form based on their area of responsibility. Of particular importance are the assignment of the waste-stream description, Waste Matrix Code Group, and Summary Category Groups, the results of waste analyses, the acceptable knowledge documentation, the methods used for characterization, the WAC certification, and appropriate designation of EPA hazardous waste code(s). If the waste stream profile form is considered to be inaccurate, efforts will be made to resolve discrepancies by contacting the generator site. If discrepancies in the waste stream are detected at the generator site, the QAPP requires the site to implement a non-conformance program to identify, document, and report discrepancies (Appendix C8, Section C8-13). The QAPP requires that site management at all levels shall foster a "no fault" attitude to encourage the earliest identification of discrepancies and/or deviations from protocols. The Waste Stream Profile Form must pass all verification checks at the WIPP facility in order for the waste stream to be approved for shipment to the WIPP facility.

The identified EPA hazardous waste codes for the wastes that appear on the Waste Stream Profile Form will be compared to those in the WIPP RCRA Part A to ensure that only wastes that contain constituents contained in the Part A are approved for shipment to the WIPP. The analytical data package summaries will be reviewed to verify that the waste has been classified correctly. The analytical method used will be compared to those listed in Tables C-9, C-10, and C-11 to assure that only approved analytical methods were used for analysis of the waste. Waste Operations will verify that WAC certification has been granted to the generator.

Environmental Compliance and Support will verify three different types of data related to WAC on every container holding TRU mixed waste before a shipment leaves the generator site for the WIPP facility. The three verifications will be performed on data from the following determinations: 1) an assignment of the waste stream's waste description (by waste matrix codes) and Waste Matrix Code Group; 2) a determination of ignitability, reactivity, and corrosivity; and 3) a determination of compatibility. The verification of waste stream description will be performed by reviewing the waste characterization data package for consistency in the waste stream description. The data package will also indicate if the waste has been checked for the characteristics of ignitability, corrosivity, and reactivity. The final verification of waste

compatibility will be performed using Appendix C1, the compatibility study. Since the Part A does not include hazardous waste codes that are not consistent with the WAC, a consistency check between the hazardous waste codes listed in the data package for the waste stream and the hazardous waste codes listed on the Part A will verify that the waste stream is not ignitable, corrosive, or reactive, and that it is compatible with the other waste to be disposed of at the WIPP facility.

Generator/Storage Site Waste Screening and Acceptance Audit Program

An important part of the WIPP's verification process is the Generator/Storage Site Waste Screening and Acceptance Audit Program implemented by representatives of the DOE/CAO and WID. The focus of this audit program is compliance with the QAPP, site QAPjPs, this WAP, and the RCRA. The RCRA compliance portion of the audits will be performed by the Environmental Compliance and Support section. This audit program addresses all waste sampling and analysis activities, from waste-stream classification assignment through final loading of the TRUPACT-II or shielded road cask, and ensures that SOPs are being followed and the QAPjPs are fully implemented. Audits will assure that containers and their associated documentation are adequately tracked throughout the waste handling process. Operator qualifications will be verified, and QA/QC procedures will be surveyed. Results of all generator site audits will be kept in the WIPP facility operating record until closure of the facility.

An initial audit will be performed at each generator site performing waste characterization activities prior to the formal acceptance of the Waste Stream Profile Forms and/or any waste characterization data supplied by the sites. Audits will be performed at least annually thereafter, including the possibility of unannounced audits (this means not a regularly scheduled audit). These audits will verify that the generator site has implemented a QA program for the characterization of waste. The accuracy of physical waste description and waste stream assignment provided by the generator site will be verified by review of the radiography results, and visual examination of data records and radiography videotapes (as necessary) during audits. More detail on this audit process is provided in Appendix C11.

C-5b Phase II Waste Shipment Screening and Verification

Phase II of the waste shipment screening and verification process includes examination of a waste shipment after the waste shipment has arrived. The second-phase determinations are: 1) a determination of the completeness and accuracy of the EPA Hazardous Waste Manifest; 2) a determination of waste shipment completeness; 3) a determination of land disposal restriction notice completeness; and 4) an identification and resolution of waste shipment irregularities. Only those waste containers that pass all Phase II waste-screening determinations will be emplaced at the WIPP. For each container shipped, the generator site must provide the following information:

Typical Hazardous Waste Manifest Information:

- Generator site name and EPA ID
- Generator site contact name and phone number
- Quantity of waste
- List of the hazardous waste codes in the shipment
- Listing of all container IDs
- Signature of authorized generator representative

Typical Land Disposal Restriction Notice Information:

- EPA Hazardous Waste Number(s)
- Applicable treatment standards for F001-F005 wastes (D001-D003 wastes prohibited by the WAC)
- Supporting analyses and/or references to previously supplied analytical data (Such as Characterization Reports and data submitted to the WWIS)

Specific Container information:

- Waste Stream Identification Number
- List of Hazardous Codes per Container
- Certification Data (Nuclide info, etc.)
- Shipping Data (Assembly numbers, ship date, shipping category, etc.)

This information must also be supplied electronically to the WWIS and may be provided to the WWIS as part of the Phase I Screening or may be supplied at the time of shipment.

Waste Operations personnel will verify that all this information is provided for each container received. The ID will be compared with a list of those approved for disposal at the WIPP.

Examination of the EPA Uniform Hazardous Waste Manifest and Associated Waste Tracking Information

Upon receipt of a waste shipment, Waste Operations will make a determination of EPA Uniform Hazardous Waste Manifest completeness and sign the manifest to allow the driver to depart. Waste Operations will make a determination of waste shipment completeness by checking the unique, bar-coded identification number found on each container holding TRU mixed waste after opening the TRUPACT-II or shielded road cask. The bar-coded identification number(s) will be noted and checked against the WWIS database. The RH waste canister has a unique identification number stamped into it which will be verified in the Hot Cell during transfer to the facility cask. The WWIS computer database will maintain waste container receipt and emplacement information provided by the WIPP site. It will include, among other items, the following information associated with each container of TRU mixed waste:

- Package (container) receipt date
- Overpack identification number (if appropriate)
- Package (container) emplacement date
- Package (container) emplacement location (panel/room)

The WWIS links the bar-coded identification numbers of all containers in a specific waste shipment to the waste assembly (for 7-packs) and to the shipment identification number, which is also written on the EPA Hazardous Waste Manifest. Generators electronically transmit the waste shipment information to the WWIS before the waste shipment is transported. Once a waste shipment arrives, WIPP facility personnel can verify the identity of each container using the data already in the WWIS.

If there are discrepancies on the manifest, the generator will be contacted for resolution. A manifest discrepancy is a difference between the quantity or type of hazardous waste designated on the manifest and the quantity or type of hazardous waste a facility actually receives. Manifest discrepancy resolution is accomplished by contacting the generator site technical contact (as listed on the manifest). If the discrepancy is identified prior to the containers being removed from the TRUPACT-II, the waste will be retained in the parking area. If the discrepancy is identified after the waste containers are removed from the TRUPACT-II, the waste will be retained in the WHB. Errors on the manifest can be corrected by the accepting facility with a verbal concurrence by the generator. Discrepancies not resolved within 15 days of receiving the waste will be reported to the NMED. Notifications to the NMED will consist of a letter describing the discrepancies, attempts to reconcile the discrepancies, and a copy of the manifest. If the waste containers reside in the TRUPACT-II and the manifest discrepancies have not been resolved within 30 days of waste receipt, the shipment will be returned to the generator/storage facility. If it becomes necessary to return waste containers to the generator site, a new EPA Uniform Hazardous Waste Manifest will be prepared.

Documentation of the returned containers will be covered by Waste Operations protocols and the WWIS. Changes will be made to the WWIS data to indicate the current status of the container(s), and a reason will be required to change the data. This reason, plus the record of the WWIS data change will be maintained in the change log of the WWIS and will provide an auditable record of the returned shipment.

The Waste Operations section will be responsible for resolution of discrepancies, notification of the NMED, as well as returning the original copy of the manifest to the generator. The manifest will be returned within 30 days of delivery of the waste.

Examination of the Land Disposal Restriction (LDR) Notice

Unless TRU mixed waste is otherwise exempted from the LDRs, the DOE intends to petition the EPA for a variance from the prohibition on land disposal of untreated TRU mixed waste at the WIPP facility. If successful, the WIPP facility may dispose of the restricted waste. With each waste shipment of LDR waste, the generator must provide the WIPP facility with a LDR determination and a notice that the waste is not prohibited from land disposal because the waste is covered by a no-migration determination (NMD). (This assumes that a Disposal-Phase NMD will be made by the EPA. Wastes will be in conformance with conditions of the NMD.) WIPP facility personnel will review this notice for accuracy and completeness. The generator will prepare this notice in accordance with the requirements of 20 NMAC 4.1, §268.7(a)(3).

Verification

Waste Operations will make a determination of waste shipment irregularities. The following items will be noted for each waste shipment arriving at the WIPP facility:

- The number and type of containers holding TRU mixed waste match the information in the WWIS
- Container defects

Waste Operations will verify that the containers (as identified by their container ID numbers) are the containers for which accepted data already exists in the WWIS. A check will be performed by Waste Operations comparing the data on the WWIS Shipment Summary Report for the shipment to the actual shipping papers (including the EPA Hazardous Waste Manifest). This check also verifies that the containers included in the shipment are those for which approved shipping data already exist in the WWIS Transportation Data Module (Table C-12). For SWBs and TDOPs, this check will include comparing the barcode on the container with the shipping papers and the data on the WWIS Shipment Summary Report. For 7-pack assemblies, one of the seven container barcodes will be read by the barcode reader and compared to the assembly information for this container on the WWIS Shipment Summary Report. This will automatically identify the remaining six containers in the assembly. This process enables Waste Operations

to identify all of the containers in the assembly with minimum exposure. If all of the container IDs and the information on the shipping papers agree with the WWIS Shipment Summary Report, the operator is assured that the containers have been approved for disposal at the WIPP facility.

Waste Shipment Screening QA/QC

Waste shipment screening QA/QC ensures that waste received is that which has been approved for shipment during the Phase I screening. This is accomplished by maintaining stringent QA/QC control of the waste shipment screening process. The screening process will be controlled by administrative processes which will generate records documenting waste receipt that will become part of the waste receipt record. The waste receipt record documents that container identifications correspond to shipping information and approved waste streams. The WIPP extends QA/QC practices to the management of all records associated with waste shipment screening determinations.

Records Management

As part of the WIPP facility's operating record, data and documents associated with waste characterization data are managed in accordance with standard records management practices. The storage of WIPP's copy of the manifest, LDR information, waste characterization data, waste stream profile forms, and other related records will be identified on the appropriate records inventory and disposition schedule for Waste Operations.

Waste characterization data and documents related to waste characterization that are part of the WIPP facility operating record are managed in accordance with the following guidelines:

General Requirements

- Records must be legible
- Corrections must be made with a single line through the incorrect information, and a date and initial of the person making the correction
- Records must be paginated indicating the total number of pages that make up the record
- Black ink is encouraged, unless a copy test has been conducted to ensure the other color ink will copy
- Use of highlighters on records is discouraged
- Records must be reviewed for completeness
- Records must be validated by the cognizant manager

Records Storage

- Active records must be stored when not in use

- Quality records must be kept in a one-hour (certified) fire-rated container or a copy of a record must be stored separately (sufficiently remote from the original) in order to prevent destruction of both copies as a result of a single event such as fire or natural disaster
- Unauthorized access to the records is controlled by locking the storage container or controlling personnel access to the storage area

The following records will be maintained for waste characterization purposes as part of the WIPP facility operating record:

- Completed WIPP Waste Stream Profile Forms and accompanying documentation
- Completed Waste Receipt Checklists
- WIPP WWIS Container Emplacement Report
- Audit reports and corrective action reports from Generator/Storage Site Waste Screening and Acceptance Audit Program audits

These records will be maintained for each TRU mixed waste container managed at the WIPP facility.

Records at the WIPP facility will be managed in accordance with the CAO Quality Assurance Program Description (QAPD) record management requirements. The QAPD provides for generation of QA records; QA guidelines; indexing of QA records; classification of QA records; receipt of QA records; storage, preservation, and disposition of QA records; and retrieval of QA records.

Waste Shipment Tracking QA/QC

The Transportation Tracking and Communications System is a unique waste shipment monitoring system that will provide 24-hour-per-day feedback to the WIPP facility via satellite on the location and status of each waste shipment during transport.

C-6 List of References

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TABLES

TABLE C-1
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Homogeneous Solids—S3000	Solidified Inorganics	1000	AL-W005	Solidified Aqueous Liquids/Slurries				
	Solidified Inorganics	3150	IN-W157	Solidified Process Residues	ID 213	004	4	Solidified Liquid
	Solidified Inorganics	3150	IN-W166	Solidified Process Residues	ID 114	114	1	Inorganic Process Solids and Soils
	Solidified Inorganics	3150	IN-W177	Solidified Process Residues		835		
	Solidified Inorganics	3150	IN-W179	Solidified Process Residues	MD 111A	836	1	
	Solidified Inorganics	3150	IN-W181	Solidified Process Residues	ID 211A	978	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3150	IN-W188	Solidified Process Residues	ID 211A	976	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3150	IN-W216	Solidified Process Residues	ID 211A	001	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3150	IN-W220	Solidified Process Residues	ID 111	111	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3113	IN-W221	Absorbed Aqueous Liquids	ID 113	113	4	Solidified Liquid
	Solidified Inorganics	3150	IN-W222	Solidified Process Residues	ID NYD	292		
	Solidified Inorganics	3121	IN-W228	Solidified Wastewater Treatment Sludges	ID 211A	002	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3150	IN-W332	Solidified Process Residues		204		
	Solidified Inorganics	3113	IN-W347	Absorbed Aqueous Liquids		102		

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Homogeneous Solids—S3000	Solidified Inorganics	---	LA-W002	Solidified Aqueous Waste	LA 111A; 211A	002	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	---	LA-W003	Dewatered Sludge	LA 111B; 211B	003	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	---	LA-W006	Cemented Process Resldues	LA 114A	006	1	Inorganic Process Solids and Soil
	Solidified Inorganics	---	LL-W019	Solidified Waste	LL 111	002	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3150	MD-W002	Absorbed Aqueous Liquids				
	Solidified Inorganics	3120	OR-W042	Inactive Storage Tank Contents—MTRU Sludge				
	Solidified Inorganics	1220	PA-W014	Solidified TRU Waste Liquids				
	Solidified Inorganics	3129	PA-W015	TRU Solid				
	Solidified Inorganics	1190	PA-W015A	TRU and Technetium Waste				
	Solidified Inorganics	3150	RF-M001	Solidified Process/TRM	RF 114	806	1	Inorganic Process Solids and Soils
	Solidified Inorganics	3150	RF-W010	Solidified Aqueous Sludge/ TRM	RF 111	800 803 807	1	Inorganic Waste Water Treatment Sludge
	Solidified Inorganics	3121	RF-W038	Solidified Laboratory Waste/TRM	RF 113	802	4	Solidified Liquid

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Homogeneous Solids—S3000	Solidified Inorganics	3111	RF-W040	Incinerator Ash/TRM		419 420 421 425 428		
	Solidified Inorganics	3119	RF-W059	Sand, Slag, and Crucible/ TRM		387 392 390 393 395 394 396 399 391		
	Solidified Inorganics	1190	RF-W063	Miscellaneous TRM		070 503 400 508 401 527 500 541		
	Solidified Inorganics	6290	RF-W065	Calcium Metal/TRM		333		
	Solidified Inorganics	3129	RF-W068	Particulate Sludge/TRM		292 299 372 823		
	Solidified Inorganics	3119	RF-W076	Process Residues/TRM		289 372 292 422 299 423 340		
	Solidified Inorganics	---	RL-M005	TRU Mixed Homogeneous Solids with Mercury				
	Solidified Inorganics	---	RL-M032	TRU Mixed Inorganic Homogeneous Solids				

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Homogeneous Solids—S3000	Solidified Inorganics	3111	SR-W053	Ash				
	Solidified Inorganics	3129	IN-W146	Uncategorized Inorganic Sludges				
	Solidifed Inorganics	3000	OR-W046	Solidified Liquid Low Level Waste Tanks - Sludge				
	Solidified Organics	3150	IN-W167	Solidified Process Residues	ID 112	112	4	Organic Liquid and Sludge
	Solidified Organics	3113	IN-W174	Absorbed Aqueous Liquids		834		
	Solidified Organics	3114	IN-W309	Organic Setups	ID 212	003	4	Organic Liquid and Sludge
	Solidified Organics	3222	RF-W013	Solidified Organics/TRM	RF 112	801	4	Organic Liquid and Sludge
	Solidified Organics	3212	RF-W069	Organic Resins/TRM	RF 126	430 431 809	3	Cation and Anion Exchange Resins
	Solidified Organics	---	RL-M017	TRU Mixed Organic Labpacks				
	Solidified Organics	---	RL-M018	TRU Mixed Organic Labpacks (State only)				
	Solidified Organics	---	RL-M024	TRU Mixed Organic Labpacks with polychlorinated biphenyls (PCB)				
	Solidified Organics	2000	SR-W006	Organic TRU				
	Salt Waste	3140	IN-W311	Salt Waste		409		
	Salt Waste	3140	IN-W312	Salt Waste	ID 124	124	2	Pyrochemical Salt
	Salt Waste	3140	IN-W314	Salt Waste		409		

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Homogeneous Solids—S3000	Salt Waste	3141	RF-W058	Miscellaneous Pu Recovery By-products/TRM	RF 124	365 414 404 415 405 418 406 427 407 429 408 433 409 434 410 435 411 473 412 654 413	2	Pyrochemical Salt
	Salt Waste	---	IN-M001	Electrorefiner Stripped Salts—Barium (Ba) & Cadmium (Cd)				
Soils/Gravel—S4000	Soils	4200	IN-W263	Contaminated Soils/Debris	MD 111B	842	1	
	Soils	---	RL-M007	TRU Mixed Soils without Mercury				
Debris Waste—S5000	Combustible	5310	IN-W198	Plastic/Rubber Debris	ID 216C	337	3	Combustibles
	Combustible	5320	IN-W202	Wood Debris	ID 216A	970	3	Combustibles
	Combustible	5300	IN-W205	Combustible Debris	ID 216B	900	3	Combustibles
	Combustible	5311	IN-W250	Leaded Gloves/Aprons Debris	ID 123	123	3	Leaded Rubber
	Combustible	5311	IN-W252	Leaded Gloves/Aprons Debris	ID 123; 223A	339	3	Leaded Rubber
	Combustible	5311	IN-W254	Leaded Gloves/Aprons Debris	ID 223A	463	3	Leaded Rubber
	Combustible	5311	IN-W256	Leaded Gloves/Aprons Debris		802		

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Combustible	5300	IN-W325	Unknown Solids		815		
	Combustible	5300	IN-W327	Combustible Debris		847		
	Combustible	5310	IN-W330	Plastic/Rubber Debris		801		
	Combustible	5300	IN-W336	Combustible Debris		202		
	Combustible	---	LA-W004	Combustible Waste	LA 116A	004	3	
	Combustible	---	LL-M001	Research and Development Glovebox Waste	LL 116	001	3	
	Combustible	---	RL-M009	TRU Mixed Organic Debris with Corrosives				
	Combustible	---	RL-M010	TRU Mixed Organic Debris with Mercury				
	Combustible	---	RL-M011	TRU Mixed Organic Debris without Mercury				
	Combustible	---	RL-M012	TRU Mixed Organic Debris/ Contaminated without Organics				
	Combustible	---	RL-M013	TRU Mixed Organic Debris/ Contaminated with Organics				
	Combustible	---	RL-M014	TRU Mixed Leaded Gloves/ Aprons with Mercury				
	Combustible	---	RL-M015	TRU Mixed Leaded Gloves/ Aprons Metals without Mercury				

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Combustible	---	RL-M016	TRU Mixed Leaded Gloves/ Aprons Metals/Organics without Mercury				
	Combustible	---	RL-M022	TRU Mixed Leaded Gloves/ Aprons PCBs with Mercury				
	Combustible	---	RL-M023	TRU Mixed Resource Conservation and Recovery Act (RCRA) Organic Debris with PCBs				
	Filter	5410	IN-W214	Composite Filters		813		
	Filter	5410	RF-W066	Filters & Media/TRM	RF 119	328 376 331 490 335 491 342	3	Filters
	Filter	5410	RF-W067	Cemented Filters/TRM	RF 119	376 338	3	Filters
	Filter	5410	AW-M003	TRU Waste Used Pre-filters				
	Graphite	5000	IN-W272	Debris Waste	ID 115	312	2	Graphite
	Graphite	5000	IN-W275	Debris Waste		301		
	Graphite	5000	IN-W276	Debris Waste	ID 215A	300	2	Graphite
	Graphite	3119	RF-W060	Coarse Graphite/TRM	RF 115	303 312	2	Graphite
	Heterogeneous	5440	IN-W169	Predominantly Combustible Debris	ID 216C	330	3	Combustibles

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Heterogeneous	5440	IN-W170	Predominantly Combustible Debris	AE 116A AE 116B	120		Combustibles
	Heterogeneous	5440	IN-W171	Predominantly Combustible Debris	AE 116A AE 116B	110		Combustibles
	Heterogeneous	5440	IN-W172	Predominantly Combustible Debris		010		
	Heterogeneous	5440	IN-W186	Predominantly Combustible Debris	ID 116	116	3	Combustibles
	Heterogeneous	5440	IN-W189	Predominantly Combustible Debris	ID 221A	464	3	Benelex® and Plexiglas®
	Heterogeneous	5440	IN-W197	Predominantly Combustible Debris	ID 216A	336	3	Combustibles
	Heterogeneous	5440	IN-W203	Predominantly Combustible Debris		826		
	Heterogeneous	5440	IN-W204	Predominately Combustible Debris	MD 116A	827	3	
	Heterogeneous	5440	IN-W225	Predominantly Combustible Debris	ID 221A	302	3	Benelex® and Plexiglas®
	Heterogeneous	5400	IN-W259	Heterogeneous Debris		104		
	Heterogeneous	5430	IN-W265	Predominately Inorganic Nonmetal Debris	ID 121	374	3	Benelex® and Plexiglas®
	Heterogeneous	5000	IN-W269A	Debris Waste		150		
	Heterogeneous	3190	IN-W271	Uncategorized Inorganic Process Residues		814		

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Heterogeneous	5400	IN-W281	Heterogeneous Debris	MD 117A	824		
	Heterogeneous	5400	IN-W283	Heterogeneous Debris	ID 225A	241	3	Combustibles and Noncombustibles
	Heterogeneous	5400	IN-W285	Heterogeneous Debris		201		
	Heterogeneous	8200	IN-W289	Unknown Solids	AE 116A	121		
	Heterogeneous	5000	IN-W291	Debris Waste		100		
	Heterogeneous	8200	IN-W302	Unknown Solids		020		
	Heterogeneous	5400	IN-W329	Heterogeneous Debris		848		
	Heterogeneous	5000	IN-W334	Debris Waste		203		
	Heterogeneous	5000	IN-W345	Debris Waste		155		
	Heterogeneous	5000	IN-W351	Debris Waste		105		
	Heterogeneous	5490	NT-W001	Heterogeneous Debris, Uncategorized	NT 111; 116; 211; 225		1 & 3	
	Heterogeneous	5400	OR-W044	CH TRU Heterogeneous Debris	OR 125A; 125B		3	
	Heterogeneous	8000	OR-W045	CH TRU Uncategorized				
	Heterogeneous	5400	OR-W047	CH TRU Heterogeneous Debris				
	Heterogeneous	5330	RF-M002	Supercompacted Combustibles/TRM	RF 116C	2116	3	Combustibles

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Heterogeneous	5900	RF-W008	Soil & Cleanup Debris/TRM	RF 121	374	3	Benelex® and Plexiglas®
	Heterogeneous	5330	RF-W012	Combustibles/TRM	RF 116	330 831 336 832 337 833	3	Combustibles
	Heterogeneous	3119	RF-W036	Firebrick, Pulverized or Fines/ TRM	RF 122	377 378	2	Firebrick and Ceramic Crucibles
	Heterogeneous	---	RL-M004	TRU Mixed Heterogeneous Debris (State only)				
	Heterogeneous	---	RL-M006	TRU Mixed Inorganic Homogeneous Solids without Mercury				
	Heterogeneous	---	RL-M031	TRU Mixed Heterogeneous Debris (State only)				
	Heterogeneous	8900	SA-W134	TRU Waste at Hot Cell Facility				
	Heterogeneous	5400	SR-W026	Heterogeneous Debris				
	Heterogeneous	5400	SR-W027	Heterogeneous Debris				
	Heterogeneous	5400	AW-W020	TRU-Cd-Hot Cell Waste				
	Heterogeneous	---	IN-M002	TRU-Cd-Hot Cell Waste				
	Heterogeneous	---	IN-W139	TRU Contaminated Lead Debris				
	Heterogeneous	---	IN-W269B	Debris Waste		150		
	Heterogeneous	5440	IN-W323	Predominantly Combustible Debris		153		

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Heterogeneous	5000	KA-W016	TRU Debris				
	Heterogeneous	5400	OR-W040	RH TRU Heterogeneous Debris				
	Heterogeneous	5400	RL-M201	Projected RH-MTRU Waste				
	Inorganic Nonmetal	5230	IN-W161	Ceramic/Brick Debris	ID 122; 222B	371	2	Firebrick and Ceramic Crucibles
	Inorganic Nonmetal	5200	IN-W230	Inorganic Nonmetal Debris	ID 122	122	2	Firebrick and Ceramic Crucibles
	Inorganic Nonmetal	5220	IN-W240	Glass Debris	ID 118	118	2	Glass
	Inorganic Nonmetal	5220	IN-W243	Glass Debris	ID 218B	440	2	Glass
	Inorganic Nonmetal	8900	IN-W245	Uncategorized Unknown	ID 225B	441	3	Combustibles and Noncombustibles
	Inorganic Nonmetal	8900	IN-W247	Uncategorized Unknown	ID 218A	442	2	Glass
	Inorganic Nonmetal	8900	IN-W249	Uncategorized Unknown		810		
	Inorganic Nonmetal	5250	MD-M001	Asbestos Debris				
	Inorganic Nonmetal	3114	RF-W026	Used Absorbents/TRM	RF 122	375	2	Firebrick and Ceramic Crucibles
	Inorganic Nonmetal	3119	RF-W032	Ground Glass/TRM	RF 118	444	2	Glass
	Inorganic Nonmetal	5122	RF-W052	Glass/TRM	RF 118	440 442 441 856	2	Glass

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Inorganic Nonmetal	5123	RF-W056	Magnesium (Mg) Oxide Crucibles/TRM	RF 118	370 368 655	2	Glass
	Inorganic Nonmetal	5129	RF-W057	Insulation/TRM	RF 122	438	2	Firebrick and Ceramic Crucibles
	Lead/Cadmium Metal Waste	5400	AW-M001	ALHC Upgrade Decon Debris				
	Lead/Cadmium Metal Waste	5311	AW-M002	Lead/Cadmium Metal Waste				
	Lead/Cadmium Metal Waste	---	ET-M001	Hot Laboratory & Pu Facility D&D				
	Lead/Cadmium Metal Waste	5311	RF-W029	Leaded Gloves/TRM	RF 123	339	3	Leaded Rubber
	Lead/Cadmium Metal Waste	5311	RF-W041	Leaded Gloves-Acid Contaminated/TRM		341		
	Lead/Cadmium Metal Waste	---	RL-M019	TRU Mixed Elemental Hazardous Metals with Mercury				
	Lead/Cadmium Metal Waste	---	RL-M020	TRU Mixed Elemental Hazardous Metals without Mercury				
	Lead/Cadmium Metal Waste	3190	AW-W016	Electrorefiner Stripped Cadmium				
	Lead/Cadmium Metal Waste	3150	AW-W022	Electrorefiner Insolubles with Cadmium				

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Lead/Cadmium Metal Waste	---	IN-M004	Electrorefiner Stripped Cadmium				
	Lead/Cadmium Metal Waste	---	IN-M005	Electrorefiner Insolubles with Cadmium				
	Uncategorized Metal	3100	IN-W260A	Inorganic Process Residues		040		
	Uncategorized Metal	5100	IN-W280	Metal Debris		803	1	
	Uncategorized Metal	5100	IN-W287	Metal Debris		101		
	Uncategorized Metal	5100	IN-W294	Metal Debris	ID 217C	481	2	Metal
	Uncategorized Metal	5100	IN-W296	Metal Debris	ID 217C	480	2	Metal
	Uncategorized Metal	5100	IN-W298	Metal Debris	ID 117	320	2	Metal
	Uncategorized Metal	5100	IN-W300	Metal Debris	ID 117	117	2	Metal
	Uncategorized Metal	---	LA-W001	Mixed Metal Scrap and Incidental Combustibles	LA 125A	001	3	
	Uncategorized Metal	---	LA-W005	Noncombustible Scrap	LA 117A; 118A	005 006	2	
	Uncategorized Metal	---	LA-W009	Metal Waste from Gloveboxes and Equipment				
	Uncategorized Metal	---	LL-W018	Combined Metal Scrap and Incidental Combustibles	LL 125	003	3	
	Uncategorized Metal	5112	RF-W011	Metal/TRM	RF 117	480 481	2	Metal
	Uncategorized Metal	5190	RF-W037	Heavy Metal (non-SS)/TRU	RF 117	320	2	Metal

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

Summary Category Group	Waste Matrix Code Group	Waste Matrix Code	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	IDC	Type	Waste Category
Debris Waste—S5000	Uncategorized Metal	---	RL-M001	TRU Mixed Inorganic Debris with Mercury				
	Uncategorized Metal	---	RL-M002	TRU Mixed Inorganic Debris Metals without Mercury				
	Uncategorized Metal	---	RL-M003	TRU Mixed Inorganic Debris Metal with Corrosives				
	Uncategorized Metal	---	RL-M008	TRU Mixed Inorganic Debris Metals without Mercury				
	Uncategorized Metal	---	RL-M021	TRU Mixed Inorganic Debris PCBs with Mercury				
	Uncategorized Metal	6200	AW-W018	Sodium-TRU				
	Uncategorized Metal	6200	AW-W019	Sodium Potassium-(NaK)-TRU				
	Uncategorized Metal	5100	AW-W021	Metal Debris				
	Uncategorized Metal	---	IN-M003	Element Hardware FCF Waste				
	Uncategorized Metal	3100	IN-W260B	Inorganic Process Residues		040		
	Uncategorized Metal	5190	IN-W322	Sample Fuel		154		
	Uncategorized Metal	---	LA-WR01	Mixed Metal Scrap and Incidental Combustibles				
	Uncategorized Metal	---	LA-WR05	Noncombustible Scrap				

TABLE C-1 *(Continued)*
WASTE IDENTIFIERS CROSS-CORRELATION

[a] Waste stream unique identifications (ID) are taken from the U.S. Department of Energy (DOE), 1995, "Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report," CAO-94-1005, Rev. 1, U.S. Department of Energy, Albuquerque, New Mexico.

[b] TRUCON = TRUPACT-II Content

TABLE C-2
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	AL-W005	Solidified Aqueous Liquids/Slurries[c]		This waste stream will be generated during the remediation of a glovebox that has been used for plutonium (Pu) and other transuranic research. The glovebox continues to be used for transuranic research. Some of the contents of the glovebox will become mixed transuranic (MTRU) waste. It has not yet been determined what volume will be MTRU and what will be TRU. Isotopes that are known to be in the glovebox are: Pu-239, Pu-240, Pu-242, Np-237, Pa-233, U-235, U-236, and U-238. Concentrations of the TRU components range from 1 part per million (ppm) to 2,300 ppm in various concentrations of nitric acid. Uranium concentrations range from 0.1 ppb to 407,770 ppm. Note: This stream may contain Toxic Substance Control Act (TSCA) waste at unknown levels.	d D004 D005 D006 D007 D008 D010 D011
	Solidified Inorganics	IN-W157	Solidified Process Residues	ID 213	This waste comes from the Rocky Flats Plant (RFP). It contains alcohols and organic acids such as ethylene diamine tetra acetic acid (Versenes) set in portland and magnesia cements.	d D006 D008 F001 F002 F003
	Solidified Inorganics	IN-W166	Solidified Process Residues	ID 114	Solid inorganic process solution waste consists of cemented inorganic particulates of sludge-like (not chemically precipitated) wastes from Pu recovery operations.	D008 F001 F002 F003
	Solidified Inorganics	IN-W177	Solidified Process Residues		This waste comes from Mound Laboratory. It consists of caustic waste and neutralized waste liquids, adsorbed onto a clay called Florco®.	d

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	IN-W179	Solidified Process Residues		This waste comes from Mound Laboratory. The waste consists of shower water, decontamination water, cooling water, and some acids and caustics that have been solidified in portland cement.	d D006 D007 D008 D009 D010 D011 F001 F003 P015
	Solidified Inorganics	IN-W181	Solidified Process Residues	ID 211A	This waste is from RFP. The waste consists of sludge from laundry operations that have been cemented in portland. The cement is described as a poor grade.	d D006 D007 D008 D009 F001 F002 F003 P015
	Solidified Inorganics	IN-W188	Solidified Process Residues	ID 211A	This waste is from RFP. The waste consists of sludge from floor drains in a Pu process facility that have been cemented in portland cement, described as poor grade.	d D006 D007 D008 D009 D022 D028 F001 F002 F003 P015

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	IN-W216	Solidified Process Residues	ID 211A	The waste stream generated at RFP, consists of first- and second-stage sludges. Sludges were combined starting in 1979 to reduce the radiation levels of first stage sludge. Portland cement was added to absorb free liquids.	d D005 D006 D007 D008 D009 D011 D022 D028 F001 F002 F003 P015
	Solidified Inorganics	IN-W220	Solidified Process Residues	ID 111	This waste includes waste generated at Argonne National Laboratory-East (ANL-E) and solid wet sludge from RFP. The ANL-E waste is derived from research activities performed in a laboratory environment. The waste includes concrete and laboratory apparatus. The RFP solid wet sludge is cemented or dewatered sludge precipitated from aqueous waste treatment processes. Soils that are not contaminated with or by chemicals are also included.	d D004 D005 D006 D007 D008 D009 F001 F002 F003 P015
	Solidified Inorganics	IN-W221	Absorbed Aqueous Liquids	ID 113	Solid laboratory waste consists of cemented or absorbed neutralized aqueous laboratory waste.	d F003

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	IN-W222	Solidified Process Residues	ID NYD	This waste stream, generated at RFP, consists of sludge from the incinerator off-gas system, recovery building filter plenums, pumps, etc. Portland cement is added to absorb free liquids. The sludge may contain a limited number of surgical gloves.	d D006 D008 F001 F002 F003
	Solidified Inorganics	IN-W228	Solidified Wastewater Treatment Sludges	ID 211A	This waste stream, generated at RFP, consists of wet sludge from treatment of all other plant radioactive and/or chemical contaminated wastes and further treatment of the first stage effluent. Some pre-1973 wastes may include nonsludge wastes such as electric motors, mercury and lithium batteries, bottles of liquid chemicals, and small amounts of mercury in pint bottles. Portland cement was added to absorb the residual liquids.	d D005 D006 D007 D008 D009 D011 D022 D028 F001 F002 F003 P015
	Solidified Inorganics	IN-W332	Solidified Process Residues		This waste comes from the Battelle Columbus Laboratories. It is a turco soap decontamination solution (used to decontaminate glove boxes from a Pu laboratory) that is solidified in a plaster-of-paris.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	IN-W347	Absorbed Aqueous Liquids		This waste comes from ANL-E. It consists of liquids adjusted to pH 10 using NaOH, which are then absorbed in vermiculite.	e
	Solidified Inorganics	LA-W002	Solidified Aqueous Waste,	LA 111A; 211A	Solidified aqueous waste, cemented sludge.	d
	Solidified Inorganics	LA-W003	Dewatered Sludge.	LA 111B; 211B	Dewatered sludge from Pu recovery operations.	D004
	Solidified Inorganics	LA-W006	Cemented Process Residues	LA 114A	Cemented process residues derived from decontamination activities.	D007
	Solidified Inorganics	LL-W019	Solidified Waste	LL 111	50 to 90% of this waste matrix consists of liquids solidified in 1- to 5-gallon (gal) plastic containers using portland cement or Aquaset® for the water-based liquids and Envirostone® or Petroset® for the oil-based liquids. The remainder consists of glovebox waste.	D040 F002
	Solidified Inorganics	MD-W002	Absorbed Aqueous Liquids[c]		TRU waste from PP-113, R-140, R-149. Note: This stream may contain TSCA waste at unknown levels.	e
	Solidified Inorganics	OR-W042	Inactive Storage Tank Contents—MTRU Sludge[c]		The waste stream is comprised of MTRU sludge that has settled and separated from wastewater that has been stored in large underground storage tanks. The waste is a product of past operations at Oak Ridge National Laboratories (ORNL) involving various nuclear research and radioisotope fabrication processes. Note: This stream may contain TSCA waste at unknown levels.	D006 D007 D008 D009
	Solidified Inorganics	PA-W014	Solidified TRU Waste Liquids		Aqueous Slurries—Basic. This stream is generated from the shutdown of the neptunium/technetium recovery system.	d

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	PA-W015	TRU Solid		Other inorganic sludges generated from the shutdown of the neptunium/technetium recovery system	D007
	Solidified Inorganics	PA-W015A	TRU and Technetium Waste		Other wastewaters. This stream is generated from the shutdown of the neptunium/technetium recovery system.	e
	Solidified Inorganics	RF-M001	Solidified Process/TRM	RF 114	This waste stream represents the solidified final form of all particulate and sludge-type materials. Particulates and sludge-type materials are immobilized with portland cement. The cemented wastes are cast into 1-gal molds and allowed to cure prior to packaging. This is the final waste form for Firebrick, Pulverized or Fines/TRM, Incinerator Ash/TRM, Particulate Sludge/TRM, and Sand, Slag, and Crucible/TRM.	d D004 D005 D006 D007 D008 D009 D010 D011 D018 D019 D035 D040 F001 F002 F003 F005

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	RF-W010	Solidified Aqueous Sludge/ TRM	RF 111	This waste stream consists of aqueous sludge from wastewater treatment mixed with 30% portland cement. The waste is generated as a result of process wastewater treatment in Building 374 and 774. Aqueous sludge is produced by vacuum filtration of precipitated solids from pretreated aqueous waste slurry. Untrapped solids are skimmed off the surface of the filter medium of the rotating drum as wet sludge. The precipitated solids are chiefly hydroxides with pH of 10 to 12. The final waste form is obtained by mixing the wet sludge with approximately 30% portland cement. RFP has several drums of aqueous sludge that were returned by Idaho National Engineering Laboratory (INEL). These old drums were packaged by alternating the layers of cement and wet sludge or by adding cement to the top and bottom of a drum containing wet sludge.	D006 D008 F001 F002 F005
	Solidified Inorganics	RF-W038	Solidified Laboratory Waste/TRM	RF 113	This waste stream is liquid waste solidified with portland cement. This waste consists of waste liquids from the analytical laboratories, research and development laboratories, and maintenance shops that are packaged and sent to Building 774 for immobilization with portland cement and absorbent cement. These are wastes which are incompatible with the process collection system and the liquid waste treatment plant. Acidic wastes are neutralized before immobilization. Immobilization is done in 55-gal drums. Approximately 21 gal of waste are added to each drum prior to storage.	D007

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	RF-W040	Incinerator Ash/TRM		This waste stream was previously named "fluidized bed incinerator ash (TRU)-mixed." Ash is generated from operation of a fluidized bed incinerator in Building 776 or an incinerator in RFP Building 771. The incinerator was used to burn office trash, combustible waste generated in process areas, combustible oils from refrigeration units, diesel fuel, and crank case oils. The oil had been accumulated as a low-level mixed waste. Fluid bed incinerator ash was packaged in 55-gal drums lined with a rigid polyethylene liner and one bag liner. It is a portion of the waste stream entitled "fluidized bed incinerator ash/LLW mixed" in the inventory report. The ash normally assays as low-level waste (LLW) but this portion was found to be TRU.	D004 D005 D006 D007 D008 D009 D010 D011 F001 F002 F005
	Solidified Inorganics	RF-W059	Sand, Slag, and Crucible/ TRM		This waste includes unpulverized slag, unpulverized sand and crucible, unpulverized sand, slag and crucible, sand slag and crucible heel, sand from button breakout, pulverized sand slag and crucible, and pulverized slag and crucible. This waste is generated during the reduction of Pu tetrafluoride to Pu metal. Its composition includes magnesium oxide sand, crucible, calcium metal, and stainless steel (SS).	d D007
	Solidified Inorganics	RF-W063	Miscellaneous TRM		As result of the shutdown of Pu operations at RFP in November 1989, several hundred plastic bottles and several tanks of process liquids remained in storage in Buildings 371, 559, 771, and 779.	d D007
	Solidified Inorganics	RF-W065	Calcium Metal/TRM		This material is elemental calcium used in Pu reduction operations. Calcium metal pellets are mixed with Pu tetrafluoride during the reduction process as a pyrotechnic initiator.	d

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	RF-W068	Particulate Sludge/TRM		This waste stream was previously named "Particulate-Sludge/TRU Mixed (2)." This waste was generated from Pu recovery operations in RFP Building 771. The waste consists of incineration sludge, miscellaneous sludge, sludge from size reduction area, grit, and cemented miscellaneous sludge. Spent ion exchange resin waste is not included in this data. The waste is packaged in 55-gal drums with multiple bag liners. This waste consists of a variety of organically contaminated sludges with particulate fines of heavy metals that are TRU contaminated.	d D006 D007 D008 F001 F002 F005
	Solidified Inorganics	RF-W076	Process Residues/TRM		This waste stream was previously named "Particulate-Sludge/TRU Mixed (2)." This waste was generated from Pu recovery operations in RFP Building 771. The waste consists of low-purity oxide heel, incineration sludge, miscellaneous sludge, sludge from size reduction area, grit, soot, and soot heel. The waste is packaged in 55-gal drums with multiple bag liners.	d D006 D007 D008 F001 F002 F005
	Solidified Inorganics	RL-M005	TRU Mixed Homogeneous Solids with Mercury[c]		This waste stream consists primarily of homogeneous solids. Some of the containers contain organic debris (plastic, cellulosics). Note: This stream may contain TSCA waste at unknown levels.	d D009
	Solidified Inorganics	RL-M032	TRU Mixed Inorganic Homogeneous Solids		This waste stream consists primarily of inorganic homogeneous solids (absorbents).	d D007 F003
	Solidified Inorganics	SR-W053	Ash		Ash from the RFP incinerator was sent to the Savannah River Site (SRS) for Pu recovery research purposes. It is stored in a satellite area in 235-F. The sample material was sent to SRS to investigate possible flow sheets for the recovery of Pu. The ash was classified as waste by the Colorado Court System, and the flow-sheet experiments were cancelled.	D004 D005 D006 D007 D008 D009 D010 D011 F001 F002 F005

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Organics	IN-W167	Solidified Process Residues	ID 112	TRU solid organic waste consisting of cemented or absorbed organic liquids from production or laboratory processes.	D022 F001 F003
	Solidified Organics	IN-W174	Absorbed Aqueous Liquids		This waste comes from Mound Laboratory. It consists of acid liquids, mainly nitric, absorbed onto a clay called Florco®.	d
	Solidified Organics	IN-W309	Organic Setups[c]	ID 212	This waste stream contains liquid organic wastes generated at RFP. About 47% of the organic waste stream is lathe coolant, which is 60% Texaco Regal oil and 40% carbon tetrachloride. About 10% of the organic waste stream is trichloroethane. The remainder is other organic wastes. These liquid wastes were mixed with calcium silicate to form a grease or paste-like material. Note: This stream may contain TSCA waste at unknown levels.	D005 D011 F001 F002 F004 P015
	Solidified Organics	RF-W013	Solidified Organics/TRM	RF 112	This waste stream includes waste TRU organic fluids that are transferred to RFP Building 774 for cementation from Buildings 707, 776, and 777. The liquids are mixed with gypsum cement within 55-gal drums. The drum is lined with one or two bag liners with a rigid polyethylene liner. This waste stream includes cemented solids and organic sludges/particulates.	F001 F002
	Solidified Organics	RF-W069	Organic Resins/TRM	RF 126	This waste stream was previously named "Particulate-Sludge/TRU Mixed (2)." This waste was generated from Pu recovery operations in Building 771. It consists of unleached resin and leached resin. The waste is packaged in 5-gal drums with multiple bag liners. Final waste form for this waste stream is cemented resin.	d D006 D007 D008 F001 F002 F005
	Solidified Organics	RL-M017	TRU Mixed Organic Labpacks		This waste stream consists primarily of organic labpacks. Some of the containers contain inorganic debris (metals), organic debris (plastic, cellulosics).	d F003
	Solidified Organics	RL-M018	TRU Mixed Organic Labpacks (State only)		This waste stream consists primarily of organic labpacks. Some of the containers contain organic debris (plastic, cellulosics).	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Organics	RL-M024	TRU Mixed Organic Labpacks with polychlorinated biphenyls (PCB)[c]		This waste stream consists primarily of organic labpacks. Some of the containers contain organic debris (plastic, rubber, cellulosics), and PCBs.	d
	Solidified Organics	SR-W006	Organic TRU		Laboratory waste from Pu extractions generated in the Savannah River Technology Center (SRTC) 773-A Facility. Homogeneous, liquid, flammable, xylene-based chelating agent. TTA - Thenoyl trifluoroacetone.	d
	Salt Waste	IN-W311	Salt Waste		This waste was generated at the RFP.	D028 F001
	Salt Waste	IN-W312	Salt Waste	ID 124	Pyrochemical salt consists of used chloride salts from pyrochemical processes such as electrorefining, molten salt extraction or direct oxide reduction.	d
	Salt Waste	IN-W314	Salt Waste		This waste, generated at the RFP, consists of chunks of salt and ceramic.	F001
	Salt Waste	RF-W058	Miscellaneous Pu Recovery By-products/TRM	RF 124	This waste is generated during Pu recovery operations such as direct oxide reduction molten salt extraction, electrorefining, and salt scrub. Its composition includes mixed salts, a probable presence of magnesium, sodium and potassium metals and chromium. This waste consists of reactive molten and electrorefining (ER) salt residues from Pu purification and direct oxide reduction.	d D007

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Soils/Gravel—S4000	Soils	IN-W263	Contaminated Soils/Debris		This waste, generated at Mound Laboratory, consists of soils, including small rocks and pebbles, generated from cleanup of a leak. All soil waste was dry when packaged. A few waste boxes also include picks, shovels, metal cans, rubber gloves, booties, respirators, plastic, and possibly an air hammer and chisel.	d D006 D007 D008 D009 D010 D011
	Soils	RL-M007	TRU Mixed Soils without Mercury		This waste stream consist primarily of soils. Some of the containers contain organic debris (rubber, cellulosics, plastic) and inorganic debris (metal).	D007 D010
Debris Waste - S5000	Combustible	IN-W198	Plastic/Rubber Debris	ID 216C	The waste stream is from the RFP and consists of various types of plastics such as polyethylene (PE), polyvinyl chloride (PVC), teflon (TFE), and nonleaded rubber items. The waste may be bags, vials, bottles, sheeting, and surgical gloves. Some other combustible wastes such as respirator facemasks and paper may be included. Some small amounts of noncombustible wastes may also be present.	D008 D022 D029 F001 F002 F003 F005
	Combustible	IN-W202	Wood Debris	ID 216A	This waste stream is from the RFP and primarily consists of wood in the form of lumber, plywood, filter frames, and possibly ladders. Some of the items such as plastic sheeting, Kimwipes®, and other combustibles are also present. Plastic sheeting may have some paint coatings. Limited noncombustibles such as nails and sheetrock may also be included.	D008 F001 F002 F003
	Combustible	IN-W205	Combustible Debris	ID 216B	This waste stream from the RFP primarily consists of line- and nonline-generated combustible materials such as plastics, paper, empty PE bottles, booties, paper, plastic sheeting, and surgical gloves. The waste may be dry or damp. Limited amounts of noncombustibles may also be present.	D008 F001 F002 F003
	Combustible	IN-W250	Leaded Gloves/Aprons Debris	ID 123	Discarded leaded glovebox gloves and leaded aprons.	D008

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Combustible	IN-W252	Leaded Gloves/Aprons Debris	ID 123; 223A	This waste comes from RFP. It consists of leaded rubber gloves and aprons. A limited amount of unleaded gloves, lead bricks, and lead sheeting may also be present.	D008 D022 D028 D029 F001 F002 F003 F005
	Combustible	IN-W254	Leaded Gloves/Aprons Debris	ID 223A	This waste comes from RFP. It consists of leaded rubber gloves and aprons. A limited amount of unleaded gloves, lead bricks, and lead sheeting may also be present.	D008 F001 F002
	Combustible	IN-W256	Leaded Gloves/Aprons Debris		This waste stream is generated at the Mound Laboratory. The waste consists of neoprene dry box (glovebox) gloves, neoprene, O-rings, and lead-lined gloves.	D008
	Combustible	IN-W325	Unknown Solids[e]		This waste stream was generated at Mound Laboratory and consists of classified parts.	e
	Combustible	IN-W327	Combustible Debris		This waste stream is from Mound Laboratory and consists of nonline generated combustible wastes such as plastic sheeting, paper, reagents, gloves (rubber and cloth), plastic bottles, wood, paper suits, and shoe covers. About 75% of the waste is compacted. The waste may be either dry or damp.	e
	Combustible	IN-W330	Plastic/Rubber Debris		This waste stream, generated at Mound Laboratory, consists of various types of plastics (PVC, PE, Tygon®, etc.) in the form of tubing, piping, sample vials, gaskets, manipulator boots, etc. Limited amounts of other combustible wastes may also be included. One drum contains liquid mercury. The wastes are primarily from decommissioning and decontamination (D&D) activities at the Pu processing and research buildings. Limited amounts of waste may be damp.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Combustible	IN-W336	Combustible Debris		This waste stream, generated at Battelle Columbus Laboratories, contains such combustible items as wood, plastic suits, nylon reinforced plastic tent structures, shoe covers, rubber gloves, and air hose. The waste is from decontamination and deactivation of the Pu laboratory.	e
	Combustible	LA-W004	Combustible Waste	LA 116A	Combustible waste - paper, rags, plastic, rubber, etc.	D005
	Combustible	LL-M001	Research and Development Glovebox Waste	LL 116	The waste consists mostly of untreated dry solids such as tissues, paper, assorted plastics, glassware, ceramics, and metals. Portland cement or Aquaset® is used to solidify small amounts of water-based liquids; Envirostone® or Petroset® is used to solidify small amounts of solvents and oil-based liquids. The composition varies considerably, but it is predominantly organics (> 90% by weight).	d D006 D008 D009 D040
	Combustible	RL-M009	TRU Mixed Organic Debris with Corrosives		This waste stream consists primarily of organic debris. Some of the containers contain inorganic debris (metals) and soils.	d
	Combustible	RL-M010	TRU Mixed Organic Debris with Mercury		This waste stream consists primarily of organic debris. Some of the containers contain inorganic debris (metals, including mercury) and soils.	d D006 D009
	Combustible	RL-M011	TRU Mixed Organic Debris without Mercury		This waste stream consists primarily of organic debris. Some of the containers contain inorganic debris (metals) and soils.	d D007 D008
	Combustible	RL-M012	TRU Mixed Organic Debris/ Contaminated without Organics		This waste stream consists primarily of organic debris. Some of the containers contain inorganic debris (metals) and soils.	D019

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
	Combustible	RL-M013	TRU Mixed Organic Debris/ Contaminated with Organics		This waste stream consists primarily of organic debris. Some of the containers with organics contain inorganic debris (metals) and soils.	D019 F001 F002 F003 F004 F005
Debris Waste - S5000	Combustible	RL-M014	TRU Mixed Leaded Gloves/ Aprons with Mercury		This waste stream consists primarily of leaded gloves/aprons. Some of the containers contain inorganic debris (metals, including mercury), organic debris (plastic, rubber, cellulosics), and soils.	d D005 D006 D007 D008 D009
	Combustible	RL-M015	TRU Mixed Leaded Gloves/ Aprons Metals without Mercury		This waste stream consists primarily of leaded gloves/aprons. Some of containers contain inorganic debris metals, without mercury), organic debris plastic, rubber, cellulosics), and soils.	d D005 D006 D007 D008
	Combustible	RL-M016	TRU Mixed Leaded Gloves/ Aprons Metals/Organics without Mercury		This waste stream consists primarily of leaded gloves/aprons. Some of the containers contain inorganic debris metals), organic debris (plastic, rubber, cellulosics), and soils.	D007 D008 D019
	Combustible	RL-M022	TRU Mixed Leaded Gloves/ Aprons PCBs with Mercury[c]		This waste stream consists primarily of leaded gloves/aprons. Some of the containers contain inorganic debris (metal), organic debris (plastic) and hazardous constituents including PCBs and mercury. Note: This waste stream may contain TSCA waste at unknown levels.	D006 D008 D009
	Combustible	RL-M023	TRU Mixed Resource Conservation and Recovery Act (RCRA) Organic Debris with PCBs[c]		This waste stream consists primarily of organic debris contaminated with PCBs. Note: This waste may contain TSCA waste at unknown levels.	d

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
	Filter	IN-W214	Composite Filters		This waste stream, generated at the Mound Laboratory, consists primarily of spun glass filters and fiberglass glovebox prefilters. The waste may include limited amounts of other noncombustibles.	d D009
Debris Waste - S5000	Filter	RF-W066	Filters & Media/TRM	RF 119	This waste stream was previously named "Filter Waste/TRU." Filter waste is generated from process operations throughout the RFP site. This waste consists of Ful-flo filters from the Building 771 incinerator, Ful-flo filters from nonincineration operations, absolute glovebox filters from nonacid contaminated operations, acid contaminated absolute glovebox filters, acid contaminated high-efficiency particulate air (HEPA) filters, nonacid contaminated HEPA filters, plenum prefilters, filter media, and processed filter media. Processed filter media is material which has been treated using portland cement to absorb moisture and neutralize acid contamination. Filter waste is packaged in 55-gal drums and metal standard waste boxes.	d D004 D006 D007 D008 D009 D010 D011 F001 F002 F005
	Filter	RF-W067	Cemented Filters/TRM	RF 119	This waste stream was previously named "Filter Waste/TRU." Filter waste is generated from process operations throughout the RFP site. Processed filter media is material that has been treated using portland cement to absorb moisture and neutralize acid contamination. Filter waste is packaged in 55-gal drums and metal standard waste boxes. Hazardous constituents originate in liquid and gaseous effluents from processing operations.	d D005 D006 D007 D008 D009 F001 F002 F003
	Graphite	IN-W272	Debris Waste	ID 115	Coarse graphite chunks.	F001 F002
	Graphite	IN-W275	Debris Waste		This waste stream, generated at the RFP, is similar to graphite molds. A graphite core is part of the shaped graphite mold to cast Pu metal. The graphite has broken into pieces, and some of the graphite has been scarfed or wire brushed to remove any above-discard deposits of Pu.	F001

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Graphite	IN-W276	Debris Waste	ID 215A	This waste stream, generated at the RFP, consists of graphite molds used in casting Pu metal. The waste may also include small amounts of surgical gloves. The graphite is in the form of broken mold pieces. Some of the graphite has been scarfed or wire-brushed to remove above-discard deposits of Pu.	D022 D028 F001 F002 F003 F005
	Graphite	RF-W060	Coarse Graphite/TRM	RF 115	This waste form includes scarfed graphite chunks and coarse graphite. This waste is a result of broken graphite molds from the classified weapons shape casting process.	D006
	Heterogeneous	IN-W169	Predominantly Combustible Debris	ID 216C	The waste stream is from RFP and primarily consists of line- and nonline-generated dry combustible materials such as paper, rags, plastics, surgical gloves, cloth overalls and booties, cardboard, wood, wood filters frames, and laundry lint. Some combustibles may be damp or moist. Limited amounts of noncombustibles such as glass, concrete, cement, lead glovebox gloves, batteries, and metal scrap may also be present.	D008 D022 D029 F001 F002 F003 F005
	Heterogeneous	IN-W170	Predominantly Combustible Debris		This waste is generated at ANL-E. The waste is derived from decontamination and disposal of facilities and ancillary systems (e.g., gloveboxes).	D004 D006 D008 F003
	Heterogeneous	IN-W171	Predominantly Combustible Debris		This waste is generated at ANL-E. The waste is derived from research activities performed in a research environment. The waste includes soft plastics, cardboard, rags, paper, and cloth from various processes. The waste is packaged in 55-gal drums or in standard waste boxes.	D004 D006 D008 F003

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W172	Predominantly Combustible Debris		This waste stream, generated at Bettis Atomic Power Laboratory, consists primarily of rags, gloves, plastic, paper, carbo-wax, filters, oil-contaminated absorbent (diatomaceous earth), and rubber. The waste stream may also contain noncombustible items.	F001 F002
	Heterogeneous	IN-W186	Predominantly Combustible Debris	ID 116	Combustible waste consists of cellulosic, plastic or cloth waste from various processes.	D008 F001 F002
	Heterogeneous	IN-W189	Predominantly Combustible Debris	ID 221A	This waste, generated at RFP, contains mainly Benelex® which is a dense, laminated, lignocellulose hardboard made from wood chips and particles. Benelex® is generally 2 inches (in.) thick. Some of the Benelex® has lead shielding attached to it. Metal hinges and angle iron strongbacks are also present. Plexiglas™ is the other major constituent in the waste. The Plexiglas™ thickness ranges from 2 to 4 in. Both the Benelex® and the Plexiglas™ are combustible.	D008 F001
	Heterogeneous	IN-W197	Predominantly Combustible Debris	ID 216A	The waste stream is from the RFP and primarily consists of damp or wet line- and nonline-generated dry combustible materials such as paper, rags, plastics, surgical gloves, canvas, cardboard, wood, and rubber. Some combustibles may be damp or moist. Moisture content may range from damp to wet, and may include water, soaps, nitric acid, or caustic solutions. Limited amounts of noncombustibles such as glass, concrete, cement, leaded glovebox gloves, and metal scrap may also be present. These wastes are mostly from decontamination and cleanup work, and may be from any Pu area.	d D008 D022 F001 F002 F003 F005

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W203	Predominantly Combustible Debris		This waste stream, generated at Mound Laboratory, includes two different types waste depending on when the waste was generated. Prior to 1980 waste consisted of glovebox floor sweepings and rust. After 1980, waste may consist of large combustible waste such as plastic tanks, Plexiglas™ shielding and windows, wood, and fiberglass conveyor glovebox sections. Limited amounts of small combustibles such as shoe covers and surgical gloves are also included.	D009
	Heterogeneous	IN-W204	Predominately Combustible Debris		This waste stream is smaller combustible items from Mound Laboratory that fit into drums.	D008 D009
	Heterogeneous	IN-W225	Predominantly Combustible Debris	ID 221A	The waste, generated at RFP, contains mainly Benelex® which is a dense, laminated, lignocellulose hardboard made from wood chips and particles. Benelex® is generally 2 in. thick. Some of the Benelex® has lead shielding attached to it. Metal hinges, and angle iron strongbacks are also present. Plexiglas™ is the other major constituent in the waste. The Plexiglas™ thickness ranges from 2 to 4 in. Both the Benelex® and the Plexiglas™ are combustible.	D008 F001
	Heterogeneous	IN-W259	Heterogeneous Debris		This waste stream, generated at ANL-E, contains alpha hot cell waste. Noncombustible and combustible waste are segregated. Combustible wastes include: paper, plastic and PVC containers, rubber O-rings and gloves, rags, and Q-tips. Noncombustible wastes include: laboratory equipment, tools, fixtures, glassware, pipe, tubing, fitting, fasteners, firebrick, ferrous and nonferrous metal scraps and parts, and small electric motors. Sodium in the waste is reacted with ethyl alcohol, mixed with pelletized clay, and dried. Nitrates and oxidizing agents are neutralized or reduced, mixed with pelletized clay.	D008

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W265	Predominately Inorganic Nonmetal Debris	ID 121	This waste contains blacktop, concrete, reinforced concrete, cinder blocks, bricks, dirt and sand. Limited amounts of waste may be damp. A limited amount may contain combustibles such as coveralls and gloves. The waste is generated from cleanup of spills and leaks, process changes, maintenance, and D&D operations. Portland cement is added to containers that contain wet or damp waste.	F001 F002 F003 F004
	Heterogeneous	IN-W269A	Debris Waste		This waste stream, generated at INEL, contains laboratory waste from ANL-W including fluxwire, fission counters, analytical samples dissolved and absorbed on Oil-Dri, glassware, vials, miscellaneous waste from gloveboxes, dissolved pellets absorbed on Oil-Dri, enriched and normal U308 pellets, aluminum foil and capsules, TREAT® waste capsules, chlorinated Ion exchange resins, Pu sources. Laboratory waste includes Kimwipes®, trash, glassware, dissolved samples absorbed in Oil-Dri, analytical samples, gloves, etc.	e
	Heterogeneous	IN-W271	Uncategorized Inorganic Process Residues[e]		This waste stream was generated at Mound Laboratory. The records at Mound Laboratory and at INEL do not agree on the content. The waste most likely is graphite crucibles and electrodes, with some containers of mercury.	D009
	Heterogeneous	IN-W281	Heterogeneous Debris		This waste stream, generated at the Mound Laboratory, consists of large, noncombustible wastes such as tanks (SS and tantalum), piping, ducts, conduit, electric motors, pumps, metallurgical presses, lathes, dissolvers, evaporators, furnaces, ladders, vacuum sweepers, 24- x 24- x 12-in. HEPA filters, fume hoods, gloveboxes, Plexiglas™ glovebox windows, and floor tile. Limited amounts of combustible wastes (plastic tanks, fiberglass gloveboxes, plastic contamination control tents, etc.) are also included.	D005 D006 D007 D008 D009 D010 D011

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W283	Heterogeneous Debris	ID 225A	This waste stream, generated at the RFP, consists of piping, flanges, valves, tools, equipment, PVC piping, glassware (flasks, broken ion exchange columns, etc.), glass filters, leaded glovebox gloves, paper, and plastics. Wastes from renovations of the americium recovery line were shipped only in 1972 and 1973. Some of the containers are lead-lined.	d D008 F002 F003
	Heterogeneous	IN-W285	Heterogeneous Debris		This waste stream, generated at Battelle Columbus Laboratories, contains noncombustible items such as tools, crucibles, piping, valves, pieces of equipment, lead bricks, Plexiglas™, and filters.	D008
	Heterogeneous	IN-W289	Unknown Solids[e]		This waste is generated at ANL-E and RFP. The waste is derived from decontamination and disposal of facilities and ancillary systems.	D004 D005 D006 D007 D008 D009 F001 F002 P015
	Heterogeneous	IN-W291	Debris Waste		This waste stream, generated at ANL-E, contains combustible and noncombustible items such as paper, rags, rubber gloves, plastic bottles, glassware, small tools, balances, and empty metal cans. The waste is usually separated into combustible and noncombustible streams.	d F003

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W302	Unknown Solids[c]		This waste stream, generated at Bettis Atomic Power Laboratory, contains noncompressible and noncombustible items such as absolute filters, solidified chemical waste, contaminated metal equipment, furnace brick, and highly contaminated glovebox equipment. Metal scrap could include bars, sheet, fixtures, small equipment tools, etc. made of carbon steel, SS, inconnel, aluminum, copper, brass and zirconium. Chemical wastes include spent chemical solutions and associated solids from the isotope and isotopic dilution analysis of nuclear fuel specimens. The residues were neutralized before being either mixed with absorbent material solidified.	d F001 F002
	Heterogeneous	IN-W329	Heterogeneous Debris		This waste stream, generated at Mound Laboratory, consists of nonline generated noncombustible wastes such as tools, pipe, equipment, metal, glass, concrete, plaster, bricks, and dirt. Limited amounts of combustible wastes such as paper, rags, etc. are also included.	e
	Heterogeneous	IN-W334	Debris Waste		This waste stream, generated at Battelle Columbus Laboratories, contains a mixture of combustible and noncombustible items in roughly equal proportions. Combustible items include paper and paper products. Noncombustibles are primarily metal and some glass.	e
	Heterogeneous	IN-W345	Debris Waste		This waste stream, generated at INEL, consists of a plastic glovebox, a hydraulic pump containing oil, vacuum pump, centrifuges, tools, and experimental fuel capsules. The presence of hazardous materials is not known, but some absorbed oil is likely.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W351	Debris Waste		This waste stream, generated at ANL-E, consists of glass bottles used to transport liquid wastes.	e
	Heterogeneous	NT-W001	Heterogeneous Debris, Uncategorized	NT 111; 116; 211;225	This waste stream consists of glovebox parts, laboratory trash, contaminated equipment, and solidified sludges. Real-time radiography has been performed on the waste to verify there are no free liquids present, with the exception of liquid in aerosol cans. Most of the waste is contact handled (CH) TRU waste; one and 3 drums are remote-handled (RH). The waste stream was generated at Lawrence Livermore National Laboratory, Livermore, CA (LLNL) and shipped to the Nevada Test Site (NTS) from 1974 until 1990. The waste was declared as potentially mixed TRU waste by the generator in April 1991.	d D006 D007 D008 D011 F001 F002 F003 P015
	Heterogeneous	OR-W044	CH TRU Heterogeneous Debris[c]	OR 125A; 125B	This waste stream consists of CH TRU waste which is classified as contaminated equipment, decontamination debris or dry solids. The physical form is solid. These wastes do not contain free or containerized liquids. Note: This stream may contain TSCA waste at unknown levels.	D006 D008 D009 D011
	Heterogeneous	OR-W045	CH TRU Uncategorized[c,e]		This waste stream consists of CH TRU waste which is not classified. The physical form is either solid, liquid, mixed (both solid and liquid), or unknown. Note: This stream may contain TSCA waste at unknown levels.	D006 D008 D009 D011
	Heterogeneous	OR-W047	CH TRU Heterogeneous Debris[c]		This waste stream consists of CH TRU waste which is classified as contamination equipment, decontaminated debris, or dry solids. The physical form is solid. Note: This stream may contain TSCA waste at unknown levels.	D006 D008 D009 D011
	Heterogeneous	RF-M002	Supercompacted Combustibles/TRM	RF-116C	This waste consists of cloth and paper products from cleanup of gloveboxes and spills, which has been supercompacted for volume reduction.	F001 F002 F005

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	RF-W008	Soil & Cleanup Debris/TRM	RF 121	This waste stream is construction rubble generated during D&D activities. The waste consists of blacktop/concrete/dirt/sand. The waste is generated from construction/demolition within the Pu process buildings. The waste is usually packed in 55-gal drums with multiple bag liners, a fiberboard liner, and a rigid polyethylene liner. Also, the waste can be packaged in DOT 7A, Type A metal boxes which are lined with a fiberboard and PVC liner. Metals are considered to be potentially present in the rubble from demolition and cleanup activities. Solvents are potentially present from the materials used during decontamination.	D006 D007 D008 F001 F002 F005
	Heterogeneous	RF-W012	Combustibles/TRM	RF 116	The waste consists mainly of cloth and paper products from cleanup of gloveboxes and spills, involving hazardous solvents. The bulk of these wastes are packaged in 55-gal drums with one rigid polyethylene liner and several bag liners. In addition the waste may be repackaged into DOT 7A, Type A metal boxes which are lined with a fiberboard and PVC liner.	F001 F002 F005
	Heterogeneous	RF-W036	Firebrick, Pulverized or Fines/TRM	RF 122	This waste stream was previously named "Firebrick - Pulverized or Fines." This waste is generated from replacement of fire brick in the Pu recovery incinerator in RFP Building 771. The fire brick must be replaced periodically because of the Pu buildup. The fire brick is pulverized to facilitate Pu recovery. Material which assays below the economic discard limit is discarded as pulverized fire brick waste. The waste is packaged in 55-gal drums lined with a rigid polyethylene liner.	D004 D006 D007 D008 F001 F002 F005
	Heterogeneous	RL-M004	TRU Mixed Heterogeneous Debris (State only)		This waste stream consists primarily of heterogeneous debris (filters). Some of the containers contain organic debris (plastic).	e
	Heterogeneous	RL-M006	TRU Mixed Inorganic Homogeneous Solids without Mercury		This waste stream consists primarily of inorganic homogeneous solids. Some of the containers contain organic debris (rubber, cellulosics).	d D019 F003

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	RL-M031	TRU Mixed Heterogeneous Debris (State only)		This waste stream consists primarily of heterogeneous debris. The waste is hazardous by state regulation.	e
	Heterogeneous	SA-W134	TRU Waste at Hot Cell Facility		Predominantly metal laboratory trash including saw blades, copper and brass fittings. Balance of waste is combustible laboratory trash including rubber gloves and Tygon® tubing. There are no liquids.	e
	Heterogeneous	SR-W026	Heterogeneous Debris		200 Areas (F and H Separations Facilities). This waste is primarily solids consisting of mainly booties, laboratory coats, floor sweepings, rags, labware, and other job control wastes. This waste is generated primarily through separation activities in the course of Pu production, includes small amounts of TRU waste from on-site laboratories.	d D004 D006 D007 D008 D009 D011 D018 D019 D022 D023 D024 D025 D026 P015

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	SR-W027	Heterogeneous Debris		200 Areas (F and H Separations Facilities). This waste is generated primarily through separation activities in the course of Pu production and includes small amounts of TRU waste from on-site laboratories. This waste stream is primarily solids consisting of booties, laboratory coats, floor sweepings, labware, rags, and other job control waste.	d D004 D006 D007 D008 D009 D011 D018 D019 D022 D023 D024 D025 D026 F001 F002 F003 F005 P015
	Inorganic Nonmetal	IN-W161	Ceramic/Brick Debris	ID 122; 222B	This waste contains whole and broken pieces of construction bricks, cinderblocks, and firebrick. Waste generated in the 1971 to 1973 period includes firebrick from the Pu recovery incinerator and related refractory development and from four boilers; cinderblocks and other brick from routine maintenance and from following the RFP fire. Waste generated since 1973 is mostly firebrick from Pu recovery operations. The firebrick generated since 1973 is a high-alumina, high-strength brick manufactured by Plibrico (Plicast 40®). Some of the incinerator firebrick is scarfed to remove surface contamination and then leached with nitric acid to recover Pu.	F001 F002

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Inorganic Nonmetal	IN-W230	Inorganic Nonmetal Debris	ID 122	Insulation, firebrick, and concrete.	F001 F002
	Inorganic Nonmetal	IN-W240	Glass Debris	ID 118	Glass waste consists of discarded labware, windows, containers or raschig rings from various processes.	D008 D009 F001
	Inorganic Nonmetal	IN-W243	Glass Debris	ID 218B	This waste stream, generated at the RFP, consists of glass sample vials, bottles, lead-taped sample vials, ion exchange columns, dissolver pyrex laboratory glassware such as Pyrex™ flasks and beakers, glovebox windows (glass, Plexiglas™, leaded glass), and crushed and ground glass. The waste includes limited amounts of other noncombustibles such as metals, and limited amounts of combustible wastes. No sludges should be present although some glass vials may contain limited amounts of residual liquids.	D008 D029 F001 F002 F003 F005
	Inorganic Nonmetal	IN-W245	Uncategorized Unknown[e]	ID 225B	This waste stream, generated at the RFP, consists of boronated glass rings used to minimize neutron multiplication in liquid storage tanks. Unleached rashig rings was used from 1971–79 as a separate stream and then combined with leached rashig rings. The rings are about 1.75 in. high and 1.5 in. in diameter, with a 0.25 in. wall thickness. The rings are heat and chemical resistant borosilicate glass. Some of the rings, which had above-discard amounts of Pu, were leached with nitric acid to recover the Pu and then rinsed with water, and dried. Some of the rings may be contaminated with small amounts of oil.	d D008 F001

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Inorganic Nonmetal	IN-W247	Uncategorized Unknown[e]	ID 218A	This waste stream, generated at the RFP, consists of boronated glass rings used to minimize neutron multiplication in liquid storage tanks. Unleached rashig rings was used from 1971–79 as a separate stream and then combined leached rashig rings. The rings are about 1.75 in. high and 1.5 in. in diameter, with a 0.25 in. wall thickness. The rings are heat and chemical resistant borosilicate glass. Some of the rings, which had above-discard amounts of Pu, were leached with nitric acid to recover the Pu and then rinsed with water, and dried. Some of the rings may be contaminated with small amounts of oil.	d D008 D028 D029 F001 F002 F003 F005
	Inorganic Nonmetal	IN-W249	Uncategorized Unknown[e]		This waste stream, generated at Mound Laboratory, consists mostly of whole and broken glassware and glass sample vials. The majority of the glass is Pyrex™. Limited amounts of other noncombustibles may be present.	D009
	Inorganic Nonmetal	MD-M001	Asbestos Debris[c]		(24) Asbestos filters, (1) glass filter. Note: This waste may contain TSCA waste at unknown levels.	e
	Inorganic Nonmetal	RF-W026	Used Absorbents/TRM	RF 122	This waste stream was previously named "Spent Absorbent/TRU (Oil Dry)". This waste stream was not specifically identified in the Storage and Inventory Report prepared by RFP in fulfillment of Federal Facility Compliance Act requirements. This waste is the TRU fraction of the waste titled "Oil Dry/LLW Mixed" in the Inventory Report. Normally it is low-level waste (LLW) but occasionally some assays as TRU. Absorbents, usually vermiculite materials, which are used in the absorption, or absorption of any liquids as needed. One of the most commonly used absorbents is Oil Dri®. Spent absorbents are assumed to be radiologically contaminated. The waste is packaged in 55-gal drums lined with two polyethylene bags.	F001

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Inorganic Nonmetal	RF-W032	Ground Glass/TRM	RF 118	This waste stream is crushed fluorescent lights with some leached glass. Glass waste consists of crushed fluorescent lamps that come from the fluorescent lights used throughout the Pu and uranium processing areas, as well as ground leaded glass. Small amounts of leached glass may be mixed with the crushed fluorescent lamp waste. This glass waste is packaged in 55-gal drums that are lined with one fiberboard liner and two polyethylene bags.	D008
	Inorganic Nonmetal	RF-W052	Glass/TRM	RF 118	This waste stream is glass from D&D, labs, etc. This waste stream is made up of glass from analytical laboratories, recovery processes, ceramics, and glovebox windows. This waste stream was previously named "glass." This waste form has been characterized by toxicity characteristic leaching procedure (TCLP) analytical data and process knowledge. Ground glass is characterized by process knowledged and limited analytical data.	D005 D008 F001 F002
	Inorganic Nonmetal	RF-W056	Magnesium (Mg) Oxide Crucibles/TRM	RF 118	This waste stream includes any type or size of ceramic crucibles or liners including LECO crucibles. This waste consists of magnesium oxide crucible, magnesium oxide crucible fragments with reactive salts of calcium, magnesium, sodium, and/or potassium adhering to the surface and containing Pu residue. This waste stream was generated during Pu recovery using pyrochemical and electro-chemical processing. Waste is placed in 4-liter poly bottles and double plastic bagged or placed in 1 gal or 1 quart paint cans, then placed into 55-gal drums.	d D006
	Inorganic Nonmetal	RF-W057	Insulation/TRM	RF 122	This waste stream is contaminated insulation. The insulation is generated from construction and demolition on site. This waste was characterized using process knowledge for manifesting purposes in 1987 and 1989 to determine if any reportable quantities per 49 CFR 172 were present. These are spent solvents from degreasing of Pu or other metals.	F001 F002

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Lead/Cadmium Metal Waste	AW-M001	ALHC Upgrade Decon Debris		Waste packaged for WIPP containing: radioactive cadmium debris from CH-ANL-242T, solidified to meet WIPP-WAC requirement for particulate immobilization, and bags of lead-lined gloves were placed in the solidified drums to fill the void space.	D006 D007 D008
	Lead/Cadmium Metal Waste	AW-M002	Lead/Cadmium Metal Waste		This waste is typically lead lined gloves replaced at the Experimental Fuel Laboratory glovebox.	D008
	Lead/Cadmium Metal Waste	ET-M001	Hot Laboratory & Pu Facility D&D		1 lead shielding brick plus additional hot material.	D008
	Lead/Cadmium Metal Waste	RF-W029	Leaded Gloves/TRM	RF 123	This waste stream consists of leaded rubber gloves that are used on gloveboxes to reduce radiation exposure to personnel. Gloves that are damaged or that do not meet safety inspection requirements are replaced with new gloves and discarded as waste. The gloves are packaged in 55-gal drums lined with a rigid polyethylene liner and one bag liner.	D008
	Lead/Cadmium Metal Waste	RF-W041	Leaded Gloves-Acid Contaminated/TRM		This waste stream consists of leaded rubber gloves used in the glovebox system for Pu recovery operations in RFP Buildings 771 and 371. These gloves are contaminated with nitric acid and other acids when replaced and discarded as waste. The gloves are packaged in 55-gal drums lined with a rigid polyethylene liner and a bag liner. Leaded gloves as waste are currently characterized by process knowledge and sample analysis using the Extraction Procedure (EP) Toxicity Test.	D008

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Lead/Cadmium Metal Waste	RL-M019	TRU Mixed Elemental Hazardous Metals with Mercury		This waste stream consists primarily of elemental hazardous metals. Some of the containers contain inorganic debris (metals, including mercury), organic debris (plastic, rubber, cellulosics), and soils.	d D005 D006 D007 D008 D009
	Lead/Cadmium Metal Waste	RL-M020	TRU Mixed Elemental Hazardous Metals without Mercury		This waste stream consists primarily of elemental hazardous metals. Some of the containers contain inorganic debris (metals without mercury), organic debris (plastic, rubber, cellulosics), and soils.	D007 D008
	Uncategorized Metal	IN-W260A	Inorganic Process Residues		This waste stream, generated at Bettis Atomic Power Laboratory, contains solid binary scrap as powder, pellets, or rods. The material is made of ceramic based UO_2 and ThO_2. Some kilorods or fuel rods constructed of fuel pellets within hollow zirconium tubes are also included.	e
	Uncategorized Metal	IN-W280	Metal Debris		This waste comes from Mound Laboratory. It consists of SS, carbon steel, and small amounts of aluminum-metal wastes in the form of valves, piping, wrenches, nuts, bolts, SS tubing, spatulas, pans, hotplates, ringstands, etc. Limited amounts of combustible and noncombustible waste also present from. Most of the waste is metal waste that is primarily from D&D operations. Some of the metals were leached with nitric acid, ultrasonically cleaned and dried to remove above-discard amounts of Pu.	D009
	Uncategorized Metal	IN-W287	Metal Debris		This waste stream, generated at ANL-E, contains glovebox sections and associated equipment from decontamination and decommissioning operations. The waste is predominantly noncombustible.	D008

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Uncategorized Metal	IN-W294	Metal Debris	ID 217C	This waste comes from RFP. It consists of the smaller pieces of the waste that have been washed with water to recover Pu.	D008 D022 F001 F002 F005
	Uncategorized Metal	IN-W296	Metal Debris	ID 217C	The waste comes from RFP. It consists of nonline- and line-generated wastes. The waste may be in the form of gloveboxes, glovebox windows, furnaces, lathes, drill presses, ducting, piping, angle iron, tanks, downdraft tables, part carriers, respirator filters, ultrasonic cleaners, control panels, electronic instrumentation, vacuum sweepers, pumps, motors, railing stairs, metal racks and trays, hotplates, empty metal produce and paint cans, carts, power tools (saws, drills, etc.), hand tools (wrenches, hammers, saws, chisels, gauges, etc.), chairs, desks, tables, typewriters, filing cabinets, crushed 55-gal drums, etc. The waste may also include limited amounts of combustible waste.	D008 D028 D029 F001 F002 F003 F005
	Uncategorized Metal	IN-W298	Metal Debris	ID 117	This waste comes from the RFP. It consists of used tantalum crucibles, funnels, funnel inserts, and pour rods.	D008 F001 F002
	Uncategorized Metal	IN-W300	Metal Debris	ID 117	Discarded metal.	D008 F001 F002 P015
	Uncategorized Metal	LA-W001	Mixed Metal Scrap and Incidental Combustibles	LA 125A	Mixed metal scrap and incidental combustibles.	d

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Uncategorized Metal	LA-W005	Noncombustible Scrap	LA 117A; 118A	Noncombustible scrap—small tools, cans, small equipment items, broken glass, etc.	D006
	Uncategorized Metal	LA-W009	Metal Waste from Gloveboxes and Equipment		Metal waste from gloveboxes and equipment	F001 F002 F005
	Uncategorized Metal	LL-W018	Combined Metal Scrap & Incidental Combustibles	LL 125	The waste consists mostly of metal scrap such as decommissioned gloveboxes, hoods, and other large equipment as well as laboratory trash. Typically, it will contain metal components, glassware, ceramics, plastics, paper, and wood. It will be mostly inorganic material but can vary widely.	D008
	Uncategorized Metal	RF-W011	Metal/TRM	RF 117	This waste includes items such as gloveboxes and machinery and empty containers. Items that are difficult to reduce to a size that would fit in a 55-gal drum are placed in DOT 7A, Type A metal boxes. These drums are lined with a rigid polyethylene liner, fiberboard liner and several bag liners. The boxes are lined with a fiberboard and PVC liner.	D008 F001 F002
	Uncategorized Metal	RF-W037	Heavy Metal (non-SS)/TRU	RF 117	Heavy (non-SS) metal waste is generated at various locations throughout the RFP. Heavy scrap metal is defined at RFP as metal elements above copper (Cu) on the periodic chart. Typically, these scrap metals consist of crucibles, funnels, rods and fixturing from several processes and production operations. Tantalum, tungsten, and platinum are examples of scrap metals at the RFP.	D008
	Uncategorized Metal	RL-M001	TRU Mixed Inorganic Debris with Mercury		This waste stream consists primarily of with mercury inorganic debris. Some of the containers contain organic debris (plastic and cellulosics).	D006 D009
	Uncategorized Metal	RL-M002	TRU Mixed Inorganic Debris Metals without Mercury		This waste stream consists primarily of inorganic metal debris. Some of the containers contain organic debris (plastic, rubber, cellulosics).	D008

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
CONTACT-HANDLED TRANSURANIC WASTE

CH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste—S5000	Uncategorized Metal	RL-M003	TRU Mixed Inorganic Debris Metal with Corrosives		This waste stream consists primarily of inorganic debris. Some of the containers contain organic debris (plastic, cellulosics, rubber).	d
	Uncategorized Metal	RL-M008	TRU Mixed Inorganic Debris Metals without Mercury		This waste stream consist primarily of inorganic debris metals. Some of the containers contain organic debris (plastic, rubber, cellulosics), and soils.	d D006 D007 D008
	Uncategorized Metal	RL-M021	TRU Mixed Inorganic Debris PCBs with Mercury[c]		This waste stream consists primarily of inorganic debris. Some of the containers contain organic debris (plastic, cellulosics). The hazardous constituents include PCBs and mercury. Note: This waste may contain TSCA waste at unknown levels.	D006 D008 D009

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
REMOTE-HANDLED TRANSURANIC WASTE

RH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Homogeneous Solids—S3000	Solidified Inorganics	IN-W146	Uncategorized Inorganic Sludges		Ten drums of TRU mixed waste sludge was generated from cleaning of four catch tanks. Concentrations of radionuclides and hazardous waste vary from drum to drum.	D006 D007 D008 D009 D011
	Solidified Inorganics	OR-W046	Solidified Liquid Low Level Waste Tanks - Sludge[c]		This waste stream is comprised of liquid low-level waste (LLLW) that has been concentrated by evaporation and subsequently stored in large underground storage tanks. The waste is generated as relative dilute low level waste in various nuclear research and radioisotope fabrication processes. These streams are collected centrally and the volumes reduced in an evaporation facility. After the waste has been stored, it separates into phases. The resulting solids (sludge phase) is fairly homogeneous chemically and radiochemically. Because the sludge is a product of solids concentration, it has been classified as a TRU waste. Note: This stream may contain TSCA waste at unknown levels.	D006 D007 D008 D009
	Salt Waste	IN-M001	Electrorefiner Stripped Salts—Barium (Ba) & Cadmium (Cd)		Chloride salts containing residual amounts of Cd and Ba.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
REMOTE-HANDLED TRANSURANIC WASTE

RH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Filter	AW-M003	TRU Waste Used Pre-filters		The waste consists of metal or wood framed pre-filters. Prefilters are 2 x 2 x 0.5 feet (ft). HEPA filters are 2 x 2 x 1 ft. Both types of filters have screen mesh covering high-efficiency filtering media. The concentrations of radioisotopes and RCRA toxic metals vary in each filter. These filters were generated from the decontamination of the analytical hot cell in 1993.	e
	Heterogeneous	AW-W020	TRU-Cd-Hot Cell Waste		This waste stream consists of metallic cadmium, soils, and associated cleanup materials (paper towels and cloth rags). The waste is contaminated with activation and fission products as well as with Pu. This waste stream is generated for Fuel Cycle Facility demonstration support experiments.	D006
	Heterogeneous	IN-M002	TRU-Cd-Hot Cell Waste		Metallic cadmium, salts, and cleanup material such as paper towels and rags.	e
	Heterogeneous	IN-W139	TRU Contaminated Lead Debris		This waste is lead contaminated lead debris from various sources. This debris includes lead pieces, galvanized sheet metal, copper/bronzeware, silicon, impregnated fiberglass, paper, HEPA filters, duct, etc.	D008
	Heterogeneous	IN-W269B	Debris Waste		This waste stream, generated at Idaho National Engineering Laboratory, contains laboratory waste from ANL-W including fluxwire, fission counters, HEDL samples, analytical samples dissolved and absorbed on Oil-Dri, glassware, vials, miscellaneous waste from gloveboxes, dissolved pellets absorbed on Oil-Dri, enriched and normal U-308 pellets, aluminum foil and capsules, TREAT® waste capsules, chlorinated ion exchange resins, Pu sources. Laboratory waste includes Kimwipes®, trash, glassware, dissolved samples absorbed in Oil-Dri, analytical samples, gloves, etc.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
REMOTE-HANDLED TRANSURANIC WASTE

RH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Heterogeneous	IN-W323	Predominantly Combustible Debris		This waste stream was generated at ANL-W and at INEL. Most of the waste is organic and combustible materials including paper, wood, PVC and plastic containers and items, rubber gaskets and gloves, leather, rags, towels, Q-tips, tubing, filter media, abrasive media and metal pieces. Small residuals of moderators and fuel are trapped on the filters. Drums of CH waste are stored at the TRU Storage Area (TSA). Drums of RH waste are stored at the Intermediate Level TRU Storage Facility (ILTSF).	D008
	Heterogeneous	OR-W040	RH TRU Heterogeneous Debris[c]		This waste stream consists of RH TRU waste which is classified as contaminated equipment, decontamination debris or dry solids. The physical form is solid. Note: This stream may contain TSCA waste at unknown levels.	D006 D008 D009 D011
Debris Waste - S5000	Heterogeneous	RL-M201	Projected RH-MTRU Waste		The waste includes failed and obsolete equipment or material, including tanks, pumps, agitators, ovens, heaters, hoods, jumpers, and accessories. Some waste will contain wood, plastics, paper, rubber, and soils.	e
	Lead/Cadmium Metal Waste	AW-W016	Electrorefiner Stripped Cadmium		This waste stream consists of cadmium dispersed in a copper alloy matrix. This waste stream will be generated from the electrorefiner station in the ANL-Fuel Cycle Facility.	D006
	Lead/Cadmium Metal Waste	AW-W022	Electro Refiner Insolubles with Cadmium		This waste stream consists of cadmium metal with other heavy metals and "mable" metals (that is, they are not reactive in the FCF electrorefining process). This waste stream will be generated from the electrorefiner station in the ANL-W Fuel Cycle Facility Integral Fast Reactor demonstration. This waste stream includes inorganic sludges/particulates.	D006
	Lead/Cadmium Metal Waste	IN-M004	Electrorefiner Stripped Cadmium		Encapsulated waste cadmium metal.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
REMOTE-HANDLED TRANSURANIC WASTE

RH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Lead/Cadmium Metal Waste	IN-M005	Electrorefiner Insolubles with Cadmium		Cadmium and other heavy metals.	e
	Uncategorized Metal	AW-W018	Sodium - TRU		Sodium is used as a primary and secondary coolant for the EBR-II Reactor. Waste sodium metal is a hazardous constituent of the TRU waste stored at the ANL-W Radioactive Scrap and Waste Facility (RSWF). Waste at RSWF is RH. This waste is generated during maintenance and operational activities. The sodium typically coats waste metal equipment, experiments and components removed during reactor operations and maintenance activities.	d
	Uncategorized Metal	AW-W019	Sodium Potassium-(NaK) - TRU		Sodium potassium alloy is used as a coolant for some components of the EBR-II reactor. Waste NaK metal is stored at the ANL-W RSWF. The RH NaK waste at the RSWF is contained in SS capsules or tubing and placed inside carbon steel waste cans which are then placed in SS outer cans. The entire package is then stored in RSWF storage liners (carbon steel soil storage vaults). The NaK is generated during maintenance and operational activities. NaK waste is in canisters with TRU waste metal pieces and rods from reactor experiments.	d
	Uncategorized Metal	AW-W021	Metal Debris		This waste stream consists of metal, and of EER N fuel elements. This waste stream will be generated from the "Element Chopper" station in the ANL-W Fuel Cycle Facility demonstration.	D005 D006
Debris Waste - S5000	Uncategorized Metal	IN-M003	Element Hardware FCF Waste		Small pieces of SS from nuclear fuel.	e
	Uncategorized Metal	IN-W260B	Inorganic Process Residues		This waste stream, generated at Bettis Atomic Power Laboratory, contains solid binary scrap as powder, pellets, or rods. The material is made of ceramic based UO_2 and ThO_2. Some kilorods or fuel rods constructed of fuel pellets within hollow zirconium tubes are also included.	e

TABLE C-2 (CONTINUED)
TRU MIXED WASTE CHARACTERIZATION INFORMATION
REMOTE-HANDLED TRANSURANIC WASTE

RH TRU Waste Summary Category Group Description	Waste Matrix Code Group	Waste Stream Unique ID[a]	Waste Stream Name	TRUCON[b] Code	Waste Description (WTWBIR)[a]	EPA Code
Debris Waste - S5000	Uncategorized Metal	IN-W322	Sample Fuel		Waste consists of actinide neutron sources, a tadrum needle, small vials of fuel, and metal containers of experimental fuel capsules.	e
	Uncategorized Metal	LA-WR01	Mixed Metal Scrap and Incidental Combustibles		Mixed metal scrap and incidental combustibles.	e
	Uncategorized Metal	LA-WR05	Noncombustible Scrap		Noncombustible scrap—small tools, cans, equipment items, broken glass, etc.	e

[a]Waste stream unique identifications (ID) and waste descriptions are taken from the U.S. Department of Energy (DOE), 1995, "Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report," CAO-94-1005, Rev. 1, U.S. Department of Energy, Albuquerque, New Mexico. The WTWBIR contains the most complete description information available at this time. Hazardous contents listed for individual waste streams are subject to verification through the WIPP Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C8).
[b]TRUCON = TRUPACT-II Content
[c]Waste streams with unknown levels of TSCA waste, PCBs, or asbestos will have to meet WAP acceptability criteria.
[d]Although waste generators have previously indicated that some waste streams may have had the potential for reactivity, ignitability, or corrosivity (based on known waste generating processes), the final waste form accepted for disposal at the WIPP facility would not be permitted with these characteristics.
[e]EPA hazardous waste codes have not been reported by the generators at this time. These wastes will be subjected to the characterization requirements of this WAP prior to acceptance. These may or may not actually be TRU mixed wastes but are retained in the table for completeness.
[f]Classification of waste matrix code group is based on the waste stream being at least 50 percent of the indicated waste form (e.g., solidified inorganics). Therefore, a cement matrix containing trace quantities of F-listed solvents is classified as solidified inorganics.

NOTE: The use of trade names or brand names in this table does not constitute endorsement by the DOE or its contractors.

TABLE C-3
RATIONALE FOR SELECTION OF PARAMETERS OF INTEREST

Compound[a]	Synonyms	CAS[b] Number	Toxicity Characteristic Contaminant	Other Listed Constituent	Appendix VIII Constituent
Acetone	2-Propanone, dimethyl ketone	67-64-1		F003	
Antimony		7440-36-0			+
Arsenic		7440-38-2	D004		+
Barium		7440-39-3	D005		+
Benzene	Benzol	71-43-2	D018	F005	+
Beryllium		7440-41-7		P015	+
Bromoform	Tribromomethane, methyl tribromide	75-25-2			+
n-Butyl alcohol	Butanol, 1-butanol, n-butanol	71-36-3		F003	
Cadmium		7440-43-9	D006		+
Carbon disulfide	Carbon bisulfide	75-15-0		F005	+
Carbon tetrachloride	Tetrachloromethane	56-23-5	D019	F001	+
Chlorobenzene		108-90-7	D021	F002	+
Chloroform	Trichloromethane	67-66-3	D022		+
Chromium	Chrome	7440-47-3	D007		+
Cresols	Cresylic acid	1319-77-3	D026	F004	+
1,4-Dichlorobenzene	p-Dichlorobenzene	106-46-7	D027		+
1,2-Dichlorobenzene	o-Dichlorobenzene	95-50-1		F002	+
1,1-Dichloroethane	Ethylidene dichloride	75-34-3			+
1,2-Dichloroethane	Ethylene dichloride	107-06-2	D028		+
cis-1,2-Dichloroethylene	cis-1,2-Dichloroethene, sym-Dichloroethylene	156-60-5			+
1,1-Dichloroethylene	1,1-Dichloroethene, vinylidene chloride	75-35-4	D029		+
2,4 Dinitrophenol		51-28-5			+
2,4-Dinitrotoluene	1-methyl-2, 4-dinitrobenzene	121-14-2	D030		+
Ethyl benzene		100-41-4		F003	
Ethyl ether	Diethyl ether, ether	60-29-7		F003	
Formaldehyde[c]		50-00-0			+
Hexachlorobenzene		118-74-1	D032		+
Hexachloroethane		67-72-1	D034		+
Hydrazine[d]		302-01-2			+
Isobutanol	Isobutyl alcohol, 2-methyl-1-propanol	78-83-1		F005	+
Lead		7439-92-1	D008		+
Mercury		7439-97-6	D009		+
Methanol	Methyl alcohol	67-56-1		F003	
Methyl ethyl ketone	2-Butanone	78-93-3	D035	F005	+
Methyl isobutyl ketone	4-Methyl-2-pentanone, hexone	108-10-1		F003	
Methylene chloride	Dichloromethane	75-09-2		F001,F002	+
Nickel		7440-02-0			+
Nitrobenzene	Nitrobenzol	98-95-3	D036	F004	+
Pentachlorophenol	PCP	87-86-5	D037		+
Polychlorinated biphenyls (PCBs)		1336-36-3			+
Pyridine		110-86-1	D038	F005	+
Selenium		7782-49-2	D010		+
Silver		7440-22-4	D011		+

TABLE C-3 (CONTINUED)
RATIONALE FOR SELECTION OF PARAMETERS OF INTEREST

Compound[a]	Synonyms	CAS[b] Number	Toxicity Characteristic Contaminant	Other Listed Constituent	Appendix VIII Constituent
1,1,2,2-Tetrachloroethane		79-34-5			+
Tetrachloroethylene	Tetrachloroethene, perchloroethylene	127-18-4	D039	F001,F002	+
Thallium		7440-28-0			+
Toluene	Methyl benzene	108-88-3		F005	+
1,1,1-Trichloroethane	Methyl chloroform	71-55-6		F001,F002	+
1,1,2-Trichloroethane	Ethane trichloride	79-00-5		F002	+
Trichloroethylene	Trichloroethene	79-01-6	D040	F001,F002	+
Trichlorofluoromethane	Freon-11	75-69-4		F001,F002	+
1,1,2-Trichloro-1,2,2-trifluoroethane	Freon-113	76-13-1		F001,F002	
Vanadium		7440-62-2			
Vinyl chloride	Chloroethene	75-01-4	D043		+
m-Xylene	1,3-Dimethylbenzene	108-38-3		F003	
o-Xylene	1,2-Dimethylbenzene	95-47-6		F003	
p-Xylene	1,4-Dimethylbenzene	106-42-3		F003	
Zinc[c]		7440-66-6			

[a] U.S. Department of Energy (DOE), 1995a, "Transuranic Waste Characterization Quality Assurance Program Plan" (QAPP), CAO-94-1010, Rev. 0, Carlsbad Area Office, Carlsbad, New Mexico.

[b] CAS=Chemical Abstracts Number

[c] Reported only by Los Alamos National Laboratory.

[d] Reported only by Oak Ridge National Laboratory and Savannah River Site.

[e] Zinc was added during development of the QAPP.

TABLE C-4
RATIONALE FOR COMPLIANCE WITH PROHIBITED CHARACTERISTIC WASTES

Prohibited Characteristics	Rationale for Transuranic Mixed Waste Compliance
Ignitability	Ignitability
• Liquid waste.	• Waste is not a liquid. Verified by radiography.
• Contains pyrophorics or materials capable of spontaneous chemical changes.	• Final waste form precludes pyrophorics or spontaneous reactions.[a] Pyrophorics prohibited by waste acceptance criteria (WAC).
• Contains ignitable compressed gases as defined in 49 Code of Federal Regulations (CFR) §173.300.	• Containers capable of containing any compressed gases are prohibited by the WAC . Verified by radiography.
• Contains oxidizers as defined in Title 49 CFR §173.151.	• Acceptable knowledge and final waste form precludes oxidizers.
Corrosivity	Corrosivity
• Contains aqueous or nonaqueous liquid waste.	• Liquid waste (greater than one percent by volume) is prohibited by WAC.
Reactivity	Reactivity
• Unstable and will readily undergo violent change without detonating.	• Final waste form precludes reactivity[a].
• When mixed with water, will react violently, form a potentially explosive mixture, or generate harmful toxic gases, vapors, or fumes.	• Acceptable knowledge and final waste form[a].
• If subjected to a strong initiating force or if heated under confinement, will detonate or explode.	• Acceptable knowledge and final waste form[a].
• Cyanide- or sulfide-bearing waste.	• Acceptable knowledge and final waste form[a].
• Capable of detonation or explosive decomposition at standard temperature and pressure.	• Final waste form precludes detonation or explosive decomposition[a].
• A forbidden explosive as defined in 49 CFR §173.51, a Class A explosive as defined in 49 CFR §173.53 or a Class B explosive as defined in 49 CFR §173.88.	• Explosives prohibited by WAC.

[a]Waste compatibility analysis in Appendix C1 shows that these reactions will not occur based on waste constituents and final waste form.

TABLE C-5
VOC HEADSPACE CONCENTRATION LIMITS

COMPOUND	VOC HEADSPACE CONCENTRATION LIMITS[a] (PPM)
Carbon Tetrachloride	7,510
Chlorobenzene	17,660
Chloroform	6,325
1,1-Dichloroethene	28,750
1,2-Dichloroethane	9,100
Methylene Chloride	100,000
1,1,2,2-Tetrachloroethane	7,924
Toluene	41,135
1,1,1-Trichloroethane	100,000

[a] There are no maximum headspace limits for other VOCs. These concentrations are based on calculations provided in Appendix D9.

TABLE C-6
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR CH TRANSURANIC MIXED WASTE (STORED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S3000-Homogeneous Solids S4000-Soil/Gravel	• Solidified inorganics • Salt waste • Solidified organics • Contaminated soil/debris	Physical waste form	100% radiography or visual examination	• Verify waste matrix • Demonstrate compliance with waste acceptance criteria (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas volatile organic compounds (VOC)	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of transuranic (TRU) waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Statistical sampling[a] (see Tables C-10 and C-11)	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-6 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR CH TRANSURANIC MIXED WASTE (STORED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S5000–Debris Waste	• Uncategorized metal (metal waste other than lead/cadmium) • Lead/cadmium waste • Inorganic nonmetal waste • Combustible waste • Graphite waste • Heterogeneous waste • Composite filter waste	Physical waste form	100% Radiography Visual examination (statistical sample)[a]	• Verify waste matrix • Demonstrate compliance with waste acceptance (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas VOCs	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of TRU waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs • Verify acceptable knowledge
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Acceptable knowledge	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-6 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR CH TRANSURANIC MIXED WASTE (NEWLY GENERATED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S3000-Homogeneous Solids S4000-Soil/Gravel	• Solidified inorganics • Salt waste • Solidified organics • Contaminated soil/debris	Physical waste form	Documentation and verification[b]	• Verify waste matrix • Demonstrate compliance with waste acceptance criteria (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas VOCs (VOCs)	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of TRU waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Statistical sampling[a] (see Tables C-10 and C-11)	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-6 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR CH TRANSURANIC MIXED WASTE (NEWLY GENERATED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S5000–Debris Waste	• Uncategorized metal (metal waste other than lead/cadmium) • Lead/cadmium waste • Inorganic nonmetal waste • Combustible waste • Graphite waste • Heterogeneous waste • Composite filter waste	Physical waste form	Documentation and verification[b]	• Verify waste matrix • Demonstrate compliance with waste acceptance (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas VOCs	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of TRU waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs • Verify acceptable knowledge
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Acceptable knowledge	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-6 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR CH TRANSURANIC MIXED WASTE (STORED WASTE)

[a] Number determined per Quality Assurance Program Plan (QAPP), Section 5.0.

[b] See discussion in Section 5.3.3 of the QAPP.

U.S. Department of Energy (DOE), 1995, "TRU Waste Characterization Quality Assurance Program Plan," CAO-94-1010, Rev 0, Carlsbad Area Office, Carlsbad, New Mexico.

TABLE C-7
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR RH TRANSURANIC MIXED WASTE (STORED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S3000-Homogeneous Solids S4000-Soil/Gravel	• Solidified inorganics • Salt waste • Solidified organics • Contaminated soil/debris	Physical waste form	Radiography for wastes <1 rem/hour Acceptable knowledge	• Verify waste matrix • Demonstrate compliance with waste acceptance criteria (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas VOCs	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable volatile organic compounds (VOCs) • Determine potential flammability of transuranic (TRU) waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Statistical sampling (see Tables C-10 and C-11)	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-7 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR RH TRANSURANIC MIXED WASTE (STORED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S5000–Debris Waste	• Uncategorized metal (metal waste other than lead/cadmium) • Lead/cadmium waste • Inorganic nonmetal waste • Combustible waste • Graphite waste • Heterogeneous waste • Composite filter waste	Physical waste form	100% Radiography	• Verify waste matrix • Demonstrate compliance with waste acceptance (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas VOCs	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of TRU waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs • Verify acceptable knowledge
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Acceptable knowledge	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-7 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR RH TRANSURANIC MIXED WASTE (NEWLY GENERATED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S3000-Homogeneous Solids S4000-Soil/Gravel	• Solidified inorganics • Salt waste • Solidified organics • Contaminated soil/debris	Physical waste form	Documentation and verification	• Verify waste matrix • Demonstrate compliance with waste acceptance criteria (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas volatile organic compounds (VOCs)	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of TRU waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Statistical sampling (see Tables C-10 and C-11)	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-7 (CONTINUED)
SUMMARY OF PARAMETERS, CHARACTERIZATION METHODS, AND RATIONALE FOR RH TRANSURANIC MIXED WASTE (NEWLY GENERATED WASTE)

Waste Matrix Code Summary Categories	Waste Matrix Code Groups	Characterization Parameter	Method	Rationale
S5000–Debris Waste	• Uncategorized metal (metal waste other than lead/cadmium) • Lead/cadmium waste • Inorganic nonmetal waste • Combustible waste • Graphite waste • Heterogeneous waste • Composite filter waste	Physical waste form	Documentation and verification	• Verify waste matrix • Demonstrate compliance with waste acceptance (e.g., no free liquids, no incompatible wastes, no compressed gases)
		Headspace gases • Gas VOCs	100% gas sampling and analysis (see Table C-9)	• Quantify concentration of flammable VOCs • Determine potential flammability of TRU waste headspace gases • Quantify concentrations of VOC constituents in headspace of containers • Support demonstration of no migration by headspace VOCs • Verify acceptable knowledge
		Hazardous constituents • Total metals • Total VOCs • Total semi-VOCs	Acceptable knowledge	• Determine characteristic metals and organics • Determine total quantity of metals, VOCs, and semi-VOCs

TABLE C-8

SUMMARY OF HAZARDOUS WASTE CHARACTERIZATION REQUIREMENTS FOR TRANSURANIC MIXED WASTE[a]

Parameter	Techniques and Methods Manual Procedure
Physical Waste Form Matrix Parameter Categories Summary Category Names S3000 Homogeneous Solid S4000 Soil/Gravel S5000 Debris Wastes	**Waste Inspection Procedures** Radiography, Procedure 310.1 Visual Examination, Procedure 310.2 (QAPP Section 10.0)
Headspace Gases **Volatile Organic Compounds** Benzene Bromoform Carbon tetrachloride Chlorobenzene Chloroform 1,1-Dichloroethane 1,2-Dichloroethane 1,1-Dichloroethylene (cis)-1,2-Dichloroethylene Ethyl benzene Ethyl ether Formaldehyde[b] Hydrazine[c] Methylene chloride 1,1,2,2-Tetrachloroethane Tetrachloroethylene Toluene 1,1,1-Trichloroethane Trichloroethylene 1,1,2-Trichloro-1,2,2-trifluoroethane Xylenes Alcohols and Ketones Acetone Butanol Methanol Methyl ethyl ketone Methyl isobutyl ketone	**Gas Analysis** Gas Chromatography (GC)/Mass Spectroscopy (MS), Procedure 430.1 or 430.2 (QAPP Section 12.0) GC/MS GC/Flame Ionization Detector (FID), Procedure 440.1 (QAPP Section 12.0) Fourier Transform Infrared Spectroscopy (FTIRS), Procedure 430.7

TABLE C-8 (CONTINUED)
SUMMARY OF HAZARDOUS WASTE CHARACTERIZATION REQUIREMENTS FOR TRANSURANIC MIXED WASTE[a]

Parameter		Techniques and Methods Manual Procedure
Total Volatile Organic Compounds		**Total Volatile Organic Compound Analysis**
Acetone	Isobutanol	GC/MS, Procedure 430.3 or 430.4 GC/FID, Procedure 440.2 (QAPP Section 13.0) Acceptable Knowledge for Matrix Parameter Summary Category S5000 (Debris Wastes)
Benzene	Methanol	
Bromoform	Methyl ethyl ketone	
Butanol	Methylene chloride	
Carbon disulfide	Pyridine[d]	
Carbon tetrachloride	1,1,2,2-Tetrachloroethane	
Chlorobenzene	Tetrachloroethylene	
Chloroform	Toluene	
1,4-Dichlorobenzene[d]	1,1,2-Trichloro-1,2,2-trifluoroethane	
1,2-Dichlorobenzene[d]	Trichlorofluoromethane	
1,2-Dichloroethane	1,1,1-Trichloroethane	
1,1-Dichloroethylene	1,1,2-Trichloroethane	
Ethyl benzene	Trichloroethylene	
Ethyl ether	Vinyl chloride	
Formaldehyde[b]	Xylenes	
Hydrazine[c]		
Total Semivolatile Organic Compounds		**Total Semivolatile Organic Compound Analysis** GC/MS, Procedure 430.5 or 430.6 GC/ECD for PCBs , Procedure 440.3 (QAPP Section 14.0) Acceptable Knowledge for Matrix Parameter Summary Category S5000 (Debris Wastes)
Cresols		
1,4-Dichlorobenzene[e]		
1,2-Dichlorobenzene[e]		
2,4-Dinitrophenol		
2,4-Dinitrotoluene		
Hexachlorobenzene		
Hexachloroethane		
Nitrobenzene		
Polychlorinated biphenyls		
Pentachlorophenol		
Pyridine[e]		
Total Metals		**Total Metals Analysis** Atomic MS, Procedure 630.1 Atomic Emission Spectroscopy, Procedure 640.1 Atomic Absorption Spectroscopy , Procedures 650.1 through 650.7 (QAPP Section 15.0) Acceptable Knowledge for Matrix Parameter Summary Category S5000 (Debris Wastes)
Antimony	Mercury	
Arsenic	Nickel	
Barium	Selenium	
Beryllium	Silver	
Cadmium	Thallium	
Chromium	Vanadium	
Lead	Zinc	

[a] U.S. Department of Energy (DOE), 1995a, "TRU Waste Characterization Quality Assurance Program Plan" (QAPP), CAO-94-1010, Rev. 0, Carlsbad Area Office, Carlsbad, New Mexico.
[b] Required only for homogeneous solids and soil/gravel from Los Alamos National Laboratory.
[c] Required only for homogeneous solids and soil/gravel from Oak Ridge National Laboratory and Savannah River Site.
[d] Can also be analyzed as a semi-volatile organic compound.
[e] Can also be analyzed as a volatile organic compound.

TABLE C-9
HEADSPACE TARGET ANALYTE LIST AND METHODS

Parameter	Methods Manual Procedure	EPA Specified Analytical Method
Benzene Bromoform Carbon tetrachloride Chlorobenzene Chloroform 1,1-Dichloroethane 1,2-Dichloroethane 1,1-Dichloroethylene (cis)-1,2-Dichloroethylene Ethyl benzene Ethyl ether Formaldehyde[b] Hydrazine[c] Methylene chloride 1,1,2,2-Tetrachloroethane Tetrachloroethylene Toluene 1,1,1-Trichloroethane Trichloroethylene 1,1,2-Trichloro-1,2,2-trifluoroethane Xylenes	430.1 430.2 430.7	EPA: Modified TO-14[a]; Modified 8240/8260 EPA - Approved Fourier Transform Infrared Spectroscopy
Acetone Butanol Methanol Methy ethyl ketone Methyl isobutyl ketone	430.1 430.2 430.7 440.1	EPA: Modified TO-14[a]; Modified 8240/8260 EPA - Approved Fourier Transform Infrared Spectroscopy No Equivalent EPA Method for Methods Manual Procedure 440.1

[a] U.S. Environmental Protection Agency (EPA), 1988, "Compendium Method TO-14, the Determination of Volatile Organic Compounds (VOC) in Ambient Air Using SUMMA® Passivated Canister Sampling and Gas Chromatographic Analysis," in Compendium of Methods for the Determination of Toxic Organic Compounds on Ambient Air. Research Triangle Park, North Carolina, Quality Assurance Division, Monitoring System Laboratory, U.S. EPA. The most current revision of the specified methods will be used.

[b] Required only for containers of homogeneous solids and soil/gravel waste from Los Alamos National Laboratory.

[c] Required only for containers of homogeneous solids and soil/gravel waste from Oak Ridge National Laboratory and the Savannah River Site.

TABLE C-10
REQUIRED TOTAL ORGANIC ANALYSES AND TEST METHODS ORGANIZED BY ORGANIC ANALYTICAL GROUPS

Organic Analytical Group	Required Organic Analyses	Methods Manual Procedure	EPA Specified Analytical Method[a]
Nonhalogenated Volatile Organic Compounds (VOCs)	Acetone Benzene n-Butanol Carbon disulfide Ethyl benzene Ethyl ether Formaldehyde Hydrazine[b] Isobutanol Methanol Methyl ethyl ketone Toluene Xylenes	430.3 430.4 440.2	8240B 8260A
Halogenated VOCs	Bromoform Carbon tetrachloride Chlorobenzene Chloroform 1,2-Dichloroethane 1,1-Dichloroethylene Methylene chloride 1,1,2,2-Tetrachloroethane Tetrachloroethylene 1,1,2-Trichloroethane 1,1,1-Trichloroethane Trichloroethylene Trichlorofluoromethane 1,1,2-Trichloro-1,2,2-trifluoroethane Vinyl Chloride	430.3 430.4	8240B 8260A
Semivolatile Organic Compounds (SVOCs)	Cresols (o, m, p) 1,2-Dichlorobenzene[c] 1,4-Dichlorobenzene[c] 2,4-Dinitrophenol 2,4-Dinitrotoluene Hexachlorobenzene Hexachloroethane Nitrobenzene Polychlorinated biphenyls (PCB)[d] Pentachlorophenol Pyridine[c]	430.5 430.6 440.3 (for PCBs only)	8250A 8270B 3620 8081 (for PCBs only) 3550

TABLE C-10 (CONTINUED)
REQUIRED ORGANIC ANALYSES AND TEST METHODS
ORGANIZED BY ORGANIC ANALYTICAL GROUPS

[a] U.S. Environmental Protection Agency (EPA), 1993, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846, Third Edition Final Update I and Final Update II. Equivalent methods are demonstrated by meeting the quality assurance/quality control requirements specified in the QAPP and SW-846 protocols.

[b] Sites will have to develop an analytical method for hydrazine. This method will be submitted to the DOE CAO for approval.

[c] These compounds may also be analyzed as VOCs by SW-846 Methods 8240B and 8260A.

[d] Transformer oils containing PCBs have been identified in a limited number of waste streams included in the organic sludges waste matrix code. Therefore, only waste streams included in the solidified organics final waste form must be analyzed for PCBs.

TABLE C-11
SUMMARY OF SAMPLE PREPARATION AND ANALYTICAL METHODS FOR TOTAL METALS

Parameters	Methods Manual Procedure	EPA-Specified Analytical Methods[a]
Sample Preparation	610.1	3051, or equivalent, as appropriate for analytical method
Total Antimony	630.1, 640.1, 650.1, 650.2, 650.5	6010A, 6020, 7040, 7041, 7062
Total Arsenic	630.1, 640.1, 650.4, 650.5	6010A, 6020, 7060A, 7061A, 7062
Total Barium	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7080A, 7081
Total Beryllium	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7090, 7091
Total Cadmium	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7130, 7131A
Total Chromium	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7190, 7191
Total Lead	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7420, 7421
Total Mercury	650.3	7471A
Total Nickel	630.1, 640.1, 650.1	6010A, 6020, 7520
Total Selenium	630.1, 650.2, 650.6, 650.7	6010A, 7740, 7741A, 7742
Total Silver	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7760A, 7761
Total Thallium	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7840, 7841
Total Vanadium	630.1, 650.1, 650.2	6010A, 7910, 7911
Total Zinc	630.1, 640.1, 650.1, 650.2	6010A, 6020, 7950, 7951

[a] U.S. Environmental Protection Agency (EPA), 1986 as amended by FR 46040, August 31, 1993. "Test Methods for Evaluating Solid Waste," Laboratory Manual Physical/Chemical Methods, SW-846, 3rd ed., U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C. Equivalent methods are demonstrated by meeting the quality assurance/quality control requirements specified in the Quality Assurance Program Plan (QAPP) and SW-846 protocols.

TABLE C-12
WIPP WASTE INFORMATION SYSTEM DATA FIELDS[a]

Characterization Module Data Fields [b]	
Container ID [c]	Total VOC Sample Date
Generator EPA ID	Total VOC Analysis Date
Generator Address	Total VOC Analyte Name [d]
Generator Name	Total VOC Analyte Concentration [d]
Generator Contact	Total Metal Sample Date
Hazardous Code	Total Metal Analysis Date
Headspace Gas Sample Date	Total Metal Analyte Name [d]
Headspace Gas Analysis Date	Total Metal Analyte Concentration [d]
Headspace Gas Analyte [d]	Semi-VOC Sample Date
Headspace Gas Concentration [d]	Semi-VOC Analysis Date
Headspace Gas Char. Method [d]	Semi-VOC Analyte Name [d]
Total VOC Char. Method [d]	Semi-VOC Concentration [d]
Total Metals Char. Method [d]	Transporter EPA ID
Total Semi-VOC Char. Method [d]	Transporter Name
Item Description Code	Visual Exam Container [e]
Haz. Manifest Number	Waste Material Parameter [d]
NDE Complete [e]	Waste Material Weight [d]
PCB Concentration [f]	Waste Matrix Code
	Waste Matrix Code Group
	Waste Stream Profile Number

Certification Module Data Fields	
Container ID [c]	Fissile Gram Equiv.
Container type	Radioassay (RA) Date
Container Weight	RA Method
Contact Dose Rate	Radionuclide [d]
Container Certification date	Radionuclide Quan.[d]
Container Closure Date	Handling Code
Container Liner Type	Waste Weight
Decay Heat	Waste Fill %
Overpack Number (if any)	Surface Contamination
PE Curie Equiv.	Alpha Activity

Transportation Data Module	
Shipment Number	Layers of Packaging
TRUPACT Number	Ship Category
Assembly Number[g]	Ship Certification Date
Container IDs [c,d]	Ship Date
Filter Model	Receive Date
Filter Date	Vehicle Type
ICV Closure Date	

TABLE C-12 (CONTINUED)
WIPP WASTE INFORMATION SYSTEM DATA FIELDS

Disposal Module Data
Container ID [c]
Disposal Date
Disposal Location

[a] This is not a complete list of the WWIS data fields, but is a subset that contains the fields that are pertinent to RCRA.

[b] Some of the fields required for characterization are also required for certification and/or transportation.

[c] Container ID is the main relational field in the WWIS Database.

[d] This is a multiple occurring field for each analyte, nuclide, etc.

[e] These are logical fields requiring only a yes/no.

[f] Limits are applied to many fields. The limit for PCBs is 50 ppm.

[g] Required for 7-Packs of 55 gal drums to tie all of the drums in that assembly together. This facilitates the identification of waste containers in a shipment without need to breakup the assembly.

TABLE C-13
REQUIRED PROGRAM RECORDS MAINTAINED IN SITE PROJECT FILES

Lifetime Records

- Field sampling data forms
- Field and laboratory chain-of-custody forms
- Laboratory analytical data reports
- Analytical results of all QA/QC samples
- Reports and data transmittals sent to DOE/CAO
- Nonconformance and corrective action documentation
- Sampling Plans
- Audit plans, reports, responses, and final closure of corrective actions
- Quality assurance reports to management
- Data reduction, validation, and reporting records
- Gas canister tags
- Audio/video tapes

Non-Permanent Records

- Performance Demonstration Program analytical results
- Sampler certifications
- All pertinent incoming and outgoing correspondence, memoranda, and telephone records related to QA/QC
- Documentation of calculations and computer programs with associated verification
- Reference material relevant to the waste characterization program
- Training/qualification records
- Documentation of revisions or changes to the QAPP or QAPjPs
- Calibration records
- Electronic instrument data (e.g., GC/MS files)
- Procurement records
- QC standard certification statements

FIGURES

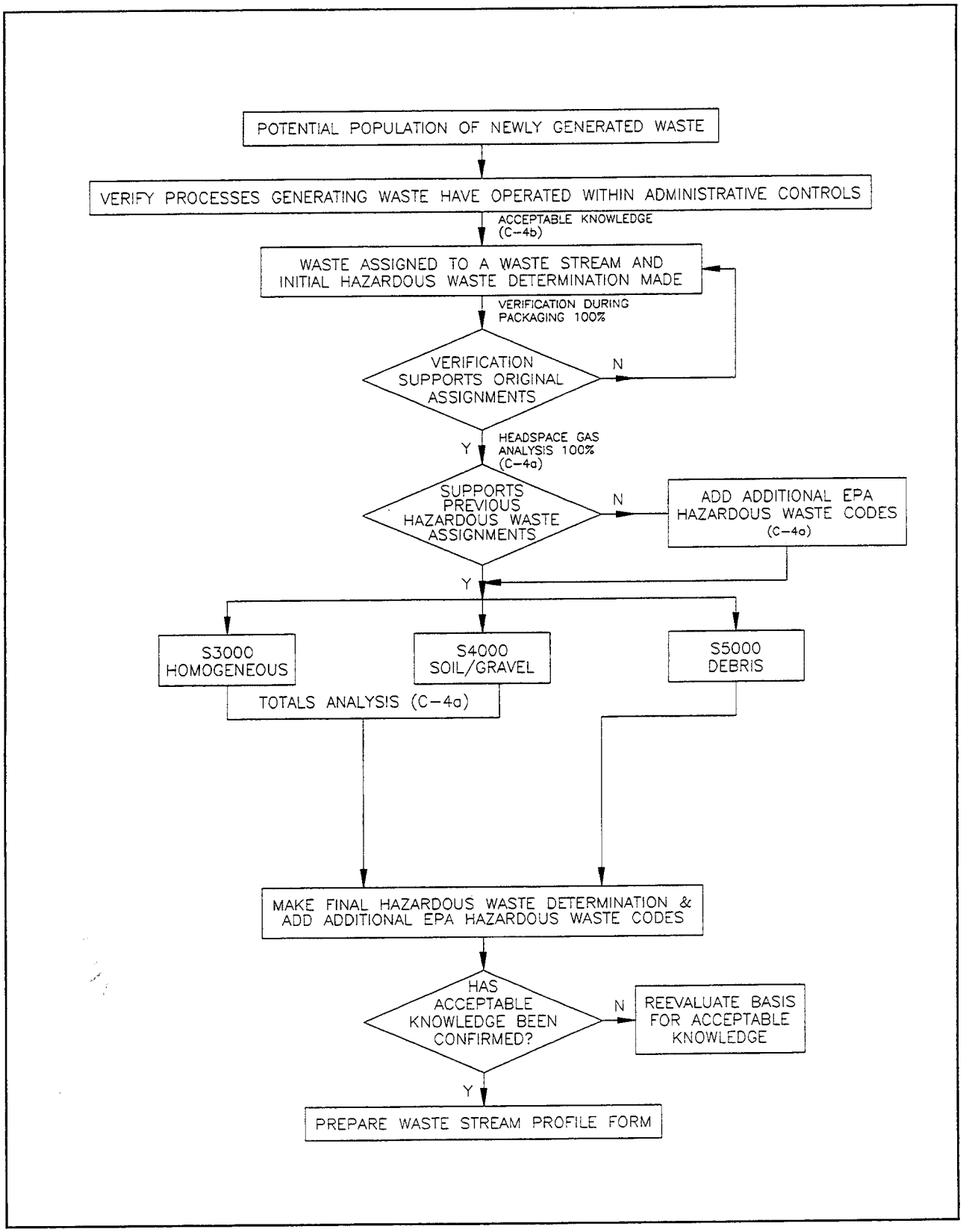

Figure C-1

Data Collection Design for Characterization of Newly Generated Waste

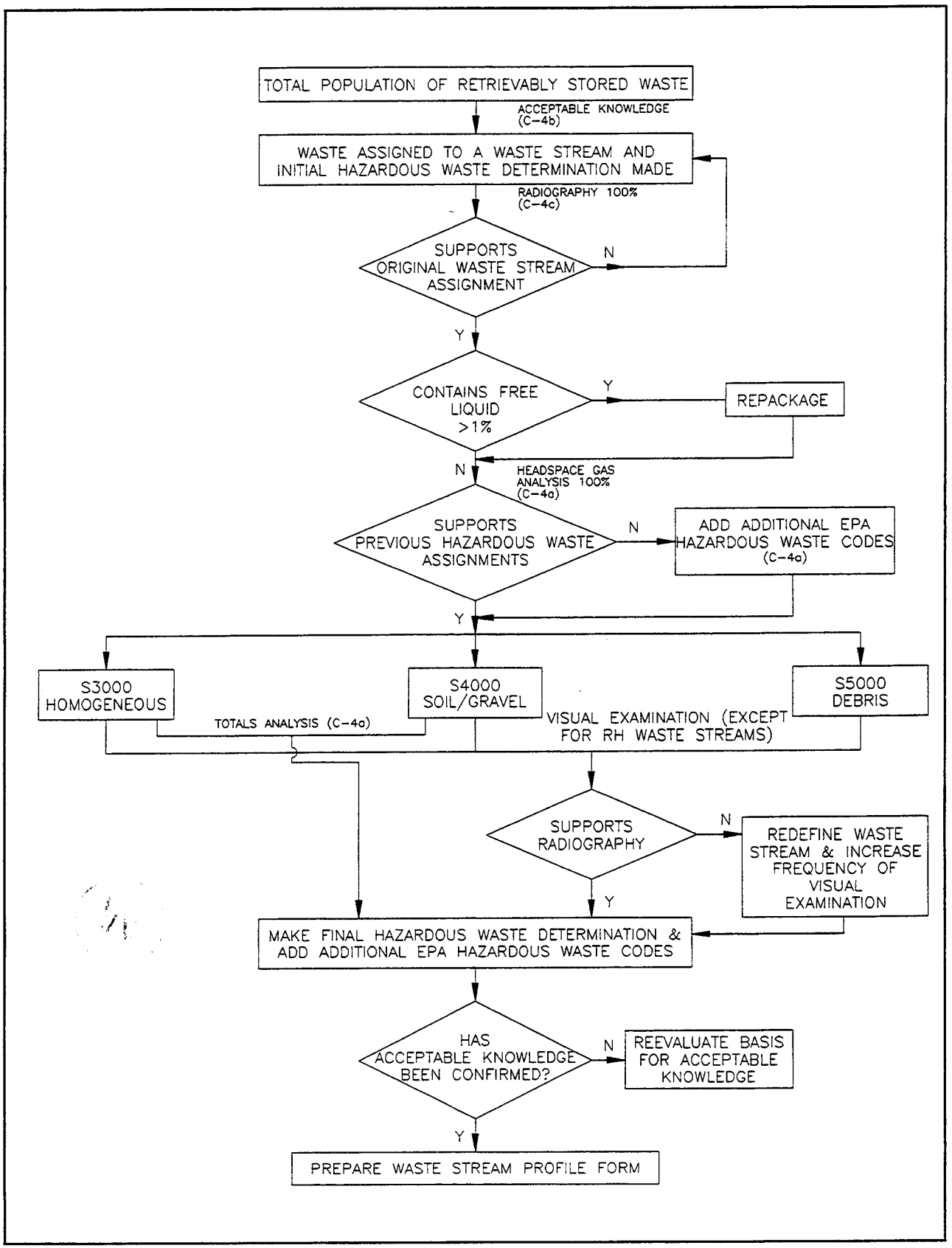

Figure C-2

Data Collection Design for Characterization of Retrievably Stored Waste

AL Ames Laboratory
AE Argonne National Laboratory–East
AW Argonne National Laboratory–West
ET Energy Technology Engineering Center
IN Idaho National Engineering Laboratory
KA Knolls Atomic Power Laboratory–Knolls Site
LA Los Alamos National Laboratory
LB Lawrence Berkeley Laboratory
LL Lawrence Livermore National Laboratory
MD Mound Plant
MU University of Missouri
NT Nevada Test Site
OR Oak Ridge National Laboratory
PA Paducah Gaseous Diffusion Plant
RF Rocky Flats Environmental Technology Site
RL Richland (Hanford) Site
SA Sandia National Laboratories/New Mexico
SR Savannah River Site

★ Indicates Major Site
◊ Indicates Minor Site

Figure C-3
U.S. Department of Energy Transuranic Mixed Waste Generator/Storage Sites

Form Number_____
Page ____ of ____

WIPP WASTE STREAM PROFILE FORM

Shipper/Generator Information:

Site Name _____ / EPA ID _____

Tech. Contact _____ / Phone _____

Orig. Generator _____ / EPA ID _____

Waste Stream Information:

Check one: ☐ CH ☐ RH

Waste Stream WIPP ID _____

Summary Category Group _____ /Waste Matrix Code Group _____

Waste Stream Name _____

Description _____

_____

_____

Date of WAC Certification _____

Title, version number, and date of documents used for WAC certification:

_____

Number of SWBs _____ Number of Drums _____ Number of Canisters _____

List all applicable EPA Hazardous Waste Codes _____

Acceptable Knowledge Information:

Required Program Information		Supporting Documentation Used (References and dates)
☐	Map of Site	_____
☐	Facility Mission Description	_____
☐	Description of Operations that Generate Waste	_____
☐	Waste Identification/Categorization Schemes	_____
☐	Types and quantities of waste generated	_____
☐	Correlation of waste streams generated from the same building and process, as appropriate	_____
☐	Waste certification procedures	_____

Required Waste Stream Information

☐	Area(s) and building(s) from which the waste stream was generated	_____
☐	Waste stream volume and time period of generation	_____
☐	Process flow diagrams	_____

Figure C-4
WIPP Waste Stream Profile Form

Form Number_____
Page ____ of ____

☐ Waste Generating Process Description _____
☐ Material inputs of other information identifying chemical/radionuclide content and physical waste form _____

Supplemental Documentation

☐ Process design documents _____
☐ Standard operating procedures _____
☐ Safety Analysis Reports _____
☐ Waste Packaging Logs _____
☐ Test Plans/Research Project Reports _____
☐ Site Databases _____
☐ Information from Site Personnel _____
☐ Standard Industry Documents _____
☐ Previous Analytical Data _____
☐ Material Safety Data Sheets _____
☐ Sampling and Analysis Data from Comparable/Surrogate Waste _____
☐ Laboratory Notebooks _____

Sampling and Analysis Information*: Sampling and Analysis Procedures (reference and date)

☐ Radiography _____
☐ Visual Examination _____
☐ Headspace Gas Analysis
VOCs _____
Other Gases (Specify) _____
☐ Homogeneous Solids/Soil/Gravel Sample Analysis
VOCs _____
Semi-VOCs _____
PCBs _____
Total Metals _____
Other (specify) _____

☐ Ignitable ☐ Corrosive ☐ Reactive ☐ Compatible

Waste Characterization Data Package Numbers: _____

* Attach signed waste characterization summary data package to support hazardous waste code assignment to form

Certification:
I hereby certify that I have reviewed the information in this Waste Stream Profile Form, and it is complete and accurate to the best of my knowledge. I understand that this information will be made available to regulatory agencies and that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

_____ _____ _____
Signature of Site Project Manager Printed Name and Title Date

Figure C-4
WIPP Waste Stream Profile Form (Continued)

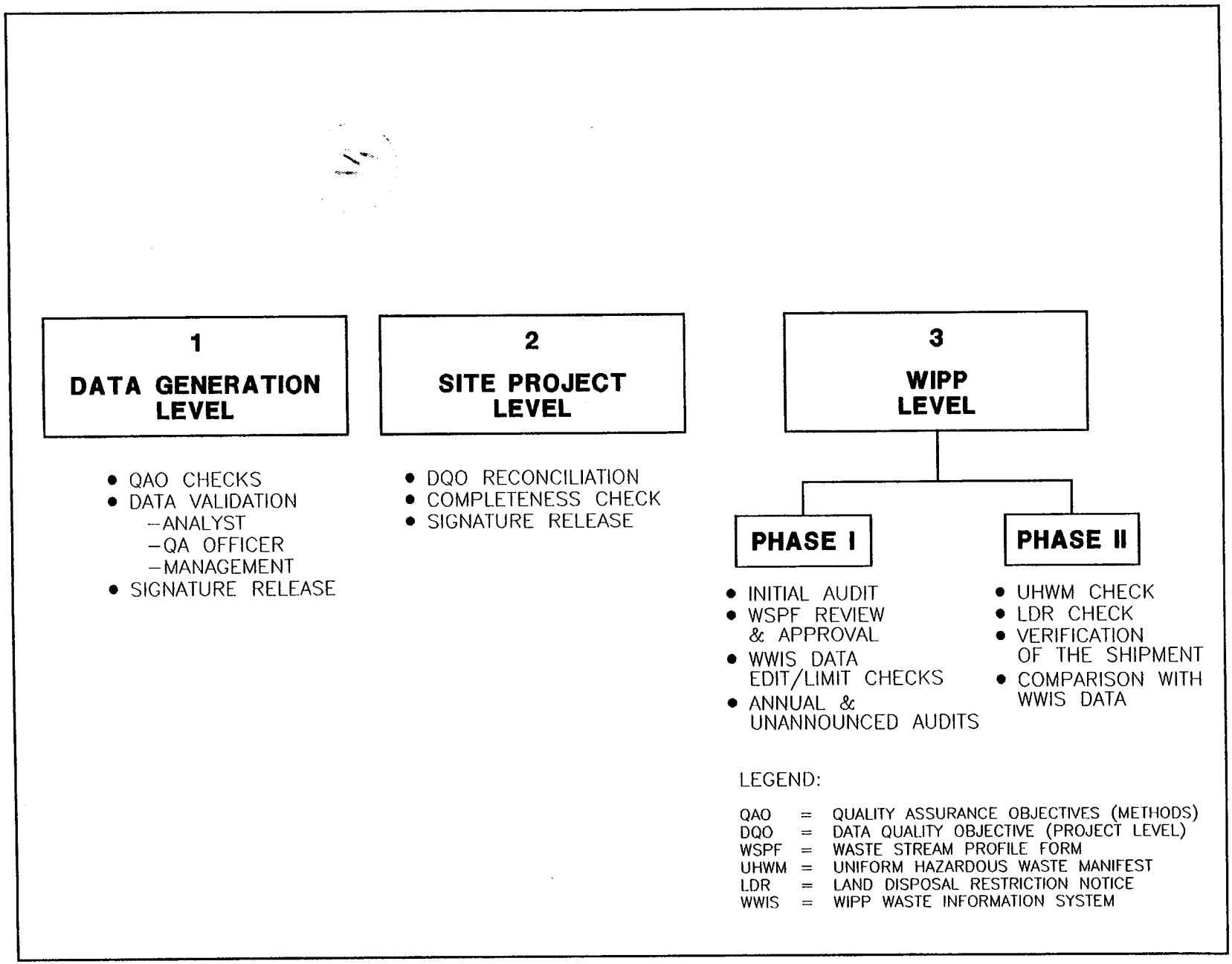

Figure C-5
Levels of Data Verification

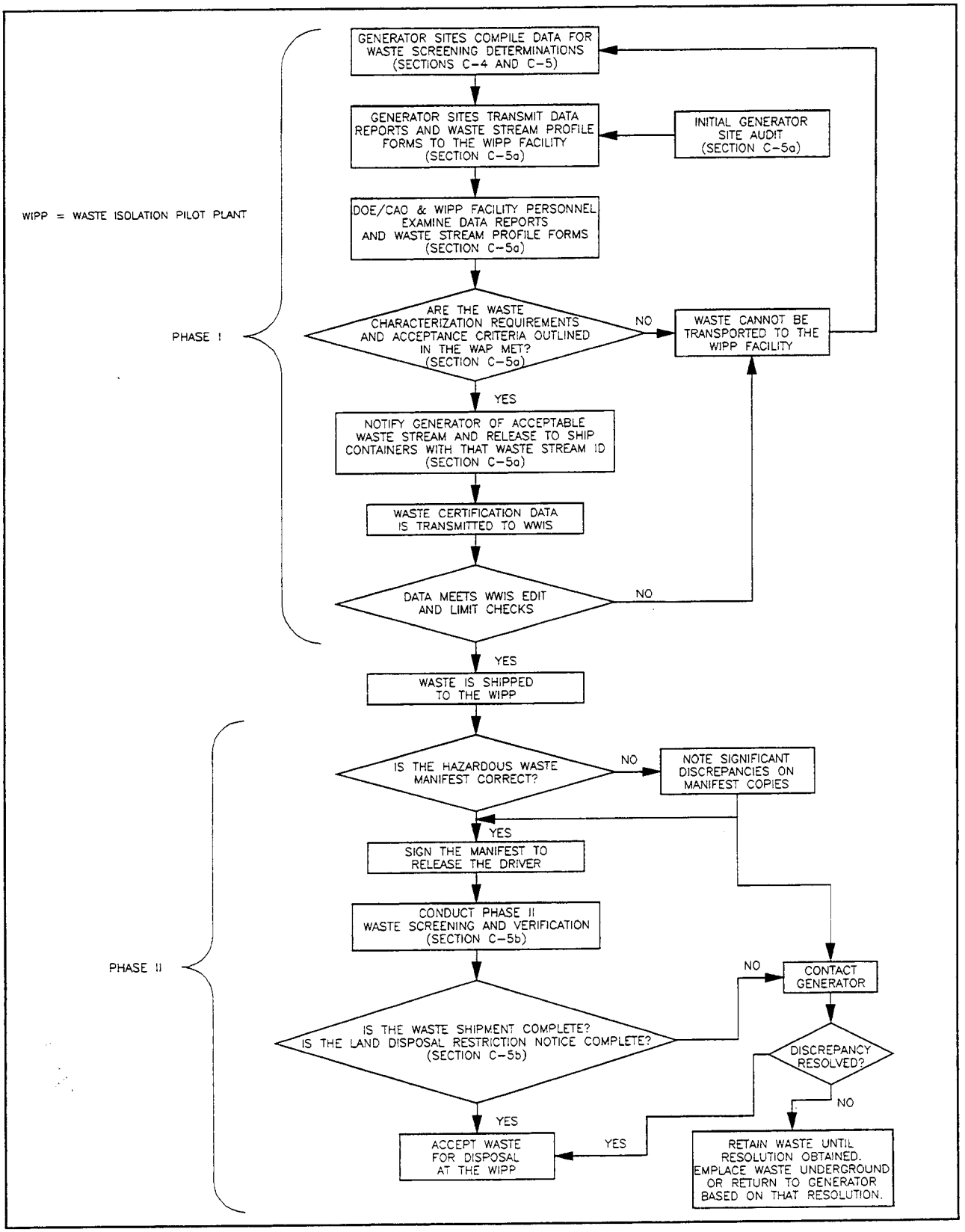

Figure C-6
TRU Waste Screening Flow Diagram

APPENDIX C1
CHEMICAL COMPATIBILITY ANALYSIS
OF WASTE FORMS AND CONTAINER MATERIALS

APPENDIX C1
CHEMICAL COMPATIBILITY ANALYSIS OF WASTE FORMS AND CONTAINER MATERIALS

The chemical compatibility analysis was carried out with all defense generated, contact-handled (CH) and remote-handled (RH) transuranic (TRU)-mixed waste streams reported in the Waste Isolation Pilot Plant (WIPP) Transuranic Waste Baseline Inventory Report (WTWBIR) (DOE, 1995). A summary of these waste streams is given in Table C-1 (Chapter C). The reported content of CH and RH streams will be verified through the WIPP Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C11).

All information for the chemical lists and compatibility study is maintained in databases on a personal computer. The chemicals reported by the generator sites are classified into reaction groups as defined by the U.S. Environmental Protection Agency (EPA) document, A Method for Determining the Compatibility of Hazardous Wastes (Hatayama et al., 1980). The chemical lists are derived from the TRUPACT-II database, EPA hazardous waste codes listed in the WTWBIR, and waste descriptions.

A database program was developed to evaluate the chemical compatibility of the WTWBIR waste streams. Potential incompatibilities are defined on Figure 6 of the EPA document (Hatayama et al., 1980), which identifies combinations of chemical groups that are incompatible and the consequences (e.g., heat generation) of mixing incompatible chemical groups. All incompatible mixtures have been entered into a reference data base to be used in assessing the chemical compatibility of a given list of chemicals. The logic of the program used in evaluating the chemical compatibility by content code is described in detail below.

As an initial step, the program indexes the entire database according to the WTWBIR waste stream codes. The program then locates the first reaction group within the first waste stream code and picks the highest concentration of any chemical in that group. The selected reaction group is then paired with every other reaction group in the waste stream to check for incompatibility. If a potential incompatibility is found, it is printed out along with the corresponding waste stream codes. After finding all potential incompatibilities for a given waste stream code, the program moves on to the next waste stream code until all waste stream codes have been processed.

To ensure accuracy, the reference database was printed and checked against the EPA document for chemical compatibility, and the WTWBIR waste stream database was printed and checked against the original WTWBIR forms from the generator sites. The list of potential chemical incompatibilities reported by the program was hand checked using the EPA document as a reference to assure proper functioning of the program. All potential chemical incompatibilities were then evaluated on a case-by-case basis to identify which, if any, of the reactions could occur, given the nature of the waste, and the its chemical constituents, and final waste form.

Waste streams are classified as "incompatible" if the potential exists for any of the following reactions:

- corrosion
- explosion
- heat generation
- gas generation (flammable gases)
- pressure build-up (nonflammable gases)
- toxic by-product generation

Each generator and storage site has produced a comprehensive list of all possible chemicals present in its waste. The chemical components found in each waste generation process are determined by examination of the process technology, by chemical analysis, or by process flow analysis. Under this system, all chemical inputs into the system are accounted for, even though all of these components may not be a part of the waste. For example, generator sites might include both acids and bases in their lists, even though the two groups have been neutralized prior to placement in a waste container.

In addition to the chemicals listed in Appendix 2 of the EPA document (Hatayama et al., 1980), the following components that exhibit toxicity characteristics defined under 40 CFR §261.24 were added to the chemical list in trace (<1 weight percent) quantities:

Group 3 Acids, Organic
2,4-D
2,4,5-TP (Silvex)

Group 17 Halogenated Organics
Methoxychlor
Toxaphene
2,4-D
Hexachlorobutadiene
Hexachloroethane
Tetrachloroethylene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

All hazardous constituents listed in the Part A Permit are present in the chemical lists and accounted for in the compatibility analysis.

The compounds listed on the Material Safety Data Sheet for Radiac™ wash were added to the chemical compatibility assessment. The reactive compounds associated with Radiac™ wash are:

GROUP	COMPOUND	CONCENTRATION
3	citric acid	M
106	water	D

The compounds found in the fire suppressants in use at the WIPP facility were added to evaluate chemical compatibility of these materials with the test wastes. The following reactive compounds were added:

GROUP	COMPOUND	CONCENTRATION
14	diethylene glycol monobutyl ether	D
15	fluorosurfactants	D
106	water	D

Ansulite 6 percent AFFF (AFC-3) contains diethylene glycol monobutyl ether, fluorosurfactants, and water. The FORAY Dry Chemical Extinguishing Agent contains potassium aluminum silicate, magnesium aluminum silicate, monoammonium phosphate, ammonium sulfate, and methyl hydrogen polysiloxane, which are not hazardous reactive constituents.

To account for packaging, container, and backfill materials, the following components were added to the database for each content code in dominant (>10 weight %) quantities:

Group 10 Caustics
Magnesium Oxide

Group 23 Metals, other elemental and alloys as sheets, rods, moldings, drops, etc.
Low Carbon Steel D

Group 101 Combustible Materials
Polyethylene D

The chemical concentration levels are reported as either Trace (T) (<1% by weight), Minor (M) (1-10%), or Dominant (D) (>10%). The chemical list is divided into groups based on chemical properties and structure (e.g., acids, caustics, metals, etc.). If incompatible groups are combined, the possibility exists for the reactions listed above. For example, a reaction between Group 1 (Acids, Mineral, Non-oxidizing) and Group 10 (Caustics) could result in heat generation.

Possible chemical incompatibilities between compounds present in trace quantities (<1 percent by weight) and compounds present in concentrations $\geq$ 1 percent by weight (i.e., D x T, D x T1, D x T2, D x T3, M x T, M x T1, M x T2, or M x T3) are included in this report. However, interactions between compounds present in trace quantities (<1 percent by weight) and compounds present in concentrations $\leq$ 1 percent by weight do not pose an incompatibility problem for the following reasons:

- The trace chemicals reported by the sites are in concentrations well below the trace limit of 1 weight percent. Sampling programs show that the concentration levels of these compounds are significantly lower than the upper limit of 1 percent.

- The trace chemicals are usually dispersed in the waste, which further dilutes concentrations of these materials.

- Trace chemicals that might be incompatible with major and dominant materials/chemicals would have reacted during the waste treatment process prior to placement in waste containers.

- Because of restrictions imposed by the EPA on reporting of hazardous wastes, some chemicals are listed in trace quantities even if they have already reacted. Hazardous waste regulations as promulgated by the EPA (EPA, 1988) (known as the mixture rule) require that a mixture of any solid waste and a hazardous waste listed in 40 CFR Part 261, Subpart D, be considered a hazardous waste subject to Resource Conservation and Recovery Act regulations. However, Subpart D does not list minimum concentrations for these listed wastes, with the result that any such mixtures must be considered hazardous waste even if the Subpart D constituent is at or below detection limits.

- The waste is either solidified and immobilized (solidified materials) or present in bulk form as a solid (solid materials). In almost all cases, any possible reactions take place before the waste is generated in its final form.

- Total trace chemicals within a payload container are limited to less than 5 weight percent.

All potential incompatibilities between trace, minor, and dominant compounds have been analyzed on a case-by-case basis for each waste stream reported in Table C-2 (Chapter C). Some chemicals listed as being present in the waste have reacted prior to placement in a waste container. For example, a site listing a caustic (Group 10) and an acid (Group 1) in its waste has only the neutralized product present in an immobilized form. Further reactions of this type do not occur once the waste is neutralized in its final form. An additional constraint on the chemicals and materials that can be present within each waste stream code is their gas generation potential due to radiolysis.

Unresolved incompatibilities between trace and minor, trace and dominant, minor and dominant, minor and minor, or dominant and dominant waste constituents were identified and segregated. These wastes cannot be transported until the incompatibilities are resolved (NuPac, 1989). Table C1-1 presents the chemical compatibility analysis for the modified chemical lists for the

waste streams presented in Table C-2 (Chapter C). A list of explanations describing any noted incompatibilities precedes Table C1-1.

Summary of Potential Incompatibilities for Waste Forms and Container Material

The following is a listing and explanation of compatibility code numbers used to identify potential incompatibilities in Table C1-1. Where incompatibilities are noted, it is important to remember that these potential incompatibilities will be removed prior to shipment of the waste to WIPP. That is, unacceptable waste properties listed in Chapter C, Section C1-b will be removed prior to shipping. Verification of the compatibility of final waste forms will be carried out by the WIPP Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C8).

Explanation Code Number Descriptions

00 (1 x 10, 2 x 10, 3 x 10, 5 x 10, 10 x 13, 10 x 17, 10 x 18, 10 x 19, 10 x 21, 10 x 22, 10 x 23, 10 x 24, 10 x 25, 10 x 27, 10 x 32, 10 x 102, 10 x 107) These potential incompatibilities result from the addition of magnesium oxide backfill material. However, the hydration of magnesium oxide results in the formation of brucite ($Mg[OH]_2$), which buffers the pH of the solution at approximately 8.5. Therefore, caustic conditions are not produced by the use of magnesium oxide backfill.

0a. (1 x 4) The potential chemical incompatibility is the possible dehydration or displacement reactions between non-oxidizing mineral acids (Group 1) and alcohols and glycols in waste forms (Group 4) resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of non-oxidizing acid in generator waste streams. However, the non-oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

0aa. (1 x 10) The potential chemical incompatibility is the possible acid-base reaction between strong mineral acids (Group 1) and strong caustics (Group 10) resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of non-oxidizing acid in generator waste streams. However, the non-oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

0aaa. (1 x 14) The potential chemical incompatibility is the possible hydrolysis reaction between strong mineral acids (Group 1) and ethers (Group 14), resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of non-oxidizing acid in generator waste streams. However, the non-oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

0aaaa. (1 x 15) The potential chemical incompatibility is the possible formation of hydrogen fluoride when strong mineral acids (Group 1) mix with inorganic fluorides (Group 15), resulting in toxic gas generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of non-oxidizing acid in generator waste streams. However, the non-oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

0b. (1 x 17) The potential chemical incompatibility is the possible reaction between strong mineral acids (Group 1) and halogenated organics (Group 17), resulting in generation of heat and toxic hydrogen halide fumes. The potential chemical incompatibility results from reporting trace quantities (<1%) of non-oxidizing acid in generator waste streams. However, the non-oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

0bb. (1 x 19) The potential chemical incompatibility is the possible condensation reaction between strong mineral acids (Group 1) and ketones (Group 19), resulting in generation of heat. The potential chemical incompatibility results from reporting trace quantities (<1%) of non-oxidizing acid in generator waste streams. However, the non-oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

1. (1 x 23) The potential chemical incompatibility is the possible reaction between non-oxidizing mineral acids (Group 1) and metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The non-oxidizing mineral acids are present only in trace quantities (<1%) and are neutralized and bound in the cemented waste form. Due to the immobilization and prior reaction of the acids, the materials in this waste stream are considered chemically compatible.

2. (1 x 24) The potential chemical incompatibility is the tendency of non-oxidizing mineral acids (Group 1) to solubilize toxic metals and metal compounds (Group 24). The mineral acids are present only in trace quantities (<1%) and are neutralized and bound in the cemented waste form. Due to the immobilization and prior reaction of the non-oxidizing acids, the materials in this waste stream are considered chemically compatible.

3. (1 x 101) The potential chemical incompatibility is the possible reaction between non-oxidizing mineral acids (Group 1) and combustible materials (Group 101). The mineral acids are present only in trace quantities (<1%) and are neutralized and bound in the cemented waste form. An absorbent has been added to immobilize free liquids. Due to the immobilization and prior reaction of the non-oxidizing acids, the materials in this waste stream are considered chemically compatible.

3a. (1 x 102) The potential chemical incompatibility is the possible violent reaction between non-oxidizing mineral acids (Group 1) and explosives (Group 102). However, explosives are not allowed to be shipped to WIPP unless treatment renders them inert. Additionally, mineral acids are present only in trace quantities (<1%) and are neutralized prior to loading in waste containers. Therefore, the materials in this waste stream are considered chemically compatible.

3aa. (1 x 104) The potential chemical incompatibility is the possible reaction between non-oxidizing mineral acids (Group 1) and strong oxidizing agents (Group 104), resulting in heat and generation of toxic and corrosive gases. However, the mineral acids and oxidizing agents are present in trace quantities (<1%) and neutralized prior to loading in waste containers. Therefore, the materials in this waste stream are considered chemically compatible.

3b. (1 x 106) The potential chemical incompatibility is the possible reaction between mineral acids (Group 1) and water (Group 106), resulting in the generation of heat. This potential incompatibility results from the presence of water in Ansulite™ fire extinguishing agents and/or Radiac™ wash solutions and/or absorbed water. However, the mineral acids are present only in trace quantities (<1%) and are neutralized prior to loading in waste containers. In addition, the presence of any absorbed liquids are immobilized in an absorbent and would not be available for reaction.

3c. (2 x 3) The potential chemical incompatibility is the reaction of oxidizing mineral acids (Group 2) with organic acids (Group 3) resulting in heat and gas generation. The potential chemical incompatibility results from the use of citric acid in Radiac™ wash solutions. The solid citric acid is diluted during preparation of the Radiac™ wash and is often further diluted prior to use for decontamination. As a result, the potential for reactions of solid citric acid with oxidizing mineral acids in waste forms is removed.

3d. (2 x 4) The potential chemical incompatibility is the possible dehydration or displacement reactions between oxidizing mineral acids (Group 2) and alcohols and glycols (Group 4), resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3e. (2 x 10) The potential chemical incompatibility is the possible acid-base reaction between oxidizing mineral acids (Group 2) and strong caustics (Group 10), resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3ee. (2 x 13) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and esters (Group 13), resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3f. (2 x 14) The potential chemical incompatibility is the possible hydrolysis reaction between oxidizing mineral acids (Group 2) and ethers (Group 14), resulting in heat generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3g. (2 x 15) The potential chemical incompatibility is the possible formation of hydrogen fluoride when oxidizing mineral acids (Group 2) mix with inorganic fluorides (Group 15), resulting in toxic gas generation. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3gg. (2 x 16) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and aromatic hydrocarbons (Group 16). Oxidation of the hydrocarbon may produce enough heat to ignite the mixture. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3h. (2 x 17) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and halogenated organics (Group 17), resulting in generation of heat and toxic hydrogen halide fumes. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3i. (2 x 19) The potential chemical incompatibility is the possible condensation reaction between oxidizing mineral acids (Group 2) and ketones (Group 19), resulting in generation of heat. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

3j. (2 x 20) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and mercaptans (Group 20), resulting in generation of heat and toxic hydrogen sulfide fumes. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

4. (2 x 23) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The oxidizing mineral acids are present only in trace quantities (<1%) and are reacted prior to loading in waste containers. In addition, the oxidizing mineral acids are fixed in the solidified product and would not be available to react with the metal.

5. (2 x 23) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The oxidizing mineral acids are present only in trace quantities (<1%) as residues on glass or rubber gloves, and not as free liquids that could react with metals.

6. (2 x 24) The potential chemical incompatibility is the solubilization of toxic metals and metal compounds (Group 24) in oxidizing mineral acids (Group 2). The oxidizing mineral acids are present only in trace quantities (<1%) and are reacted prior to loading in waste containers. In addition, the oxidizing mineral acids are fixed in the solidified product and would not be available to react with the metal.

7. (2 x 24) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and toxic metals and compounds (Group 24). The oxidizing mineral acids are present only in trace quantities (<1%) as residues on glass or rubber gloves, and not as free liquids that could react with metals.

7a. (2 x 27) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and nitro compounds (Group 27), resulting in generation of heat and toxic nitrogen oxide fumes. The potential chemical incompatibility results from reporting trace quantities (<1%) of oxidizing acid in generator waste streams. However, the oxidizing mineral acids are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

8. (2 x 101) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and combustible materials (Group 101). The oxidizing mineral acids are present only in trace quantities (<1%) as residues on glass or rubber gloves, and not as free liquids that could react with metals.

9. (2 x 101) The potential chemical incompatibility is the possible decomposition of combustible materials (Group 101) by the oxidizing mineral acids (Group 2). The oxidizing mineral acids are present only in trace quantities (<1%) and are reacted prior to loading in waste containers. In addition, the oxidizing mineral acids are fixed in the solidified product and would not be available to react with the combustible materials.

9a. (2 x 102) The potential chemical incompatibility is the possible violent reaction between oxidizing mineral acids (Group 2) and explosives (Group 102). However, explosives are not allowed to be shipped to WIPP unless treatment renders them inert. Additionally, mineral acids are present only in trace quantities (<1%) and are neutralized prior to loading in waste containers. Therefore, the materials in this waste stream are considered chemically compatible.

10. (2 x 106) The potential chemical incompatibility is the possible dissolution of oxidizing mineral acids (Group 2) by water (Group 106). The oxidizing mineral acids are present only in trace quantities (<1%) and reacted prior to loading in waste containers. Both the water and the oxidizing mineral acids are fixed in the solidified product and would not be available for reaction.

10a. (2 x 106) The potential chemical incompatibility is the possible reaction between oxidizing mineral acids (Group 2) and water (Group 106), resulting in the generation of heat. This potential incompatibility results from the presence of water in Ansulite™ fire extinguishing agents and/or Radiac™ wash solutions and/or absorbed water. However, the mineral acids are present only in trace quantities (<1%) and are neutralized prior to loading in waste containers. In addition, the presence of any absorbed liquids are immobilized in an absorbent and would not be available for reaction.

11. (3 x 4) The potential chemical incompatibility is the possible reaction between organic acids (Group 3) and alcohols and glycols (Group 4). The organic acids are immobilized in a cement matrix and not available to react with the alcohols and glycols. The alcohols and glycols are also immobilized in the solidified product.

11aa. (3 x 4) The potential chemical incompatibility is the heat generated by polymerization of alcohols and glycols (Group 4) by organic acids (Group 3). Carboxylic acids with α-halogen substituents, or α- or β-hydroxyl substituents (e.g., citric acid) are the main concern among the organic acids (Group 3). The potential chemical incompatibility results from the use of citric acid in Radiac™ wash solutions. The solid citric acid is diluted during preparation of the Radiac™ wash and is often further diluted prior to use for decontamination. As a result, the potential for reactions of solid citric acid with alcohols and glycols (Group 4) that are dispersed and fixed in waste forms is removed.

11b. (3 x 10) The potential chemical incompatibility is the possibility of acid-base reactions. The organic acids (Group 3) are neutralized in a cement matrix and are not available to react with the Caustics (Group 10). Thus, this potential chemical incompatibility would not occur.

11c. (3 x 10) The potential chemical incompatibility is the heat generated by reactions of organic acids (Group 3) with caustics (Group 10). The potential chemical incompatibility results from the use of citric acid in Radiac™ wash solutions. The solid citric acid is diluted during preparation of the Radiac™ wash and is often further diluted prior to use for decontamination. As a result, the potential for reactions of solid citric acid with caustics in test waste forms is removed. The caustic in the waste forms is calcium oxide. Thus, the more significant incompatibility is potential hydrolysis reaction between water and calcium oxide to release heat. Because the calcium oxide is dispersed in the wastes, reaction is considered unlikely.

11d. (3 x 15) The potential chemical incompatibility is toxic and corrosive fumes generated by reactions of organic acids (Group 3) with metal fluoride salts (Group 15). The potential chemical incompatibility results from the use of citric acid in Radiac™ wash solutions. The solid citric acid is diluted during preparation of the Radiac™ wash and is often further diluted prior to use for decontamination. As a result, the potential for reactions of solid citric acid with fluoride salts in waste forms is removed.

12. (3 x 24) The potential chemical incompatibility is the possible reaction between organic acids (Group 3) and toxic metals and compounds (Group 24). The organic acids are basified prior to cementation and do not exist as free acids in the resulting product. Based on the immobilization of the acids, reactions are considered highly unlikely. In this case, solubilization is not possible.

12aa. (3 x 24) The potential chemical incompatibility is solubilization of toxic metals (Group 24) by complexation with organic acids (Group 3). The potential chemical incompatibility results from the use of citric acid in Radiac™ wash solutions. The solid citric acid is diluted during preparation of the Radiac™ wash and is often further diluted prior to use for decontamination. As a result, the potential for reactions of solid citric acid with toxic metals in waste forms is removed.

12bbb. (3 x 104) The potential chemical incompatibility is decomposition of the hydrocarbon moiety of organic acids (Group 3) by oxidizing agents (Group 104) resulting in heat and gas formation. The potential chemical incompatibility results from the use of citric acid in Radiac™ wash solutions. The solid citric acid is diluted during preparation of the Radiac™ wash and is often further diluted prior to use for decontamination. As a result, the potential for reactions of solid citric acid with oxidizing agents that are dispersed and fixed in waste forms is removed.

12bb. (4 x 104) The potential chemical incompatibility is formation of unstable compounds by reaction of alcohols and glycols (Group 4) with oxidizing agents (Group 104). However the alcohols and glycols are present as trace quantities (<1%) in the waste stream, and they are further isolated by dissemination within the waste stream. Additionally, oxidizing agents must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

12b. (7 x 17) The potential chemical incompatibility between amines (Group 7) and halogenated organics (Group 17) would not occur because the halogenated organics are solidified and are not available for reaction.

12c. (7 x 24) The potential chemical incompatibility is the possible increase in the solubility of toxic metal compounds in water due to amines acting as potential surfactants. The amines are present only in trace (<1%) and are immobilized through absorption on sorbent materials. Also, these solid waste forms usually contain very little water and excess sorbents are added to waste containers to sorb any fluids.

12d. (7 x 104) The potential chemical incompatibility is formation of toxic nitrogen oxide fumes by reaction of amines (Group 7) with oxidizing agents (Group 104). However, the alcohols and glycols are present as trace quantities (<1%) in the waste stream, they are further isolated by dissemination within the waste stream. Additionally, oxidizing agents must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

12e. (8 x 23) The potential chemical incompatibility is combustion of some azo compounds (Group 8) on contact with surfaces of metal sheets, rods, drops, etc (Group 23). However the azo compounds are present as trace quantities (<1%) in the waste stream and are further isolated by dissemination within the waste stream. Therefore, spontaneous combustion by reaction with metal surfaces is unlikely.

12f. (8 x 106) The potential chemical incompatibility is the generation of nitrogen gas by reaction of some azo compounds (Group 8) with water (Group 106). This potential incompatibility results from the presence of water in Ansulite™ fire extinguishing agents and/or Radiac™ wash solutions and/or absorbed water. However, the azo compounds are present only in trace quantities (T<1%) and are disseminated in the waste containers, which minimizes their potential to form nitrogen gas. In addition, the presence of any absorbed liquids are immobilized in an absorbent and would not be available for reaction.

13. (10 x 17) The potential chemical incompatibility is the possible reaction between caustics (Group 10) and halogenated organics (Group 17). The caustic in this content code is calcium oxide, a solid, which is dispersed in the chloride salts. The halogenated

organics are present in only trace quantities (T<1%) and are absorbed, immobilized, or solidified. Due to the immobilization of the calcium oxide in the salt, reactions are considered highly unlikely.

13a. (10 x 19) The potential chemical incompatibility is the possible self-condensation of ketones (Group 19) catalyzed by caustics (Group 10). The caustic in this content code is calcium oxide, a solid, which is dispersed in the chloride salts. Due to the immobilization of the calcium oxide in salt, reactions are considered highly unlikely.

14. (10 x 23) The potential incompatibility is the possible reaction between caustics (Group 10) metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The caustic in this waste stream code is calcium oxide, a solid, which is dispersed in the chloride salts. Due to the immobilization of the calcium oxide in salt, dissolution of metals in caustics is not possible.

15. (10 x 23) The potential incompatibility is the possible dissolution of metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23) in caustics (Group 10). The caustics are present only in trace quantities (<1%) and are reacted prior to loading in waste containers. In addition, the caustics are fixed in the cemented sludge and would not be available to react with the metals.

16. (10 x 24) The potential chemical incompatibility is the possible solubilization of toxic metals (Group 24) in caustics (Group 10). The caustic in this content code is calcium oxide, a solid, which is dispersed in the chloride salts. In this case, solubilization is not possible.

16a. (10 x 24) The potential incompatibility is the possible solubility of toxic metals (Group 24) in caustics (Group 10). The caustics are present only in trace (<1% quantities and are reacted prior to loading in waste containers. In addition, the caustics are fixed in the cemented sludge and would not be available to react with the metals.

16b. (10 x 27) The potential chemical incompatibility is the formation of salts from nitro alkanes (Group 27) and caustics (Group 10) in the presence of water. The only caustic in this content code is calcium oxide, a solid, which is dispersed in the chloride salts. In addition, liquids are immobilized through absorption on sorbent materials. Due to the immobilization of the caustic in the fused salt, this reaction would not occur.

16c. (10 x 102) The potential chemical incompatibility is the possible violent reaction between caustics (Group 10) and explosives (Group 102) due to the generation of heat. However, explosives are not allowed to be shipped to WIPP unless treatment renders them inert. Additionally, caustics are present only in minor quantities (<10%) and are

neutralized prior to loading in waste containers. Therefore, the materials in this waste stream are considered chemically compatible.

17. (10 x 107) This potential incompatibility is an artifact of the EPA method. Calcium oxide appears in Groups 10 and 107, and is compatible within itself.

17a. (14 x 104) This potential incompatibility is the reaction of ethers (Group 14) with strong oxidizers (Group 104) to produce heat, and possibly ignition or explosions. This incompatibility arises from the presence of diethylene glycol monobutyl ether in Ansulite™ fire extinguishing agents. However, the strong oxidizers are present in trace quantities (<1%) and disseminated in the waste, making ignition or explosions unlikely in the event the fire extinguishers are used.

17b. (14 x 107) This potential chemical incompatibility is the reaction of ethers (Group 14) with water reactives (Group 107). This incompatibility arises from the presence of diethylene glycol monobutyl ether in Ansulite™ fire extinguishing agents. However, the water reactive substances are present in trace quantities (<1%) and disseminated in the waste, making reactions unlikely in the event the fire extinguishers are used.

18. (15 x 107) This potential chemical incompatibility is the reaction of fluorides (Group 15) and water reactive substances (Group 107). The solid fluorides are present in only trace quantities (T<1%) and form part of the pyrochemical salt matrix. Calcium oxide, the only water reactive substance present, is a solid dispersed in the pyrochemical salt matrix. These salts always occur with each other and are compatible.

18a. (17 x 20) The potential chemical incompatibility is the possible reaction between halogenated organics (Group 17) and mercaptans (Group 20), resulting in generation of heat. The potential chemical incompatibility results from reporting trace quantities (<1%) of halogenated organics and mercaptans in generator waste streams. However, the chemicals are neutralized prior to packaging, and the materials in this waste stream are considered chemically compatible.

19. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are present in only trace quantities (T1<1%) and are fixed in cemented sludge and would not be available to react with the metals.

20. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys, as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are present in only trace quantities (T<1%) and are absorbed on combustibles. The halogenated organics are not present as free liquids to react with the metals.

21. (17 x 23) The potential chemical incompatibility is the potential reaction between halogenated organics (Group 17) and metals and other elemental alloys as sheets, rods, drops, moldings, etc. (Group 23). Aluminum and magnesium in bulk forms are especially reactive with halogenated hydrocarbons, releasing much heat. Although this is a potential incompatibility, the potential effects are considered minimal for the following reasons. First, the halogenated hydrocarbons are only present in trace quantities (<1 percent by weight) and are immobilized through absorption on sorbent materials or solidification with calcium silicates or gypsum-base processes. Second, although the metals of concern may occur in dominant quantities in the content code, the metals only occur as large pieces and not in powder form. Due to the trace quantities of immobilized halogenated organics and the non-powder size of the metal pieces, any reaction that may occur will produce minimal heat.

22. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys, as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are present in only very small trace quantities (<1 part per million) as residual films on the glass and not as free liquids that could react with metals.

23. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are present in only trace quantities (<1%) as coatings on solid organic materials and are not present as free liquids that could react with metals.

24. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are present in only trace quantities (<1%) as coating on the inorganic solid materials and are not present as free liquids that could react with metals.

25. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are fixed in the cemented product and would not be available for reaction.

26. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys, as sheets, rods, moldings, drops, etc. (Group 23). The halogenated organics are fixed in the solidified product and are not available for reaction with the metals.

27. (17 x 23) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with metals and other elemental alloys, as sheets, rods, moldings, drops, etc. (Group 23). An absorbent has been added to immobilize any free liquids that may exist. Due to the trace quantities and immobilization of the halogenated organics, reactions are highly unlikely.

28. (17 x 104) The potential chemical incompatibility is the reaction of halogenated organics (Group 17) with oxidizing agents (Group 107), resulting in the liberation of heat and formation of toxic gases. The halogenated organics are present in only trace quantities (<1%) and are not in the form of free liquids. Additionally, the oxidizing agents are neutralized prior to loading waste containers. Therefore, based on the neutralization of the oxidizing agents, reactions are considered highly unlikely.

28a. (18 x 106) The potential incompatibility is the possible reaction between isocyanates (Group 18) with water (Group 106). The isocyanates are present only in trace quantities (<1%). The water is usually fixed in the solidified product and would not be available for reaction.

28aa. (18 x 106) The potential chemical incompatibility is between isocyanates (Group 18) and water (Group 106) to generate carbon dioxide gas and heat. The potential chemical incompatibility results from the use of water in Ansulite™ fire extinguishing agents and Radiac™ wash solutions. However, isocyanates in the waste forms are present in trace quantities (<1%), are neutralized and fixed prior to loading the waste containers, and are not available for reaction. Therefore, the final waste form contains compatible materials.

28aaa. (19 x 20) The potential chemical incompatibility is the reaction between ketones (Group 19) and mercaptans (Group 20), resulting in heat generation. These chemicals are present only in trace quantities (<1%) as coatings on laboratory glassware. Therefore, contact between the chemicals, if it occurs, will be limited.

28b. (21 x 101) The potential chemical incompatibility is the reaction of alkali and alkaline earth metals (Group 21) with residual water present in the combustible materials (101), resulting in heat generation and ignition of the combustible materials. However, the combustible materials are polyethylene and polyvinyl chloride packaging materials which contain no residual water. Additionally, alkali and alkaline earth metals must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

28c. (21 x 104) The potential chemical incompatibility is the violent reaction between alkali and alkaline earth metals (Group 21) and oxidizing agents (Group 104). Oxidizing agents are present in trace quantities (<1%) and are neutralized prior to packaging.

Additionally, alkali and alkaline earth metals must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

28d. (21 x 106) The potential chemical incompatibility is the violent reaction between alkali and alkaline earth metals (Group 21) and water (Group 106), resulting in the evolution of hydrogen gas and formation of strong caustics. However, alkali and alkaline earth metals must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

28e. (22 x 106) The potential chemical incompatibility is the reaction of metal powders (Group 22) with water (Group 106), resulting in the evolution of hydrogen gas and production of heat. Metal powders or shavings are present as trace quantities (<1%) on paper, rags, and rubber. This potential incompatibility results from the presence of water in Ansulite™ fire extinguishing agents and/or Radiac™ wash solutions and/or absorbed water. However, metal powders or shavings are present as trace quantities (<1%) on paper, rags, and rubber, which minimizes their potential to form hydrogen gas. In addition, the presence of any absorbed liquids are immobilized in an absorbent and would not be available for reaction.

29. (23 x 104) The potential incompatibility is the possible reaction between metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23) and oxidizing agents (Group 104). The oxidizing agents are present only in trace quantities (<1%) and reacted prior to loading in waste containers. The waste is mixed with cement to absorb any residual liquid. Due to the immobilization and prior reaction of the oxidizing agents, reactions are highly unlikely.

30. (23 x 104) The potential incompatibility is the possible reaction between metals, other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23) and oxidizing agents (Group 104). The oxidizing agents are present only in trace quantities (<1%) and dissolved in aqueous solutions that were cemented into a solid monolith-type structure. Due to the immobilization and prior reaction of the oxidizing agents, reactions will not occur.

31. (23 x 107) The potential incompatibility is the possible reaction between metals and other elemental alloys, as sheets, rods, moldings, drops, etc. (Group 23) and water reactive substances (Group 107). The outer low carbon steel drum is the only Group 23 metal found in this content code. Calcium oxide, the only water reactive substance present, is a solid dispersed in the chloride salts. Based on the immobilization of the calcium oxide in the salt, reactions are considered highly unlikely.

32. (23 x 107) The potential incompatibility is the possible reaction between metals and other elemental alloys as sheets, rods, moldings, drops, etc. (Group 23) and water reactive substances (Group 107). Calcium oxide, the only water reactive substance present, is a solid dispersed in the chloride salts. Based on the immobilization of the calcium oxide in the salt, reactions are considered highly unlikely.

33. (24 x 106) The potential chemical incompatibility is the possible solubilization of toxic metals (Group 24), which is not a concern since the water (Group 106) from the sludge is fixed in the cemented product and would not be available for reaction.

33a. (24 x 106) The potential chemical incompatibility is the possible solubilization of toxic metals (Group 24) by water (Group 106). This potential chemical incompatibility results from the use of water in Ansulite™ fire extinguishing agents or Radiac™ wash solutions. Metals in the test waste forms are present in trace quantities (T<1%) as large pieces and not in powdered form. As a result, only minimal heat is expected to be formed.

34. (24 x 106) The potential incompatibility is the possible solubilization of toxic metals (Group 24). The water (Group 106) is fixed the in the cemented product and would not be available for reaction.

35. (24 x 107) The potential incompatibility is the possible reaction between toxic metals and metal compounds (Group 24) and water reactive substances (Group 107). The metals are present only in trace quantities (<1% by weight). Calcium oxide, the only water reactive substance present, is a solid dispersed in the chloride salts. Based on the immobilization of the calcium oxide in the salt, reactions are considered highly unlikely.

36. (24 x 107) The potential incompatibility is the possible reaction between toxic metals and metal compounds (Group 24) and water reactive substances (Group 107). Calcium oxide, the only water reactive substance present, is dispersed in chloride salts. Based on the immobilization of the calcium oxide in the salts, reactions are considered highly unlikely.

36a. (25 x 101) The potential chemical incompatibility is the reaction of nitrides (Group 25) with residual water present in the combustible materials (Group 101), resulting in formation of ammonia gas, heat generation, and possible ignition of the combustible materials. However, the combustible materials are polyethylene and polyvinyl chloride packaging materials which contain no residual water. Additionally, any reactive nitrides must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

36aa. (25 x 106) The potential chemical incompatibility is the reaction of nitrides (Group 25) with water present in the combustible materials (101), resulting in formation of ammonia gas, heat generation, and possible ignition of the combustible materials. However, any reactive nitrides must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

36b. (27 x 104) The potential incompatibility is the possible reaction between nitro compounds (Group 27) and oxidizing agents (Group 107). Calcium oxide, the only water reactive substance present, is dispersed in chloride salts. Reactive oxidizing agents must be neutralized prior to shipment to WIPP. Based on the immobilization of the calcium oxide in the salts and neutralization of oxidizing agents, reactions are considered highly unlikely.

36c. (29 x 104) The potential incompatibility is the possible reaction between saturated aliphatics (Group 29) and oxidizing agents (Group 104). However, reactive oxidizing agents must be neutralized prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

36d. (101 x 102) The potential incompatibility is the possible oxidation reaction between combustibles (Group 101) and explosives (102). However, explosives must be reacted prior to shipment to WIPP. Therefore, the final waste form will contain compatible materials.

37. (101 x 104) The potential incompatibility is the possible reaction between combustible materials (Group 101) and oxidizing agents (Group 104). The oxidizing agents are present only in trace quantities (<1%) and are reacted prior to loading in waste containers. In addition, cement is added to absorb any residual liquid. Due to the immobilization and prior reaction of the oxidizing agents, this content code is considered to be chemically compatible.

38. (101 x 104) The potential incompatibility is the possible reaction between combustible materials (Group 101) and oxidizing agents (Group 104). The oxidizing agents are present only in trace quantities (<1%) and are fixed in the solidified product. Due to the immobilization and prior reaction of the oxidizing agents, this content code is considered to be chemically compatible.

39. (101 x 107) The potential incompatibility is the possible reaction between combustible and flammable materials (Group 101) and water reactive substances (Group 107). The dominant combustible material in Group 101 is the polyethylene rigid drum liner. Calcium oxide, the only water reactive substance present, is a solid dispersed in the chloride salts. Based on the immobilization of the calcium oxide in the salt, reactions are considered highly unlikely.

40. (102 x 104) The potential incompatibility is the possible violent reaction between explosives (Group 102) and oxidizing agents (Group 104). However, both of these groups must be neutralized before shipment to WIPP. Therefore, the final waste form will contain compatible materials.

41. (104 x 107) The potential incompatibility is the possible violent reaction between oxidizing agents (Group 104) and water reactives (Group 107). However, both of these groups must be neutralized before shipment to WIPP. Therefore, the final waste form will contain compatible materials.

List of References for Appendix C1

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TABLES

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	IN W198	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
COMBUSTIBLE	IN W198	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x T	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W198	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	IN W198	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W202	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
COMBUSTIBLE	IN W202	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x T	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W202	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	IN W202	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W205	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	IN W205	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x T	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W205	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	IN W205	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W250	AMINES, ALIPHATIC & AROMATIC x METALS & METAL COMPOUNDS, TOXIC	T x D	S	12c
		(7 x 24)			
COMBUSTIBLE	IN W250	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W250	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
COMBUSTIBLE	IN W250	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W252	AMINES, ALIPHATIC & AROMATIC x METALS & METAL COMPOUNDS, TOXIC	T x D	S	12c
		(7 x 24)			
COMBUSTIBLE	IN W252	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	IN W252	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
COMBUSTIBLE	IN W252	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W254	AMINES, ALIPHATIC & AROMATIC x METALS & METAL COMPOUNDS, TOXIC	T x D	S	12c
		(7 x 24)			
COMBUSTIBLE	IN W254	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W254	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
COMBUSTIBLE	IN W254	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W256	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W256	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
COMBUSTIBLE	IN W256	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	IN W325	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W327	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W330	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	IN W330	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	IN W330	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	IN W336	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	T1 x D	H	00
		(1 x 10)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T1 x D	H	0aaa
		(1 x 14)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T1 x D	GT	0aaaa
		(1 x 15)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	LA W004	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	GF H F	1
		(1 x 23)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T1 x D	H G	3
		(1 x 101)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T1 x D	H	3b
		(1 x 106)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T1 x D	H	00
		(2 x 10)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, OXIDIZING x ETHERS	T1 x D	H F	3f
		(2 x 14)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T1 x D	GT	3g
		(2 x 15)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	GF H F	4
		(2 x 23)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T1 x D	H F GT	9
		(2 x 101)			
COMBUSTIBLE	LA W004	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T1 x D	H	10a
		(2 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	LA W004	ACIDS, ORGANIC x CAUSTICS	T x D	H	00
		(3 x 10)			
COMBUSTIBLE	LA W004	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
COMBUSTIBLE	LA W004	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
COMBUSTIBLE	LA W004	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
COMBUSTIBLE	LA W004	CAUSTICS x METALS OTHER ELEMENTAL & ALLOYS IN THE FORM OF POWDERS, VAPORS OR SPONGES	D x T2	GF H	00
		(10 x 22)			
COMBUSTIBLE	LA W004	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
COMBUSTIBLE	LA W004	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T1	S	00
		(10 x 24)			
COMBUSTIBLE	LA W004	CAUSTICS x NITRIDES	D x T1	U	00
		(10 x 25)			
COMBUSTIBLE	LA W004	CAUSTICS x NITRO COMPOUNDS	D x T1	H E	00
		(10 x 27)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	LA W004	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T1	H E	00
		(10 x 32)			
COMBUSTIBLE	LA W004	CAUSTICS x EXPLOSIVES	D x T2	H E	00
		(10 x 102)			
COMBUSTIBLE	LA W004	CAUSTICS x WATER REACTIVE SUBSTANCES	D x T	EXTREMELY	00
		(10 x 107)			
COMBUSTIBLE	LA W004	ETHERS x OXIDIZING AGENTS, STRONG	D x T1	H F	17a
		(14 x 104)			
COMBUSTIBLE	LA W004	ETHERS x WATER REACTIVE SUBSTANCES	D x T	EXTREMELY	17b
		(14 x 107)			
COMBUSTIBLE	LA W004	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES	D x T	EXTREMELY	18
		(15 x 107)			
COMBUSTIBLE	LA W004	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	20
		(17 x 23)			
COMBUSTIBLE	LA W004	METALS OTHER ELEMENTAL & ALLOYS IN THE FORM OF POWDERS, VAPORS OR SPONGES x WATER & MIXTURES CONTAINING WATER	T2 x D	GF H	28e
		(22 x 106)			
COMBUSTIBLE	LA W004	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T1	H F	29
		(23 x 104)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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COMBUSTIBLE	LA W004	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x WATER REACTIVE SUBSTANCES	D x T	EXTREMELY	31
		(23 x 107)			
COMBUSTIBLE	LA W004	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T1 x D	S	33a
		(24 x 106)			
COMBUSTIBLE	LA W004	NITRIDES x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T1 x D	H GF F	36a
		(25 x 101)			
COMBUSTIBLE	LA W004	NITRIDES x WATER & MIXTURES CONTAINING WATER	T1 x D	GF H	36aa
		(25 x 106)			
COMBUSTIBLE	LA W004	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T2	H E	36d
		(101 x 102)			
COMBUSTIBLE	LA W004	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T1	H F G	38
		(101 x 104)			
COMBUSTIBLE	LA W004	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x WATER REACTIVE SUBSTANCES	D x T	EXTREMELY	39
		(101 x 107)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	T x D	H	00
		(1 x 10)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T x D	H	0aaa
		(1 x 14)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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COMBUSTIBLE	LL M001	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T x D	GT	0aaaa
		(1 x 15)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	1
		(1 x 23)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G	3
		(1 x 101)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	3b
		(1 x 106)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
COMBUSTIBLE	LL M001	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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COMBUSTIBLE	LL M001	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10
		(2 x 106)			
COMBUSTIBLE	LL M001	ACIDS, ORGANIC x CAUSTICS	T x D	H	00
		(3 x 10)			
COMBUSTIBLE	LL M001	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
COMBUSTIBLE	LL M001	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
COMBUSTIBLE	LL M001	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
COMBUSTIBLE	LL M001	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x T	GF H	00
		(10 x 21)			
COMBUSTIBLE	LL M001	CAUSTICS x METALS OTHER ELEMENTAL & ALLOYS IN THE FORM OF POWDERS, VAPORS OR SPONGES	D x T	GF H	00
		(10 x 22)			
COMBUSTIBLE	LL M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
COMBUSTIBLE	LL M001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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COMBUSTIBLE	LL M001	CAUSTICS x EXPLOSIVES	D x T	H E	00
		(10 x 102)			
COMBUSTIBLE	LL M001	ETHERS x OXIDIZING AGENTS, STRONG	D x T	H F	17a
		(14 x 104)			
COMBUSTIBLE	LL M001	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	26
		(17 x 23)			
COMBUSTIBLE	LL M001	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G F	28b
		(21 x 101)			
COMBUSTIBLE	LL M001	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	T x D	GF H	28d
		(21 x 106)			
COMBUSTIBLE	LL M001	METALS OTHER ELEMENTAL & ALLOYS IN THE FORM OF POWDERS, VAPORS OR SPONGES x WATER & MIXTURES CONTAINING WATER	T x D	GF H	28e
		(22 x 106)			
COMBUSTIBLE	LL M001	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T	H F	30
		(23 x 104)			
COMBUSTIBLE	LL M001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
COMBUSTIBLE	LL M001	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T	H E	36d
		(101 x 102)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	LL M001	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T	H F G	38
		(101 x 104)			
COMBUSTIBLE	RL M009	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M010	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M010	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	RL M010	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	RL M011	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M011	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	RL M011	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	RL M012	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	RL M012	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M012	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
COMBUSTIBLE	RL M013	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
COMBUSTIBLE	RL M013	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
COMBUSTIBLE	RL M013	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
COMBUSTIBLE	RL M013	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M013	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
COMBUSTIBLE	RL M013	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
COMBUSTIBLE	RL M014	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	RL M014	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	RL M014	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	RL M015	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M015	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	RL M015	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	RL M016	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
COMBUSTIBLE	RL M016	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M016	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	RL M016	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
COMBUSTIBLE	RL M016	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	RL M022	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
COMBUSTIBLE	RL M022	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
COMBUSTIBLE	RL M022	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
COMBUSTIBLE	RL M023	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
FILTER	AW M003	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
FILTER	AW M003	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
FILTER	AW M003	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
FILTER	IN W214	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
FILTER	IN W214	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
FILTER	IN W214	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
FILTER	RF W066	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
FILTER	RF W066	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
FILTER	RF W066	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	21
		(17 x 23)			
FILTER	RF W067	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
FILTER	RF W067	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
FILTER	RF W067	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	23
		(17 x 23)			
GRAPHITE	IN W272	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
GRAPHITE	IN W272	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
GRAPHITE	IN W272	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
GRAPHITE	IN W275	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
GRAPHITE	IN W275	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
GRAPHITE	IN W275	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
GRAPHITE	IN W276	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
GRAPHITE	IN W276	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
GRAPHITE	IN W276	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
GRAPHITE	RF W060	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
GRAPHITE	RF W060	CAUSTICS x METALS & METAL COMPOUNDS,TOXIC	D x M	S	00
		(10 x 24)			
GRAPHITE	RF W060	METALS & METAL COMPOUNDS,TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			
HETEROGENEOUS	AW W020	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	AW W020	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	AW W020	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN M002	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN M002	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	IN M002	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W139	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W139	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	IN W139	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W169	AMINES, ALIPHATIC & AROMATIC x HALOGENATED ORGANICS	D x T	H G	12b
		(7 x 17)			
HETEROGENEOUS	IN W169	AMINES, ALIPHATIC & AROMATIC x METALS & METAL COMPOUNDS, TOXIC	D x T	S	12c
		(7 x 24)			
HETEROGENEOUS	IN W169	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W169	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W169	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W169	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	IN W169	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W170	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
HETEROGENEOUS	IN W170	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
HETEROGENEOUS	IN W170	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W170	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W170	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W171	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
HETEROGENEOUS	IN W171	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
HETEROGENEOUS	IN W171	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W171	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W171	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W172	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W172	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W172	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	33a
		(17 x 23)			
HETEROGENEOUS	IN W186	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W186	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W186	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W186	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	IN W186	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W189	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W189	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	IN W189	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W197	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W197	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x T	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W197	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W197	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W203	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W203	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W203	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W204	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W204	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W204	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W225	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W225	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	IN W225	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W259	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W259	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W259	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W265	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W265	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W265	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	IN W265	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
HETEROGENEOUS	IN W265	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W269	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W271	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W271	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W271	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W281	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W281	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W281	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	T x D	H	00
		(1 x 10)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T x D	H	0aaa
		(1 x 14)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T x D	GT	0aaaa
		(1 x 15)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	1
		(1 x 23)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	T x M	S	2
		(1 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G	3
		(1 x 101)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	3b
		(1 x 106)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	5
		(2 x 23)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	T x M	S	7
		(2 x 24)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	8
		(2 x 101)			
HETEROGENEOUS	IN W283	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W283	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W283	CAUSTICS x ISOCYANATES	D x T	H P G	00
		(10 x 18)			
HETEROGENEOUS	IN W283	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W283	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
HETEROGENEOUS	IN W283	ETHERS x OXIDIZING AGENTS, STRONG	D x T	H F	17a
		(14 x 104)			
HETEROGENEOUS	IN W283	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
HETEROGENEOUS	IN W283	ISOCYANATES x WATER & MIXTURES CONTAINING WATER	T x D	H G	28aa
		(18 x 106)			
HETEROGENEOUS	IN W283	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T	H F	30
		(23 x 104)			
HETEROGENEOUS	IN W283	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W283	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T	H F G	37
		(101 x 104)			
HETEROGENEOUS	IN W285	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W285	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
HETEROGENEOUS	IN W285	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
HETEROGENEOUS	IN W289	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W289	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W289	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W289	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	IN W289	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W291	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
HETEROGENEOUS	IN W291	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
HETEROGENEOUS	IN W291	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W302	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	IN W302	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W302	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	IN W323	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W323	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	IN W323	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	IN W329	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W334	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W345	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	IN W351	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	INW269B	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x ALCOHOLS & GLYCOLS	M x T	H	0a
		(1 x 4)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	M x D	H	0aa 00
		(1 x 10)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	M x D	H	0aaa
		(1 x 14)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	M x D	GT	0aaaa
		(1 x 15)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x HALOGENATED ORGANICS	M x T	H GT	0b
		(1 x 17)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x KETONES	M x T	H	0bb
		(1 x 19)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	M x T	S	2
		(1 x 24)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	M x T	H G	3
		(1 x 101)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x EXPLOSIVES	M x T	H E	3a
		(1 x 102)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x OXIDIZING AGENTS, STRONG	M x T	H GT	3aa
		(1 x 104)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	M x D	H	3b
		(1 x 106)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x ACIDS, ORGANIC	M x T	G H	3c
		(2 x 3)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x ALCOHOLS & GLYCOLS	M x T	H F	3d
		(2 x 4)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x CAUSTICS	M x D	H	3e 00
		(2 x 10)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x ETHERS	M x D	H F	3f
		(2 x 14)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	M x D	GT	3g
		(2 x 15)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x HALOGENATED ORGANICS	M x T	H F GT	3h
		(2 x 17)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x KETONES	M x T	H F	3i
		(2 x 19)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	M x T	S	6 7
		(2 x 24)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	M x T	H F GT	8 9
		(2 x 101)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x EXPLOSIVES	M x T	H E	9a
		(2 x 102)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	M x D	H	10a
		(2 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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HETEROGENEOUS	NT W001	ACIDS, ORGANIC x CAUSTICS	T x D	H	11b 00
		(3 x 10)			
HETEROGENEOUS	NT W001	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
HETEROGENEOUS	NT W001	CAUSTICS x HALOGENATED ORGANICS	D x T	H	13 00
		(10 x 17)			
HETEROGENEOUS	NT W001	CAUSTICS x KETONES	D x T	H	13a 00
		(10 x 19)			
HETEROGENEOUS	NT W001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	16a 00
		(10 x 24)			
HETEROGENEOUS	NT W001	CAUSTICS x EXPLOSIVES	D x T	H E	16c 00
		(10 x 102)			
HETEROGENEOUS	NT W001	ETHERS x OXIDIZING AGENTS, STRONG	D x T	H F	17a
		(14 x 104)			
HETEROGENEOUS	NT W001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a
		(24 x 106)			
HETEROGENEOUS	NT W001	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x M	GF H F	1
		(1 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	NT W001	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x M	GF H F	4 5
		(2 x 23)			
HETEROGENEOUS	NT W001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x M	GF H	15 00
		(10 x 23)			
HETEROGENEOUS	NT W001	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x M	H F	20 24
		(17 x 23)			
HETEROGENEOUS	NT W001	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G F	28b
		(21 x 101)			
HETEROGENEOUS	NT W001	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	M x T	H F	30
		(23 x 104)			
HETEROGENEOUS	NT W001	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T	H E	36d
		(101 x 102)			
HETEROGENEOUS	NT W001	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T	H F G	38
		(101 x 104)			
HETEROGENEOUS	OR W040	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	OR W040	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	OR W040	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	T x D	H	00
		(1 x 10)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T x D	H	0aaa
		(1 x 14)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T x D	GT	0aaaa
		(1 x 15)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	1
		(1 x 23)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G	3
		(1 x 101)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	3b
		(1 x 106)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	OR W044	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	5
		(2 x 23)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	8
		(2 x 101)			
HETEROGENEOUS	OR W044	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			
HETEROGENEOUS	OR W044	ACIDS, ORGANIC x CAUSTICS	T2 x D	H	00
		(3 x 10)			
HETEROGENEOUS	OR W044	ACIDS, ORGANIC x FLUORIDES, INORANIC	T2 x D	GT	11d
		(3 x 15)			
HETEROGENEOUS	OR W044	AZO COMPOUNDS, DIAZO COMPOUNDS, & HYDRAZINES x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	H F G	12e
		(8 x 23)			
HETEROGENEOUS	OR W044	AZO COMPOUNDS, DIAZO COMPOUNDS, & HYDRAZINES x WATER & MIXTURES CONTAINING WATER	T2 x D	G	12f
		(8 x 106)			
HETEROGENEOUS	OR W044	CAUSTICS x ESTERS	D x T2	H	00
		(10 x 13)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	OR W044	CAUSTICS x HALOGENATED ORGANICS	D x T2	H	00
		(10 x 17)			
HETEROGENEOUS	OR W044	CAUSTICS x KETONES	D x T2	H	00
		(10 x 19)			
HETEROGENEOUS	OR W044	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
HETEROGENEOUS	OR W044	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	OR W044	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T1	H E	00
		(10 x 32)			
HETEROGENEOUS	OR W044	ETHERS x OXIDIZING AGENTS, STRONG	D x T1	H F	17a
		(14 x 104)			
HETEROGENEOUS	OR W044	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	H F	20 22
		(17 x 23)			
HETEROGENEOUS	OR W044	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T1	H F	29
		(23 x 104)			
HETEROGENEOUS	OR W044	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	OR W044	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T1	H F G	38
		(101 x 104)			
HETEROGENEOUS	OR W045	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	OR W045	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	OR W045	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	OR W047	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	OR W047	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	OR W047	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	RF M002	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	RF M002	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	RF M002	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RF M002	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
HETEROGENEOUS	RF M002	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	RF W008	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	RF W008	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RF W008	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	23
		(17 x 23)			
HETEROGENEOUS	RF W012	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	RF W012	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RF W012	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	RF W036	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	RF W036	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RF W036	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	RF W036	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
HETEROGENEOUS	RF W036	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	RL M004	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RL M006	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
HETEROGENEOUS	RL M006	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	RL M006	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
HETEROGENEOUS	RL M006	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RL M006	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	RL M031	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	RL M201	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	SA W134	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	SR W026	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	SR W026	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	SR W026	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	SR W026	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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HETEROGENEOUS	SR W026	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
HETEROGENEOUS	SR W027	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
HETEROGENEOUS	SR W027	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
HETEROGENEOUS	SR W027	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
HETEROGENEOUS	SR W027	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
HETEROGENEOUS	SR W027	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
HETEROGENEOUS	SR W027	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
HETEROGENEOUS	SR W027	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
HETEROGENEOUS	SR W027	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	IN W161	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W161	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
INORGANIC NON-METAL	IN W161	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	IN W230	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
INORGANIC NON-METAL	IN W230	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W230	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
INORGANIC NON-METAL	IN W240	CAUSTICS x HALOGENATED ORGANICS	D x T3	H	00
		(10 x 17)			
INORGANIC NON-METAL	IN W240	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W240	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

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INORGANIC NON-METAL	IN W240	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T3 x D	H F	24
		(17 x 23)			
INORGANIC NON-METAL	IN W240	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	IN W243	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
INORGANIC NON-METAL	IN W243	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	5
		(2 x 23)			
INORGANIC NON-METAL	IN W243	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISCELLANEOUS	T x D	H F GT	8
		(2 x 101)			
INORGANIC NON-METAL	IN W243	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			
INORGANIC NON-METAL	IN W243	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
INORGANIC NON-METAL	IN W243	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
INORGANIC NON-METAL	IN W243	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	IN W243	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W243	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
INORGANIC NON-METAL	IN W243	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
INORGANIC NON-METAL	IN W243	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
INORGANIC NON-METAL	IN W243	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	IN W245	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
INORGANIC NON-METAL	IN W245	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
INORGANIC NON-METAL	IN W245	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
INORGANIC NON-METAL	IN W245	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	5
		(2 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	IN W245	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	8
		(2 x 101)			
INORGANIC NON-METAL	IN W245	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			
INORGANIC NON-METAL	IN W245	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
INORGANIC NON-METAL	IN W245	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W245	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
INORGANIC NON-METAL	IN W245	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
INORGANIC NON-METAL	IN W245	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	IN W247	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
INORGANIC NON-METAL	IN W247	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	IN W247	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
INORGANIC NON-METAL	IN W247	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	8
		(2 x 101)			
INORGANIC NON-METAL	IN W247	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			
INORGANIC NON-METAL	IN W247	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
INORGANIC NON-METAL	IN W247	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x T	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W247	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
INORGANIC NON-METAL	IN W247	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	IN W249	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	IN W249	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	IN W249	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	MD M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	RF W026	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
INORGANIC NON-METAL	RF W026	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	RF W026	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
INORGANIC NON-METAL	RF W032	CAUSTICS x HALOGENATED ORGANICS	D x T3	H	00
		(10 x 17)			
INORGANIC NON-METAL	RF W032	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	RF W032	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
INORGANIC NON-METAL	RF W032	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T3 x D	H F	22
		(17 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	RF W032	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	RF W052	CAUSTICS x HALOGENATED ORGANICS	D x T3	H	00
		(10 x 17)			
INORGANIC NON-METAL	RF W052	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	RF W052	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
INORGANIC NON-METAL	RF W052	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T3 x D	H F	22
		(17 x 23)			
INORGANIC NON-METAL	RF W052	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	RF W056	CAUSTICS x HALOGENATED ORGANICS	D x T3	H	00
		(10 x 17)			
INORGANIC NON-METAL	RF W056	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	RF W056	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
INORGANIC NON-METAL	RF W056	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T3 x D	H F	22
		(17 x 23)			
INORGANIC NON-METAL	RF W056	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
INORGANIC NON-METAL	RF W057	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
INORGANIC NON-METAL	RF W057	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
INORGANIC NON-METAL	RF W057	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	22
		(17 x 23)			
LEAD/CADMIUM METAL WASTE	AW M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	AW M001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	AW M001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a 34
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	AW M002	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
LEAD/CADMIUM METAL WASTE	AW M002	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	AW M002	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	AW W016	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	AW W016	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	AW W016	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	AW W022	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	AW W022	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	AW W022	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a 34
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	ET M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
LEAD/CADMIUM METAL WASTE	ET M001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	ET M001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	IN M004	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	IN M004	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	IN M004	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	IN M005	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	IN M005	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	IN M005	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	RF W029	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
LEAD/CADMIUM METAL WASTE	RF W029	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	RF W029	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	5
		(2 x 23)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	T x D	S	7
		(2 x 24)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	8
		(2 x 101)			
LEAD/CADMIUM METAL WASTE	RF W041	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
LEAD/CADMIUM METAL WASTE	RF W041	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	RF W041	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	RF W041	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	RL M019	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	RL M019	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	RL M019	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
LEAD/CADMIUM METAL WASTE	RL M020	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
LEAD/CADMIUM METAL WASTE	RL M020	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
LEAD/CADMIUM METAL WASTE	RL M020	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SALT WASTE	IN M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SALT WASTE	IN M001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SALT WASTE	IN M001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SALT WASTE	IN W311	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SALT WASTE	IN W311	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SALT WASTE	IN W311	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
SALT WASTE	IN W312	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	14 00
		(10 x 23)			
SALT WASTE	IN W312	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T1	S	16 00
		(10 x 24)			
SALT WASTE	IN W312	CAUSTICS x WATER REACTIVE SUBSTANCES	D x M	EXTREMELY	17 00
		(10 x 107)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SALT WASTE	IN W312	ETHERS x WATER REACTIVE SUBSTANCES (14 x 107)	D x M	EXTREMELY	17b
SALT WASTE	IN W312	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES (15 x 107)	D x M	EXTREMELY	18
SALT WASTE	IN W312	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x WATER REACTIVE SUBSTANCES (23 x 107)	D x M	EXTREMELY	31
SALT WASTE	IN W312	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER (24 x 106)	T1 x D	S	33a
SALT WASTE	IN W312	METALS & METAL COMPOUNDS, TOXIC x WATER REACTIVE SUBSTANCES (24 x 107)	T1 x M	EXTREMELY	35
SALT WASTE	IN W312	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x WATER REACTIVE SUBSTANCES (101 x 107)	D x M	EXTREMELY	39
SALT WASTE	IN W314	CAUSTICS x HALOGENATED ORGANICS (10 x 17)	D x T	H	00
SALT WASTE	IN W314	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (10 x 23)	D x D	GF H	00
SALT WASTE	IN W314	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (17 x 23)	T x D	H F	20

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SALT WASTE	RF W058	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SALT WASTE	RF W058	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T1	S	16 00
		(10 x 24)			
SALT WASTE	RF W058	CAUSTICS x WATER REACTIVE SUBSTANCES	D x M	EXTREMELY	17 00
		(10 x 107)			
SALT WASTE	RF W058	ETHERS x WATER REACTIVE SUBSTANCES	D x M	EXTREMELY	17b
		(14 x 107)			
SALT WASTE	RF W058	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES	D x M	EXTREMELY	18
		(15 x 107)			
SALT WASTE	RF W058	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x WATER REACTIVE SUBSTANCES	D x M	EXTREMELY	31
		(23 x 107)			
SALT WASTE	RF W058	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T1 x D	S	33a
		(24 x 106)			
SALT WASTE	RF W058	METALS & METAL COMPOUNDS, TOXIC x WATER REACTIVE SUBSTANCES	T1 x M	EXTREMELY	35
		(24 x 107)			
SALT WASTE	RF W058	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x WATER REACTIVE SUBSTANCES	D x M	EXTREMELY	39
		(101 x 107)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOILS	IN W263	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOILS	IN W263	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOILS	IN W263	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOILS	RL M007	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOILS	RL M007	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOILS	RL M007	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	AL W005	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	AL W005	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	AL W005	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	AL W005	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	AL W005	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	AL W005	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10 10a
		(2 x 106)			
SOLIDIFIED INORGANICS	AL W005	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	AL W005	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	AL W005	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W146	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W146	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W146	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W157	ACIDS, ORGANIC x ALCOHOLS & GLYCOLS	M x T	H P	11 11a
		(3 x 4)			
SOLIDIFIED INORGANICS	IN W157	ACIDS, ORGANIC x CAUSTICS	M x D	H	00
		(3 x 10)			
SOLIDIFIED INORGANICS	IN W157	ACIDS, ORGANIC x FLUORIDES, INORANIC	M x D	GT	11d
		(3 x 15)			
SOLIDIFIED INORGANICS	IN W157	ACIDS, ORGANIC x METALS & METAL COMPOUNDS, TOXIC	M x T	S	12 12aa
		(3 x 24)			
SOLIDIFIED INORGANICS	IN W157	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W157	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W157	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W157	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W157	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W166	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W166	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W166	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T1	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W166	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W166	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T1 x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W177	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	T x D	H	00
		(1 x 10)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T x D	H	0aaa
		(1 x 14)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T x D	GT	0aaaa
		(1 x 15)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	1
		(1 x 23)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G	3
		(1 x 101)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	3b
		(1 x 106)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W179	ACIDS, ORGANIC x CAUSTICS	T x D	H	00
		(3 x 10)			
SOLIDIFIED INORGANICS	IN W179	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
SOLIDIFIED INORGANICS	IN W179	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
SOLIDIFIED INORGANICS	IN W179	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W179	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	IN W179	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W179	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W179	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	19
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W179	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W181	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	IN W181	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	IN W181	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	IN W181	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	IN W181	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	IN W181	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10 10a
		(2 x 106)			
SOLIDIFIED INORGANICS	IN W181	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W181	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W181	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W181	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W181	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W188	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	IN W188	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	IN W188	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	IN W188	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	IN W188	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	IN W188	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10
		(2 x 106)			
SOLIDIFIED INORGANICS	IN W188	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W188	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W188	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W188	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W188	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W216	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	IN W216	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	IN W216	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	IN W216	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	IN W216	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W216	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10
		(2 x 106)			
SOLIDIFIED INORGANICS	IN W216	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W216	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W216	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W216	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W216	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W220	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	IN W220	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	IN W220	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W220	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	IN W220	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	IN W220	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10
		(2 x 106)			
SOLIDIFIED INORGANICS	IN W220	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W220	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W220	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W220	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T3	H E	00
		(10 x 32)			
SOLIDIFIED INORGANICS	IN W220	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W220	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a 34
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W221	ACIDS, ORGANIC x ALCOHOLS & GLYCOLS	M x T1	H P	11
		(3 x 4)			
SOLIDIFIED INORGANICS	IN W221	ACIDS, ORGANIC x CAUSTICS	M x D	H	00
		(3 x 10)			
SOLIDIFIED INORGANICS	IN W221	ACIDS, ORGANIC x FLUORIDES, INORANIC	M x D	GT	11d
		(3 x 15)			
SOLIDIFIED INORGANICS	IN W221	ACIDS, ORGANIC x METALS & METAL COMPOUNDS, TOXIC	M x T	S	12
		(3 x 24)			
SOLIDIFIED INORGANICS	IN W221	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W221	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	IN W221	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W221	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W221	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T	H E	00
		(10 x 32)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W221	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W221	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W222	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
SOLIDIFIED INORGANICS	IN W222	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W222	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	IN W222	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W222	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	IN W222	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W222	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W228	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
SOLIDIFIED INORGANICS	IN W228	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	IN W228	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	IN W228	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	IN W228	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	IN W228	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10
		(2 x 106)			
SOLIDIFIED INORGANICS	IN W228	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	IN W228	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W228	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	IN W228	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	IN W228	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a
		(24 x 106)			
SOLIDIFIED INORGANICS	IN W332	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	IN W347	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	LA W002	CAUSTICS x KETONES	D x T3	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	LA W002	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T2	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	LA W002	CAUSTICS x EXPLOSIVES	D x T2	H E	00
		(10 x 102)			
SOLIDIFIED INORGANICS	LA W002	CAUSTICS x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	00
		(10 x 107)			
SOLIDIFIED INORGANICS	LA W002	ETHERS x OXIDIZING AGENTS, STRONG	D x T2	H F	17a
		(14 x 104)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LA W002	ETHERS x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	17b
		(14 x 107)			
SOLIDIFIED INORGANICS	LA W002	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	18
		(15 x 107)			
SOLIDIFIED INORGANICS	LA W002	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T2 x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	LA W003	CAUSTICS x KETONES	D x T3	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	LA W003	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T3	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	LA W003	CAUSTICS x EXPLOSIVES	D x T2	H E	00
		(10 x 102)			
SOLIDIFIED INORGANICS	LA W003	CAUSTICS x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	00
		(10 x 107)			
SOLIDIFIED INORGANICS	LA W003	ETHERS x OXIDIZING AGENTS, STRONG	D x T2	H F	17a
		(14 x 104)			
SOLIDIFIED INORGANICS	LA W003	ETHERS x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	17b
		(14 x 107)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LA W003	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	18
		(15 x 107)			
SOLIDIFIED INORGANICS	LA W003	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T3 x D	S	33 33a
		(24 x 106)			
SOLIDIFIED INORGANICS	LA W003	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T2	H E	36d
		(101 x 102)			
SOLIDIFIED INORGANICS	LA W003	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T2	H F G	37
		(101 x 104)			
SOLIDIFIED INORGANICS	LA W003	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	39
		(101 x 107)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T2 x D	H	0aaa
		(1 x 14)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T2 x D	GT	0aaaa
		(1 x 15)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	GF H F	1
		(1 x 23)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T2 x D	H G	3
		(1 x 101)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, NON-OXIDIZING x OXIDIZING AGENTS, STRONG	T2 x D	H GT	3aa
		(1 x 104)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T2 x D	H	3b
		(1 x 106)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T2 x D	H	
		(2 x 10)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, OXIDIZING x ETHERS	T2 x D	H F	3f
		(2 x 14)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T2 x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T2 x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T2 x D	H	10
		(2 x 106)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, ORGANIC x CAUSTICS	T2 x D	H	00
		(3 x 10)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SOLIDIFIED INORGANICS	LA W006	ACIDS, ORGANIC x FLUORIDES, INORANIC	T2 x D	GT	11d
		(3 x 15)			
SOLIDIFIED INORGANICS	LA W006	ACIDS, ORGANIC x OXIDIZING AGENTS, STRONG	T2 x D	H GT	12bbb
		(3 x 104)			
SOLIDIFIED INORGANICS	LA W006	ALCOHOLS & GLYCOLS x OXIDIZING AGENTS, STRONG	T2 x D	H F	12bb
		(4 x 104)			
SOLIDIFIED INORGANICS	LA W006	AMINES, ALIPHATIC & AROMATIC x OXIDIZING AGENTS, STRONG	T2 x D	H F GT	12d
		(7 x 104)			
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x HALOGENATED ORGANICS	D x T2	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x T	GF H	00
		(10 x 21)			
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T1	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x NITRO COMPOUNDS	D x T2	H E	00
		(10 x 27)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x EXPLOSIVES	D x T	H E	00
		(10 x 102)			
SOLIDIFIED INORGANICS	LA W006	CAUSTICS x WATER REACTIVE SUBSTANCES	D x T1	EXTREMELY	00
		(10 x 107)			
SOLIDIFIED INORGANICS	LA W006	ETHERS x OXIDIZING AGENTS, STRONG	D x D	H F	17a
		(14 x 104)			
SOLIDIFIED INORGANICS	LA W006	ETHERS x WATER REACTIVE SUBSTANCES	D x T1	EXTREMELY	17b
		(14 x 107)			
SOLIDIFIED INORGANICS	LA W006	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES	D x T1	EXTREMELY	18
		(15 x 107)			
SOLIDIFIED INORGANICS	LA W006	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	LA W006	HALOGENATED ORGANICS x OXIDIZING AGENTS, STRONG	T2 x D	H GT	28
		(17 x 104)			
SOLIDIFIED INORGANICS	LA W006	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G F	28b
		(21 x 101)			
SOLIDIFIED INORGANICS	LA W006	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x OXIDIZING AGENTS, STRONG	T x D	H F E	28c
		(21 x 104)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LA W006	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	T x D	GF H	28d
		(21 x 106)			
SOLIDIFIED INORGANICS	LA W006	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x D	H F	29
		(23 x 104)			
SOLIDIFIED INORGANICS	LA W006	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x WATER REACTIVE SUBSTANCES	D x T1	EXTREMELY	31
		(23 x 107)			
SOLIDIFIED INORGANICS	LA W006	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T1 x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	LA W006	NITRO COMPOUNDS x OXIDIZING AGENTS, STRONG	T2 x D	H E	36b
		(27 x 104)			
SOLIDIFIED INORGANICS	LA W006	HYDROCARBON, ALIPHATIC, SATURATED x OXIDIZING AGENTS, STRONG	T2 x D	H F	36c
		(29 x 104)			
SOLIDIFIED INORGANICS	LA W006	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T	H E	36d
		(101 x 102)			
SOLIDIFIED INORGANICS	LA W006	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x D	H F G	37
		(101 x 104)			
SOLIDIFIED INORGANICS	LA W006	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x WATER REACTIVE SUBSTANCES	D x T1	EXTREMELY	39
		(101 x 107)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LA W006	EXPLOSIVES x OXIDIZING AGENTS, STRONG	T x D	H E	40
		(102 x 104)			
SOLIDIFIED INORGANICS	LA W006	OXIDIZING AGENTS, STRONG x WATER REACTIVE SUBSTANCES	D x T1	EXTREMELY	41
		(104 x 107)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x ALCOHOLS & GLYCOLS	M x T	H	0a
		(1 x 4)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	M x D	H	0aa 00
		(1 x 10)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	M x D	H	0aaa
		(1 x 14)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	M x D	GT	0aaaa
		(1 x 15)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x HALOGENATED ORGANICS	M x T	H GT	0b
		(1 x 17)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x KETONES	M x T	H	0bb
		(1 x 19)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	M x D	GF H F	1
		(1 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	M x T	S	2
		(1 x 24)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	M x D	H G	3
		(1 x 101)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x EXPLOSIVES	M x T	H E	3a
		(1 x 102)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x OXIDIZING AGENTS, STRONG	M x T	H GT	3aa
		(1 x 104)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	M x D	H	3b
		(1 x 106)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x ACIDS, ORGANIC	M x T	G H	3c
		(2 x 3)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x ALCOHOLS & GLYCOLS	M x T	H F	3d
		(2 x 4)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x CAUSTICS	M x D	H	3e 00
		(2 x 10)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x ETHERS	M x D	H F	3f
		(2 x 14)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	M x D	GT	3g
		(2 x 15)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x HALOGENATED ORGANICS	M x T	H F GT	3h
		(2 x 17)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x KETONES	M x T	H F	3i
		(2 x 19)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	M x D	GF H F	4
		(2 x 23)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x METALS & METAL COMPOUNDS, TOXIC	M x T	S	6
		(2 x 24)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	M x D	H F GT	9
		(2 x 101)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x EXPLOSIVES	M x T	H E	9a
		(2 x 102)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	M x D	H	10 10a
		(2 x 106)			
SOLIDIFIED INORGANICS	LL W019	ACIDS, ORGANIC x CAUSTICS	T x D	H	11b 00
		(3 x 10)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LL W019	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
SOLIDIFIED INORGANICS	LL W019	CAUSTICS x HALOGENATED ORGANICS	D x T	H	13 00
		(10 x 17)			
SOLIDIFIED INORGANICS	LL W019	CAUSTICS x KETONES	D x T	H	13a 00
		(10 x 19)			
SOLIDIFIED INORGANICS	LL W019	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	16a 00
		(10 x 23)			
SOLIDIFIED INORGANICS	LL W019	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	16a 00
		(10 x 24)			
SOLIDIFIED INORGANICS	LL W019	CAUSTICS x EXPLOSIVES	D x T	H E	16c 00
		(10 x 102)			
SOLIDIFIED INORGANICS	LL W019	ETHERS x OXIDIZING AGENTS, STRONG	D x T	H F	17a
		(14 x 104)			
SOLIDIFIED INORGANICS	LL W019	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	25
		(17 x 23)			
SOLIDIFIED INORGANICS	LL W019	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T	H F	29
		(23 x 104)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	LL W019	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	LL W019	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T	H E	36d
		(101 x 102)			
SOLIDIFIED INORGANICS	LL W019	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T	H F G	37
		(101 x 104)			
SOLIDIFIED INORGANICS	MD W002	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	OR W042	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	OR W042	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	OR W042	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a
		(24 x 106)			
SOLIDIFIED INORGANICS	OR W046	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	OR W046	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

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SOLIDIFIED INORGANICS	OR W046	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	PA W014	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	PA W015	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	PA W015	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	PA W015	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	PAW015A	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF M001	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	RF M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF M001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T1	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SOLIDIFIED INORGANICS	RF M001	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	19
		(17 x 23)			
SOLIDIFIED INORGANICS	RF M001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T1 x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	RF W010	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	RF W010	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF W010	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RF W010	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T3	H E	00
		(10 x 32)			
SOLIDIFIED INORGANICS	RF W010	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	19
		(17 x 23)			
SOLIDIFIED INORGANICS	RF W010	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	RF W038	ACIDS, ORGANIC x CAUSTICS	T x D	H	00
		(3 x 10)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

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SOLIDIFIED INORGANICS	RF W038	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
SOLIDIFIED INORGANICS	RF W038	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	RF W038	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF W038	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T	H E	00
		(10 x 32)			
SOLIDIFIED INORGANICS	RF W040	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	RF W040	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	RF W040	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF W040	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RF W040	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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SOLIDIFIED INORGANICS	RF W040	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	26
		(17 x 23)			
SOLIDIFIED INORGANICS	RF W040	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	RF W059	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x D	GF H	00
		(10 x 21)			
SOLIDIFIED INORGANICS	RF W059	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF W059	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RF W059	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	D x D	H G F	28b
		(21 x 101)			
SOLIDIFIED INORGANICS	RF W059	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	D x D	GF H	28d
		(21 x 106)			
SOLIDIFIED INORGANICS	RF W059	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	RF W063	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	RF W063	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RF W063	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	RF W065	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x D	GF H	00
		(10 x 21)			
SOLIDIFIED INORGANICS	RF W065	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF W065	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	D x D	H G F	28b
		(21 x 101)			
SOLIDIFIED INORGANICS	RF W065	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	D x D	GF H	28d
		(21 x 106)			
SOLIDIFIED INORGANICS	RF W068	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	RF W068	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	RF W068	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	RF W068	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RF W068	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
SOLIDIFIED INORGANICS	RF W068	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	19
		(17 x 23)			
SOLIDIFIED INORGANICS	RF W068	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	RF W076	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	RF W076	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	RF W076	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RF W076	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RF W076	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	RF W076	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	19
		(17 x 23)			
SOLIDIFIED INORGANICS	RF W076	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33 33a
		(24 x 106)			
SOLIDIFIED INORGANICS	RL M005	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RL M005	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	RL M005	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a 34
		(24 x 106)			
SOLIDIFIED INORGANICS	RL M032	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
SOLIDIFIED INORGANICS	RL M032	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	RL M032	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	RL M032	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED INORGANICS	RL M032	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED INORGANICS	SR W053	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
SOLIDIFIED INORGANICS	SR W053	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
SOLIDIFIED INORGANICS	SR W053	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED INORGANICS	SR W053	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED INORGANICS	SR W053	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
SOLIDIFIED INORGANICS	SR W053	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	19
		(17 x 23)			
SOLIDIFIED INORGANICS	SR W053	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED ORGANICS	IN W167	CAUSTICS x HALOGENATED ORGANICS	D x D	H	00
		(10 x 17)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED ORGANICS	IN W167	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED ORGANICS	IN W167	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED ORGANICS	IN W167	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	H F	23
		(17 x 23)			
SOLIDIFIED ORGANICS	IN W167	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED ORGANICS	IN W174	ACIDS, MINERAL, OXIDIZING x CAUSTICS	D x D	H	00
		(2 x 10)			
SOLIDIFIED ORGANICS	IN W174	ACIDS, MINERAL, OXIDIZING x ETHERS	D x D	H F	3f
		(2 x 14)			
SOLIDIFIED ORGANICS	IN W174	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	D x D	GT	3g
		(2 x 15)			
SOLIDIFIED ORGANICS	IN W174	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H F	4
		(2 x 23)			
SOLIDIFIED ORGANICS	IN W174	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	D x D	H F GT	9
		(2 x 101)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED ORGANICS	IN W174	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	D x D	H	10a
		(2 x 106)			
SOLIDIFIED ORGANICS	IN W174	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED ORGANICS	IN W309	CAUSTICS x HALOGENATED ORGANICS	D x D	H	00
		(10 x 17)			
SOLIDIFIED ORGANICS	IN W309	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED ORGANICS	IN W309	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
SOLIDIFIED ORGANICS	IN W309	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	H F	23
		(17 x 23)			
SOLIDIFIED ORGANICS	IN W309	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
SOLIDIFIED ORGANICS	RF W013	CAUSTICS x HALOGENATED ORGANICS	D x D	H	00
		(10 x 17)			
SOLIDIFIED ORGANICS	RF W013	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED ORGANICS	RF W013	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (17 x 23)	D x D	H F	25
SOLIDIFIED ORGANICS	RF W069	CAUSTICS x HALOGENATED ORGANICS (10 x 17)	D x T	H	00
SOLIDIFIED ORGANICS	RF W069	CAUSTICS x KETONES (10 x 19)	D x T	H	00
SOLIDIFIED ORGANICS	RF W069	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (10 x 23)	D x D	GF H	00
SOLIDIFIED ORGANICS	RF W069	CAUSTICS x NITRO COMPOUNDS (10 x 27)	D x T	H E	00
SOLIDIFIED ORGANICS	RF W069	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (17 x 23)	T x D	H F	23 26
SOLIDIFIED ORGANICS	RL M017	CAUSTICS x ESTERS (10 x 13)	D x T	H	00
SOLIDIFIED ORGANICS	RL M017	CAUSTICS x KETONES (10 x 19)	D x T	H	00
SOLIDIFIED ORGANICS	RL M017	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (10 x 23)	D x D	GF H	00

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
SOLIDIFIED ORGANICS	RL M018	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED ORGANICS	RL M024	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
SOLIDIFIED ORGANICS	SR W006	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	AW W018	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x D	GF H	00
		(10 x 21)			
UNCATEGORIZED METAL	AW W018	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	AW W018	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	D x D	H G F	28b
		(21 x 101)			
UNCATEGORIZED METAL	AW W018	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	D x D	GF H	28d
		(21 x 106)			
UNCATEGORIZED METAL	AW W019	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x D	GF H	00
		(10 x 21)			
UNCATEGORIZED METAL	AW W019	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	AW W019	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	D x D	H G F	28b
		(21 x 101)			
UNCATEGORIZED METAL	AW W019	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	D x D	GF H	28d
		(21 x 106)			
UNCATEGORIZED METAL	AW W021	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	AW W021	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	AW W021	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	IN M003	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	IN W280	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	IN W280	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	IN W280	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	IN W287	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	IN W287	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x M	S	00
		(10 x 24)			
UNCATEGORIZED METAL	IN W287	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	M x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	IN W294	AMINES, ALIPHATIC & AROMATIC x HALOGENATED ORGANICS	D x D	H G	12b
		(7 x 17)			
UNCATEGORIZED METAL	IN W294	AMINES, ALIPHATIC & AROMATIC x METALS & METAL COMPOUNDS, TOXIC	D x D	S	12c
		(7 x 24)			
UNCATEGORIZED METAL	IN W294	CAUSTICS x HALOGENATED ORGANICS	D x D	H	00
		(10 x 17)			
UNCATEGORIZED METAL	IN W294	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	IN W294	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
UNCATEGORIZED METAL	IN W294	CAUSTICS x NITRO COMPOUNDS	D x D	H E	00
		(10 x 27)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	IN W294	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	H F	24
		(17 x 23)			
UNCATEGORIZED METAL	IN W294	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	IN W296	AMINES, ALIPHATIC & AROMATIC x METALS & METAL COMPOUNDS, TOXIC	T x D	S	12c
		(7 x 24)			
UNCATEGORIZED METAL	IN W296	CAUSTICS x ESTERS	D x T	H	00
		(10 x 13)			
UNCATEGORIZED METAL	IN W296	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
UNCATEGORIZED METAL	IN W296	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
UNCATEGORIZED METAL	IN W296	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	IN W296	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
UNCATEGORIZED METAL	IN W296	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	IN W296	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
UNCATEGORIZED METAL	IN W296	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	IN W298	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
UNCATEGORIZED METAL	IN W298	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	IN W298	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
UNCATEGORIZED METAL	IN W298	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	24
		(17 x 23)			
UNCATEGORIZED METAL	IN W298	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	IN W300	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
UNCATEGORIZED METAL	IN W300	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	IN W300	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC (10 x 24)	D x D	S	00
UNCATEGORIZED METAL	IN W300	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (17 x 23)	T1 x D	H F	24
UNCATEGORIZED METAL	IN W300	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER (24 x 106)	D x D	S	33a
UNCATEGORIZED METAL	IN W322	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (10 x 23)	D x D	GF H	00
UNCATEGORIZED METAL	INW260A	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (10 x 23)	D x D	GF H	00
UNCATEGORIZED METAL	LA W001	ALDEHYDES x CAUSTICS (5 x 10)	T2 x D	H	00
UNCATEGORIZED METAL	LA W001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC (10 x 23)	D x D	GF H	00
UNCATEGORIZED METAL	LA W001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC (10 x 24)	D x D	S	00
UNCATEGORIZED METAL	LA W001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER (24 x 106)	D x D	S	33a

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T2 x D	H	0aaa
		(1 x 14)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T2 x D	GT	0aaaa
		(1 x 15)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	GF H F	1
		(1 x 23)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T2 x D	H G	3
		(1 x 101)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T2 x D	H	3b
		(1 x 106)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, OXIDIZING x ETHERS	T2 x D	H F	3f
		(2 x 14)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T2 x D	GT	3g
		(2 x 15)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	GF H F	5
		(2 x 23)			
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T2 x D	H F GT	8
		(2 x 101)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LA W005	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T2 x D	H	10a
		(2 x 106)			
UNCATEGORIZED METAL	LA W005	ACIDS, ORGANIC x CAUSTICS	T2 x D	H	00
		(3 x 10)			
UNCATEGORIZED METAL	LA W005	ACIDS, ORGANIC x FLUORIDES, INORANIC	T2 x D	GT	11d
		(3 x 15)			
UNCATEGORIZED METAL	LA W005	CAUSTICS x HALOGENATED ORGANICS	D x T2	H	00
		(10 x 17)			
UNCATEGORIZED METAL	LA W005	CAUSTICS x KETONES	D x T2	H	00
		(10 x 19)			
UNCATEGORIZED METAL	LA W005	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15
		(10 x 23)			
UNCATEGORIZED METAL	LA W005	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	LA W005	CAUSTICS x ORHANOPHOSPHATES, PHOSPHOTHIOATES & PHOSPHODITHIOATES	D x T2	H E	00
		(10 x 32)			
UNCATEGORIZED METAL	LA W005	CAUSTICS x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	00
		(10 x 107)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LA W005	ETHERS x OXIDIZING AGENTS, STRONG	D x T2	H F	17a
		(14 x 104)			
UNCATEGORIZED METAL	LA W005	ETHERS x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	17b
		(14 x 107)			
UNCATEGORIZED METAL	LA W005	FLUORIDES, INORANIC x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	18
		(15 x 107)			
UNCATEGORIZED METAL	LA W005	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T2 x D	H F	24
		(17 x 23)			
UNCATEGORIZED METAL	LA W005	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T2	H F	30
		(23 x 104)			
UNCATEGORIZED METAL	LA W005	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	32
		(23 x 107)			
UNCATEGORIZED METAL	LA W005	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	LA W005	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T2	H F G	38
		(101 x 104)			
UNCATEGORIZED METAL	LA W005	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x WATER REACTIVE SUBSTANCES	D x T2	EXTREMELY	39
		(101 x 107)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LA W009	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
UNCATEGORIZED METAL	LA W009	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
UNCATEGORIZED METAL	LA W009	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	LA W009	CAUSTICS x NITRO COMPOUNDS	D x T	H E	00
		(10 x 27)			
UNCATEGORIZED METAL	LA W009	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	20
		(17 x 23)			
UNCATEGORIZED METAL	LA WR01	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	LA WR05	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, NON-OXIDIZING x CAUSTICS	T x D	H	00
		(1 x 10)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, NON-OXIDIZING x ETHERS	T x D	H	0aaaa
		(1 x 14)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, NON-OXIDIZING x FLUORIDES, INORANIC	T x D	GT	0aaa
		(1 x 15)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, NON-OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	1
		(1 x 23)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, NON-OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G	3
		(1 x 101)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, NON-OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	3b
		(1 x 106)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, OXIDIZING x CAUSTICS	T x D	H	00
		(2 x 10)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, OXIDIZING x ETHERS	T x D	H F	3f
		(2 x 14)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, OXIDIZING x FLUORIDES, INORANIC	T x D	GT	3g
		(2 x 15)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, OXIDIZING x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	GF H F	5
		(2 x 23)			
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, OXIDIZING x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H F GT	8
		(2 x 101)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LL W018	ACIDS, MINERAL, OXIDIZING x WATER & MIXTURES CONTAINING WATER	T x D	H	10a
		(2 x 106)			
UNCATEGORIZED METAL	LL W018	ACIDS, ORGANIC x CAUSTICS	T x D	H	00
		(3 x 10)			
UNCATEGORIZED METAL	LL W018	ACIDS, ORGANIC x FLUORIDES, INORANIC	T x D	GT	11d
		(3 x 15)			
UNCATEGORIZED METAL	LL W018	CAUSTICS x HALOGENATED ORGANICS	D x T	H	00
		(10 x 17)			
UNCATEGORIZED METAL	LL W018	CAUSTICS x KETONES	D x T	H	00
		(10 x 19)			
UNCATEGORIZED METAL	LL W018	CAUSTICS x METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS	D x T	GF H	00
		(10 x 21)			
UNCATEGORIZED METAL	LL W018	CAUSTICS x METALS OTHER ELEMENTAL & ALLOYS IN THE FORM OF POWDERS, VAPORS OR SPONGES	D x T	GF H	00
		(10 x 22)			
UNCATEGORIZED METAL	LL W018	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	15 00
		(10 x 23)			
UNCATEGORIZED METAL	LL W018	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LL W018	CAUSTICS x EXPLOSIVES	D x T	H E	00
		(10 x 102)			
UNCATEGORIZED METAL	LL W018	ETHERS x OXIDIZING AGENTS, STRONG	D x T	H F	17a
		(14 x 104)			
UNCATEGORIZED METAL	LL W018	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T x D	H F	22
		(17 x 23)			
UNCATEGORIZED METAL	LL W018	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x COMBUSTIBLE & FLAMMABLE MATERIALS, MISC	T x D	H G F	28b
		(21 x 101)			
UNCATEGORIZED METAL	LL W018	METALS, ALKALI & ALKALINE EARTH, ELEMENTAL & ALLOYS x WATER & MIXTURES CONTAINING WATER	T x D	GF H	28d
		(21 x 106)			
UNCATEGORIZED METAL	LL W018	METALS OTHER ELEMENTAL & ALLOYS IN THE FORM OF POWDERS, VAPORS OR SPONGES x WATER & MIXTURES CONTAINING WATER	T x D	GF H	28e
		(22 x 106)			
UNCATEGORIZED METAL	LL W018	METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC x OXIDIZING AGENTS, STRONG	D x T	H F	30
		(23 x 104)			
UNCATEGORIZED METAL	LL W018	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	LL W018	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x EXPLOSIVES	D x T	H E	36d
		(101 x 102)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

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WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	LL W018	COMBUSTIBLE & FLAMMABLE MATERIALS, MISC x OXIDIZING AGENTS, STRONG	D x T	H F G	38
		(101 x 104)			
UNCATEGORIZED METAL	RF W011	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
UNCATEGORIZED METAL	RF W011	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	RF W011	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			
UNCATEGORIZED METAL	RF W011	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	21
		(17 x 23)			
UNCATEGORIZED METAL	RF W011	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	RF W037	CAUSTICS x HALOGENATED ORGANICS	D x T1	H	00
		(10 x 17)			
UNCATEGORIZED METAL	RF W037	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	RF W037	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x D	S	00
		(10 x 24)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	RF W037	HALOGENATED ORGANICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	T1 x D	H F	24
		(17 x 23)			
UNCATEGORIZED METAL	RF W037	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	D x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	RL M001	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	RL M001	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	RL M001	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	RL M002	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	RL M002	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	RL M002	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	RL M003	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

TABLE C1-1
SUMMARY OF POTENTIAL INCOMPATIBILITIES FOR WASTE FORMS AND CONTAINER

WASTE MATRIX CODE GROUP	WASTE STREAM UNIQUE ID	POTENTIAL CHEMICAL COMPATIBILITY REACTION	CONCENTRATION OF REACTANTS(a)	REACTION CODE(b)	EXPLANATION CODE NUMBER(c)
UNCATEGORIZED METAL	RL M008	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	RL M008	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	RL M008	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			
UNCATEGORIZED METAL	RL M021	CAUSTICS x METALS, OTHER ELEMENTAL, & ALLOY, AS SHEETS, RODS, MOLDINGS, DROPS, ETC	D x D	GF H	00
		(10 x 23)			
UNCATEGORIZED METAL	RL M021	CAUSTICS x METALS & METAL COMPOUNDS, TOXIC	D x T	S	00
		(10 x 24)			
UNCATEGORIZED METAL	RL M021	METALS & METAL COMPOUNDS, TOXIC x WATER & MIXTURES CONTAINING WATER	T x D	S	33a
		(24 x 106)			

x=Combined with

(a) Concentration of reactants: T=Trace (<1% by wt.); T1=Trace (<0.1% by wt.); T2=Trace (low ppm range); T3=Trace (<1 ppm range); M=Minor (1-10% by wt.); D=Dominant (>10% by wt.)

(b)Reaction code: H=heat generation; S= solubilization of toxic substances; F=fire; GF= flammable gas generation; G= nonflammable gas generation GT=toxic gas generation; P=violent polymerization; E=explosive

(c) See text

APPENDIX C2

DATA ACCUMULATED FROM HEADSPACE-GAS ANALYSES

APPENDIX C2
DATA ACCUMULATED FROM HEADSPACE GAS ANALYSES

This appendix presents all available headspace waste characterization data. The data include drum headspace analytical results for approximately 900 drums of transuranic mixed waste from Idaho National Engineering Laboratory (INEL) and Rocky Flats Environmental Technology Site (RFETS). The waste characterization data cut-off date was September 29, 1995. Item Description Code, and Transuranic Package Transporter Content (TRUCON) Code column entries correspond to Waste Matrix Code groups as described in Chapter C, Table C-1.

To reflect expected proportions of different waste types, the data were weighted according to Waste Matrix Code Group volumes reported in the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (BIR). Table C2-1 presents the weighted average headspace concentrations. The Waste Matrix Code Group (WMCG) volumes and the weighting factors used to calculate the average concentrations are presented in Table C2-2.

Before the data could be manipulated, the RFETS database structure was converted into a modified INEL database structure, and the data from the two sites were combined into a single database. The weighted averages were calculated using computer codes developed for this effort that were validated and verified through independent review of the codes and associated documentation.

The database was modified as follows before the weighted averages were calculated:

- TRUCON codes assigned to each waste drum were converted to a Waste Stream ID using the cross-correlation table in the BIR (DOE 1995a, app. F).

- The Waste Profile Forms from the BIR (DOE 1995a, vol. II) were used to determine the WMCG for each waste stream.

- If the data qualifier was "U," then one-half of the associated value, the sample quantitation limit (SQL) was used for the concentration in calculating the weighted average.

- If the qualifier was "E" or "JE" and a dilution analysis was available for that sample number, the dilution analysis was used for all analytes. Analytes in the diluted sample, qualified as "U," were treated as above.

- All "J"-qualified (estimated) data were used.

- All "B"-qualified (constituent found in blanks) data were used. This was a conservative treatment of the data in the absence of information on the level of contamination observed in the blank.

All WMCGs, with the exception of soils and unknown waste, were represented by the data from the INEL and RFETS. Since the soils and unknown waste groups comprise a small percentage of the entire inventory (0.74 and 0.97 percent, respectively), their contribution to the calculated average concentrations was assumed to be insignificant. The weighted averages were calculated by:

$$\bar{x} = \sum_{i=1}^{t} w_i \bar{x}_i \qquad \text{(C2-1)}$$

where,

$\bar{x}$ = weighted average
$\bar{x}_i$ = average for WMCG *i*
w_i = weighting factor for WMCG *i*
t = number of WMCGs,

and $\bar{x}_i$ was calculated by:

$$\bar{x}_i = \frac{1}{n_i} \sum_{j=1}^{n_i} x_{ij} \qquad \text{(C2-2)}$$

where,

n_i = number of samples in WMCG *i*
x_{ij} = analysis *j* for WMCG *i.*

For several volatile organic compounds (VOC) (carbon disulfide, isobutanol, 1,1,2-trichloroethane, trichlorofluoromethane, and vinyl chloride), headspace sampling data were not available. The headspace concentrations of these VOCs for screening purposes and for calculation of migration concentrations were assumed to be equal to one-half of the SQL. The SQLs for these VOCs were calculated from information on the required method detection limits (8 nanograms per 10-milliliter sample) contained in the *Transuranic Waste Characterization Quality Assurance Program Plan Transuranic Waste Characterization Program Sampling and Analysis Methods Manual:*

The SQL is the Method Detection Limit (MDL) expressed in part(s) per million per volume (ppmv).

$$SQL = \frac{R \times T}{P \times MW} \times MDL \times (10^6\ ppmv/mole\text{-}fraction) \qquad \text{(C2-3)}$$

where,

SQL = sample quantitation limit for the VOC, ppmv
R = Ideal Gas Constant, 0.082 L•atm/mol•K
T = temperature, 298 K
P = pressure, 1 atm
MW = molecular weight of VOC, g/mole
MDL = method detection limit of VOC, g/L

The minimum, maximum, and median concentrations for each compound are shown in Table C2-3, separated by the waste matrix code. These values show that the distribution of data is not normal and, therefore, using the weighted average headspace concentrations in calculations is a conservative approach.

Table C2-4 contains the headspace gas data by drum number.

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REFERENCE

DOE (U.S. Department of Energy). 1995a. *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. DOE/CAO-94-1005, Rev. 1. U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM.

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DOE (U.S. Department of Energy). 1995b. *Transuranic Waste Characterization Quality Assurance Program Plan*. Rev. 0. U.S. Department of Energy, Carlsbad Area Office, Waste Isolation Pilot Plant, Carlsbad, NM.

DOE (U.S. Department of Energy). 1995c. *Transuranic Waste Characterization Sampling and Analysis Methods Manual*. Rev. 0. U.S. Department of Energy, Carlsbad Area Office, Waste Isolation Pilot Plant, Carlsbad, NM.

TABLE C2-1
WEIGHTED AVERAGE CONCENTRATIONS OF HEADSPACE GASES

Constituent	Weighted Average (ppmv)
1,1,1-Trichloroethane	3.17E+02
1,1,2,2-Tetrachloroethane	9.35E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	3.30E+01
1,1-Dichloroethane	1.02E+01
1,1-Dichloroethylene	1.15E+01
1,2,4-Trimethylbenzene	1.22E+01
1,2-Dichloroethane	9.07E+00
1,3,5-Trimethylbenzene	8.62E+00
Butanol	7.81E+01
Methyl ethyl ketone	6.37E+01
Methyl isobutyl ketone	7.90E+01
Acetone	7.98E+01
Benzene	9.25E+00
Bromoform	9.38E+00
Carbon tetrachloride	3.76E+02
Chlorobenzene	1.25E+01
Chloroform	2.53E+01
(cis)-1,2-Dichloroethylene	8.97E+00
Cyclohexane	2.75E+01
Ethyl benzene	1.16E+01
Ethyl ether	1.33E+01
Methanol	2.13E+02
Methylene chloride	3.68E+02
o-Xylene	1.60E+01
p/m-Xylene	1.93E+01
Tetrachloroethylene	9.40E+00
Toluene	1.94E+01
Trichloroethylene	2.51E+01

Table C2-2
TRU Waste Disposal Inventory and Weighting Factors for Weighted Average Calculation

Waste Matrix Code Groups	Stored Volumes (cubic meters)	Projected Volumes (cubic meters)	Scaled Volumes (cubic meters)	Weighting Factor
Contact-Handled Waste				
Combustible	7.10E+03	2.70E+04	6.20E+04	3.53E-01
Filter	4.30E+02	1.10E+03	2.60E+03	1.48E-02
Graphite	6.70E+02	4.30E+01	7.60E+02	4.30E-03
Heterogeneous	3.00E+04	4.60E+03	3.90E+04	2.22E-01
Inorganic non-metal	1.20E+03	3.20E+02	1.80E+03	1.02E-02
Lead/cadmium metal	5.60E+01	1.30E+02	3.10E+02	1.80E-03
Salt waste	3.30E+01	6.00E+01	1.50E+02	8.52E-04
Soils	3.70E+02	4.50E+02	1.30E+03	7.39E-03
Solidified inorganics	1.70E+04	8.00E+03	3.40E+04	1.94E-01
Solidified organics	1.50E+03	3.00E+02	2.10E+03	1.20E-02
Uncategorized metal	1.20E+04	8.60E+03	3.00E+04	1.71E-01
Unknown	1.70E+03	0.00E+00	1.70E+03	9.66E-03
TOTAL	7.21E+04	5.06E+04	1.76E+05	1.00
Remote-Handled Waste				
Combustible	1.50E+01	3.20E+00	2.00E+01	2.80E-03
Filter	8.90E-01	2.10E+00	4.30E+01	6.02E-03
Heterogeneous	4.40E+02	3.30E+03	5.90E+03	8.26E-01
Inorganic non-metal				
Lead/cadmium metal	0.00E+00	6.00E+00	9.80E+00	1.37E-03
Salt waste	0.00E+00	2.80E+00	4.60E+00	6.44E-04
Solidified inorganic	6.10E+02	1.70E+02	9.00E+02	1.26E-01
Uncategorized metal	8.80E+01	8.60E+01	2.30E+02	3.22E-02
Unknown	1.10E+01	2.40E+01	3.50E+01	4.90E-03
TOTAL	1.16E+03	3.59E+03	7.14E+03	1.00

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups

Waste Matrix Code Group	Value	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoroethane	1,1-Dichloroethene	Acetone	Methylene Chloride	1,1-Dichloroethane	(cis)-1,2-Dichloroethene
Combustible	Minimum	5.00	0.02	0.03	0.02	3.60	0.15	0.02	0.01
	Maximum	360.00	110.00	180.00	120.00	59.00	270.00	130.00	93.00
	Median	17.00	0.44	0.50	0.52	17.00	2.70	0.37	0.30
Filter	Minimum	1.30	0.02	0.03	0.02	0.56	0.02	0.04	0.02
	Maximum	245.44	1.60	3.08	5.20	844.03	2.22	2.00	0.76
	Median	17.00	0.20	0.22	0.26	17.00	0.40	0.21	0.16
Graphite	Minimum	5.00	0.01	0.03	0.02	5.00	0.02	0.01	0.01
	Maximum	610.00	2.60	1.60	2.40	51.00	23.00	35.00	1.20
	Median	17.00	0.02	0.04	0.02	17.00	0.07	0.03	0.02
Heterogeneous	Minimum	1.30	0.03	0.06	0.10	0.50	0.10	0.02	0.02
	Maximum	4750.00	384.00	798.33	880.24	3000.00	29668.00	250.00	250.00
	Median	16.26	0.40	0.40	0.40	9.60	0.54	0.40	0.30
Inorganic non-metal	Minimum	1.96	0.01	0.04	0.02	2.40	0.03	0.02	0.01
	Maximum	147.84	3.80	2.40	44.00	62.00	56.00	52.00	2.10
	Median	17.00	0.18	0.14	0.17	17.00	0.56	0.26	0.09
Lead/cadmium metal waste	Minimum	1.30	0.20	0.10	0.10	3.15	0.10	0.10	0.06
	Maximum	1710.00	90.00	90.00	113.67	1080.00	90.00	90.00	90.00
	Median	8.47	0.47	0.28	0.24	23.83	5.80	0.75	0.24

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups (Continued)

Waste Matrix Code Group	Value	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoroethane	1,1-Dichloroethene	Acetone	Methylene Chloride	1,1-Dichloroethane	(cis)-1,2-Dichloroethene
Salt waste	Minimum	5.00	0.02	0.04	0.02	5.00	0.05	0.01	0.01
	Maximum	17.00	1.00	6.70	1.00	37.00	3.30	2.20	0.47
	Median	5.00	0.06	0.06	0.07	5.00	0.25	0.05	0.03
Soils	Minimum	-	-	-	-	-	-	-	-
	Maximum	-	-	-	-	-	-	-	-
	Median	-	-	-	-	-	-	-	-
Solidified Inorganics	Minimum	1.30	0.01	0.01	0.02	0.00	0.02	0.01	0.01
	Maximum	4900.00	500.00	12000.00	460.00	130.00	440.00	380.00	230.00
	Median	6.06	0.20	0.46	0.26	5.00	0.36	0.21	0.13
Solidified Organics	Minimum	1.90	0.06	0.05	0.05	1.20	0.08	0.02	0.03
	Maximum	82991.00	4367.90	20000.00	4367.9	52415.00	8080.9	4367.90	4367.90
	Median	17.00	2.08	1.85	5.00	17.00	3.38	1.00	1.00
Uncategorized metal	Minimum	2.70	0.01	0.02	0.02	0.50	0.02	0.01	0.01
	Maximum	30221.00	2400.00	1200.00	1200.00	6000.00	179752.0	1200.00	1200.00
	Median	17.00	0.39	0.30	0.32	17.00	0.78	0.24	0.24
Unknown	Minimum	-	-	-	-	-	-	-	-
	Maximum	-	-	-	-	-	-	-	-
	Median	-	-	-	-	-	-	-	-

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups
(Continued)

Waste Matrix Code Group	Value	2-Butanone	Chloroform	1,1,1-Trichlroroethane	Cyclohexane	Carbon Tetrachloride	Benzene	1,2-Dichloroethane	1-Butanol
Combustible	Minimum	1.00	0.06	0.05	0.02	0.02	0.04	0.02	1.20
	Maximum	18.00	1100.00	920.00	740.00	25000.00	78.00	110.00	18.00
	Median	17.00	2.80	48.00	0.45	0.83	0.42	0.42	17.00
Filter	Minimum	0.50	0.01	0.03	0.02	0.02	0.01	0.02	0.50
	Maximum	17.00	0.82	120.00	2.69	36.00	6.90	1.50	17.00
	Median	5.58	0.26	0.50	0.27	0.22	0.26	0.21	6.00
Graphite	Minimum	5.00	0.01	0.02	0.01	0.02	0.01	0.01	5.00
	Maximum	17.00	1.60	250.00	0.19	1.20	1.50	1.20	17.00
	Median	17.00	0.02	0.10	0.02	0.06	0.02	0.02	17.00
Heterogeneous	Minimum	0.50	0.04	0.10	0.03	0.09	0.06	0.03	0.50
	Maximum	2250.00	2074.30	14569.00	1922.1	6912.50	250.00	250.00	2304.0
	Median	4.50	0.40	0.67	1.18	0.55	0.50	0.37	3.85
Inorganic non-metal	Minimum	0.60	0.01	0.09	0.02	0.07	0.01	0.01	0.87
	Maximum	17.00	22.00	320.00	110.00	83.00	2.20	1.70	17.00
	Median	17.00	0.30	9.80	0.14	0.33	0.19	0.10	17.00
Lead/cadmium metal waste	Minimum	0.50	0.10	0.10	0.10	0.10	0.10	0.10	1.10
	Maximum	810.00	90.00	5612.30	90.00	2006.3	90.00	90.00	450.00
	Median	4.67	1.70	0.32	0.29	2.62	2.35	0.86	4.30

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups (Continued)

Waste Matrix Code Group	Value	2-Butanone	Chloroform	1,1,1-Trichlroroethane	Cyclohexane	Carbon Tetrachloride	Benzene	1,2-Dichloroethane	1-Butanol
Salt Waste	Minimum	5.00	0.01	0.10	0.01	0.07	0.01	0.01	5.00
	Maximum	17.00	2.30	23.00	0.72	50.00	0.58	0.46	17.00
	Median	5.00	0.06	0.39	0.10	0.16	0.09	0.03	5.00
Soils	Minimum	-	-	-	-	-	-	-	-
	Maximum	-	-	-	-	-	-	-	-
	Median	-	-	-	-	-	-	-	-
Solidified inorganic	Minimum	0.50	0.01	0.04	0.01	0.01	0.01	0.01	0.50
	Maximum	130.00	250.00	21000.00	1700.00	43000.00	290.00	230.00	132.00
	Median	5.00	0.13	4.70	0.29	0.28	0.24	0.13	5.00
Solidified organic	Minimum	0.50	0.04	0.12	0.04	0.07	0.10	0.03	0.50
	Maximum	39311.00	6023.40	85795.00	4367.9	88979.00	4367.90	4367.9	32467.00
	Median	17.00	1.35	81.50	1.75	1.60	3.00	0.99	17.00
Uncategorized metal	Minimum	0.50	0.01	0.05	0.01	0.02	0.01	0.01	0.50
	Maximum	6000.00	1200.0	5400.00	1200.00	1200.00	1200.00	1200.00	14400.00
	Median	17.00	0.32	12.50	0.31	0.39	0.37	0.24	17.00
Unknown	Minimum	-	-	-	-	-	-	-	-
	Maximum	-	-	-	-	-	-	-	-
	Median	-	-	-	-	-	-	-	-

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups (Continued)

Waste Matrix Code Group	Value	Trichlororo ethylene	Methyl isobutyl ketone	Toluene	Tetrachloro ethene	Chlorobenzene	Ethyl benzene	m,p-Xylene	o-Xylene
Combustible	Minimum	0.02	1.10	0.18	0.01	0.02	0.02	0.05	0.02
	Maximum	340.00	18.00	130.00	110.00	120.00	130.00	150.00	130.0
	Median	0.61	17.00	4.00	0.33	0.34	0.38	0.55	0.46
Filter	Minimum	0.02	0.10	0.03	0.02	0.02	0.02	0.02	0.02
	Maximum	260.00	17.00	53.00	2.80	1.20	1.00	1.40	1.00
	Median	0.40	4.59	2.77	0.30	0.20	0.20	0.24	0.21
Graphite	Minimum	0.01	5.00	0.02	0.01	0.01	0.01	0.01	0.01
	Maximum	3.00	51.00	9.40	1.10	1.40	2.30	7.60	2.50
	Median	0.02	17.00	0.07	0.02	0.02	0.02	0.02	0.02
Heterogeneous	Minimum	0.03	0.60	0.13	0.03	0.03	0.03	0.05	0.03
	Maximum	1600.00	2750.00	574.53	250.00	384.00	1996.80	8500.1	2764.00
	Median	0.40	4.40	13.98	0.30	0.40	0.40	0.46	0.60
Inorganic non-metal	Minimum	0.01	1.10	0.06	0.01	0.01	0.01	0.01	0.01
	Maximum	390.00	18.00	45.00	14.00	2.00	2.10	5.10	2.30
	Median	0.24	17.00	2.10	0.09	0.10	0.12	0.13	0.13
Lead/cadmium metal waste	Minimum	0.05	0.60	0.22	0.05	0.06	0.06	0.10	0.10
	Maximum	90.00	990.00	90.00	90.00	90.00	90.00	90.00	180.00
	Median	0.24	2.79	5.62	0.24	0.47	0.29	0.54	0.91

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups
(Continued)

Waste Matrix Code Group	Value	Trichlororo ethylene	Methyl isobutyl ketone	Toluene	Tetrachloro ethene	Chlorobenzene	Ethyl benzene	m,p-Xylene	o-Xylene
Salt waste	Minimum	0.01	5.00	0.43	0.01	0.01	0.01	0.01	0.01
	Maximum	12.00	17.00	12.00	0.46	0.54	0.57	0.57	0.57
	Median	0.11	5.00	5.00	0.03	0.03	0.04	0.05	0.04
Soils	Minimum	-	-	-	-	-	-	-	-
	Maximum	-	-	-	-	-	-	-	-
	Median	-	-	-	-	-	-	-	-
Solidified inorganics	Minimum	0.01	0.60	0.01	0.01	0.01	0.01	0.01	0.01
	Maximum	230.00	130.00	320.00	220.00	260.00	280.00	386.14	0.280
	Median	0.16	5.00	2.20	0.12	0.18	0.15	0.26	0.20
Solidified Organics	Minimum	0.03	0.60	0.43	0.03	0.03	0.03	0.03	0.03
	Maximum	4367.90	48047.50	6991.60	4367.90	4367.9	4367.90	8626.8	8735.9
	Median	20.50	17.00	18.00	1.40	1.20	1.25	1.30	1.45
Uncategorized metals	Minimum	0.01	0.70	0.02	0.01	0.01	0.01	0.01	0.01
	Maximum	1821.1	8400.00	1494.70	1200.00	2400.00	1200.0	1200.0	1200.00
	Median	0.40	17.00	5.10	0.24	0.28	0.29	0.32	0.30
Unknown	Minimum	-	-	-	-	-	-	-	-
	Maximum	-	-	-	-	-	-	-	-
	Median	-	-	-	-	-	-	-	-

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups
(Continued)

Waste Matrix Code Group	Value	Bromoform	1,1,2,2-Tetra chlororethane	1,3,5-Trimethyl benzene	1,2,4-Trimethyl benzene
Combustible	Minimum	0.02	0.02	0.01	0.01
	Maximum	160.00	140.00	77.00	93.00
	Median	0.40	0.38	0.24	0.26
Filter	Minimum	0.03	0.02	0.01	0.02
	Maximum	1.30	1.10	0.61	1.20
	Median	0.20	0.20	0.13	0.20
Graphite	Minimum	0.01	0.01	0.01	0.01
	Maximum	1.20	1.40	0.95	2.00
	Median	0.02	0.02	0.01	0.02
Heterogeneous	Minimum	0.03	0.03	0.02	0.02
	Maximum	250.00	250.00	250.00	384.00
	Median	0.30	0.30	0.30	0.40
Inorganic non-metal	Minimum	0.01	0.01	0.01	0.01
	Maximum	5.00	2.00	1.40	1.60
	Median	0.09	0.10	0.07	0.08
Lead/cadmium metal waste	Minimum	0.05	0.06	0.04	0.06
	Maximum	90.00	90.00	90.00	90.00
	Median	0.24	0.24	0.24	0.47
Salt waste	Minimum	0.01	0.01	0.01	0.01
	Maximum	0.48	0.54	0.38	0.38
	Median	0.03	0.03	0.03	0.04

Table C2-3
Minimum, Maximum, and Median Values of Waste Matrix Code Groups
(Continued)

Waste Matrix Code Group	Value	Bromoform	1,1,2,2-Tetra chlororethane	1,3,5-Trimethyl benzene	1,2,4-Trimethyl benzene
Soils	Minimum	-	-	-	-
	Maximum	-	-	-	-
	Median	-	-	-	-
Solidified inorganics	Minimum	0.01	0.01	0.01	0.01
	Maximum	240.00	270.00	190.00	250.00
	Median	0.13	0.13	0.10	0.18
Solidified organics	Minimum	0.03	0.03	0.02	0.02
	Maximum	4367.90	4367.96	4367.90	4367.90
	Median	1.05	1.20	0.83	0.99
Uncategorized metals	Minimum	0.01	0.01	0.01	0.01
	Maximum	1200.00	1200.00	1200.00	2400.00
	Median	0.23	0.26	0.20	0.23
Unknown	Minimum	-	-	-	-
	Maximum	-	-	-	-
	Median	-	-	-	-

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
000365	RFETS	Uncategorized Metal	217	480	17.00 U	24.00 U	15.00 U	22.00 U	32.00 J	280.00	18.00 U	11.00 U
000371	INEL	Graphite	215	300	17.00 U	0.02 U	0.60 J	0.03 U	17.00 U	0.76 J	0.03 U	0.03 U
000373	INEL	Graphite	215	300	17.00 U	0.02 U	0.04 J	0.02 U	17.00 U	0.07 J	0.02 U	0.02 U
000384	RFETS	Uncategorized Metal	217	320	5.00 U	0.02 U	0.02 J	0.02 U	5.00 U	0.05 J	0.01 U	0.01 U
000393	INEL	Uncategorized Metal	217	480	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	0.17 J	0.04 U	0.03 U
000401	RFETS	Inorganic Non-metal	222	371	5.00 U	0.03 U	0.04 J	0.03 U	8.70 J	0.51 U	0.02 U	0.01 U
000403	INEL	Inorganic Non-metal	218	440	17.00 U	0.06 U	0.13 J	0.05 U	17.00 U	0.33 J	0.04 U	0.03 U
000405	RFETS	Uncategorized Metal	217	480	8.00 J	1.80 U	1.10 U	1.60 U	55.00 J	250.00	1.30 U	0.81 U
000436	INEL	Solidified Organics	212	3	17.00 U	35.00 U	740.00	44.00 U	17.00 U	56.00 U	42.00 U	40.00 U
000442	INEL	Solidified Inorganics	213	4	3300.0	0.04 U	0.08 U	0.06 U	51.00 U	1.90	0.05 U	0.05 U
000446	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.04 J	0.02 U	5.00 U	0.08 J	0.01 U	0.01 U
000478	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.05 J	0.02 U	5.00 U	0.13	0.01 U	0.01 U
000501	INEL	Graphite	215	300	17.00 U	0.02 U	0.03 J	0.02 U	17.00 U	0.05 J	0.02 U	0.02 U
000558	INEL	Heterogeneous	221	464	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.35 J	0.14 U	0.09 U
000567	RFETS	Inorganic Non-metal	222	371	17.00 J	3.20 U	2.00 J	3.00 U	5.00 U	56.00	2.40 U	1.50 U
000568	RFETS	Solidified Organics	226	432	17.00 U	2.00 U	1.20 U	1.80 U	17.00 U	1.40 U	1.50 U	0.90 U
000593	INEL	Solidified Inorganics	211	7	17.00 U	0.01 U	0.30 J	0.02 U	17.00 U	0.13 J	0.02 U	0.02 U
000613	INEL	Graphite	215	300	17.00 U	0.06 U	0.04 J	0.05 U	17.00 U	0.04 U	0.04 U	0.03 U
000630	INEL	Solidified Inorganics	213	4	4300.0	0.05 U	0.10 U	0.07 U	51.00 U	0.23 J	0.07 U	0.06 U
000648	RFETS	Solidified Inorganics	213	4	1700.0 D	0.06 U	0.04 U	0.05 U	70.00 U	0.47 D	0.04 U	0.03 U
000675	RFETS	Inorganic Non-metal	218	440	6.20 J	0.30 U	0.19 J	0.27 U	14.00 J	0.62 J	0.22 U	0.14 U
000823	RFETS	Solidified Inorganics	213	4	3700.0 D	0.04 U	0.19 JB	0.04 U	120.00 U	1.50	0.03 U	0.02 U
000828	INEL	Graphite	215	300	17.00 U	0.02 U	0.04 J	0.02 U	17.00 U	0.05 J	0.02 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
001016	INEL	Graphite	215	300	17.00 U	0.02 U	0.03 J	0.02 U	17.00 U	0.05 J	0.02 U	0.02 U
001024	INEL	Graphite	215	300	24.00 J	0.02 U	0.03 J	0.02 U	17.00 U	0.07 J	0.02 U	0.02 U
001084	INEL	Solidified Inorganics	213	4	17.00 U	0.02 U	0.13 JB	0.02 U	17.00 U	0.19 J	0.02 U	0.02 U
001139	INEL	Solidified Inorganics	211	7	17.00 U	0.13 U	0.31 J	0.76 J	17.00 U	0.21 U	0.19 J	0.15 U
001157	INEL	Combustible	223	339	17.00 U	0.06 U	0.04 J	0.05 U	17.00 U	1.60	0.07 J	0.03 U
001161	INEL	Graphite	215	300	17.00 U	0.02 U	0.03 U	0.03 U	17.00 U	0.05 J	0.03 U	0.02 U
001258	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.16	0.02 U	5.00 U	0.09 J	0.01 U	0.01 U
001370	INEL	Combustible	223	339	17.00 U	0.11 U	0.77 J	0.12 U	17.00 U	2.00	0.13 U	0.09 U
001377	INEL	Combustible	223	339	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	4.10	0.02 U	0.04 J
001410	INEL	Solidified Inorganics	214	292	17.00 U	0.24 U	0.15 U	0.22 U	17.00 U	0.19 J	0.18 U	0.11 U
001437	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	0.03 J	0.04 J	7.20 J	0.45	0.02 J	0.01 U
001475	RFETS	Solidified Inorganics	211	1	5.00 U	0.39 U	23.00 D	0.36 U	5.00 U	0.21 U	0.29 U	0.18 U
001493	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.15	0.02 U	5.00 U	0.08 J	0.01 U	0.01 U
001619	INEL	Graphite	215	300	17.00 U	0.06 U	0.06 J	0.05 U	17.00 U	0.05 J	0.04 U	0.03 U
001625	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.08 J	0.02 U	0.02 U
001633	INEL	Solidified Organics	226	432	17.00 U	1.40 U	0.89 U	1.30 U	17.00 U	0.98 U	1.00 U	0.89 J
001655	INEL	Combustible	223	339	17.00 U	3.80 U	2.40 U	3.40 U	17.00 U	3.00 J	0.02 U	1.70 U
001662	INEL	Graphite	215	300	17.00 U	0.01 U	0.06 J	0.02 U	17.00 U	0.04 J	0.02 U	0.02 U
001663	RFETS	Solidified Organics	226	432	17.00 U	0.84 U	0.53 U	0.77 U	17.00 U	140.00	0.63 U	0.39 U
001667	INEL	Graphite	215	300	17.00 U	0.01 U	0.06 J	0.02 U	17.00 U	0.08 J	0.02 U	0.02 U
001670	RFETS	Salt Waste	224	411	5.00 U	0.07 U	0.06 J	0.07 U	5.00 U	0.85	0.06 U	0.03 U
001677	INEL	Heterogeneous	221	302	17.00 U	0.38 U	0.70 U	0.50 J	17.00 U	0.74 J	0.46 U	0.58 J
001678	RFETS	Combustible	223	339	5.00 U	0.20 U	0.28 J	0.18 U	18.00 J	7.40	1.20	0.09 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
001689	INEL	Heterogeneous	221	302	17.00 U	0.07 U	0.06 J	0.07 U	17.00 U	0.68	0.06 U	0.03 U
001692	RFETS	Solidified Organics	226	432	17.00 U	0.51 U	0.32 U	0.46 U	17.00 U	0.35 U	0.38 U	0.23 U
001695	INEL	Combustible	223	339	17.00 U	3.20 U	2.00 U	3.00 U	2.40 U	4.80 J	0.03 U	1.50 U
001697	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	17.00 U	0.07 J	0.02 U	0.02 U
001751	RFETS	Uncategorized Metal	217	320	5.00 U	0.02 U	0.03 J	0.02 U	5.00 U	0.09 J	0.01 U	0.01 U
001752	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.08 J	0.02 U	0.02 U
001754	INEL	Uncategorized Metal	217	320	11.00 U	0.37 U	0.15 J	0.20 U	17.00 U	1.70 B	5.60 U	0.04 U
001757	INEL	Inorganic Non-metal	222	371	17.00 U	0.06 U	0.07 JB	0.05 U	17.00 U	0.19 J	0.04 U	0.03 U
001773	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.10 J	35.00 U	0.02 U
001779	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.04 J	0.04 U	0.02 U
001784	INEL	Combustible	223	339	17.00 U	0.06 U	0.07 J	0.05 U	17.00 U	1.10	0.02 U	0.03 U
001813	INEL	Solidified Inorganics	213	4	17.00 U	4.60 U	8.60 JB	5.90 U	17.00 U	7.40 U	0.30 J	5.40 U
001873	INEL	Solidified Inorganics	214	292	17.00 U	0.07 U	0.05 J	0.06 U	17.00 U	0.05 U	0.05 U	0.03 U
001899	RFETS	Solidified Inorganics	211	3	92.00 J	260.00 U	3300.0 B	240.00 U	5.70 J	230.00 U	200.00 U	120.00
001900	INEL	Solidified Inorganics	214	292	17.00 U	0.07 U	0.07 J	0.08 J	17.00 U	0.05 J	0.05 U	0.03 U
001919	RFETS	Uncategorized Metal	217	320	5.00 U	0.02 U	0.03 J	0.02 U	5.00 U	0.20	0.01 U	0.01 U
001937	RFETS	Solidified Organics	212	3	74.00 J	31.00 U	31.00 JB	29.00 U	6.90 J	27.00 U	24.00 U	14.00 U
002013	RFETS	Solidified Organics	212	3	68.00 J	22.00 U	17.00 JB	20.00 U	5.00 U	20.00 U	17.00 U	10.00 U
002046	INEL	Solidified Organics	212	3	17.00 U	29.00 U	140.00	37.00 U	17.00 U	46.00 U	1.30	34.00 U
002065	INEL	Solidified Inorganics	214	292	5.00 U	0.21 U	0.13 U	0.19 U	5.00 U	0.18 U	0.16 U	0.10 U
002084	INEL	Solidified Inorganics	213	4	1900.0	0.03 U	0.11 J	0.04 U	0.00	0.47 J	7.60 U	0.03 U
002220	RFETS	Uncategorized Metal	217	481	5.00 U	0.06 U	0.04 U	0.05 U	5.00 U	0.98	1.10	0.03 U
002222	INEL	Graphite	215	300	79.00 J	0.02 U	0.06 J	0.02 U	17.00 U	0.07 J	0.07 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
002338	RFETS	Inorganic Non-metal	222	371	17.00 U	1.60 U	1.00 U	1.40 U	17.00 U	1.10 U	1.20 U	0.72 U
002354	INEL	Combustible	223	339	17.00 U	0.06 U	0.09 U	0.07 U	17.00 U	4.20	0.04 U	0.05 U
002363	INEL	Inorganic Non-metal	222	371	17.00 U	0.06 U	0.09 JB	0.05 U	17.00 U	0.32 J	0.04 U	0.03 U
002365	INEL	Uncategorized Metal	217	480	17.00 U	0.14 U	0.09 U	0.13 U	17.00 U	6.20	0.04 U	0.06 U
002542	INEL	Solidified Organics	212	3	17.00 U	6.30 U	47.00	7.90 U	17.00 U	10.00 U	77.00 U	7.30 U
002678	RFETS	Solidified Organics	226	432	17.00 U	1.80 U	1.10 U	1.60 U	17.00 U	1.30 U	1.40 U	0.82 U
002791	INEL	Inorganic Non-metal	222	371	17.00 U	0.09 U	0.11 J	0.09 U	17.00 U	0.64	36.00 U	0.04 U
002797	RFETS	Solidified Organics	226	432	17.00 U	0.90 U	0.57 U	0.82 U	17.00 U	0.63 U	0.67 U	0.41 U
002814	RFETS	Solidified Inorganics	211	7	5.00 U	0.41 U	31.00	0.52 J	5.00 U	0.36 U	0.31 U	0.19 U
003017	INEL	Solidified Inorganics	211	1	5.00 U	0.10 U	0.06 U	0.09 U	5.00 U	1.00	0.08 U	0.05 U
003088	INEL	Inorganic Non-metal	222	371	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	0.56	0.04 J	0.03 U
003091	RFETS	Inorganic Non-metal	222	371	64.00 J	0.06 U	0.07 J	0.05 U	17.00 U	0.14 J	0.04 U	0.03 U
003111	INEL	Inorganic Non-metal	222	371	17.00 U	0.06 U	0.10 J	0.05 U	15.00 U	0.46	0.25 J	0.03 U
003121	RFETS	Solidified Inorganics	211	7	5.00 U	0.28 U	17.00 D	0.25 U	5.00 U	0.24 U	0.21 U	0.13 U
003129	RFETS	Solidified Inorganics	211	7	5.00 U	0.04 U	2.40	0.06 J	5.00 U	0.10 J	0.03 U	0.02 U
003130	RFETS	Solidified Inorganics	211	7	5.00 U	0.08 U	5.00 D	0.09 JD	5.00 U	0.13 JD	0.06 U	0.04 U
003173	RFETS	Solidified Inorganics	211	7	5.00 U	0.03 U	1.00	0.03 J	5.00 U	0.12 J	0.03 U	0.02 U
003181	RFETS	Solidified Inorganics	211	7	5.00 U	0.03 U	0.23	0.03 U	5.00 U	0.05 J	0.02 U	0.01 U
003189	INEL	Solidified Organics	212	3	17.00 U	64.00 U	1800.0	81.00 U	17.00 U	100.00 U	0.02 U	74.00 U
003192	RFETS	Solidified Inorganics	211	7	5.00 U	0.46 U	20.00	0.77 J	7.10 J	7.20	0.35 U	0.21 U
003215	RFETS	Solidified Inorganics	211	7	5.00 U	0.03 U	1.60	0.08 J	5.00 U	0.12 J	0.02 U	0.01 U
003277	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.04 J	0.02 U	5.00 U	0.08 J	0.01 U	0.01 U
003394	RFETS	Solidified Inorganics	211	7	5.00 U	0.06 U	0.09 J	0.07 J	5.00 U	0.26 J	0.04 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
003406	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	1.00	0.02 J	5.00 U	0.06 J	0.01 U	0.01 U
003455	RFETS	Solidified Inorganics	211	3	190.00	500.00 U	12000 B	460.00 U	10.00 J	440.00 U	380.00 U	230.00 U
003547	RFETS	Solidified Inorganics	211	7	5.00 U	0.18 U	0.51 J	0.17 U	5.00 U	0.16 U	0.14 U	0.08 U
003577	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.04 J	0.02 U	5.00 U	0.07 J	0.02 U	0.01 U
003854	INEL	Solidified Organics	212	3	17.00 U	29.00 U	400.00	37.00 U	17.00 U	47.00 U	0.04 J	34.00 U
003890	INEL	Solidified Inorganics	111	7	5.00 U	0.06 U	0.13 J	0.05 U	5.00 U	0.11 J	0.04 U	0.03 U
003921	INEL	Solidified Inorganics	111	7	5.00 U	0.07 U	0.17 J	0.06 U	5.00 U	0.14 J	0.05 U	0.03 U
003991	INEL	Combustible	223	339	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	1.30	0.02 U	0.02 U
003997	INEL	Combustible	223	339	15.00 U	0.04 U	0.06 U	0.04 U	17.00 U	5.00	130.00 U	0.03 U
004099	INEL	Solidified Inorganics	211	1	5.00 U	0.03 U	0.04 J	0.03 U	5.00 U	0.06 J	0.02 U	0.01 U
004111	RFETS	Salt Waste	224	411	5.00 U	0.06 U	0.04 U	0.05 U	5.00 U	0.25 J	0.04 U	0.03 U
004112	INEL	Graphite	215	300	17.00 U	0.02 U	0.04 J	0.02 U	17.00 U	0.09 J	0.04 J	0.02 U
004123	INEL	Combustible	223	339	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	3.00	0.02 U	0.02 U
004125	INEL	Uncategorized Metal	217	480	17.00 U	0.06 U	0.04 U	0.05 U	17.00 U	0.37 J	0.04 U	0.03 U
004150	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	15.00 U	0.06 J	0.10 J	0.02 U
004160	INEL	Combustible	223	339	110.00	110.00 U	180.00	120.00 U	17.00 U	100.00 U	0.02 U	93.00 U
004166	INEL	Inorganic Non-metal	222	371	40.00 J	0.06 U	0.09 J	0.05 U	17.00 U	0.23 J	0.04 U	0.03 U
004186	INEL	Combustible	223	339	17.00 U	0.02 U	0.16 J	0.02 U	17.00 U	1.20	0.02 U	0.02 U
004195	RFETS	Salt Waste	224	411	5.00 U	0.02 U	0.03 J	0.02 U	5.00 U	0.11	0.01 U	0.01 U
004196	INEL	Graphite	215	300	17.00 U	0.02 U	0.04 J	0.02 U	17.00 U	0.29 J	0.02 U	0.02 U
004206	INEL	Combustible	223	339	15.00 U	0.02 U	0.03 J	0.02 U	17.00 U	2.70	0.02 U	0.01 U
004208	INEL	Graphite	215	300	17.00 U	0.02 U	0.03 U	0.02 U	51.00 U	0.05 J	0.03 U	0.02 U
004283	INEL	Solidified Inorganics	211	1	17.00 U	0.01 U	4.40	0.02 U	22.00 J	2.70	0.50 J	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
004326	INEL	Solidified Inorganics	213	4	1100.0	0.01 U	0.11 J	0.02 U	17.00 U	0.32 J	0.02 U	0.02 U
004393	INEL	Solidified Inorganics	211	1	5.00 U	0.03 U	0.06 J	0.03 U	5.00 U	0.62	0.03 U	0.02 U
004410	INEL	Solidified Inorganics	211	1	5.00 U	0.06 U	0.10 J	0.05 U	5.00 U	0.12 J	0.04 U	0.03 U
004495	INEL	Solidified Inorganics	213	4	17.00 U	0.01 U	0.08 J	0.02 U	17.00 U	0.13 J	220.00 U	0.02 U
004516	INEL	Solidified Inorganics	211	1	5.00 U	0.06 U	0.05 J	0.05 U	5.00 U	0.12 J	0.04 U	0.03 U
004884	INEL	Solidified Inorganics	213	4	4000.0	0.02 U	0.04 U	0.03 U	17.00 U	1.30	0.02 U	0.03 U
004963	INEL	Combustible	223	339	31.00 J	0.06 U	0.15 J	0.07 U	17.00 U	4.10	0.02 U	0.05 U
004968	RFETS	Uncategorized Metal	217	320	5.00 U	1.10 U	1.00 J	1.00 U	12.00 J	0.96 U	0.82 U	0.51 U
004981	RFETS	Uncategorized Metal	217	320	5.00 U	0.02 U	0.19	0.02 U	5.00 U	0.07 J	0.01 U	0.01 U
004988	RFETS	Salt Waste	224	411	5.00 U	0.06 U	0.04 U	0.05 U	5.00 U	0.36	0.04 U	0.03 U
005006	RFETS	Salt Waste	224	411	5.00 U	0.06 U	0.04 J	0.05 U	5.00 U	0.41	0.04 U	0.03 U
005012	INEL	Combustible	223	339	17.00 U	0.01 U	0.11 J	0.02 U	17.00 U	0.61 J	0.04 U	0.02 U
005015	INEL	Solidified Organics	226	432	17.00 U	2.80 U	1.80 U	2.60 U	17.00 U	38.00	2.10 U	1.30 U
005235	INEL	Solidified Organics	226	432	17.00 U	0.06 U	0.09 JB	0.05 U	17.00 U	0.08 U	0.04 U	0.03 U
005262	INEL	Solidified Organics	212	3	80.00 J	180.00 U	6400.0 B	230.00 U	17.00 U	290.00 U	0.10 J	210.00 U
005358	INEL	Solidified Inorganics	211	1	17.00 U	0.01 U	0.20 J	0.02 U	17.00 U	0.14 J	0.05 J	0.02 U
005398	INEL	Solidified Inorganics	211	1	5.00 U	0.06 U	18.00 E	0.10 J	5.00 U	0.05 U	0.04 U	0.03 U
005415	INEL	Solidified Inorganics	211	1	5.00 U	0.06 U	0.04 J	0.05 U	5.00 U	0.06 J	0.04 U	0.03 U
005530	INEL	Graphite	215	303	17.00 U	0.02 U	0.06 J	0.02 U	33.00 J	0.20 J	3.00 U	0.02 U
005535	INEL	Solidified Organics	226	432	17.00 U	0.11 U	0.07 J	0.10 U	17.00 U	0.08 JD	0.08 U	0.05 U
005735	INEL	Solidified Inorganics	211	7	5.00 U	0.06 U	2.20	0.05 U	5.00 U	0.06 J	0.04 U	0.03 U
005738	INEL	Solidified Inorganics	211	7	5.00 U	0.04 U	0.40	0.04 U	5.00 U	0.05 J	0.03 U	0.02 U
006242	INEL	Inorganic Non-metal	222	371	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	0.37	2.40 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
006252	RFETS	Lead/Cadmium Metal Waste	123	339	5.00 U	7.40 U	4.70 U	6.80 U	16.00 J	6.50 U	5.60 U	3.40 U
006325	RFETS	Solidified Inorganics	213	4	2700.0 D	0.02 U	0.04 JB	0.02 U	100.00 U	0.22	0.02 U	0.01 U
006669	INEL	Solidified Inorganics	214	292	5.00 U	0.28 U	0.18 U	0.26 U	5.00 U	0.24 U	0.21 U	0.13 U
006773	RFETS	Solidified Inorganics	213	4	2800.0 D	0.21 U	0.44 JB	13.00	120.00 U	1.80	14.00	0.10 U
006857	INEL	Combustible	223	339	17.00 U	0.02 U	0.04 J	0.02 U	18.00 U	1.10	12.00	0.02 J
006865	RFETS	Solidified Organics	226	432	5.00 U	0.15 U	0.36 J	0.14 U	5.00 U	0.13 U	0.11 U	0.07 U
006876	INEL	Filter	219	335	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	0.78 J	0.17 U	0.02 U
006879	INEL	Solidified Organics	226	432	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.13 U	0.14 U	0.09 U
006886	INEL	Solidified Organics	226	432	17.00 U	0.62 U	0.39 U	0.57 U	17.00 U	0.43 U	0.46 U	0.97 J
007034	INEL	Combustible	216	337	15.00 U	4.00 U	2.50 U	3.60 U	17.00 U	2.80 U	0.20 U	2.60
007146	INEL	Inorganic Non-metal	222	371	17.00 U	3.20 U	2.00 U	3.10	17.00 U	2.20 U	0.02 U	1.90
007170	INEL	Combustible	216	337	18.00 U	0.31 U	0.49 U	0.35 U	39.00 J	0.32 J	4.60	0.26 U
007231	INEL	Filter	219	338	17.00 U	0.14 U	0.22 U	0.16 U	17.00 U	0.22 J	0.07 J	0.12 U
007511	INEL	Inorganic Non-metal	122	374	17.00 U	0.07 U	0.10 J	0.06 U	17.00 U	0.21 J	0.05 U	0.03 U
007518	INEL	Inorganic Non-metal	122	374	17.00 U	0.11 U	0.07 J	0.10 U	27.00 J	0.93	0.08 U	0.05 U
007667	INEL	Salt Waste	124	411	5.00 U	0.02 U	0.04 J	0.02 U	5.00 U	0.05 J	0.01 U	0.01 U
007920	INEL	Filter	121	302	17.00 U	0.45 U	0.28 U	0.41 U	17.00 U	0.39 U	0.34 U	0.21 U
008203	INEL	Inorganic Non-metal	118	440	17.00 U	0.11 U	0.08 J	0.10 U	17.00 U	0.16 J	0.08 U	0.05 U
008207	INEL	Heterogeneous	116	336	17.00 U	0.14 U	0.09 U	0.13 U	36.00 J	7.40 J	1.00 U	0.08 J
008218	INEL	Heterogeneous	116	330	17.00 U	0.14 U	0.10 J	0.13 U	36.00 J	6.40	0.77 J	0.06 U
008269	INEL	Uncategorized Metal	117	320	17.00 U	0.36 U	0.23 U	0.34 U	17.00 U	0.32 U	0.27 U	0.17 U
008287	INEL	Inorganic Non-metal	122	374	17.00 U	0.06 U	0.06 J	0.05 U	17.00 U	0.13 J	0.04 U	0.03 U
008359	INEL	Heterogeneous	116	330	33.00 J	0.36 U	0.23 U	0.34 U	33.00 J	6.80	0.82 J	0.17 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
008383	INEL	Lead/Cadmium Metal Waste	123	339	13.00 J	9.90 U	6.30 J	13.00 J	5.00 U	8.60 U	7.40 U	4.60 U
008848	INEL	Inorganic Non-metal	218	440	120.00	0.16 U	0.30 U	0.28 J	17.00 U	2.60	16.00	0.19 U
008859	INEL	Inorganic Non-metal	218	440	17.00 U	0.84 U	0.53 U	0.77 U	17.00 U	0.59 U	0.55 U	0.39 U
008860	INEL	Uncategorized Metal	217	480	17.00 U	2.10 U	1.40 U	2.00 U	17.00 U	15.00	1.60 U	0.98 U
008864	INEL	Uncategorized Metal	217	480	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.21 J	0.14 U	0.09 U
008872	INEL	Solidified Inorganics	214	292	5.00 U	0.07 U	0.05 U	0.07 U	5.00 U	0.07 U	0.06 U	0.03 U
008874	RFETS	Uncategorized Metal	217	480	5.00 U	66.00 U	42.00 U	61.00 U	14.00 J	58.00 U	50.00 U	30.00 U
008878	INEL	Uncategorized Metal	217	480	17.00 U	9.00 U	5.70 U	8.30 U	17.00 U	6.30 U	6.70 U	4.10 U
008880	RFETS	Graphite	115	312	5.00 U	2.60 U	1.60 J	2.40 U	8.40 J	23.00	1.90 U	1.20 U
009006	INEL	Solidified Inorganics	211	7	17.00 U	0.02 U	18.00 E	0.05 J	18.00 U	0.02 U	0.09 U	0.02 U
009011	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	0.58	0.04 J	5.00 U	0.33	0.02 U	0.01
009061	RFETS	Inorganic Non-metal	218	440	5.00 U	0.18 U	0.13 J	0.17 U	5.00 U	1.10	0.14 U	0.08 U
009180	INEL	Combustible	223	339	17.00 U	0.71 U	10.00	1.00	17.00 U	14.00	0.70 U	0.59 U
009225	INEL	Uncategorized Metal	217	481	17.00 U	0.06 U	0.13 J	0.05 U	18.00 U	0.07 U	0.22 U	0.03 U
009252	INEL	Combustible	223	339	17.00 U	40.00 U	25.00 U	36.00 U	17.00 U	270.00	11.00	18.00 U
009296	INEL	Combustible	223	339	17.00 U	5.60 U	3.60 U	5.20 U	17.00 U	3.90 U	0.02 U	2.60 U
009299	INEL	Combustible	223	339	17.00 U	0.02 U	0.03 U	0.02 U	22.00 J	1.90	6.10	0.02 U
009399	INEL	Inorganic Non-metal	218	440	17.00 U	0.73 U	0.46 U	0.67 U	17.00 U	0.61 J	0.55 U	0.34 U
009422	RFETS	Combustible	216	337	5.00 U	10.00 U	6.60 U	9.60 U	5.00 U	150.00 D	7.80 U	4.80 U
009423	INEL	Combustible	216	337	17.00 U	1.40 U	2.70 U	7.30	17.00 U	11.00	1.10 U	1.70 U
009435	INEL	Combustible	216	337	39.00 J	0.73 U	0.46 U	0.67 U	17.00 U	0.51 U	0.32 U	0.34 U
009449	INEL	Inorganic Non-metal	218	440	17.00 U	0.08 U	0.15 J	0.07 U	17.00 U	0.31 J	0.85 J	0.04 U
009471	INEL	Combustible	216	337	18.00 U	0.07 U	0.11 U	0.08 U	18.00 U	0.23 J	0.16 U	0.06 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
009475	INEL	Inorganic Non-metal	218	442	17.00 U	0.58 U	1.10 U	0.73 U	17.00 U	4.90	0.12 J	0.67 U
009489	INEL	Combustible	216	337	18.00 U	0.18 U	0.29 U	0.21 U	3.60 J	3.30	0.52 J	0.15 U
009587	INEL	Uncategorized Metal	117	320	5.00 U	0.02 U	0.04 J	0.02 U	5.00 U	0.08 J	0.01 U	0.01 U
009591	INEL	Inorganic Non-metal	118	440	17.00 U	0.07 U	0.06 J	0.06 U	17.00 U	0.13 J	0.05 U	0.03 U
009592	INEL	Inorganic Non-metal	118	440	17.00 U	0.14 U	0.09 U	0.13 U	17.00 U	0.16 J	0.10 U	0.06 U
009596	INEL	Uncategorized Metal	117	320	17.00 U	0.26 U	0.16 U	0.23 U	17.00 U	0.22 U	0.19 U	0.12 U
009599	INEL	Inorganic Non-metal	118	440	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	0.21 J	0.04 U	0.03 U
009602	INEL	Inorganic Non-metal	218	442	17.00 U	3.80 U	2.40 U	3.50 U	17.00 U	54.00	2.80 U	1.70 U
009694	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.09 J	0.04 U	0.02 U
009735	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	17.00 U	0.05 J	0.02 U	0.02 U
009773	INEL	Combustible	223	339	17.00 U	4.40 U	8.10 U	5.50 U	17.00 U	29.00	0.14 J	5.10 U
009787	RFETS	Solidified Organics	212	3	8.90 J	350.00 U	20000	320.00 U	5.00 U	300.00 U	260.00 U	160.00 U
009873	RFETS	Solidified Inorganics	211	1	5.00 U	0.09 U	0.10 J	0.14 J	5.00 U	0.43 J	0.07 U	0.04 U
010216	INEL	Filter	219	338	17.00 U	0.89 U	1.40 U	5.20	17.00 U	0.83 U	0.82 U	0.74 U
010224	INEL	Filter	219	338	17.00 U	0.27 U	0.42 U	0.30 U	17.00 U	0.44 J	0.16 J	0.22 U
010230	INEL	Heterogeneous	216	330	17.00 U	0.14 U	0.22 U	3.60	18.00 U	0.75 J	0.55 U	2.30
010273	INEL	Combustible	216	337	18.00 U	0.13 U	0.20 U	0.18 J	18.00 U	1.30	0.44 U	0.11 U
010295	INEL	Inorganic Non-metal	218	442	17.00 U	0.11 U	0.14 J	0.10 U	17.00 U	3.00	0.15 U	0.05 U
010305	RFETS	Inorganic Non-metal	218	442	91.00 J	1.30 U	0.84 U	1.20 U	5.00 U	1.20 U	0.99 U	0.61 U
010364	RFETS	Combustible	216	337	5.00 U	1.70 U	1.10 U	1.50 U	5.00 U	2.80 J	1.30 U	0.77 U
010371	INEL	Combustible	216	337	6.60 U	0.27 U	63.00 E	1.70	17.00 U	8.50	0.37 U	0.39 U
010407	RFETS	Uncategorized Metal	217	480	5.00 U	0.23 U	1.30 J	0.21 U	13.00 J	0.56 J	0.17 U	0.11 U
010411	INEL	Combustible	216	337	160.00	3.80 U	2.40 U	3.40 U	15.00 U	2.60 U	0.42 U	1.70 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
010415	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 U	0.06 J	0.05 U	17.00 U	0.04 U	0.14 U	0.03 U
010426	INEL	Inorganic Non-metal	218	442	17.00 U	0.01 U	0.11 J	0.05 J	17.00 U	3.30	2.50	0.02 U
010463	INEL	Solidified Inorganics	213	4	860.00 U	0.56 U	0.36 U	1.50 J	34.00 U	0.39 U	1.40 J	0.26 U
010487	INEL	Salt Waste	224	414	17.00 U	1.00 U	6.70	0.94 U	37.00 J	3.30 J	2.20 J	0.47 U
010492	INEL	Uncategorized Metal	217	480	17.00 U	1.10 U	0.70 U	1.00 U	94.00 U	0.77	2.00	0.50 U
010498	INEL	Uncategorized Metal	217	480	17.00 U	0.04 U	0.11 J	0.06 J	17.00 U	2.30	1.20	0.04 U
010510	RFETS	Heterogeneous	216	336	5.00 U	3.20 U	2.00 U	3.00 U	9.60 J	2.80 U	2.40 U	1.50 U
010546	RFETS	Heterogeneous	216	330	10.00 U	88.00 U	300.00 J	81.00 U	270.00	3000.0	66.00 U	40.00 U
010578	INEL	Solidified Organics	226	432	17.00 U	1.90 U	5.00 J	1.80 U	17.00 U	1.30 U	1.40 U	0.88 U
010588	RFETS	Solidified Inorganics	211	2	5.00 U	1.60 U	1.00 U	1.50 U	5.00 U	1.40 U	1.20 U	0.76 U
010663	INEL	Combustible	216	337	18.00 U	0.46 U	0.72 U	0.52 U	18.00 U	0.43 U	0.55 U	0.38 U
010676	INEL	Heterogeneous	216	330	18.00 U	0.37 U	0.57 U	1.40	17.00 U	0.34 U	1.60	0.31 U
010800	INEL	Filter	219	338	17.00 U	0.12 U	0.19 U	0.20 J	17.00 U	0.12 U	0.07 J	0.15 J
010807	INEL	Combustible	216	337	17.00 U	2.50 U	1.60 U	2.30 U	17.00 U	1.70 U	1.30 U	1.20 U
010808	INEL	Combustible	216	337	17.00 U	0.30 U	0.56 U	0.38 U	18.00 U	0.49 U	1.80 U	0.56 J
010814	RFETS	Solidified Inorganics	211	1	5.00 U	0.67 U	0.42 U	0.61 U	5.00 U	0.58 U	0.50 U	0.31 U
010837	INEL	Solidified Organics	226	432	17.00 U	0.84 U	0.53 U	0.77 U	17.00 U	0.59 U	0.63 U	0.39 U
010848	INEL	Filter	219	338	15.00 U	0.35 U	0.54 U	0.39 U	17.00 U	0.53 J	0.59 U	0.29 U
010883	INEL	Solidified Organics	226	432	17.00 U	2.20 U	1.40 U	2.00 U	17.00 U	1.50 U	1.60 U	1.00 U
010921	INEL	Inorganic Non-metal	222	371	17.00 U	0.19 U	0.12 U	17.00	18.00 U	0.13 U	0.66 U	0.09 U
011004	INEL	Uncategorized Metal	217	480	17.00 U	0.06 U	0.06 J	0.05 U	17.00 U	0.09 J	0.04 U	0.03 U
011021	INEL	Solidified Organics	226	432	17.00 U	0.34 U	0.21 U	0.78 J	17.00 U	0.24 U	2.20	0.16 U
011042	INEL	Inorganic Non-metal	218	442	17.00 U	1.20 U	0.75 U	1.40	17.00 U	16.00	2.80 U	0.54 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
011044	INEL	Inorganic Non-metal	218	440	17.00 U	0.67 U	0.43 U	0.62 U	17.00 U	0.47 U	0.21 U	0.31 U
011067	RFETS	Solidified Inorganics	213	4	610.00	2.20 U	1.40 U	5.50 J	25.00 U	1.90 U	1.90 J	1.00 U
011102	RFETS	Solidified Inorganics	211	1	5.00 U	0.53 U	0.34 U	1.20 J	5.00 U	4.60	0.40 U	0.24 U
011109	INEL	Solidified Inorganics	211	1	17.00 U	0.17 U	1.20	3.40	17.00 U	4.10	0.02 U	0.20 U
011147	INEL	Solidified Inorganics	213	4	4900.0	0.20 U	0.37 U	1.00	17.00 U	1.60	1.70 U	0.23 U
011173	INEL	Uncategorized Metal	217	480	17.00 U	0.05 U	0.16 J	0.06 U	17.00 U	1.50	0.04 U	0.06 U
011194	INEL	Inorganic Non-metal	218	442	83.00 J	0.14 U	0.09 U	0.13 U	17.00 U	0.10 U	0.02 U	0.06 U
011393	INEL	Uncategorized Metal	217	480	59.00 J	0.28 U	0.18 U	0.26 U	17.00 U	0.52 J	0.21 U	0.13 U
011416	INEL	Combustible	216	337	17.00 U	1.20 U	0.78 U	1.10 U	17.00 U	0.86 U	0.93 U	0.57 U
011433	INEL	Heterogeneous	216	330	18.00 U	0.46 U	0.72 U	2.70	17.00 U	0.47 J	4.20 U	0.38 U
011498	RFETS	Solidified Organics	226	432	17.00 U	3.20 U	2.00 U	3.00 U	17.00 U	2.20 U	2.40 U	1.50 U
011529	INEL	Uncategorized Metal	217	480	17.00 U	0.06 U	0.04 U	0.05 U	17.00 U	0.07 J	0.04 U	0.03 U
011601	INEL	Heterogeneous	216	336	17.00 U	1.10 U	1.70 U	1.20 U	17.00 U	1.00 U	1.30 U	1.80
011607	INEL	Heterogeneous	216	330	17.00 U	0.03 U	0.30 J	0.05 J	37.00 J	0.16 J	0.67 U	0.02 U
011637	RFETS	Filter	219	338	8.40 J	1.60 U	1.00 U	1.50 U	6.20 J	1.40 U	1.20 U	0.76 U
011735	INEL	Heterogeneous	216	330	17.00 U	1.70 U	1.10 U	1.60 U	17.00 U	1.20 U	0.48 U	0.77 U
011749	INEL	Inorganic Non-metal	225	441	100.00	0.48 U	0.30 U	0.44 U	62.00 J	0.33 U	0.56 J	0.22 U
011785	RFETS	Solidified Inorganics	211	1	5.00 U	0.06 U	0.06 J	0.05 U	5.00 U	0.08 J	0.04 U	0.03 U
012021	INEL	Solidified Inorganics	211	1	17.00 U	0.73 U	0.46 U	0.81 J	17.00 U	0.51 U	0.65 J	0.34 U
012108	INEL	Solidified Inorganics	214	292	17.00 U	0.73 U	0.46 U	0.67 U	17.00 U	0.51 U	0.55 U	0.34 U
012111	INEL	Combustible	216	337	18.00 U	1.50 U	2.30 U	1.80	17.00 U	13.00	0.02 U	1.20 U
012215	INEL	Uncategorized Metal	217	480	17.00 U	0.79 U	0.50 U	0.72 U	17.00 U	0.55 U	0.58 U	0.36 U
012313	INEL	Heterogeneous	216	336	18.00 U	0.55 U	0.86 U	0.62 U	17.00 U	0.59 J	0.02 U	0.62 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
012320	INEL	Heterogeneous	216	336	17.00 U	3.70 U	2.40 U	3.40 U	17.00 U	2.60 U	0.04 U	2.50
012356	INEL	Filter	219	338	110.00	0.20 U	0.38 U	0.26 U	18.00 J	0.33 U	2.00	0.24 U
012357	RFETS	Uncategorized Metal	217	480	8.00 J	6.00 U	3.80 U	5.50 U	22.00 J	5.20 U	4.50 U	2.70 U
012433	INEL	Filter	219	338	17.00 U	0.18 U	0.28 U	0.95 J	17.00 U	0.60 J	0.59 J	0.15 U
012469	RFETS	Solidified Inorganics	211	1	5.00 U	0.68 U	0.75 JB	0.62 U	5.00 U	0.59 U	0.51 U	0.31 U
012471	RFETS	Filter	219	338	5.00 U	0.35 U	0.22 U	0.32 U	10.00 J	1.30 J	0.26 U	0.16 U
012487	INEL	Inorganic Non-metal	218	440	17.00 U	0.02 U	0.05 JB	0.02 U	17.00 U	0.03 U	0.06 U	0.02 U
012494	INEL	Heterogeneous	216	330	17.00 U	2.20 U	1.40 U	2.10 U	17.00 U	1.60 U	2.80 U	1.00 U
012541	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 U	0.06 J	0.05 U	17.00 U	0.14 J	0.05 U	0.03 U
012553	INEL	Solidified Inorganics	211	1	17.00 U	0.06 U	0.04 J	0.05 U	17.00 U	0.28 J	0.04 U	0.03 U
012571	INEL	Uncategorized Metal	217	320	17.00 U	0.01 U	0.05 J	0.02 U	38.00 J	0.28 J	11.00 U	0.02 U
012611	INEL	Solidified Inorganics	211	1	17.00 U	1.20 U	0.75 U	1.10 U	17.00 U	7.00 J	0.88 U	0.54 U
012634	INEL	Solidified Inorganics	211	1	17.00 U	3.20 U	2.00 U	3.00 U	17.00 U	12.00 J	2.40 U	1.50 U
012749	INEL	Solidified Inorganics	211	1	17.00 U	0.62 U	0.39 U	0.60 J	17.00 U	0.43 U	0.46 U	0.28 U
012766	INEL	Heterogeneous	216	336	17.00 U	5.60 U	3.60 U	7.30	17.00 U	3.90 U	0.02 U	2.60 U
012802	INEL	Combustible	216	337	17.00 U	1.00 U	1.90 U	2.60	17.00 U	1.70 U	0.38 J	1.20 U
012875	RFETS	Solidified Organics	226	432	17.00 U	7.60 U	4.80 U	7.00 U	17.00 U	5.30 U	8.30	3.50 U
012878	INEL	Uncategorized Metal	217	480	17.00 U	0.55 U	1.00 U	0.70 U	17.00 U	0.88 U	0.03 U	0.64 U
012891	INEL	Heterogeneous	216	330	17.00 U	0.65 U	0.41 U	0.59 U	17.00 U	2.60	0.07 U	0.51 J
012902	INEL	Filter	219	338	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	0.02 U	0.04 J	0.02 U
012920	INEL	Inorganic Non-metal	222	371	17.00 U	2.20 U	1.40 U	44.00	17.00 U	1.60 U	1.70 U	1.00 U
012985	INEL	Inorganic Non-metal	222	371	17.00 U	3.80 U	2.40 U	3.40 U	17.00 U	2.60 U	0.32 J	2.10 J
012986	INEL	Heterogeneous	221	302	43.00 J	0.48 U	0.89 U	0.68 J	2.40 U	0.77 U	0.05 U	0.56 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
012998	INEL	Combustible	216	337	17.00 U	1.30 U	0.82 U	1.20 U	17.00 U	1.60	0.97 U	0.87 J
013106	INEL	Solidified Inorganics	111	7	5.00 U	0.03 U	1.70	0.03 U	5.00 U	0.08 J	0.04 J	0.01 U
013229	RFETS	Solidified Organics	226	432	17.00 U	0.28 U	0.18 U	0.26 U	17.00 U	0.20 U	0.21 U	0.13 U
013231	INEL	Graphite	215	300	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	0.09 J	0.07 U	0.02 U
013252	INEL	Inorganic Non-metal	222	371	19.00 J	0.06 U	0.07 JB	0.05 U	17.00 U	0.19 J	52.00 U	0.03 U
013266	INEL	Combustible	223	339	17.00 U	0.79 U	0.50 U	0.72 U	17.00 U	3.90	0.02 U	0.36 U
013269	INEL	Inorganic Non-metal	218	440	17.00 U	0.05 U	0.09 U	0.06 U	17.00 U	2.80	0.02 U	0.06 U
013313	INEL	Inorganic Non-metal	218	440	17.00 U	0.06 U	0.09 U	0.05 U	17.00 U	0.04 U	0.02 U	0.03 U
013331	INEL	Salt Waste	124	411	17.00 U	0.14 U	0.09 U	0.13 U	17.00 U	0.25 J	0.10 U	0.06 U
013342	INEL	Inorganic Non-metal	218	440	17.00 U	0.01 U	0.06 J	0.02 U	17.00 U	0.72 J	0.04 J	0.02 U
013346	RFETS	Inorganic Non-metal	222	371	12.00 J	0.04 U	0.04 J	0.04 U	5.00 U	0.11 J	0.03 U	0.02
013618	INEL	Heterogeneous	216	330	17.00 U	3.80 U	2.40 U	3.40 U	17.00 U	2.60	0.04 U	1.70 U
013677	INEL	Filter	219	338	17.00 U	0.05 U	0.07 U	0.05 U	17.00 U	0.04 U	0.04 J	0.04 U
013751	INEL	Uncategorized Metal	217	480	17.00 U	1.70 U	1.10 U	1.60 U	17.00 U	1.20 U	1.30 U	0.77 U
013763	INEL	Combustible	223	339	6.60 U	11.00 U	50.00	11.00 U	17.00 U	12.00	0.32 J	16.00 U
013773	RFETS	Solidified Inorganics	111	7	5.00 U	0.15 U	0.84 J	0.26 J	5.00 U	0.13 U	0.11 U	0.07 U
013818	RFETS	Solidified Inorganics	211	1	94.00 J	0.04 U	0.04 J	0.04 U	5.00 U	0.10 J	0.03 U	0.02 U
013820	RFETS	Solidified Inorganics	211	1	11.00 U	0.05 U	0.05 J	0.04 U	11.00 U	0.28 J	0.04 U	0.02 U
013847	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.05 J	0.02 U	0.02 U
013860	INEL	Combustible	223	339	17.00 U	0.06 U	0.24 J	0.07 U	17.00 U	2.70	0.18 U	0.05 U
013876	RFETS	Solidified Inorganics	211	7	5.00 U	0.18 U	3.60	0.17 U	5.00 U	0.16 U	0.14 U	0.08 U
014007	INEL	Solidified Inorganics	211	1	17.00 U	0.02 U	0.07 J	0.02 U	17.00 U	0.20 J	0.25 U	0.02 U
014009	INEL	Solidified Inorganics	211	7	17.00 U	0.06 U	3.40	0.37 J	17.00 U	0.09 U	3.50 U	0.07 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
014010	INEL	Solidified Inorganics	211	7	17.00 U	0.01 U	3.30	0.10 J	17.00 U	0.13 J	0.29 J	0.02 U
014127	RFETS	Solidified Inorganics	211	7	5.00 U	0.03 U	2.10	0.03 U	5.00 U	0.24	0.03 U	0.02 U
014170	INEL	Solidified Inorganics	211	7	5.00 U	0.03 U	0.21	0.03 U	5.00 U	0.08 J	0.03 U	0.02 U
014330	INEL	Graphite	215	303	21.00 J	0.04 U	0.06 U	0.04 U	17.00 U	6.20	0.30 J	0.03 U
014334	INEL	Filter	219	335	11.00 U	0.05 U	0.10 J	0.05 U	17.00 U	0.22 J	0.04 U	0.07 U
014339	INEL	Solidified Organics	226	432	17.00 U	0.11 U	0.07 U	0.10 U	17.00 U	0.08 U	0.08 U	0.05 U
014342	INEL	Graphite	215	303	17.00 U	0.06 U	0.09 U	0.07 U	17.00 U	0.43 J	0.04 U	0.05 U
014345	INEL	Solidified Organics	226	432	17.00 U	0.09 U	0.10 JB	0.09 U	17.00 U	0.09 J	0.07 U	0.04 U
014346	INEL	Combustible	223	339	17.00 U	0.02 U	2.30	0.04 J	17.00 U	3.30	0.04 J	0.02 J
014348	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	17.00 U	0.04 J	0.02 U	0.02 U
014354	RFETS	Uncategorized Metal	217	481	5.00 U	0.02 U	0.22	0.02 U	5.00 U	0.33	0.02 U	0.01 U
014357	INEL	Combustible	223	339	11.00 U	11.00 U	14.00 U	11.00 U	17.00 U	11.00 U	1.20 U	16.00 U
014387	INEL	Solidified Inorganics	211	7	17.00 U	0.01 U	23.00 E	0.19 J	17.00 U	0.10 J	0.63 J	0.02 U
014466	INEL	Heterogeneous	221	302	17.00 U	0.62 U	0.39 U	0.57 U	17.00 U	0.43 U	0.46 U	0.28 U
014484	INEL	Graphite	215	300	17.00 U	0.01 U	0.03 J	0.02 U	17.00 U	0.12 J	0.02 U	0.02 U
014502	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.12	0.02 U	5.00 U	0.10 J	0.01 U	0.01 U
014504	RFETS	Solidified Inorganics	211	1	5.00 U	0.06 U	0.53 J	0.05 U	5.00 U	0.11 J	0.04 U	0.03 U
014773	INEL	Solidified Inorganics	214	292	5.00 U	0.10 U	0.06 U	0.09 U	5.00 U	0.09 U	0.07 U	0.05 U
015228	RFETS	Solidified Organics	226	432	17.00 U	0.34 U	0.21 U	1.90	17.00 U	0.24 U	0.72 J	0.16 U
015231	INEL	Inorganic Non-metal	218	440	17.00 U	0.06 U	0.09 J	0.05 U	17.00 U	0.99 J	0.88 U	0.03 U
015241	INEL	Inorganic Non-metal	218	442	17.00 U	0.10 U	0.11 J	0.09 U	17.00 U	0.45 J	0.46 U	0.04 U
015249	INEL	Graphite	215	300	17.00 U	0.02 U	0.04 J	0.02 U	17.00 U	0.13 J	0.04 U	0.02 U
015262	RFETS	Solidified Organics	226	432	17.00 U	3.20 U	2.00 U	36.00	17.00 U	2.20 U	10.00	1.50 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
015267	INEL	Uncategorized Metal	217	480	17.00 U	2.80 U	1.80 U	2.60 U	17.00 U	2.00 U	2.10 U	1.30 U
015338	INEL	Solidified Inorganics	211	7	29.00 J	0.02 U	22.00 E	0.09 J	17.00 U	0.02 U	0.20 U	0.02 U
015434	RFETS	Solidified Organics	226	432	17.00 U	0.08 U	0.05 J	6.80	17.00 U	0.78 J	0.09 J	0.04 U
015440	RFETS	Solidified Organics	226	432	17.00 U	0.73 U	0.46 U	5.40	17.00 U	1.20	22.00	0.34 U
015515	RFETS	Solidified Organics	212	3	5.00 U	53.00 U	37.00 J	49.00 U	5.00 U	47.00 U	40.00 U	24.00 U
015532	RFETS	Solidified Organics	212	3	5.00 U	160.00 U	100.00 U	150.00 U	6.00 J	140.00 U	120.00 U	75.00 U
015543	INEL	Solidified Organics	212	3	17.00 U	70.00 U	44.00 U	64.00 U	17.00 U	49.00 U	0.39 J	32.00 U
015627	INEL	Graphite	215	300	17.00 U	0.02 U	0.03 U	0.02 U	32.00 J	0.02 U	0.14 U	0.02 U
015655	INEL	Solidified Inorganics	211	7	17.00 U	0.01 U	0.50 J	0.02 U	17.00 U	0.07 J	0.21 J	0.02 U
015674	INEL	Graphite	215	300	17.00 U	0.01 U	0.08 J	0.02 U	17.00 U	0.16 J	0.03 J	0.02 U
015675	INEL	Uncategorized Metal	217	480	17.00 U	0.14 U	0.09 U	0.13 U	17.00 U	5.50	0.75 J	0.06 U
015777	RFETS	Solidified Organics	226	432	17.00 U	0.14 U	0.09 U	1.60	17.00 U	0.20 J	3.40	0.06 U
015785	RFETS	Solidified Inorganics	211	1	15.00 U	0.65 U	0.41 U	0.85 J	15.00 U	6.40	0.48 U	0.30 U
015786	INEL	Solidified Inorganics	211	1	17.00 U	0.02 U	0.05 U	0.17 J	17.00 U	0.25 J	0.76 U	0.03 U
016242	INEL	Graphite	215	300	17.00 U	0.01 U	0.04 J	0.02 U	17.00 U	0.09 J	0.02 U	0.02 U
016612	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	0.17 J	0.22 J	0.03 U
016613	INEL	Solidified Organics	226	432	17.00 U	0.39 U	0.33 J	1.90 J	17.00 U	0.28 U	0.30 U	0.18 U
016707	INEL	Graphite	215	300	17.00 U	0.01 U	0.03 U	0.02 U	17.00 U	0.02 U	0.02 U	0.02 U
016738	RFETS	Solidified Inorganics	211	7	5.00 U	2.50 U	1.60 U	3.40 J	5.00 U	39.00	1.90 U	1.10 U
016790	INEL	Graphite	215	300	610.00	0.02 U	0.04 J	0.14 J	17.00 U	0.18 J	0.21 U	0.02 U
016807	INEL	Solidified Inorganics	211	1	17.00 U	0.13 U	0.24 U	0.42 J	17.00 U	2.80	1.80 U	0.15 U
016842	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	27.00 J	0.07 J	0.85 J	0.02 U
016855	RFETS	Solidified Organics	212	3	8.70 J	250.00 U	790.00 JD	230.00 U	8.30 J	220.00 U	190.00 U	120.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
016869	INEL	Solidified Inorganics	211	7	17.00 U	0.14 U	18.00	0.66 J	17.00 U	12.00	1.50	0.17 U
016964	RFETS	Solidified Inorganics	211	7	5.00 U	2.20 U	2.00 J	2.50 J	5.00 U	33.00	1.60 U	1.00 U
016986	INEL	Inorganic Non-metal	218	442	17.00 U	0.34 U	0.21 U	0.31 U	17.00 U	0.24 U	0.02 U	0.16 U
017148	INEL	Solidified Organics	226	432	17.00 U	1.20 U	0.76 U	87.00	17.00 U	3.60	0.90 U	0.55 U
017190	INEL	Solidified Inorganics	211	7	17.00 U	2.90 U	19.00	13.00	17.00 U	260.00	3.30	3.40 U
017444	INEL	Graphite	215	300	17.00 U	0.06 U	0.06 J	0.05 U	17.00 U	0.18 J	0.04 U	0.03 U
017453	INEL	Solidified Organics	212	3	5.00 U	73.00 U	46.00 U	67.00 U	7.00 J	64.00 U	54.00 U	33.00 U
017486	INEL	Solidified Inorganics	211	1	17.00 U	0.13 U	0.24 U	0.16 U	17.00 U	0.21 U	2.10 U	0.15 U
017491	INEL	Graphite	215	300	17.00 U	0.14 U	0.27 U	0.18 U	17.00 U	6.20	0.50 J	0.17 U
017495	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 U	0.08 J	0.05 U	17.00 U	0.16 J	0.62 U	0.03 U
017496	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 U	0.07 J	0.05 U	17.00 U	0.15 J	0.36 J	0.03 U
017698	RFETS	Solidified Inorganics	211	292	5.00 U	4.60 U	2.90 U	4.30 U	5.00 U	4.00 U	3.50 U	2.10 U
017709	INEL	Solidified Inorganics	211	1	17.00 U	0.01 U	0.10 J	0.03 J	17.00 U	0.40 J	0.93 J	0.02 U
017728	RFETS	Solidified Inorganics	211	1	5.00 U	1.30 U	0.84 U	1.20 U	5.00 U	14.00	0.99 U	0.61 U
017742	INEL	Inorganic Non-metal	218	440	17.00 U	1.10 U	0.71 U	1.00 U	17.00 U	2.50	1.40	0.52 U
017756	RFETS	Solidified Organics	226	432	17.00 U	3.20 U	2.00 U	130.00	17.00 U	13.00 U	2.40 U	1.50 U
017759	INEL	Solidified Organics	226	432	17.00 U	2.20 U	1.40 J	110.00	17.00 U	21.00	1.70 U	1.00 U
017788	INEL	Solidified Inorganics	211	7	17.00 U	0.97 U	15.00	3.00	17.00 U	78.00	0.88 U	1.10 U
017863	INEL	Filter	119	376	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.67 J	0.14 U	0.09 U
018111	RFETS	Solidified Inorganics	211	1	5.00 U	0.03 U	0.09 J	0.03 U	5.00 U	0.14 J	0.02 U	0.01 U
018219	RFETS	Solidified Inorganics	211	7	5.00 U	2.20 U	1.40 U	2.00 U	5.00 U	48.00	2.30 J	1.00 U
018299	INEL	Filter	119	376	17.00 U	0.28 U	0.22 J	0.26 U	17.00 U	1.20 J	0.21 U	0.13 U
018413	INEL	Graphite	115	300	5.00 U	0.02 U	0.03 J	0.02 U	5.00 U	0.04 J	0.01 U	0.01 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
018441	INEL	Graphite	115	300	17.00 U	0.06 U	0.04 J	0.05 U	17.00 U	0.16 J	0.04 U	0.03 U
018464	INEL	Graphite	115	300	5.00 U	0.02 U	0.03 J	0.02 U	5.00 U	0.07 J	0.02 U	0.01 U
018476	INEL	Solidified Inorganics	111	292	5.00 U	0.18 U	0.12 U	0.17 U	5.00 U	0.16 U	0.14 U	0.08 U
018491	INEL	Graphite	115	300	17.00 U	0.06 U	0.05 J	0.05 U	17.00 U	0.08 J	0.04 U	0.03 U
019410	INEL	Lead/Cadmium Metal Waste	123	339	5.00 U	1.20 U	9.20 D	1.10 U	6.00 J	1.10 U	0.92 U	0.56 U
019413	INEL	Lead/Cadmium Metal Waste	123	339	5.00 U	5.40 U	6.20 J	4.90 U	7.90 J	4.70 U	4.00 U	2.50 U
019572	INEL	Lead/Cadmium Metal Waste	123	339	17.00 U	0.11 U	0.28 J	0.10 U	43.00 J	7.20	0.53 J	0.06 J
021031	RFETS	Solidified Inorganics	214	292	5.00 U	0.08 U	0.10 J	0.08 U	5.00 U	0.07 U	0.06 U	0.04 U
021172	RFETS	Inorganic Non-metal	218	442	5.00 U	0.02 U	0.04 J	0.02 U	5.00 U	0.08 J	0.02 U	0.01 U
021306	INEL	Solidified Inorganics	213	4	580.00	0.06 U	0.04 U	0.05 U	17.00 U	0.04 U	0.04 U	0.03 U
021392	RFETS	Solidified Inorganics	214	292	5.00 U	0.31 U	0.56 J	0.31 J	5.00 U	4.90	0.25 J	0.14 U
021442	INEL	Solidified Inorganics	211	1	17.00 U	0.41 U	0.75 U	0.69 J	17.00 U	5.30	0.45 J	0.47 U
021488	RFETS	Inorganic Non-metal	218	442	5.00 U	0.07 U	0.22 J	0.07 U	5.00 U	0.20 J	0.06 U	0.03 U
021503	RFETS	Inorganic Non-metal	218	440	5.00 U	0.31 U	0.20 U	0.29 U	5.00 U	0.27 U	0.24 U	0.14 U
021511	RFETS	Solidified Inorganics	213	4	54.00 J	0.08 U	0.05 U	0.08 U	5.00 U	0.10 J	0.06 U	0.04 U
021512	INEL	Solidified Inorganics	211	7	17.00 U	1.80 U	1.10 U	1.60 U	17.00 U	3.90 J	1.40 U	0.82 U
021523	INEL	Solidified Organics	226	432	17.00 U	1.10 U	0.99 J	9.80	17.00 U	2.60	2.40	0.52 U
021565	INEL	Solidified Inorganics	211	7	17.00 U	0.73 U	1.30 U	2.20	17.00 U	31.00	2.60 U	0.84 U
021572	INEL	Solidified Inorganics	211	7	17.00 U	0.38 U	0.70 U	1.30	17.00 U	16.00	1.40 U	0.44 U
021600	RFETS	Solidified Inorganics	211	1	5.00 U	0.53 U	0.48 J	0.48 U	5.00 U	0.51 J	0.40 U	0.24
021631	INEL	Inorganic Non-metal	218	442	21.00 J	0.06 U	0.07 J	0.05 U	17.00 U	0.04 U	1.20	0.03 U
021698	INEL	Inorganic Non-metal	218	440	17.00 U	2.10 U	1.30 U	1.90 U	17.00 U	1.50 U	1.60 U	0.97 U
021699	INEL	Solidified Inorganics	213	4	2600.0	0.62 U	0.39 U	0.57 U	68.00 U	0.43 U	0.46 U	0.28 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
021700	RFETS	Solidified Inorganics	213	4	5.00 U	0.02 U	0.01 J	0.02 U	5.00 U	0.02 J	0.01 U	0.01 U
021806	INEL	Inorganic Non-metal	218	440	17.00 U	0.17 U	0.31 U	0.21 U	17.00 U	0.27 U	0.30 U	0.20 U
021816	INEL	Solidified Inorganics	211	1	42.00 J	0.09 U	0.16 U	1.20	17.00 U	3.70	0.27 J	0.10 U
021865	INEL	Solidified Inorganics	211	1	17.00 U	1.80 U	1.10 U	1.60 U	17.00 U	4.80 J	1.40 U	0.82 U
021993	INEL	Solidified Inorganics	211	2	17.00 U	0.84 U	0.53 U	0.77 U	17.00 U	4.10 J	0.64 J	0.39 U
022000	INEL	Inorganic Non-metal	218	440	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.13 U	0.55 U	0.09 U
022036	INEL	Uncategorized Metal	217	480	17.00 U	0.06 U	0.14 J	0.08 U	17.00 U	0.10 U	0.14 U	0.07 U
022038	RFETS	Uncategorized Metal	217	481	11.00 J	0.35 U	4.00	0.66 J	28.00 J	0.30 U	1.30 J	0.52 J
022052	INEL	Uncategorized Metal	217	481	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	0.02 J	0.54 J	0.02 U
022102	INEL	Solidified Organics	226	432	17.00 U	0.19 U	0.12 U	2.00	17.00 U	0.13 U	3.90	0.09 U
022105	INEL	Solidified Inorganics	211	1	17.00 U	0.79 U	0.50 U	0.72 U	17.00 U	0.55 U	0.59 U	0.36 U
022119	INEL	Inorganic Non-metal	222	371	17.00 U	1.00 U	0.64 U	0.93 U	17.00 U	7.70	0.88 U	0.46 U
022121	INEL	Solidified Inorganics	211	7	17.00 U	0.13 U	19.00	0.33 J	15.00 U	9.00	0.66 J	0.15 U
022135	INEL	Solidified Inorganics	211	7	17.00 U	1.30 U	46.00	1.20 U	17.00 U	24.00	0.97 U	0.59 U
022136	RFETS	Solidified Inorganics	211	7	5.00 U	1.60 U	4.10 J	1.50 J	5.00 U	11.00	1.20 U	0.76 U
022149	RFETS	Solidified Inorganics	211	7	5.00 U	0.41 U	1.10 J	0.38 U	5.00 U	1.90 J	6.70	0.19 U
022224	INEL	Solidified Inorganics	211	1	17.00 U	0.79 U	0.50 U	2.50 J	17.00 U	4.80	1.30 J	1.90 J
022226	RFETS	Inorganic Non-metal	222	371	14.00 J	2.20 U	1.40 U	2.00 U	11.00 J	2.30 JD	1.60 U	1.00 U
022228	INEL	Inorganic Non-metal	222	371	17.00 U	0.28 U	0.18 U	0.26 U	18.00 U	3.20	0.10 U	0.13 U
022230	INEL	Inorganic Non-metal	222	371	17.00 U	0.22 U	0.14 U	0.21 U	17.00 U	4.80	0.17 U	0.10 U
022249	INEL	Uncategorized Metal	217	480	17.00 U	1.50 U	2.70 U	1.80 U	17.00 U	2.30 U	3.30 U	1.70 U
022275	INEL	Uncategorized Metal	217	480	64.00 J	0.33 U	0.61 U	0.58 J	17.00 U	12.00	0.88 U	0.38 U
022286	RFETS	Uncategorized Metal	217	480	65.00 J	0.94 U	0.60 U	0.87 U	8.90 J	8.60	0.71 U	0.43 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
022296	INEL	Solidified Inorganics	211	1	17.00 U	0.72 U	1.30 U	2.00	17.00 U	8.20	0.14 U	0.84 U
022306	INEL	Inorganic Non-metal	218	440	17.00 U	1.70 U	1.10 U	1.60 U	15.00 U	1.20	0.56 U	0.77 U
022338	INEL	Solidified Organics	212	3	17.00 U	220.00 U	5500.0	210.00 U	27.00 J	160.00 U	170.00 U	100.00 U
022347	INEL	Inorganic Non-metal	218	440	17.00 U	0.22 U	0.42 U	0.34 J	17.00 U	1.70	0.27 U	0.26 U
022358	INEL	Uncategorized Metal	217	480	17.00 U	0.02 U	0.07 J	0.24 J	17.00 U	0.02 U	0.08 J	0.02 U
022416	RFETS	Uncategorized Metal	217	320	12.00 J	0.10 U	0.10 JB	0.09 U	8.20 J	0.78	0.07 U	0.05 U
022434	INEL	Solidified Organics	226	432	17.00 U	0.73 U	0.46 U	3.70	17.00 U	0.51 U	7.60	0.34 U
022442	INEL	Solidified Organics	226	432	17.00 U	2.15 U	1.36 U	19.00	17.00 U	2.00 U	9.00 J	0.99 U
022450	RFETS	Uncategorized Metal	217	320	5.00 U	0.17 U	0.10 U	0.15 U	5.00 U	1.60	0.12 U	0.08 U
022453	RFETS	Solidified Inorganics	211	2	5.00 U	0.15 U	0.17 J	0.91	5.00 U	0.13 U	0.11 U	0.07 U
022486	RFETS	Inorganic Non-metal	218	440	5.00 U	3.30 U	2.10 U	3.10 U	11.00 J	2.90 U	2.50 U	1.50 U
022511	INEL	Uncategorized Metal	217	480	17.00 U	1.70 U	1.10 U	1.60 U	18.00 U	2.20	0.35 U	0.80 U
022513	INEL	Solidified Organics	212	1	17.00 U	0.51 U	0.32 U	0.49 J	17.00 U	1.10 J	0.38 U	0.23 U
022517	INEL	Solidified Organics	226	432	17.00 U	0.22 U	0.14 U	2.60	17.00 U	0.15 U	2.30 J	0.10 U
022539	INEL	Solidified Organics	226	432	17.00 U	0.22 U	0.14 U	1.60	17.00 U	0.15 U	1.60	0.10 U
022549	INEL	Uncategorized Metal	217	480	17.00 U	2.80 U	1.80 U	2.60 U	18.00 U	2.00 U	0.34 U	1.30 U
022552	INEL	Inorganic Non-metal	218	442	17.00 U	0.65 U	0.41 U	0.59 U	17.00 U	6.40	1.90 U	0.30 U
022557	INEL	Uncategorized Metal	217	480	17.00 U	0.51 U	0.95 U	0.65 U	17.00 U	3.70	0.02 U	0.60 U
022595	INEL	Solidified Inorganics	211	1	17.00 U	0.25 U	0.46 U	0.31 U	15.00 U	7.00	0.48 U	0.29 U
022600	RFETS	Solidified Inorganics	213	4	3800.0 D	0.52 U	0.33 U	2.10 J	130.00 U	0.45 U	0.69 J	0.24 U
022780	INEL	Solidified Inorganics	211	7	17.00 U	0.36 U	12.00	0.96 J	18.00 U	30.00	0.53 U	0.42 U
022789	INEL	Solidified Inorganics	211	7	17.00 U	1.20 U	6.00	1.10 U	17.00 U	19.00	0.93 U	0.57 U
022790	INEL	Solidified Inorganics	214	292	17.00 U	0.17 U	0.32 U	0.22 U	18.00 U	1.90	0.22 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
022803	INEL	Inorganic Non-metal	222	371	17.00 U	1.20 U	0.75 U	1.10 U	15.00 U	3.80 J	1.00 U	0.54 U
022807	INEL	Salt Waste	224	414	17.00 U	0.23 U	0.15 U	0.27 J	17.00 U	0.81 J	0.18 U	0.11 U
022811	INEL	Solidified Inorganics	211	7	17.00 U	0.30 U	19.00	0.65 J	17.00 U	20.00	0.32 U	0.35 U
022833	INEL	Solidified Inorganics	211	7	17.00 U	2.20 U	38.00	3.70	15.00 U	120.00	0.74 U	2.50 U
022841	INEL	Solidified Inorganics	211	7	17.00 U	1.20 U	5.20	2.80	17.00 U	84.00	0.04 U	1.40 U
022850	INEL	Solidified Inorganics	211	7	17.00 U	0.72 U	47.00	1.80	17.00 U	41.00	0.14 U	0.84 U
022874	INEL	Inorganic Non-metal	222	371	17.00 U	0.40 U	0.25 U	0.36 U	17.00 U	5.00	0.38 U	0.18 U
022894	INEL	Solidified Inorganics	211	1	17.00 U	0.10 U	0.29 J	0.34 J	15.00 U	3.50	0.19 U	0.12 U
022923	INEL	Inorganic Non-metal	218	440	17.00 U	0.73 U	0.46 U	0.67 U	17.00 U	0.61 J	0.05 U	0.34 U
023005	INEL	Solidified Inorganics	211	7	17.00 U	0.34 U	9.30	0.31 U	17.00 U	4.00	0.25 U	0.16 U
023027	RFETS	Uncategorized Metal	217	480	5.00 U	0.33 U	0.21 U	0.30 U	5.00 U	0.29 U	0.25 U	0.15 U
023041	RFETS	Inorganic Non-metal	222	371	13.00 J	0.54 U	0.34 U	0.49 U	10.00 J	1.10 J	0.40 U	0.25 U
023046	RFETS	Solidified Inorganics	211	7	5.00 U	0.95 U	6.50	0.87 U	5.90 J	10.00	0.71 U	0.43 U
023048	RFETS	Solidified Organics	226	432	17.00 U	0.79 U	0.50 U	12.00	17.00 U	0.55 U	1.90	0.36 U
023062	INEL	Solidified Inorganics	211	7	17.00 U	0.34 U	2.50	0.31 U	17.00 U	4.90	0.25 U	0.16 U
023211	INEL	Filter	119	376	17.00 U	0.11 U	0.09 J	0.10 U	17.00 U	0.34 J	0.08 U	0.05 U
023212	RFETS	Uncategorized Metal	217	480	5.00 U	1.10 U	0.70 U	3.20 J	9.20 J	5.20 J	1.30 J	0.51 U
023227	INEL	Uncategorized Metal	217	480	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.25 J	0.50 U	0.09 U
023229	INEL	Combustible	216	337	17.00 U	1.10 U	0.71 U	1.00 U	17.00 U	0.78 U	0.84 U	0.52 U
023235	RFETS	Heterogeneous	216	336	95.00 J	0.30 U	0.19 U	0.27 U	23.00 J	4.30	0.66 J	0.14 U
023238	INEL	Solidified Inorganics	211	1	17.00 U	0.16 U	0.62 J	0.75 J	17.00 U	4.50	4.10	0.18 U
023277	INEL	Inorganic Non-metal	222	371	17.00 U	2.00 U	1.20 U	1.80 U	17.00 U	9.20 J	1.50 U	0.90 U
023285	INEL	Solidified Inorganics	211	7	17.00 U	3.80 U	3.40 J	4.10 J	17.00 U	27.00	5.00 J	1.70 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
023312	INEL	Uncategorized Metal	217	480	17.00 U	0.73 U	1.40 U	1.80	17.00 U	5.80	0.35 J	0.84 U
023341	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	1.40 E	0.05 J	5.00 U	0.94	0.02 J	0.01 U
023357	INEL	Solidified Inorganics	211	1	17.00 U	0.28 U	0.18 U	0.89 J	17.00 U	0.72 J	1.30 J	0.13 U
023383	RFETS	Uncategorized Metal	217	481	5.00 U	0.02 U	0.06 J	0.02 U	5.00 U	0.07 J	0.02 J	0.01 U
023384	INEL	Combustible	223	339	15.00 U	0.09 U	0.15 U	0.11 U	15.00 U	14.00	2.20 U	0.08 U
023388	INEL	Heterogeneous	216	330	18.00 U	0.08 U	0.12 U	0.12 J	15.00 U	1.30	1.30 U	0.07 U
023392	INEL	Solidified Inorganics	213	4	1000.0	1.30 U	0.80 U	2.60 J	43.00 U	0.88 U	3.00 J	0.58 U
023407	INEL	Solidified Organics	212	3	17.00 U	44.00 U	28.00 U	40.00 U	17.00 U	31.00 U	33.00 U	20.00 U
023460	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 U	0.06 J	0.05 U	23.00 J	0.88 J	0.66 J	0.03 U
023469	INEL	Solidified Organics	212	3	17.00 U	0.67 U	45.00	4.60	17.00 U	22.00	2.10 J	0.31 U
023492	INEL	Solidified Inorganics	211	7	17.00 U	1.40 U	1.20 J	1.30 U	17.00 U	7.10 J	1.00 U	0.64 U
023519	INEL	Solidified Organics	212	3	17.00 U	2.80 U	49.00	3.50 U	17.00 U	44.00	0.44 J	3.20 U
023535	INEL	Solidified Inorganics	211	7	17.00 U	0.72 U	1.60	1.70	15.00 U	30.00	3.90	0.84 U
023552	INEL	Solidified Inorganics	211	1	17.00 U	1.60 U	1.00 U	1.40 U	17.00 U	9.40 J	1.20 U	0.72 U
023662	INEL	Inorganic Non-metal	218	442	17.00 U	0.19 U	0.12 U	0.17 U	2.40 U	1.30	0.55 J	0.09 U
023681	INEL	Solidified Inorganics	211	1	36.00 J	0.67 U	0.43 U	0.63 J	17.00 U	0.47 U	0.93 J	0.31 U
023695	RFETS	Solidified Inorganics	211	2	5.00 U	0.35 U	0.39 J	0.32 U	5.00 U	2.50	0.29 J	0.16 U
023771	RFETS	Heterogeneous	216	330	12.00 J	0.36 U	0.23 U	0.33 U	35.00 J	8.00	4.70	0.17 U
023776	INEL	Heterogeneous	216	330	15.00 U	0.74 U	0.47 U	0.68 U	51.00 J	2.50	0.77 J	0.34 U
023805	INEL	Uncategorized Metal	217	480	17.00 U	0.01 U	0.07 J	0.02 U	17.00 U	1.10	0.17 U	0.02 U
023827	RFETS	Uncategorized Metal	217	320	5.00 U	0.02 U	0.03 J	0.02 U	5.00 U	0.61	0.03 J	0.01 U
023840	INEL	Combustible	216	337	150.00	0.29 U	0.46 U	0.42 J	17.00 U	5.20	0.81 J	0.24 U
023901	INEL	Heterogeneous	216	330	18.00 U	0.28 U	0.44 U	2.70	27.00 J	0.26 U	0.16 U	0.23 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
023929	RFETS	Inorganic Non-metal	218	440	5.00 U	1.10 U	0.71 U	1.00 U	5.00 U	0.98 U	0.84 U	0.51 U
023959	INEL	Uncategorized Metal	217	480	17.00 U	2.50 U	1.60 U	2.30 U	17.00 U	14.00	0.05 J	1.20 U
024028	RFETS	Inorganic Non-metal	218	440	5.00 U	0.23 U	0.15 U	0.22 U	5.00 U	1.00 J	0.18 U	0.11 U
024029	INEL	Uncategorized Metal	217	480	17.00 U	0.02 U	0.03 U	0.02 U	18.00 J	0.02 U	0.37 J	0.02 U
024058	INEL	Solidified Inorganics	211	1	17.00 U	0.84 U	0.53 U	0.77 U	17.00 U	0.59 U	0.63 U	0.39 U
024059	INEL	Solidified Inorganics	214	292	17.00 U	0.34 U	0.21 U	0.31 U	17.00 U	0.25 J	0.25 U	0.16 U
024088	INEL	Combustible	216	337	15.00 U	0.64 U	0.41 U	0.59 U	15.00 J	1.30	11.00 U	0.30 U
024090	INEL	Combustible	216	337	55.00 J	0.44 U	0.69 U	0.50 U	17.00 U	2.10	0.02 U	0.37 U
024092	INEL	Combustible	216	337	17.00 U	2.80 U	1.90	2.60 U	17.00 U	4.10	0.05 J	1.30 U
024095	INEL	Combustible	216	337	18.00 U	0.18 U	0.29 U	0.21 U	17.00 U	0.17 U	0.02 U	0.15 U
024102	INEL	Combustible	216	337	120.00	0.96 U	0.61 U	0.88 U	17.00 U	0.67 U	0.10 J	0.44 U
024106	INEL	Combustible	216	337	360.00	1.40 U	1.50	1.30 U	17.00 U	0.98 U	0.04 U	0.64 U
024113	INEL	Combustible	216	337	140.00	0.42 U	0.27 U	0.39 U	17.00 U	0.29 U	0.02 U	0.19 U
024147	INEL	Solidified Inorganics	211	1	17.00 U	1.30 U	0.82 U	1.20 U	17.00 U	2.40 J	0.97 U	0.59 U
024165	INEL	Combustible	216	337	230.00	0.99 U	0.63 U	0.91 U	17.00 U	2.30	2.10 U	0.46 U
024168	INEL	Heterogeneous	216	330	17.00 U	0.06 U	0.04 U	0.05 U	17.00 U	0.04 U	0.10 J	0.03 U
024185	INEL	Salt Waste	224	409	17.00 U	0.06 U	0.09 J	0.10 J	17.00 U	0.21 J	0.05 U	0.03 U
024254	INEL	Salt Waste	224	414	17.00 U	0.09 U	0.06 U	0.09 U	17.00 U	0.07 U	0.07 U	0.04 U
024271	INEL	Inorganic Non-metal	218	442	17.00 U	0.19 U	0.12 U	0.17 U	17.00 U	0.55 J	2.80 U	0.09 U
024273	INEL	Inorganic Non-metal	218	442	17.00 U	0.36 U	0.23 U	0.34 U	17.00 U	0.26	0.27 U	0.17 U
024289	RFETS	Inorganic Non-metal	218	440	5.20 J	0.66 U	0.69 J	0.61 U	5.30 J	0.67 J	0.50 U	0.30 U
024295	INEL	Salt Waste	224	414	17.00 U	0.19 U	0.12 U	1.00 J	17.00 U	0.13 U	0.14 U	0.09 U
024308	INEL	Solidified Inorganics	211	2	17.00 U	0.28 U	0.18 U	0.26 U	17.00 U	0.20 U	0.21 U	0.13 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
024309	INEL	Solidified Inorganics	211	2	17.00 U	0.23 U	0.14 U	0.41 J	17.00 U	0.16 U	0.17 U	0.10 U
024311	INEL	Solidified Inorganics	211	2	41.00 U	0.46 U	0.29 U	0.42 U	41.00 U	0.32 U	0.34 U	0.21 U
024318	INEL	Solidified Inorganics	211	2	17.00 U	0.45 U	0.28 U	0.41 U	17.00 U	0.31 U	0.34 U	0.21 U
024506	INEL	Inorganic Non-metal	122	374	17.00 U	0.11 U	0.07 U	0.10 U	17.00 U	0.10 U	0.08 U	0.05 U
024507	INEL	Uncategorized Metal	117	480	17.00 U	0.19 J	0.09 U	0.13 U	17.00 U	0.20 J	0.10 U	0.06 U
024600	INEL	Uncategorized Metal	217	480	17.00 U	0.51 U	0.32 U	0.46 U	18.00 J	0.35 U	2.40 U	0.23 U
024638	INEL	Heterogeneous	216	330	15.00 U	0.25 U	0.16 U	0.23 U	17.00 U	0.17 U	0.04 U	0.11 U
024670	INEL	Solidified Inorganics	211	1	17.00 U	1.00 U	0.64 U	0.93 U	17.00 U	3.10 J	0.76 U	0.46 U
024765	INEL	Uncategorized Metal	217	480	17.00 U	0.05 U	0.07 U	0.11 J	17.00 U	1.30	0.63 U	0.04 U
024786	INEL	Uncategorized Metal	217	480	17.00 U	0.68 U	0.43 U	0.62 U	17.00 U	5.60	0.13 J	0.31 U
024850	INEL	Solidified Organics	226	432	17.00 U	0.19 U	0.12 BJ	0.98 J	17.00 U	0.13 U	7.10	0.09 U
024884	INEL	Uncategorized Metal	217	480	17.00 U	0.45 U	0.28 U	0.41 U	17.00 U	0.31 U	0.34 U	0.21 U
024897	INEL	Solidified Inorganics	211	1	17.00 U	0.45 U	0.28 U	0.41 U	17.00 U	0.31 U	0.34 U	0.21 U
024920	INEL	Solidified Inorganics	211	1	17.00 U	1.30 U	0.82 U	1.20 U	17.00 U	0.90 U	0.97 U	0.59 U
024991	INEL	Solidified Inorganics	211	1	17.00 U	0.62 U	0.39 U	0.57 U	17.00 U	0.43 U	0.46 U	0.28 U
025001	INEL	Solidified Organics	212	3	17.00 U	2.20 U	1.40 U	2.10 U	17.00 U	1.60 U	1.70 J	1.00 U
032284	INEL	Combustible	223	339	17.00 U	0.30 U	0.46 U	0.53 J	17.00 U	46.00	4.20 U	0.25 U
032287	RFETS	Solidified Inorganics	211	7	5.00 U	2.20 U	8.20 JB	2.00 U	6.00 J	29.00	1.60 U	1.00 U
032467	INEL	Combustible	216	337	17.00 U	0.45 U	0.28 U	0.41 U	59.00 J	0.31 U	58.00 J	0.21 U
032469	RFETS	Combustible	216	337	5.00 U	0.73 U	2.10 JB	0.67 U	5.00 U	0.64 U	0.55 U	0.34 U
032473	INEL	Combustible	216	337	15.00 U	3.00 U	1.90 U	2.80 U	17.00 U	19.00	0.06 U	1.40 U
032485	INEL	Combustible	216	337	72.00 J	1.80 U	2.20	1.60 U	17.00 U	1.40	1.90 U	0.80 U
032517	RFETS	Combustible	223	339	5.00 U	0.16 U	0.10 U	0.15 U	18.00 J	8.40	0.53 J	0.08 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
032521	INEL	Combustible	223	339	17.00 U	0.07 U	0.10 U	0.07 U	17.00 U	17.00	0.88 U	0.05 U
032525	INEL	Combustible	223	339	17.00 U	0.04 U	0.24 J	0.05 J	17.00 U	12.00	0.50 U	0.03 U
032526	INEL	Combustible	223	339	15.00 U	0.55 U	1.20	0.62 U	17.00 U	24.00	0.10 U	0.46 U
032529	INEL	Heterogeneous	216	336	11.00 U	1.80 U	0.32 U	1.00 U	17.00 U	55.00 B	0.07 U	0.18 U
032540	INEL	Uncategorized Metal	217	480	18.00 J	0.73 U	0.46 U	1.10	17.00 U	19.00	0.84 U	0.34 U
032632	INEL	Uncategorized Metal	217	480	17.00 U	0.14 U	0.22 U	0.39 J	17.00 U	3.40	1.30 U	0.12 U
032659	RFETS	Uncategorized Metal	217	480	5.00 U	0.58 U	0.37 U	0.53 U	9.50 J	6.40	0.43 U	0.26 U
032669	RFETS	Uncategorized Metal	217	480	7.60 J	0.63 U	0.40 U	0.58 U	18.00 J	2.30 J	0.47 U	0.29 U
032712	INEL	Uncategorized Metal	217	480	17.00 U	0.54 U	0.34 U	0.49 U	17.00 U	0.55 J	0.06 J	0.25 U
032715	RFETS	Combustible	216	337	5.00 U	0.17 U	0.28 JB	0.15 U	5.00 U	0.15 J	0.13 U	0.08 U
032748	INEL	Combustible	223	339	11.00 U	1.80 U	0.32 U	1.00 U	17.00 U	36.00 B	0.72 U	0.18 U
032753	INEL	Uncategorized Metal	217	481	17.00 U	0.06 U	0.04 J	0.05 U	17.00 U	0.04 U	0.04 U	0.03 U
033091	INEL	Combustible	223	339	17.00 U	0.02 U	0.03 U	0.02 U	17.00 U	1.60	26.00	0.02 U
D01332	RFETS	Heterogeneous	116	832	31.27 J	1.00 U	0.50 U	0.50 U	16.95 J	0.50 U	0.50 U	0.50 U
D06288	RFETS	Filter	119	338	1.30 U	0.20 U	0.10 U	0.10 U	0.56 J	0.10 U	0.10 U	0.10 U
D06339	RFETS	Heterogeneous	0	337	32.49 J	0.40 U	0.20 U	0.20 U	144.65 J	3.84	0.27 J	0.20 U
D11129	RFETS	Filter	119	338	5.87 J	0.20 U	0.10 U	0.10 U	2.76 J	0.29 J	0.10 U	0.10 U
D13364	RFETS	Uncategorized Metal	117	480	37.92 J	0.10 U	0.10 U	0.10 U	46.78 J	3.15	0.33 J	0.10 U
D15680	RFETS	Heterogeneous	116	831	866.66 U	133.33 U	66.67 U	66.67 U	333.33 U	66.67 U	66.67 U	66.67 U
D17184	RFETS	Solidified Inorganics	111	800	1.90 U	0.10 U	0.45 J	0.12 J	1.20 U	0.26 J	0.10 U	0.10 U
D32439	RFETS	Filter	119	338	5.96 J	0.20 U	0.10 U	0.10 U	4.57 J	1.19	0.10 U	0.10 U
D32978	RFETS	Solidified Inorganics	111	803	73.67 U	11.33 U	73.26	19.57 J	28.34 U	161.84	7.44 J	5.67 U
D35301	RFETS	Solidified Inorganics	111	800	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D35306	RFETS	Lead/Cadmium Metal Waste	123	339	22.26 J	0.40 U	0.20 U	0.20 U	92.37 J	22.22	1.17 J	0.20 U
D36606	RFETS	Uncategorized Metal	117	480	9.44 J	0.80 U	0.40 U	0.40 U	2.00 U	0.40 U	0.40 U	0.40 U
D38859	RFETS	Solidified Inorganics	111	803	2.74 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D38989	RFETS	Heterogeneous	0	336	1.69 J	0.20 U	0.10 U	0.10 U	17.99 J	1.18	0.19 J	0.10 U
D41681	RFETS	Filter	119	338	52.16 J	0.20 U	0.10 U	0.10 U	35.93 J	2.22	0.13 J	0.10 U
D42280	RFETS	Solidified Organics	112	801	5416.6 U	833.33 U	1682.9 J	416.67 U	2083.3 U	416.67 U	416.67 U	416.67 U
D47501	RFETS	Lead/Cadmium Metal Waste	0	341	11.85 J	0.20 U	0.10 U	0.10 U	31.67 J	0.52 J	0.10 U	0.10 U
D48182	RFETS	Filter	119	376	50.37 J	0.40 U	0.40 U	0.40 U	4.80 U	0.40 U	0.40 U	0.40 U
D48200	RFETS	Heterogeneous	116	831	152.00 U	8.00 U	8.00 U	8.00 U	96.00 U	8.00 U	8.00 U	8.00 U
D48377	RFETS	Inorganic Non-metal	118	368	1.90 U	0.10 U	0.10 U	0.10 U	4.95 J	0.12 J	0.10 U	0.10 U
D49662	RFETS	Solidified Inorganics	0	292	1.38 J	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D49880	RFETS	Heterogeneous	0	336	3.47 U	0.53 U	0.27 U	0.27 U	22.48 J	3.36	0.66 J	0.27 U
D52318	RFETS	Lead/Cadmium Metal Waste	117	321	5.08 J	0.20 U	0.10 U	0.10 U	3.15 J	0.10 U	0.10 U	0.10 U
D52362	RFETS	Heterogeneous	116	821	7.99 J	0.20 U	0.20 U	0.20 U	2.40 U	0.23 J	0.20 U	0.20 U
D52726	RFETS	Heterogeneous	116	833	10.40 U	1.60 U	0.80 U	0.80 U	4.00 U	0.80 U	0.80 U	0.80 U
D53672	RFETS	Inorganic Non-metal	118	440	147.84 J	0.20 U	0.21 J	0.20 U	7.22 J	0.20 U	0.20 U	0.20 U
D55656	RFETS	Heterogeneous	116	831	5.70 U	0.30 U	0.34 J	0.30 U	6.81 J	0.30 U	0.30 U	0.30 U
D55680	RFETS	Heterogeneous	116	821	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D55938	RFETS	Heterogeneous	116	831	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D56095	RFETS	Heterogeneous	0	337	10.20 J	0.20 U	0.10 U	0.10 U	0.59 J	0.10 U	0.10 U	0.10 U
D56595	RFETS	Heterogeneous	116	831	173.33 U	26.67 U	798.33	13.33 U	66.67 U	13.33 U	13.33 U	13.33 U
D56755	RFETS	Heterogeneous	116	821	1.90 U	0.10 U	0.16 J	0.10 U	1.20 U	0.32 J	0.10 U	0.10 U
D56823	RFETS	Heterogeneous	116	831	29.77 J	0.40 U	0.40 J	0.40 U	4.80 U	0.40 U	0.40 U	0.40 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D57179	RFETS	Heterogeneous	0	330	27.22 J	4.00 U	35.83	4.85 J	10.00 U	2.00 U	2.00 U	2.00 U
D57522	RFETS	Heterogeneous	0	336	292.23 J	0.80 U	0.40 U	0.40 U	61.39 J	0.40 U	0.40 U	0.40 U
D57847	RFETS	Uncategorized Metal	117	480	18.12 J	0.80 U	0.65 J	0.40 U	7.25 J	0.40 U	0.40 U	0.40 U
D58143	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	0.65 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D58154	RFETS	Heterogeneous	116	831	33.35 J	0.80 U	0.40 U	0.40 U	19.22 J	1.10 J	0.40 U	0.40 U
D58627	RFETS	Heterogeneous	116	831	9.82 J	0.40 U	0.20 U	0.20 U	1.00 U	0.47 J	0.20 U	0.20 U
D58889	RFETS	Heterogeneous	116	831	2.60 U	0.40 U	0.20 U	0.20 U	1.00 U	0.20 U	0.20 U	0.20 U
D58970	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	0.79 J	0.10 U	1.20 U	0.16 J	0.10 U	0.10 U
D59053	RFETS	Lead/Cadmium Metal Waste	0	341	4.44 J	0.20 U	0.10 U	0.10 U	32.29 J	5.31	0.45 J	0.10 U
D59703	RFETS	Heterogeneous	116	831	13.44 J	1.00 U	0.50 U	0.50 U	15.55 J	1.67 J	0.50 U	0.50 U
D59899	RFETS	Filter	0	331	18.73 Ja	1.00 U	0.50 U	0.50 U	844.03 J	0.50 U	0.50 U	0.50 U
D60056	RFETS	Lead/Cadmium Metal Waste	0	341	23.41 J	0.53 U	0.27 U	0.27 U	118.24 J	13.76	0.96 J	0.27 U
D60218	RFETS	Heterogeneous	116	821	26.43 J	0.20 U	0.20 U	0.20 U	35.91 J	0.20 U	0.20 U	0.20 U
D60298	RFETS	Solidified Organics	112	801	10893 U	573.33 U	605.44 J	573.33 U	6880.0 U	573.33 U	573.33 U	573.33 U
D60320	RFETS	Heterogeneous	0	330	364.00 U	56.00 U	28.70 J	28.00 U	144.48 J	28.00 U	28.00 U	28.00 U
D60463	RFETS	Inorganic Non-metal	118	440	9.15 J	0.10 U	0.29 J	0.10 U	2.58 J	0.18 J	0.10 U	0.10 U
D60511	RFETS	Filter	119	491	194.76 J	0.20 U	0.20 U	0.20 U	11.29 J	0.20 U	0.20 U	0.20 U
D60635	RFETS	Filter	119	491	12.71 J	0.10 U	0.10 U	0.10 U	1.28 J	0.18 J	0.10 U	0.10 U
D61245	RFETS	Heterogeneous	0	336	93.88 J	0.93 U	1.08 J	0.47 U	143.48 J	1.12 J	0.47 U	0.47 U
D61278	RFETS	Heterogeneous	0	336	110.62 J	0.53 U	0.27 U	0.27 U	45.34 J	22.83	1.16 J	0.27 U
D61473	RFETS	Heterogeneous	0	377	79.38 J	0.30 U	0.30 U	0.30 U	2.60 U	0.33 J	0.30 U	0.30 U
D61504	RFETS	Lead/Cadmium Metal Waste	0	341	27.30 J	0.20 U	0.10 U	0.10 U	87.45 J	9.88	0.57 J	0.10 U
D61747	RFETS	Heterogeneous	0	330	21.66 J	0.53 U	0.27 U	0.27 U	30.03 J	1.43 J	0.27 U	0.27 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D62340	RFETS	Heterogeneous	116	821	7.60 U	0.40 U	0.40 U	0.40 U	6.66 J	0.43 J	0.40 U	0.40 U
D62478	RFETS	Filter	119	376	77.31 J	0.40 U	0.40 U	0.40 U	4.80 U	0.40 U	0.40 U	0.40 U
D62714	RFETS	Heterogeneous	116	831	13.00 U	2.00 U	1.00 U	1.00 U	5.00 U	1.00 U	1.00 U	1.00 U
D62851	RFETS	Heterogeneous	116	825	10.44 J	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D62855	RFETS	Heterogeneous	116	821	114.00 U	6.00 U	6.00 U	6.00 U	72.00 U	6.00 U	6.00 U	6.00 U
D63098	RFETS	Filter	0	331	16.50 Ja	1.00 U	3.08 J	0.50 U	715.70 J	0.50 U	0.50 U	0.50 U
D63229	RFETS	Heterogeneous	116	831	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D63281	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	0.15 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D63460	RFETS	Heterogeneous	116	831	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	2.64	0.10 J	0.10 U
D63654	RFETS	Solidified Inorganics	111	807	2.95 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D63808	RFETS	Heterogeneous	116	831	43.27 J	0.80 U	0.80 U	0.80 U	9.60 U	0.80 U	0.80 U	0.80 U
D63817	RFETS	Heterogeneous	116	821	30.40 U	1.60 U	1.60 U	1.60 U	19.20 U	202.29	1.60 U	1.60 U
D63819	RFETS	Solidified Inorganics	111	807	3.80 U	0.20 U	0.58 J	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D63999	RFETS	Filter	119	491	245.84 J	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D64004	RFETS	Filter	0	331	185.61 Ja	0.80 U	0.40 U	0.40 U	409.36 J	0.40 U	0.40 U	0.40 U
D64137	RFETS	Filter	119	335	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D64448	RFETS	Heterogeneous	116	821	2090.0 U	110.00 U	110.00 U	110.00 U	1320.0 U	110.00 U	110.00 U	110.00 U
D64555	RFETS	Solidified Organics	112	801	10893 U	573.33 U	573.33 U	573.33 U	6880.0 U	573.33 U	573.33 U	573.33 U
D64632	RFETS	Solidified Inorganics	111	800	2.58 J	0.10 U	0.23 J	0.12 J	1.20 U	0.32 J	0.10 U	0.10 U
D64752	RFETS	Uncategorized Metal	117	480	26.00 U	4.00 U	2.00 U	2.68 J	10.00 U	2.00 U	2.00 U	2.00 U
D64758	RFETS	Heterogeneous	116	831	20.93 J	1.00 U	0.71 J	0.50 U	13.05 J	0.59 J	0.50 U	0.50 U
D64860	RFETS	Heterogeneous	116	831	156.00 U	24.00 U	12.00 U	12.00 U	60.00 U	12.00 U	12.00 U	12.00 U
D65212	RFETS	Heterogeneous	116	831	117.00 U	18.00 U	88.80 J	330.62	45.00 U	9.00 U	9.00 U	9.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D65213	RFETS	Heterogeneous	116	831	104.00 U	16.00 U	8.00 U	8.00 U	40.00 U	70.37 J	8.00 U	8.00 U
D65214	RFETS	Heterogeneous	116	831	1399.6 U	73.67 U	73.67 U	73.67 U	884.00 U	73.67 U	73.67 U	73.67 U
D65530	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	0.89 J	0.13 J	1.20 U	0.10 J	0.10 U	0.10 U
D65535	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	0.33 J	0.41 J	1.20 U	0.10 U	0.10 U	0.10 U
D65546	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	0.33 J	0.37 J	1.20 U	0.10 U	0.10 U	0.10 U
D65600	RFETS	Solidified Inorganics	111	807	1.90 U	0.10 U	1.25	1.02	1.20 U	0.10 J	0.12 J	0.10 U
D65731	RFETS	Inorganic Non-metal	122	375	12.20 J	0.40 U	1.81 J	0.40 U	5.01 J	0.62 J	0.40 U	0.40 U
D65734	RFETS	Uncategorized Metal	117	480	33.76 J	0.70 U	0.70 U	0.70 U	30.96 J	89.04	0.70 U	0.70 U
D65754	RFETS	Heterogeneous	116	831	10.46 J	1.33 U	3.60 J	0.67 U	106.20 J	0.67 U	0.67 U	0.67 U
D65757	RFETS	Heterogeneous	116	831	39.00 U	6.00 U	3.00 U	3.00 U	15.00 U	3.00 U	3.00 U	3.00 U
D65972	RFETS	Filter	119	376	18.35 J	0.30 U	0.30 J	0.30 U	3.60 U	0.50 J	0.30 U	0.30 U
D66128	RFETS	Heterogeneous	116	831	24.20 J	1.00 U	3.03 J	0.50 U	2.87 J	0.50 U	0.50 U	0.50 U
D66157	RFETS	Uncategorized Metal	117	480	29.29 J	4.00 U	2.00 U	2.00 U	56.91 J	2.00 U	2.00 U	2.00 U
D66162	RFETS	Lead/Cadmium Metal Waste	123	339	1710.0 U	90.00 U	90.00 U	113.67 J	1080.0 U	90.00 U	90.00 U	90.00 U
D66211	RFETS	Heterogeneous	116	833	19.95 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D66213	RFETS	Heterogeneous	116	831	7.49 J	0.60 U	2.63 J	8.85	5.57 J	0.30 U	0.30 U	0.30 U
D66356	RFETS	Heterogeneous	116	831	2166.6 U	333.33 U	166.67 U	166.67 U	833.33 U	166.67 U	166.67 U	166.67 U
D66378	RFETS	Heterogeneous	116	831	2496.0 U	384.00 U	192.00 U	192.00 U	960.00 U	192.00 U	192.00 U	192.00 U
D66438	RFETS	Uncategorized Metal	117	480	30.40 U	1.60 U	107.82	1.60 U	19.20 U	12.16 J	1.60 U	1.60 U
D66523	RFETS	Solidified Organics	112	801	10893 U	573.33 U	649.01 J	573.33 U	6880.0 U	573.33 U	573.33 U	573.33 U
D66525	RFETS	Solidified Inorganics	111	800	3.47 U	0.53 U	0.27 U	0.27 U	1.53 J	0.27 U	0.27 U	0.27 U
D66631	RFETS	Heterogeneous	116	831	9.82 J	0.50 U	0.50 U	0.50 U	9.29 J	0.50 U	0.50 U	0.50 U
D66637	RFETS	Heterogeneous	116	831	104.00 U	16.00 U	8.00 U	8.00 U	40.00 U	8.00 U	8.00 U	8.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D66641	RFETS	Heterogeneous	116	831	1140.0 U	60.00 U	60.00 U	60.00 U	720.00 U	60.00 U	60.00 U	60.00 U
D66649	RFETS	Lead/Cadmium Metal Waste	123	339	1064.0 U	56.00 U	56.00 U	60.65 J	672.00 U	56.00 U	56.00 U	56.00 U
D66773	RFETS	Uncategorized Metal	117	480	16.38 J	0.30 U	0.30 U	0.30 U	11.15 J	0.44 J	0.30 U	0.30 U
D66783	RFETS	Heterogeneous	116	831	4750.0 U	250.00 U	250.00 U	250.00 U	3000.0 U	250.00 U	250.00 U	250.00 U
D66792	RFETS	Heterogeneous	116	831	1900.0 U	100.00 U	100.00 U	100.00 U	1200.0 U	100.00 U	100.00 U	100.00 U
D66860	RFETS	Heterogeneous	116	833	12.16 J	0.20 U	13.02	0.20 U	20.46 J	2.49	0.20 U	0.20 U
D66875	RFETS	Heterogeneous	116	832	1.90 U	0.10 U	0.10 U	0.23 J	1.20 U	0.10 U	0.10 U	0.10 U
D66948	RFETS	Heterogeneous	116	831	114.00 U	6.00 U	6.00 U	6.00 U	72.00 U	6.00 U	6.00 U	6.00 U
D66949	RFETS	Heterogeneous	116	831	11.40 U	0.60 U	0.60 U	0.60 U	7.20 U	0.60 U	0.60 U	0.60 U
D66953	RFETS	Uncategorized Metal	117	480	20.80 U	3.20 U	1.60 U	1.60 U	8.00 U	1.60 U	1.60 U	1.60 U
D66958	RFETS	Heterogeneous	116	831	12.97 J	0.30 U	0.33 J	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D67009	RFETS	Solidified Organics	112	801	6460.0 U	340.00 U	624.24 J	340.00 U	4080.0 U	340.00 U	340.00 U	340.00 U
D67012	RFETS	Solidified Organics	112	801	17100 U	900.00 U	3386.7 J	900.00 U	10800 U	900.00 U	900.00 U	900.00 U
D67047	RFETS	Solidified Inorganics	111	807	5.58 J	0.20 U	1.59 J	0.20 U	3.21 J	0.20 U	0.20 U	0.20 U
D67251	RFETS	Uncategorized Metal	117	480	30221 J	2400.0 U	1200.0 U	1200.0 U	6000.0 U	179752	1200.0 U	1200.0 U
D67263	RFETS	Heterogeneous	116	831	171.00 U	9.00 U	9.00 U	11.37 J	108.00 U	9.00 U	10.00 J	9.00 U
D67277	RFETS	Heterogeneous	116	831	266.00 U	14.00 U	14.00 U	14.00 U	168.00 U	14.00 U	14.00 U	14.00 U
D67278	RFETS	Heterogeneous	116	831	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.53 J	0.10 U	0.10 U
D67312	RFETS	Heterogeneous	116	825	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D67317	RFETS	Uncategorized Metal	117	480	24.15 J	0.53 U	0.27 U	0.27 U	11.63 J	0.77 J	0.27 U	0.27 U
D67390	RFETS	Solidified Organics	112	801	2470.0 U	130.00 U	330.07 J	130.00 U	1560.0 U	130.00 U	130.00 U	130.00 U
D67391	RFETS	Heterogeneous	116	833	10.08 J	0.53 U	0.27 U	0.27 U	1.33 U	0.53 J	0.27 U	0.27 U
D67413	RFETS	Solidified Organics	112	801	14250 U	750.00 U	1446.0 J	750.00 U	9000.0 U	750.00 U	750.00 U	750.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D67434	RFETS	Solidified Inorganics	111	800	6.06 J	0.80 U	0.49 J	0.40 U	2.00 U	0.70 J	0.40 U	0.40 U
D67436	RFETS	Solidified Inorganics	111	800	5.75 J	0.27 U	0.58 J	0.13 U	0.73 J	0.49 J	0.13 U	0.13 U
D67441	RFETS	Solidified Inorganics	111	800	5.72 J	0.80 U	0.72 J	0.40 U	2.00 U	0.40 U	0.40 U	0.40 U
D67448	RFETS	Heterogeneous	116	852	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	2.50	0.10 U	0.10 U
D67455	RFETS	Filter	119	490	18.05 J	0.40 U	0.40 J	0.40 U	67.52 J	2.09 J	0.40 U	0.40 U
D67464	RFETS	Heterogeneous	116	831	4560.0 U	240.00 U	240.00 U	240.00 U	2880.0 U	240.00 U	240.00 U	240.00 U
D67524	RFETS	Heterogeneous	116	832	368.35 J	18.59 U	18.59 U	18.59 U	223.12 U	18.59 U	18.59 U	18.59 U
D67532	RFETS	Lead/Cadmium Metal Waste	123	339	119.70 U	6.30 U	6.30 U	6.30 U	75.60 U	6.30 U	6.30 U	6.30 U
D67535	RFETS	Heterogeneous	116	831	4.31 J	0.40 U	0.23 J	0.20 U	1.00 U	0.20 U	0.20 U	0.20 U
D67539	RFETS	Solidified Organics	112	801	6080.0 U	320.00 U	1238.4 J	320.00 U	3840.0 U	320.00 U	320.00 U	320.00 U
D67541	RFETS	Heterogeneous	116	825	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D67545	RFETS	Solidified Organics	112	801	1710.0 U	90.00 U	227.16 J	90.00 U	1080.0 U	90.00 U	90.00 U	90.00 U
D67567	RFETS	Heterogeneous	116	831	19.53 J	0.30 U	0.30 U	0.30 U	10.53 J	0.72 J	0.30 U	0.30 U
D67582	RFETS	Heterogeneous	116	831	87.17 J	0.40 U	0.73 J	0.40 U	10.79 J	0.40 U	0.40 U	0.40 U
D67603	RFETS	Uncategorized Metal	117	480	293.37 J	13.00 U	13.00 U	13.00 J	156.00 U	13.00 U	13.00 U	13.00 U
D67654	RFETS	Solidified Inorganics	111	800	3.47 U	0.53 U	0.33 J	0.27 U	1.57 J	0.47 J	0.27 U	0.27 U
D67657	RFETS	Solidified Inorganics	111	800	8.88 J	0.53 U	0.66 J	0.27 U	1.33 U	0.27 U	0.27 U	0.27 U
D67678	RFETS	Heterogeneous	116	825	20.37 J	0.43 U	0.43 U	0.43 U	11.98 J	0.43 U	0.43 U	0.43 U
D67698	RFETS	Heterogeneous	116	831	20.80 U	3.20 U	1.60 U	1.60 U	146.01 J	239.94	1.60 U	1.60 U
D67707	RFETS	Heterogeneous	116	831	6.50 U	1.00 U	0.50 U	0.50 U	2.50 U	0.50 U	0.50 U	0.50 U
D67734	RFETS	Heterogeneous	116	831	2090.0 U	110.00 U	110.00 U	252.34 J	1320.0 U	110.00 U	110.00 U	110.00 U
D67735	RFETS	Uncategorized Metal	117	480	34.20 U	1.80 U	1.80 U	2.04 J	21.60 U	1.80 U	1.80 U	1.80 U
D67759	RFETS	Heterogeneous	116	831	53.20 U	2.80 U	2.80 U	2.80 U	33.60 U	220.86	2.80 U	2.80 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D67764	RFETS	Heterogeneous	116	831	26.00 U	4.00 U	2.00 U	2.00 U.	10.00 U	298.84	2.00 U	2.00 U
D67766	RFETS	Heterogeneous	116	831	19.50 U	3.00 U	1.50 U	1.50 U	7.50 U	233.17	1.50 U	1.50 U
D67781	RFETS	Heterogeneous	116	831	7.13 J	0.30 U	0.30 U	0.30 U	11.63 J	0.49 J	0.30 U	0.30 U
D67908	RFETS	Heterogeneous	116	832	2.52 J	0.10 U	0.10 U	0.10 U	1.20 U	0.75 J	0.10 U	0.10 U
D67929	RFETS	Heterogeneous	116	832	1.30 U	0.20 U	0.10 U	0.10 J	0.50 U	0.10 U	0.10 U	0.10 U
D67989	RFETS	Heterogeneous	116	831	9.50 U	0.50 U	0.50 U	0.50 U	6.00 U	0.50 U	0.50 U	0.50 U
D67994	RFETS	Heterogeneous	116	831	39.51 J	5.33 U	2.67 J	2.67 U	13.34 U	2.67 U	2.67 U	2.67 U
D68044	RFETS	Heterogeneous	116	825	9.50 U	0.50 U	0.50 U	0.50 U	6.00 U	0.50 U	0.50 U	0.50 U
D68096	RFETS	Heterogeneous	116	821	5.34 J	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D68247	RFETS	Solidified Inorganics	111	800	1.73 U	0.27 U	0.15 J	0.13 U	0.67 U	0.13 U	0.13 U	0.13 U
D68248	RFETS	Solidified Organics	112	801	2850.0 U	150.00 U	566.85 J	150.00 U	1800.0 U	150.00 U	150.00 U	150.00 U
D68250	RFETS	Solidified Organics	112	801	3230.0 U	170.00 U	577.32 J	170.00 U	2040.0 U	170.00 U	170.00 U	170.00 U
D68254	RFETS	Solidified Inorganics	111	800	3.47 U	0.53 U	0.27 U	0.27 U	2.83 J	0.27 U	0.27 U	0.27 U
D68256	RFETS	Solidified Inorganics	111	800	5.20 U	0.80 U	0.50 J	0.40 U	2.00 U	0.49 J	0.40 U	0.40 U
D68276	RFETS	Heterogeneous	116	852	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	1.38	0.16 J	0.10 U
D68277	RFETS	Uncategorized Metal	117	480	10.42 J	0.50 U	0.50 U	0.50 U	8.70 J	0.50 U	0.50 U	0.50 U
D68377	RFETS	Uncategorized Metal	117	480	4.24 J	0.40 U	0.20 U	0.20 U	1.36 J	0.20 U	0.20 U	0.20 U
D68460	RFETS	Heterogeneous	116	832	1.30 U	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D68480	RFETS	Solidified Inorganics	111	800	9.99 J	0.20 U	0.10 U	0.10 U	0.71 J	4.09	0.10 U	0.10 U
D68486	RFETS	Solidified Organics	112	801	2660.0 U	140.00 U	196.98 J	140.00 U	1680.0 U	140.00 U	140.00 U	140.00 U
D68514	RFETS	Uncategorized Metal	117	480	20.24 J	0.10 U	0.10 U	0.10 U	7.15 J	0.10 U	0.10 U	0.10 U
D68538	RFETS	Lead/Cadmium Metal Waste	123	339	1.30 U	0.20 U	0.10 U	0.10 U	7.50 J	0.47 J	0.10 U	0.10 U
D68600	RFETS	Heterogeneous	116	825	342.00 U	18.00 U	85.91 J	18.00 U	216.00 U	18.00 U	18.00 U	18.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D68601	RFETS	Heterogeneous	116	825	133.00 U	7.00 U	40.26 J	7.00 U	84.00 U	7.00 U	7.00 U	7.00 U
D68702	RFETS	Heterogeneous	116	833	1.90 U	0.10 U	0.11 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D68724	RFETS	Heterogeneous	116	831	3420.0 U	180.00 U	180.00 U	180.00 U	2160.0 U	180.00 U	180.00 U	180.00 U
D68756	RFETS	Heterogeneous	116	831	2.60 U	0.40 U	0.20 U	0.20 U	1.00 U	0.20 U	0.20 U	0.20 U
D68885	RFETS	Heterogeneous	116	831	760.00 U	40.00 U	40.00 U	40.00 U	480.00 U	40.00 U	40.00 U	40.00 U
D68896	RFETS	Heterogeneous	116	831	4047.0 U	213.00 U	213.00 U	335.05 J	2556.0 U	213.00 U	213.00 U	213.00 U
D68975	RFETS	Solidified Organics	112	801	10260 U	540.00 U	553.50 J	540.00 U	6480.0 U	540.00 U	540.00 U	540.00 U
D68999	RFETS	Heterogeneous	116	821	7.60 U	0.40 U	0.40 U	0.40 U	14.03 J	0.74 J	0.40 U	0.40 U
D69091	RFETS	Heterogeneous	116	825	9.50 U	0.50 U	0.50 U	0.50 U	6.00 U	0.50 U	0.50 U	0.50 U
D69095	RFETS	Heterogeneous	116	833	10.26 U	0.54 U	0.54 U	0.54 U	6.48 U	0.54 U	0.54 U	0.54 U
D69113	RFETS	Heterogeneous	116	831	912.00 U	48.00 U	49.20 J	48.00 J	576.00 U	48.00 U	48.00 U	48.00 U
D69250	RFETS	Heterogeneous	116	833	4.29 J	0.10 U	0.11 J	0.10 U	2.15 J	0.10 U	0.10 U	0.10 U
D69287	RFETS	Heterogeneous	116	821	2622.0 U	138.00 U	138.00 U	138.00 U	1656.0 U	138.00 U	138.00 U	138.00 U
D69306	RFETS	Solidified Organics	112	801	4750.0 U	250.00 U	250.00 U	250.00 U	3000.0 U	250.00 U	250.00 U	250.00 U
D69312	RFETS	Solidified Inorganics	111	800	8.61 J	0.80 U	0.47 J	0.40 U	2.00 U	0.40 U	0.40 U	0.40 U
D69364	RFETS	Heterogeneous	116	833	18.66 J	0.30 U	0.30 U	0.30 U	15.17 J	0.30 U	0.30 U	0.30 U
D69400	RFETS	Heterogeneous	116	831	703.00 U	37.00 U	37.00 U	37.00 U	444.00 U	37.00 U	37.00 U	37.00 U
D69406	RFETS	Heterogeneous	116	831	950.00 U	50.00 U	50.00 U	50.00 U	600.00 U	50.00 U	50.00 U	50.00 U
D69413	RFETS	Heterogeneous	116	831	11.40 U	0.60 U	0.60 U	0.60 U	7.20 U	0.60 U	0.60 U	0.60 U
D69418	RFETS	Heterogeneous	116	831	1884.0 J	73.40 U	73.40 U	73.40 U	880.80 U	73.40 U	73.40 U	73.40 U
D69431	RFETS	Heterogeneous	116	831	693.33 U	106.67 U	53.33 U	53.33 U	266.67 U	53.33 U	53.33 U	53.33 U
D69518	RFETS	Heterogeneous	116	833	10.34 J	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D69602	RFETS	Heterogeneous	116	821	19.00 U	1.00 U	1.00 U	1.00 U	12.00 U	1.00 U	1.00 U	1.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D69759	RFETS	Heterogeneous	116	833	5.84 J	0.30 U	0.30 U	0.46 J	3.60 U	0.30 U	0.30 U	0.30 U
D69855	RFETS	Heterogeneous	116	833	25.25 J	0.20 U	0.20 U	0.20 U	6.60 J	0.20 U	0.20 U	0.20 U
D69877	RFETS	Heterogeneous	116	825	13.44 J	0.50 U	0.50 U	0.50 U	12.09 J	0.50 U	0.50 U	0.50 U
D69883	RFETS	Heterogeneous	116	825	5.70 U	0.30 U	0.30 U	0.30 U	5.97 J	0.30 U	0.30 U	0.30 U
D69975	RFETS	Heterogeneous	116	821	13.30 U	0.70 U	0.70 U	0.70 U	8.40 U	0.70 U	0.70 U	0.70 U
D70063	RFETS	Heterogeneous	116	821	9.69 U	0.51 U	0.85 J	0.51 U	6.12 U	0.51 U	0.51 U	0.51 U
D70077	RFETS	Heterogeneous	116	831	1140.0 U	60.00 U	60.00 U	60.00 U	720.00 U	60.00 U	60.00 U	60.00 U
D70229	RFETS	Heterogeneous	116	831	5.41 J	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D70353	RFETS	Heterogeneous	116	833	6.79 J	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D70370	RFETS	Heterogeneous	116	821	14.73 J	0.30 U	0.30 U	0.30 U	7.78 J	3.02	0.30 U	0.30 U
D70379	RFETS	Heterogeneous	116	833	6.20 J	0.10 U	0.10 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D70383	RFETS	Heterogeneous	116	833	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D70446	RFETS	Uncategorized Metal	117	480	19.29 J	2.00 U	16.42	1.00 U	17.99 J	1.14 J	1.00 U	1.00 U
D70448	RFETS	Heterogeneous	116	831	2850.0 U	150.00 U	150.00 U	150.00 U	1800.0 U	150.00 U	150.00 U	150.00 U
D70455	RFETS	Heterogeneous	116	831	13.30 U	0.70 U	1.07 J	0.70 U	8.40 U	0.80 J	0.70 U	0.70 U
D70543	RFETS	Solidified Organics	112	801	15732 U	828.00 U	7954.6 J	828.00 U	9936.0 U	828.00 U	828.00 U	828.00 U
D70661	RFETS	Filter	0	331	8.58 J	1.20 U	0.60 U	0.60 U	227.94 J	0.60 U	0.60 U	0.60 U
D70669	RFETS	Uncategorized Metal	117	480	41.70 J	0.10 U	0.10 U	0.16 J	1.20 U	0.10 U	0.10 U	0.10 U
D70675	RFETS	Solidified Organics	112	801	10.25 J	0.10 U	0.10 U	0.42 J	17.69 J	0.10 U	0.17 J	0.42 J
D70682	RFETS	Heterogeneous	116	831	855.00 U	45.00 U	45.00 U	45.00 U	540.00 U	45.00 U	45.00 U	45.00 U
D70696	RFETS	Heterogeneous	116	821	57.57 J	0.60 U	0.60 U	0.60 U	7.20 U	0.60 U	0.60 U	0.60 U
D70734	RFETS	Heterogeneous	116	833	2.14 J	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D70780	RFETS	Heterogeneous	116	832	1.30 U	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D70856	RFETS	Heterogeneous	116	833	1.90 U	0.10 U	0.10 U	0.10 U	1.65 J	0.10 U	0.10 U	0.10 U
D70882	RFETS	Heterogeneous	116	831	266.00 U	14.00 U	14.00 U	22.74 J	168.00 U	14.00 U	14.00 U	14.00 U
D70937	RFETS	Filter	0	331	6.50 U	1.00 U	0.50 U	0.50 U	374.16 J	0.50 U	0.50 U	0.50 U
D71019	RFETS	Solidified Organics	112	801	24.70 U	1.30 U	1.30 U	2.48 J	15.60 U	1.30 U	1.30 U	1.30 U
D71020	RFETS	Solidified Organics	112	801	17318 U	911.50 U	4880.1 J	911.50 U	10938 U	911.50 U	911.50 U	911.50 U
D71022	RFETS	Solidified Organics	112	801	15600 U	2400.0 U	3597.6 J	1200.0 U	6000.0 U	1200.0 U	1200.0 U	1200.0 U
D71241	RFETS	Heterogeneous	116	833	2.33 J	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D71351	RFETS	Uncategorized Metal	117	480	3.81 J	0.20 U	0.10 U	0.10 U	5.90 J	0.25 J	0.10 U	0.10 U
D71354	RFETS	Uncategorized Metal	117	480	2.70 J	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D71385	RFETS	Heterogeneous	116	833	10.75 J	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D71494	RFETS	Solidified Organics	112	801	7.11 J	0.10 U	0.10 U	0.15 J	7.80 J	0.10 U	0.10 U	0.23 J
D71504	RFETS	Solidified Organics	112	801	3.80 U	0.20 U	0.20 U	0.20 U	7.96 J	0.20 U	0.20 U	0.20 U
D71514	RFETS	Heterogeneous	116	833	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D71521	RFETS	Heterogeneous	116	825	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D71638	RFETS	Uncategorized Metal	117	480	13.00 U	2.00 U	1.00 U	1.00 U	5.00 U	1.00 U	1.00 U	1.00 U
D71804	RFETS	Heterogeneous	116	832	1.89 J	0.20 U	0.10 U	0.10 U	4.23 J	1.17	0.26 J	0.10 U
D71829	RFETS	Heterogeneous	116	852	4180.0 U	220.00 U	220.00 U	220.00 U	2640.0 U	29668	220.00 U	220.00 U
D71838	RFETS	Heterogeneous	116	831	144.40 U	7.60 U	442.97	7.60 U	91.20 U	7.60 U	7.60 U	7.60 U
D71921	RFETS	Heterogeneous	116	833	24.57 J	0.20 U	0.10 U	0.10 U	1.67 J	0.10 U	0.10 U	0.10 U
D71932	RFETS	Solidified Organics	112	801	82991 U	4367.9 U	7014.9 J	4367.9 U	52415 U	4367.9 U	4367.9 U	4367.9 U
D71933	RFETS	Solidified Organics	112	801	10.20 J	0.20 U	0.10 U	0.10 U	4.94 J	0.10 U	0.10 U	0.10 U
D71934	RFETS	Solidified Organics	112	801	13.70 J	0.20 U	0.10 U	0.10 U	9.11 J	0.10 U	0.10 U	0.10 U
D71936	RFETS	Heterogeneous	116	833	411.67 U	21.67 U	85.52 J	59.76 J	260.00 U	21.67 U	21.67 U	21.67 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D71937	RFETS	Heterogeneous	116	833	433.33 U	66.67 U	74.43 J	33.33 U	166.67 U	33.33 U	33.33 U	33.33 U
D71938	RFETS	Heterogeneous	116	833	34.20 U	1.80 U	1.80 U	1.80 U	21.60 U	1.80 U	1.80 U	1.80 U
D71940	RFETS	Solidified Organics	112	801	19000 U	1000.0 U	3580.0 J	1000.0 U	12000 U	1000.0 U	1000.0 U	1000.0 U
D71941	RFETS	Solidified Organics	112	801	19000 U	1000.0 U	8276.0 J	1000.0 U	12000 U	1000.0 U	1000.0 U	1000.0 U
D72010	RFETS	Heterogeneous	116	832	38.55 J	0.60 U	0.30 U	0.30 U	17.91 J	0.30 U	0.30 U	0.30 U
D72079	RFETS	Uncategorized Metal	117	480	123.50 U	6.50 U	6.50 U	6.50 U	78.00 U	6.50 U	6.50 U	6.50 U
D72127	RFETS	Solidified Organics	112	801	7.60 U	0.40 U	0.40 U	0.42 J	4.80 U	0.40 U	0.40 U	0.40 U
D72128	RFETS	Solidified Organics	112	801	6359.9 J	130.00 U	130.00 U	130.00 U	4542.0 J	2721.4	130.00 U	130.00 U
D72131	RFETS	Heterogeneous	116	833	3.47 U	0.53 U	0.27 U	0.27 U	2.44 J	0.27 U	0.27 U	0.27 U
D72132	RFETS	Solidified Organics	112	801	1612.4 J	96.00 U	48.00 U	48.00 U	283.06 J	8080.9	48.00 U	48.00 U
D72133	RFETS	Solidified Organics	112	801	4.48 J	0.20 U	0.20 J	0.20 U	3.54 J	0.20 U	0.20 U	0.20 U
D72136	RFETS	Solidified Organics	112	801	399.00 U	21.00 U	21.00 U	21.00 U	252.00 U	665.70	21.00 U	21.00 U
D72139	RFETS	Solidified Organics	112	801	36.10 U	1.90 U	1.90 U	1.90 U	24.65 J	22.74	1.90 U	1.90 U
D72178	RFETS	Heterogeneous	116	821	5.70 U	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D72186	RFETS	Heterogeneous	116	821	16.26 J	0.20 U	0.20 U	0.20 U	2.40 U	0.21 J	0.20 U	0.20 U
D72195	RFETS	Heterogeneous	116	833	15.12 J	0.10 U	0.30 J	0.10 U	6.84 J	0.25 J	0.10 U	0.11 J
D72255	RFETS	Heterogeneous	116	833	25.68 J	0.30 U	0.30 U	0.30 U	9.46 J	0.30 U	0.30 U	0.30 U
D72267	RFETS	Solidified Inorganics	111	800	1.30 U	0.20 U	0.15 J	0.10 U	0.50 U	0.10 U	0.11 J	0.10 U
D72293	RFETS	Heterogeneous	116	833	6.63 J	0.10 U	0.14 J	0.10 U	16.50 J	0.77 J	0.17 J	0.10 U
D72333	RFETS	Heterogeneous	116	831	5.70 U	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D72339	RFETS	Heterogeneous	116	821	9.50 U	0.50 U	0.50 U	0.50 U	6.00 U	0.50 U	0.50 U	0.50 U
D72347	RFETS	Heterogeneous	116	833	8.58 J	0.10 U	0.10 U	0.10 U	3.45 J	0.89 J	0.10 U	0.10 U
D72375	RFETS	Heterogeneous	116	831	1520.0 U	80.00 U	80.00 U	80.00 U	960.00 U	80.00 U	80.00 U	80.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D72434	RFETS	Heterogeneous	116	831	3990.0 U	210.00 U	210.00 U	210.00 U	2520.0 U	210.00 U	210.00 U	210.00 U
D72436	RFETS	Uncategorized Metal	117	480	66.00 J	0.60 U	0.30 U	0.30 U	2.60 J	0.30 U	0.30 U	0.30 U
D72542	RFETS	Heterogeneous	116	832	130.00 U	20.00 U	10.00 U	10.00 U	50.00 U	10.00 U	10.00 U	10.00 U
D72545	RFETS	Solidified Inorganics	111	800	2.46 J	0.20 U	0.10 U	0.10 U	0.52 J	0.10 U	0.10 U	0.10 U
D72546	RFETS	Heterogeneous	116	832	195.00 U	30.00 U	15.00 U	15.00 U	75.00 U	15.00 U	15.00 U	15.00 U
D72566	RFETS	Solidified Organics	112	801	15.20 U	0.80 U	0.80 U	0.80 U	21.82 J	0.80 U	0.80 U	0.80 U
D72598	RFETS	Heterogeneous	116	821	11.40 U	0.60 U	4.11 J	0.60 U	7.20 U	0.60 U	0.60 U	0.60 U
D72618	RFETS	Heterogeneous	116	833	2.83 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D72619	RFETS	Solidified Organics	112	801	1.90 U	0.10 U	0.10 U	0.10 U	314.00 J	0.10 U	0.10 U	0.10 U
D72623	RFETS	Solidified Organics	112	801	6.50 U	1.00 U	0.50 U	0.50 U	6.19 J	0.50 U	0.50 U	0.50 U
D72631	RFETS	Solidified Organics	112	801	1.90 U	0.10 U	0.10 U	0.34 J	6.46 J	0.10 U	0.10 U	0.10 U
D72632	RFETS	Solidified Organics	112	801	2.64 J	0.10 U	0.10 U	0.29 J	8.42 J	0.10 U	0.10 U	0.10 U
D72673	RFETS	Heterogeneous	116	833	17.92 J	0.20 U	1.29 J	0.42 J	18.02 J	0.20 U	0.20 U	0.26 J
D72819	RFETS	Heterogeneous	116	833	29.08 J	0.40 U	0.40 U	0.40 U	7.14 J	0.40 U	0.40 U	0.40 U
D72822	RFETS	Heterogeneous	116	831	3.47 U	0.53 U	0.81 J	0.27 U	1.34 U	0.27 U	0.27 U	0.27 U
D72831	RFETS	Uncategorized Metal	117	480	52.00 U	8.00 U	4.00 U	4.00 U	20.00 U	4.00 U	4.00 U	4.00 U
D72887	RFETS	Heterogeneous	116	833	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D72923	RFETS	Heterogeneous	116	833	54.23 J	0.40 U	0.40 U	0.40 U	17.22 J	0.40 U	0.40 U	0.40 U
D72932	RFETS	Heterogeneous	116	825	8.68 J	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D73054	RFETS	Heterogeneous	0	336	1473.3 U	226.67 U	113.33 U	113.33 U	566.67 U	508.19 U	113.33 U	113.33 U
D73074	RFETS	Heterogeneous	116	833	75.28 J	0.20 U	0.20 U	0.20 J	9.61 J	1.00 J	0.20 U	0.20 U
D73117	RFETS	Uncategorized Metal	117	480	5.20 U	0.80 U	0.40 U	0.40 U	2.00 U	0.40 U	0.40 U	0.40 U
D73123	RFETS	Heterogeneous	116	831	2394.0 U	126.00 U	126.00 U	880.24 J	1512.0 U	126.00 U	126.00 U	126.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D73134	RFETS	Heterogeneous	116	831	936.00 U	144.00 U	72.00 U	72.00 U	360.00 U	72.00 U	72.00 U	72.00 U
D73136	RFETS	Solidified Inorganics	111	807	2.19 J	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D73274	RFETS	Heterogeneous	116	831	950.00 U	50.00 U	50.00 U	50.00 U	600.00 U	50.00 U	50.00 U	50.00 U
D73285	RFETS	Solidified Organics	112	801	7.06 J	0.10 U	0.10 J	0.14 J	5.84 J	0.10 U	0.10 U	0.10 U
D73293	RFETS	Solidified Organics	112	801	3.27 J	0.10 U	0.22 J	0.33 J	1.20 U	0.10 U	0.10 U	0.10 U
D73295	RFETS	Solidified Organics	112	801	6.58 J	0.10 U	0.10 U	0.21 J	3.42 J	0.10 U	0.10 U	0.10 U
D73296	RFETS	Solidified Organics	112	801	1.90 U	0.10 U	0.96 J	0.14 J	1.20 U	0.25 J	0.12 J	0.10 U
D73301	RFETS	Solidified Organics	112	801	10.40 J	0.20 U	0.20 U	1.24 J	8.20 J	0.20 U	0.20 U	0.20 U
D73605	RFETS	Lead/Cadmium Metal Waste	123	339	1.30 U	0.20 U	0.15 J	0.10 U	5.07 J	0.15 J	0.10 U	0.10 U
D73632	RFETS	Heterogeneous	116	825	13.30 U	0.70 U	0.70 U	0.70 U	8.40 U	0.70 U	0.70 U	0.70 U
D73667	RFETS	Solidified Organics	112	801	2.64 J	0.10 U	0.10 U	0.10 U	5.79 J	0.10 U	0.10 U	0.10 U
D73672	RFETS	Solidified Organics	112	801	4.94 J	0.10 U	0.10 U	0.22 J	1.20 U	0.10 U	0.10 U	0.10 U
D73745	RFETS	Heterogeneous	116	832	1.89 J	0.20 U	0.10 J	0.10 U	11.29 J	0.10 U	0.10 U	0.10 U
D73828	RFETS	Heterogeneous	116	833	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D73848	RFETS	Heterogeneous	116	821	2.80 J	0.13 U	0.13 U	0.13 U	1.60 U	0.13 U	0.13 U	0.13 U
D73987	RFETS	Lead/Cadmium Metal Waste	123	339	3.90 U	0.60 U	20.72	0.30 U	4.47 J	0.30 U	0.30 U	0.30 U
D74007	RFETS	Uncategorized Metal	117	480	11.47 J	0.60 U	0.30 U	0.30 U	6.01 J	0.30 U	0.30 U	0.30 U
D74110	RFETS	Heterogeneous	116	833	1.90 U	0.10 U	0.14 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D74147	RFETS	Solidified Organics	112	801	15.20 U	0.80 U	6.00 J	1.82 J	9.60 U	3.15 J	2.12 J	0.80 U
D74156	RFETS	Solidified Organics	112	801	11.40 U	0.60 U	4.17 J	1.92 J	7.20 U	3.65 J	2.15 J	0.60 U
D74374	RFETS	Heterogeneous	116	833	4.98 J	0.20 U	0.16 J	0.10 U	0.94 J	0.10 U	0.10 U	0.10 U
D74683	RFETS	Heterogeneous	116	821	28.50 U	1.50 U	1.50 U	0.15 U	18.00 U	1.50 U	1.50 U	1.50 U
D74904	RFETS	Heterogeneous	116	832	2.60 J	0.20 U	0.10 U	0.10 U	0.83 J	0.10 U	0.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D74913	RFETS	Heterogeneous	116	832	5.70 U	0.30 U	0.30 U	0.30 U	43.43 J	0.33 J	0.30 U	0.30 U
D75039	RFETS	Heterogeneous	116	832	158.92 J	0.30 U	0.30 U	0.30 U	35.16 J	0.30 U	0.30 U	0.39 J
D75265	RFETS	Heterogeneous	116	833	63.88 J	1.20 U	0.12 U	0.12 U	19.11 J	1.20 U	1.20 U	1.20 U
D75267	RFETS	Heterogeneous	116	832	3.80 U	0.20 U	0.20 U	0.20 U	2.92 J	0.20 U	0.20 U	0.20 U
D75278	RFETS	Heterogeneous	116	832	17.98 J	0.30 U	0.30 U	0.30 U	10.17 J	1.50 J	0.30 U	0.30 U
D75399	RFETS	Heterogeneous	116	833	7.60 U	0.40 U	0.40 U	0.40 U	4.80 U	0.40 U	0.40 U	0.40 U
D75564	RFETS	Heterogeneous	116	825	4.47 J	0.13 U	0.13 U	0.13 U	1.60 U	0.13 U	0.13 U	0.13 U
D75868	RFETS	Heterogeneous	116	825	11.40 U	0.60 U	0.60 U	0.60 U	7.20 U	0.60 U	0.60 U	0.60 U
D75888	RFETS	Heterogeneous	116	833	7.77 J	0.10 U	0.12 J	0.10 U	4.92 J	0.10 U	0.10 U	0.10 U
D75926	RFETS	Heterogeneous	116	832	7.60 U	0.40 U	0.40 U	0.40 U	4.80 U	0.40 U	0.40 U	0.40 U
D75930	RFETS	Heterogeneous	116	832	1300.0 U	200.00 U	100.00 U	100.00 U	500.00 J	100.00 U	100.00 U	100.00 U
D75947	RFETS	Heterogeneous	116	832	5.27 J	0.10 U	0.10 U	0.10 U	2.82 J	0.10 U	0.10 U	0.10 U
D75976	RFETS	Heterogeneous	116	833	5.57 J	0.27 U	0.13 U	0.13 U	0.67 U	0.13 U	0.13 U	0.13 U
D76044	RFETS	Heterogeneous	116	831	18.17 J	0.27 U	0.27 U	0.27 U	4.29 J	0.27 U	0.27 U	0.27 U
D76050	RFETS	Heterogeneous	116	832	1.90 U	0.10 U	0.10 U	0.10 J	1.20 U	0.10 U	0.10 U	0.10 U
D76054	RFETS	Heterogeneous	116	831	5.70 U	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D76098	RFETS	Heterogeneous	116	832	2.60 U	0.40 U	0.20 U	0.20 U	4.22 J	0.20 U	0.20 U	0.20 U
D76135	RFETS	Solidified Organics	112	801	346.67 U	53.33 U	26.67 U	26.67 U	133.34 U	26.67 U	26.67 U	26.67 U
D76136	RFETS	Solidified Inorganics	111	803	5.20 U	0.80 U	1.30 J	1.42 J	2.00 U	5.00	0.40 U	0.40 U
D76138	RFETS	Solidified Inorganics	111	800	1.30 U	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76142	RFETS	Solidified Inorganics	111	800	3.12 U	0.48 U	0.66 J	0.24 U	5.55 J	0.24 U	0.24 U	0.24 U
D76143	RFETS	Solidified Inorganics	111	803	3.90 U	0.60 U	0.90 J	0.96 J	1.50 U	3.26	0.30 U	0.30 U
D76144	RFETS	Solidified Inorganics	111	800	8.67 U	1.33 U	0.67 U	0.98 J	3.34 U	1.50 J	0.67 U	0.67 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D76146	RFETS	Solidified Inorganics	0	292	1.30 U	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76147	RFETS	Solidified Inorganics	111	803	1.90 U	0.10 U	1.66	0.25 J	4.53 J	0.10 U	0.20 J	0.10 U
D76182	RFETS	Solidified Inorganics	111	800	13.30 U	0.70 U	4.07 J	0.70 U	8.40 U	0.70 U	0.70 U	0.70 U
D76183	RFETS	Solidified Inorganics	111	800	1.73 U	0.27 U	0.47 J	0.18 J	0.92 J	0.37 J	0.13 U	0.13 U
D76185	RFETS	Solidified Inorganics	111	800	1.30 U	0.20 U	0.12 J	0.10 U	0.50 J	0.10 U	0.10 U	0.10 U
D76187	RFETS	Solidified Inorganics	111	803	6.50 U	1.00 U	1.56 J	1.44 J	2.50 U	6.37	0.50 U	0.50 U
D76189	RFETS	Solidified Inorganics	111	803	26.00 U	4.00 U	2.00 U	4.64 J	10.00 U	12.57 J	2.00 U	2.00 U
D76192	RFETS	Solidified Inorganics	111	803	1.30 U	0.20 U	0.32 J	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76194	RFETS	Solidified Inorganics	111	800	1.30 U	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76195	RFETS	Solidified Organics	112	801	9120.0 U	480.00 U	480.00 U	480.00 U	5760.0 U	480.00 U	480.00 U	480.00 U
D76196	RFETS	Solidified Organics	112	801	3732.5 J	333.33 U	2042.3	166.67 U	833.34 U	166.67 U	166.67 U	166.67 U
D76199	RFETS	Solidified Inorganics	111	800	1.30 U	0.20 U	0.19 J	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76200	RFETS	Solidified Organics	112	801	8233.3 U	1266.6 U	2371.8 J	633.33 U	3166.6 U	633.33 U	633.33 U	633.33 U
D76203	RFETS	Solidified Organics	112	801	2903.3 U	446.67 U	283.41 J	223.33 U	1116.6 U	223.33 U	223.33 U	223.33 U
D76205	RFETS	Solidified Inorganics	111	800	1.30 U	0.20 U	0.10 U	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76206	RFETS	Solidified Inorganics	111	803	5.20 U	0.80 U	0.51 J	0.74 J	2.00 U	4.19	0.40 U	0.40 U
D76217	RFETS	Heterogeneous	116	833	20.84 J	2.00 U	60.66	1.00 U	7.67 J	1.00 U	1.00 U	1.00 U
D76282	RFETS	Solidified Inorganics	111	800	147.33 U	22.67 U	39.18 J	11.33 U	56.67 U	11.33 U	11.33 U	11.33 U
D76283	RFETS	Solidified Organics	112	801	1170.0 U	180.00 U	90.00 J	90.00 U	450.00 U	90.00 U	90.00 U	90.00 U
D76287	RFETS	Solidified Inorganics	111	800	69.33 U	10.67 U	14.69 J	5.33 U	26.67 U	5.33 U	5.33 U	5.33 U
D76293	RFETS	Heterogeneous	116	833	7.60 U	0.40 U	0.40 U	0.40 U	4.80 U	0.40 U	0.40 U	0.40 U
D76302	RFETS	Solidified Inorganics	111	800	39.00 U	6.00 U	3.00 U	3.00 U	15.00 U	3.00 U	3.00 U	3.00 U
D76303	RFETS	Solidified Inorganics	111	803	3.47 U	0.53 U	1.03 J	1.64 J	5.51 J	1.98 J	0.27 U	0.27 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D76305	RFETS	Solidified Inorganics	111	800	156.00 U	24.00 U	22.21 J	12.00 U	60.00 U	12.00 U	12.00 U	12.00 U
D76306	RFETS	Heterogeneous	116	833	18.88 J	0.80 U	1.15 J	0.80 U	9.60 U	0.80 U	0.80 U	0.80 U
D76362	RFETS	Heterogeneous	116	833	97.62 J	13.33 U	13.46 J	6.67 U	33.34 U	6.67 U	6.67 U	6.67 U
D76406	RFETS	Heterogeneous	116	831	1.90 U	0.10 U	0.16 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D76437	RFETS	Heterogeneous	116	833	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 J	0.20 U	0.20 U
D76443	RFETS	Heterogeneous	116	825	16.85 J	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D76452	RFETS	Heterogeneous	116	825	14.20 J	0.20 U	0.20 U	0.20 U	2.00 U	0.20 U	0.20 U	0.20 U
D76454	RFETS	Heterogeneous	116	825	1.90 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D76456	RFETS	Heterogeneous	116	825	11.80 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D76461	RFETS	Heterogeneous	116	825	5.70 U	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D76463	RFETS	Heterogeneous	116	825	5.70 U	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U	0.30 U	0.30 U
D76470	RFETS	Solidified Inorganics	111	803	1.30 U	0.20 U	0.42 J	0.10 U	0.50 U	0.10 U	0.10 U	0.10 U
D76587	RFETS	Heterogeneous	116	825	1.90 U	0.10 U	0.14 J	0.12 J	1.20 U	0.17 J	0.10 U	0.10 U
D76596	RFETS	Heterogeneous	116	825	25.44 J	0.10 U	0.11 J	0.18 J	2.27 J	0.25 J	0.10 U	0.10 U
D76627	RFETS	Heterogeneous	116	825	1.90 U	0.10 U	0.10 J	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D76630	RFETS	Heterogeneous	116	825	14.78 J	0.10 U	0.10 U	0.11 J	3.66 J	0.17 J	0.10 U	0.10 U
D76635	RFETS	Heterogeneous	116	825	3.80 U	0.20 U	0.20 U	0.20 U	2.40 U	0.21 J	0.20 U	0.20 U
D76652	RFETS	Heterogeneous	116	833	6.87 J	0.20 U	0.10 U	0.10 U	0.57 J	0.10 U	0.10 U	0.10 U
D76677	RFETS	Solidified Inorganics	111	800	45.60 U	2.40 U	2.53 J	7.61 J	28.80 U	6.65 J	2.40 U	2.40 U
D76710	RFETS	Heterogeneous	116	833	38.00 U	2.00 U	2.51 J	2.00 U	24.00 U	2.00 U	2.00 U	2.00 U
D76712	RFETS	Heterogeneous	116	833	11.83 J	0.30 U	0.30 U	0.30 U	106.59 J	1.80 J	0.30 U	0.30 U
D76715	RFETS	Heterogeneous	116	832	4.34 J	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D76811	RFETS	Heterogeneous	116	832	3.80 U	0.20 U	0.20 U	0.20 U	3.95 J	0.20 U	0.20 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methanol	Ethyl Ether	1,1,2-Trichloro-1,2,2-Trifluoro ethane	1,1-Di-chloro-ethene	Acetone	Methylene Chloride	1,1-Di-chloro-ethane	cis-1,2-Dichloro-ethene
D76908	RFETS	Heterogeneous	116	833	53.56 J	0.10 U	6.99	0.10 U	1.20 U	0.10 U	0.10 U	0.10 U
D76911	RFETS	Heterogeneous	116	832	2.60 U	0.40 U	0.20 U	0.20 U	1.00 U	0.20 U	0.20 U	0.20 U
D77088	RFETS	Heterogeneous	116	833	11.76 J	0.40 U	0.20 U	0.20 U	1.00 J	0.20 U	0.20 U	0.20 U
D77227	RFETS	Heterogeneous	116	833	5.20 U	0.80 U	0.40 U	0.40 U	2.00 U	0.40 U	0.40 U	0.40 U
D77285	RFETS	Heterogeneous	116	833	3.80 U	0.20 U	0.20 U	0.20 U	4.60 J	0.20 U	0.20 U	0.20 U
D77621	RFETS	Heterogeneous	0	336	3.47 U	0.53 U	6.22	0.27 U	1.34 U	0.27 U	0.27 U	0.27 U
D80765	RFETS	Heterogeneous	116	833	3.80 U	0.20 U	0.30 J	0.20 U	2.40 U	0.20 U	0.20 U	0.20 U
D80772	RFETS	Heterogeneous	116	833	19.00 U	1.00 U	1.00 U	1.00 U	12.00 U	1.00 U	1.00 U	1.00 U
D80774	RFETS	Heterogeneous	116	833	58.90 U	3.10 U	4.13 J	3.10 U	37.20 U	3.10 U	3.10 U	3.10 U
D80776	RFETS	Heterogeneous	116	832	24.39 J	0.10 U	0.10 U	0.13 J	39.82 J	1.68	0.51 J	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
000365	RFETS	Uncategorized Metal	217	480	17.00 U	12.00 U	1600.0 J	17.00 U	11.00 U	13.00	11.00 U	17.00 U	28.00 J
000371	INEL	Graphite	215	300	17.00 U	0.03 U	9.20	0.03 U	0.10 J	0.03 U	0.03 U	17.00 U	0.26 J
000373	INEL	Graphite	215	300	17.00 U	0.01 U	0.66 J	0.02 U	0.03 J	0.01 U	0.02 U	17.00 U	0.02 U
000384	RFETS	Uncategorized Metal	217	320	5.00 U	0.01 J	0.09 U	0.01 U	0.10	0.14	0.01 U	5.00 U	0.01 U
000393	INEL	Uncategorized Metal	217	480	17.00 U	0.03 U	0.14 J	0.04 U	0.05 J	0.18 J	0.03 J	17.00 U	0.03 U
000401	RFETS	Inorganic Non-metal	222	371	5.00 U	1.80	0.15 J	0.02 U	0.07 JB	0.06	0.03 J	5.00 U	0.01 J
000403	INEL	Inorganic Non-metal	218	440	17.00 U	8.20 E	0.27 J	0.04 U	1.80	0.21 J	0.05 J	17.00 U	0.03 J
000405	RFETS	Uncategorized Metal	217	480	7.30 J	0.88 U	53.00 J	1.20 U	0.85 U	1.00	0.80 U	5.00 U	1.50 J
000436	INEL	Solidified Organics	212	3	17.00 U	44.00 U	1500.0	42.00 U	8200.0	46.00 U	42.00 U	17.00 U	42.00 U
000442	INEL	Solidified Inorganics	213	4	51.00 U	0.06 U	0.32 J	0.55 J	0.36 J	0.18 J	0.05 U	51.00 U	0.05 U
000446	RFETS	Solidified Inorganics	211	1	5.00 U	0.01 U	0.49 J	0.01 U	0.10 JB	0.11	0.01 U	5.00 U	0.02 J
000478	RFETS	Solidified Inorganics	211	1	5.00 U	0.01 U	0.20 J	0.01 U	0.18	0.05	0.01 U	5.00 U	0.05 J
000501	INEL	Graphite	215	300	17.00 U	0.01 U	0.12 J	0.02 U	0.02 J	0.01 U	0.02 U	17.00 U	0.02 U
000558	INEL	Heterogeneous	221	464	17.00 U	0.15 J	0.17 J	0.36 J	0.27 J	0.18 J	0.08 U	17.00 U	0.08 U
000567	RFETS	Inorganic Non-metal	222	371	5.00 U	3.50 J	320.00 U	2.30 U	2.50 J	1.80	1.50 U	5.00 U	1.50 U
000568	RFETS	Solidified Organics	226	432	17.00 U	0.98 U	0.87 U	2.90 J	0.95 U	1.10	0.88 U	17.00 U	0.89 U
000593	INEL	Solidified Inorganics	211	7	17.00 U	0.02 U	0.33 J	0.02 U	0.13 J	0.06 J	0.02 U	17.00 U	0.02 U
000613	INEL	Graphite	215	300	17.00 U	0.03 U	0.08 J	0.04 U	0.06 J	0.03 U	0.03 U	17.00 U	0.03 U
000630	INEL	Solidified Inorganics	213	4	51.00 U	0.07 U	0.46 J	12.00	0.34 J	0.46 J	0.07 U	51.00 U	0.07 U
000648	RFETS	Solidified Inorganics	213	4	70.00 U	0.03 U	0.09 U	5.40 D	0.25 JD	0.25	0.03 U	70.00 U	0.03 U
000675	RFETS	Inorganic Non-metal	218	440	12.00 J	0.39 J	0.23 U	0.64 J	0.90 J	0.50	0.13 U	5.00 U	0.13 U
000823	RFETS	Solidified Inorganics	213	4	120.00 U	0.02 U	0.28 J	1.50	0.85	0.20	0.02 U	120.00 U	0.03 J
000828	INEL	Graphite	215	300	17.00 U	0.01 U	0.08 J	0.09 J	0.05 J	0.01 U	0.02 U	17.00 U	0.02 U
001016	INEL	Graphite	215	300	17.00 U	0.01 U	0.09 J	0.19 J	0.03 J	0.01 U	0.02 U	17.00 U	0.02 U
001024	INEL	Graphite	215	300	17.00 U	0.01 U	0.07 J	0.09 J	0.04 J	0.01 U	0.02 U	17.00 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
001084	INEL	Solidified Inorganics	213	4	17.00 U	0.04 J	0.25 J	0.66 J	0.34 J	0.02 U	0.02 U	17.00 U	0.02 U
001139	INEL	Solidified Inorganics	211	7	17.00 U	0.17 U	34.00	0.16 U	0.23 J	0.17 U	0.16 U	17.00 U	0.16 U
001157	INEL	Combustible	223	339	17.00 U	0.47 J	0.12 J	0.04 U	0.35 J	0.09 U	0.23 J	17.00 U	0.03 U
001161	INEL	Graphite	215	300	17.00 U	0.02 U	0.06 J	0.03 U	0.04 J	0.02 U	0.02 U	17.00 U	0.03 U
001258	RFETS	Solidified Inorganics	211	1	5.00 U	0.01 U	0.15 J	0.01 U	0.14	0.29	0.01 U	5.00 U	0.02 J
001370	INEL	Combustible	223	339	17.00 U	2.70	0.78 J	0.12 U	28.00	0.13 J	0.24 J	17.00 U	0.22 J
001377	INEL	Combustible	223	339	17.00 U	0.36	0.18 J	0.04 U	0.20 J	0.21 J	0.64	17.00 U	0.03 J
001410	INEL	Solidified Inorganics	214	292	17.00 U	0.12 U	0.22 J	0.61 J	0.12 U	0.14 U	0.11 U	17.00 U	0.11 U
001437	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 J	1.40 J	0.01 U	0.08 J	0.16	0.01 U	5.00 U	0.07 J
001475	RFETS	Solidified Inorganics	211	1	5.00 U	0.20 U	0.04 U	0.28 U	0.42 JB	3.40	0.18 U	5.00 U	0.18 U
001493	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 J	0.15 J	0.06 J	0.18	0.18	0.01 U	5.00 U	0.06 J
001619	INEL	Graphite	215	300	17.00 U	0.03 U	0.08 J	0.04 U	0.07 J	0.03 U	0.03 U	17.00 U	0.03 U
001625	INEL	Graphite	215	300	17.00 U	0.02 U	0.13 J	0.02 U	0.05 J	0.02 U	0.02 U	17.00 U	0.02 U
001633	INEL	Solidified Organics	226	432	17.00 U	0.70 U	36.00 B	2.60 J	0.68 U	0.80 U	0.63 U	17.00 U	150.00
001655	INEL	Combustible	223	339	17.00 U	21.00 J	12.00 J	2.60 U	290.00	2.10 U	1.70 U	17.00 U	16.00 J
001662	INEL	Graphite	215	300	17.00 U	0.02 U	0.08 J	0.02 U	0.07 J	0.02 U	0.02 U	17.00 U	0.02 U
001663	RFETS	Solidified Organics	226	432	17.00 U	5.50	0.38 U	0.59 U	0.57 J	4.40	0.38 U	17.00 U	0.38 U
001667	INEL	Graphite	215	300	17.00 U	0.02 U	0.17 J	0.05 J	0.05 J	0.02 U	0.02 U	17.00 U	0.02 U
001670	RFETS	Salt Waste	224	411	5.00 U	0.09 J	1.10 B	0.14 J	0.16 JB	0.10	0.03 U	5.00 U	1.80 B
001677	INEL	Heterogeneous	221	302	17.00 U	2.00	45.00	0.45 U	0.50 U	1.00	0.46 U	17.00 U	130.00
001678	RFETS	Combustible	223	339	5.00 U	23.00	0.39 J	0.14 U	64.00 E	0.99	0.45 J	5.00 U	0.14 J
001689	INEL	Heterogeneous	221	302	17.00 U	0.04 J	0.20 J	0.13 J	0.22 J	0.09 J	0.03 U	17.00 U	0.03 U
001692	RFETS	Solidified Organics	226	432	17.00 U	0.25 U	0.22 U	0.40 J	0.24 U	1.30	0.23 U	17.00 U	0.23 U
001695	INEL	Combustible	223	339	17.00 U	13.00 J	4.80 BJ	2.30 U	290.00	1.80 U	1.40 U	17.00 U	1.50 J
001697	INEL	Graphite	215	300	17.00 U	0.02 U	0.09 J	0.02 U	0.04 J	0.02 U	0.02 U	17.00 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
001751	RFETS	Uncategorized Metal	217	320	5.00 U	0.01 U	0.12 J	0.01 U	0.08 J	0.02	0.01 U	5.00 U	0.02 J
001752	INEL	Graphite	215	300	17.00 U	0.02 U	0.10 J	0.02 U	0.04 J	0.02 U	0.02 U	17.00 U	0.02 U
001754	INEL	Uncategorized Metal	217	320	1.30 U	0.04 U	0.43 J	0.28 J	0.11 J	0.04 U	0.06 U	1.30 U	0.06 U
001757	INEL	Inorganic Non-metal	222	371	17.00 U	2.40	0.62	0.04 U	0.96	0.03 U	0.03 U	17.00 U	0.03 J
001773	INEL	Graphite	215	300	17.00 U	0.02 U	0.10 J	0.02 U	0.04 J	0.02 U	0.02 U	17.00 U	0.02 U
001779	INEL	Graphite	215	300	17.00 U	0.02 U	0.06 J	0.02 U	0.03 J	0.02 U	0.02 U	17.00 U	0.02 U
001784	INEL	Combustible	223	339	17.00 U	0.73 J	0.17 J	0.04 U	0.13 J	0.26 J	0.12 J	17.00 U	0.03 U
001813	INEL	Solidified Inorganics	213	4	17.00 U	6.00 U	6.00 U	1700.0	6.10 U	6.20 U	5.70 U	17.00 U	5.70 U
001873	INEL	Solidified Inorganics	214	292	17.00 U	0.04 U	0.11 J	0.07 J	0.17 J	0.04 U	0.03 U	17.00 U	0.03 U
001899	RFETS	Solidified Inorganics	211	3	5.00 U	130.00 U	15000 U	180.00 U	23000	150.00	120.00 U	5.00 U	120.00 U
001900	INEL	Solidified Inorganics	214	292	17.00 U	0.04 U	0.15 J	0.19 J	0.20 J	0.12 J	0.03 U	17.00 U	0.03 U
001919	RFETS	Uncategorized Metal	217	320	5.00 U	0.02 J	0.53 J	0.01 U	0.09 J	0.01	0.01 U	5.00 U	0.01 J
001937	RFETS	Solidified Organics	212	3	5.00 U	16.00 U	180.00 U	22.00 U	2100.0	18.00	14.00 U	5.00 U	14.00 U
002013	RFETS	Solidified Organics	212	3	5.00 U	11.00 U	120.00 U	16.00 U	1600.0	13.00	10.00 U	5.00 U	10.00 U
002046	INEL	Solidified Organics	212	3	17.00 U	37.00 U	530.00	35.00 U	5600.0	39.00 U	35.00 U	17.00 U	35.00 U
002065	INEL	Solidified Inorganics	214	292	5.00 J	0.10 J	0.16 U	0.26 U	0.16 U	0.12 U	0.09 U	5.00 U	0.09 U
002084	INEL	Solidified Inorganics	213	4	34.00 U	0.04 U	0.19 J	0.04 U	0.18 J	0.10 J	0.04 U	34.00 U	0.04 U
002220	RFETS	Uncategorized Metal	217	481	5.00 U	0.03 U	4.00 JB	0.04 U	0.03 U	0.03	0.03 U	5.00 U	0.17 JB
002222	INEL	Graphite	215	300	17.00 U	0.02 U	0.12 J	0.02 U	0.12 J	0.02 U	0.02 U	17.00 U	0.02 U
002338	RFETS	Inorganic Non-metal	222	371	17.00 U	0.78 U	32.00	1.10 U	0.76 U	0.90	0.71 U	17.00 U	140.00
002354	INEL	Combustible	223	339	17.00 U	2.80	8.20	0.07 U	15.00	0.87 J	0.42 J	17.00 U	0.09 J
002363	INEL	Inorganic Non-metal	222	371	17.00 U	0.20 J	0.25 J	0.04 U	0.14 J	0.40	0.06 J	17.00 U	0.04 J
002365	INEL	Uncategorized Metal	217	480	17.00 U	0.07 U	13.00	0.10 U	0.09 J	0.43 J	0.13 J	17.00 U	0.06 U
002542	INEL	Solidified Organics	212	3	17.00 U	11.00	180.00	7.60 U	2100.0	8.40 U	7.70 U	17.00 U	7.70 U
002678	RFETS	Solidified Organics	226	432	17.00 U	0.89 U	130.00	1.30 U	0.87 U	1.00	0.81 U	17.00 U	170.00

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
002791	INEL	Inorganic Non-metal	222	371	17.00 U	10.00	0.72	0.07 U	0.35 J	0.05 U	0.08 J	17.00 U	0.06 J
002797	RFETS	Solidified Organics	226	432	17.00 U	2.60 J	0.40 U	1.20 J	0.43 U	2.40	0.40 U	17.00 U	0.41 U
002814	RFETS	Solidified Inorganics	211	7	5.00 U	0.20 U	40.00 J	0.29 U	0.58 J	0.24	0.19 U	5.00 U	1.60 J
003017	INEL	Solidified Inorganics	211	1	5.00 U	0.05 U	5.80 U	0.07 U	0.13 J	0.15 J	0.05 U	5.00 U	0.05 U
003088	INEL	Inorganic Non-metal	222	371	17.00 U	0.31 J	0.27 J	0.04 U	0.28 J	0.13 J	0.05 J	17.00 U	0.03 J
003091	RFETS	Inorganic Non-metal	222	371	17.00 U	0.04 U	0.62 J	0.04 U	0.20 J	0.08	0.03 U	17.00 U	0.03 J
003111	INEL	Inorganic Non-metal	222	371	17.00 U	7.30 E	0.29 J	0.04 U	0.25 J	0.03 U	0.04 J	17.00 U	0.04 J
003121	RFETS	Solidified Inorganics	211	7	5.00 U	0.14 U	2.50 U	0.50 JD	0.13 U	0.16	0.12 U	5.00 U	0.12 U
003129	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	1.50 J	0.03 U	0.08 J	0.07	0.02 U	5.00 U	0.04 J
003130	RFETS	Solidified Inorganics	211	7	5.00 U	0.04 U	1.90 JD	0.06 U	0.08 JD	0.10	0.04 U	5.00 U	0.10 JD
003173	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	1.80	0.02 U	0.14 J	0.07	0.02 U	5.00 U	0.32
003181	RFETS	Solidified Inorganics	211	7	5.00 U	0.01 U	0.18 J	0.02 U	0.07 J	0.02	0.01 U	5.00 U	0.01 J
003189	INEL	Solidified Organics	212	3	17.00 U	82.00 U	4100.0	77.00 U	15000	85.00 U	78.00 U	17.00 U	78.00 U
003192	RFETS	Solidified Inorganics	211	7	5.00 U	0.23 U	46.00 U	0.33 U	0.62 J	0.26	0.21 U	5.00 U	0.21 U
003215	RFETS	Solidified Inorganics	211	7	5.00 U	0.01 U	1.00 J	0.02 U	0.07 J	0.02	0.06 J	5.00 U	0.03 J
003277	RFETS	Solidified Inorganics	211	1	5.00 U	0.01 J	0.14 J	0.01 U	0.17	0.10	0.01 U	5.00 U	0.04 J
003394	RFETS	Solidified Inorganics	211	7	5.00 U	0.03 U	4.70 J	0.04 U	0.12 J	0.03	0.03 U	5.00 U	0.10 J
003406	RFETS	Solidified Inorganics	211	7	5.00 U	0.01 U	0.80 J	0.01 U	0.13	0.03	0.01 J	5.00 U	0.02 J
003455	RFETS	Solidified Inorganics	211	3	5.70 J	250.00 U	21000 U	350.00 U	43000	290.00	230.00 U	5.00 U	230.00 U
003547	RFETS	Solidified Inorganics	211	7	5.00 U	0.09 U	15.00 J	0.13 U	0.12 J	0.10	0.08 U	5.00 U	0.15 J
003577	RFETS	Solidified Inorganics	211	1	5.00 U	0.01 U	0.10 J	0.36	0.11 J	0.06	0.10 J	5.00 U	0.03 J
003854	INEL	Solidified Organics	212	3	17.00 U	50.00	1800.0	35.00 U	6700.0	39.00 U	36.00 U	17.00 U	36.00 U
003890	INEL	Solidified Inorganics	111	7	5.00 U	0.03 U	0.92	0.08 J	0.19 J	0.06 J	0.03 U	5.00 U	0.03 U
003921	INEL	Solidified Inorganics	111	7	5.00 U	0.03 U	2.90	0.05 U	0.32 J	0.04 U	0.03 U	5.00 U	0.03 U
003991	INEL	Combustible	223	339	17.00 U	0.13 J	0.05 J	0.02 U	0.03 J	0.06 J	0.02 J	17.00 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
003997	INEL	Combustible	223	339	15.00 U	0.23 J	0.13 J	0.04 U	0.04 U	0.29 J	0.39 J	15.00 U	0.05 U
004099	INEL	Solidified Inorganics	211	1	5.00 U	0.10 J	0.25	0.02 U	0.01 J	0.12 J	0.01 U	5.00 U	0.02 J
004111	RFETS	Salt Waste	224	411	5.00 U	0.06 J	0.12 U	0.13 J	0.10 JB	0.06	0.03 U	5.00 U	0.03 U
004112	INEL	Graphite	215	300	17.00 U	0.01 U	0.09 J	0.02 U	0.03 J	0.01 U	0.02 U	17.00 U	0.02 U
004123	INEL	Combustible	223	339	17.00 U	0.10 J	0.09 J	0.02 U	0.06 J	0.08 J	0.17 J	17.00 U	0.02 U
004125	INEL	Uncategorized Metal	217	480	17.00 U	0.03 U	0.05 J	0.04 U	0.05 J	0.07 J	0.03 U	17.00 U	0.03 U
004150	INEL	Graphite	215	300	17.00 U	0.02 U	0.11 J	0.02 U	0.08 J	0.02 U	0.02 U	17.00 U	0.02 U
004160	INEL	Combustible	223	339	17.00 U	580.00	290.00	120.00 U	25000	78.00 U	110.00 U	17.00 U	130.00 U
004166	INEL	Inorganic Non-metal	222	371	17.00 U	0.03 U	0.28 J	0.04 U	0.26 J	0.05 J	0.03 U	17.00 U	0.03 U
004186	INEL	Combustible	223	339	17.00 U	0.29 J	0.06 J	0.11 J	1.20	0.07 J	0.11 J	17.00 U	0.02 U
004195	RFETS	Salt Waste	224	411	5.00 U	0.01 U	0.11 J	0.14	0.16 B	0.01	0.01 U	5.00 U	0.02 J
004196	INEL	Graphite	215	300	17.00 U	0.03 J	0.13 J	0.02 U	0.07 J	0.08 J	0.03 J	17.00 U	0.02 U
004206	INEL	Combustible	223	339	15.00 U	0.36 J	0.13 J	0.18 J	0.05 J	0.19 J	0.26 J	15.00 U	0.02 U
004208	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	0.03 J	0.01 U	0.02 U	17.00 U	0.02 U
004283	INEL	Solidified Inorganics	211	1	17.00 U	0.02 U	0.17 J	0.29 J	0.12 J	0.14 J	0.02 U	17.00 U	0.02 U
004326	INEL	Solidified Inorganics	213	4	17.00 U	0.02 J	0.23 J	0.02 U	0.39 J	0.09 J	0.02 U	17.00 U	0.02 J
004393	INEL	Solidified Inorganics	211	1	5.00 U	0.02 U	0.43	0.02 U	0.08 J	0.08 J	0.02 U	5.00 U	0.02 U
004410	INEL	Solidified Inorganics	211	1	5.00 U	0.03 U	0.28 J	0.04 U	0.20 J	0.11 J	0.03 U	5.00 U	0.03 U
004495	INEL	Solidified Inorganics	213	4	17.00 U	0.02 U	0.15 J	0.23 J	0.19 J	0.02 U	0.02 U	17.00 U	0.02 J
004516	INEL	Solidified Inorganics	211	1	5.00 U	0.03 U	0.21 J	0.09 J	0.12 J	0.60	0.03 U	5.00 U	0.03 U
004884	INEL	Solidified Inorganics	213	4	51.00 U	0.03 U	0.59 J	6.10	0.60 J	0.54 J	0.03 U	51.00 U	0.03 U
004963	INEL	Combustible	223	339	17.00 U	7.10	0.19 J	0.07 U	13.00	0.91 J	0.40 J	17.00 U	0.07 U
004968	RFETS	Uncategorized Metal	217	320	22.00 J	0.55 U	1.70 U	0.78 U	2.90 J	0.63	0.50 U	5.00 U	0.50 U
004981	RFETS	Uncategorized Metal	217	320	5.00 U	0.01 J	0.39 J	0.01 U	0.49	0.01	0.01 U	5.00 U	0.01 J
004988	RFETS	Salt Waste	224	411	5.00 U	0.06 J	0.30 J	0.04 U	0.10 JB	0.09	0.03 U	5.00 U	0.32 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
005006	RFETS	Salt Waste	224	411	5.00 U	0.04 J	0.39	0.04 U	0.07 JB	0.10	0.03 U	5.00 U	0.42
005012	INEL	Combustible	223	339	17.00 U	0.06 J	0.18 J	0.02 U	0.18 J	0.04 J	0.04 J	17.00 U	0.02 J
005015	INEL	Solidified Organics	226	432	17.00 U	1.40 U	82.00	2.00 U	1.40 U	1.60 U	1.30 U	17.00 U	230.00
005235	INEL	Solidified Organics	226	432	17.00 U	0.28 J	0.61 JB	0.04 U	0.38 J	1.30	0.03 U	17.00 U	0.03 U
005262	INEL	Solidified Organics	212	3	17.00 U	230.00 U	33000	220.00 U	52000	240.00 U	220.00 U	17.00 U	220.00 U
005358	INEL	Solidified Inorganics	211	1	17.00 U	0.03 J	0.30 J	0.80 J	0.23 J	1.00	0.02 U	17.00 U	0.02 U
005398	INEL	Solidified Inorganics	211	1	5.00 U	0.03 U	4.90	0.04 U	0.07 J	0.04 J	0.03 U	5.00 U	0.03 U
005415	INEL	Solidified Inorganics	211	1	5.00 U	0.03 U	0.16 J	0.10 J	0.09 J	0.31 J	0.03 U	5.00 U	0.03 U
005530	INEL	Graphite	215	303	17.00 U	0.07 J	0.11 J	0.02 U	0.06 J	0.05 J	0.02 J	17.00 U	0.02 U
005535	INEL	Solidified Organics	226	432	17.00 U	0.06 U	0.17 JD	0.16 JD	0.17 JD	2.80 D	0.05 U	17.00 U	0.05 U
005735	INEL	Solidified Inorganics	211	7	5.00 U	0.03 U	0.56	0.16 J	0.08 J	0.04 J	0.03 U	5.00 U	0.03 U
005738	INEL	Solidified Inorganics	211	7	5.00 U	0.02 U	0.29	0.03 U	0.08 J	0.02 U	0.02 U	5.00 U	0.02 U
006242	INEL	Inorganic Non-metal	222	371	17.00 U	3.70	0.26 J	0.04 U	0.28 J	0.03 U	0.04 J	17.00 U	0.03 J
006252	RFETS	Lead/Cadmium Metal	123	339	5.00 U	9.20 JD	5.80 U	5.20 U	460.00 D	4.20	3.30 U	5.00 U	3.40 U
006325	RFETS	Solidified Inorganics	213	4	100.00 U	0.01 U	0.12 J	0.70	0.11 J	0.33	0.01 U	100.00 U	0.08 J
006669	INEL	Solidified Inorganics	214	292	5.00 U	0.14 U	0.33 J	1.20 J	0.37 J	0.16 U	0.13 U	5.00 U	0.22 J
006773	RFETS	Solidified Inorganics	213	4	120.00 U	0.10 U	18.00 J	20.00	0.17 J	0.40	0.09 U	120.00 U	0.18 J
006857	INEL	Combustible	223	339	17.00 U	0.34 J	0.11 J	0.02 U	0.70 J	0.15 J	0.26 J	17.00 U	0.04 J
006865	RFETS	Solidified Organics	226	432	5.00 U	0.07 U	0.66 J	0.63 J	0.88 J	1.40	0.07 U	5.00 U	0.08 J
006876	INEL	Filter	219	335	17.00 U	0.04 J	0.03 J	0.06 J	0.02 J	0.34 J	0.12 J	17.00 U	0.02 U
006879	INEL	Solidified Organics	226	432	17.00 U	0.09 U	0.17 J	0.18 J	0.16 J	0.99 J	0.08 U	17.00 U	0.09 U
006886	INEL	Solidified Organics	226	432	17.00 U	0.31 U	12.00 B	2.60	0.30 U	0.54 J	0.28 U	17.00 U	57.00
007034	INEL	Combustible	216	337	15.00 U	210.00	290.00	2.80 U	1.90 U	2.30 U	1.80 U	15.00 U	310.00
007146	INEL	Inorganic Non-metal	222	371	17.00 U	1.60 U	150.00	2.30 U	1.60 U	1.80 U	1.40 U	17.00 U	280.00
007170	INEL	Combustible	216	337	18.00 U	0.25 U	71.00	0.35 U	0.34 U	0.22 U	0.31 U	18.00 U	92.00

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
007231	INEL	Filter	219	338	17.00 U	0.11 U	21.00	0.16 U	0.15 U	0.10 U	0.90 J	17.00 U	6.20
007511	INEL	Inorganic Non-metal	122	374	17.00 U	0.04 U	0.48	0.06 J	0.35 J	0.04 U	0.03 U	17.00 U	0.03 U
007518	INEL	Inorganic Non-metal	122	374	17.00 U	0.12 J	0.44 J	0.08 U	0.16 J	1.30	0.10 J	17.00 U	0.05 U
007667	INEL	Salt Waste	124	411	5.00 U	0.01 J	0.10 J	0.01 U	0.12	0.02 J	0.01 U	5.00 U	0.01 U
007920	INEL	Filter	121	302	17.00 U	0.22 U	1.80 J	0.72 J	0.22 U	0.26 U	0.20 U	17.00 U	0.29 J
008203	INEL	Inorganic Non-metal	118	440	17.00 U	0.06 U	0.10 J	0.20 J	0.13 J	0.39 J	0.05 U	17.00 U	0.05 U
008207	INEL	Heterogeneous	116	336	20.00 J	0.87 U	0.27 J	0.10 U	0.12 J	2.00 J	1.30 U	17.00 U	0.06 U
008218	INEL	Heterogeneous	116	330	17.00 U	1.70	0.20 J	0.10 U	0.16 J	1.30	0.84 J	17.00 U	0.06 U
008269	INEL	Uncategorized Metal	117	320	17.00 U	0.18 U	0.28 U	0.64 JD	0.32 JD	0.21 U	0.16 U	17.00 U	0.16 U
008287	INEL	Inorganic Non-metal	122	374	17.00 U	0.03 U	0.20 J	0.09 J	0.16 J	0.03 U	0.03 U	17.00 U	0.03 U
008359	INEL	Heterogeneous	116	330	17.00 U	1.50 J	0.28 U	0.73 J	0.18 U	2.70	2.00 J	17.00 U	0.16 U
008383	INEL	Lead/Cadmium Metal	123	339	6.10 J	13.00 J	1000.0	7.00 U	930.00	5.60 U	4.50 U	5.00 U	4.50 U
008848	INEL	Inorganic Non-metal	218	440	17.00 U	22.00	36.00	0.20 U	0.47 J	0.22 U	0.20 U	17.00 U	1.30
008859	INEL	Inorganic Non-metal	218	440	17.00 U	1.10	11.00	0.59 U	66.00	0.48 U	0.38 U	17.00 U	0.80 J
008860	INEL	Uncategorized Metal	217	480	17.00 U	1.10 U	160.00	1.50 U	1.00 U	1.20 U	0.96 U	17.00 U	4.30
008864	INEL	Uncategorized Metal	217	480	17.00 U	0.09 U	20.00	0.13 U	0.14 J	0.11 U	0.08 U	17.00 U	0.98 J
008872	INEL	Solidified Inorganics	214	292	5.00 U	0.04 U	0.23 J	0.31 J	0.12 J	0.09 J	0.03 U	5.00 U	0.06 J
008874	RFETS	Uncategorized Metal	217	480	12.00 J	33.00 U	5400.0 U	46.00 U	32.00 U	38.00	30.00 U	5.00 U	30.00 U
008878	INEL	Uncategorized Metal	217	480	17.00 U	4.50 U	580.00	6.30 U	4.30 U	5.10 U	4.00 U	17.00 U	4.10
008880	RFETS	Graphite	115	312	5.00 U	1.60 J	250.00 J	1.80 U	1.20 J	1.50	1.20 U	5.00 U	3.00 J
009006	INEL	Solidified Inorganics	211	7	17.00 U	0.04 J	0.63 J	0.02 U	0.18 J	0.08 J	0.02 U	17.00 U	0.02 U
009011	RFETS	Solidified Inorganics	211	7	5.00 U	0.01 U	2.30 JB	0.02 U	0.17 B	0.04	0.01 U	5.00 U	0.09 JB
009061	RFETS	Inorganic Non-metal	218	440	5.00 U	0.43 J	6.00	0.13 U	0.49 J	0.10	0.08 U	5.00 U	18.00
009180	INEL	Combustible	223	339	17.00 U	22.00	220.00	0.79 U	150.00	0.68 J	0.70 U	17.00 U	0.81 U
009225	INEL	Uncategorized Metal	217	481	17.00 U	0.03 U	2.20	0.04 U	0.03 J	0.03 U	0.03 U	17.00 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
009252	INEL	Combustible	223	339	17.00 U	1100.0	390.00	28.00 U	3700.0	22.00 U	18.00 U	17.00 U	18.00 J
009296	INEL	Combustible	223	339	17.00 U	2.80 U	2.50 U	740.00	2.70 U	3.20 U	4.10	17.00 U	2.50 U
009299	INEL	Combustible	223	339	17.00 U	0.10 J	1.10	0.03 J	0.02 U	0.04 J	0.11 J	17.00 U	0.02 U
009399	INEL	Inorganic Non-metal	218	440	17.00 U	1.30	37.00	0.52 U	83.00 E	0.42 U	0.33 U	17.00 U	2.10
009422	RFETS	Combustible	216	337	5.00 U	5.70 JD	920.00 JD	7.40 U	26.00 JD	6.00	4.70 U	5.00 U	5.20 JD
009423	INEL	Combustible	216	337	17.00 U	1.90 U	300.00	160.00	1.90 U	1.90 U	1.80 U	17.00 U	1.80 U
009435	INEL	Combustible	216	337	17.00 U	15.00	55.00	0.52 U	0.43 J	0.42 U	0.33 U	17.00 U	0.33 U
009449	INEL	Inorganic Non-metal	218	440	17.00 U	3.10	0.23 J	0.06 U	0.66 J	0.36 J	0.06 J	17.00 U	0.04 U
009471	INEL	Combustible	216	337	18.00 U	4.50	24.00	0.08 U	0.08 U	0.50 U	0.07 U	18.00 U	0.08 U
009475	INEL	Inorganic Non-metal	218	442	17.00 U	0.74 U	140.00	0.70 U	0.77 U	1.10	0.71 U	17.00 U	0.71 U
009489	INEL	Combustible	216	337	18.00 U	4.60	59.00	0.20 U	0.20 U	0.13 U	0.18 U	18.00 U	0.21 U
009587	INEL	Uncategorized Metal	117	320	5.00 U	0.01 J	0.24	0.15	0.24	0.01 U	0.01 U	5.00 U	0.01 J
009591	INEL	Inorganic Non-metal	118	440	17.00 U	0.04 U	0.09 J	0.05 U	0.10 J	0.05 J	0.03 U	17.00 U	0.03 U
009592	INEL	Inorganic Non-metal	118	440	17.00 U	0.07 U	0.11 J	0.14 J	0.13 J	0.26 J	0.06 U	17.00 U	0.06 U
009596	INEL	Uncategorized Metal	117	320	17.00 U	0.13 U	17.00	0.18 U	0.25 J	0.15 U	0.12 U	17.00 U	0.54 J
009599	INEL	Inorganic Non-metal	118	440	17.00 U	0.11 J	0.33 J	0.04 U	0.18 J	0.37	0.04 J	17.00 U	0.03 U
009602	INEL	Inorganic Non-metal	218	442	17.00 U	1.90 U	250.00	2.70 U	1.80 U	2.20 U	1.70 U	17.00 U	1.70 U
009694	INEL	Graphite	215	300	17.00 U	0.02 U	0.18 J	0.02 U	0.15 J	0.02 U	0.02 U	17.00 U	0.02 U
009735	INEL	Graphite	215	300	17.00 U	0.02 U	0.12 J	0.02 U	0.06 J	0.02 U	0.02 U	17.00 U	0.22 J
009773	INEL	Combustible	223	339	17.00 U	74.00	450.00	5.20 U	1300.0	5.80 U	5.30 U	17.00 U	5.30 U
009787	RFETS	Solidified Organics	212	3	5.00 U	180.00 J	10000 U	240.00 U	32000 B	200.00	160.00 U	5.00 U	160.00 U
009873	RFETS	Solidified Inorganics	211	1	5.00 U	0.05 U	8.10 U	0.06 U	0.20 J	0.16	0.04 U	5.00 U	0.04 U
010216	INEL	Filter	219	338	17.00 U	0.70 U	88.00	0.99 U	5.60	0.62 U	0.89 U	17.00 U	260.00
010224	INEL	Filter	219	338	17.00 U	0.21 U	42.00	0.30 U	0.29 U	0.19 U	0.78 J	17.00 U	20.00
010230	INEL	Heterogeneous	216	330	17.00 U	0.11 U	200.00 E	0.16 U	0.76 J	2.20	0.34 J	17.00 U	290.00 E

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
010273	INEL	Combustible	216	337	18.00 U	4.40	37.00	0.14 U	0.14 U	0.09 U	0.13 U	18.00 U	0.15 U
010295	INEL	Inorganic Non-metal	218	442	17.00 U	0.40 J	7.00	0.08 U	0.26 J	0.10 J	0.24 J	17.00 U	0.05 U
010305	RFETS	Inorganic Non-metal	218	442	5.00 U	0.66 U	110.00 U	0.93 U	0.66 J	0.75	0.59 U	5.00 U	0.60 U
010364	RFETS	Combustible	216	337	5.00 U	5.20 J	120.00 U	1.20 U	0.81 U	0.95	0.75 U	5.00 U	0.76 U
010371	INEL	Combustible	216	337	1.00 U	46.00	140.00 E	350.00 E	0.75 J	0.42 J	0.34 U	1.20 U	0.75 J
010407	RFETS	Uncategorized Metal	217	480	16.00 J	0.73 J	13.00 J	0.16 U	6.30	0.16	0.10 U	5.00 U	0.12 J
010411	INEL	Combustible	216	337	17.00 U	78.00	140.00	120.00	1.80 U	2.10 U	1.70 U	17.00 U	1.70 U
010415	INEL	Inorganic Non-metal	218	442	17.00 U	0.03 U	4.00	0.04 U	0.18 J	0.03 U	0.03 U	17.00 U	0.03 U
010426	INEL	Inorganic Non-metal	218	442	17.00 U	0.41 J	12.00 E	0.02 U	0.26 J	0.08 J	0.30 J	17.00 U	0.02 J
010463	INEL	Solidified Inorganics	213	4	34.00 U	0.28 U	40.00 J	0.40 U	0.35 J	0.32 U	0.25 U	34.00 U	0.25 U
010487	INEL	Salt Waste	224	414	17.00 U	2.30 J	23.00	0.72 U	50.00	0.58 U	0.46 U	17.00 U	0.46 U
010492	INEL	Uncategorized Metal	217	480	17.00 U	0.55 U	74.00	0.77 U	0.53 U	0.63 U	0.49 U	17.00 U	0.50 U
010498	INEL	Uncategorized Metal	217	480	17.00 U	0.37 J	12.00	0.04 U	0.09 J	0.49 J	0.13 J	17.00 U	0.04 U
010510	RFETS	Heterogeneous	216	336	5.00 U	9.40 J	240.00 B	18.00 J	3.80 JB	1.80	1.40 U	5.00 U	340.00 B
010546	RFETS	Heterogeneous	216	330	16.00 J	44.00 U	6600.0 B	62.00 U	42.00 U	50.00	40.00 U	10.00 U	1600.0 B
010578	INEL	Solidified Organics	226	432	17.00 U	0.95 U	65.00	1.40 U	0.92 U	1.10 U	0.86 U	17.00 U	200.00
010588	RFETS	Solidified Inorganics	211	2	5.00 U	0.82 U	76.00	1.20 U	0.84 J	0.94	0.74 U	5.00 U	160.00
010663	INEL	Combustible	216	337	18.00 U	0.36 U	110.00	0.51 U	0.49 U	0.32 U	0.46 U	18.00 U	140.00
010676	INEL	Heterogeneous	216	330	18.00 U	0.29 U	92.00	0.41 U	0.49 J	0.95 J	0.37 U	18.00 U	110.00
010800	INEL	Filter	219	338	17.00 U	0.10 U	23.00	0.14 U	0.13 U	0.14 J	0.12 U	17.00 U	42.00
010807	INEL	Combustible	216	337	17.00 U	1.20 U	120.00	1.80 U	1.20 U	1.40 U	1.10 U	17.00 U	240.00
010808	INEL	Combustible	216	337	17.00 U	3.60	53.00	21.00	0.40 U	0.41 U	0.37 U	17.00 U	120.00
010814	RFETS	Solidified Inorganics	211	1	5.00 U	0.33 U	53.00 E	0.47 U	0.80 JB	0.38	0.30 U	5.00 U	96.00 E
010837	INEL	Solidified Organics	226	432	17.00 U	0.42 U	35.00	0.59 U	1.30 J	0.48 U	0.38 U	17.00 U	78.00
010848	INEL	Filter	219	338	15.00 U	0.28 U	100.00	0.39 U	0.37 U	0.24 U	0.92 J	15.00 U	95.00

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
010883	INEL	Solidified Organics	226	432	17.00 U	1.10 U	81.00	1.50 U	1.00 U	1.20 U	0.98 U	17.00 U	190.00
010921	INEL	Inorganic Non-metal	222	371	17.00 U	0.09 U	3.60	0.13 U	0.22 J	0.11 U	0.08 U	17.00 U	20.00
011004	INEL	Uncategorized Metal	217	480	17.00 U	0.03 U	10.00 E	0.04 U	0.13 J	0.03 U	0.03 U	17.00 U	0.03 U
011021	INEL	Solidified Organics	226	432	17.00 U	0.17 U	7.20	0.24 U	0.19 J	7.50	0.15 U	17.00 U	0.29 J
011042	INEL	Inorganic Non-metal	218	442	17.00 U	0.59 U	83.00	0.83 U	0.57 U	0.67 U	0.53 U	17.00 U	0.53 U
011044	INEL	Inorganic Non-metal	218	440	17.00 U	0.98 J	22.00	0.48 U	63.00	0.38 U	0.30 U	17.00 U	0.30 U
011067	RFETS	Solidified Inorganics	213	4	5.00 U	1.10 U	190.00 U	1.60 U	1.70 J	1.30	1.00 U	5.00 U	1.00 U
011102	RFETS	Solidified Inorganics	211	1	5.00 U	0.26 U	54.00 U	0.37 U	2.70 J	0.30	0.24 U	5.00 U	0.24 U
011109	INEL	Solidified Inorganics	211	1	17.00 U	0.22 U	44.00	0.21 U	0.23 U	0.23 U	0.21 U	17.00 U	0.78 J
011147	INEL	Solidified Inorganics	213	4	94.00 U	0.26 U	56.00	0.24 U	0.27 J	0.26 U	0.24 U	94.00 U	0.24 U
011173	INEL	Uncategorized Metal	217	480	17.00 U	19.00	11.00	0.06 U	5.50	0.37 J	0.07 J	17.00 U	0.48 J
011194	INEL	Inorganic Non-metal	218	442	17.00 U	0.07 U	14.00	0.10 U	0.39 J	0.08 U	0.06 U	17.00 U	2.40
011393	INEL	Uncategorized Metal	217	480	17.00 U	0.14 U	22.00	0.20 U	0.17 J	0.16 U	0.13 U	17.00 U	1.00
011416	INEL	Combustible	216	337	17.00 U	0.61 U	82.00	0.87 U	0.83 J	0.70 U	0.56 U	17.00 U	90.00
011433	INEL	Heterogeneous	216	330	18.00 U	0.36 U	75.00	0.51 U	0.49 U	0.48 J	0.46 U	18.00 U	150.00
011498	RFETS	Solidified Organics	226	432	17.00 U	1.60 U	140.00	2.30 U	1.60 U	1.80	1.40 U	17.00 U	270.00
011529	INEL	Uncategorized Metal	217	480	17.00 U	0.03 U	0.66 J	0.04 U	0.06 J	0.03 U	0.03 U	17.00 U	0.03 U
011601	INEL	Heterogeneous	216	336	17.00 U	0.85 U	160.00	1.20 U	1.20 U	0.75 U	1.10 U	17.00 U	260.00
011607	INEL	Heterogeneous	216	330	17.00 U	3.50	5.80	0.03 U	0.13 J	0.06 J	0.03 U	17.00 U	0.14 J
011637	RFETS	Filter	219	338	5.00 U	0.82 U	120.00 D	1.20 U	0.80 U	0.94	0.74 U	5.00 U	150.00 D
011735	INEL	Heterogeneous	216	330	17.00 U	0.84 U	85.00	1.20 U	2.90	0.96 U	0.76 U	17.00 U	130.00
011749	INEL	Inorganic Non-metal	225	441	17.00 U	0.24 U	39.00	0.34 U	0.65 J	0.27 U	0.22 U	17.00 U	5.50
011785	RFETS	Solidified Inorganics	211	1	5.00 U	0.03 U	0.15 U	0.04 J	0.50	0.13	0.03 U	5.00 U	0.03 U
012021	INEL	Solidified Inorganics	211	1	17.00 U	0.36 U	45.00	0.52 U	0.35 U	0.42 U	0.33 U	17.00 U	18.00
012108	INEL	Solidified Inorganics	214	292	17.00 U	0.36 U	40.00	0.52 U	0.35 U	0.42 U	0.33 U	17.00 U	2.00 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
012111	INEL	Combustible	216	337	18.00 U	1.20 U	160.00	590.00	1.60 U	1.00 U	1.50 U	18.00 U	1.70 U
012215	INEL	Uncategorized Metal	217	480	17.00 U	0.39 U	56.00	0.55 U	0.38 U	0.45 U	0.35 U	17.00 U	9.80
012313	INEL	Heterogeneous	216	336	18.00 U	7.80	92.00	30.00	0.59 U	0.38 U	0.55 U	18.00 U	110.00
012320	INEL	Heterogeneous	216	336	17.00 U	12.00	200.00	2.60 U	1.80 U	2.10 U	1.70 U	17.00 U	300.00
012356	INEL	Filter	219	338	17.00 U	0.26 U	41.00	0.24 U	0.27 U	0.27 U	1.50	17.00 U	29.00
012357	RFETS	Uncategorized Metal	217	480	5.00 U	3.00 U	190.00	4.20 U	2.90 U	3.40	2.70 U	5.00 U	610.00
012433	INEL	Filter	219	338	17.00 U	0.72 J	44.00	0.20 U	36.00	0.12 U	0.21 J	17.00 U	61.00
012469	RFETS	Solidified Inorganics	211	1	5.00 U	0.34 U	23.00	0.48 U	0.57 J	0.38	0.30 U	5.00 U	60.00
012471	RFETS	Filter	219	338	5.00 U	0.56 J	35.00	0.25 U	0.17 U	0.91	0.16 U	5.00 U	10.00
012487	INEL	Inorganic Non-metal	218	440	17.00 U	0.15 J	2.90	2.40	0.19 J	0.06 J	0.02 U	17.00 U	19.00 E
012494	INEL	Heterogeneous	216	330	17.00 U	1.10	85.00	1.60 U	14.00	2.30	1.00 U	17.00 U	160.00
012541	INEL	Inorganic Non-metal	218	442	17.00 U	0.03 U	8.40 E	0.04 U	0.19 J	0.03 U	0.03 U	17.00 U	2.90
012553	INEL	Solidified Inorganics	211	1	17.00 U	0.03 U	6.70 E	0.04 U	0.17 J	0.03 U	0.03 U	17.00 U	0.06 J
012571	INEL	Uncategorized Metal	217	320	17.00 U	0.08 J	0.33 J	0.02 U	0.12 J	0.02 U	0.02 U	17.00 U	0.03 J
012611	INEL	Solidified Inorganics	211	1	17.00 U	0.59 U	66.00	0.83 U	0.57 U	0.67 U	0.53 U	17.00 U	0.53 U
012634	INEL	Solidified Inorganics	211	1	17.00 U	1.60 U	220.00	2.30 U	1.60 U	1.80 U	1.40 U	17.00 U	1.40 U
012749	INEL	Solidified Inorganics	211	1	17.00 U	0.31 U	40.00	0.44 U	0.30 U	0.35 U	0.28 U	17.00 U	6.80
012766	INEL	Heterogeneous	216	336	17.00 U	2.80 U	310.00	4.00 U	4.00	3.20 U	2.50 U	17.00 U	400.00
012802	INEL	Combustible	216	337	17.00 U	1.40 U	250.00	1.30 U	42.00	1.40 U	1.30 U	17.00 U	340.00
012875	RFETS	Solidified Organics	226	432	17.00 U	3.80 U	310.00	5.30 U	3.70 U	4.30	3.40 U	17.00 U	630.00
012878	INEL	Uncategorized Metal	217	480	17.00 U	0.71 U	48.00	0.66 U	0.73 U	0.73 U	0.67 U	17.00 U	210.00
012891	INEL	Heterogeneous	216	330	17.00 U	0.32 U	44.00	0.46 U	0.44 J	0.37 U	0.29 U	17.00 U	51.00
012902	INEL	Filter	219	338	17.00 U	0.01 U	0.49 J	0.02 U	0.02 U	0.01 U	0.02 U	17.00 U	0.70 J
012920	INEL	Inorganic Non-metal	222	371	17.00 U	1.10 U	11.00	1.60 U	1.10 U	1.30 U	1.00 U	17.00 U	180.00
012985	INEL	Inorganic Non-metal	222	371	17.00 U	1.90 U	200.00	2.60 U	1.80 U	2.10 U	1.70 U	17.00 U	390.00

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
012986	INEL	Heterogeneous	221	302	17.00 U	0.62 U	120.00	0.58 U	0.63 U	0.64 U	0.58 U	17.00 U	170.00
012998	INEL	Combustible	216	337	17.00 U	0.64 U	50.00	0.91 U	0.98 J	0.74 U	0.58 U	17.00 U	97.00
013106	INEL	Solidified Inorganics	111	7	5.00 U	0.01 U	0.85	0.02 U	0.23	0.02 U	0.01 U	5.00 U	0.05 J
013229	RFETS	Solidified Organics	226	432	17.00 U	0.14 U	0.12 U	0.32 J	0.14 U	0.27	0.13 U	17.00 U	0.13 U
013231	INEL	Graphite	215	300	17.00 U	0.01 U	0.05 J	0.02 U	0.02 J	0.01 U	0.02 U	17.00 U	0.02 U
013252	INEL	Inorganic Non-metal	222	371	17.00 U	0.16 J	0.25 J	0.04 U	0.22 J	0.03 U	0.03 U	17.00 U	0.03 U
013266	INEL	Combustible	223	339	17.00 U	16.00	0.45 J	0.55 U	65.00	0.45 U	0.35 U	17.00 U	0.36 U
013269	INEL	Inorganic Non-metal	218	440	17.00 U	0.06 U	12.00	0.06 U	0.09 J	0.06 U	0.06 U	17.00 U	0.10 J
013313	INEL	Inorganic Non-metal	218	440	17.00 U	0.08 J	0.25 J	0.04 U	0.24 J	0.03 U	0.03 U	17.00 U	0.03 U
013331	INEL	Salt Waste	124	411	17.00 U	0.07 U	0.12 J	0.10 U	0.10 J	0.26 J	0.06 U	17.00 U	0.06 U
013342	INEL	Inorganic Non-metal	218	440	17.00 U	0.02 U	0.10 J	0.15 J	1.20	0.15 J	0.02 U	17.00 U	0.02 U
013346	RFETS	Inorganic Non-metal	222	371	5.00 U	0.10 J	0.10 U	0.03 U	0.08 JB	0.02	0.02 U	5.00 U	0.02 U
013618	INEL	Heterogeneous	216	330	17.00 U	1.90 U	70.00	2.60 U	1.80 U	2.10 U	1.70 U	17.00 U	290.00
013677	INEL	Filter	219	338	17.00 U	0.04 U	13.00	0.05 U	0.05 J	0.13 J	0.11 J	17.00 U	3.70
013751	INEL	Uncategorized Metal	217	480	17.00 U	0.84 U	58.00	1.20 U	0.81 U	0.96 U	0.76 U	17.00 U	170.00
013763	INEL	Combustible	223	339	2.60 J	78.00	84.00	13.00 U	3800.0 E	13.00 U	14.00 U	1.20 U	15.00 U
013773	RFETS	Solidified Inorganics	111	7	5.00 U	0.07 U	11.00 U	0.10 U	0.09 JB	0.09	0.07 U	5.00 U	0.07 U
013818	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 U	0.25 U	0.03 U	0.10 JB	0.30	0.02 U	5.00 U	0.02 U
013820	RFETS	Solidified Inorganics	211	1	11.00 U	0.22 J	0.18 J	0.04 J	0.12 JB	0.16	0.02 U	11.00 U	0.04 J
013847	INEL	Graphite	215	300	17.00 U	0.02 U	0.08 J	0.02 U	0.03 J	0.02 U	0.02 U	17.00 U	0.02 U
013860	INEL	Combustible	223	339	17.00 U	0.68 J	19.00	0.07 U	1.00	0.62 J	0.36 J	17.00 U	0.07 U
013876	RFETS	Solidified Inorganics	211	7	5.00 U	0.09 U	6.90 U	0.13 U	13.00	0.10	0.08 U	5.00 U	0.08 U
014007	INEL	Solidified Inorganics	211	1	17.00 U	0.02 U	0.16 J	0.02 U	0.10 J	0.06 J	0.02 U	17.00 U	0.03 J
014009	INEL	Solidified Inorganics	211	7	17.00 U	0.08 U	22.00	0.07 U	0.41 J	0.10 J	0.07 U	17.00 U	0.07 U
014010	INEL	Solidified Inorganics	211	7	17.00 U	0.02 U	6.00	0.02 U	0.07 J	0.06 J	0.02 U	17.00 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
014127	RFETS	Solidified Inorganics	211	7	5.00 U	0.02 U	0.83 J	0.02 U	0.09 J	0.05	0.02 U	5.00 U	0.03 J
014170	INEL	Solidified Inorganics	211	7	5.00 U	0.02 J	0.24	0.02 U	0.14 J	0.14 J	0.02 U	5.00 U	0.02 U
014330	INEL	Graphite	215	303	17.00 U	0.35 J	11.00	0.04 U	0.06 J	0.08 J	0.16 J	17.00 U	0.04 U
014334	INEL	Filter	219	335	1.30 U	0.06 U	0.34 J	0.09 J	0.13 J	0.05 U	0.06 U	1.30 U	0.06 U
014339	INEL	Solidified Organics	226	432	17.00 U	0.06 U	0.15 JD	0.31 JD	0.13 JD	0.65 JD	0.05 U	17.00 U	0.05 U
014342	INEL	Graphite	215	303	17.00 U	0.05 U	16.00	0.07 U	0.06 U	0.04 U	0.06 U	17.00 U	0.07 U
014345	INEL	Solidified Organics	226	432	17.00 U	0.05 U	0.23 JB	0.12 J	0.07 J	0.97 J	0.04 U	17.00 U	0.04 U
014346	INEL	Combustible	223	339	17.00 U	5.50	0.55 J	0.02 U	20.00 E	0.54 J	0.20 J	17.00 U	0.03 J
014348	INEL	Graphite	215	300	17.00 U	0.02 U	0.07 J	0.02 U	0.04 J	0.02 U	0.02 U	17.00 U	0.02 U
014354	RFETS	Uncategorized Metal	217	481	5.00 U	0.02 J	0.87 J	0.02 U	0.02 JB	0.01	0.01 U	5.00 U	0.04 J
014357	INEL	Combustible	223	339	2.10 J	48.00	820.00	85.00	3400.0 E	13.00 U	14.00 U	1.30 U	15.00 U
014387	INEL	Solidified Inorganics	211	7	17.00 U	0.02 U	4.30	0.02 U	0.07 J	0.22 J	0.02 U	17.00 U	0.38 J
014466	INEL	Heterogeneous	221	302	17.00 U	0.31 U	50.00	0.44 U	0.30 U	0.35 U	0.28 U	17.00 U	67.00
014484	INEL	Graphite	215	300	17.00 U	0.02 U	0.07 J	0.02 U	0.10 J	0.05 J	0.02 U	17.00 U	0.02 U
014502	RFETS	Solidified Inorganics	211	1	5.00 U	0.02 J	0.29 J	0.01 U	0.10	0.10	0.01 U	5.00 U	0.04 J
014504	RFETS	Solidified Inorganics	211	1	5.00 U	0.03 U	0.30 J	0.04 J	0.16 J	0.46	0.03 U	5.00 U	0.04 J
014773	INEL	Solidified Inorganics	214	292	5.00 U	0.05 U	0.18 J	0.16 J	0.26 J	0.06 U	0.05 U	5.00 U	0.08 J
015228	RFETS	Solidified Organics	226	432	17.00 U	0.17 U	30.00	0.24 U	0.25 J	1.30	0.15 U	17.00 U	1.50
015231	INEL	Inorganic Non-metal	218	440	17.00 U	0.45 J	1.30	0.04 U	0.25 J	0.08 J	0.07 J	17.00 U	0.03
015241	INEL	Inorganic Non-metal	218	442	17.00 U	0.05 U	13.00 E	0.07 U	0.32 J	0.06 U	0.04 U	17.00 U	0.14 J
015249	INEL	Graphite	215	300	17.00 U	0.06 J	2.10	0.02 U	0.07 J	0.01 U	0.02 U	17.00 U	0.02 U
015262	RFETS	Solidified Organics	226	432	17.00 U	1.60 U	230.00 U	2.30 U	1.60 U	3.60	1.40 U	17.00 U	1.40 U
015267	INEL	Uncategorized Metal	217	480	17.00 U	1.40 U	180.00	2.00 U	1.40 U	1.60 U	1.30 U	17.00 U	1.30 U
015338	INEL	Solidified Inorganics	211	7	17.00 U	0.01 U	3.20	0.02 U	0.02 U	0.07 J	0.02 U	17.00 U	0.02 U
015434	RFETS	Solidified Organics	226	432	17.00 U	0.04 U	5.40 J	0.06 U	0.14 J	0.89	0.04 U	17.00 U	0.09 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
015440	RFETS	Solidified Organics	226	432	17.00 U	0.36 U	53.00 J	0.52 U	0.35 U	5.40	0.33 U	17.00 U	0.78 J
015515	RFETS	Solidified Organics	212	3	5.00 U	26.00 U	210.00 U	38.00 U	4400.0	30.00	24.00 U	5.00 U	24.00 U
015532	RFETS	Solidified Organics	212	3	5.00 U	81.00 U	6600.0 U	120.00 U	15000	93.00	73.00 U	5.00 U	74.00 U
015543	INEL	Solidified Organics	212	3	17.00 U	35.00 U	620.00	49.00 U	6000.0	40.00 U	32.00 U	17.00 U	32.00 U
015627	INEL	Graphite	215	300	17.00 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	17.00 U	0.10 J
015655	INEL	Solidified Inorganics	211	7	17.00 U	0.02 U	0.87 J	0.02 U	0.03 J	0.02 U	0.02 U	17.00 U	0.04 J
015674	INEL	Graphite	215	300	17.00 U	0.07 J	3.20	0.02 U	0.19 J	0.02 U	0.02 U	17.00 U	0.02 U
015675	INEL	Uncategorized Metal	217	480	17.00 U	0.07 U	15.00	0.10 U	0.07	0.15 J	0.07 J	17.00 U	0.25 J
015777	RFETS	Solidified Organics	226	432	17.00 U	0.07 U	12.00 J	0.10 U	0.18 J	4.50	0.06 U	17.00 U	0.08 J
015785	RFETS	Solidified Inorganics	211	1	15.00 U	0.32 U	50.00 J	0.46 U	2.10 JB	0.37	0.29 U	15.00 U	0.37 J
015786	INEL	Solidified Inorganics	211	1	17.00 U	0.03 U	6.40	0.03 U	0.07 J	0.30 J	0.03 U	17.00 U	0.09 J
016242	INEL	Graphite	215	300	17.00 U	0.02 U	0.09 J	0.02 U	0.10 J	0.02 U	0.02 U	17.00 U	0.02 U
016612	INEL	Inorganic Non-metal	218	442	17.00 U	0.10 J	3.60	0.04 U	0.22 J	0.03 U	0.03 U	17.00 U	0.03 J
016613	INEL	Solidified Organics	226	432	17.00 U	0.20 U	7.40	0.28 U	2.00 J	0.22 U	0.18 U	17.00 U	0.18 U
016707	INEL	Graphite	215	300	17.00 U	0.02 U	0.04 J	0.02 U	0.02 U	0.02 U	0.02 U	17.00 U	0.02 U
016738	RFETS	Solidified Inorganics	211	7	5.00 U	1.20 U	250.00 JB	1.80 U	1.20 U	1.40	1.10 U	5.00 U	8.00 JB
016790	INEL	Graphite	215	300	17.00 U	0.02 U	12.00 E	0.12 J	0.03 J	0.05 J	0.02 J	17.00 U	1.50
016807	INEL	Solidified Inorganics	211	1	17.00 U	0.17 U	38.00	0.16 U	0.36 J	0.17 U	0.16 U	17.00 U	3.20
016842	INEL	Graphite	215	300	17.00 U	0.02 U	0.35 J	0.02 U	0.04 J	0.02 U	0.02 U	17.00 U	0.02 U
016855	RFETS	Solidified Organics	212	3	5.00 U	130.00 U	2200.0 U	180.00 U	16000 D	140.00	110.00 U	5.00 U	110.00 U
016869	INEL	Solidified Inorganics	211	7	17.00 U	0.19 U	40.00	0.17 U	0.19 U	0.19 U	0.18 U	17.00 U	0.45 J
016964	RFETS	Solidified Inorganics	211	7	5.00 U	1.10 U	170.00 J	1.60 U	1.10 U	1.30	0.99 U	5.00 U	5.90 J
016986	INEL	Inorganic Non-metal	218	442	17.00 U	0.17 U	26.00	0.24 U	0.28 J	0.19 U	0.15 U	17.00 U	2.90
017148	INEL	Solidified Organics	226	432	17.00 U	0.60 U	120.00	0.85 U	0.58 U	0.68 U	0.54 U	17.00 U	0.54 U
017190	INEL	Solidified Inorganics	211	7	17.00 U	3.70 U	680.00	3.50 U	3.80 U	3.90 U	3.50 U	17.00 U	3.50 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
017444	INEL	Graphite	215	300	17.00 U	0.03 U	3.60	0.04 U	0.09 J	0.03 U	0.03 U	17.00 U	0.09 J
017453	INEL	Solidified Organics	212	3	5.00 U	36.00 U	690.00 J	51.00 U	6300.0 J	41.00 U	33.00 U	5.00 U	33.00 U
017486	INEL	Solidified Inorganics	211	1	17.00 U	0.17 U	13.00	0.16 U	1.40	0.43 J	0.16 U	17.00 U	0.75 J
017491	INEL	Graphite	215	300	17.00 U	0.19 U	43.00	0.17 U	0.19 U	0.19 U	0.18 U	17.00 U	0.74 J
017495	INEL	Inorganic Non-metal	218	442	17.00 U	0.07 J	2.60	0.04 U	0.35 J	0.03 U	0.03 U	17.00 U	0.04 J
017496	INEL	Inorganic Non-metal	218	442	17.00 U	0.03 U	1.00	0.04 U	0.23 J	0.03 U	0.03 U	17.00 U	0.03
017698	RFETS	Solidified Inorganics	211	292	5.00 U	2.30 U	510.00 J	3.30 U	3.50 J	2.60	2.10 U	5.00 U	2.50 J
017709	INEL	Solidified Inorganics	211	1	17.00 U	0.02 U	4.70	0.02 U	0.25 J	0.04 J	0.02 U	17.00 U	0.14 J
017728	RFETS	Solidified Inorganics	211	1	5.00 U	0.66 U	61.00 U	0.93 U	3.00 JB	0.75	0.59 U	5.00 U	0.60 U
017742	INEL	Inorganic Non-metal	218	440	17.00 U	0.56 U	33.00	110.00	0.54 U	0.64 U	0.60 J	17.00 U	2.00
017756	RFETS	Solidified Organics	226	432	17.00 U	1.60 U	230.00 U	2.30 U	1.60 U	1.80	1.40 U	17.00 U	2.20 U
017759	INEL	Solidified Organics	226	432	17.00 U	1.10 U	240.00	1.60 U	1.10 U	1.30 U	1.00 U	17.00 U	1.00 U
017788	INEL	Solidified Inorganics	211	7	17.00 U	1.20 U	210.00	1.20 U	1.30 U	1.30 U	1.20 U	17.00 U	1.20 U
017863	INEL	Filter	119	376	17.00 U	0.09 U	0.35 J	0.23 J	0.16 J	0.11 U	0.13 J	17.00 U	0.08 U
018111	RFETS	Solidified Inorganics	211	1	5.00 U	0.01 U	2.20 J	0.02 U	0.47	0.02	0.01 U	5.00 U	0.02 J
018219	RFETS	Solidified Inorganics	211	7	5.00 U	1.10 U	160.00 J	1.60 U	1.10 U	1.20	0.99 U	5.00 U	4.10 J
018299	INEL	Filter	119	376	17.00 U	0.24 J	0.29 J	0.27 J	0.14 U	0.26 J	0.13 U	17.00 U	0.13 U
018413	INEL	Graphite	115	300	5.00 U	0.01 U	0.12	0.01 U	0.09 J	0.01 U	0.01 U	5.00 U	0.01 U
018441	INEL	Graphite	115	300	17.00 U	0.03 U	0.07 J	0.04 U	0.06 J	1.10	0.03 U	17.00 U	0.03 U
018464	INEL	Graphite	115	300	5.00 U	0.02 J	0.49	0.02 U	0.41	0.01 U	0.01 U	5.00 U	0.01 U
018476	INEL	Solidified Inorganics	111	292	5.00 U	0.09 U	0.23 J	0.22 J	0.12 J	0.10 U	0.08 U	5.00 U	0.08 U
018491	INEL	Graphite	115	300	17.00 U	0.03 U	0.07 J	0.04 U	0.09 J	0.03 U	0.03 U	17.00 U	0.03 U
019410	INEL	Lead/Cadmium Metal	123	339	5.00 U	0.61 U	0.95 U	0.86 U	83.00 D	0.70 U	0.55 U	5.00 U	0.55 U
019413	INEL	Lead/Cadmium Metal	123	339	5.00 U	5.50 J	7.70 J	3.80 U	430.00	3.10 U	2.40 U	5.00 U	2.40 U
019572	INEL	Lead/Cadmium Metal	123	339	17.00 U	3.70	0.34 J	0.30 J	7.90	0.52 J	0.81	17.00 U	0.05 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
021031	RFETS	Solidified Inorganics	214	292	5.00 U	0.04 U	0.18 J	0.06 U	0.24 J	0.08	0.04 U	5.00 U	0.05 J
021172	RFETS	Inorganic Non-metal	218	442	5.00 U	0.01 J	0.84 J	0.02 U	0.14 B	0.01	0.01 U	5.00 U	0.02 J
021306	INEL	Solidified Inorganics	213	4	17.00 U	0.03 U	1.80	0.04 U	0.14 J	0.03 U	0.03 U	17.00 U	0.03 J
021392	RFETS	Solidified Inorganics	214	292	5.00 U	0.15 U	32.00 U	0.22 U	19.00	0.18	0.14 U	5.00 U	0.14 U
021442	INEL	Solidified Inorganics	211	1	17.00 U	0.52 U	98.00	0.49 U	0.54 U	0.54 U	0.50 U	17.00 U	7.20
021488	RFETS	Inorganic Non-metal	218	442	5.00 U	0.21 J	3.20 J	0.05 U	7.50 E	0.04	0.03 U	5.00 U	0.33 J
021503	RFETS	Inorganic Non-metal	218	440	5.00 U	0.16 U	18.00 U	0.22 U	0.29 J	0.18	0.14 U	5.00 U	0.14 U
021511	RFETS	Solidified Inorganics	213	4	5.00 U	0.04 U	6.80 U	0.06 U	0.16 J	0.05	0.04 U	5.00 U	0.04 U
021512	INEL	Solidified Inorganics	211	7	17.00 U	0.89 U	110.00	1.30 U	0.87 U	1.00 U	0.81 U	17.00 U	5.00 J
021523	INEL	Solidified Organics	226	432	17.00 U	0.57 U	66.00	0.80 U	0.55 U	2.30	0.51 U	17.00 U	0.52 U
021565	INEL	Solidified Inorganics	211	7	17.00 U	0.93 U	190.00	0.87 U	0.97 J	0.97 U	0.89 U	17.00 U	1.00
021572	INEL	Solidified Inorganics	211	7	17.00 U	0.48 U	92.00	0.45 U	0.50 U	0.50 U	0.46 U	17.00 U	0.78 J
021600	RFETS	Solidified Inorganics	211	1	5.00 U	0.26 U	55.00	0.37 U	0.40 J	0.30	0.24 U	5.00 U	3.40
021631	INEL	Inorganic Non-metal	218	442	17.00 U	0.03 U	8.60 E	0.04 U	0.32 J	0.04 J	0.09 J	17.00 U	2.20
021698	INEL	Inorganic Non-metal	218	440	17.00 U	1.00 U	37.00	86.00	2.30	1.20 U	0.95 U	17.00 U	16.00
021699	INEL	Solidified Inorganics	213	4	68.00 U	0.31 U	47.00	0.44 U	0.68 J	0.35 U	0.28 U	68.00 U	26.00
021700	RFETS	Solidified Inorganics	213	4	5.00 U	0.04 J	0.26	0.01 U	0.48	0.01	0.01 U	5.00 U	0.13
021806	INEL	Inorganic Non-metal	218	440	17.00 U	0.22 U	16.00	84.00	0.44 J	0.22 U	0.33 J	17.00 U	6.60
021816	INEL	Solidified Inorganics	211	1	17.00 U	0.11 U	29.00	0.10 U	0.31 J	0.31 J	0.11 U	17.00 U	0.11 U
021865	INEL	Solidified Inorganics	211	1	17.00 U	0.89 U	120.00	1.30 U	0.87 U	1.00 U	0.81 U	17.00 U	0.81 U
021993	INEL	Solidified Inorganics	211	2	17.00 U	0.42 U	51.00	0.59 U	0.41 U	0.48 U	0.38 U	17.00 U	3.00 J
022000	INEL	Inorganic Non-metal	218	440	17.00 U	1.10	18.00	0.13 U	0.32 J	0.21 J	0.08 U	17.00 U	6.20
022036	INEL	Uncategorized Metal	217	480	17.00 U	0.32 J	19.00	0.07 U	0.10 J	0.33 J	0.07 J	17.00 U	3.00
022038	RFETS	Uncategorized Metal	217	481	18.00 J	0.38 J	29.00	0.24 U	1.50 JB	0.51	0.16 U	5.00 U	7.50
022052	INEL	Uncategorized Metal	217	481	17.00 U	0.02 J	0.84 J	0.02 U	0.02 U	0.01 U	0.02 U	17.00 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
022102	INEL	Solidified Organics	226	432	17.00 U	0.09 U	17.00	0.13 U	0.20 J	2.00	0.08 U	17.00 U	0.68 J
022105	INEL	Solidified Inorganics	211	1	17.00 U	0.39 U	50.00	0.55 U	0.50 J	0.45 U	0.35 U	17.00 U	20.00
022119	INEL	Inorganic Non-metal	222	371	17.00 U	0.50 U	66.00	0.71 U	0.49 U	0.58 U	0.46 U	17.00 U	0.46 U
022121	INEL	Solidified Inorganics	211	7	17.00 U	0.17 U	38.00	0.16 U	0.23 J	0.17 U	0.16 U	17.00 U	0.16 U
022135	INEL	Solidified Inorganics	211	7	17.00 U	0.64 U	92.00	0.91 U	0.62 U	0.74 U	0.58 U	17.00 U	0.58 U
022136	RFETS	Solidified Inorganics	211	7	5.00 U	0.82 U	160.00 U	1.20 U	0.80 U	0.94	0.74 U	11.00 J	0.75 U
022149	RFETS	Solidified Inorganics	211	7	5.00 U	0.20 U	38.00 U	0.29 U	0.20 U	0.24	0.19 U	5.00 U	0.19 U
022224	INEL	Solidified Inorganics	211	1	17.00 U	0.39 U	39.00	0.55 U	0.38 U	0.45 U	0.35 U	17.00 U	60.00
022226	RFETS	Inorganic Non-metal	222	371	5.00 U	1.10 U	200.00 U	1.60 U	1.00 U	1.20	0.99 U	5.00 U	0.99 U
022228	INEL	Inorganic Non-metal	222	371	17.00 U	0.14 U	24.00	0.20 U	0.21 J	0.16 U	0.13 U	17.00 U	0.13 U
022230	INEL	Inorganic Non-metal	222	371	17.00 U	0.11 U	29.00 E	0.16 U	0.19 J	0.13 U	0.10 U	17.00 U	0.10 U
022249	INEL	Uncategorized Metal	217	480	17.00 U	1.90 U	480.00	1.80 U	1.90 U	1.90 U	1.80 U	17.00 U	1.80 U
022275	INEL	Uncategorized Metal	217	480	17.00 U	0.42 U	94.00	0.39 U	0.43 U	0.72 J	0.40 U	17.00 U	0.40 U
022286	RFETS	Uncategorized Metal	217	480	6.10 J	0.47 U	96.00 J	0.67 U	0.46 U	0.54	0.42 U	5.00 U	0.59 J
022296	INEL	Solidified Inorganics	211	1	17.00 U	0.93 U	150.00	0.87 U	0.96 U	0.96 U	0.88 U	17.00 U	7.00
022306	INEL	Inorganic Non-metal	218	440	17.00 U	0.84 U	75.00	34.00	0.81 U	0.96 U	0.76 U	17.00 U	1.10
022338	INEL	Solidified Organics	212	3	17.00 U	820.00 J	18000	160.00 U	10000	130.00 U	100.00 U	17.00 U	100.00 U
022347	INEL	Inorganic Non-metal	218	440	17.00 U	2.10	58.00	0.27 U	0.30 U	0.43 J	0.28 U	17.00 U	0.28 U
022358	INEL	Uncategorized Metal	217	480	17.00 U	0.02 U	8.10 E	0.02 U	0.16 J	1.50	0.02 U	17.00 U	0.04 J
022416	RFETS	Uncategorized Metal	217	320	5.00 U	1.10	7.60 J	0.07 U	0.12 J	0.06	0.16 J	5.00 U	0.40 J
022434	INEL	Solidified Organics	226	432	17.00 U	0.36 U	55.00	0.52 U	0.35 U	7.50	0.33 U	17.00 U	3.00
022442	INEL	Solidified Organics	226	432	17.00 U	1.07 U	138.50	1.50 U	1.05 U	2.05 J	0.98 U	17.00 U	0.98 U
022450	RFETS	Uncategorized Metal	217	320	5.00 U	0.12 J	11.00 U	0.12 U	0.13 JB	0.09	0.07 U	5.00 U	0.07 U
022453	RFETS	Solidified Inorganics	211	2	5.00 U	0.07 U	15.00	0.10 U	0.45 J	0.13	0.07 U	5.00 U	5.10
022486	RFETS	Inorganic Non-metal	218	440	5.00 U	1.70 U	120.00	110.00	1.80 JB	1.90	1.50 U	5.00 U	42.00

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
022511	INEL	Uncategorized Metal	217	480	17.00 U	0.86 U	130.00	1.20 U	0.84 U	0.99 U	0.78 U	17.00 U	0.79 U
022513	INEL	Solidified Organics	212	1	17.00 U	0.25 U	30.00	0.36 U	0.24 U	0.29 U	0.23 U	17.00 U	1.50 J
022517	INEL	Solidified Organics	226	432	17.00 U	0.11 U	23.00 B	0.15 U	0.27 J	2.50 J	0.10 U	17.00 U	0.94 J
022539	INEL	Solidified Organics	226	432	17.00 U	0.11 U	7.20	0.15 U	0.26 J	3.20	0.10 U	17.00 U	0.31 J
022549	INEL	Uncategorized Metal	217	480	17.00 U	1.40 U	230.00	2.00 U	1.40 U	1.60 U	1.30 U	17.00 U	1.30 U
022552	INEL	Inorganic Non-metal	218	442	17.00 U	0.32 U	44.00	0.46 U	0.31 U	0.37 U	0.29 U	17.00 U	0.54 J
022557	INEL	Uncategorized Metal	217	480	17.00 U	0.66 U	130.00	0.62 U	0.79 J	0.68 U	0.62 U	17.00 U	0.63 U
022595	INEL	Solidified Inorganics	211	1	17.00 U	0.32 U	63.00	0.30 U	0.33 U	0.33 U	0.30 U	17.00 U	0.30 U
022600	RFETS	Solidified Inorganics	213	4	130.00 U	0.26 U	46.00	0.36 U	0.25 U	0.34	0.23 U	130.00 U	9.00
022780	INEL	Solidified Inorganics	211	7	17.00 U	0.47 U	130.00	0.44 U	0.78 J	0.48 U	0.44 U	17.00 U	0.44 U
022789	INEL	Solidified Inorganics	211	7	17.00 U	0.62 U	82.00	0.88 U	0.60 U	0.71 U	0.56 U	17.00 U	0.56 U
022790	INEL	Solidified Inorganics	214	292	17.00 U	1.50	51.00	0.21 U	1.40	0.23 U	0.21 U	17.00 U	0.21 U
022803	INEL	Inorganic Non-metal	222	371	17.00 U	0.59 U	80.00	0.83 U	0.57 U	0.67 U	0.53 U	17.00 U	0.53 U
022807	INEL	Salt Waste	224	414	17.00 U	0.12 U	15.00	0.16 U	0.25 J	0.13 U	0.10 U	17.00 U	0.11 U
022811	INEL	Solidified Inorganics	211	7	17.00 U	0.39 U	75.00	0.37 U	0.54 J	0.40 U	0.37 U	17.00 U	0.37 U
022833	INEL	Solidified Inorganics	211	7	17.00 U	2.80 U	490.00	2.60 U	2.90 U	2.90 U	2.60 U	17.00 U	2.60 U
022841	INEL	Solidified Inorganics	211	7	17.00 U	1.50 U	290.00	1.40 U	1.50 U	1.50 U	1.40 U	17.00 U	1.40 U
022850	INEL	Solidified Inorganics	211	7	17.00 U	0.93 U	170.00	0.87 U	0.96 U	0.97 U	0.88 U	17.00 U	0.88 U
022874	INEL	Inorganic Non-metal	222	371	17.00 U	0.20 U	34.00	0.28 U	0.36 J	0.22 U	0.18 U	17.00 U	0.18 U
022894	INEL	Solidified Inorganics	211	1	17.00 U	0.13 U	38.00	0.12 U	0.93 J	0.14 U	0.13 U	17.00 U	0.13 U
022923	INEL	Inorganic Non-metal	218	440	17.00 U	0.36 U	50.00	0.52 U	0.35 U	0.42 U	0.33 U	17.00 U	0.33 U
023005	INEL	Solidified Inorganics	211	7	17.00 U	0.17 U	14.00	0.24 U	0.30 J	0.19 U	0.15 U	17.00 U	0.15 U
023027	RFETS	Uncategorized Metal	217	480	5.00 U	0.16 U	34.00 B	0.23 U	0.70 JB	0.19	0.15 U	5.00 U	4.50 B
023041	RFETS	Inorganic Non-metal	222	371	5.00 U	0.29 J	39.00 J	0.38 U	1.70 JB	0.31	0.24 U	5.00 U	0.28 J
023046	RFETS	Solidified Inorganics	211	7	5.00 U	0.47 U	97.00 U	0.67 U	0.70 J	0.54	0.42 U	5.00 U	0.43 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
023048	RFETS	Solidified Organics	226	432	17.00 U	0.39 U	60.00 U	0.55 U	0.38 U	0.86	0.35 U	17.00 U	0.36 U
023062	INEL	Solidified Inorganics	211	7	17.00 U	0.17 U	18.00	0.24 U	0.18 J	0.19 U	0.15 U	17.00 U	0.15 U
023211	INEL	Filter	119	376	17.00 U	0.06 U	0.10 J	0.08 U	0.47 J	0.41 J	0.05 U	17.00 U	0.05 U
023212	RFETS	Uncategorized Metal	217	480	5.80 J	0.63 J	94.00 U	0.78 U	1.10 J	0.63	0.50 U	7.50 J	0.50 U
023227	INEL	Uncategorized Metal	217	480	17.00 U	0.09 U	12.00	0.13 U	0.12 J	0.11 U	0.08 U	17.00 U	0.08 U
023229	INEL	Combustible	216	337	17.00 U	0.56 U	74.00	0.79 U	0.55 J	0.64 U	0.50 U	17.00 U	0.51 U
023235	RFETS	Heterogeneous	216	336	7.10 J	0.15 U	29.00 U	0.21 U	5.70	1.00	0.13 U	5.00 U	0.13 U
023238	INEL	Solidified Inorganics	211	1	17.00 U	0.20 U	43.00	0.19 U	1.80	0.21 U	0.20 U	17.00 U	0.20 U
023277	INEL	Inorganic Non-metal	222	371	17.00 U	0.98 U	130.00	1.40 U	0.95 U	1.10 U	0.88 U	17.00 U	0.89 U
023285	INEL	Solidified Inorganics	211	7	17.00 U	1.90 U	260.00	2.60 U	1.80 U	2.10 U	1.70 U	17.00 U	1.70 U
023312	INEL	Uncategorized Metal	217	480	17.00 U	0.93 U	180.00	0.87 U	0.96 U	0.97 U	0.89 U	17.00 U	0.89 U
023341	RFETS	Solidified Inorganics	211	7	5.00 U	0.01 U	4.60 J	0.01 U	0.18	0.05	0.04 J	5.00 U	0.06 J
023357	INEL	Solidified Inorganics	211	1	17.00 U	0.14 U	19.00	0.20 U	0.26 J	0.16 J	0.13 U	17.00 U	0.16 J
023383	RFETS	Uncategorized Metal	217	481	5.00 U	0.02 J	0.88 U	0.01 U	0.03 JB	0.03	0.01 U	5.00 U	0.01 U
023384	INEL	Combustible	223	339	15.00 U	0.44 J	32.00	0.10 U	0.10 U	0.11 J	0.21 J	15.00 U	0.11 U
023388	INEL	Heterogeneous	216	330	18.00 U	0.06 U	23.00	0.09 U	0.09 U	0.06 U	0.08 U	18.00 U	0.09 U
023392	INEL	Solidified Inorganics	213	4	43.00 U	0.63 U	80.00	0.89 U	0.61 U	0.72 U	0.57 U	43.00 U	0.57 U
023407	INEL	Solidified Organics	212	3	17.00 U	22.00 U	360.00	31.00 U	3200.0	25.00 U	20.00 U	17.00 U	20.00 U
023460	INEL	Inorganic Non-metal	218	442	17.00 U	0.31 J	5.40	0.04 U	0.19 J	0.12 J	0.24 J	17.00 U	0.45 J
023469	INEL	Solidified Organics	212	3	17.00 U	86.00 E	280.00 E	0.48 U	300.00 E	0.38 U	0.30 U	17.00 U	3.10 J
023492	INEL	Solidified Inorganics	211	7	17.00 U	0.70 U	78.00	0.99 U	0.68 U	0.80 U	0.63 U	17.00 U	0.63 U
023519	INEL	Solidified Organics	212	3	17.00 U	8.80	140.00	3.30 U	640.00	3.70 U	3.40 U	17.00 U	3.40 U
023535	INEL	Solidified Inorganics	211	7	17.00 U	0.93 U	180.00	0.87 U	0.96 U	0.96 U	0.88 U	17.00 U	0.88 U
023552	INEL	Solidified Inorganics	211	1	17.00 U	0.78 U	100.00	1.10 U	0.76 U	0.90 U	0.71 U	17.00 U	0.71 U
023662	INEL	Inorganic Non-metal	218	442	17.00 U	0.73 J	16.00	0.13 U	0.38 J	0.11 J	0.15 J	17.00 U	1.80

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
023681	INEL	Solidified Inorganics	211	1	17.00 U	0.34 U	69.00	0.48 U	0.40 J	0.38 U	0.30 U	17.00 U	33.00
023695	RFETS	Solidified Inorganics	211	2	5.00 U	0.17 U	33.00 J	0.24 U	0.19 J	0.20	0.16 U	5.00 U	1.60 J
023771	RFETS	Heterogeneous	216	330	12.00 J	0.18 U	7.70 J	0.72 J	1.10 JB	4.90	0.16 U	5.00 U	0.23 J
023776	INEL	Heterogeneous	216	330	15.00 U	0.37 U	56.00	0.52 U	0.36 U	0.42 U	0.33 U	15.00 U	10.00
023805	INEL	Uncategorized Metal	217	480	17.00 U	0.23 J	1.20	0.02 U	0.10 J	0.12 J	0.11 J	17.00 U	0.23 J
023827	RFETS	Uncategorized Metal	217	320	5.00 U	0.11	1.40 J	0.01 U	0.10 B	0.03	0.05 J	5.00 U	0.01 J
023840	INEL	Combustible	216	337	18.00 U	58.00	76.00	0.33 U	0.32 U	0.21 U	0.29 U	18.00 U	0.34 U
023901	INEL	Heterogeneous	216	330	18.00 U	0.22 U	91.00	0.31 U	0.36 J	0.20 U	0.28 U	18.00 U	19.00
023929	RFETS	Inorganic Non-metal	218	440	0.60 U	0.56 U	42.00 U	32.00	1.80 JB	0.64	0.50 U	5.00 U	0.50 U
023959	INEL	Uncategorized Metal	217	480	17.00 U	1.20 U	170.00	1.80 U	1.20 U	1.40 U	1.10 U	17.00 U	1.10 U
024028	RFETS	Inorganic Non-metal	218	440	5.00 U	0.19 J	21.00 U	0.16 U	1.00 J	0.13	0.10 U	5.00 U	0.11 U
024029	INEL	Uncategorized Metal	217	480	17.00 U	0.01 U	1.20	0.02 U	0.02 U	0.08 J	0.02 U	17.00 U	0.02 U
024058	INEL	Solidified Inorganics	211	1	17.00 U	0.42 U	51.00	0.59 U	0.41 U	0.48 U	0.38 U	17.00 U	22.00
024059	INEL	Solidified Inorganics	214	292	17.00 U	0.17 U	30.00	0.24 U	0.26 J	0.19 U	0.15 U	17.00 U	1.40 J
024088	INEL	Combustible	216	337	15.00 U	0.32 U	48.00 B	0.45 U	0.31 U	0.37 U	0.29 U	15.00 U	2.10 B
024090	INEL	Combustible	216	337	18.00 U	26.00	48.00	30.00	0.47 U	0.31 U	0.44 U	18.00 U	0.61 J
024092	INEL	Combustible	216	337	17.00 U	11.00	180.00	2.00 U	140.00	1.60 U	1.30 U	17.00 U	2.40
024095	INEL	Combustible	216	337	18.00 U	53.00	12.00	0.20 U	0.20 U	0.13 U	0.18 U	18.00 U	1.80
024102	INEL	Combustible	216	337	17.00 U	47.00	65.00	0.68 U	0.46 U	0.54 U	0.43 U	17.00 U	12.00
024106	INEL	Combustible	216	337	15.00 U	53.00	88.00	0.99 U	3.80	0.80 U	0.63 U	15.00 U	20.00
024113	INEL	Combustible	216	337	17.00 U	35.00	29.00	0.30 U	22.00	0.24 U	0.19 U	17.00 U	3.40
024147	INEL	Solidified Inorganics	211	1	17.00 U	0.64 U	86.00	0.91 U	0.62 U	0.74 U	0.58 U	17.00 U	0.58 U
024165	INEL	Combustible	216	337	15.00 U	68.00	48.00	0.70 U	0.48 U	0.56 U	0.45 U	15.00 U	1.60
024168	INEL	Heterogeneous	216	330	17.00 U	0.08 J	3.00	0.04 U	0.09 J	0.56 J	0.05 J	17.00 U	0.32 J
024185	INEL	Salt Waste	224	409	17.00 U	0.03 U	5.60	0.04 U	0.33 J	0.04 U	0.03 U	17.00 U	0.04 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
024254	INEL	Salt Waste	224	414	17.00 U	0.05 U	5.00	0.07 U	0.20 J	0.05 U	0.04 U	17.00 U	1.70
024271	INEL	Inorganic Non-metal	218	442	17.00 U	0.09 U	21.00 E	0.13 U	0.31 J	0.12 J	0.08 U	17.00 U	3.10
024273	INEL	Inorganic Non-metal	218	442	17.00 U	0.18 U	33.00	0.26 U	0.44 J	0.21 U	0.16 U	17.00 U	4.50
024289	RFETS	Inorganic Non-metal	218	440	5.00 U	0.33 U	61.00	76.00	0.58 J	0.38	0.41 J	5.00 U	18.00
024295	INEL	Salt Waste	224	414	17.00 U	0.09 U	7.50	0.13 U	0.28 J	0.11 U	0.08 U	17.00 U	12.00
024308	INEL	Solidified Inorganics	211	2	17.00 U	0.14 U	16.00	0.20 U	0.47 J	0.16 U	0.13 U	17.00 U	8.40
024309	INEL	Solidified Inorganics	211	2	17.00 U	0.11 U	14.00	0.16 U	0.28 J	0.13 U	0.10 U	17.00 U	6.10
024311	INEL	Solidified Inorganics	211	2	41.00 U	0.23 U	18.00	0.32 U	0.30 J	0.26 U	0.20 U	41.00 U	6.60
024318	INEL	Solidified Inorganics	211	2	17.00 U	0.23 U	27.00	0.32 U	0.48 J	0.26 U	0.20 U	17.00 U	16.00
024506	INEL	Inorganic Non-metal	122	374	17.00 U	0.06 U	0.12 J	0.08 U	0.12 J	0.06 U	0.05 U	17.00 U	0.05 U
024507	INEL	Uncategorized Metal	117	480	17.00 U	0.07 U	0.68 J	0.47 J	0.16 J	0.08 U	0.06 U	17.00 U	0.06 U
024600	INEL	Uncategorized Metal	217	480	17.00 U	0.25 U	42.00	0.36 U	0.56 J	0.29 U	0.23 U	17.00 U	14.00
024638	INEL	Heterogeneous	216	330	15.00 U	0.12 U	24.00	0.18 U	0.12 U	0.14 U	0.11 U	15.00 U	10.00
024670	INEL	Solidified Inorganics	211	1	17.00 U	0.50 U	63.00	0.71 U	0.54 J	0.58 U	0.46 U	17.00 U	0.46 U
024765	INEL	Uncategorized Metal	217	480	17.00 U	0.04 U	14.00	0.05 U	0.05 U	0.03 U	0.04 U	17.00 U	0.05 U
024786	INEL	Uncategorized Metal	217	480	17.00 U	0.34 U	56.00	0.48 U	0.32 U	0.38 U	0.30 U	17.00 U	0.30 U
024850	INEL	Solidified Organics	226	432	17.00 U	0.09 U	17.00	0.13 U	0.21 J	5.10	0.08 U	17.00 U	0.51 J
024884	INEL	Uncategorized Metal	217	480	17.00 U	0.49 J	30.00	0.32 U	29.00	0.26 U	0.20 U	17.00 U	7.40
024897	INEL	Solidified Inorganics	211	1	17.00 U	0.22 U	23.00	0.32 U	0.27 J	0.26 U	0.20 U	17.00 U	7.60
024920	INEL	Solidified Inorganics	211	1	17.00 U	0.64 U	81.00	0.91 U	0.62 U	0.74 U	0.58 U	17.00 U	36.00
024991	INEL	Solidified Inorganics	211	1	17.00 U	0.31 U	35.00	0.44 U	0.68 J	0.35 U	0.28 U	17.00 U	16.00
025001	INEL	Solidified Organics	212	3	17.00 U	1.10 U	140.00	1.60 U	1.10 U	1.30 U	1.00 U	17.00 U	47.00
032284	INEL	Combustible	223	339	17.00 U	1.10	97.00	0.33 U	0.32 U	0.33 J	0.62 J	17.00 U	0.34 U
032287	RFETS	Solidified Inorganics	211	7	5.00 U	1.10 U	200.00 U	1.60 U	1.10 U	1.30	0.99 U	5.00 U	1.00 U
032467	INEL	Combustible	216	337	17.00 U	0.22 U	38.00	0.32 U	1.00	0.26 U	0.20 U	17.00 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
032469	RFETS	Combustible	216	337	5.00 U	0.36 U	51.00 U	48.00	0.35 U	0.42	0.33 U	5.00 U	0.33 U
032473	INEL	Combustible	216	337	15.00 U	26.00	200.00 B	2.10 U	1.40 U	1.70 U	1.40 U	15.00 U	1.40 U
032485	INEL	Combustible	216	337	15.00 U	19.00	53.00	68.00	0.84 U	1.00 U	0.78 U	15.00 U	0.79 U
032517	RFETS	Combustible	223	339	5.00 U	0.48 J	14.00 J	0.12 U	0.26 JB	0.18	0.29 J	5.00 U	0.10 J
032521	INEL	Combustible	223	339	17.00 U	1.10	14.00	0.07 U	0.10 J	0.31 J	0.51 J	17.00 U	0.10 J
032525	INEL	Combustible	223	339	17.00 U	0.70 J	12.00	0.04 U	0.07 J	0.27 J	0.83 J	17.00 U	0.04 U
032526	INEL	Combustible	223	339	15.00 U	24.00	70.00	0.61 U	130.00	0.38 U	0.55 U	15.00 U	0.63 U
032529	INEL	Heterogeneous	216	336	1.30 U	0.19 U	250.00 E	0.27 U	1.10	0.21 U	0.30 U	1.30 U	0.31 U
032540	INEL	Uncategorized Metal	217	480	17.00 U	0.36 U	60.00	0.52 U	0.35 U	2.70	0.33 U	17.00 U	0.33 U
032632	INEL	Uncategorized Metal	217	480	17.00 U	0.11 U	44.00	0.16 U	0.21 J	0.10 U	0.14 U	17.00 U	0.16 U
032659	RFETS	Uncategorized Metal	217	480	5.00 U	0.29 U	57.00 U	0.41 U	0.16 U	0.33	0.26 U	5.00 U	0.26 U
032669	RFETS	Uncategorized Metal	217	480	5.00 U	0.31 U	61.00 U	0.44 U	0.30 U	0.36	0.28 U	5.00 U	0.28 U
032712	INEL	Uncategorized Metal	217	480	17.00 U	0.27 U	40.00	0.38 U	0.51 J	0.30 U	0.24 U	17.00 U	0.24 U
032715	RFETS	Combustible	216	337	5.00 U	2.20	13.00 J	0.12 U	4.90	0.10	0.08 U	5.00 U	1.00 J
032748	INEL	Combustible	223	339	2.30 J	0.19 U	84.00	0.27 U	1.10	0.21 U	0.30 U	1.30 U	0.31 U
032753	INEL	Uncategorized Metal	217	481	17.00 U	0.03 U	2.80	0.04 U	0.07 J	0.03 U	0.03 U	17.00 U	0.03 U
033091	INEL	Combustible	223	339	17.00 U	0.11 J	2.60	0.02 U	0.03 J	0.60 J	0.05 J	17.00 U	0.02 U
D01332	RFETS	Heterogeneous	116	832	7.06 J	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	9.11 J	0.50 U
D06288	RFETS	Filter	119	338	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D06339	RFETS	Heterogeneous	0	337	12.73 J	0.28 J	0.20 U	0.20 U	0.20 U	3.45	0.44 J	4.78 J	0.20 U
D11129	RFETS	Filter	119	338	0.50 U	0.18 J	0.10 U	0.10 U	0.10 U	0.10 U	0.36 J	1.13 J	0.10 U
D13364	RFETS	Uncategorized Metal	117	480	10.47 J	0.78 J	0.27 J	0.18 J	2.45	0.55 J	0.33 J	0.50 U	0.10 U
D15680	RFETS	Heterogeneous	116	831	333.33 U	66.67 U	4587.4	66.67 U	66.67 U	66.67 U	66.67 U	733.33 U	66.67 U
D17184	RFETS	Solidified Inorganics	111	800	0.90 U	0.10 U	0.32 J	0.39 J	0.23 J	0.83 J	0.10 U	0.50 U	0.10 U
D32439	RFETS	Filter	119	338	0.67 J	0.62 J	0.10 U	0.10 U	0.10 U	0.10 U	0.13 J	1.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D32978	RFETS	Solidified Inorganics	111	803	28.34 U	5.67 U	429.17	5.67 U	5.67 U	5.67 U	5.67 U	62.34 U	5.67 U
D35301	RFETS	Solidified Inorganics	111	800	0.90 U	0.10 U	0.10 U	0.10 U	0.10 J	0.10 U	0.10 U	0.50 U	0.10 U
D35306	RFETS	Lead/Cadmium Metal	123	339	3.12 J	3.87	0.20 U	0.20 U	0.20 U	14.44	2.43	2.20 U	0.20 U
D36606	RFETS	Uncategorized Metal	117	480	2.00 U	0.40 U	1.08 J	0.40 U	0.45 J	0.40 U	0.40 U	4.80 U	0.40 U
D38859	RFETS	Solidified Inorganics	111	803	0.90 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.20 J	0.10 U
D38989	RFETS	Heterogeneous	0	336	5.78 J	0.10 U	0.10 U	0.10 U	0.14 J	8.13	0.10 U	1.10 U	0.10 U
D41681	RFETS	Filter	119	338	3.58 J	0.47 J	0.10 U	0.10 U	0.10 U	0.52 J	0.12 J	1.10 U	0.10 U
D42280	RFETS	Solidified Organics	112	801	2083.3 U	1017.9 J	24947	416.67 U	30767	416.67 U	416.67 U	4583.3 U	416.67 U
D47501	RFETS	Lead/Cadmium Metal	0	341	4.50 J	0.10 U	0.10 U	0.10 U	0.10 U	0.48 J	0.10 U	1.10 U	0.10 U
D48182	RFETS	Filter	119	376	3.60 U	0.40 U	0.40 U	1.83 J	0.40 U	0.40 U	0.40 U	2.00 U	0.40 U
D48200	RFETS	Heterogeneous	116	831	72.00 U	8.00 U	349.15	8.00 U	8.00 U	8.00 U	8.00 U	98.30 J	8.00 U
D48377	RFETS	Inorganic Non-metal	118	368	0.90 U	0.10 U	0.10 U	0.10 U	0.10 U	0.15 J	0.10 U	0.87 J	0.10 U
D49662	RFETS	Solidified Inorganics	0	292	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D49880	RFETS	Heterogeneous	0	336	9.09 J	0.28 J	0.27 U	0.27 U	0.27 U	39.84	0.27 U	2.94 U	0.27 U
D52318	RFETS	Lead/Cadmium Metal	117	321	0.61 J	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D52362	RFETS	Heterogeneous	116	821	1.80 U	0.20 U	2.01	1.05 J	0.31 J	0.20 U	0.20 U	1.00 U	0.20 U
D52726	RFETS	Heterogeneous	116	833	4.00 U	0.80 U	62.32	2.02 J	0.80 J	0.80 U	0.80 U	8.80 U	21.12
D53672	RFETS	Inorganic Non-metal	118	440	2.93 J	0.20 U	0.36 J	0.53 J	0.25 J	0.20 U	0.20 U	1.00 U	0.20 U
D55656	RFETS	Heterogeneous	116	831	3.25 J	0.30 U	0.31 J	0.30 U	0.33 J	0.30 U	0.30 U	1.50 U	0.30 U
D55680	RFETS	Heterogeneous	116	821	1.80 U	0.20 U	0.32 J	0.20 J	0.55 J	0.20 U	0.20 U	1.00 U	0.20 U
D55938	RFETS	Heterogeneous	116	831	1.80 U	0.20 U	0.68 J	0.40 U	0.24 J	0.20 U	0.20 U	1.00 U	0.20 U
D56095	RFETS	Heterogeneous	0	337	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D56595	RFETS	Heterogeneous	116	831	66.67 U	13.33 U	13.33 U	13.33 U	13.33 U	13.33 U	13.33 U	146.66 U	13.33 U
D56755	RFETS	Heterogeneous	116	821	0.90 U	0.10 U	0.32 J	0.11 J	0.52 J	0.10 U	0.10 U	0.50 U	0.10 U
D56823	RFETS	Heterogeneous	116	831	3.60 U	0.40 U	3.96 J	0.99 J	1.50 J	0.40 U	0.40 U	2.00 U	0.40 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D57179	RFETS	Heterogeneous	0	330	10.00 U	2.00 U	108.25	2.00 U	2.00 U	2.00 U	2.00 U	30.93 J	2.00 U
D57522	RFETS	Heterogeneous	0	336	2.00 U	0.40 U	0.40 U	0.40 U	0.40 U	1.06 J	0.40 U	4.40 U	0.40 U
D57847	RFETS	Uncategorized Metal	117	480	2.00 U	0.40 U	0.40 U	0.86 J	0.40 U	0.74 J	0.40 U	4.80 U	0.40 U
D58143	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.10 U	0.88 J	0.21 J	0.10 U	0.10 U	0.50 U	0.10 U
D58154	RFETS	Heterogeneous	116	831	5.55 J	0.73 J	0.76 J	4.52	0.61 J	3.10 J	0.40 U	4.40 U	0.40 U
D58627	RFETS	Heterogeneous	116	831	1.00 U	0.20 U	0.51 J	0.20 U	0.20 U	0.20 U	0.20 U	2.20 U	0.20 U
D58889	RFETS	Heterogeneous	116	831	1.00 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U
D58970	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.43 J	0.57 J	0.69 J	0.10 U	0.10 U	0.51 J	0.10 U
D59053	RFETS	Lead/Cadmium Metal	0	341	2.26 J	1.17	0.10 U	0.10 U	0.10 U	1.59	0.92 J	1.10 U	0.10 U
D59703	RFETS	Heterogeneous	116	831	12.74 J	0.50 U	0.52 J	1.91 J	0.50 U	0.77 J	0.50 U	6.00 U	0.50 U
D59899	RFETS	Filter	0	331	6.81 Ja	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	6.00 U	0.50 U
D60056	RFETS	Lead/Cadmium Metal	0	341	2.57 J	1.94 J	0.27 U	0.27 U	0.27 U	3.53	2.10 J	2.94 U	0.27 U
D60218	RFETS	Heterogeneous	116	821	1.80 U	0.20 U	0.23 J	0.29 J	0.35 J	0.20 U	0.20 U	2.21 J	0.20 U
D60298	RFETS	Solidified Organics	112	801	5160.0 U	573.33 U	12909	573.33 U	16369	573.33 U	573.33 U	4036.8 J	573.33 U
D60320	RFETS	Heterogeneous	0	330	166.35 J	68.40 J	28.00 U	28.00 U	1265.6	28.00 U	28.00 U	475.47 J	28.00 U
D60463	RFETS	Inorganic Non-metal	118	440	0.90 U	0.14 J	0.10 U	0.26 J	0.10 J	0.12 J	0.10 U	2.21 J	0.10 U
D60511	RFETS	Filter	119	491	2.09 J	0.20 U	9.99	0.47 J	0.20 U	0.20 U	0.20 U	1.13 J	0.20 U
D60635	RFETS	Filter	119	491	0.90 U	0.10 U	1.37	0.28 J	0.10 U	0.10 U	0.10 U	0.50 U	0.10 U
D61245	RFETS	Heterogeneous	0	336	16.09 J	0.47 U	0.47 U	0.47 U	0.47 U	5.02	0.47 U	18.25 J	0.47 U
D61278	RFETS	Heterogeneous	0	336	2.96 J	4.74	0.27 U	0.27 U	0.48 J	22.81	1.12 J	2.94 U	0.27 U
D61473	RFETS	Heterogeneous	0	377	2.70 U	0.30 U	0.30 U	0.66 J	0.30 U	0.34 J	0.30 U	1.50 U	0.30 U
D61504	RFETS	Lead/Cadmium Metal	0	341	4.83 J	1.47	0.10 U	0.10 U	0.10 U	5.11	0.77 J	9.60 J	0.10 U
D61747	RFETS	Heterogeneous	0	330	7.76 J	0.27 U	0.27 U	0.27 U	0.27 U	12.64	0.40 J	7.81 J	0.27 U
D62340	RFETS	Heterogeneous	116	821	3.60 U	0.40 U	0.49 J	0.40 U	0.40 U	0.40 J	0.40 U	2.00 U	0.40 U
D62478	RFETS	Filter	119	376	3.60 U	0.40 U	0.40 U	2.69 J	0.40 U	0.40 U	0.40 U	2.00 U	0.40 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D62714	RFETS	Heterogeneous	116	831	5.00 U	1.00 U	30.09	1.00 U	15.72	1.00 U	1.00 U	12.00 U	1.00 U
D62851	RFETS	Heterogeneous	116	825	2.70 U	0.30 U	3.32	1.34 J	0.48 J	0.30 U	0.30 U	1.50 U	0.30 U
D62855	RFETS	Heterogeneous	116	821	54.00 U	6.00 U	6.00 U	6.00 U	214.07	6.00 U	6.00 U	30.00 U	6.00 U
D63098	RFETS	Filter	0	331	8.26 Ja	0.50 U	0.50 U	0.50 U	0.50 U	0.62 J	0.50 U	6.00 U	0.50 U
D63229	RFETS	Heterogeneous	116	831	1.80 U	0.20 U	0.20 J	1.43 J	0.26 J	0.20 U	0.20 U	1.00 U	0.20 U
D63281	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.10 U	0.65 J	0.10 U	0.10 U	0.10 U	0.50 U	0.10 U
D63460	RFETS	Heterogeneous	116	831	0.90 U	0.10 U	2.43	1.09	1.36	0.10 J	0.10 U	0.50 U	0.10 U
D63654	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.10 J	0.17 J	0.30 J	0.10 U	0.10 U	0.50 U	0.10 U
D63808	RFETS	Heterogeneous	116	831	7.20 U	0.80 U	45.12	2.42 J	1.77 J	0.80 U	0.80 U	4.00 U	0.80 U
D63817	RFETS	Heterogeneous	116	821	14.40 U	1.60 U	1.60 U	1.60 U	1.60 U	1.60 U	1.60 U	8.00 U	1.60 U
D63819	RFETS	Solidified Inorganics	111	807	1.80 U	0.20 U	1.40 J	0.44 J	2.30	0.20 U	0.20 U	1.00 U	0.20 U
D63999	RFETS	Filter	119	491	2.70 U	0.30 U	0.31 J	0.31 J	0.56 J	0.30 U	0.30 U	1.50 U	0.30 U
D64004	RFETS	Filter	0	331	5.58 Ja	0.40 U	0.40 U	0.40 U	0.40 U	0.86 Ja	0.40 U	4.80 U	0.40 U
D64137	RFETS	Filter	119	335	0.90 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.50 U	0.10 U
D64448	RFETS	Heterogeneous	116	821	990.00 U	110.00 U	110.00 U	110.00 U	110.00 U	110.00 U	110.00 U	2110.9 J	110.00 U
D64555	RFETS	Solidified Organics	112	801	5160.0 U	573.33 U	904.15 J	573.33 U	18198	573.33 U	573.33 U	2866.6 U	573.33 U
D64632	RFETS	Solidified Inorganics	111	800	0.90 U	0.10 U	0.90 J	0.76 J	1.09	0.70 J	0.10 U	0.54 J	0.10 U
D64752	RFETS	Uncategorized Metal	117	480	10.00 U	2.00 U	175.17	2.00 U	2.00 U	2.00 U	2.00 U	24.00 U	2.00 U
D64758	RFETS	Heterogeneous	116	831	2.50 U	0.59 J	1.52 J	3.67 J	0.78 J	0.86 J	0.50 U	5.50 U	0.50 U
D64860	RFETS	Heterogeneous	116	831	60.00 U	12.00 U	681.08	12.00 U	12.00 U	12.00 U	12.00 U	144.00 U	12.00 U
D65212	RFETS	Heterogeneous	116	831	45.00 U	9.00 U	664.72	9.00 U	9.00 U	9.00 U	9.00 U	108.00 U	9.00 U
D65213	RFETS	Heterogeneous	116	831	40.00 U	8.00 U	394.11	8.00 U	8.00 U	8.00 U	8.00 U	96.00 U	8.00 U
D65214	RFETS	Heterogeneous	116	831	663.00 U	73.67 U	4170.2	73.67 U	73.67 U	73.67 U	73.67 U	823.82 J	73.67 U
D65530	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.12 J	0.33 J	0.10 U	0.14 J	0.10 U	0.50 U	0.10 U
D65535	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.30 J	0.22 J	0.65 J	0.10 U	0.10 U	0.50 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D65546	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.98 J	0.42 J	0.22 J	0.10 J	0.10 U	0.50 U	0.10 U
D65600	RFETS	Solidified Inorganics	111	807	0.90 U	0.10 U	0.14 J	0.76 J	0.10 U	0.10 U	0.10 U	0.50 U	0.10 U
D65731	RFETS	Inorganic Non-metal	122	375	3.60 U	4.11	0.40 U	0.40 J	20.60	0.40 U	0.40 U	6.13 J	0.40 U
D65734	RFETS	Uncategorized Metal	117	480	6.30 U	0.70 U	2.27 J	0.70 U	0.70 U	0.95 J	0.70 U	3.50 U	0.70 U
D65754	RFETS	Heterogeneous	116	831	3.34 U	0.67 U	0.67 U	0.67 U	0.67 U	0.67 U	0.67 U	7.34 U	0.67 U
D65757	RFETS	Heterogeneous	116	831	15.00 U	3.00 U	34.29	3.00 U	133.99	3.00 U	3.00 U	33.55 J	3.00 U
D65972	RFETS	Filter	119	376	2.70 U	0.30 U	1.99 J	2.26 J	2.30 J	0.30 U	0.30 U	6.67 J	0.30 U
D66128	RFETS	Heterogeneous	116	831	2.50 U	0.52 J	1.13 J	1.50 J	21.90	0.50 U	0.50 U	7.66 J	0.50 U
D66157	RFETS	Uncategorized Metal	117	480	18.75 J	2.00 U	2.00 U	6.63 J	2.00 U	2.00 U	2.00 U	189.97 J	2.00 U
D66162	RFETS	Lead/Cadmium Metal	123	339	810.00 U	90.00 U	5612.3	90.00 U	413.64 J	90.00 U	90.00 U	450.00 U	90.00 U
D66211	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.19 J	0.10 U	0.38 J	0.10 U	0.10 U	0.50 U	0.10 U
D66213	RFETS	Heterogeneous	116	831	1.50 U	0.30 U	23.08	5.20	10.07	0.30 U	0.30 U	3.30 U	0.70 J
D66356	RFETS	Heterogeneous	116	831	833.33 U	166.67 U	10386	166.67 U	166.67 U	166.67 U	166.67 U	1833.3 U	166.67 U
D66378	RFETS	Heterogeneous	116	831	960.00 U	192.00 U	9184.5	192.00 U	192.00 U	192.00 U	192.00 U	2304.0 U	192.00 U
D66438	RFETS	Uncategorized Metal	117	480	14.40 U	54.53	1.60 U	1.60 U	25.18	1.60 U	1.60 U	8.00 U	1.60 U
D66523	RFETS	Solidified Organics	112	801	5160.0 U	573.33 U	12516	573.33 U	19219	573.33 U	573.33 U	2866.6 U	573.33 U
D66525	RFETS	Solidified Inorganics	111	800	1.33 U	0.27 U	1.26 J	1.22 J	0.27 U	0.45 J	0.27 U	3.20 U	0.43 J
D66631	RFETS	Heterogeneous	116	831	4.50 U	0.50 U	4.86 J	0.50 U	4.48 J	0.50 U	0.50 U	5.87 J	0.50 U
D66637	RFETS	Heterogeneous	116	831	40.00 U	8.00 U	403.75	8.00 U	8.00 U	8.00 U	8.00 U	96.00 U	8.00 U
D66641	RFETS	Heterogeneous	116	831	540.00 U	60.00 U	4144.3	60.00 U	60.00 U	60.00 U	60.00 U	300.00 U	60.00 U
D66649	RFETS	Lead/Cadmium Metal	123	339	504.00 U	56.00 U	1594.3	56.00 U	2006.3	56.00 U	56.00 U	280.00 U	56.00 U
D66773	RFETS	Uncategorized Metal	117	480	2.70 U	0.30 U	0.30 U	0.30 U	0.30 U	1.63 J	0.30 U	1.50 U	0.30 U
D66783	RFETS	Heterogeneous	116	831	2250.0 U	250.00 U	14569	250.00 U	250.00 U	250.00 U	250.00 U	1250.0 U	250.00 U
D66792	RFETS	Heterogeneous	116	831	900.00 U	100.00 U	6432.5	100.00 U	100.00 U	100.00 U	100.00 U	500.00 U	100.00 U
D66860	RFETS	Heterogeneous	116	833	1.80 U	0.22 J	0.20 U	0.86 J	0.25 J	0.71 J	0.20 U	2.35 J	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D66875	RFETS	Heterogeneous	116	832	0.90 U	0.10 U	0.10 U	1.38	0.33 J	0.10 U	0.10 U	1.64 J	0.10 U
D66948	RFETS	Heterogeneous	116	831	54.00 U	6.00 U	348.67	6.00 U	6.00 U	6.00 U	6.00 U	38.93 J	6.00 U
D66949	RFETS	Heterogeneous	116	831	5.40 U	0.60 U	36.09	0.60 U	3.54 J	0.60 U	0.60 U	7.95 J	0.60 U
D66953	RFETS	Uncategorized Metal	117	480	8.00 U	1.60 U	117.31	1.60 U	1.60 U	1.60 U	1.60 U	19.20 U	1.60 U
D66958	RFETS	Heterogeneous	116	831	2.70 U	0.30 U	1.23 J	0.30 U	4.06	0.30 U	0.30 U	4.27 J	0.30 U
D67009	RFETS	Solidified Organics	112	801	3060.0 U	340.00 U	3392.8	340.00 U	12288	340.00 U	340.00 U	1700.0 U	340.00 U
D67012	RFETS	Solidified Organics	112	801	8100.0 U	900.00 U	8430.3 J	900.00 U	34118	900.00 U	900.00 U	4500.0 U	900.00 U
D67047	RFETS	Solidified Inorganics	111	807	1.80 U	0.20 U	0.20 U	0.70 J	0.20 U	0.20 U	0.20 U	6.60 J	0.20 U
D67251	RFETS	Uncategorized Metal	117	480	6000.0 U	1200.0 U	1686.5 J	1200.0 U	1200.0 U	1200.0 U	1200.0 U	14400 U	1821.1 J
D67263	RFETS	Heterogeneous	116	831	81.00 U	9.00 U	481.60	9.00 U	9.00 U	9.00 U	9.00 U	45.00 U	9.00 U
D67277	RFETS	Heterogeneous	116	831	126.00 U	14.00 U	45.18 J	14.00 U	1170.2	14.00 U	14.00 U	70.00 U	14.00 U
D67278	RFETS	Heterogeneous	116	831	0.90 U	0.10 U	0.10 U	0.10 U	0.26 J	0.10 U	0.10 U	0.50 U	0.10 U
D67312	RFETS	Heterogeneous	116	825	1.80 U	0.20 U	0.20 U	0.20 U	0.27 J	0.20 U	0.20 U	1.00 U	0.20 U
D67317	RFETS	Uncategorized Metal	117	480	1.44 J	0.27 U	0.27 U	0.27 U	1.00 J	2.03 J	0.27 U	3.20 U	0.27 U
D67390	RFETS	Solidified Organics	112	801	1170.0 U	194.61 J	916.24 J	130.00 U	4459.1	130.00 U	130.00 U	650.00 U	130.00 U
D67391	RFETS	Heterogeneous	116	833	3.30 J	0.27 U	0.27 U	0.27 U	0.27 U	0.27 U	0.27 U	2.93 U	0.27 U
D67413	RFETS	Solidified Organics	112	801	6750.0 U	750.00 U	18543	750.00 U	27354	750.00 U	750.00 U	6834.0 J	750.00 U
D67434	RFETS	Solidified Inorganics	111	800	2.00 U	0.40 U	0.40 U	0.86 J	0.40 U	0.64 J	0.40 U	4.80 U	0.40 U
D67436	RFETS	Solidified Inorganics	111	800	0.67 U	0.13 U	0.28 J	0.76 J	0.13 U	0.42 J	0.13 U	2.25 J	0.13 U
D67441	RFETS	Solidified Inorganics	111	800	2.00 U	0.40 U	1.80 J	0.40 U	0.40 U	0.40 U	0.40 U	4.80 U	0.73 J
D67448	RFETS	Heterogeneous	116	852	0.90 U	0.10 U	0.56 J	0.10 U	0.10 U	0.10 U	0.10 U	0.88 J	0.10 U
D67455	RFETS	Filter	119	490	7.08 J	0.40 U	0.40 U	0.40 U	0.40 U	6.90	0.40 U	2.00 U	0.40 U
D67464	RFETS	Heterogeneous	116	831	2160.0 U	240.00 U	14009	240.00 U	240.00 U	240.00 U	240.00 U	1200.0 U	240.00 U
D67524	RFETS	Heterogeneous	116	832	167.34 U	33.34 J	18.59 U	18.59 U	887.74	18.59 U	18.59 U	266.96 J	18.59 U
D67532	RFETS	Lead/Cadmium Metal	123	339	56.70 U	6.30 U	456.31	6.30 U	6.30 U	6.30 U	6.30 U	62.62 J	6.30 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D67535	RFETS	Heterogeneous	116	831	1.00 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U
D67539	RFETS	Solidified Organics	112	801	2880.0 U	320.00 U	4071.6	320.00 U	12796	320.00 U	320.00 U	1600.0 U	320.00 U
D67541	RFETS	Heterogeneous	116	825	0.90 U	0.10 U	0.10 U	0.33 J	0.26 J	0.10 U	0.10 U	0.54 J	0.10 U
D67545	RFETS	Solidified Organics	112	801	810.00 U	147.15 J	731.16 J	90.00 U	2836.4	90.00 U	90.00 U	450.00 U	90.00 U
D67567	RFETS	Heterogeneous	116	831	5.62 J	0.30 U	0.31 J	1.91 J	0.30 U	1.75 J	0.30 U	1.50 U	0.30 U
D67582	RFETS	Heterogeneous	116	831	9.56 J	0.40 U	3.04 J	2.22 J	8.78	0.40 U	0.40 U	54.34 J	0.40 U
D67603	RFETS	Uncategorized Metal	117	480	117.00 U	13.00 U	912.67	13.00 U	13.00 U	13.00 U	13.00 U	251.28 J	13.00 U
D67654	RFETS	Solidified Inorganics	111	800	1.33 U	0.27 U	0.56 J	1.15 J	0.27 U	0.38 J	0.27 U	3.20 U	0.27 U
D67657	RFETS	Solidified Inorganics	111	800	1.33 U	0.27 U	0.46 J	1.43 J	0.27 U	0.40 J	0.27 U	3.20 U	0.27 U
D67678	RFETS	Heterogeneous	116	825	3.87 U	0.43 U	2.30 J	19.19	0.55 J	1.61 J	0.43 U	2.15 U	0.43 U
D67698	RFETS	Heterogeneous	116	831	8.00 U	1.60 U	1.60 U	1.60 U	1.60 U	1.60 U	1.60 U	17.60 U	1.60 U
D67707	RFETS	Heterogeneous	116	831	2.50 U	0.94 J	0.50 U	0.50 U	36.34	0.50 U	0.50 U	5.50 U	0.50 U
D67734	RFETS	Heterogeneous	116	831	990.00 U	110.00 U	7283.8	110.00 U	110.00 U	110.00 U	110.00 U	550.00 U	110.00 U
D67735	RFETS	Uncategorized Metal	117	480	16.20 U	1.80 U	130.61	1.80 U	1.80 U	1.80 U	1.80 U	9.00 U	1.80 U
D67759	RFETS	Heterogeneous	116	831	25.20 U	2.80 U	2.80 U	2.80 U	2.80 U	2.80 U	2.80 U	14.00 U	2.80 U
D67764	RFETS	Heterogeneous	116	831	10.00 U	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	22.00 U	2.00 U
D67766	RFETS	Heterogeneous	116	831	7.50 U	1.50 U	1.50 U	1.50 U	1.50 U	3.46 J	1.50 U	16.50 U	1.50 U
D67781	RFETS	Heterogeneous	116	831	2.70 U	0.30 U	0.52 J	1.94 J	0.30 U	0.55 J	0.30 U	2.15 J	0.30 U
D67908	RFETS	Heterogeneous	116	832	0.90 U	0.10 U	2.49	0.10 U	0.22 J	0.10 U	0.10 U	2.28 J	0.10 U
D67929	RFETS	Heterogeneous	116	832	0.50 U	0.10 U	0.20 J	0.81 J	0.13 J	0.10 U	0.10 U	1.10 U	0.10 U
D67989	RFETS	Heterogeneous	116	831	4.50 U	0.76 J	11.24	0.50 U	43.36	0.50 U	0.50 U	2.50 U	0.50 U
D67994	RFETS	Heterogeneous	116	831	13.34 U	2.67 U	29.48	2.67 U	164.99	2.67 U	2.67 U	29.34 U	2.67 U
D68044	RFETS	Heterogeneous	116	825	4.50 U	0.50 U	0.50 U	12.13	0.50 U	0.52 J	0.50 U	2.50 U	0.50 U
D68096	RFETS	Heterogeneous	116	821	2.46 J	0.20 U	0.37 J	0.60 J	0.61 J	0.28 J	0.20 U	1.00 U	0.20 U
D68247	RFETS	Solidified Inorganics	111	800	0.67 U	0.13 U	0.32 J	0.13 U	0.13 U	0.25 J	0.13 U	1.60 U	0.13 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D68248	RFETS	Solidified Organics	112	801	1350.0 U	150.00 U	2762.7	150.00 U	6364.6	150.00 U	150.00 U	750.00 U	150.00 U
D68250	RFETS	Solidified Organics	112	801	1530.0 U	170.00 U	2796.8	170.00 U	6225.7	170.00 U	170.00 U	850.00 U	170.00 U
D68254	RFETS	Solidified Inorganics	111	800	1.33 U	0.27 U	0.68 J	0.66 J	0.27 U	0.35 J	0.27 U	3.20 U	0.41 J
D68256	RFETS	Solidified Inorganics	111	800	2.00 U	0.40 U	1.83 J	1.32 J	0.40 U	0.55 J	0.40 U	4.80 U	0.68 J
D68276	RFETS	Heterogeneous	116	852	0.90 U	0.10 U	0.50 J	0.37 J	0.10 U	0.10 U	0.10 U	0.50 U	0.10 U
D68277	RFETS	Uncategorized Metal	117	480	4.50 U	0.50 U	1.97 J	0.98 J	37.08	0.50 U	0.50 U	3.38 J	0.50 U
D68377	RFETS	Uncategorized Metal	117	480	1.00 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U
D68460	RFETS	Heterogeneous	116	832	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D68480	RFETS	Solidified Inorganics	111	800	0.50 J	0.10 U	0.13 J	0.17 J	0.10 U	0.26 J	0.10 U	2.36 J	0.10 U
D68486	RFETS	Solidified Organics	112	801	1260.0 U	206.92 J	8439.3	140.00 U	4240.3	140.00 U	140.00 U	831.18 J	140.00 U
D68514	RFETS	Uncategorized Metal	117	480	1.11 J	0.10 U	0.10 U	0.70 J	0.10 U	0.10 U	0.10 U	0.50 U	0.10 U
D68538	RFETS	Lead/Cadmium Metal	123	339	0.50 U	0.10 U	0.16 J	0.12 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U
D68600	RFETS	Heterogeneous	116	825	162.00 U	18.00 U	18.00 U	1922.1	18.00 U	18.00 U	18.00 U	90.00 U	18.00 U
D68601	RFETS	Heterogeneous	116	825	63.00 U	7.00 U	7.00 U	745.07	7.00 U	7.00 U	7.00 U	35.00 U	7.00 U
D68702	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.10 U	0.17 J	0.13 J	0.10 U	0.10 U	0.50 U	0.10 U
D68724	RFETS	Heterogeneous	116	831	1620.0 U	180.00 U	10740	180.00 U	180.00 U	180.00 U	180.00 U	900.00 U	180.00 U
D68756	RFETS	Heterogeneous	116	831	1.37 J	0.20 U	0.20 U	1.06 J	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U
D68885	RFETS	Heterogeneous	116	831	360.00 U	40.00 U	2205.7	40.00 U	334.76 J	40.00 U	40.00 U	200.00 U	40.00 U
D68896	RFETS	Heterogeneous	116	831	1917.0 U	213.00 U	4021.8	213.00 U	213.00 U	213.00 U	213.00 U	1065.0 U	213.00 U
D68975	RFETS	Solidified Organics	112	801	4860.0 U	540.00 U	13431	540.00 U	15676	540.00 U	540.00 U	2700.0 U	540.00 U
D68999	RFETS	Heterogeneous	116	821	3.60 U	0.40 U	0.67 J	2.00 J	0.60 J	0.50 J	0.40 U	2.00 U	0.40 U
D69091	RFETS	Heterogeneous	116	825	4.50 U	0.50 U	0.50 U	3.56 J	0.50 U	0.50 U	0.50 U	2.50 U	0.50 U
D69095	RFETS	Heterogeneous	116	833	4.86 U	0.54 U	0.54 U	32.79	0.54 U	0.54 U	0.54 U	2.70 U	0.54 U
D69113	RFETS	Heterogeneous	116	831	432.00 U	48.00 U	2954.0	48.00 U	48.00 U	48.00 U	48.00 U	240.00 U	48.00 U
D69250	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.47 J	0.67 J	0.24 J	0.10 U	0.10 U	0.50 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D69287	RFETS	Heterogeneous	116	821	1242.0 U	138.00 U	8372.6	138.00 U	138.00 U	138.00 U	138.00 U	690.00 U	138.00 U
D69306	RFETS	Solidified Organics	112	801	2250.0 U	250.00 U	13804	250.00 U	6213.5	250.00 U	250.00 U	1250.0 U	250.00 U
D69312	RFETS	Solidified Inorganics	111	800	2.00 U	0.40 U	1.11 J	1.39 J	0.40 U	0.57 J	0.40 U	4.80 U	0.69 J
D69364	RFETS	Heterogeneous	116	833	2.70 U	0.30 U	0.30 U	3.20	0.30 U	0.42 J	0.30 U	1.95 J	0.30 U
D69400	RFETS	Heterogeneous	116	831	333.00 U	37.00 U	2679.9	37.00 U	37.00 U	37.00 U	37.00 U	185.00 U	37.00 U
D69406	RFETS	Heterogeneous	116	831	450.00 U	50.00 U	3750.4	50.00 U	50.00 U	50.00 U	50.00 U	250.00 U	50.00 U
D69413	RFETS	Heterogeneous	116	831	5.40 U	0.60 U	15.20	0.60 U	0.60 U	0.60 U	0.60 U	3.00 U	0.60 U
D69418	RFETS	Heterogeneous	116	831	660.60 U	73.40 U	4816.7	73.40 U	73.40 U	73.40 U	73.40 U	699.21 J	73.40 U
D69431	RFETS	Heterogeneous	116	831	266.67 U	53.33 U	4070.6	53.33 U	53.33 U	53.33 U	53.33 U	586.66 U	53.33 U
D69518	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.36 J	2.40	0.28 J	0.20 U	0.20 U	1.00 U	0.20 U
D69602	RFETS	Heterogeneous	116	821	9.00 U	1.00 U	1.00 U	3.40 J	1.00 U	1.00 U	1.00 U	5.00 U	1.00 U
D69759	RFETS	Heterogeneous	116	833	2.70 U	0.30 U	20.43	2.40 J	0.34 J	0.30 U	0.30 U	1.53 J	7.59
D69855	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	1.01 J	8.75	0.74 J	0.28 J	0.20 U	1.00 U	0.20 U
D69877	RFETS	Heterogeneous	116	825	4.50 U	0.50 U	0.53 J	1.79 J	0.50 U	0.50 U	0.50 U	2.50 U	0.50 U
D69883	RFETS	Heterogeneous	116	825	2.70 U	0.30 U	0.95 J	0.30 U	0.51 J	1.72 J	0.30 U	1.50 U	0.30 U
D69975	RFETS	Heterogeneous	116	821	6.30 U	0.70 U	4.64 J	4.42 J	0.81 J	0.70 U	0.70 U	3.50 U	0.70 U
D70063	RFETS	Heterogeneous	116	821	4.59 U	0.57 J	0.51 U	2.00 J	7.12	0.51 U	0.51 U	2.55 U	0.51 U
D70077	RFETS	Heterogeneous	116	831	540.00 U	60.00 U	3533.4	60.00 U	60.00 U	60.00 U	60.00 U	300.00 U	60.00 U
D70229	RFETS	Heterogeneous	116	831	1.80 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	1.00 U	0.20 U
D70353	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.20 J	1.94 J	0.65 J	0.20 U	0.20 U	5.36 J	0.20 U
D70370	RFETS	Heterogeneous	116	821	2.70 U	0.30 U	0.52 J	0.92 J	0.58 J	0.30 U	0.30 U	1.50 U	0.30 U
D70379	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.48 J	0.10 U	0.33 J	0.10 U	0.10 U	0.50 U	0.10 U
D70383	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.20 U	1.78 J	0.20 U	0.20 U	0.20 U	1.00 U	0.20 U
D70446	RFETS	Uncategorized Metal	117	480	5.00 U	5.85 J	1.00 U	1.00 U	58.86	1.00 U	1.00 U	12.00 U	1.00 U
D70448	RFETS	Heterogeneous	116	831	1350.0 U	150.00 U	8313.3	150.00 U	150.00 U	150.00 U	150.00 U	750.00 U	150.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D70455	RFETS	Heterogeneous	116	831	6.30 U	5.12 J	0.70 U	4.62 J	11.69	0.70 U	0.70 U	3.50 U	0.70 U
D70543	RFETS	Solidified Organics	112	801	7452.0 U	828.00 U	55410	828.00 U	62380	828.00 U	828.00 U	4140.0 U	828.00 U
D70661	RFETS	Filter	0	331	3.17 J	0.60 U	0.76 J	0.60 U	0.60 U	0.60 U	0.60 U	6.60 U	0.60 U
D70669	RFETS	Uncategorized Metal	117	480	0.90 U	0.10 U	0.10 U	0.10 U	0.13 J	0.10 U	0.10 U	0.54 J	0.10 U
D70675	RFETS	Solidified Organics	112	801	0.99 J	0.10 U	6.31	0.69 J	1.29	0.45 J	0.10 U	1.85 J	8.47
D70682	RFETS	Heterogeneous	116	831	405.00 U	45.00 U	2682.6	45.00 U	45.00 U	45.00 U	45.00 U	225.00 U	45.00 U
D70696	RFETS	Heterogeneous	116	821	5.40 U	0.60 U	0.60 U	3.33 J	0.60 U	0.60 U	0.60 U	3.00 U	0.60 U
D70734	RFETS	Heterogeneous	116	833	0.57 J	0.10 U	0.14 J	0.10 U	0.14 J	0.10 U	0.10 U	1.10 U	0.10 U
D70780	RFETS	Heterogeneous	116	832	0.50 U	0.10 U	0.10 U	0.10 U	0.13 J	0.10 U	0.10 U	1.10 U	0.10 U
D70856	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.21 J	0.52 J	0.23 J	1.21	0.10 U	0.94 J	0.10 U
D70882	RFETS	Heterogeneous	116	831	126.00 U	14.00 U	1277.8	14.00 U	14.00 U	14.00 U	14.00 U	70.00 U	14.00 U
D70937	RFETS	Filter	0	331	5.08 J	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	5.50 U	0.50 U
D71019	RFETS	Solidified Organics	112	801	11.70 U	1.30 U	21.30	1.30 U	1.32 J	1.30 U	1.30 U	6.50 U	97.64
D71020	RFETS	Solidified Organics	112	801	9988.2 J	911.50 U	44413	911.50 U	61914	911.50 U	911.50 U	32467 J	911.50 U
D71022	RFETS	Solidified Organics	112	801	6000.0 U	1200.0 U	32496	1200.0 U	66727	1200.0 U	1200.0 U	13200 U	1200.0 U
D71241	RFETS	Heterogeneous	116	833	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D71351	RFETS	Uncategorized Metal	117	480	0.67 J	0.18 J	0.10 U	0.10 U	0.20 J	0.10 U	0.10 U	1.20 U	0.10 U
D71354	RFETS	Uncategorized Metal	117	480	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U
D71385	RFETS	Heterogeneous	116	833	2.70 U	0.30 U	0.30 U	4.10	0.30 U	0.30 U	0.30 U	1.50 U	0.30 U
D71494	RFETS	Solidified Organics	112	801	1.07 J	0.10 U	1.69	0.42 J	0.25 J	0.23 J	0.10 U	3.13 J	10.16
D71504	RFETS	Solidified Organics	112	801	1.80 U	0.20 U	1.91 J	0.20 U	0.20 U	0.20 U	0.20 U	1.00 U	11.44
D71514	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.20 U	1.13 J	0.33 J	0.20 U	0.20 U	1.00 U	0.20 U
D71521	RFETS	Heterogeneous	116	825	1.80 U	0.20 U	0.20 U	1.00 J	0.33 J	0.20 U	0.20 U	1.00 U	0.20 U
D71638	RFETS	Uncategorized Metal	117	480	5.00 U	1.02 J	1.00 U	1.00 U	62.96	1.00 U	1.00 U	12.00 U	1.00 U
D71804	RFETS	Heterogeneous	116	832	0.81 J	0.60 J	0.23 J	0.10 U	0.10 U	2.07	0.70 J	1.20 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D71829	RFETS	Heterogeneous	116	852	1980.0 U	220.00 U	220.00 U	220.00 U	220.00 U	220.00 U	220.00 U	1100.0 U	220.00 U
D71838	RFETS	Heterogeneous	116	831	68.40 U	7.60 U	364.82	7.60 U	7.60 U	7.60 U	7.60 U	50.37 J	7.60 U
D71921	RFETS	Heterogeneous	116	833	0.50 U	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U	52.84 J	0.10 U
D71932	RFETS	Solidified Organics	112	801	39311 U	6023.4 J	85795	4367.9 U	88612	4367.9 U	4367.9 U	21839 U	4367.9 U
D71933	RFETS	Solidified Organics	112	801	0.50 U	0.10 U	2.59	0.10 U	0.89 J	0.10 U	0.10 U	1.10 U	10.21
D71934	RFETS	Solidified Organics	112	801	0.88 J	0.10 U	3.66	0.10 U	2.43	0.10 U	0.10 U	2.53 J	4.17
D71936	RFETS	Heterogeneous	116	833	195.00 U	21.67 U	1264.7	21.67 U	1946.0	21.67 U	21.67 U	108.34 U	21.67 U
D71937	RFETS	Heterogeneous	116	833	166.67 U	33.33 U	1343.4	33.33 U	2458.8	33.33 U	33.33 U	366.66 U	33.33 U
D71938	RFETS	Heterogeneous	116	833	16.20 U	1.80 U	97.42	1.80 U	69.15	1.80 U	1.80 U	9.00 U	1.80 U
D71940	RFETS	Solidified Organics	112	801	9000.0 U	1000.0 U	24298	1000.0 U	67524	1000.0 U	1000.0 U	5000.0 U	1000.0 U
D71941	RFETS	Solidified Organics	112	801	9000.0 U	1000.0 U	36373	1000.0 U	88979	1000.0 U	1000.0 U	6075.0 J	1000.0 U
D72010	RFETS	Heterogeneous	116	832	1.50 U	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	3.60 U	0.30 U
D72079	RFETS	Uncategorized Metal	117	480	58.50 U	6.50 U	544.22	6.50 U	6.50 U	6.50 U	6.50 U	32.50 U	6.50 U
D72127	RFETS	Solidified Organics	112	801	3.60 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	2.00 U	24.63
D72128	RFETS	Solidified Organics	112	801	3570.0 J	130.00 U	130.00 U	130.00 U	130.00 U	130.00 U	130.00 U	5061.2 J	130.00 U
D72131	RFETS	Heterogeneous	116	833	1.34 U	0.27 U	12.25	0.27 U	0.27 U	0.27 U	0.27 U	2.94 U	19.86
D72132	RFETS	Solidified Organics	112	801	316.85 J	48.00 U	48.00 U	48.00 U	48.00 U	48.00 U	48.00 U	1245.8 J	48.00 U
D72133	RFETS	Solidified Organics	112	801	1.80 U	0.20 U	0.93 J	0.20 U	1.52 J	0.20 U	0.20 U	3.84 J	1.32 J
D72136	RFETS	Solidified Organics	112	801	189.00 U	21.00 U	21.00 U	21.00 U	21.00 U	21.00 U	21.00 U	105.00 U	21.00 J
D72139	RFETS	Solidified Organics	112	801	17.10 U	1.90 U	8.18 J	1.90 U	12.29 J	1.90 U	1.90 U	9.50 U	3.72 J
D72178	RFETS	Heterogeneous	116	821	2.70 U	0.30 U	0.30 U	0.35 J	0.35 J	0.30 U	0.30 U	1.50 U	0.30 U
D72186	RFETS	Heterogeneous	116	821	1.80 U	0.20 U	0.46 J	0.56 J	0.45 J	0.20 U	0.20 U	1.00 U	0.20 U
D72195	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	3.12	1.68	0.22 J	0.10 U	0.10 U	0.50 U	0.10 U
D72255	RFETS	Heterogeneous	116	833	2.70 U	22.90	0.30 U	0.93 J	0.30 U	0.37 J	0.30 U	1.50 U	0.30 U
D72267	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.36 J	0.10 U	0.10 U	0.24 J	0.10 U	1.20 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D72293	RFETS	Heterogeneous	116	833	3.22 J	0.11 J	0.51 J	0.10 U	0.21 J	3.14	0.11 J	0.55 J	0.10 U
D72333	RFETS	Heterogeneous	116	831	2.70 U	0.30 U	0.30 J	1.13 J	0.31 J	0.30 U	0.30 U	1.50 U	0.30 U
D72339	RFETS	Heterogeneous	116	821	4.50 U	0.50 U	0.50 U	0.50 U	0.56 J	0.50 U	0.50 U	2.50 U	0.50 U
D72347	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.13 J	15.33	0.23 J	0.10 U	0.10 U	0.50 U	0.10 U
D72375	RFETS	Heterogeneous	116	831	720.00 U	80.00 U	4620.7	80.00 U	80.00 U	80.00 U	80.00 U	400.00 U	80.00 U
D72434	RFETS	Heterogeneous	116	831	1890.0 U	210.00 U	10516	210.00 U	210.00 U	210.00 U	210.00 U	2174.5 J	210.00 U
D72436	RFETS	Uncategorized Metal	117	480	2.00 J	0.30 U	20.40	0.30 U	0.30 U	0.30 U	0.30 U	11.10 J	0.60 J
D72542	RFETS	Heterogeneous	116	832	50.00 U	10.00 U	10.00 U	1394.3	10.00 U	10.00 U	10.00 U	110.00 U	10.00 U
D72545	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.12 J	0.21 J	0.10 U	0.15 J	0.10 U	1.20 U	0.10 U
D72546	RFETS	Heterogeneous	116	832	75.00 U	15.00 U	15.00 U	1801.2	15.00 U	15.00 U	15.00 U	165.00 U	15.00 U
D72566	RFETS	Solidified Organics	112	801	7.20 U	0.80 U	16.52	0.80 U	0.80 U	0.80 U	0.80 U	4.09 J	57.15
D72598	RFETS	Heterogeneous	116	821	5.40 U	0.60 U	0.60 U	2.29 J	1.16 J	1.70 J	0.60 U	4.14 J	0.60 U
D72618	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.17 J	0.22 J	0.30 J	0.10 U	0.10 U	0.50 U	0.10 U
D72619	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	0.99 J	0.10 U	0.23 J	0.10 U	0.10 U	0.83 J	1.75
D72623	RFETS	Solidified Organics	112	801	2.50 U	0.50 U	6.29	0.50 U	0.50 U	0.50 U	0.50 U	5.50 U	26.30
D72631	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	1.79	0.10 U	0.21 J	0.10 U	0.10 U	0.90 J	10.15
D72632	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	1.52	0.10 U	0.24 J	0.10 U	0.10 U	2.95 J	6.93
D72673	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	3.61	1.49 J	5.78	0.23 J	0.20 U	1.00 U	0.20 U
D72819	RFETS	Heterogeneous	116	833	3.60 U	3.26 J	0.82 J	1.89 J	0.49 J	0.47 J	0.40 U	2.00 U	0.40 U
D72822	RFETS	Heterogeneous	116	831	1.34 U	0.27 U	0.27 U	0.27 U	15.11	0.27 J	0.27 U	2.94 U	0.27 U
D72831	RFETS	Uncategorized Metal	117	480	20.00 U	4.00 U	305.00	4.00 U	4.00 U	4.00 U	4.00 U	48.00 U	4.00 U
D72887	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.15 J	0.87 J	0.30 J	0.10 U	0.10 U	0.50 U	0.10 U
D72923	RFETS	Heterogeneous	116	833	9.66 J	6.55	0.49 J	0.95 J	0.40 U	0.68 J	0.40 U	42.52 J	0.40 U
D72932	RFETS	Heterogeneous	116	825	2.70 U	0.30 U	0.73 J	5.12	0.46 J	0.30 U	0.30 U	1.50 U	0.30 U
D73054	RFETS	Heterogeneous	0	336	566.67 U	2074.3	113.33 U	113.33 U	5153.2	113.33 U	113.33 U	1580.3 J	113.33 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D73074	RFETS	Heterogeneous	116	833	1.80 J	0.81 J	0.20 U	0.20 U	0.64 J	0.20 U	0.20 U	4.17 J	0.20 U
D73117	RFETS	Uncategorized Metal	117	480	2.00 U	0.40 U	30.42	0.40 U	0.40 U	0.40 U	0.40 U	4.80 U	0.40 U
D73123	RFETS	Heterogeneous	116	831	1134.0 U	126.00 U	7343.0	126.00 U	126.00 U	126.00 U	126.00 U	630.00 U	126.00 U
D73134	RFETS	Heterogeneous	116	831	360.00 U	72.00 U	3648.5	72.00 U	72.00 U	72.00 U	72.00 U	792.00 U	72.00 U
D73136	RFETS	Solidified Inorganics	111	807	0.50 U	0.10 U	0.10 U	0.18 J	0.10 U	0.10 U	0.10 U	1.20 U	0.10 U
D73274	RFETS	Heterogeneous	116	831	450.00 U	50.00 U	2711.7	50.00 U	50.00 U	50.00 U	50.00 U	250.00 U	50.00 U
D73285	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	1.53	0.39 J	0.10 J	0.10 U	0.10 U	2.15 J	10.59
D73293	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	3.18	0.10 U	2.42	0.10 U	0.10 U	1.17 J	3.25
D73295	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	1.55	0.10 U	0.86 J	0.10 U	0.10 U	0.50 U	2.35
D73296	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	2.51	0.10 J	0.14 J	0.10 U	0.10 U	0.61 J	0.95 J
D73301	RFETS	Solidified Organics	112	801	1.80 U	0.20 U	1.42 J	0.43 J	2.30	0.20 U	0.20 U	1.44 J	12.42
D73605	RFETS	Lead/Cadmium Metal	123	339	0.50 U	0.10 U	2.96	0.10 U	3.87	0.12 J	0.10 U	1.20 U	0.10 U
D73632	RFETS	Heterogeneous	116	825	6.30 U	0.70 U	33.16	0.70 U	0.70 U	0.70 U	0.70 U	3.50 U	35.70
D73667	RFETS	Solidified Organics	112	801	0.90 U	0.10 U	1.03	0.17 J	0.10 U	0.10 U	0.10 U	1.16 J	2.36
D73672	RFETS	Solidified Organics	112	801	0.90 U	0.24 J	1.75	0.29 J	0.19 J	0.10 U	0.10 U	0.50 U	2.27
D73745	RFETS	Heterogeneous	116	832	0.50 U	0.18 J	1.89	10.64	1.75	0.10 U	0.10 U	1.20 U	0.10 U
D73828	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.17 J	0.65 J	0.31 J	0.10 U	0.10 U	0.50 U	0.10 U
D73848	RFETS	Heterogeneous	116	821	1.20 U	0.13 U	0.21 J	1.46	0.25 J	0.13 U	0.13 U	0.67 U	0.13 U
D73987	RFETS	Lead/Cadmium Metal	123	339	1.50 U	0.30 U	0.30 U	0.30 U	1.36 J	0.30 U	0.30 U	3.60 U	0.30 U
D74007	RFETS	Uncategorized Metal	117	480	1.74 J	0.30 U	0.56 J	0.30 U	0.74 J	0.30 U	0.30 U	3.60 U	0.30 U
D74110	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.28 J	6.63	0.60 J	0.10 U	0.10 U	0.50 U	0.10 U
D74147	RFETS	Solidified Organics	112	801	7.20 U	0.80 U	36.24	0.80 U	0.80 U	0.80 U	0.80 U	4.00 U	2.73 J
D74156	RFETS	Solidified Organics	112	801	5.40 U	0.60 U	36.75	0.60 U	4.68 J	0.60 U	0.60 U	3.00 U	3.09 J
D74374	RFETS	Heterogeneous	116	833	0.55 J	0.13 J	0.45 J	0.88 J	1.87	0.10 U	0.10 U	1.10 U	1.83
D74683	RFETS	Heterogeneous	116	821	29.51 J	1.50 U	1.50 U	5.85 J	1.50 U	1.50 U	1.50 U	7.50 U	1.50 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D74904	RFETS	Heterogeneous	116	832	0.50 U	0.10 U	0.10 U	0.39 J	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D74913	RFETS	Heterogeneous	116	832	2.70 U	0.30 U	0.30 U	1.50 J	0.30 U	0.30 U	0.30 U	1.50 U	0.30 U
D75039	RFETS	Heterogeneous	116	832	2.70 U	0.30 U	0.35 J	0.30 U	0.30 U	0.30 U	0.30 U	1.99 J	0.30 U
D75265	RFETS	Heterogeneous	116	833	14.89 J	1.20 U	1.20 U	3.95 J	63.67	1.20 U	1.20 U	6.00 U	1.20 U
D75267	RFETS	Heterogeneous	116	832	1.80 U	0.20 U	0.20 U	2.39	0.20 U	0.20 U	0.20 U	1.27 J	0.20 U
D75278	RFETS	Heterogeneous	116	832	2.70 U	0.30 U	0.30 U	3.74	0.30 U	0.30 U	0.30 U	3.85 J	0.30 U
D75399	RFETS	Heterogeneous	116	833	3.60 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	7.01 J	0.40 U
D75564	RFETS	Heterogeneous	116	825	1.20 U	0.13 U	0.13 U	0.85 J	0.24 J	0.13 U	0.13 U	0.92 J	0.13 U
D75868	RFETS	Heterogeneous	116	825	5.40 U	0.60 U	0.60 U	2.53 J	0.60 U	0.60 U	0.60 U	3.56 J	0.60 U
D75888	RFETS	Heterogeneous	116	833	1.18 J	0.10 U	0.20 J	0.10 U	0.31 J	0.13 J	0.10 U	0.50 U	0.10 U
D75926	RFETS	Heterogeneous	116	832	10.19 J	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	2.00 U	0.40 U
D75930	RFETS	Heterogeneous	116	832	500.00 U	100.00 U	100.00 U	100.00 U	6912.5	100.00 U	100.00 U	1100.0 U	100.00 U
D75947	RFETS	Heterogeneous	116	832	0.90 U	0.29 J	0.10 U	0.87 J	0.40 J	0.10 U	0.10 U	0.99 J	0.10 U
D75976	RFETS	Heterogeneous	116	833	3.37 J	0.13 U	0.13 U	1.50	0.13 U	0.13 U	0.13 U	1.46 U	0.13 U
D76044	RFETS	Heterogeneous	116	831	3.63 J	0.27 U	0.27 U	2.39 J	0.27 U	0.27 U	0.27 U	7.19 J	0.27 U
D76050	RFETS	Heterogeneous	116	832	1.02 J	0.10 U	0.10 U	0.99 J	0.10 U	0.10 U	0.10 U	0.73 J	0.10 U
D76054	RFETS	Heterogeneous	116	831	2.70 U	0.30 U	0.30 U	5.36	0.30 U	0.30 U	0.30 U	1.50 U	0.30 U
D76098	RFETS	Heterogeneous	116	832	1.00 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	2.40 U	0.20 U
D76135	RFETS	Solidified Organics	112	801	133.34 U	26.67 U	257.42 J	26.67 U	1583.9	26.67 U	26.67 U	293.34 U	26.67 U
D76136	RFETS	Solidified Inorganics	111	803	2.00 U	0.40 U	41.04	0.40 U	10.00	0.40 U	0.40 U	4.40 U	1.10 J
D76138	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D76142	RFETS	Solidified Inorganics	111	800	1.36 J	0.24 U	7.62	0.24 U	0.84 J	1.82 J	0.24 U	2.64 U	0.24 U
D76143	RFETS	Solidified Inorganics	111	803	1.50 U	0.30 U	31.39	0.30 U	4.26	0.30 U	0.30 U	3.30 U	0.87 J
D76144	RFETS	Solidified Inorganics	111	800	3.34 U	0.67 U	48.10	0.67 U	0.67 U	0.68 J	0.67 U	7.34 U	2.78 J
D76146	RFETS	Solidified Inorganics	0	292	0.50 U	0.10 U	0.18 J	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D76147	RFETS	Solidified Inorganics	111	803	1.39 J	0.10 U	2.44	0.13 J	0.15 J	0.15 J	0.10 U	1.84 J	0.13 J
D76182	RFETS	Solidified Inorganics	111	800	6.30 U	0.70 U	0.70 U	0.70 U	1.04 J	4.03 J	0.70 U	3.50 U	0.70 U
D76183	RFETS	Solidified Inorganics	111	800	0.67 U	0.13 U	4.25	0.13 U	0.13 U	0.93 J	0.13 U	1.46 U	0.13 U
D76185	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.55 J	0.10 U
D76187	RFETS	Solidified Inorganics	111	803	2.50 U	0.50 U	49.01	0.50 U	11.65	0.50 U	0.50 U	5.50 U	1.46 J
D76189	RFETS	Solidified Inorganics	111	803	10.00 U	2.00 U	165.71	2.00 U	2.00 U	2.00 U	2.00 U	22.00 U	7.50 J
D76192	RFETS	Solidified Inorganics	111	803	0.50 U	0.10 U	0.93 J	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.57 J
D76194	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.10 U
D76195	RFETS	Solidified Organics	112	801	4320.0 U	480.00 U	13758	480.00 U	6208.6	480.00 U	480.00 U	3249.5 J	480.00 U
D76196	RFETS	Solidified Organics	112	801	833.34 U	166.67 U	1020.1 J	166.67 U	12990	166.67 U	166.67 U	1833.3 U	166.67 U
D76199	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	1.13 J	0.10 U
D76200	RFETS	Solidified Organics	112	801	3166.6 U	633.33 U	4123.0 J	633.33 U	43418	633.33 U	633.33 U	6966.6 U	633.33 U
D76203	RFETS	Solidified Organics	112	801	1116.6 J	223.33 U	3535.3	223.33 U	13365	223.33 U	223.33 U	2456.6 U	223.33 U
D76205	RFETS	Solidified Inorganics	111	800	0.50 U	0.10 U	0.62 J	0.18 J	0.86 J	0.46 J	0.10 U	1.10 U	0.10 U
D76206	RFETS	Solidified Inorganics	111	803	2.00 U	0.40 U	28.65	0.40 U	0.40 U	0.40 U	0.40 U	4.40 U	0.87 J
D76217	RFETS	Heterogeneous	116	833	5.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	12.29 J	1.00 U
D76282	RFETS	Solidified Inorganics	111	800	56.67 U	11.33 U	118.35	11.33 U	675.83	11.33 U	11.33 U	124.66 U	11.33 U
D76283	RFETS	Solidified Organics	112	801	450.00 U	90.00 U	1068.5	90.00 U	5328.1	90.00 U	90.00 U	990.00 U	90.00 U
D76287	RFETS	Solidified Inorganics	111	800	26.67 U	5.33 U	72.31	5.33 U	402.58	5.33 U	5.33 U	58.66 U	5.33 U
D76293	RFETS	Heterogeneous	116	833	3.60 U	0.40 U	5.02	0.40 U	22.39	0.40 U	0.40 U	3.53 J	0.40 U
D76302	RFETS	Solidified Inorganics	111	800	15.00 U	3.00 U	3.00 U	3.00 U	3.00 U	3.00 U	3.00 U	33.00 U	3.00 U
D76303	RFETS	Solidified Inorganics	111	803	1.34 U	0.27 U	21.61	0.27 U	0.27 U	0.27 U	0.27 U	2.94 U	0.70 J
D76305	RFETS	Solidified Inorganics	111	800	60.00 U	12.00 U	91.70 J	12.00 U	494.26	12.00 U	12.00 U	132.00 U	12.00 U
D76306	RFETS	Heterogeneous	116	833	7.20 U	0.80 U	17.00	0.80 U	37.08	0.80 U	0.80 U	5.52 J	0.80 U
D76362	RFETS	Heterogeneous	116	833	33.34 U	554.17	6.67 U	6.67 U	6.67 U	6.67 U	6.67 U	183.17 J	6.67 U

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(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D76406	RFETS	Heterogeneous	116	831	0.90 U	0.10 U	0.45 J	0.10 U	0.37 J	0.10 U	0.10 U	0.50 U	0.10 U
D76437	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.20 U	2.24	0.20 U	0.20 U	0.20 U	1.44 J	0.20 U
D76443	RFETS	Heterogeneous	116	825	2.70 U	0.30 U	0.30 U	0.63 J	0.33 J	0.30 U	0.30 U	1.50 U	0.30 U
D76452	RFETS	Heterogeneous	116	825	1.70 J	0.20 U	0.20 J	0.20 U	0.40 J	0.20 U	0.20 U	1.10 J	0.20 U
D76454	RFETS	Heterogeneous	116	825	0.90 U	0.10 U	0.12 J	0.66 J	0.21 J	0.10 U	0.10 U	0.50 U	0.10 U
D76456	RFETS	Heterogeneous	116	825	0.90 U	0.10 U	0.13 J	0.72 J	0.23 J	0.10 U	0.10 U	1.95 J	0.10 U
D76461	RFETS	Heterogeneous	116	825	2.70 U	0.30 U	0.30 U	1.89 J	0.30 U	0.30 U	0.30 U	1.50 U	0.39 J
D76463	RFETS	Heterogeneous	116	825	2.70 U	0.30 U	0.33 J	1.09 J	0.31 J	0.30 U	0.30 U	1.50 U	0.30 U
D76470	RFETS	Solidified Inorganics	111	803	0.50 U	0.10 U	0.83 J	0.10 U	0.10 U	0.10 U	0.10 U	1.10 U	0.28 J
D76587	RFETS	Heterogeneous	116	825	0.90 U	0.10 U	0.20 J	1.07	0.69 J	0.10 U	0.10 U	0.90 U	0.10 U
D76596	RFETS	Heterogeneous	116	825	3.13 J	0.10 U	0.20 J	1.67	0.97 J	0.10 U	0.10 U	5.14 J	0.10 U
D76627	RFETS	Heterogeneous	116	825	0.90 U	0.10 U	0.10 J	0.91 J	0.21 J	0.10 U	0.10 U	0.79 J	0.10 U
D76630	RFETS	Heterogeneous	116	825	2.01 J	0.10 U	0.20 J	0.89 J	0.65 J	0.10 U	0.10 U	1.30 J	0.10 U
D76635	RFETS	Heterogeneous	116	825	1.80 U	0.20 U	0.25 J	0.61 J	0.81 J	0.20 U	0.20 U	1.71 J	0.20 U
D76652	RFETS	Heterogeneous	116	833	0.66 J	0.10 U	0.11 J	0.47 J	0.10 U	0.10 U	0.10 U	2.98 J	0.10 U
D76677	RFETS	Solidified Inorganics	111	800	21.60 U	2.40 U	199.52	2.40 U	2.40 U	2.40 U	2.40 U	12.00 U	14.06 J
D76710	RFETS	Heterogeneous	116	833	18.00 U	136.89	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	10.00 U	2.00 U
D76712	RFETS	Heterogeneous	116	833	2.70 U	0.95 J	0.30 U	0.30 U	0.30 U	0.30 U	0.30 U	1.50 U	0.30 U
D76715	RFETS	Heterogeneous	116	832	1.80 U	0.20 U	0.20 U	1.88 J	0.20 U	0.20 U	0.20 U	2.35 J	0.20 U
D76811	RFETS	Heterogeneous	116	832	2.46 J	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	8.62 J	0.20 U
D76908	RFETS	Heterogeneous	116	833	0.90 U	0.10 U	0.14 J	0.66 J	0.79 J	0.10 U	0.10 U	0.50 U	0.32 J
D76911	RFETS	Heterogeneous	116	832	1.00 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	2.20 U	0.20 U
D77088	RFETS	Heterogeneous	116	833	2.93 J	0.20 U	0.20 U	0.20 U	0.30 J	0.20 U	0.20 U	2.20 J	0.20 U
D77227	RFETS	Heterogeneous	116	833	2.00 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U	4.40 U	0.40 U
D77285	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.27 J	1.18 J	0.20 U	0.20 U	0.20 U	1.00 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl ethyl Ketone	Chloroform	1,1,1-Tri chloro-ethane	Cyclo-hexane	Carbon Tetra-chloride	Benzene	1,2-Di-chloro-ethane	1-Butanol	Trichloro-ethene
D77621	RFETS	Heterogeneous	0	336	1.34 U	0.27 U	0.27 U	0.27 U	19.30	0.27 U	0.27 U	3.20 U	0.27 U
D80765	RFETS	Heterogeneous	116	833	1.80 U	0.20 U	0.20 U	2.61	0.20 U	0.20 U	0.20 U	2.79 J	0.20 U
D80772	RFETS	Heterogeneous	116	833	9.00 U	1.00 U	47.56	5.62 J	1.00 U	1.00 U	1.00 U	5.00 U	13.18
D80774	RFETS	Heterogeneous	116	833	27.90 U	3.10 U	53.30	3.10 U	127.73	3.10 U	3.10 U	15.50 U	3.10 U
D80776	RFETS	Heterogeneous	116	832	7.59 J	2.48	0.10 U	0.10 U	0.20 J	1.23	0.18 J	5.18 J	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
000365	RFETS	Uncategorized Metal	217	480	17.00 U	15.00	11.00 U	12.00 U	13.00 U	13.00 U	13.00 U	11.00 U
000371	INEL	Graphite	215	300	17.00 U	3.30	0.02 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
000373	INEL	Graphite	215	300	17.00 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04 U
000384	RFETS	Uncategorized Metal	217	320	5.00 U	0.29	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
000393	INEL	Uncategorized Metal	217	480	17.00 U	4.80	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
000401	RFETS	Inorganic Non-metal	222	371	5.00 U	2.60	0.01 U	0.01 U	0.02 U	0.02 J	0.02 U	0.01 U
000403	INEL	Inorganic Non-metal	218	440	17.00 U	1.50	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
000405	RFETS	Uncategorized Metal	217	480	5.00 U	27.00	0.79 U	0.93 U	0.99 U	0.99 U	0.99 U	0.83 U
000436	INEL	Solidified Organics	212	3	17.00 U	39.00 U	30.00 U	38.00 U	36.00 U	44.00 U	42.00 U	45.00 U
000442	INEL	Solidified Inorganics	213	4	51.00 U	6.50	0.04 U	0.05 U	0.05 U	0.10 J	0.05 U	0.06 U
000446	RFETS	Solidified Inorganics	211	1	5.00 U	0.56	0.01 U	0.01 U	0.01 U	0.02 J	0.01 U	0.01 U
000478	RFETS	Solidified Inorganics	211	1	5.00 U	0.48	0.01 U	0.01 U	0.02 J	0.04 J	0.01 J	0.01 U
000501	INEL	Graphite	215	300	17.00 U	0.03 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
000558	INEL	Heterogeneous	221	464	17.00 U	16.00	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
000567	RFETS	Inorganic Non-metal	222	371	5.00 U	3.70	1.40 U	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
000568	RFETS	Solidified Organics	226	432	17.00 U	67.00	0.88 U	1.00 U	1.10 U	1.10 U	1.10 U	0.92 U
000593	INEL	Solidified Inorganics	211	7	17.00 U	2.40	0.01 U	0.02 U	0.02 U	0.05 J	0.02 J	0.02 U
000613	INEL	Graphite	215	300	17.00 U	0.04 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
000630	INEL	Solidified Inorganics	213	4	51.00 U	7.40 B	0.05 U	0.06 U	0.06 U	0.09 J	0.07 U	0.07 U
000648	RFETS	Solidified Inorganics	213	4	70.00 U	1.10	0.03 U	0.03 U	0.03 U	0.08 JD	0.03 U	0.03 U
000675	RFETS	Inorganic Non-metal	218	440	5.00 U	45.00	0.13 U	0.16 U	0.17 U	0.17 U	0.17 U	0.14 U
000823	RFETS	Solidified Inorganics	213	4	120.00 U	4.60	0.02 U	0.02 U	0.02 U	0.05 J	0.02 U	0.02 U
000828	INEL	Graphite	215	300	17.00 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04 U
001016	INEL	Graphite	215	300	17.00 U	0.08 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
001024	INEL	Graphite	215	300	17.00 U	0.07 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
001084	INEL	Solidified Inorganics	213	4	17.00 U	10.00 B	0.02 U	0.02 U	0.03 J	0.07 JB	0.02 U	0.02 U
001139	INEL	Solidified Inorganics	211	7	17.00 U	3.60	0.11 U	0.14 U	0.14 U	0.17 U	0.16 U	0.17 U
001157	INEL	Combustible	223	339	17.00 U	1.80	0.03 U	0.03 U	0.08 U	0.19 J	0.20 J	0.03 U
001161	INEL	Graphite	215	300	17.00 U	0.03 U	0.02 U	0.02 U	0.03 U	0.03 U	0.03 U	0.05 U
001258	RFETS	Solidified Inorganics	211	1	5.00 U	1.60	0.01 U	0.01 U	0.06 J	0.14	0.02 J	0.01 U
001370	INEL	Combustible	223	339	17.00 U	1.10	0.11 U	0.12 U	0.13 U	0.27 J	0.25 J	0.16 U
001377	INEL	Combustible	223	339	17.00 U	7.90	0.03 U	0.03 U	0.37	0.96	0.81	0.03 U
001410	INEL	Solidified Inorganics	214	292	17.00 U	29.00	0.11 U	0.13 U	0.13 U	0.13 U	0.13 U	0.11 U
001437	RFETS	Solidified Inorganics	211	7	5.00 U	2.40	0.01 U	0.01 U	0.01 U	0.03 J	0.01 U	0.01 U
001475	RFETS	Solidified Inorganics	211	1	15.00 J	13.00	0.18 U	0.21 U	0.85 JD	2.80 D	0.22 U	0.18 U
001493	RFETS	Solidified Inorganics	211	1	5.00 U	1.10	0.01 U	0.01 U	0.01 U	0.02 J	0.01 U	0.01 U
001619	INEL	Graphite	215	300	17.00 U	0.04 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
001625	INEL	Graphite	215	300	17.00 U	0.08 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
001633	INEL	Solidified Organics	226	432	17.00 U	4.20 J	0.63 U	0.74 U	0.78 U	0.78 U	0.78 U	0.66 U
001655	INEL	Combustible	223	339	17.00 U	2.40 U	1.70 U	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U
001662	INEL	Graphite	215	300	17.00 U	0.06 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
001663	RFETS	Solidified Organics	226	432	17.00 U	19.00	0.38 U	0.44 U	0.47 U	0.47 U	0.47 U	0.40 U
001667	INEL	Graphite	215	300	17.00 U	0.34 J	0.01 U	0.02 U	0.12 J	0.02 U	0.02 U	0.02 U
001670	RFETS	Salt Waste	224	411	5.00 U	10.00	0.03 U	0.39 U	0.04 U	0.05 J	0.04 U	0.04 U
001677	INEL	Heterogeneous	221	302	17.00 U	9.70	0.73 J	0.42 U	0.39 U	0.48 U	0.46 U	0.49 U
001678	RFETS	Combustible	223	339	5.00 U	18.00	0.11 J	0.10 U	0.11 U	0.20 J	0.11 U	0.09 U
001689	INEL	Heterogeneous	221	302	17.00 U	21.00 E	0.03 U	0.04 U	0.19 J	0.39 J	0.09 J	0.03 U
001692	RFETS	Solidified Organics	226	432	17.00 U	22.00	0.23 U	0.27 U	0.28 U	0.28 U	0.28 U	0.24 U
001695	INEL	Combustible	223	339	1.10 U	23.00	1.40 U	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
001697	INEL	Graphite	215	300	17.00 U	0.13 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
001751	RFETS	Uncategorized Metal	217	320	5.00 U	2.60	0.01 U	0.01 U	0.04 J	0.13	0.14	0.01 U
001752	INEL	Graphite	215	300	17.00 U	0.06 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
001754	INEL	Uncategorized Metal	217	320	17.00 U	13.00	0.05 U	0.07 U	0.21 J	0.70 J	0.19 J	0.03 U
001757	INEL	Inorganic Non-metal	222	371	17.00 U	0.36	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
001773	INEL	Graphite	215	300	17.00 U	0.05 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
001779	INEL	Graphite	215	300	34.00 U	0.11 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
001784	INEL	Combustible	223	339	17.00 U	1.90	0.03 U	0.03 U	0.05 J	0.09 J	0.09 J	0.03 U
001813	INEL	Solidified Inorganics	213	4	17.00 U	6.60 B	4.00 U	5.10 U	4.80 U	6.00 U	5.60 U	6.00 U
001873	INEL	Solidified Inorganics	214	292	17.00 U	5.70	0.03 U	0.04 U	0.04 U	0.04 U	0.04 U	0.03 U
001899	RFETS	Solidified Inorganics	211	3	5.00 U	170.00	120.00 U	140.00 U	150.00 U	150.00 U	150.00 U	120.00 U
001900	INEL	Solidified Inorganics	214	292	17.00 U	8.00	0.06 J	0.04 U	0.04 U	0.04 U	0.04 U	0.03 U
001919	RFETS	Uncategorized Metal	217	320	5.00 U	0.30	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
001937	RFETS	Solidified Organics	212	3	5.00 U	20.00	14.00 U	16.00 U	18.00 U	18.00 U	18.00 U	15.00 U
002013	RFETS	Solidified Organics	212	3	5.00 U	14.00	10.00 U	12.00 U	12.00 U	12.00 U	12.00 U	10.00 U
002046	INEL	Solidified Organics	212	3	17.00 U	33.00 U	25.00 U	32.00 U	30.00 U	37.00 U	35.00 U	38.00 U
002065	INEL	Solidified Inorganics	214	292	5.00 U	27.00 U	0.09	0.11 U	0.12 U	0.12 U	0.12 U	0.10 U
002084	INEL	Solidified Inorganics	213	4	17.00 U	0.54 JB	0.03 U	0.03 U	0.03 U	0.06 JB	0.04 U	0.04 U
002220	RFETS	Uncategorized Metal	217	481	5.00 U	0.06	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
002222	INEL	Graphite	215	300	17.00 U	0.09 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
002338	RFETS	Inorganic Non-metal	222	371	17.00 U	5.10	0.71 U	0.83 U	0.88 U	0.88 U	0.88 U	0.74 U
002354	INEL	Combustible	223	339	17.00 U	1.30	0.06 U	0.06 U	0.07 U	0.08 U	0.09 J	0.09 U
002363	INEL	Inorganic Non-metal	222	371	17.00 U	0.28 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
002365	INEL	Uncategorized Metal	217	480	17.00 U	1.80	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
002542	INEL	Solidified Organics	212	3	17.00 U	7.10 U	5.50 U	6.90 U	6.50 U	8.10 U	7.60 U	8.10 U
002678	RFETS	Solidified Organics	226	432	17.00 U	6.20	14.00 U	0.95 U	1.00 U	1.00 U	1.00 U	0.84 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
002791	INEL	Inorganic Non-metal	222	371	17.00 U	4.30	0.04 U	0.05 U	0.05 U	0.05 U	0.05 U	0.04 U
002797	RFETS	Solidified Organics	226	432	17.00 U	57.00	0.40 U	0.47 U	0.50 U	0.50 U	0.50 U	0.42 U
002814	RFETS	Solidified Inorganics	211	7	5.00 U	2.60	0.18 U	0.22 U	0.23 U	0.23 U	0.23 U	0.19 U
003017	INEL	Solidified Inorganics	211	1	5.00 U	5.00	0.05 U	0.05 U	0.06 U	0.06 U	0.06 U	0.05 U
003088	INEL	Inorganic Non-metal	222	371	17.00 U	4.20	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
003091	RFETS	Inorganic Non-metal	222	371	17.00 U	0.59	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
003111	INEL	Inorganic Non-metal	222	371	15.00 U	2.00	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
003121	RFETS	Solidified Inorganics	211	7	5.00 U	1.60	0.12 U	0.14 U	0.15 U	0.15 U	0.15 U	0.13 U
003129	RFETS	Solidified Inorganics	211	7	5.00 U	1.80	0.02 U	0.02 U	0.14 J	0.46	0.05 J	0.02 U
003130	RFETS	Solidified Inorganics	211	7	5.00 U	2.20	0.04 U	0.04 U	0.06 JD	0.22 JD	0.05 U	0.04 U
003173	RFETS	Solidified Inorganics	211	7	5.00 U	2.50	0.02 U	0.02 U	0.02 U	0.06 J	0.02 U	0.02 U
003181	RFETS	Solidified Inorganics	211	7	5.00 U	2.00	0.01 U	0.01 U	0.02 U	0.02 U	0.02 U	0.01 U
003189	INEL	Solidified Organics	212	3	17.00 U	72.00 U	56.00 U	71.00 U	66.00 U	82.00 U	78.00 U	83.00 U
003192	RFETS	Solidified Inorganics	211	7	5.00 U	1.70	0.21 U	0.24 U	0.26 U	0.26 U	0.26 U	0.22 U
003215	RFETS	Solidified Inorganics	211	7	5.00 U	2.10	0.01 U	0.01 U	0.02 J	0.08 J	0.02 U	0.01 U
003277	RFETS	Solidified Inorganics	211	1	5.00 U	0.23	0.01 U	0.01 U	0.01 U	0.02 J	0.01 U	0.01 U
003394	RFETS	Solidified Inorganics	211	7	5.00 U	1.80	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
003406	RFETS	Solidified Inorganics	211	7	5.00 U	0.86	0.01 J	0.01 U	0.01 U	0.03 J	0.01 J	0.01 U
003455	RFETS	Solidified Inorganics	211	3	5.00 U	320.00	220.00 U	260.00 U	280.00 U	280.00 U	280.00 U	240.00 U
003547	RFETS	Solidified Inorganics	211	7	5.00 U	0.91	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
003577	RFETS	Solidified Inorganics	211	1	5.00 U	1.70	0.01 U	0.01 U	0.01 U	0.02 J	0.01 U	0.01 U
003854	INEL	Solidified Organics	212	3	17.00 U	33.00 U	26.00 U	32.00 U	30.00 U	38.00 U	36.00 U	38.00 U
003890	INEL	Solidified Inorganics	111	7	5.00 U	1.80	0.03 U	0.03 U	0.03 U	0.03 J	0.03 U	0.03 U
003921	INEL	Solidified Inorganics	111	7	5.00 U	2.00	0.03 U	0.04 U	0.04 U	0.07 J	0.04 U	0.03 U
003991	INEL	Combustible	223	339	17.00 U	0.71 J	0.02 U	0.02 U	0.05 J	0.08 J	0.11 J	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
003997	INEL	Combustible	223	339	17.00 U	5.10	0.04 U	0.04 U	0.14 J	0.33 J	0.33 J	0.06 U
004099	INEL	Solidified Inorganics	211	1	5.00 U	1.90	0.02 J	0.01 U	0.02 U	0.02 U	0.02 U	0.01 U
004111	RFETS	Salt Waste	224	411	5.00 U	5.00	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
004112	INEL	Graphite	215	300	17.00 U	0.07 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
004123	INEL	Combustible	223	339	17.00 U	1.50	0.02 U	0.02 U	0.10 J	0.24 J	0.27 J	0.03 U
004125	INEL	Uncategorized Metal	217	480	17.00 U	1.80	0.03 U	0.03 U	0.03 U	0.03 J	0.03 U	0.03 U
004150	INEL	Graphite	215	300	15.00 U	0.02 U	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
004160	INEL	Combustible	223	339	17.00 U	130.00 U	110.00 U	120.00 U	130.00 U	150.00 U	130.00 U	160.00 U
004166	INEL	Inorganic Non-metal	222	371	17.00 U	0.31 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
004186	INEL	Combustible	223	339	17.00 U	2.00	0.02 U	0.02 U	0.06 J	0.17 J	0.13 J	0.03 U
004195	RFETS	Salt Waste	224	411	5.00 U	1.20	0.01 U	0.01 U	0.01 U	0.01 J	0.01 U	0.01 U
004196	INEL	Graphite	215	300	17.00 U	0.26 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04 U
004206	INEL	Combustible	223	339	17.00 U	1.40	0.02 U	0.02 U	0.06 J	0.09 J	0.12 J	0.02 U
004208	INEL	Graphite	215	300	51.00 U	0.18 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
004283	INEL	Solidified Inorganics	211	1	17.00 U	1.10	0.01 U	0.02 U	0.14 J	0.40 J	0.07 J	0.02 U
004326	INEL	Solidified Inorganics	213	4	17.00 U	2.70 B	0.01 U	0.02 U	0.09 J	0.35 JB	0.13 J	0.02 U
004393	INEL	Solidified Inorganics	211	1	5.00 U	2.10	0.02 U	0.02 U	0.02 U	0.03 J	0.02 U	0.02 U
004410	INEL	Solidified Inorganics	211	1	5.00 U	4.10	0.03 U	0.03 U	0.03 U	0.04 J	0.03 U	0.03 U
004495	INEL	Solidified Inorganics	213	4	17.00 U	2.50	0.01 U	0.02 U	0.02 U	0.02 J	0.02 U	0.02 U
004516	INEL	Solidified Inorganics	211	1	5.00 U	5.40	0.03 U	0.03 U	0.03 U	0.10 J	0.03 U	0.03 U
004884	INEL	Solidified Inorganics	213	4	17.00 U	5.10	0.02 U	0.02 U	0.04 J	0.13 J	0.03 J	0.03 U
004963	INEL	Combustible	223	339	17.00 U	10.00	0.06 U	0.06 U	0.21 J	0.57 J	0.23 J	0.09 U
004968	RFETS	Uncategorized Metal	217	320	5.00 U	170.00	0.49 U	0.58 U	0.62 U	0.62 U	0.62 U	0.52 U
004981	RFETS	Uncategorized Metal	217	320	5.00 U	0.22	0.01 U	0.01 U	0.01 U	0.01 J	0.01 U	0.01 U
004988	RFETS	Salt Waste	224	411	5.00 U	6.50	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
005006	RFETS	Salt Waste	224	411	5.00 U	5.00	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
005012	INEL	Combustible	223	339	17.00 U	0.31 J	0.01 U	0.02 U	0.04 J	0.05 J	0.02 J	0.02 U
005015	INEL	Solidified Organics	226	432	17.00 U	4.30 J	1.30 U	1.50 U	1.60 U	1.60 U	1.60 U	1.30 U
005235	INEL	Solidified Organics	226	432	17.00 U	5.70	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
005262	INEL	Solidified Organics	212	3	17.00 U	200.00 U	160.00 U	200.00 U	190.00 U	230.00 U	220.00 U	240.00 U
005358	INEL	Solidified Inorganics	211	1	17.00 U	6.90	0.01 U	0.02 U	0.45 J	1.70	0.30 J	0.02 U
005398	INEL	Solidified Inorganics	211	1	5.00 U	3.60	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
005415	INEL	Solidified Inorganics	211	1	5.00 U	5.90	0.03 U	0.03 U	0.03 U	0.07 J	0.03 U	0.03 U
005530	INEL	Graphite	215	303	15.00 U	0.98 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04 U
005535	INEL	Solidified Organics	226	432	17.00 U	15.00 D	0.05 U	0.06 U	0.06 U	0.06 U	0.06 U	0.05 U
005735	INEL	Solidified Inorganics	211	7	5.00 U	3.80	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
005738	INEL	Solidified Inorganics	211	7	5.00 U	3.40	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
006242	INEL	Inorganic Non-metal	222	371	17.00 U	1.70	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
006252	RFETS	Lead/Cadmium Metal	123	339	5.00 U	5.80	3.30 U	3.90 U	4.20 U	4.20 U	4.20 U	3.50 U
006325	RFETS	Solidified Inorganics	213	4	100.00 U	3.30	0.01 U	0.01 U	0.02 J	0.05 J	0.02 J	0.01 U
006669	INEL	Solidified Inorganics	214	292	5.00 U	38.00	0.13 U	0.15 U	0.16 U	0.16 U	0.16 U	0.13 U
006773	RFETS	Solidified Inorganics	213	4	120.00 U	3.40	0.09 U	0.11 U	0.12 U	0.14 J	0.12 U	0.10 U
006857	INEL	Combustible	223	339	18.00 U	7.20	0.02 U	0.02 U	0.02 J	0.06 J	0.05 J	0.03 U
006865	RFETS	Solidified Organics	226	432	5.00 U	18.00	0.07 U	0.08 U	0.08 U	0.08 U	0.08 U	0.07 U
006876	INEL	Filter	219	335	17.00 U	0.75 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
006879	INEL	Solidified Organics	226	432	17.00 U	19.00	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
006886	INEL	Solidified Organics	226	432	17.00 U	6.20	0.82 J	0.33 U	0.34 U	0.38 J	0.34 U	0.29 U
007034	INEL	Combustible	216	337	17.00 U	3.30	1.80 U	2.10 U	2.20 U	2.20 U	2.20 U	1.90 U
007146	INEL	Inorganic Non-metal	222	371	17.00 U	2.10 U	3.30	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
007170	INEL	Combustible	216	337	17.00 U	0.94 J	0.37 J	0.34 U	0.36 U	0.41 U	0.37 U	0.68 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
007231	INEL	Filter	219	338	17.00 U	0.29 J	0.67 J	0.15 U	0.16 U	0.19 U	0.17 U	0.20 U
007511	INEL	Inorganic Non-metal	122	374	17.00 U	2.90	0.03 U	0.04 U	0.16 J	0.58	0.29 J	0.03 U
007518	INEL	Inorganic Non-metal	122	374	17.00 U	6.60	0.05 U	0.06 U	0.06 U	0.13 J	0.08 J	0.05 U
007667	INEL	Salt Waste	124	411	5.00 U	0.43	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
007920	INEL	Filter	121	302	17.00 U	53.00	0.20 U	0.24 U	0.25 U	0.25 U	0.25 U	0.21 U
008203	INEL	Inorganic Non-metal	118	440	17.00 U	13.00	0.05 U	0.06 U	0.06 U	0.06 U	0.06 U	0.05 U
008207	INEL	Heterogeneous	116	336	17.00 U	2.30	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
008218	INEL	Heterogeneous	116	330	17.00 U	2.90	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
008269	INEL	Uncategorized Metal	117	320	17.00 U	34.00 D	0.16 U	0.19 U	0.28 JD	0.85 JD	0.22 JD	0.17 U
008287	INEL	Inorganic Non-metal	122	374	17.00 U	1.00	0.03 U	0.03 U	1.50	5.10	2.30	0.03 U
008359	INEL	Heterogeneous	116	330	17.00 U	40.00	0.16 U	0.19 U	0.20 U	0.20 U	0.20 U	0.17 U
008383	INEL	Lead/Cadmium Metal	123	339	5.00 U	12.00 J	4.40 U	5.20 U	5.50 U	5.50 U	5.50 U	4.60 U
008848	INEL	Inorganic Non-metal	218	440	17.00 U	5.70	0.14 U	0.18 U	0.17 U	0.21 U	0.20 U	0.22 J
008859	INEL	Inorganic Non-metal	218	440	17.00 U	7.40	0.38 U	0.44 U	0.47 U	0.76 J	0.47 U	0.40 U
008860	INEL	Uncategorized Metal	217	480	17.00 U	8.40	0.96 U	1.10 U	1.20 U	1.20 U	1.20 U	1.00 U
008864	INEL	Uncategorized Metal	217	480	17.00 U	2.40	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
008872	INEL	Solidified Inorganics	214	292	5.00 U	6.60	0.03 U	0.04 U	0.04 U	0.04 U	0.04 U	0.04 U
008874	RFETS	Uncategorized Metal	217	480	5.00 U	42.00	30.00 U	35.00 U	37.00 U	37.00 U	37.00 U	31.00 U
008878	INEL	Uncategorized Metal	217	480	17.00 U	5.80 U	4.00 U	4.70 U	5.00 U	5.00 U	5.00 U	4.20 U
008880	RFETS	Graphite	115	312	5.00 U	9.40	1.10 U	1.40 U	1.40 U	1.40 U	1.40 U	1.20 U
009006	INEL	Solidified Inorganics	211	7	18.00 U	1.30	0.04 J	0.02 U	0.05 J	0.15 J	0.04 J	0.02 U
009011	RFETS	Solidified Inorganics	211	7	5.00 U	1.90	0.02 J	0.01 U	0.05 J	0.19	0.02 J	0.01 U
009061	RFETS	Inorganic Non-metal	218	440	5.00 U	0.41	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
009180	INEL	Combustible	223	339	17.00 U	5.30	0.69 U	0.76 U	0.81 U	1.00	0.83 U	1.00 U
009225	INEL	Uncategorized Metal	217	481	18.00 U	0.04 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
009252	INEL	Combustible	223	339	17.00 U	27.00 J	18.00 U	21.00 U	22.00 U	22.00 U	22.00 U	18.00 U
009296	INEL	Combustible	223	339	17.00 U	16.00	2.50 U	3.00 U	3.10 U	3.10 U	3.10 U	2.60 U
009299	INEL	Combustible	223	339	17.00 U	0.32 J	0.02 U	0.02 U	0.04 J	0.07 J	0.08 J	0.03 U
009399	INEL	Inorganic Non-metal	218	440	17.00 U	2.10	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U
009422	RFETS	Combustible	216	337	5.00 U	8.50	4.70 U	5.50 U	5.90 U	5.90 U	5.90 U	4.90 U
009423	INEL	Combustible	216	337	17.00 U	3.60	1.30 U	1.60 U	1.50 U	1.90 U	1.80 U	1.90 U
009435	INEL	Combustible	216	337	17.00 U	6.40	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U
009449	INEL	Inorganic Non-metal	218	440	17.00 U	15.00 E	0.04 U	0.04 U	0.05 U	0.10 J	0.05 U	0.04 U
009471	INEL	Combustible	216	337	18.00 U	0.85 J	0.07 U	0.08 U	0.08 U	0.09 U	0.08 U	0.15 U
009475	INEL	Inorganic Non-metal	218	442	17.00 U	0.65 U	0.51 U	0.64 U	0.60 U	0.74 U	0.70 U	0.75 U
009489	INEL	Combustible	216	337	1.10 U	0.94 J	0.18 U	0.20 U	0.21 U	0.24 U	0.22 U	0.40 U
009587	INEL	Uncategorized Metal	117	320	5.00 U	1.20	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
009591	INEL	Inorganic Non-metal	118	440	17.00 U	2.00	0.03 U	0.04 U	0.04 U	0.04 U	0.04 U	0.03 U
009592	INEL	Inorganic Non-metal	118	440	17.00 U	11.00	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
009596	INEL	Uncategorized Metal	117	320	17.00 U	8.80	0.11 U	0.14 U	0.14 U	0.14 U	0.14 U	0.12 U
009599	INEL	Inorganic Non-metal	118	440	17.00 U	1.30	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
009602	INEL	Inorganic Non-metal	218	442	17.00 U	2.40	1.70 U	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U
009694	INEL	Graphite	215	300	17.00 U	0.04 J	0.01 U	0.02 U	0.02 U	0.03 J	0.02 J	0.02 U
009735	INEL	Graphite	215	300	17.00 U	0.04 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
009773	INEL	Combustible	223	339	17.00 U	7.00	3.80 U	4.80 U	4.50 U	5.60 U	5.30 U	5.60 U
009787	RFETS	Solidified Organics	212	3	5.00 U	220.00	160.00 U	180.00 U	190.00 U	190.00 U	190.00 U	160.00 U
009873	RFETS	Solidified Inorganics	211	1	5.00 U	3.00	0.04 U	0.05 U	0.05 U	0.05 U	0.05 U	0.04 U
010216	INEL	Filter	219	338	17.00 U	1.00 U	2.80	0.96 U	1.00 U	1.20 U	1.00 U	1.30 U
010224	INEL	Filter	219	338	17.00 U	1.20	1.20	0.29 U	0.31 U	0.35 U	0.32 U	0.38 U
010230	INEL	Heterogeneous	216	330	18.00 U	11.00	1.50	0.15 U	0.16 U	0.19 U	0.17 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
010273	INEL	Combustible	216	337	18.00 U	2.00	0.13 U	0.14 U	0.15 U	0.17 U	0.15 U	0.28 U
010295	INEL	Inorganic Non-metal	218	442	17.00 U	0.60 J	0.05 U	0.06 U	0.06 U	0.06 U	0.06 U	0.05 U
010305	RFETS	Inorganic Non-metal	218	442	5.00 U	8.40	0.59 U	0.70 U	0.74 U	0.74 U	0.74 U	0.62 U
010364	RFETS	Combustible	216	337	5.00 U	4.20	0.75 U	0.88 U	0.94 U	0.94 U	0.94 U	0.79 U
010371	INEL	Combustible	216	337	17.00 U	22.00	0.35 U	0.33 U	0.35 U	0.44 U	0.37 U	0.29 U
010407	RFETS	Uncategorized Metal	217	480	5.00 U	25.00	0.10 U	0.12 U	0.39 J	0.89 J	0.43 J	0.11 U
010411	INEL	Combustible	216	337	15.00 U	18.00	1.70 U	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U
010415	INEL	Inorganic Non-metal	218	442	17.00 U	0.20 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
010426	INEL	Inorganic Non-metal	218	442	17.00 U	0.11 JB	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
010463	INEL	Solidified Inorganics	213	4	34.00 U	2.20 J	0.25 U	0.30 U	0.31 U	0.31 U	0.31 U	0.26 U
010487	INEL	Salt Waste	224	414	17.00 U	5.70 J	0.46 U	0.54 U	0.57 U	0.57 U	0.57 U	0.48 U
010492	INEL	Uncategorized Metal	217	480	17.00 U	7.10	0.49 U	0.58 U	0.61 U	0.61 U	0.61 U	0.52 U
010498	INEL	Uncategorized Metal	217	480	17.00 U	4.60	0.03 U	0.04 U	0.04 U	0.05 U	0.04 U	0.05 U
010510	RFETS	Heterogeneous	216	336	5.00 U	12.00	1.60 J	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
010546	RFETS	Heterogeneous	216	330	10.00 U	57.00	39.00 U	46.00 U	49.00 U	49.00 U	49.00 U	41.00 U
010578	INEL	Solidified Organics	226	432	17.00 U	9.90 J	1.50 J	1.00 U	1.10 U	1.10 U	1.10 U	0.90 U
010588	RFETS	Solidified Inorganics	211	2	5.00 U	1.10	11.00	0.87 U	0.92 U	0.92 U	0.92 U	0.78 U
010663	INEL	Combustible	216	337	18.00 U	2.60	2.60	0.49 U	0.53 U	0.61 U	0.54 U	1.00 U
010676	INEL	Heterogeneous	216	330	17.00 U	7.20	1.90	0.40 U	0.42 U	0.48 U	0.43 U	0.80 U
010800	INEL	Filter	219	338	17.00 U	1.50	0.37 J	0.13 U	0.14 U	0.16 U	0.15 U	0.18 U
010807	INEL	Combustible	216	337	17.00 U	4.90	1.10 U	1.30 U	1.40 U	1.40 U	1.40 U	1.20 U
010808	INEL	Combustible	216	337	18.00 U	4.10	0.56 J	0.34 U	0.32 U	0.58 J	0.37 U	0.40 U
010814	RFETS	Solidified Inorganics	211	1	5.00 U	0.83	41.00	0.35 U	0.37 U	0.37 U	0.37 U	0.31 U
010837	INEL	Solidified Organics	226	432	17.00 U	1.70 J	0.80 J	0.44 U	0.47 U	0.47 U	0.47 U	0.40 U
010848	INEL	Filter	219	338	17.00 U	3.20	2.20	0.37 U	0.40 U	0.46 U	0.41 U	0.50 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
010883	INEL	Solidified Organics	226	432	17.00 U	7.20	8.60	1.20 U	1.20 U	1.20 U	1.20 U	1.00 U
010921	INEL	Inorganic Non-metal	222	371	18.00 U	0.12 U	0.13 J	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
011004	INEL	Uncategorized Metal	217	480	17.00 U	1.00	0.03 U	0.03 U	0.05 J	0.09 J	0.04 J	0.03 U
011021	INEL	Solidified Organics	226	432	17.00 U	23.00	0.15 U	0.18 U	0.19 U	0.19 U	0.19 U	0.16 U
011042	INEL	Inorganic Non-metal	218	442	17.00 U	2.90	0.53 U	0.62 U	0.66 U	0.66 U	0.66 U	0.55 U
011044	INEL	Inorganic Non-metal	218	440	17.00 U	3.50	0.30 U	0.36 U	0.38 U	0.38 U	0.38 U	0.32 U
011067	RFETS	Solidified Inorganics	213	4	5.00 U	2.20	0.99 U	1.20 U	1.20 U	1.20 U	1.20 U	1.00 U
011102	RFETS	Solidified Inorganics	211	1	5.00 U	1.10	0.24 U	0.28 U	0.30 U	0.30 U	0.30 U	0.25 U
011109	INEL	Solidified Inorganics	211	1	17.00 U	0.94 J	2.00	0.19 U	0.18 U	0.22 U	0.21 U	0.22 U
011147	INEL	Solidified Inorganics	213	4	17.00 U	3.20 B	0.17 U	0.22 U	0.21 U	0.26 U	0.24 U	0.26 U
011173	INEL	Uncategorized Metal	217	480	17.00 U	2.90	0.21 J	0.05 U	0.05 U	0.06 U	0.06 U	0.06 U
011194	INEL	Inorganic Non-metal	218	442	17.00 U	2.00	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
011393	INEL	Uncategorized Metal	217	480	17.00 U	4.90	0.13 U	0.15 U	0.16 U	0.18 J	0.16 U	0.13 U
011416	INEL	Combustible	216	337	17.00 U	0.80 U	0.55 U	0.65 U	0.69 U	0.69 U	0.69 U	0.58 U
011433	INEL	Heterogeneous	216	330	17.00 U	3.10	0.88 J	0.49 U	0.53 U	0.61 U	0.54 U	1.00 U
011498	RFETS	Solidified Organics	226	432	17.00 U	3.90	22.00	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
011529	INEL	Uncategorized Metal	217	480	17.00 U	0.04 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
011601	INEL	Heterogeneous	216	336	17.00 U	6.20	1.00 U	1.20 U	1.20 U	1.40 U	1.30 U	1.50 U
011607	INEL	Heterogeneous	216	330	17.00 U	0.65 J	0.06 J	0.03 U	3.40	8.00	1.60	0.04 U
011637	RFETS	Filter	219	338	5.00 U	2.70	1.90 JD	0.87 U	0.92 U	0.92 U	0.92 U	0.78 U
011735	INEL	Heterogeneous	216	330	17.00 U	4.60	1.00	0.89 U	0.94 U	0.94 U	0.94 U	0.79 U
011749	INEL	Inorganic Non-metal	225	441	17.00 U	0.31 U	12.00	0.25 U	0.27 U	0.27 U	0.27 U	0.22 U
011785	RFETS	Solidified Inorganics	211	1	5.00 U	4.40	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
012021	INEL	Solidified Inorganics	211	1	17.00 U	1.40 J	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U
012108	INEL	Solidified Inorganics	214	292	17.00 U	4.10 J	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
012111	INEL	Combustible	216	337	17.00 U	2.50	1.40 U	1.60 U	2.10	5.10	1.70 U	3.20 U
012215	INEL	Uncategorized Metal	217	480	17.00 U	7.00	0.35 U	0.41 U	0.44 U	0.44 U	0.44 U	0.37 U
012313	INEL	Heterogeneous	216	336	17.00 U	2.10	0.68 J	0.59 U	0.63 U	0.73 U	0.65 U	1.20 U
012320	INEL	Heterogeneous	216	336	17.00 U	13.00	5.20	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U
012356	INEL	Filter	219	338	17.00 U	2.40	1.30	0.22 U	0.21 U	0.26 U	0.25 U	0.26 U
012357	RFETS	Uncategorized Metal	217	480	7.10 J	4.00	34.00 J	3.10 U	3.30 U	3.30 U	3.30 U	2.80 U
012433	INEL	Filter	219	338	17.00 U	1.30	2.00	0.19 U	0.20 U	0.24 U	0.21 U	0.25 U
012469	RFETS	Solidified Inorganics	211	1	5.00 U	0.75	1.30 J	0.36 U	0.38 U	0.38 U	0.38 U	0.32 U
012471	RFETS	Filter	219	338	5.00 U	2.50	0.29 J	0.18 U	0.20 U	0.20 U	0.20 U	0.16 U
012487	INEL	Inorganic Non-metal	218	440	17.00 U	0.58 JB	1.70	0.02 U	0.03 J	0.10 JB	0.05 U	0.02 U
012494	INEL	Heterogeneous	216	330	17.00 U	6.50	2.30	1.20 U	2.20	5.50	1.30 U	1.10 U
012541	INEL	Inorganic Non-metal	218	442	17.00 U	2.70	0.03 U	0.03 U	0.03 U	0.06 J	0.04 J	0.03 U
012553	INEL	Solidified Inorganics	211	1	17.00 U	0.15 J	0.03 U	0.03 U	0.03 U	0.03 U	0.05 J	0.03 U
012571	INEL	Uncategorized Metal	217	320	1.10 U	0.03 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
012611	INEL	Solidified Inorganics	211	1	17.00 U	2.40 J	0.53 U	0.62 U	0.66 U	0.66 U	0.66 U	0.55 U
012634	INEL	Solidified Inorganics	211	1	17.00 U	2.60 J	1.40 U	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
012749	INEL	Solidified Inorganics	211	1	17.00 U	0.58 J	0.28 U	0.33 U	0.34 U	0.34 U	0.34 U	0.29 U
012766	INEL	Heterogeneous	216	336	17.00 U	4.80	2.50 U	3.00 U	3.10 U	3.10 U	3.10 U	2.60 U
012802	INEL	Combustible	216	337	17.00 U	15.00	3.40	1.20 U	1.10 U	1.40 U	1.30 U	1.40 U
012875	RFETS	Solidified Organics	226	432	17.00 U	6.90	3.40 U	4.00 U	4.20 U	4.20 U	4.20 U	3.60 U
012878	INEL	Uncategorized Metal	217	480	17.00 U	2.20	1.20	0.61 U	0.57 U	0.71 U	0.67 U	0.71 U
012891	INEL	Heterogeneous	216	330	17.00 U	4.70	0.29 U	0.34 U	0.36 U	1.40	0.46 J	0.30 U
012902	INEL	Filter	219	338	17.00 U	0.03 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
012920	INEL	Inorganic Non-metal	222	371	17.00 U	1.40 U	1.00 U	1.20 U	1.30 U	1.30 U	1.30 U	1.10 U
012985	INEL	Inorganic Non-metal	222	371	17.00 U	5.80 J	14.00 J	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
012986	INEL	Heterogeneous	221	302	1.10 U	22.00	2.60	0.53 U	0.50 U	0.61 U	0.58 U	0.62 U
012998	INEL	Combustible	216	337	17.00 U	3.90	10.00	0.68 U	0.72 U	0.72 U	0.72 U	0.61 U
013106	INEL	Solidified Inorganics	111	7	5.00 U	0.84	0.01 U	0.01 U	0.02 U	0.04 J	0.02 U	0.01 U
013229	RFETS	Solidified Organics	226	432	17.00 U	21.00	0.13 U	0.15 U	0.16 U	0.16 U	0.16 U	0.13 U
013231	INEL	Graphite	215	300	17.00 U	0.03 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
013252	INEL	Inorganic Non-metal	222	371	17.00 U	3.00	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
013266	INEL	Combustible	223	339	17.00 U	14.00	0.35 U	0.41 U	0.44 U	0.44 U	0.44 U	0.37 U
013269	INEL	Inorganic Non-metal	218	440	17.00 U	12.00	0.04 U	0.05 U	0.05 U	0.06 U	0.06 U	0.06 U
013313	INEL	Inorganic Non-metal	218	440	17.00 U	3.30	0.03 U	0.03 U	0.20 J	0.54 J	0.15 J	0.03 U
013331	INEL	Salt Waste	124	411	17.00 U	12.00	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
013342	INEL	Inorganic Non-metal	218	440	17.00 U	23.00 E	0.01 U	0.02 U	0.02 J	0.04 J	0.02 U	0.02 U
013346	RFETS	Inorganic Non-metal	222	371	5.00 U	3.70	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
013618	INEL	Heterogeneous	216	330	17.00 U	11.00	1.70 U	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U
013677	INEL	Filter	219	338	17.00 U	0.41 J	0.17 J	0.05 U	0.05 U	0.06 U	0.05 U	0.06 U
013751	INEL	Uncategorized Metal	217	480	17.00 U	1.00	4.30	0.89 U	0.94 U	0.94 U	0.94 U	0.79 U
013763	INEL	Combustible	223	339	17.00 U	13.00 U	14.00 U	13.00 U	14.00 U	18.00 U	15.00 U	12.00 U
013773	RFETS	Solidified Inorganics	111	7	5.00 U	2.50	0.07 U	0.08 U	0.34 J	1.30	0.30 J	0.07 U
013818	RFETS	Solidified Inorganics	211	1	7.10 J	2.50	0.02 U	0.02 U	0.09 J	0.35	0.07 J	0.02 U
013820	RFETS	Solidified Inorganics	211	1	11.00 U	3.40	0.02 U	0.03 U	0.03 U	0.05 JB	0.03 U	0.02 U
013847	INEL	Graphite	215	300	17.00 U	0.06 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
013860	INEL	Combustible	223	339	17.00 U	1.50	0.06 U	0.06 U	0.07 U	0.08 U	0.07 U	0.09 U
013876	RFETS	Solidified Inorganics	211	7	5.00 U	0.84	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
014007	INEL	Solidified Inorganics	211	1	17.00 U	4.10	0.02 U	0.02 U	0.03 U	0.03 U	0.03 U	0.03 U
014009	INEL	Solidified Inorganics	211	7	17.00 U	2.20	0.05 U	0.06 U	0.06 U	0.13 J	0.07 U	0.08 U
014010	INEL	Solidified Inorganics	211	7	17.00 U	0.64 J	0.01 U	0.02 U	0.03 J	0.09 J	0.02 J	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
014127	RFETS	Solidified Inorganics	211	7	5.00 U	1.50	0.02 U	0.02 U	0.04 J	0.14 J	0.02 J	0.02 U
014170	INEL	Solidified Inorganics	211	7	5.00 U	2.40	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
014330	INEL	Graphite	215	303	17.00 U	0.47 J	0.04 U	0.04 U	0.04 U	0.05 U	0.04 U	0.08 U
014334	INEL	Filter	219	335	17.00 U	0.10 J	0.06 U	0.05 U	0.06 U	0.07 U	0.06 U	0.05 U
014339	INEL	Solidified Organics	226	432	17.00 U	15.00 D	0.05 U	0.06 U	0.06 U	0.06 U	0.06 U	0.05 U
014342	INEL	Graphite	215	303	17.00 U	0.12 J	0.06 U	0.06 U	0.07 U	0.08 U	0.07 U	0.13 U
014345	INEL	Solidified Organics	226	432	17.00 U	14.00	0.04 U	0.05 U	0.05 U	0.05 U	0.05 U	0.04 U
014346	INEL	Combustible	223	339	17.00 U	4.00	0.07 J	0.02 U	0.04 J	0.09 J	0.07 J	0.03 U
014348	INEL	Graphite	215	300	17.00 U	0.24 J	0.01 U	0.02 U	0.02 U	0.02 J	0.02 U	0.02 U
014354	RFETS	Uncategorized Metal	217	481	5.00 U	0.14	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
014357	INEL	Combustible	223	339	17.00 U	16.00	14.00 U	13.00 U	14.00 U	18.00 U	15.00 U	12.00 U
014387	INEL	Solidified Inorganics	211	7	17.00 U	4.60	0.01 U	0.02 U	0.11 J	0.33 J	0.06 J	0.02 U
014466	INEL	Heterogeneous	221	302	17.00 U	4.80	2.00 J	0.33 U	0.35 U	0.35 U	0.35 U	0.29 U
014484	INEL	Graphite	215	300	17.00 U	0.26 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
014502	RFETS	Solidified Inorganics	211	1	5.00 U	2.00	0.01 U	0.01 U	0.01 U	0.03 J	0.01 J	0.01 U
014504	RFETS	Solidified Inorganics	211	1	5.00 U	5.40	0.03 U	0.03 U	0.03 U	0.04 J	0.03 U	0.46 U
014773	INEL	Solidified Inorganics	214	292	5.00 U	11.00	0.04 U	0.05 U	0.06 U	0.06 U	0.06 U	0.05 U
015228	RFETS	Solidified Organics	226	432	17.00 U	4.20	0.15 U	0.18 U	0.19 U	0.26 J	0.19 U	0.16 U
015231	INEL	Inorganic Non-metal	218	440	17.00 U	2.10	0.03 U	0.03 U	0.03 J	0.05 J	0.03 U	0.03 U
015241	INEL	Inorganic Non-metal	218	442	17.00 U	0.33 J	0.04 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
015249	INEL	Graphite	215	300	17.00 U	0.04 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04 U
015262	RFETS	Solidified Organics	226	432	17.00 U	12.00	1.40 U	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
015267	INEL	Uncategorized Metal	217	480	17.00 U	11.00	1.30 U	1.50 U	1.60 U	1.60 U	1.60 U	1.30 U
015338	INEL	Solidified Inorganics	211	7	17.00 U	3.50	0.09 J	0.02 U	0.08 J	0.29 J	0.03 J	0.03 U
015434	RFETS	Solidified Organics	226	432	17.00 U	13.00	0.04 U	0.04 U	0.05 U	0.08 J	0.05 U	0.04 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
015440	RFETS	Solidified Organics	226	432	17.00 U	7.60	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U
015515	RFETS	Solidified Organics	212	3	5.00 U	34.00	24.00 U	28.00 U	30.00 U	30.00 U	30.00 U	25.00 U
015532	RFETS	Solidified Organics	212	3	5.00 U	100.00	73.00 U	86.00 U	91.00 U	91.00 U	91.00 U	77.00 U
015543	INEL	Solidified Organics	212	3	17.00 U	45.00 U	31.00 U	37.00 U	39.00 U	39.00 U	39.00 U	33.00 U
015627	INEL	Graphite	215	300	17.00 U	0.02 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
015655	INEL	Solidified Inorganics	211	7	17.00 U	0.17 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
015674	INEL	Graphite	215	300	17.00 U	0.52 J	0.04 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
015675	INEL	Uncategorized Metal	217	480	17.00 U	1.10	0.06 U	0.07 U	0.08 U	0.08 U	0.08 U	0.07 U
015777	RFETS	Solidified Organics	226	432	17.00 U	5.00	0.07 J	0.07 U	0.09 J	0.08 U	0.08 U	0.07 U
015785	RFETS	Solidified Inorganics	211	1	15.00 U	0.80	0.29 U	0.34 U	0.36 U	0.36 U	0.36 U	0.30 U
015786	INEL	Solidified Inorganics	211	1	17.00 U	1.20	0.02 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
016242	INEL	Graphite	215	300	17.00 U	0.02 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
016612	INEL	Inorganic Non-metal	218	442	17.00 U	0.11 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
016613	INEL	Solidified Organics	226	432	17.00 U	5.50	0.18 U	0.21 U	0.22 U	0.22 U	0.22 U	0.18 U
016707	INEL	Graphite	215	300	17.00 U	0.02 U	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
016738	RFETS	Solidified Inorganics	211	7	5.00 U	1.60	1.10 U	1.30 U	1.40 U	1.40 U	1.40 U	1.20 U
016790	INEL	Graphite	215	300	17.00 U	7.60	0.02 U	0.02 U	2.30	7.60	2.50	0.02 U
016807	INEL	Solidified Inorganics	211	1	17.00 U	0.93 J	0.11 U	0.14 U	0.14 U	0.30 J	0.16 J	0.17 U
016842	INEL	Graphite	215	300	17.00 U	0.03 J	0.01 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
016855	RFETS	Solidified Organics	212	3	5.00 U	160.00	110.00 U	130.00 U	140.00 U	140.00 U	140.00 U	120.00 U
016869	INEL	Solidified Inorganics	211	7	17.00 U	1.70	0.13 U	0.16 U	0.15 U	0.19 U	0.18 U	0.19 U
016964	RFETS	Solidified Inorganics	211	7	5.00 U	1.40	0.98 U	1.20 U	1.20 U	1.20 U	1.20 U	1.00 U
016986	INEL	Inorganic Non-metal	218	442	17.00 U	3.90	0.15 U	0.18 U	0.19 U	0.19 U	0.19 U	0.16 U
017148	INEL	Solidified Organics	226	432	17.00 U	9.60	0.54 U	0.63 U	0.67 U	0.67 U	0.67 U	0.56 U
017190	INEL	Solidified Inorganics	211	7	17.00 U	3.30 U	2.50 U	3.20 U	3.00 U	3.70 U	3.50 U	3.80 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
017444	INEL	Graphite	215	300	17.00 U	0.64 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
017453	INEL	Solidified Organics	212	3	5.00 U	47.00 U	32.00 U	38.00 U	41.00 U	41.00 U	41.00 U	34.00 U
017486	INEL	Solidified Inorganics	211	1	17.00 U	4.90	0.11 U	0.14 U	0.14 U	0.17 U	0.16 U	0.17 U
017491	INEL	Graphite	215	300	17.00 U	1.30	0.13 U	0.16 U	0.15 U	0.19 U	0.18 U	0.19 U
017495	INEL	Inorganic Non-metal	218	442	17.00 U	0.06 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
017496	INEL	Inorganic Non-metal	218	442	17.00 U	0.13 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
017698	RFETS	Solidified Inorganics	211	292	5.00 U	8.10	2.10 U	2.40 U	2.60 U	2.60 U	2.60 U	2.20 U
017709	INEL	Solidified Inorganics	211	1	17.00 U	0.30 J	0.05 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
017728	RFETS	Solidified Inorganics	211	1	5.00 U	0.86	0.59 U	0.70 U	0.74 U	0.74 U	0.74 U	0.62 U
017742	INEL	Inorganic Non-metal	218	440	17.00 U	4.30	0.50 U	0.59 U	0.63 U	0.63 U	0.63 U	0.53 U
017756	RFETS	Solidified Organics	226	432	17.00 U	9.10	1.40 U	1.70 U	1.80 U	1.80 U	1.80 U	1.50 U
017759	INEL	Solidified Organics	226	432	17.00 U	13.00 J	1.00 U	1.20 U	1.30 U	1.30 U	1.30 U	1.10 U
017788	INEL	Solidified Inorganics	211	7	17.00 U	1.40	0.84 U	1.10 U	1.00 U	1.20 U	1.20 U	1.20 U
017863	INEL	Filter	119	376	17.00 U	16.00	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
018111	RFETS	Solidified Inorganics	211	1	5.00 U	0.27	0.01 U	0.01 U	0.02 U	0.02 U	0.02 U	0.01 U
018219	RFETS	Solidified Inorganics	211	7	5.00 U	1.40	0.98 U	1.20 U	1.20 U	1.20 U	1.20 U	1.00 U
018299	INEL	Filter	119	376	17.00 U	29.00	0.13 U	0.15 U	0.16 U	1.40 J	0.16 U	0.13 U
018413	INEL	Graphite	115	300	5.00 U	0.14	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
018441	INEL	Graphite	115	300	17.00 U	0.04 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
018464	INEL	Graphite	115	300	5.00 U	0.46	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
018476	INEL	Solidified Inorganics	111	292	5.00 U	24.00	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
018491	INEL	Graphite	115	300	17.00 U	0.06 J	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
019410	INEL	Lead/Cadmium Metal	123	339	5.00 U	5.40 JD	0.55 U	0.64 U	0.68 U	0.68 U	0.68 U	0.57 U
019413	INEL	Lead/Cadmium Metal	123	339	5.00 U	5.10 J	2.40 U	2.80 U	3.00 U	3.00 U	3.00 U	2.50 U
019572	INEL	Lead/Cadmium Metal	123	339	17.00 U	9.30	0.05 U	0.06 U	0.06 U	0.17 J	0.17 J	0.05 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
021031	RFETS	Solidified Inorganics	214	292	5.00 U	7.70	0.04 J	0.04 U	0.05 U	0.05 U	0.05 U	0.04 U
021172	RFETS	Inorganic Non-metal	218	442	5.00 U	0.08	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
021306	INEL	Solidified Inorganics	213	4	17.00 U	0.15 J	0.03 U	0.03 U	0.03 U	0.07 J	0.03 U	0.03 U
021392	RFETS	Solidified Inorganics	214	292	5.00 U	0.34	0.14 U	0.16 U	0.17 U	0.17 U	0.17 U	0.14 U
021442	INEL	Solidified Inorganics	211	1	17.00 U	0.75 J	0.36 U	0.45 U	0.42 U	0.52 U	0.49 U	0.53 U
021488	RFETS	Inorganic Non-metal	218	442	5.00 U	0.06	0.03 U	0.04 U	0.04 U	0.04 U	0.04 U	0.04 U
021503	RFETS	Inorganic Non-metal	218	440	5.00 U	1.50	0.14 U	0.16 U	0.18 U	0.18 U	0.18 U	0.15 U
021511	RFETS	Solidified Inorganics	213	4	5.00 U	0.17	0.04 U	0.04 U	0.05 U	0.05 J	0.05 U	0.04 U
021512	INEL	Solidified Inorganics	211	7	17.00 U	1.20 U	0.80 U	0.95 U	1.00 U	1.00 U	1.00 U	0.84 U
021523	INEL	Solidified Organics	226	432	17.00 U	8.80	0.70 J	0.60 U	0.96 J	2.10	0.82 J	0.54 U
021565	INEL	Solidified Inorganics	211	7	17.00 U	1.20	0.63 U	0.80 U	0.76 U	0.93 U	0.88 U	0.94 U
021572	INEL	Solidified Inorganics	211	7	17.00 U	0.70 J	0.33 U	0.42 U	0.39 U	0.48 U	0.46 U	0.49 U
021600	RFETS	Solidified Inorganics	211	1	5.00 U	1.00	0.24 J	0.28 U	0.30 U	0.30 U	0.30 U	0.25 U
021631	INEL	Inorganic Non-metal	218	442	17.00 U	1.50	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
021698	INEL	Inorganic Non-metal	218	440	17.00 U	10.00	0.94 U	1.10 U	1.20 U	1.20 U	1.20 U	0.99 U
021699	INEL	Solidified Inorganics	213	4	68.00 U	2.80	0.28 U	0.33 U	0.34 U	0.48 J	0.34 U	0.29 U
021700	RFETS	Solidified Inorganics	213	4	5.00 U	0.01	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
021806	INEL	Inorganic Non-metal	218	440	17.00 U	17.00 B	0.15 U	0.19 U	0.31 J	0.65 J	0.20 U	0.22 U
021816	INEL	Solidified Inorganics	211	1	17.00 U	2.30	0.08 U	0.10 U	0.10 J	0.31 J	0.10 U	0.11 U
021865	INEL	Solidified Inorganics	211	1	17.00 U	2.50 J	0.80 U	0.95 U	1.00 U	1.00 U	1.00 U	0.84 U
021993	INEL	Solidified Inorganics	211	2	17.00 U	0.75 J	0.46 J	0.44 U	0.47 U	0.47 U	0.47 U	0.40 U
022000	INEL	Inorganic Non-metal	218	440	17.00 U	10.00	0.08 U	0.10 U	0.18 J	0.23 J	0.10 U	0.09 U
022036	INEL	Uncategorized Metal	217	480	17.00 U	5.60	0.05 U	0.07 U	0.06 U	0.08 U	0.07 U	0.08 U
022038	RFETS	Uncategorized Metal	217	481	5.00 U	25.00	0.16 U	0.18 U	0.19 U	0.19 U	0.19 U	0.16 U
022052	INEL	Uncategorized Metal	217	481	17.00 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
022102	INEL	Solidified Organics	226	432	17.00 U	11.00	0.08 U	0.10 U	0.22 J	0.32 J	0.16 J	0.09 U
022105	INEL	Solidified Inorganics	211	1	17.00 U	1.70 J	0.34 U	0.41 U	0.44 U	0.44 U	0.44 U	0.37 U
022119	INEL	Inorganic Non-metal	222	371	17.00 U	0.65 U	0.45 U	0.53 U	0.56 U	0.56 U	0.56 U	0.47 U
022121	INEL	Solidified Inorganics	211	7	15.00 U	0.75 J	1.10	0.14 U	0.14 U	0.26 J	0.16 U	0.17 U
022135	INEL	Solidified Inorganics	211	7	17.00 U	3.00 J	1.80 J	0.68 U	0.72 U	0.72 U	0.72 U	0.61 U
022136	RFETS	Solidified Inorganics	211	7	16.00 J	6.00	0.74 U	0.87 U	1.30 J	2.50 J	0.92 U	0.78 U
022149	RFETS	Solidified Inorganics	211	7	5.00 U	2.20	0.18 U	0.22 U	0.58 J	0.72 J	0.26 J	0.19 U
022224	INEL	Solidified Inorganics	211	1	17.00 U	0.70 J	200.00 E	0.41 U	0.44 U	0.44 U	0.44 U	0.37 U
022226	RFETS	Inorganic Non-metal	222	371	5.00 U	1.40	0.98 U	1.20 U	1.20 U	1.20 U	1.20 U	1.00 U
022228	INEL	Inorganic Non-metal	222	371	18.00 U	0.68 J	0.13 U	0.15 U	0.16 U	0.23 J	0.18 J	0.13 U
022230	INEL	Inorganic Non-metal	222	371	17.00 U	0.26 J	0.10 U	0.12 U	0.13 U	0.13 U	0.13 U	0.11 U
022249	INEL	Uncategorized Metal	217	480	17.00 U	6.30	1.30 U	1.60 U	1.50 U	1.90 U	1.80 U	1.90 U
022275	INEL	Uncategorized Metal	217	480	17.00 U	15.00	0.29 U	0.36 U	0.34 U	0.42 U	0.40 U	0.42 U
022286	RFETS	Uncategorized Metal	217	480	5.00 U	19.00	0.42 U	0.50 U	2.30 J	7.60	1.30 J	0.44 U
022296	INEL	Solidified Inorganics	211	1	17.00 U	2.90	0.63 U	0.80 U	0.75 U	0.93 U	0.88 U	0.94 U
022306	INEL	Inorganic Non-metal	218	440	15.00 U	14.00	0.75 U	0.89 U	0.94 U	0.94 U	0.94 U	0.79 U
022338	INEL	Solidified Organics	212	3	17.00 U	140.00 U	120.00 J	120.00 U	130.00 U	130.00 U	130.00 U	110.00 U
022347	INEL	Inorganic Non-metal	218	440	17.00 U	5.70 B	0.20 U	0.25 U	0.23 U	0.29 U	0.27 U	0.29 U
022358	INEL	Uncategorized Metal	217	480	17.00 U	11.00 E	0.02 J	0.02 U	0.25 J	0.06 J	0.03 J	0.02 U
022416	RFETS	Uncategorized Metal	217	320	5.00 U	1.10	0.04 U	0.05 U	0.06 U	0.06 J	0.06 U	0.05 U
022434	INEL	Solidified Organics	226	432	17.00 U	19.00	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U
022442	INEL	Solidified Organics	226	432	17.00 U	27.50	0.98 U	1.14 U	1.21 U	1.21 U	1.21 U	1.00 U
022450	RFETS	Uncategorized Metal	217	320	5.00 U	1.20	0.07 U	0.09 U	0.09 U	0.09 U	0.09 U	0.08 U
022453	RFETS	Solidified Inorganics	211	2	5.00 U	1.20	0.07 U	0.08 U	0.10 J	0.34 J	0.19 J	0.07 U
022486	RFETS	Inorganic Non-metal	218	440	6.00 J	13.00	1.50 U	1.80 U	1.90 U	1.90 U	1.90 U	1.60 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
022511	INEL	Uncategorized Metal	217	480	18.00 U	2.70	0.78 U	0.92 U	0.97 U	0.97 U	0.97 U	0.82 U
022513	INEL	Solidified Organics	212	1	17.00 U	0.81 J	0.23 U	0.27 U	0.28 U	0.28 U	0.28 U	0.24 U
022517	INEL	Solidified Organics	226	432	17.00 U	16.00	0.10 U	0.11 U	0.12 U	0.12 U	0.12 U	0.10 U
022539	INEL	Solidified Organics	226	432	17.00 U	15.00	0.10 U	0.11 U	0.12 U	0.12 U	0.12 U	0.10 U
022549	INEL	Uncategorized Metal	217	480	18.00 U	3.30	1.30 U	1.50 U	1.60 U	1.60 U	1.60 U	1.30 U
022552	INEL	Inorganic Non-metal	218	442	17.00 U	0.61 J	0.29 U	0.34 U	0.36 U	0.36 U	0.36 U	0.30 U
022557	INEL	Uncategorized Metal	217	480	17.00 U	17.00	0.45 U	0.56 U	0.53 U	0.66 U	0.62 U	0.66 U
022595	INEL	Solidified Inorganics	211	1	15.00 U	1.10	0.22 U	0.27 U	0.26 U	0.32 U	0.30 U	0.32 U
022600	RFETS	Solidified Inorganics	213	4	130.00 U	2.10	0.23 U	0.27 U	0.29 U	0.29 U	0.29 U	0.24 U
022780	INEL	Solidified Inorganics	211	7	18.00 U	2.80	1.10	0.40 U	0.38 U	0.46 U	0.44 U	0.47 U
022789	INEL	Solidified Inorganics	211	7	17.00 U	0.80 U	0.70 J	0.66 U	0.70 U	0.70 U	0.70 U	0.58 U
022790	INEL	Solidified Inorganics	214	292	18.00 U	5.00 B	0.15 U	0.19 U	0.18 U	0.27 JB	0.21 U	0.23 U
022803	INEL	Inorganic Non-metal	222	371	15.00 U	0.76 U	0.53 U	0.62 U	0.66 U	0.66 U	0.66 U	0.55 U
022807	INEL	Salt Waste	224	414	17.00 U	4.00	0.10 U	0.12 U	0.15 J	0.30 J	0.13 U	0.11 U
022811	INEL	Solidified Inorganics	211	7	17.00 U	1.80	1.30	0.34 U	0.32 U	0.39 U	0.37 U	0.39 U
022833	INEL	Solidified Inorganics	211	7	15.00 U	3.90	1.90 U	2.40 U	2.30 U	2.80 U	2.60 U	2.80 U
022841	INEL	Solidified Inorganics	211	7	17.00 U	3.10	1.00 U	1.30 U	1.20 U	1.50 U	1.40 U	1.50 U
022850	INEL	Solidified Inorganics	211	7	17.00 U	2.70	1.70	0.80 U	0.75 U	0.93 U	0.88 U	0.94 U
022874	INEL	Inorganic Non-metal	222	371	17.00 U	0.88 J	0.18 U	0.21 U	0.22 U	0.22 U	0.22 U	0.19 U
022894	INEL	Solidified Inorganics	211	1	15.00 U	1.20	0.16 J	0.11 U	0.89 J	1.80	0.78 J	0.13 U
022923	INEL	Inorganic Non-metal	218	440	17.00 U	6.90	0.33 U	0.38 U	0.41 U	0.41 U	0.41 U	0.34 U
023005	INEL	Solidified Inorganics	211	7	17.00 U	1.70 J	1.30 J	0.18 U	0.30 J	0.55 J	0.19 U	0.16 U
023027	RFETS	Uncategorized Metal	217	480	5.00 U	0.46	0.43 J	0.18 U	0.18 U	0.47 J	0.36 J	0.16 U
023041	RFETS	Inorganic Non-metal	222	371	5.00 U	0.42	0.24 U	0.28 U	0.30 U	0.30 U	0.30 U	0.25 U
023046	RFETS	Solidified Inorganics	211	7	5.00 U	2.50	0.66 J	0.50 U	0.53 U	0.53 U	0.53 U	0.44 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
023048	RFETS	Solidified Organics	226	432	17.00 U	22.00	0.35 U	0.41 U	0.44 U	0.44 U	0.44 U	0.37 U
023062	INEL	Solidified Inorganics	211	7	17.00 U	1.20 J	0.58 J	0.18 U	0.19 U	0.19 U	0.19 U	0.16 U
023211	INEL	Filter	119	376	17.00 U	9.30	0.05 U	0.06 U	0.06 U	0.17 J	0.08 J	0.05 U
023212	RFETS	Uncategorized Metal	217	480	5.00 U	7.40	0.49 U	0.58 U	0.62 U	0.62 U	0.62 U	0.52 U
023227	INEL	Uncategorized Metal	217	480	17.00 U	2.50	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
023229	INEL	Combustible	216	337	17.00 U	4.00 J	0.50 U	0.59 U	0.63 U	0.63 U	0.63 U	0.53 U
023235	RFETS	Heterogeneous	216	336	5.00 U	16.00	0.13 U	0.16 U	0.32 J	0.65 J	0.17 U	0.14 U
023238	INEL	Solidified Inorganics	211	1	17.00 U	1.70	0.17 J	0.18 U	0.17 U	0.20 U	0.19 U	0.21 U
023277	INEL	Inorganic Non-metal	222	371	17.00 U	1.30 U	0.88 U	1.00 U	1.10 U	1.10 U	1.10 U	0.92 U
023285	INEL	Solidified Inorganics	211	7	17.00 U	3.30 J	1.70 U	2.00 U	2.10 U	2.10 U	2.10 U	1.80 U
023312	INEL	Uncategorized Metal	217	480	17.00 U	4.10	0.63 U	0.80 U	0.76 U	0.93 U	0.88 U	0.94 U
023341	RFETS	Solidified Inorganics	211	7	5.00 U	0.83	0.49	0.01 U	0.14	0.26	0.10	0.01 U
023357	INEL	Solidified Inorganics	211	1	17.00 U	1.70 J	0.13 U	0.15 U	0.16 U	0.16 U	0.16 U	0.13 U
023383	RFETS	Uncategorized Metal	217	481	5.00 U	0.16	0.01 U	0.01 U	0.01 U	0.03 J	0.01 U	0.01 U
023384	INEL	Combustible	223	339	15.00 U	0.18 J	0.09 U	0.10 U	0.11 U	0.17 J	0.22 J	0.13 U
023388	INEL	Heterogeneous	216	330	15.00 U	0.49 J	0.08 U	0.09 U	0.09 U	0.11 U	0.10 U	0.17 U
023392	INEL	Solidified Inorganics	213	4	43.00 U	0.95 J	0.56 U	0.67 U	0.71 U	0.71 U	0.71 U	0.59 U
023407	INEL	Solidified Organics	212	3	17.00 U	28.00 U	20.00 U	23.00 U	24.00 U	24.00 U	24.00 U	21.00 U
023460	INEL	Inorganic Non-metal	218	442	17.00 U	1.20	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
023469	INEL	Solidified Organics	212	3	17.00 U	0.43 U	0.30 U	0.36 U	0.38 U	0.88 J	0.58 J	0.32 U
023492	INEL	Solidified Inorganics	211	7	17.00 U	0.90 U	0.63 U	0.74 U	0.78 U	0.78 U	0.78 U	0.66 U
023519	INEL	Solidified Organics	212	3	17.00 U	3.10 U	2.40 U	3.00 U	2.90 U	3.50 U	3.30 U	3.60 U
023535	INEL	Solidified Inorganics	211	7	15.00 U	0.82 U	0.63 U	0.80 U	0.75 U	0.93 U	0.88 U	0.94 U
023552	INEL	Solidified Inorganics	211	1	17.00 U	1.90 J	0.70 U	0.83 U	0.88 U	0.88 U	0.88 U	0.74 U
023662	INEL	Inorganic Non-metal	218	442	1.10 U	1.40	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
023681	INEL	Solidified Inorganics	211	1	17.00 U	0.70 J	0.30 U	0.36 U	0.38 U	0.38 U	0.38 U	0.32 U
023695	RFETS	Solidified Inorganics	211	2	5.00 U	0.62	0.22 J	0.18 U	0.19 U	0.23 J	0.19 U	0.16 U
023771	RFETS	Heterogeneous	216	330	5.00 U	23.00	0.16 U	0.19 U	0.20 U	0.20 U	0.20 U	0.17 U
023776	INEL	Heterogeneous	216	330	17.00 U	6.50	0.33 U	0.39 U	0.42 U	0.42 U	0.42 U	0.35 U
023805	INEL	Uncategorized Metal	217	480	17.00 U	5.20	0.01 U	0.02 U	0.07 J	0.10 J	0.07 J	0.02 U
023827	RFETS	Uncategorized Metal	217	320	5.00 U	0.16	0.01 U	0.01 U	0.01 J	0.02 J	0.01 U	0.01 U
023840	INEL	Combustible	216	337	17.00 U	3.00	0.29 U	0.32 U	0.34 U	0.39 U	0.35 U	0.64 U
023901	INEL	Heterogeneous	216	330	1.10 U	1.20	0.27 U	0.30 U	0.32 U	0.37 U	0.33 U	0.61 U
023929	RFETS	Inorganic Non-metal	218	440	5.00 U	2.30	0.50 U	0.59 U	0.63 U	0.63 U	0.63 U	5.00 U
023959	INEL	Uncategorized Metal	217	480	17.00 U	22.00	1.10 U	1.30 U	1.40 U	1.40 U	1.40 U	1.20 U
024028	RFETS	Inorganic Non-metal	218	440	5.00 U	0.50	0.10 U	0.12 U	0.13 U	0.13 U	0.13 U	0.11 U
024029	INEL	Uncategorized Metal	217	480	17.00 U	0.13 J	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.03 U
024058	INEL	Solidified Inorganics	211	1	17.00 U	2.20 J	0.38 U	0.44 U	0.47 U	0.47 U	0.47 U	0.40 U
024059	INEL	Solidified Inorganics	214	292	17.00 U	10.00	0.15 U	0.18 U	0.29 J	0.47 J	0.28 J	0.16 U
024088	INEL	Combustible	216	337	1.10 U	11.00	0.29 U	0.34 U	7.40	20.00	3.60	0.30 U
024090	INEL	Combustible	216	337	17.00 U	8.00	0.43 U	0.47 U	0.51 U	0.58 U	0.52 U	0.96 U
024092	INEL	Combustible	216	337	17.00 U	15.00	1.30 U	1.50 U	1.60 U	1.60 U	1.60 U	1.30 U
024095	INEL	Combustible	216	337	17.00 U	2.30	0.18 U	0.20 U	0.21 U	0.24 U	0.22 U	0.40 U
024102	INEL	Combustible	216	337	17.00 U	14.00	0.43 U	0.50 U	0.54 U	0.54 U	0.54 U	0.45 U
024106	INEL	Combustible	216	337	17.00 U	22.00	0.63 U	0.74 U	0.78 U	0.78 U	0.78 U	0.66 U
024113	INEL	Combustible	216	337	17.00 U	12.00	0.19 U	0.22 U	0.24 U	0.24 U	0.24 U	0.20 U
024147	INEL	Solidified Inorganics	211	1	17.00 U	3.60 J	0.58 U	0.68 U	0.72 U	0.72 U	0.72 U	0.61 U
024165	INEL	Combustible	216	337	17.00 U	12.00	0.44 U	0.52 U	9.80	28.00	3.40	0.46 U
024168	INEL	Heterogeneous	216	330	17.00 U	0.56 J	0.03 U	0.03 U	0.03 U	0.05 J	0.03 U	0.26 U
024185	INEL	Salt Waste	224	409	17.00 U	1.90	0.03 U	0.03 U	0.14 J	0.23 J	0.14 J	0.03 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
024254	INEL	Salt Waste	224	414	17.00 U	6.30	0.04 U	0.05 U	0.09 J	0.33 J	0.23 J	0.04 U
024271	INEL	Inorganic Non-metal	218	442	17.00 U	3.90	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
024273	INEL	Inorganic Non-metal	218	442	17.00 U	4.90	0.16 U	0.19 U	0.20 U	0.20 U	0.20 U	0.17 U
024289	RFETS	Inorganic Non-metal	218	440	5.00 U	13.00	0.30 U	0.35 U	0.37 U	0.37 U	0.37 U	0.31 U
024295	INEL	Salt Waste	224	414	17.00 U	2.40	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
024308	INEL	Solidified Inorganics	211	2	17.00 U	1.40 J	0.13 U	0.15 U	0.20 J	0.64 J	0.39 J	0.13 U
024309	INEL	Solidified Inorganics	211	2	17.00 U	1.20 J	0.10 U	0.12 U	0.19 J	0.66 J	0.37 J	0.11 U
024311	INEL	Solidified Inorganics	211	2	41.00 U	0.89 J	0.20 U	0.24 U	0.26 U	0.50 J	0.30 J	0.21 U
024318	INEL	Solidified Inorganics	211	2	17.00 U	0.39 J	0.20 U	0.24 U	0.25 U	0.46 J	0.25 U	0.21 U
024506	INEL	Inorganic Non-metal	122	374	17.00 U	6.80	0.05 U	0.06 U	0.06 U	0.06 U	0.06 U	0.05 U
024507	INEL	Uncategorized Metal	117	480	17.00 U	14.00	0.06 U	0.07 U	0.08 U	0.19 J	0.09 J	0.07 U
024600	INEL	Uncategorized Metal	217	480	17.00 U	9.30	0.23 U	0.27 U	0.43 J	0.80 J	0.42 J	0.24 U
024638	INEL	Heterogeneous	216	330	17.00 U	1.40	0.11 U	0.13 U	0.14 U	0.14 U	0.14 U	0.12 U
024670	INEL	Solidified Inorganics	211	1	17.00 U	3.80 J	0.45 U	0.53 U	0.56 U	0.56 U	0.56 U	0.48 U
024765	INEL	Uncategorized Metal	217	480	17.00 U	1.90	0.04 U	0.05 U	0.05 J	0.06 U	0.05 U	0.06 U
024786	INEL	Uncategorized Metal	217	480	17.00 U	5.00	0.30 U	0.36 U	0.38 U	0.38 U	0.38 U	0.32 U
024850	INEL	Solidified Organics	226	432	17.00 U	18.00	0.08 U	0.10 U	0.10 U	0.10 U	0.10 U	0.09 U
024884	INEL	Uncategorized Metal	217	480	17.00 U	22.00	0.20 U	0.24 U	0.25 U	0.25 U	0.25 U	0.21 U
024897	INEL	Solidified Inorganics	211	1	17.00 U	1.00 J	0.20 U	0.24 U	0.25 U	0.25 U	0.25 U	0.21 U
024920	INEL	Solidified Inorganics	211	1	17.00 U	5.30 J	0.58 U	0.68 U	0.72 U	0.72 U	0.72 U	0.61 U
024991	INEL	Solidified Inorganics	211	1	17.00 U	3.90	0.28 U	0.33 U	0.35 U	0.35 U	0.35 U	0.29 U
025001	INEL	Solidified Organics	212	3	17.00 U	2.40 J	1.00 U	1.20 U	1.30 U	1.30 U	1.30 U	1.10 U
032284	INEL	Combustible	223	339	17.00 U	3.70	0.29 U	0.32 U	0.37 J	0.98 J	0.86 J	0.42 U
032287	RFETS	Solidified Inorganics	211	7	5.00 U	1.40	0.99 U	1.20 U	1.20 U	1.20 U	1.20 U	1.00 U
032467	INEL	Combustible	216	337	17.00 U	0.29 J	0.20 U	0.24 U	0.25 U	0.25 U	0.25 U	0.21 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
032469	RFETS	Combustible	216	337	5.00 U	6.80	0.33 U	0.39 U	0.41 U	0.41 U	0.41 U	0.34 U
032473	INEL	Combustible	216	337	17.00 U	9.80	1.30 U	1.60 U	1.70 U	1.70 U	1.70 U	1.40 U
032485	INEL	Combustible	216	337	17.00 U	8.60	0.78 U	0.92 U	0.98 U	0.98 U	0.98 U	0.82 U
032517	RFETS	Combustible	223	339	5.00 U	2.60	0.07 U	0.09 U	0.20 J	0.41 JB	0.46 J	0.08 U
032521	INEL	Combustible	223	339	17.00 U	3.10	0.06 U	0.07 U	0.31 J	0.55 J	0.76 J	0.09 U
032525	INEL	Combustible	223	339	17.00 U	2.00	0.04 U	0.04 U	0.11 J	0.16 J	0.23 J	0.05 U
032526	INEL	Combustible	223	339	17.00 U	2.40	0.54 U	0.59 U	0.63 U	1.30	0.83 J	0.78 U
032529	INEL	Heterogeneous	216	336	17.00 U	26.00	0.23 U	0.33 U	0.38 U	0.32 U	0.25 U	0.15 U
032540	INEL	Uncategorized Metal	217	480	17.00 U	0.94 J	0.33 U	0.39 U	0.41 U	0.41 U	0.41 U	0.34 U
032632	INEL	Uncategorized Metal	217	480	17.00 U	1.70	0.14 U	0.15 U	0.16 U	0.19 U	0.17 U	0.20 U
032659	RFETS	Uncategorized Metal	217	480	5.00 U	4.30	0.26 U	0.30 U	0.32 U	0.34 J	0.32 U	0.27 U
032669	RFETS	Uncategorized Metal	217	480	5.00 U	3.40	0.28 U	0.33 U	0.35 U	0.35 U	0.35 U	0.30 U
032712	INEL	Uncategorized Metal	217	480	17.00 U	0.82 J	0.24 U	0.28 U	0.30 U	0.30 U	0.30 U	0.25 U
032715	RFETS	Combustible	216	337	5.00 U	0.86	0.07 U	0.09 U	0.09 U	0.09 U	0.09 U	0.08 U
032748	INEL	Combustible	223	339	17.00 U	4.40	0.23 U	0.33 U	0.38 U	0.32 U	0.25 U	0.15 U
032753	INEL	Uncategorized Metal	217	481	17.00 U	0.04 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
033091	INEL	Combustible	223	339	17.00 U	2.70	0.02 U	0.02 U	0.38 J	1.10	0.86 J	0.03 U
D01332	RFETS	Heterogeneous	116	832	3.00 U	19.36	0.50 U	1.00 U	42.90	133.38	62.59	0.50 U
D06288	RFETS	Filter	119	338	0.60 U	0.10 U	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D06339	RFETS	Heterogeneous	0	337	4.72 J	1.27 J	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D11129	RFETS	Filter	119	338	0.79 J	0.10 U	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D13364	RFETS	Uncategorized Metal	117	480	1.10 U	2.48	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D15680	RFETS	Heterogeneous	116	831	400.00 U	66.67 U	66.67 U	133.33 U	66.67 U	66.67 U	66.67 U	66.67 U
D17184	RFETS	Solidified Inorganics	111	800	1.10 U	1.61	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D32439	RFETS	Filter	119	338	0.60 U	0.10 U	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D32978	RFETS	Solidified Inorganics	111	803	34.00 U	5.67 U	5.67 U	11.33 U	5.67 U	5.67 U	5.67 U	5.67 U
D35301	RFETS	Solidified Inorganics	111	800	1.10 U	0.20 J	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D35306	RFETS	Lead/Cadmium Metal	123	339	1.20 U	7.86	0.20 U	0.40 U	0.20 U	0.45 J	1.03 J	0.20 U
D36606	RFETS	Uncategorized Metal	117	480	2.80 U	40.46	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D38859	RFETS	Solidified Inorganics	111	803	1.10 U	0.45 J	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D38989	RFETS	Heterogeneous	0	336	0.60 U	9.27	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D41681	RFETS	Filter	119	338	0.10 U	3.39	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D42280	RFETS	Solidified Organics	112	801	2500.00 U	416.67 U	416.67 U	833.33 U	416.67 U	416.67 U	416.67 U	416.67 U
D47501	RFETS	Lead/Cadmium Metal	0	341	0.68 J	5.91	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D48182	RFETS	Filter	119	376	4.40 U	27.92	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D48200	RFETS	Heterogeneous	116	831	88.00 U	16.39 J	8.00 U	8.00 U	8.00 U	8.00 U	16.00 U	8.00 U
D48377	RFETS	Inorganic Non-metal	118	368	1.10 U	2.61	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D49662	RFETS	Solidified Inorganics	0	292	0.60 U	6.19	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D49880	RFETS	Heterogeneous	0	336	1.60 U	16.66	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D52318	RFETS	Lead/Cadmium Metal	117	321	0.60 U	0.22 J	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D52362	RFETS	Heterogeneous	116	821	2.20 U	9.50	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D52726	RFETS	Heterogeneous	116	833	4.80 U	11.72	0.80 U	1.60 U	0.80 U	0.80 U	0.80 U	0.80 U
D53672	RFETS	Inorganic Non-metal	118	440	2.20 U	8.14	0.20 U	0.20 U	0.20 U	0.29 J	0.40 U	0.20 U
D55656	RFETS	Heterogeneous	116	831	3.30 U	33.36	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D55680	RFETS	Heterogeneous	116	821	2.20 U	8.57	0.20 U	0.20 U	0.20 U	0.23 J	0.40 U	0.20 U
D55938	RFETS	Heterogeneous	116	831	2.20 U	12.11	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D56095	RFETS	Heterogeneous	0	337	0.60 U	3.59	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D56595	RFETS	Heterogeneous	116	831	80.00 U	13.33 U	13.33 U	26.67 U	13.33 U	13.33 U	13.33 U	13.33 U
D56755	RFETS	Heterogeneous	116	821	1.10 U	0.20 J	0.10 U	0.10 U	0.10 U	0.18 J	0.20 U	0.10 U
D56823	RFETS	Heterogeneous	116	831	4.40 U	23.57	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D57179	RFETS	Heterogeneous	0	330	12.00 U	6.90 J	2.00 U	4.00 U	2.00 U	2.00 U	2.00 U	2.00 U
D57522	RFETS	Heterogeneous	0	336	2.40 U	7.15	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D57847	RFETS	Uncategorized Metal	117	480	2.80 U	41.16	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D58143	RFETS	Solidified Inorganics	111	807	1.10 U	8.03	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D58154	RFETS	Heterogeneous	116	831	2.40 U	40.69	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D58627	RFETS	Heterogeneous	116	831	1.20 U	11.64	0.20 U	0.40 U	10.02	36.00	10.31	0.20 U
D58889	RFETS	Heterogeneous	116	831	1.40 U	12.97	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D58970	RFETS	Solidified Inorganics	111	807	1.10 U	3.12	0.10 U	0.10 U	0.10 U	0.17 J	0.20 U	0.10 U
D59053	RFETS	Lead/Cadmium Metal	0	341	0.60 U	3.49	0.10 U	0.20 U	0.15 J	0.32 J	0.78 J	0.10 U
D59703	RFETS	Heterogeneous	116	831	3.50 U	62.59	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D59899	RFETS	Filter	0	331	3.50 U	50.44 a	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D60056	RFETS	Lead/Cadmium Metal	0	341	1.60 U	5.44	0.27 U	0.53 U	0.27 U	0.63 J	1.53 J	0.27 U
D60218	RFETS	Heterogeneous	116	821	2.20 U	5.17	0.20 U	0.20 U	1.75 J	11.25	8.61	0.20 U
D60298	RFETS	Solidified Organics	112	801	6306.66 U	573.33 U	573.33 U	573.33 U	573.33 U	573.33 U	1146.6 U	573.33 U
D60320	RFETS	Heterogeneous	0	330	256.93 J	28.00 U	28.00 U	56.00 U	28.00 U	28.00 U	28.00 U	28.00 U
D60463	RFETS	Inorganic Non-metal	118	440	1.10 U	1.92	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D60511	RFETS	Filter	119	491	2.20 U	8.05	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D60635	RFETS	Filter	119	491	1.10 U	4.79	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D61245	RFETS	Heterogeneous	0	336	5.48 J	12.27	0.47 U	0.93 U	0.47 U	0.47 U	0.47 U	0.47 U
D61278	RFETS	Heterogeneous	0	336	1.60 U	18.50	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D61473	RFETS	Heterogeneous	0	377	3.30 U	26.06	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D61504	RFETS	Lead/Cadmium Metal	0	341	3.47 J	6.80	0.10 U	0.34 J	0.31 J	0.82 J	1.58	0.10 U
D61747	RFETS	Heterogeneous	0	330	3.33 J	23.52	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D62340	RFETS	Heterogeneous	116	821	4.40 U	29.08	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D62478	RFETS	Filter	119	376	4.40 U	28.29	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D62714	RFETS	Heterogeneous	116	831	7.00 U	29.92	1.00 U	2.00 U	1.00 U	1.00 U	1.00 U	1.00 U
D62851	RFETS	Heterogeneous	116	825	3.30 U	6.69	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D62855	RFETS	Heterogeneous	116	821	66.00 U	26.39 J	6.00 U	6.00 U	6.00 U	6.00 U	12.00 U	6.00 U
D63098	RFETS	Filter	0	331	4.59 J	48.86 a	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D63229	RFETS	Heterogeneous	116	831	2.20 U	22.72	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D63281	RFETS	Solidified Inorganics	111	807	1.10 U	5.39	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D63460	RFETS	Heterogeneous	116	831	1.10 U	14.84	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D63654	RFETS	Solidified Inorganics	111	807	1.10 U	5.82	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D63808	RFETS	Heterogeneous	116	831	8.80 U	44.69	0.80 U	0.80 U	0.80 U	0.80 U	1.60 U	0.80 U
D63817	RFETS	Heterogeneous	116	821	17.60 U	8.12 J	1.60 U	1.60 U	1.60 U	1.60 U	3.20 U	1.60 U
D63819	RFETS	Solidified Inorganics	111	807	2.20 U	2.57	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D63999	RFETS	Filter	119	491	3.30 U	11.61	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D64004	RFETS	Filter	0	331	2.80 U	36.31 a	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D64137	RFETS	Filter	119	335	1.10 U	0.14 J	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D64448	RFETS	Heterogeneous	116	821	1210.00 U	574.53 J	110.00 U	110.00 U	1996.8	8500.1	2764.0	110.00 U
D64555	RFETS	Solidified Organics	112	801	6306.66 U	573.33 U	573.33 U	573.33 U	573.33 U	573.33 U	1146.6 U	573.33 U
D64632	RFETS	Solidified Inorganics	111	800	1.10 U	2.64	0.10 U	0.10 U	0.10 U	0.25 J	0.20 U	0.10 U
D64752	RFETS	Uncategorized Metal	117	480	14.00 U	28.39	2.00 U	4.00 U	2.00 U	2.00 U	2.00 U	2.00 U
D64758	RFETS	Heterogeneous	116	831	3.00 U	46.17	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D64860	RFETS	Heterogeneous	116	831	84.00 U	24.89 J	12.00 U	24.00 U	12.00 U	12.00 U	12.00 U	12.00 U
D65212	RFETS	Heterogeneous	116	831	63.00 U	19.34 J	9.00 U	18.00 U	9.00 U	9.00 U	9.00 U	9.00 U
D65213	RFETS	Heterogeneous	116	831	56.00 U	27.39 J	8.00 U	16.00 U	8.00 U	8.00 U	8.00 U	8.00 U
D65214	RFETS	Heterogeneous	116	831	810.34 U	73.67 U	73.67 U	73.67 U	73.67 U	73.67 U	147.33 U	73.67 U
D65530	RFETS	Solidified Inorganics	111	807	1.10 U	5.64	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D65535	RFETS	Solidified Inorganics	111	807	1.10 U	1.84	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D65546	RFETS	Solidified Inorganics	111	807	1.10 U	5.54	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D65600	RFETS	Solidified Inorganics	111	807	1.10 U	4.21	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D65731	RFETS	Inorganic Non-metal	122	375	4.40 U	7.18	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D65734	RFETS	Uncategorized Metal	117	480	7.70 U	56.70	0.70 U	0.70 U	0.70 U	0.84 J	1.40 U	0.70 U
D65754	RFETS	Heterogeneous	116	831	4.00 U	68.61	0.67 U	1.33 U	0.67 U	0.67 U	0.67 U	0.67 U
D65757	RFETS	Heterogeneous	116	831	18.00 U	11.25 J	3.00 U	6.00 U	3.00 U	3.00 U	3.00 U	3.00 U
D65972	RFETS	Filter	119	376	3.30 U	19.73	0.30 U	0.30 U	0.30 U	0.39 J	0.60 U	0.30 U
D66128	RFETS	Heterogeneous	116	831	3.00 U	39.06	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D66157	RFETS	Uncategorized Metal	117	480	725.65 J	106.82	2.00 U	4.00 U	132.20	407.06	59.58	2.00 U
D66162	RFETS	Lead/Cadmium Metal	123	339	990.00 U	90.00 U	90.00 U	90.00 U	90.00 U	90.00 U	180.00 U	90.00 U
D66211	RFETS	Heterogeneous	116	833	1.10 U	8.42	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D66213	RFETS	Heterogeneous	116	831	1.80 U	13.19	0.30 U	0.60 U	0.30 U	0.30 U	0.30 U	0.30 U
D66356	RFETS	Heterogeneous	116	831	1000.00 U	166.67 U	166.67 U	333.33 U	166.67 U	166.67 U	166.67 U	166.67 U
D66378	RFETS	Heterogeneous	116	831	1344.00 U	192.00 U	192.00 U	384.00 U	192.00 U	192.00 U	192.00 U	192.00 U
D66438	RFETS	Uncategorized Metal	117	480	17.60 U	5.56 J	1.60 U	1.60 U	1.60 U	1.60 U	3.20 U	1.60 U
D66523	RFETS	Solidified Organics	112	801	6306.66 U	573.33 U	573.33 U	573.33 U	573.33 U	573.33 U	573.33 U	1146.6 U
D66525	RFETS	Solidified Inorganics	111	800	1.87 U	15.55	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D66631	RFETS	Heterogeneous	116	831	5.50 U	48.16	0.50 U	0.50 U	0.50 U	0.50 U	1.00 U	0.50 U
D66637	RFETS	Heterogeneous	116	831	56.00 U	25.59 J	8.00 U	16.00 U	8.00 U	8.00 U	8.00 U	8.00 U
D66641	RFETS	Heterogeneous	116	831	660.00 U	60.00 U	60.00 U	60.00 U	60.00 U	60.00 U	120.00 U	60.00 U
D66649	RFETS	Lead/Cadmium Metal	123	339	616.00 U	56.00 U	56.00 U	56.00 U	56.00 U	56.00 U	112.00 U	56.00 U
D66773	RFETS	Uncategorized Metal	117	480	3.30 U	12.48	0.30 U	0.30 U	0.90 J	1.43 J	0.60 U	0.30 U
D66783	RFETS	Heterogeneous	116	831	2750.00 U	250.00 U	250.00 U	250.00 U	250.00 U	250.00 U	500.00 U	250.00 U
D66792	RFETS	Heterogeneous	116	831	1100.00 U	100.00 U	100.00 U	100.00 U	100.00 U	100.00 U	200.00 U	100.00 U
D66860	RFETS	Heterogeneous	116	833	2.20 U	13.86	0.20 U	0.20 U	0.35 J	1.21 J	0.41 J	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D66875	RFETS	Heterogeneous	116	832	1.10 U	5.76	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D66948	RFETS	Heterogeneous	116	831	66.00 U	13.34 J	6.00 U	6.00 U	6.00 U	6.00 U	12.00 U	6.00 U
D66949	RFETS	Heterogeneous	116	831	6.60 U	13.62	0.60 U	0.60 U	0.60 U	0.60 U	1.20 U	0.60 U
D66953	RFETS	Uncategorized Metal	117	480	11.20 U	2.96 J	1.60 U	3.20 U	1.60 U	1.60 U	1.60 U	1.60 U
D66958	RFETS	Heterogeneous	116	831	3.30 U	22.22	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D67009	RFETS	Solidified Organics	112	801	3740.00 U	739.16 J	340.00 U	340.00 U	340.00 U	340.00 U	680.00 U	340.00 U
D67012	RFETS	Solidified Organics	112	801	9900.00 U	1799.1 J	900.00 U	900.00 U	900.00 U	900.00 U	1800.0 U	900.00 U
D67047	RFETS	Solidified Inorganics	111	807	2.20 U	5.32	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D67251	RFETS	Uncategorized Metal	117	480	8400.00 U	1494.7 J	1200.0 U	2400.0 U	1200.0 U	1200.0 U	1200.0 U	1200.0 U
D67263	RFETS	Heterogeneous	116	831	99.00 U	9.45 J	9.00 U	9.00 U	9.00 U	9.00 U	18.00 U	9.00 U
D67277	RFETS	Heterogeneous	116	831	154.00 U	14.00 U	14.00 U	14.00 U	14.00 U	14.00 U	28.00 U	14.00 U
D67278	RFETS	Heterogeneous	116	831	1.10 U	1.31	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D67312	RFETS	Heterogeneous	116	825	2.20 U	11.14	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D67317	RFETS	Uncategorized Metal	117	480	1.87 U	20.00	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D67390	RFETS	Solidified Organics	112	801	1430.00 U	130.00 U	130.00 U	130.00 U	130.00 U	130.00 U	260.00 U	130.00 U
D67391	RFETS	Heterogeneous	116	833	1.60 U	26.96	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D67413	RFETS	Solidified Organics	112	801	8250.00 U	1799.2 J	750.00 U	750.00 U	750.00 U	750.00 U	1500.0 U	750.00 U
D67434	RFETS	Solidified Inorganics	111	800	2.80 U	14.94	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D67436	RFETS	Solidified Inorganics	111	800	0.93 U	10.37	0.13 U	0.27 U	0.13 U	0.28 J	0.13 U	0.13 U
D67441	RFETS	Solidified Inorganics	111	800	2.80 U	7.70	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D67448	RFETS	Heterogeneous	116	852	1.10 U	4.38	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D67455	RFETS	Filter	119	490	4.40 U	2.77 J	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D67464	RFETS	Heterogeneous	116	831	2640.00 U	240.00 U	240.00 U	240.00 U	240.00 U	240.00 U	480.00 U	240.00 U
D67524	RFETS	Heterogeneous	116	832	204.52 U	18.59 U	18.59 U	18.59 U	18.59 U	18.59 U	37.19 U	18.59 U
D67532	RFETS	Lead/Cadmium Metal	123	339	69.30 U	6.30 U	6.30 U	6.30 U	6.30 U	6.30 U	12.60 U	6.30 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D67535	RFETS	Heterogeneous	116	831	1.40 U	19.28	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D67539	RFETS	Solidified Organics	112	801	3520.00 U	629.76 J	320.00 U	320.00 U	320.00 U	320.00 U	640.00 U	320.00 U
D67541	RFETS	Heterogeneous	116	825	1.10 U	7.66	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D67545	RFETS	Solidified Organics	112	801	990.00 U	90.00 U	90.00 U	90.00 U	90.00 U	90.00 U	180.00 U	90.00 U
D67567	RFETS	Heterogeneous	116	831	3.30 U	32.27	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D67582	RFETS	Heterogeneous	116	831	12.39 J	28.03	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D67603	RFETS	Uncategorized Metal	117	480	143.00 U	29.89 J	13.00 U	13.00 U	13.00 U	13.00 U	26.00 U	13.00 U
D67654	RFETS	Solidified Inorganics	111	800	1.87 U	14.87	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D67657	RFETS	Solidified Inorganics	111	800	1.87 U	20.04	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D67678	RFETS	Heterogeneous	116	825	4.73 U	33.45	0.43 U	0.43 U	0.43 U	0.43 U	0.86 U	0.43 U
D67698	RFETS	Heterogeneous	116	831	9.60 U	138.80	1.60 U	3.20 U	1.60 U	4.53 J	1.60 U	1.60 U
D67707	RFETS	Heterogeneous	116	831	3.00 U	7.89	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D67734	RFETS	Heterogeneous	116	831	1210.00 U	110.00 U	110.00 U	110.00 U	110.00 U	110.00 U	220.00 U	110.00 U
D67735	RFETS	Uncategorized Metal	117	480	19.80 U	18.17	1.80 U	1.80 U	1.80 U	1.80 U	3.60 U	1.80 U
D67759	RFETS	Heterogeneous	116	831	30.80 U	86.98	2.80 U	2.80 U	2.80 U	2.86 J	5.60 U	2.80 U
D67764	RFETS	Heterogeneous	116	831	12.00 U	142.10	2.00 U	4.00 U	2.00 U	3.15 J	2.00 U	2.00 U
D67766	RFETS	Heterogeneous	116	831	9.00 U	60.77	1.50 U	3.00 U	1.50 U	1.50 U	1.50 U	1.50 U
D67781	RFETS	Heterogeneous	116	831	3.30 U	24.04	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D67908	RFETS	Heterogeneous	116	832	1.10 U	7.25	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D67929	RFETS	Heterogeneous	116	832	0.60 U	0.88 J	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D67989	RFETS	Heterogeneous	116	831	5.50 U	4.42 J	0.50 U	0.50 U	0.50 U	0.50 U	1.00 U	0.50 U
D67994	RFETS	Heterogeneous	116	831	16.00 U	2.67 U	2.67 U	5.33 U	2.67 U	2.67 U	2.67 U	2.67 U
D68044	RFETS	Heterogeneous	116	825	5.50 U	25.12	0.50 U	0.50 U	0.50 U	0.50 U	1.00 U	0.50 U
D68096	RFETS	Heterogeneous	116	821	2.20 U	9.29	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D68247	RFETS	Solidified Inorganics	111	800	0.93 U	7.90	0.13 U	0.27 U	0.13 U	0.13 U	0.13 U	0.13 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D68248	RFETS	Solidified Organics	112	801	1650.00 U	150.00 U	150.00 U	150.00 U	150.00 U	150.00 U	300.00 U	150.00 U
D68250	RFETS	Solidified Organics	112	801	1870.00 U	170.00 U	170.00 U	170.00 U	170.00 U	170.00 U	340.00 U	170.00 U
D68254	RFETS	Solidified Inorganics	111	800	1.87 U	8.28	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D68256	RFETS	Solidified Inorganics	111	800	2.80 U	11.30	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D68276	RFETS	Heterogeneous	116	852	1.10 U	1.80	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D68277	RFETS	Uncategorized Metal	117	480	5.50 U	27.39	0.50 U	0.50 U	0.50 U	0.50 U	1.00 U	0.50 U
D68377	RFETS	Uncategorized Metal	117	480	1.40 U	2.52	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D68460	RFETS	Heterogeneous	116	832	0.60 U	0.13 J	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D68480	RFETS	Solidified Inorganics	111	800	0.89 J	3.64	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D68486	RFETS	Solidified Organics	112	801	1540.00 U	140.00 U	140.00 U	140.00 U	140.00 U	140.00 U	280.00 U	140.00 U
D68514	RFETS	Uncategorized Metal	117	480	1.10 U	7.36	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D68538	RFETS	Lead/Cadmium Metal	123	339	0.70 U	2.10	0.10 U	0.20 U	0.10 U	0.25 J	0.24 J	0.10 U
D68600	RFETS	Heterogeneous	116	825	198.00 U	18.00 U	18.00 U	18.00 U	18.00 U	18.00 U	36.00 U	18.00 U
D68601	RFETS	Heterogeneous	116	825	77.00 U	13.12 J	7.00 U	7.00 U	7.00 U	7.00 U	14.00 U	7.00 U
D68702	RFETS	Heterogeneous	116	833	1.10 U	4.93	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D68724	RFETS	Heterogeneous	116	831	1980.00 U	180.00 U	180.00 U	180.00 U	180.00 U	180.00 U	360.00 U	180.00 U
D68756	RFETS	Heterogeneous	116	831	1.40 U	17.92	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D68885	RFETS	Heterogeneous	116	831	440.00 U	40.00 U	40.00 U	40.00 U	40.00 U	40.00 U	80.00 U	40.00 U
D68896	RFETS	Heterogeneous	116	831	2343.00 U	213.00 U	213.00 U	213.00 U	213.00 U	213.00 U	426.00 U	213.00 U
D68975	RFETS	Solidified Organics	112	801	5940.00 U	540.00 U	540.00 U	540.00 U	540.00 U	540.00 U	1080.0 U	540.00 U
D68999	RFETS	Heterogeneous	116	821	4.40 U	26.90	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D69091	RFETS	Heterogeneous	116	825	5.50 U	30.60	0.50 U	0.50 U	0.50 U	0.50 U	1.00 U	0.50 U
D69095	RFETS	Heterogeneous	116	833	5.94 U	38.57	0.54 U	0.54 U	0.54 U	0.54 U	1.08 U	0.54 U
D69113	RFETS	Heterogeneous	116	831	528.00 U	48.00 U	48.00 U	48.00 U	48.00 U	48.00 U	96.00 U	48.00 U
D69250	RFETS	Heterogeneous	116	833	1.10 U	7.05	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D69287	RFETS	Heterogeneous	116	821	1518.00 U	138.00 U	138.00 U	138.00 U	138.00 U	138.00 U	276.00 U	138.00 U
D69306	RFETS	Solidified Organics	112	801	2750.00 U	250.00 U	250.00 U	250.00 U	250.00 U	250.00 U	500.00 U	250.00 U
D69312	RFETS	Solidified Inorganics	111	800	2.80 U	14.58	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D69364	RFETS	Heterogeneous	116	833	3.30 U	11.79	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D69400	RFETS	Heterogeneous	116	831	407.00 U	37.00 U	37.00 U	37.00 U	37.00 U	37.00 U	74.00 U	37.00 U
D69406	RFETS	Heterogeneous	116	831	550.00 U	50.00 U	50.00 U	50.00 U	50.00 U	50.00 U	100.00 U	50.00 U
D69413	RFETS	Heterogeneous	116	831	6.60 U	6.00	0.60 U	0.60 U	0.60 U	0.60 U	1.20 U	0.60 U
D69418	RFETS	Heterogeneous	116	831	807.40 U	73.40 U	73.40 U	73.40 U	73.40 U	73.40 U	146.80 U	73.40 U
D69431	RFETS	Heterogeneous	116	831	320.00 U	53.33 U	53.33 U	106.67 U	53.33 U	53.33 U	53.33 U	53.33 U
D69518	RFETS	Heterogeneous	116	833	2.20 U	11.12	0.20 U	0.20 U	0.20 U	0.74 J	0.47 J	0.20 U
D69602	RFETS	Heterogeneous	116	821	11.00 U	68.03	1.00 U	1.00 U	1.00 U	1.00 U	2.00 U	1.00 U
D69759	RFETS	Heterogeneous	116	833	3.30 U	16.46	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D69855	RFETS	Heterogeneous	116	833	2.20 U	8.80	0.20 U	0.20 U	0.32 J	1.19 J	0.40 U	0.20 U
D69877	RFETS	Heterogeneous	116	825	5.50 U	17.53	0.50 U	0.50 U	0.71 J	2.53 J	1.00 U	0.50 U
D69883	RFETS	Heterogeneous	116	825	3.30 U	10.62	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D69975	RFETS	Heterogeneous	116	821	7.70 U	44.47	0.70 U	0.70 U	0.70 U	0.70 U	1.40 U	0.70 U
D70063	RFETS	Heterogeneous	116	821	5.61 U	34.81	0.51 U	0.51 U	0.56 J	1.92 J	1.02 U	0.51 U
D70077	RFETS	Heterogeneous	116	831	660.00 U	60.00 U	60.00 U	60.00 U	60.00 U	60.00 U	120.00 U	60.00 U
D70229	RFETS	Heterogeneous	116	831	2.20 U	19.11	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D70353	RFETS	Heterogeneous	116	833	2.20 U	19.69	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D70370	RFETS	Heterogeneous	116	821	3.30 U	13.37	0.30 U	0.30 U	0.30 U	0.72 J	0.60 U	0.30 U
D70379	RFETS	Heterogeneous	116	833	1.10 U	10.35	0.10 U	0.10 U	0.10 U	0.10 J	0.20 U	0.10 U
D70383	RFETS	Heterogeneous	116	833	2.20 U	11.65	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D70446	RFETS	Uncategorized Metal	117	480	7.00 U	37.41	1.00 U	2.00 U	1.00 U	7.19 J	1.61 J	1.00 U
D70448	RFETS	Heterogeneous	116	831	1650.00 U	150.00 U	150.00 U	150.00 U	150.00 U	150.00 U	300.00 U	150.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D70455	RFETS	Heterogeneous	116	831	7.70 U	50.51	0.70 U	0.70 U	0.70 U	0.70 U	1.40 U	0.70 U
D70543	RFETS	Solidified Organics	112	801	9108.00 U	828.00 U	828.00 U	828.00 U	828.00 U	828.00 U	1656.0 U	828.00 U
D70661	RFETS	Filter	0	331	3.60 U	13.50	0.60 U	1.20 U	0.60 U	0.60 U	0.60 U	0.60 U
D70669	RFETS	Uncategorized Metal	117	480	1.10 U	11.84	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D70675	RFETS	Solidified Organics	112	801	2.15 J	1.88	0.60 J	0.10 U	0.11 J	0.29 J	0.20 U	0.10 U
D70682	RFETS	Heterogeneous	116	831	495.00 U	45.00 U	45.00 U	45.00 U	45.00 U	45.00 U	90.00 U	45.00 U
D70696	RFETS	Heterogeneous	116	821	6.60 U	35.16	0.60 U	0.60 U	0.60 U	0.60 U	1.20 U	0.60 U
D70734	RFETS	Heterogeneous	116	833	0.60 U	7.19	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D70780	RFETS	Heterogeneous	116	832	0.60 U	6.00	0.10 U	0.20 U	0.10 U	0.14 J	0.10 U	0.10 U
D70856	RFETS	Heterogeneous	116	833	1.10 U	5.02	0.10 U	0.10 U	0.13 J	0.42 J	0.20 U	0.10 U
D70882	RFETS	Heterogeneous	116	831	154.00 U	24.14 J	14.00 U	14.00 U	14.00 U	14.00 U	28.00 U	14.00 U
D70937	RFETS	Filter	0	331	3.00 U	15.32	0.50 U	1.00 U	0.50 U	1.11 J	0.92 J	0.50 U
D71019	RFETS	Solidified Organics	112	801	14.30 U	4.06 J	2.38 J	1.30 U	1.30 U	1.30 U	2.60 U	1.30 U
D71020	RFETS	Solidified Organics	112	801	13822.9 J	911.50 U	911.50 U	911.50 U	911.50 U	911.50 U	1823.0 U	911.50 U
D71022	RFETS	Solidified Organics	112	801	7200.00 U	1200.0 U	1200.0 U	2400.0 U	2551.2 J	8626.8 J	2212.8 J	1200.0 U
D71241	RFETS	Heterogeneous	116	833	0.60 U	5.29	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D71351	RFETS	Uncategorized Metal	117	480	0.70 U	1.19	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D71354	RFETS	Uncategorized Metal	117	480	0.70 U	1.63	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D71385	RFETS	Heterogeneous	116	833	3.30 U	23.02	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D71494	RFETS	Solidified Organics	112	801	2.31 J	2.17 J	0.10 U	0.10 U	0.10 U	0.26 J	0.20 U	0.10 U
D71504	RFETS	Solidified Organics	112	801	2.20 U	2.55	0.54 J	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D71514	RFETS	Heterogeneous	116	833	2.20 U	14.12	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D71521	RFETS	Heterogeneous	116	825	2.20 U	9.03	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D71638	RFETS	Uncategorized Metal	117	480	7.00 U	10.80	1.00 U	2.00 U	1.00 U	1.00 U	1.00 U	1.00 U
D71804	RFETS	Heterogeneous	116	832	0.70 U	1.48	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D71829	RFETS	Heterogeneous	116	852	2420.00 U	220.00 U	220.00 U	220.00 U	220.00 U	220.00 U	440.00 U	220.00 U
D71838	RFETS	Heterogeneous	116	831	83.60 U	11.96 J	7.60 U	7.60 U	7.60 U	7.60 U	15.20 U	7.60 U
D71921	RFETS	Heterogeneous	116	833	0.70 U	7.15	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D71932	RFETS	Solidified Organics	112	801	48047.5 U	4367.9 U	4367.9 U	4367.9 U	4367.9 U	4367.9 U	8735.9 U	4367.9 U
D71933	RFETS	Solidified Organics	112	801	0.60 U	2.01	0.10 U	0.20 U	0.10 U	0.16 J	0.11 J	0.10 U
D71934	RFETS	Solidified Organics	112	801	1.48 J	2.88	0.10 U	0.20 U	0.10 U	0.17 J	0.10 U	0.10 U
D71936	RFETS	Heterogeneous	116	833	238.34 U	21.67 U	21.67 U	21.67 U	21.67 U	21.67 U	43.33 U	21.67 U
D71937	RFETS	Heterogeneous	116	833	200.00 U	33.33 U	33.33 U	66.67 U	33.33 U	33.33 U	33.33 U	33.33 U
D71938	RFETS	Heterogeneous	116	833	19.80 U	1.80 U	1.80 U	1.80 U	1.80 U	1.92 J	3.60 U	1.80 U
D71940	RFETS	Solidified Organics	112	801	11000.0 U	1000.0 U	1000.0 U	1000.0 U	1000.0 U	1000.0 U	2000.0 U	1000.0 U
D71941	RFETS	Solidified Organics	112	801	11000.0 U	1000.0 U	1000.0 U	1000.0 U	1000.0 U	1000.0 U	2000.0 U	1000.0 U
D72010	RFETS	Heterogeneous	116	832	2.10 U	34.34	0.30 U	0.60 U	0.30 U	0.30 U	0.30 U	0.30 U
D72079	RFETS	Uncategorized Metal	117	480	71.50 U	43.37 J	6.50 U	6.50 U	6.50 U	6.50 U	13.00 U	6.50 U
D72127	RFETS	Solidified Organics	112	801	4.40 U	0.66 J	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D72128	RFETS	Solidified Organics	112	801	3446.04 J	6991.6	130.00 U	130.00 U	130.00 U	130.00 U	260.00 U	130.00 U
D72131	RFETS	Heterogeneous	116	833	1.60 U	0.75 J	0.48 J	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D72132	RFETS	Solidified Organics	112	801	538.32 J	370.66 J	48.00 U	96.00 U	48.00 U	48.00 U	48.00 U	48.00 U
D72133	RFETS	Solidified Organics	112	801	2.20 U	1.34 J	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D72136	RFETS	Solidified Organics	112	801	231.00 U	1395.5	21.00 U	21.00 U	21.00 U	21.00 U	42.00 U	21.00 U
D72139	RFETS	Solidified Organics	112	801	20.90 U	207.08	1.90 U	1.90 U	1.90 U	1.90 U	3.80 U	1.90 U
D72178	RFETS	Heterogeneous	116	821	3.30 U	8.16	0.30 U	0.30 U	0.37 J	1.67 J	0.60 U	0.30 U
D72186	RFETS	Heterogeneous	116	821	2.20 U	9.78	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D72195	RFETS	Heterogeneous	116	833	1.10 U	12.27	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D72255	RFETS	Heterogeneous	116	833	3.30 U	19.33	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D72267	RFETS	Solidified Inorganics	111	800	0.70 U	3.23	0.12 J	0.20 U	0.94 J	3.28	0.61 J	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D72293	RFETS	Heterogeneous	116	833	1.10 U	10.66	0.10 U	0.10 U	0.12 J	0.39 J	0.20 U	0.10 U
D72333	RFETS	Heterogeneous	116	831	3.30 U	18.22	0.30 U	0.30 U	0.30 U	0.46 J	0.60 U	0.30 U
D72339	RFETS	Heterogeneous	116	821	5.50 U	37.30	0.50 U	0.50 U	0.50 U	0.50 U	1.00 U	0.50 U
D72347	RFETS	Heterogeneous	116	833	1.10 U	9.87	0.10 U	0.10 U	0.10 U	0.11 J	0.20 U	0.10 U
D72375	RFETS	Heterogeneous	116	831	880.00 U	80.00 U	80.00 U	80.00 U	80.00 U	80.00 U	160.00 U	80.00 U
D72434	RFETS	Heterogeneous	116	831	2310.00 U	210.00 U	210.00 U	210.00 U	210.00 U	210.00 U	420.00 U	210.00 U
D72436	RFETS	Uncategorized Metal	117	480	3.50 J	17.20	0.30 U	0.60 U	0.30 U	0.30 U	0.30 U	0.30 U
D72542	RFETS	Heterogeneous	116	832	60.00 U	13.25 J	10.00 U	20.00 U	10.00 U	10.00 U	10.00 U	10.00 U
D72545	RFETS	Solidified Inorganics	111	800	0.70 U	5.28	0.10 U	0.20 U	0.10 U	0.64 J	0.13 J	0.10 U
D72546	RFETS	Heterogeneous	116	832	90.00 U	23.24 J	15.00 U	30.00 U	15.00 U	15.00 U	15.00 U	15.00 U
D72566	RFETS	Solidified Organics	112	801	8.80 U	5.58 J	7.46 J	0.80 U	0.80 U	0.80 U	1.60 U	0.80 U
D72598	RFETS	Heterogeneous	116	821	6.60 U	27.50	0.60 U	0.60 U	0.60 U	0.60 U	1.20 U	0.60 U
D72618	RFETS	Heterogeneous	116	833	1.10 U	2.48	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D72619	RFETS	Solidified Organics	112	801	1.10 U	3.60	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D72623	RFETS	Solidified Organics	112	801	3.00 U	5.45	0.50 U	1.00 U	0.50 U	0.50 U	0.50 U	0.50 U
D72631	RFETS	Solidified Organics	112	801	1.10 U	1.92	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D72632	RFETS	Solidified Organics	112	801	1.10 U	4.04	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D72673	RFETS	Heterogeneous	116	833	2.20 U	10.67	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D72819	RFETS	Heterogeneous	116	833	4.40 U	35.51	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D72822	RFETS	Heterogeneous	116	831	1.60 U	19.90	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D72831	RFETS	Uncategorized Metal	117	480	28.00 U	22.59 J	4.00 U	8.00 U	4.00 U	4.00 U	4.00 U	4.00 U
D72887	RFETS	Heterogeneous	116	833	7.35 J	9.47	0.10 U	0.10 U	0.41 J	1.53	0.40 J	0.10 U
D72923	RFETS	Heterogeneous	116	833	8.67 J	33.51	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D72932	RFETS	Heterogeneous	116	825	3.30 U	20.99	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D73054	RFETS	Heterogeneous	0	336	680.00 U	113.33 U	113.33 U	226.67 U	113.33 U	113.33 U	113.33 U	113.33 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D73074	RFETS	Heterogeneous	116	833	2.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D73117	RFETS	Uncategorized Metal	117	480	2.80 U	15.05	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D73123	RFETS	Heterogeneous	116	831	1386.00 U	126.00 U	126.00 U	126.00 U	126.00 U	126.00 U	252.00 U	126.00 U
D73134	RFETS	Heterogeneous	116	831	432.00 U	72.00 U	72.00 U	144.00 U	72.00 U	72.00 U	72.00 U	72.00 U
D73136	RFETS	Solidified Inorganics	111	807	0.70 U	3.39	0.10 U	0.20 U	0.10 U	0.49 J	0.12 J	0.10 U
D73274	RFETS	Heterogeneous	116	831	550.00 U	50.00 U	50.00 U	50.00 U	50.00 U	50.00 U	100.00 U	50.00 U
D73285	RFETS	Solidified Organics	112	801	1.10 U	4.71	0.34 J	0.10 U	0.10 U	0.12 J	0.20 U	0.10 U
D73293	RFETS	Solidified Organics	112	801	1.10 U	3.03	0.38 J	0.10 U	0.10 U	0.14 J	0.20 U	0.10 U
D73295	RFETS	Solidified Organics	112	801	1.10 U	2.65	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D73296	RFETS	Solidified Organics	112	801	1.10 U	2.37	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D73301	RFETS	Solidified Organics	112	801	2.20 U	9.08	0.50 J	0.20 U	0.20 U	0.30 J	0.40 U	0.20 U
D73605	RFETS	Lead/Cadmium Metal	123	339	0.70 U	3.87	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D73632	RFETS	Heterogeneous	116	825	7.70 U	5.16 J	0.70 U	0.70 U	0.70 U	1.49 J	1.40 U	0.70 U
D73667	RFETS	Solidified Organics	112	801	1.10 U	2.22	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D73672	RFETS	Solidified Organics	112	801	1.10 U	3.07	0.31 J	0.10 U	0.10 U	0.16 J	0.20 U	0.10 U
D73745	RFETS	Heterogeneous	116	832	0.70 U	9.49	0.10 U	0.20 U	0.40 J	1.13	0.36 J	0.10 U
D73828	RFETS	Heterogeneous	116	833	1.10 U	9.45	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D73848	RFETS	Heterogeneous	116	821	1.46 U	6.01	0.13 U	0.13 U	0.13 U	0.13 U	0.27 U	0.13 U
D73987	RFETS	Lead/Cadmium Metal	123	339	2.10 U	3.09	0.30 U	0.60 U	0.30 U	0.30 U	0.30 U	0.30 U
D74007	RFETS	Uncategorized Metal	117	480	2.10 U	19.46	0.30 U	0.60 U	0.30 U	0.30 U	0.30 U	0.30 U
D74110	RFETS	Heterogeneous	116	833	1.10 U	3.36	0.10 U	0.10 U	0.24 J	0.18 J	0.20 U	0.10 U
D74147	RFETS	Solidified Organics	112	801	8.80 U	3.80 J	0.80 U	0.80 U	0.80 U	0.80 U	1.60 U	0.80 U
D74156	RFETS	Solidified Organics	112	801	6.60 U	4.30 J	0.60 U	0.60 U	0.60 U	0.60 U	1.20 U	0.60 U
D74374	RFETS	Heterogeneous	116	833	0.60 U	14.03	0.10 U	0.20 U	0.10 U	0.77 J	0.21 J	0.10 U
D74683	RFETS	Heterogeneous	116	821	16.50 U	106.54	1.50 U	1.50 U	1.50 U	1.50 U	3.00 U	1.50 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D74904	RFETS	Heterogeneous	116	832	0.60 U	4.59	0.10 U	0.20 U	0.10 U	0.19 J	0.20 J	0.10 U
D74913	RFETS	Heterogeneous	116	832	3.30 U	11.94	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D75039	RFETS	Heterogeneous	116	832	3.30 U	1.74 J	0.30 U	0.30 U	2.22 J	19.98	12.03	0.30 U
D75265	RFETS	Heterogeneous	116	833	13.20 U	24.74	1.20 U	1.20 U	1.20 U	1.20 U	2.40 U	1.20 U
D75267	RFETS	Heterogeneous	116	832	2.20 U	18.50	0.20 U	0.20 U	0.23 J	0.47 J	0.40 U	0.20 U
D75278	RFETS	Heterogeneous	116	832	3.30 U	36.13	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D75399	RFETS	Heterogeneous	116	833	4.40 U	16.33	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D75564	RFETS	Heterogeneous	116	825	1.46 U	7.19	0.13 U	0.13 U	0.13 U	0.13 U	0.27 U	0.13 U
D75868	RFETS	Heterogeneous	116	825	6.60 U	23.45	0.60 U	0.60 U	0.60 U	0.60 U	1.20 U	0.60 U
D75888	RFETS	Heterogeneous	116	833	1.10 U	8.30	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D75926	RFETS	Heterogeneous	116	832	4.40 U	27.16	0.40 U	0.40 U	0.40 U	0.40 U	0.80 U	0.40 U
D75930	RFETS	Heterogeneous	116	832	600.00 U	100.00 U	100.00 U	200.00 U	100.00 U	100.00 U	100.00 U	100.00 U
D75947	RFETS	Heterogeneous	116	832	1.10 U	8.86	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D75976	RFETS	Heterogeneous	116	833	0.80 U	14.43	0.13 U	0.27 U	0.13 U	0.13 U	0.13 U	0.13 U
D76044	RFETS	Heterogeneous	116	831	4.05 J	25.07	0.27 U	0.27 U	0.27 U	0.27 U	0.53 U	0.27 U
D76050	RFETS	Heterogeneous	116	832	1.10 U	4.80	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D76054	RFETS	Heterogeneous	116	831	3.30 U	20.75	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D76098	RFETS	Heterogeneous	116	832	1.40 U	18.43	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D76135	RFETS	Solidified Organics	112	801	160.00 U	26.67 U	26.67 U	53.33 U	26.67 U	26.67 U	26.67 U	26.67 U
D76136	RFETS	Solidified Inorganics	111	803	2.40 U	1.89 J	0.41 J	0.80 U	0.40 U	3.02 J	0.82 J	0.40 U
D76138	RFETS	Solidified Inorganics	111	800	0.60 U	1.21	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D76142	RFETS	Solidified Inorganics	111	800	1.44 U	2.56	0.24 U	0.48 U	4.41	18.08	3.45	0.24 U
D76143	RFETS	Solidified Inorganics	111	803	1.80 U	2.12 J	0.37 J	0.60 U	0.30 J	2.25 J	0.63 J	0.30 U
D76144	RFETS	Solidified Inorganics	111	800	4.00 U	0.67 U	0.67 U	1.33 U	0.67 U	0.67 U	0.67 U	0.67 U
D76146	RFETS	Solidified Inorganics	0	292	0.60 U	3.33	0.10 U	0.20 U	0.10 U	0.22 J	0.10 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D76147	RFETS	Solidified Inorganics	111	803	1.10 U	1.69	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D76182	RFETS	Solidified Inorganics	111	800	7.70 U	71.38	0.70 U	0.70 U	9.54	38.35	7.49	0.70 U
D76183	RFETS	Solidified Inorganics	111	800	0.80 U	3.96	0.13 U	0.27 U	0.18 J	0.66 J	0.17 J	0.13 U
D76185	RFETS	Solidified Inorganics	111	800	0.60 U	0.33 J	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D76187	RFETS	Solidified Inorganics	111	803	3.00 U	1.45 J	0.50 U	1.00 U	1.11 J	3.57 J	0.91 J	0.50 U
D76189	RFETS	Solidified Inorganics	111	803	12.00 U	2.00 U	2.00 U	4.00 U	2.00 U	2.00 U	2.00 U	2.00 U
D76192	RFETS	Solidified Inorganics	111	803	0.60 U	1.11	0.10 U	0.20 U	0.10 U	0.21 J	0.10 U	0.10 U
D76194	RFETS	Solidified Inorganics	111	800	0.60 U	0.10 U	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D76195	RFETS	Solidified Organics	112	801	5280.00 U	480.00 U	480.00 U	480.00 U	480.00 U	480.00 U	960.00 U	480.00 U
D76196	RFETS	Solidified Organics	112	801	1000.00 U	166.67 U	166.67 U	333.33 U	166.67 U	166.67 U	166.67 U	166.67 U
D76199	RFETS	Solidified Inorganics	111	800	0.60 U	1.31	0.10 U	0.20 U	0.10 U	0.17 U	0.10 U	0.10 U
D76200	RFETS	Solidified Organics	112	801	3800.00 U	633.33 U	633.33 U	1266.6 U	633.33 U	633.33 U	633.33 U	633.33 U
D76203	RFETS	Solidified Organics	112	801	1340.00 J	223.33 U	223.33 U	446.67 U	223.33 U	223.33 U	223.33 U	223.33 U
D76205	RFETS	Solidified Inorganics	111	800	0.60 U	2.66	0.10 U	0.20 U	0.10 U	0.43 J	0.10 U	0.10 U
D76206	RFETS	Solidified Inorganics	111	803	2.40 U	1.09 J	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D76217	RFETS	Heterogeneous	116	833	6.75 J	7.45 J	1.00 U	2.00 U	1.00 U	1.00 U	1.00 U	1.00 U
D76282	RFETS	Solidified Inorganics	111	800	68.00 U	11.33 U	11.33 U	22.67 U	11.33 U	11.33 U	11.33 U	11.33 U
D76283	RFETS	Solidified Organics	112	801	540.00 U	90.00 U	90.00 U	180.00 U	90.00 U	90.00 U	90.00 U	90.00 U
D76287	RFETS	Solidified Inorganics	111	800	32.00 U	5.33 U	5.33 U	10.67 U	5.33 U	5.33 U	5.33 U	5.33 U
D76293	RFETS	Heterogeneous	116	833	4.40 U	0.59 J	0.40 U	0.40 U	0.96 J	2.65 J	0.80 U	0.40 U
D76302	RFETS	Solidified Inorganics	111	800	18.00 U	34.11	3.00 U	6.00 U	101.74	386.14	30.35	3.00 U
D76303	RFETS	Solidified Inorganics	111	803	1.60 U	1.56 J	0.30 J	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D76305	RFETS	Solidified Inorganics	111	800	72.00 U	12.00 U	12.00 U	24.00 U	12.00 U	12.00 U	12.00 U	12.00 U
D76306	RFETS	Heterogeneous	116	833	8.80 U	1.84 J	0.80 U	0.80 U	2.86 J	8.72	1.60 U	0.80 U
D76362	RFETS	Heterogeneous	116	833	40.00 U	6.67 U	6.67 U	13.33 U	6.67 U	6.67 U	6.67 U	6.67 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D76406	RFETS	Heterogeneous	116	831	1.10 U	4.58	0.10 U	0.10 U	0.10 U	0.15 J	0.20 U	0.10 U
D76437	RFETS	Heterogeneous	116	833	2.20 U	24.00	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D76443	RFETS	Heterogeneous	116	825	3.30 U	5.66	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D76452	RFETS	Heterogeneous	116	825	1.90 U	9.30	0.20 U	0.20 U	0.20 U	0.20 U	0.30 U	0.20 U
D76454	RFETS	Heterogeneous	116	825	1.10 U	5.19	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D76456	RFETS	Heterogeneous	116	825	1.10 U	6.59	0.10 U	0.10 U	0.10 U	0.10 J	0.20 U	0.10 U
D76461	RFETS	Heterogeneous	116	825	3.30 U	12.50	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D76463	RFETS	Heterogeneous	116	825	3.30 U	21.50	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D76470	RFETS	Solidified Inorganics	111	803	0.60 U	3.29	0.10 U	0.20 U	0.10 U	0.23 J	0.10 U	0.10 U
D76587	RFETS	Heterogeneous	116	825	1.10 U	7.16	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D76596	RFETS	Heterogeneous	116	825	1.10 U	14.57	0.10 U	0.10 U	0.10 U	0.10 J	0.20 U	0.10 U
D76627	RFETS	Heterogeneous	116	825	1.10 U	7.34	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D76630	RFETS	Heterogeneous	116	825	1.10 U	8.52	0.10 U	0.10 U	0.19 J	0.71 J	0.20 U	0.10 U
D76635	RFETS	Heterogeneous	116	825	2.20 U	5.12	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D76652	RFETS	Heterogeneous	116	833	0.60 U	8.81	0.10 U	0.20 U	0.10 U	0.10 U	0.10 U	0.10 U
D76677	RFETS	Solidified Inorganics	111	800	26.40 U	2.40 U	2.40 U	2.40 U	2.40 U	2.40 U	4.80 U	2.40 U
D76710	RFETS	Heterogeneous	116	833	22.00 U	9.15 J	2.00 U	2.00 U	2.00 U	2.00 U	4.00 U	2.00 U
D76712	RFETS	Heterogeneous	116	833	3.30 U	13.98	0.30 U	0.30 U	0.30 U	0.30 U	0.60 U	0.30 U
D76715	RFETS	Heterogeneous	116	832	2.20 U	10.09	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D76811	RFETS	Heterogeneous	116	832	2.40 J	20.45	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U
D76908	RFETS	Heterogeneous	116	833	1.10 U	3.36	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U
D76911	RFETS	Heterogeneous	116	832	1.20 U	19.65	0.20 U	0.40 U	0.56 J	1.42 J	0.20 U	0.20 U
D77088	RFETS	Heterogeneous	116	833	1.20 U	14.47	0.20 U	0.40 U	0.20 U	0.20 U	0.20 U	0.20 U
D77227	RFETS	Heterogeneous	116	833	2.40 U	32.95	0.40 U	0.80 U	0.40 U	0.40 U	0.40 U	0.40 U
D77285	RFETS	Heterogeneous	116	833	2.20 U	8.62	0.20 U	0.20 U	0.20 U	0.20 U	0.40 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	Methyl isobutyl ketone	Toluene	Tetra chloro ethene	Chloro benzene	Ethyl benzene	m,p-Xylene	o-Xylene	Bromoform
D77621	RFETS	Heterogeneous	0	336	1.87 U	9.47	0.27 U	0.53 U	0.27 U	0.27 U	0.27 U	0.27 U
D80765	RFETS	Heterogeneous	116	833	2.20 U	10.02	0.20 U	0.20 U	0.20 U	0.51 J	0.40 U	0.20 U
D80772	RFETS	Heterogeneous	116	833	11.00 U	24.39	1.00 U	1.00 U	1.00 U	1.00 U	2.00 U	1.00 U
D80774	RFETS	Heterogeneous	116	833	34.10 U	3.10 U	3.10 U	3.10 U	3.10 U	3.10 U	6.20 U	3.10 U
D80776	RFETS	Heterogeneous	116	832	1.34 J	11.32	0.10 U	0.10 U	0.10 U	0.10 U	0.20 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
000365	RFETS	Uncategorized Metal	217	480	12.00 U	8.70 U	8.70 U
000371	INEL	Graphite	215	300	0.03 U	0.01 U	0.02 U
000373	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
000384	RFETS	Uncategorized Metal	217	320	0.01 U	0.01 U	0.01 U
000393	INEL	Uncategorized Metal	217	480	0.03 U	0.02 U	0.02 U
000401	RFETS	Inorganic Non-metal	222	371	0.02 U	0.01 U	0.01 U
000403	INEL	Inorganic Non-metal	218	440	0.03 U	0.02 U	0.02 U
000405	RFETS	Uncategorized Metal	217	480	0.94 U	0.66 U	0.87 U
000436	INEL	Solidified Organics	212	3	43.00 U	19.00 U	27.00 U
000442	INEL	Solidified Inorganics	213	4	0.05 U	0.02 U	0.03 U
000446	RFETS	Solidified Inorganics	211	1	0.01 U	0.01 U	0.01 J
000478	RFETS	Solidified Inorganics	211	1	0.01 U	0.01 U	0.01 J
000501	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
000558	INEL	Heterogeneous	221	464	0.10 U	0.07 U	0.07 U
000567	RFETS	Inorganic Non-metal	222	371	1.70 U	1.20 U	1.60 U
000568	RFETS	Solidified Organics	226	432	1.00 U	0.73 U	0.73 U
000593	INEL	Solidified Inorganics	211	7	0.02 U	0.01 J	0.02 J
000613	INEL	Graphite	215	300	0.03 U	0.02 U	0.02 U
000630	INEL	Solidified Inorganics	213	4	0.07 U	0.03 U	0.04 U
000648	RFETS	Solidified Inorganics	213	4	0.03 U	0.02 U	0.03 U
000675	RFETS	Inorganic Non-metal	218	440	0.16 U	0.11 U	0.15 U
000823	RFETS	Solidified Inorganics	213	4	0.02 U	0.02 U	0.02 U
000828	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
001016	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
001024	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
001084	INEL	Solidified Inorganics	213	4	0.02 U	0.01 U	0.01 U
001139	INEL	Solidified Inorganics	211	7	0.16 U	0.07 U	0.10 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
001157	INEL	Combustible	223	339	0.03 U	0.02 U	0.02 U
001161	INEL	Graphite	215	300	0.03 U	0.02 U	0.02 U
001258	RFETS	Solidified Inorganics	211	1	0.01 U	0.01 U	0.01 U
001370	INEL	Combustible	223	339	0.14 U	0.08 U	0.09 U
001377	INEL	Combustible	223	339	0.03 U	0.02 U	0.02 U
001410	INEL	Solidified Inorganics	214	292	0.13 U	0.09 U	0.09 U
001437	RFETS	Solidified Inorganics	211	7	0.01 U	0.06 U	0.01 J
001475	RFETS	Solidified Inorganics	211	1	0.21 U	0.14 U	0.19 U
001493	RFETS	Solidified Inorganics	211	1	0.01 U	0.01 U	0.01 U
001619	INEL	Graphite	215	300	0.03 U	0.02 U	0.02 U
001625	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
001633	INEL	Solidified Organics	226	432	0.74 U	0.52 U	0.52 U
001655	INEL	Combustible	223	339	2.00 U	1.40 U	1.40 U
001662	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 JB
001663	RFETS	Solidified Organics	226	432	0.45 U	0.31 U	0.31 U
001667	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
001670	RFETS	Salt Waste	224	411	0.04 U	0.03 U	0.04 U
001677	INEL	Heterogeneous	221	302	0.46 U	0.20 U	0.29 U
001678	RFETS	Combustible	223	339	0.10 U	0.07 U	0.10 U
001689	INEL	Heterogeneous	221	302	0.04 U	0.03 U	0.03 U
001692	RFETS	Solidified Organics	226	432	0.27 U	0.19 U	0.19 U
001695	INEL	Combustible	223	339	1.70 U	1.20 U	1.20 U
001697	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
001751	RFETS	Uncategorized Metal	217	320	0.01 U	0.01 U	0.02 JB
001752	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
001754	INEL	Uncategorized Metal	217	320	0.04 U	0.03 J	0.04 J
001757	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
001773	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
001779	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
001784	INEL	Combustible	223	339	0.03 U	0.02 U	0.02 U
001813	INEL	Solidified Inorganics	213	4	5.70 U	2.50 U	3.60 U
001873	INEL	Solidified Inorganics	214	292	0.04 U	0.03 U	0.03 U
001899	RFETS	Solidified Inorganics	211	3	140.00 U	97.00 U	130.00 U
001900	INEL	Solidified Inorganics	214	292	0.04 U	0.03 U	0.03 U
001919	RFETS	Uncategorized Metal	217	320	0.01 U	0.01 U	0.01 U
001937	RFETS	Solidified Organics	212	3	17.00 U	12.00 U	16.00 U
002013	RFETS	Solidified Organics	212	3	12.00 U	8.20 U	11.00 U
002046	INEL	Solidified Organics	212	3	36.00 U	16.00 U	23.00 U
002065	INEL	Solidified Inorganics	214	292	0.11 U	0.08 U	0.10 U
002084	INEL	Solidified Inorganics	213	4	0.04 U	0.02 U	0.02 U
002220	RFETS	Uncategorized Metal	217	481	0.03 U	0.02 U	0.03 U
002222	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
002338	RFETS	Inorganic Non-metal	222	371	0.84 U	0.58 U	0.58 U
002354	INEL	Combustible	223	339	0.08 U	0.04 U	0.05 U
002363	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U
002365	INEL	Uncategorized Metal	217	480	0.07 U	0.05 U	0.05 U
002542	INEL	Solidified Organics	212	3	7.70 U	3.40 U	4.90 U
002678	RFETS	Solidified Organics	226	432	0.95 U	0.66 U	0.66 U
002791	INEL	Inorganic Non-metal	222	371	0.05 U	0.04 U	0.04 U
002797	RFETS	Solidified Organics	226	432	0.48 U	0.33 U	0.33 U
002814	RFETS	Solidified Inorganics	211	7	0.22 U	0.15 U	0.20 U
003017	INEL	Solidified Inorganics	211	1	0.05 U	0.04 U	0.05 U
003088	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U
003091	RFETS	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
003111	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U
003121	RFETS	Solidified Inorganics	211	7	0.15 U	0.10 U	0.14 U
003129	RFETS	Solidified Inorganics	211	7	0.02 U	0.02 U	0.02 J
003130	RFETS	Solidified Inorganics	211	7	0.04 U	0.03 U	0.04 J
003173	RFETS	Solidified Inorganics	211	7	0.02 U	0.01 U	0.02 J
003181	RFETS	Solidified Inorganics	211	7	0.02 U	0.01 U	0.01 U
003189	INEL	Solidified Organics	212	3	79.00 U	35.00 U	50.00 U
003192	RFETS	Solidified Inorganics	211	7	0.25 U	0.17 U	0.23 U
003215	RFETS	Solidified Inorganics	211	7	0.02 U	0.01 U	0.03 J
003277	RFETS	Solidified Inorganics	211	1	0.01 U	0.01 U	0.01 J
003394	RFETS	Solidified Inorganics	211	7	0.03 U	0.02 U	0.03 U
003406	RFETS	Solidified Inorganics	211	7	0.01 U	0.02 J	0.04 J
003455	RFETS	Solidified Inorganics	211	3	270.00 U	190.00 U	250.00 U
003547	RFETS	Solidified Inorganics	211	7	0.10 U	0.07 U	0.09 U
003577	RFETS	Solidified Inorganics	211	1	0.01 U	0.01 U	0.01 U
003854	INEL	Solidified Organics	212	3	36.00 U	16.00 U	23.00 U
003890	INEL	Solidified Inorganics	111	7	0.03 U	0.02 U	0.03 U
003921	INEL	Solidified Inorganics	111	7	0.04 U	0.02 U	0.03 U
003991	INEL	Combustible	223	339	0.02 U	0.01 U	0.02 U
003997	INEL	Combustible	223	339	0.05 U	0.03 U	0.03 U
004099	INEL	Solidified Inorganics	211	1	0.02 U	0.01 U	0.01 U
004111	RFETS	Salt Waste	224	411	0.03 U	0.02 U	0.03 U
004112	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
004123	INEL	Combustible	223	339	0.02 U	0.01 U	0.02 U
004125	INEL	Uncategorized Metal	217	480	0.03 U	0.02 U	0.02 U
004150	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
004160	INEL	Combustible	223	339	140.00 U	77.00 U	93.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
004166	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U
004186	INEL	Combustible	223	339	0.02 U	0.01 U	0.02 U
004195	RFETS	Salt Waste	224	411	0.01 U	0.01 U	0.01 U
004196	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
004206	INEL	Combustible	223	339	0.02 U	0.01 U	0.01 U
004208	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
004283	INEL	Solidified Inorganics	211	1	0.02 U	0.01 U	0.01 U
004326	INEL	Solidified Inorganics	213	4	0.02 U	0.01 U	0.01 U
004393	INEL	Solidified Inorganics	211	1	0.02 U	0.01 U	0.02 U
004410	INEL	Solidified Inorganics	211	1	0.03 U	0.02 U	0.03 U
004495	INEL	Solidified Inorganics	213	4	0.02 U	0.01 U	0.01 U
004516	INEL	Solidified Inorganics	211	1	0.03 U	0.02 U	0.03 U
004884	INEL	Solidified Inorganics	213	4	0.03 U	0.01 U	0.02 U
004963	INEL	Combustible	223	339	0.08 U	0.04 U	0.05 U
004968	RFETS	Uncategorized Metal	217	320	0.58 U	0.41 U	0.54 U
004981	RFETS	Uncategorized Metal	217	320	0.01 U	0.01 U	0.01 U
004988	RFETS	Salt Waste	224	411	0.03 U	0.02 U	0.03 U
005006	RFETS	Salt Waste	224	411	0.03 U	0.02 U	0.03 U
005012	INEL	Combustible	223	339	0.02 U	0.01 U	0.01 U
005015	INEL	Solidified Organics	226	432	1.50 U	1.00 U	1.00 U
005235	INEL	Solidified Organics	226	432	0.03 U	0.02 U	0.02 U
005262	INEL	Solidified Organics	212	3	220.00 U	98.00 U	140.00 U
005358	INEL	Solidified Inorganics	211	1	0.02 U	0.01 U	0.01 U
005398	INEL	Solidified Inorganics	211	1	0.03 U	0.02 U	0.03 U
005415	INEL	Solidified Inorganics	211	1	0.03 U	0.02 U	0.03 U
005530	INEL	Graphite	215	303	0.02 U	0.01 U	0.02 U
005535	INEL	Solidified Organics	226	432	0.06 U	0.04 U	0.04 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
005735	INEL	Solidified Inorganics	211	7	0.03 U	0.02 U	0.03 U
005738	INEL	Solidified Inorganics	211	7	0.02 U	0.02 U	0.02 U
006242	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U
006252	RFETS	Lead/Cadmium Metal Waste	123	339	3.90 U	2.80 U	3.70 U
006325	RFETS	Solidified Inorganics	213	4	0.01 U	0.01 J	0.04 J
006669	INEL	Solidified Inorganics	214	292	0.15 U	0.10 U	0.14 U
006773	RFETS	Solidified Inorganics	213	4	0.11 U	0.08 U	0.10 U
006857	INEL	Combustible	223	339	0.02 U	0.01 U	0.02 U
006865	RFETS	Solidified Organics	226	432	0.08 U	0.06 U	0.07 U
006876	INEL	Filter	219	335	0.02 U	0.01 U	0.02 U
006879	INEL	Solidified Organics	226	432	0.10 U	0.07 U	0.07 U
006886	INEL	Solidified Organics	226	432	0.33 U	0.23 U	0.23 U
007034	INEL	Combustible	216	337	2.10 U	1.50 U	1.50 U
007146	INEL	Inorganic Non-metal	222	371	1.70 U	1.20 U	1.20 U
007170	INEL	Combustible	216	337	0.40 U	0.22 U	0.26 U
007231	INEL	Filter	219	338	0.18 U	0.10 U	0.12 U
007511	INEL	Inorganic Non-metal	122	374	0.04 U	0.03 U	0.04 U
007518	INEL	Inorganic Non-metal	122	374	0.06 U	0.04 U	0.06 U
007667	INEL	Salt Waste	124	411	0.01 U	0.01 U	0.01 U
007920	INEL	Filter	121	302	0.24 U	0.17 U	0.22 U
008203	INEL	Inorganic Non-metal	118	440	0.06 U	0.04 U	0.06 U
008207	INEL	Heterogeneous	116	336	0.07 U	0.05 U	0.07 U
008218	INEL	Heterogeneous	116	330	0.07 U	0.05 U	0.07 U
008269	INEL	Uncategorized Metal	117	320	0.19 U	0.14 U	0.18 U
008287	INEL	Inorganic Non-metal	122	374	0.03 U	0.02 U	0.03 U
008359	INEL	Heterogeneous	116	330	0.19 U	0.14 U	0.18 U
008383	INEL	Lead/Cadmium Metal Waste	123	339	5.20 U	3.70 U	4.90 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
008848	INEL	Inorganic Non-metal	218	440	0.60 JB	0.28 JB	0.42 JB
008859	INEL	Inorganic Non-metal	218	440	0.45 U	0.31 U	0.31 U
008860	INEL	Uncategorized Metal	217	480	1.10 U	0.79 U	0.79 U
008864	INEL	Uncategorized Metal	217	480	0.10 U	0.07 U	0.07 U
008872	INEL	Solidified Inorganics	214	292	0.04 U	0.03 U	0.04 U
008874	RFETS	Uncategorized Metal	217	480	35.00 U	24.00 U	33.00 U
008878	INEL	Uncategorized Metal	217	480	4.80 U	3.30 U	3.30 U
008880	RFETS	Graphite	115	312	1.40 U	0.95 U	1.30 U
009006	INEL	Solidified Inorganics	211	7	0.05 JB	0.04 JB	0.06 JB
009011	RFETS	Solidified Inorganics	211	7	0.01 U	0.01 J	0.02 JB
009061	RFETS	Inorganic Non-metal	218	440	0.10 U	0.07 U	0.09 U
009180	INEL	Combustible	223	339	0.90 U	0.49 U	0.59 U
009225	INEL	Uncategorized Metal	217	481	0.03 U	0.02 U	0.02 U
009252	INEL	Combustible	223	339	21.00 U	15.00 U	15.00 U
009296	INEL	Combustible	223	339	3.00 U	2.10 U	2.10 U
009299	INEL	Combustible	223	339	0.02 U	0.01 U	0.02 U
009399	INEL	Inorganic Non-metal	218	440	0.39 U	0.27 U	0.27 U
009422	RFETS	Combustible	216	337	5.60 U	3.90 U	5.20 U
009423	INEL	Combustible	216	337	1.80 U	0.78 U	1.10 U
009435	INEL	Combustible	216	337	0.39 U	0.27 U	0.27 U
009449	INEL	Inorganic Non-metal	218	440	0.04 U	0.03 U	0.03 U
009471	INEL	Combustible	216	337	0.09 U	0.05 U	0.06 U
009475	INEL	Inorganic Non-metal	218	442	0.72 U	0.31 U	0.45 U
009489	INEL	Combustible	216	337	0.23 U	0.13 U	0.15 U
009587	INEL	Uncategorized Metal	117	320	0.01 U	0.01 U	0.01 U
009591	INEL	Inorganic Non-metal	118	440	0.04 U	0.03 U	0.04 U
009592	INEL	Inorganic Non-metal	118	440	0.07 U	0.05 U	0.08 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
009596	INEL	Uncategorized Metal	117	320	0.14 U	0.09 U	0.13 U
009599	INEL	Inorganic Non-metal	118	440	0.03 U	0.02 U	0.03 U
009602	INEL	Inorganic Non-metal	218	442	2.00 U	1.40 U	1.40 U
009694	INEL	Graphite	215	300	0.02 U	0.02 J	0.03 J
009735	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
009773	INEL	Combustible	223	339	5.40 U	2.40 U	3.40 U
009787	RFETS	Solidified Organics	212	3	180.00 U	130.00 U	170.00 U
009873	RFETS	Solidified Inorganics	211	1	0.05 U	0.03 U	0.05 U
010216	INEL	Filter	219	338	1.10 U	0.61 U	0.74 U
010224	INEL	Filter	219	338	0.34 U	0.18 U	0.22 U
010230	INEL	Heterogeneous	216	330	0.18 U	0.10 U	0.15 J
010273	INEL	Combustible	216	337	0.16 U	0.09 U	0.11 U
010295	INEL	Inorganic Non-metal	218	442	0.06 U	0.04 U	0.04 U
010305	RFETS	Inorganic Non-metal	218	442	0.70 U	0.49 U	0.65 U
010364	RFETS	Combustible	216	337	0.89 U	0.62 U	0.83 U
010371	INEL	Combustible	216	337	0.40 U	0.25 U	0.28 U
010407	RFETS	Uncategorized Metal	217	480	0.12 U	0.10 J	0.19 J
010411	INEL	Combustible	216	337	2.00 U	1.40 U	1.40 U
010415	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.02 U
010426	INEL	Inorganic Non-metal	218	442	0.02 U	0.01 U	0.01 U
010463	INEL	Solidified Inorganics	213	4	0.30 U	0.21 U	0.21 U
010487	INEL	Salt Waste	224	414	0.54 U	0.38 U	0.38 U
010492	INEL	Uncategorized Metal	217	480	0.58 U	0.41 U	0.41 U
010498	INEL	Uncategorized Metal	217	480	0.05 U	0.02 U	0.03 U
010510	RFETS	Heterogeneous	216	336	1.70 U	1.20 U	1.60 U
010546	RFETS	Heterogeneous	216	330	47.00 U	32.00 U	43.00 U
010578	INEL	Solidified Organics	226	432	1.00 U	0.71 U	0.71 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
010588	RFETS	Solidified Inorganics	211	2	0.88 U	0.61 U	0.82 U
010663	INEL	Combustible	216	337	0.58 U	0.32 U	0.38 U
010676	INEL	Heterogeneous	216	330	0.46 U	0.25 U	0.31 U
010800	INEL	Filter	219	338	0.16 U	0.09 U	0.10 U
010807	INEL	Combustible	216	337	1.30 U	0.92 U	0.92 U
010808	INEL	Combustible	216	337	0.38 U	0.16 U	0.25 JB
010814	RFETS	Solidified Inorganics	211	1	0.36 U	0.25 U	0.33 U
010837	INEL	Solidified Organics	226	432	0.45 U	0.31 U	0.31 U
010848	INEL	Filter	219	338	0.44 U	0.24 U	0.29 U
010883	INEL	Solidified Organics	226	432	1.20 U	0.81 U	0.81 U
010921	INEL	Inorganic Non-metal	222	371	0.10 U	0.07 U	0.07 U
011004	INEL	Uncategorized Metal	217	480	0.03 U	0.02 U	0.02 U
011021	INEL	Solidified Organics	226	432	0.18 U	0.12 U	0.12 U
011042	INEL	Inorganic Non-metal	218	442	0.62 U	0.44 U	0.44 U
011044	INEL	Inorganic Non-metal	218	440	0.36 U	0.25 U	0.25 U
011067	RFETS	Solidified Inorganics	213	4	1.20 U	0.82 U	1.10 U
011102	RFETS	Solidified Inorganics	211	1	0.28 U	0.20 U	0.26 U
011109	INEL	Solidified Inorganics	211	1	0.21 U	0.09 U	0.14 U
011147	INEL	Solidified Inorganics	213	4	0.25 U	0.11 U	0.16 U
011173	INEL	Uncategorized Metal	217	480	0.06 U	0.03 U	0.04 U
011194	INEL	Inorganic Non-metal	218	442	0.07 U	0.05 U	0.05 U
011393	INEL	Uncategorized Metal	217	480	0.15 U	0.10 U	0.10 U
011416	INEL	Combustible	216	337	0.66 U	0.46 U	0.46 U
011433	INEL	Heterogeneous	216	330	0.58 U	0.32 U	0.38 U
011498	RFETS	Solidified Organics	226	432	1.70 U	1.20 U	1.20 U
011529	INEL	Uncategorized Metal	217	480	0.03 U	0.02 U	0.02 U
011601	INEL	Heterogeneous	216	336	1.40 U	0.74 U	0.90 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
011607	INEL	Heterogeneous	216	330	0.03 U	0.02 U	0.02 U
011637	RFETS	Filter	219	338	0.88 U	0.61 U	0.82 U
011735	INEL	Heterogeneous	216	330	0.89 U	0.62 U	0.62 U
011749	INEL	Inorganic Non-metal	225	441	0.25 U	0.18 U	0.18 U
011785	RFETS	Solidified Inorganics	211	1	0.03 U	0.02 U	0.03 U
012021	INEL	Solidified Inorganics	211	1	0.39 U	0.27 U	0.27 U
012108	INEL	Solidified Inorganics	214	292	0.39 U	0.27 U	0.27 U
012111	INEL	Combustible	216	337	1.90 U	1.00 U	1.20 U
012215	INEL	Uncategorized Metal	217	480	0.42 U	0.29 U	0.29 U
012313	INEL	Heterogeneous	216	336	0.70 U	0.38 U	0.46 U
012320	INEL	Heterogeneous	216	336	2.00 U	1.40 U	1.40 U
012356	INEL	Filter	219	338	0.25 U	0.31 J	0.24 J
012357	RFETS	Uncategorized Metal	217	480	3.20 U	2.20 U	2.90 U
012433	INEL	Filter	219	338	0.22 U	0.12 U	0.15 U
012469	RFETS	Solidified Inorganics	211	1	0.36 U	0.25 U	0.33 U
012471	RFETS	Filter	219	338	0.19 U	0.13 U	0.27 JB
012487	INEL	Inorganic Non-metal	218	440	0.02 U	0.01 U	0.02 JB
012494	INEL	Heterogeneous	216	330	1.20 U	0.83 U	0.83 U
012541	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.03 J
012553	INEL	Solidified Inorganics	211	1	0.03 U	0.09 J	0.09 J
012571	INEL	Uncategorized Metal	217	320	0.02 U	0.01 U	0.01 U
012611	INEL	Solidified Inorganics	211	1	0.62 U	0.44 U	0.44 U
012634	INEL	Solidified Inorganics	211	1	1.70 U	1.20 U	1.20 U
012749	INEL	Solidified Inorganics	211	1	0.33 U	0.23 U	0.23 U
012766	INEL	Heterogeneous	216	336	3.00 U	2.10 U	2.10 U
012802	INEL	Combustible	216	337	1.30 U	0.57 U	0.82 U
012875	RFETS	Solidified Organics	226	432	4.00 U	2.80 U	2.80 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
012878	INEL	Uncategorized Metal	217	480	0.68 U	0.30 U	0.43 U
012891	INEL	Heterogeneous	216	330	0.34 U	0.24 U	0.24 U
012902	INEL	Filter	219	338	0.02 U	0.01 U	0.02 U
012920	INEL	Inorganic Non-metal	222	371	1.20 U	0.83 U	0.83 U
012985	INEL	Inorganic Non-metal	222	371	2.00 U	1.40 U	1.40 U
012986	INEL	Heterogeneous	221	302	1.60 B	0.96 JB	2.30 B
012998	INEL	Combustible	216	337	0.68 U	0.48 U	0.48 U
013106	INEL	Solidified Inorganics	111	7	0.02 U	0.01 JB	0.02 J
013229	RFETS	Solidified Organics	226	432	0.15 U	0.10 U	0.10 U
013231	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
013252	INEL	Inorganic Non-metal	222	371	0.03 U	0.02 U	0.02 U
013266	INEL	Combustible	223	339	0.42 U	0.29 U	0.29 U
013269	INEL	Inorganic Non-metal	218	440	0.06 U	0.03 U	0.04 U
013313	INEL	Inorganic Non-metal	218	440	0.03 U	0.02 U	0.02 U
013331	INEL	Salt Waste	124	411	0.07 U	0.05 U	0.07 U
013342	INEL	Inorganic Non-metal	218	440	0.02 U	0.01 U	0.02 J
013346	RFETS	Inorganic Non-metal	222	371	0.02 U	0.02 U	0.02 U
013618	INEL	Heterogeneous	216	330	2.00 U	1.40 U	1.40 U
013677	INEL	Filter	219	338	0.06 U	0.03 U	0.04 U
013751	INEL	Uncategorized Metal	217	480	0.89 U	0.62 U	0.62 U
013763	INEL	Combustible	223	339	16.00 U	10.00 U	11.00 U
013773	RFETS	Solidified Inorganics	111	7	0.08 U	0.07 J	0.14 JB
013818	RFETS	Solidified Inorganics	211	1	0.02 U	0.02 J	0.03 J
013820	RFETS	Solidified Inorganics	211	1	0.03 U	0.02 U	0.02 U
013847	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
013860	INEL	Combustible	223	339	0.08 U	0.04 U	0.05 U
013876	RFETS	Solidified Inorganics	211	7	0.10 U	0.07 U	0.09 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
014007	INEL	Solidified Inorganics	211	1	0.03 U	0.02 U	0.02 U
014009	INEL	Solidified Inorganics	211	7	0.19 JB	0.10 JB	0.17 JB
014010	INEL	Solidified Inorganics	211	7	0.02 U	0.01 J	0.03 J
014127	RFETS	Solidified Inorganics	211	7	0.02 U	0.02 J	0.05 J
014170	INEL	Solidified Inorganics	211	7	0.02 U	0.01 U	0.02 U
014330	INEL	Graphite	215	303	0.05 U	0.02 U	0.03 U
014334	INEL	Filter	219	335	0.07 U	0.04 U	0.05 U
014339	INEL	Solidified Organics	226	432	0.06 U	0.04 U	0.04 U
014342	INEL	Graphite	215	303	0.08 U	0.04 U	0.05 U
014345	INEL	Solidified Organics	226	432	0.05 U	0.03 U	0.04 J
014346	INEL	Combustible	223	339	0.02 U	0.01 U	0.02 U
014348	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
014354	RFETS	Uncategorized Metal	217	481	0.01 U	0.01 U	0.01 U
014357	INEL	Combustible	223	339	16.00 U	10.00 U	11.00 U
014387	INEL	Solidified Inorganics	211	7	0.04 JB	0.04 JB	0.06 JB
014466	INEL	Heterogeneous	221	302	0.33 U	0.23 U	0.23 U
014484	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
014502	RFETS	Solidified Inorganics	211	1	0.01 U	0.02 J	0.03 J
014504	RFETS	Solidified Inorganics	211	1	0.03 U	0.02 U	0.03 U
014773	INEL	Solidified Inorganics	214	292	0.05 U	0.04 U	0.05 U
015228	RFETS	Solidified Organics	226	432	0.18 U	0.12 U	0.12 U
015231	INEL	Inorganic Non-metal	218	440	0.03 U	0.02 U	0.02 U
015241	INEL	Inorganic Non-metal	218	442	0.05 U	0.04 U	0.04 U
015249	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 U
015262	RFETS	Solidified Organics	226	432	1.70 U	1.20 U	1.20 U
015267	INEL	Uncategorized Metal	217	480	1.50 U	1.00 U	1.00 U
015338	INEL	Solidified Inorganics	211	7	0.02 U	0.01 J	0.02 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
015434	RFETS	Solidified Organics	226	432	0.04 U	0.03 U	0.03 U
015440	RFETS	Solidified Organics	226	432	0.39 U	0.27 U	0.27 U
015515	RFETS	Solidified Organics	212	3	28.00 U	20.00 U	26.00 U
015532	RFETS	Solidified Organics	212	3	87.00 U	60.00 U	81.00 U
015543	INEL	Solidified Organics	212	3	37.00 U	26.00 U	26.00 U
015627	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
015655	INEL	Solidified Inorganics	211	7	0.02 U	0.01 U	0.01 U
015674	INEL	Graphite	215	300	0.02 U	0.01 U	0.02 J
015675	INEL	Uncategorized Metal	217	480	0.07 U	0.05 U	0.05 U
015777	RFETS	Solidified Organics	226	432	0.07 U	0.05 U	0.05 U
015785	RFETS	Solidified Inorganics	211	1	0.34 U	0.24 U	0.32 U
015786	INEL	Solidified Inorganics	211	1	0.03 U	0.01 U	0.02 U
016242	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 JB
016612	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.02 U
016613	INEL	Solidified Organics	226	432	0.21 U	0.15 U	0.15 U
016707	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
016738	RFETS	Solidified Inorganics	211	7	1.30 U	0.92 U	1.20 U
016790	INEL	Graphite	215	300	0.02 U	0.91 J	2.00
016807	INEL	Solidified Inorganics	211	1	0.43 JB	0.23 JB	0.34 JB
016842	INEL	Graphite	215	300	0.02 U	0.01 U	0.01 U
016855	RFETS	Solidified Organics	212	3	130.00 U	94.00 U	120.00 U
016869	INEL	Solidified Inorganics	211	7	0.18 U	0.08 U	0.11 U
016964	RFETS	Solidified Inorganics	211	7	1.20 U	0.82 U	1.10 U
016986	INEL	Inorganic Non-metal	218	442	0.18 U	0.12 U	0.12 U
017148	INEL	Solidified Organics	226	432	0.64 U	0.44 U	0.44 U
017190	INEL	Solidified Inorganics	211	7	9.90 B	4.60 B	6.80 B
017444	INEL	Graphite	215	300	0.03 U	0.02 U	0.02 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
017453	INEL	Solidified Organics	212	3	39.00 U	27.00 U	36.00 U
017486	INEL	Solidified Inorganics	211	1	0.16 U	0.07 U	0.10 U
017491	INEL	Graphite	215	300	0.18 U	0.08 U	0.11 U
017495	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.02 U
017496	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.02 U
017698	RFETS	Solidified Inorganics	211	292	2.50 U	1.70 U	2.30 U
017709	INEL	Solidified Inorganics	211	1	0.02 U	0.01 U	0.01 U
017728	RFETS	Solidified Inorganics	211	1	0.70 U	0.49 U	0.65 U
017742	INEL	Inorganic Non-metal	218	440	0.60 U	0.42 U	0.42 U
017756	RFETS	Solidified Organics	226	432	1.70 U	1.20 U	1.20 U
017759	INEL	Solidified Organics	226	432	1.20 U	0.83 U	0.83 U
017788	INEL	Solidified Inorganics	211	7	1.20 U	0.52 U	0.75 U
017863	INEL	Filter	119	376	0.10 U	0.07 U	0.09 U
018111	RFETS	Solidified Inorganics	211	1	0.02 U	0.01 U	0.01 U
018219	RFETS	Solidified Inorganics	211	7	1.20 U	0.82 U	1.10 U
018299	INEL	Filter	119	376	0.15 U	0.10 U	0.14 U
018413	INEL	Graphite	115	300	0.01 U	0.01 U	0.01 U
018441	INEL	Graphite	115	300	0.03 U	0.02 U	0.03 U
018464	INEL	Graphite	115	300	0.01 U	0.01 U	0.01 U
018476	INEL	Solidified Inorganics	111	292	0.10 U	0.07 U	0.09 U
018491	INEL	Graphite	115	300	0.03 U	0.02 U	0.03 U
019410	INEL	Lead/Cadmium Metal Waste	123	339	0.65 U	0.45 U	0.60 U
019413	INEL	Lead/Cadmium Metal Waste	123	339	2.80 U	2.00 U	2.60 U
019572	INEL	Lead/Cadmium Metal Waste	123	339	0.06 U	0.04 U	0.06 U
021031	RFETS	Solidified Inorganics	214	292	0.04 U	0.03 U	0.04 U
021172	RFETS	Inorganic Non-metal	218	442	0.01 U	0.01 U	0.01 U
021306	INEL	Solidified Inorganics	213	4	0.03 U	0.02 U	0.03 J

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
021392	RFETS	Solidified Inorganics	214	292	0.16 U	0.11 U	0.15 U
021442	INEL	Solidified Inorganics	211	1	0.50 U	0.22 U	0.32 U
021488	RFETS	Inorganic Non-metal	218	442	0.04 U	0.03 U	0.04 U
021503	RFETS	Inorganic Non-metal	218	440	0.17 U	0.12 U	0.16 U
021511	RFETS	Solidified Inorganics	213	4	0.04 U	0.03 U	0.04 U
021512	INEL	Solidified Inorganics	211	7	0.95 U	0.66 U	0.66 U
021523	INEL	Solidified Organics	226	432	0.60 U	0.43 J	0.98 J
021565	INEL	Solidified Inorganics	211	7	0.90 U	0.39 U	0.57 U
021572	INEL	Solidified Inorganics	211	7	1.30	0.64 J	0.98 J
021600	RFETS	Solidified Inorganics	211	1	0.28 U	0.20 U	0.26 U
021631	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.02 U
021698	INEL	Inorganic Non-metal	218	440	1.10 U	0.78 U	0.78 U
021699	INEL	Solidified Inorganics	213	4	0.33 U	0.23 U	0.23 U
021700	RFETS	Solidified Inorganics	213	4	0.01 U	0.01 U	0.01 U
021806	INEL	Inorganic Non-metal	218	440	0.21 U	0.09 U	0.13 U
021816	INEL	Solidified Inorganics	211	1	0.11 U	0.05 U	0.07 U
021865	INEL	Solidified Inorganics	211	1	0.95 U	0.66 U	0.66 U
021993	INEL	Solidified Inorganics	211	2	0.45 U	0.31 U	0.31 U
022000	INEL	Inorganic Non-metal	218	440	0.10 U	0.07 U	0.07 U
022036	INEL	Uncategorized Metal	217	480	0.07 U	0.03 U	0.05 U
022038	RFETS	Uncategorized Metal	217	481	0.18 U	0.13 U	0.17 U
022052	INEL	Uncategorized Metal	217	481	0.02 U	0.01 U	0.02 U
022102	INEL	Solidified Organics	226	432	0.10 U	0.12 J	0.07 J
022105	INEL	Solidified Inorganics	211	1	0.42 U	0.29 U	0.29 U
022119	INEL	Inorganic Non-metal	222	371	0.54 U	0.37 U	0.37 U
022121	INEL	Solidified Inorganics	211	7	0.16 U	0.07 U	0.10 U
022135	INEL	Solidified Inorganics	211	7	0.68 U	0.48 U	0.48 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
022136	RFETS	Solidified Inorganics	211	7	0.88 U	0.61 U	0.82 U
022149	RFETS	Solidified Inorganics	211	7	0.22 U	0.15 U	0.20 U
022224	INEL	Solidified Inorganics	211	1	0.42 U	0.29 U	0.29 U
022226	RFETS	Inorganic Non-metal	222	371	1.20 U	0.82 U	1.10 U
022228	INEL	Inorganic Non-metal	222	371	0.15 U	0.26 J	0.21 J
022230	INEL	Inorganic Non-metal	222	371	0.12 U	0.11 J	0.08 U
022249	INEL	Uncategorized Metal	217	480	1.80 U	0.79 U	1.10 U
022275	INEL	Uncategorized Metal	217	480	0.40 U	0.18 U	0.26 U
022286	RFETS	Uncategorized Metal	217	480	0.50 U	0.35 U	0.47 U
022296	INEL	Solidified Inorganics	211	1	0.89 U	0.39 U	0.56 U
022306	INEL	Inorganic Non-metal	218	440	0.89 U	0.62 U	0.62 U
022338	INEL	Solidified Organics	212	3	120.00 U	83.00 U	83.00 U
022347	INEL	Inorganic Non-metal	218	440	0.28 U	0.12 U	0.18 U
022358	INEL	Uncategorized Metal	217	480	0.02 U	0.01 U	0.01 JB
022416	RFETS	Uncategorized Metal	217	320	0.05 U	0.04 U	0.05 U
022434	INEL	Solidified Organics	226	432	0.39 U	0.27 U	0.27 U
022442	INEL	Solidified Organics	226	432	1.14 U	0.77 U	0.77 U
022450	RFETS	Uncategorized Metal	217	320	0.09 U	0.06 U	0.08 U
022453	RFETS	Solidified Inorganics	211	2	0.08 U	0.14 J	0.19 J
022486	RFETS	Inorganic Non-metal	218	440	1.80 U	1.20 U	1.60 U
022511	INEL	Uncategorized Metal	217	480	0.92 U	0.64 U	0.64 U
022513	INEL	Solidified Organics	212	1	0.27 U	0.19 U	0.19 U
022517	INEL	Solidified Organics	226	432	0.11 U	0.08 U	0.09 J
022539	INEL	Solidified Organics	226	432	0.11 U	0.08 U	0.08 U
022549	INEL	Uncategorized Metal	217	480	1.50 U	1.00 U	1.00 U
022552	INEL	Inorganic Non-metal	218	442	0.34 U	0.24 U	0.24 U
022557	INEL	Uncategorized Metal	217	480	0.63 U	0.28 U	0.40 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
022595	INEL	Solidified Inorganics	211	1	0.30 U	0.13 U	0.19 U
022600	RFETS	Solidified Inorganics	213	4	0.27 U	0.27 J	0.26 U
022780	INEL	Solidified Inorganics	211	7	0.45 U	0.23 J	0.31 J
022789	INEL	Solidified Inorganics	211	7	0.66 U	0.46 U	0.46 U
022790	INEL	Solidified Inorganics	214	292	0.22 U	0.13 JB	0.29 JB
022803	INEL	Inorganic Non-metal	222	371	0.62 U	0.44 U	0.44 U
022807	INEL	Salt Waste	224	414	0.12 U	0.09 U	0.09 U
022811	INEL	Solidified Inorganics	211	7	0.38 U	0.16 U	0.24 U
022833	INEL	Solidified Inorganics	211	7	2.70 U	1.20 U	1.70 U
022841	INEL	Solidified Inorganics	211	7	1.40 U	0.63 U	0.90 U
022850	INEL	Solidified Inorganics	211	7	0.89 U	0.39 U	0.56 U
022874	INEL	Inorganic Non-metal	222	371	0.21 U	0.15 U	0.15 U
022894	INEL	Solidified Inorganics	211	1	0.13 U	0.31 J	0.62 J
022923	INEL	Inorganic Non-metal	218	440	0.39 U	0.27 U	0.27 U
023005	INEL	Solidified Inorganics	211	7	0.18 U	0.12 U	0.12 U
023027	RFETS	Uncategorized Metal	217	480	0.18 U	0.48 JB	0.99 JB
023041	RFETS	Inorganic Non-metal	222	371	0.28 U	0.20 U	0.26 U
023046	RFETS	Solidified Inorganics	211	7	0.50 U	0.35 U	0.47 U
023048	RFETS	Solidified Organics	226	432	0.42 U	0.29 U	0.29 U
023062	INEL	Solidified Inorganics	211	7	0.18 U	0.12 U	0.12 U
023211	INEL	Filter	119	376	0.06 U	0.04 U	0.06 U
023212	RFETS	Uncategorized Metal	217	480	0.58 U	0.41 U	0.54 U
023227	INEL	Uncategorized Metal	217	480	0.10 U	0.07 U	0.07 U
023229	INEL	Combustible	216	337	0.60 U	0.42 U	0.42 U
023235	RFETS	Heterogeneous	216	336	0.16 U	0.11 U	0.26 J
023238	INEL	Solidified Inorganics	211	1	0.20 U	0.09 U	0.12 U
023277	INEL	Inorganic Non-metal	222	371	1.00 U	0.73 U	0.73 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
023285	INEL	Solidified Inorganics	211	7	2.00 U	1.40 U	1.40 U
023312	INEL	Uncategorized Metal	217	480	0.90 U	0.39 U	0.57 U
023341	RFETS	Solidified Inorganics	211	7	0.01 U	0.05 J	0.08 J
023357	INEL	Solidified Inorganics	211	1	0.15 U	0.10 U	0.10 U
023383	RFETS	Uncategorized Metal	217	481	0.01 U	0.01 U	0.01 U
023384	INEL	Combustible	223	339	0.12 U	0.07 U	0.08 U
023388	INEL	Heterogeneous	216	330	0.10 U	0.06 U	0.07 U
023392	INEL	Solidified Inorganics	213	4	0.67 U	0.47 U	0.47 U
023407	INEL	Solidified Organics	212	3	23.00 U	16.00 U	16.00 U
023460	INEL	Inorganic Non-metal	218	442	0.03 U	0.02 U	0.02 U
023469	INEL	Solidified Organics	212	3	0.36 U	1.10 J	3.00 J
023492	INEL	Solidified Inorganics	211	7	0.74 U	0.52 U	0.52 U
023519	INEL	Solidified Organics	212	3	3.40 U	1.50 U	2.20 U
023535	INEL	Solidified Inorganics	211	7	0.89 U	0.39 U	0.56 U
023552	INEL	Solidified Inorganics	211	1	0.83 U	0.58 U	0.58 U
023662	INEL	Inorganic Non-metal	218	442	0.10 U	0.07 U	0.07 U
023681	INEL	Solidified Inorganics	211	1	0.36 U	0.25 U	0.25 U
023695	RFETS	Solidified Inorganics	211	2	0.18 U	0.13 U	0.17 U
023771	RFETS	Heterogeneous	216	330	0.19 U	0.13 U	0.18 U
023776	INEL	Heterogeneous	216	330	0.39 U	0.28 U	0.28 U
023805	INEL	Uncategorized Metal	217	480	0.02 U	0.06 J	0.04 JB
023827	RFETS	Uncategorized Metal	217	320	0.01 U	0.03 J	0.02 J
023840	INEL	Combustible	216	337	0.37 U	0.20 U	0.24 U
023901	INEL	Heterogeneous	216	330	0.36 U	0.19 U	0.24 U
023929	RFETS	Inorganic Non-metal	218	440	0.59 U	0.41 U	0.55 U
023959	INEL	Uncategorized Metal	217	480	1.30 U	0.93 U	0.93 U
024028	RFETS	Inorganic Non-metal	218	440	0.12 U	0.09 U	0.12 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
024029	INEL	Uncategorized Metal	217	480	0.02 U	0.01 U	0.02 U
024058	INEL	Solidified Inorganics	211	1	0.45 U	0.31 U	0.31 U
024059	INEL	Solidified Inorganics	214	292	0.18 U	0.32 J	0.18 J
024088	INEL	Combustible	216	337	0.34 U	0.24 U	0.24 U
024090	INEL	Combustible	216	337	0.56 U	0.30 U	0.37 U
024092	INEL	Combustible	216	337	1.50 U	1.00 U	1.00 U
024095	INEL	Combustible	216	337	0.23 U	0.13 U	0.15 U
024102	INEL	Combustible	216	337	0.51 U	0.35 U	0.35 U
024106	INEL	Combustible	216	337	0.74 U	0.52 U	0.52 U
024113	INEL	Combustible	216	337	0.22 U	0.16 U	0.16 U
024147	INEL	Solidified Inorganics	211	1	0.68 U	0.48 U	0.48 U
024165	INEL	Combustible	216	337	0.53 U	0.37 U	0.37 U
024168	INEL	Heterogeneous	216	330	0.03 U	0.02 U	0.02 U
024185	INEL	Salt Waste	224	409	0.03 U	0.12 J	0.07 J
024254	INEL	Salt Waste	224	414	0.05 U	0.25 J	0.34 J
024271	INEL	Inorganic Non-metal	218	442	0.10 U	0.07 U	0.07 U
024273	INEL	Inorganic Non-metal	218	442	0.19 U	0.14 U	0.14 U
024289	RFETS	Inorganic Non-metal	218	440	0.35 U	0.24 U	0.33 U
024295	INEL	Salt Waste	224	414	0.10 U	0.07 U	0.07 U
024308	INEL	Solidified Inorganics	211	2	0.15 U	0.42 J	0.51 J
024309	INEL	Solidified Inorganics	211	2	0.12 U	0.43 J	0.49 J
024311	INEL	Solidified Inorganics	211	2	0.24 U	0.33 J	0.45 J
024318	INEL	Solidified Inorganics	211	2	0.24 U	0.17 U	0.17 U
024506	INEL	Inorganic Non-metal	122	374	0.06 U	0.04 U	0.06 U
024507	INEL	Uncategorized Metal	117	480	0.07 U	0.05 U	0.07 U
024600	INEL	Uncategorized Metal	217	480	0.27 U	0.19 U	0.19 U
024638	INEL	Heterogeneous	216	330	0.13 U	0.09 U	0.09 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
024670	INEL	Solidified Inorganics	211	1	0.54 U	0.37 U	0.37 U
024765	INEL	Uncategorized Metal	217	480	0.06 U	0.03 U	0.04 U
024786	INEL	Uncategorized Metal	217	480	0.36 U	0.25 U	0.25 U
024850	INEL	Solidified Organics	226	432	0.10 U	0.07 U	0.07 U
024884	INEL	Uncategorized Metal	217	480	0.24 U	0.17 U	0.17 U
024897	INEL	Solidified Inorganics	211	1	0.24 U	0.17 U	0.17 U
024920	INEL	Solidified Inorganics	211	1	0.68 U	0.48 U	0.48 U
024991	INEL	Solidified Inorganics	211	1	0.33 U	0.23 U	0.23 U
025001	INEL	Solidified Organics	212	3	1.20 U	0.83 U	0.83 U
032284	INEL	Combustible	223	339	0.37 U	0.20 U	0.25 U
032287	RFETS	Solidified Inorganics	211	7	1.20 U	0.82 U	1.10 U
032467	INEL	Combustible	216	337	0.24 U	0.17 U	0.17 U
032469	RFETS	Combustible	216	337	0.39 U	0.27 U	0.36 U
032473	INEL	Combustible	216	337	1.60 U	1.10 U	1.10 U
032485	INEL	Combustible	216	337	0.93 U	0.65 U	0.65 U
032517	RFETS	Combustible	223	339	0.09 U	0.06 U	0.08 U
032521	INEL	Combustible	223	339	0.08 U	0.05 U	0.06 U
032525	INEL	Combustible	223	339	0.05 U	0.02 U	0.03 U
032526	INEL	Combustible	223	339	0.70 U	0.38 U	0.46 U
032529	INEL	Heterogeneous	216	336	0.22 U	0.10 U	0.11 J
032540	INEL	Uncategorized Metal	217	480	0.39 U	0.27 U	0.27 U
032632	INEL	Uncategorized Metal	217	480	0.18 U	0.10 U	0.12 U
032659	RFETS	Uncategorized Metal	217	480	0.31 U	0.21 U	0.28 U
032669	RFETS	Uncategorized Metal	217	480	0.33 U	0.23 U	0.31 U
032712	INEL	Uncategorized Metal	217	480	0.28 U	0.20 U	0.20 U
032715	RFETS	Combustible	216	337	0.09 U	0.06 U	0.08 U
032748	INEL	Combustible	223	339	0.22 U	0.10 U	0.11 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
032753	INEL	Uncategorized Metal	217	481	0.03 U	0.02 U	0.02 U
033091	INEL	Combustible	223	339	0.02 U	0.46 J	1.10
D01332	RFETS	Heterogeneous	116	832	0.50 U	0.50 U	1.00 U
D06288	RFETS	Filter	119	338	0.10 U	0.10 U	0.20 U
D06339	RFETS	Heterogeneous	0	337	0.20 U	0.20 U	0.40 U
D11129	RFETS	Filter	119	338	0.10 U	0.10 U	0.20 U
D13364	RFETS	Uncategorized Metal	117	480	0.10 U	0.10 U	0.10 U
D15680	RFETS	Heterogeneous	116	831	66.67 U	66.67 U	133.33 U
D17184	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.10 U
D32439	RFETS	Filter	119	338	0.10 U	0.10 U	0.20 U
D32978	RFETS	Solidified Inorganics	111	803	5.67 U	5.67 U	11.33 U
D35301	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.10 U
D35306	RFETS	Lead/Cadmium Metal Waste	123	339	0.20 U	0.20 U	0.40 U
D36606	RFETS	Uncategorized Metal	117	480	0.40 U	0.40 U	0.80 U
D38859	RFETS	Solidified Inorganics	111	803	0.10 U	0.10 U	0.10 U
D38989	RFETS	Heterogeneous	0	336	0.10 U	0.10 U	0.20 U
D41681	RFETS	Filter	119	338	0.10 U	0.10 U	0.20 U
D42280	RFETS	Solidified Organics	112	801	416.67 U	416.67 U	833.33 U
D47501	RFETS	Lead/Cadmium Metal Waste	0	341	0.10 U	0.10 U	0.20 U
D48182	RFETS	Filter	119	376	0.40 U	0.40 U	0.40 U
D48200	RFETS	Heterogeneous	116	831	8.00 U	8.00 U	8.00 U
D48377	RFETS	Inorganic Non-metal	118	368	0.10 U	0.10 U	0.10 U
D49662	RFETS	Solidified Inorganics	0	292	0.10 U	0.10 U	0.20 U
D49880	RFETS	Heterogeneous	0	336	0.27 U	0.27 U	0.53 U
D52318	RFETS	Lead/Cadmium Metal Waste	117	321	0.10 U	0.10 U	0.20 U
D52362	RFETS	Heterogeneous	116	821	0.20 U	0.20 U	0.20 U
D52726	RFETS	Heterogeneous	116	833	0.80 U	0.80 U	1.60 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D53672	RFETS	Inorganic Non-metal	118	440	0.20 U	0.20 U	0.20 U
D55656	RFETS	Heterogeneous	116	831	0.30 U	0.30 U	0.30 U
D55680	RFETS	Heterogeneous	116	821	0.20 U	0.20 U	0.20 U
D55938	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.20 U
D56095	RFETS	Heterogeneous	0	337	0.10 U	0.10 U	0.20 U
D56595	RFETS	Heterogeneous	116	831	13.33 U	13.33 U	26.67 U
D56755	RFETS	Heterogeneous	116	821	0.10 U	0.10 U	0.10 U
D56823	RFETS	Heterogeneous	116	831	0.40 U	0.40 U	0.40 U
D57179	RFETS	Heterogeneous	0	330	2.00 U	2.00 U	4.00 U
D57522	RFETS	Heterogeneous	0	336	0.40 U	0.40 U	0.80 U
D57847	RFETS	Uncategorized Metal	117	480	0.40 U	0.40 U	0.80 U
D58143	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D58154	RFETS	Heterogeneous	116	831	0.40 U	0.40 U	0.80 U
D58627	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.40 U
D58889	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.40 U
D58970	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D59053	RFETS	Lead/Cadmium Metal Waste	0	341	0.10 U	0.10 U	0.20 U
D59703	RFETS	Heterogeneous	116	831	0.50 U	0.50 U	1.00 U
D59899	RFETS	Filter	0	331	0.50 U	0.50 U	1.00 U
D60056	RFETS	Lead/Cadmium Metal Waste	0	341	0.27 U	0.27 U	0.53 U
D60218	RFETS	Heterogeneous	116	821	2.20	4.61	8.44
D60298	RFETS	Solidified Organics	112	801	573.33 U	573.33 U	573.33 U
D60320	RFETS	Heterogeneous	0	330	28.00 U	28.00 U	56.00 U
D60463	RFETS	Inorganic Non-metal	118	440	0.10 U	0.10 U	0.10 U
D60511	RFETS	Filter	119	491	0.20 U	0.20 U	0.20 U
D60635	RFETS	Filter	119	491	0.10 U	0.10 U	0.10 U
D61245	RFETS	Heterogeneous	0	336	0.47 U	0.47 U	0.93 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D61278	RFETS	Heterogeneous	0	336	0.27 U	0.27 U	0.53 U
D61473	RFETS	Heterogeneous	0	377	0.30 U	0.30 U	0.30 U
D61504	RFETS	Lead/Cadmium Metal Waste	0	341	0.10 U	0.10 U	0.20 U
D61747	RFETS	Heterogeneous	0	330	0.27 U	0.27 U	0.53 U
D62340	RFETS	Heterogeneous	116	821	0.40 U	0.40 U	0.40 U
D62478	RFETS	Filter	119	376	0.40 U	0.40 U	0.40 U
D62714	RFETS	Heterogeneous	116	831	1.00 U	1.00 U	2.00 U
D62851	RFETS	Heterogeneous	116	825	0.30 U	0.30 U	0.30 U
D62855	RFETS	Heterogeneous	116	821	6.00 U	6.00 U	6.00 U
D63098	RFETS	Filter	0	331	0.50 U	0.50 U	1.00 U
D63229	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.20 U
D63281	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D63460	RFETS	Heterogeneous	116	831	0.10 U	0.10 U	0.10 U
D63654	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D63808	RFETS	Heterogeneous	116	831	0.80 U	0.80 U	0.80 U
D63817	RFETS	Heterogeneous	116	821	1.60 U	1.60 U	1.60 U
D63819	RFETS	Solidified Inorganics	111	807	0.20 U	0.20 U	0.20 U
D63999	RFETS	Filter	119	491	0.30 U	0.30 U	0.30 U
D64004	RFETS	Filter	0	331	0.40 U	0.40 U	0.80 U
D64137	RFETS	Filter	119	335	0.10 U	0.10 U	0.10 U
D64448	RFETS	Heterogeneous	116	821	110.00 U	110.00 U	110.00 U
D64555	RFETS	Solidified Organics	112	801	573.33 U	573.33 U	573.33 U
D64632	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.10 U
D64752	RFETS	Uncategorized Metal	117	480	2.00 U	2.00 U	4.00 U
D64758	RFETS	Heterogeneous	116	831	0.50 U	0.50 U	1.00 U
D64860	RFETS	Heterogeneous	116	831	12.00 U	12.00 U	24.00 U
D65212	RFETS	Heterogeneous	116	831	9.00 U	9.00 U	18.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D65213	RFETS	Heterogeneous	116	831	8.00 U	8.00 U	16.00 U
D65214	RFETS	Heterogeneous	116	831	73.67 U	73.67 U	73.67 U
D65530	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D65535	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D65546	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D65600	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.10 U
D65731	RFETS	Inorganic Non-metal	122	375	0.40 U	0.40 U	0.40 U
D65734	RFETS	Uncategorized Metal	117	480	0.70 U	0.70 U	0.70 U
D65754	RFETS	Heterogeneous	116	831	0.67 U	0.67 U	1.33 U
D65757	RFETS	Heterogeneous	116	831	3.00 U	3.00 U	6.00 U
D65972	RFETS	Filter	119	376	0.30 U	0.30 U	0.30 U
D66128	RFETS	Heterogeneous	116	831	0.50 U	0.50 U	1.00 U
D66157	RFETS	Uncategorized Metal	117	480	2.00 U	2.00 U	4.54 J
D66162	RFETS	Lead/Cadmium Metal Waste	123	339	90.00 U	90.00 U	90.00 U
D66211	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D66213	RFETS	Heterogeneous	116	831	0.30 U	0.30 U	0.60 U
D66356	RFETS	Heterogeneous	116	831	166.67 U	166.67 U	333.33 U
D66378	RFETS	Heterogeneous	116	831	192.00 U	192.00 U	384.00 U
D66438	RFETS	Uncategorized Metal	117	480	1.60 U	1.60 U	1.60 U
D66523	RFETS	Solidified Organics	112	801	573.33 U	573.33 U	573.33 U
D66525	RFETS	Solidified Inorganics	111	800	0.27 U	0.27 U	0.53 U
D66631	RFETS	Heterogeneous	116	831	0.50 U	0.50 U	0.50 U
D66637	RFETS	Heterogeneous	116	831	8.00 U	8.00 U	16.00 U
D66641	RFETS	Heterogeneous	116	831	60.00 U	60.00 U	60.00 U
D66649	RFETS	Lead/Cadmium Metal Waste	123	339	56.00 U	56.00 U	56.00 U
D66773	RFETS	Uncategorized Metal	117	480	0.30 U	0.30 U	0.30 U
D66783	RFETS	Heterogeneous	116	831	250.00 U	250.00 U	250.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D66792	RFETS	Heterogeneous	116	831	100.00 U	100.00 U	100.00 U
D66860	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D66875	RFETS	Heterogeneous	116	832	0.10 U	0.15 J	0.38 J
D66948	RFETS	Heterogeneous	116	831	6.00 U	6.00 U	6.00 U
D66949	RFETS	Heterogeneous	116	831	0.60 U	0.60 U	0.60 U
D66953	RFETS	Uncategorized Metal	117	480	1.60 U	1.60 U	3.20 U
D66958	RFETS	Heterogeneous	116	831	0.30 U	0.30 U	0.30 U
D67009	RFETS	Solidified Organics	112	801	340.00 U	340.00 U	340.00 U
D67012	RFETS	Solidified Organics	112	801	900.00 U	900.00 U	900.00 U
D67047	RFETS	Solidified Inorganics	111	807	0.20 U	0.20 U	0.20 U
D67251	RFETS	Uncategorized Metal	117	480	1200.00 U	1200.0 U	2400.0 U
D67263	RFETS	Heterogeneous	116	831	9.00 U	9.00 U	9.00 U
D67277	RFETS	Heterogeneous	116	831	14.00 U	14.00 U	14.00 U
D67278	RFETS	Heterogeneous	116	831	0.10 U	0.10 U	0.10 U
D67312	RFETS	Heterogeneous	116	825	0.20 U	0.20 U	0.20 U
D67317	RFETS	Uncategorized Metal	117	480	0.27 U	0.27 U	0.27 U
D67390	RFETS	Solidified Organics	112	801	130.00 U	130.00 U	130.00 U
D67391	RFETS	Heterogeneous	116	833	0.27 U	0.27 U	0.53 U
D67413	RFETS	Solidified Organics	112	801	750.00 U	750.00 U	750.00 U
D67434	RFETS	Solidified Inorganics	111	800	0.40 U	0.40 U	0.80 U
D67436	RFETS	Solidified Inorganics	111	800	0.13 U	0.13 U	0.27 U
D67441	RFETS	Solidified Inorganics	111	800	0.40 U	0.40 U	0.80 U
D67448	RFETS	Heterogeneous	116	852	0.10 U	0.10 U	0.10 U
D67455	RFETS	Filter	119	490	0.40 U	0.40 U	0.40 U
D67464	RFETS	Heterogeneous	116	831	240.00 U	240.00 U	240.00 U
D67524	RFETS	Heterogeneous	116	832	18.59 U	18.59 U	18.59 U
D67532	RFETS	Lead/Cadmium Metal Waste	123	339	6.30 U	6.30 U	6.30 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D67535	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.40 U
D67539	RFETS	Solidified Organics	112	801	320.00 U	320.00 U	320.00 U
D67541	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.10 U
D67545	RFETS	Solidified Organics	112	801	90.00 U	90.00 U	90.00 U
D67567	RFETS	Heterogeneous	116	831	0.30 U	0.30 U	0.30 U
D67582	RFETS	Heterogeneous	116	831	0.40 U	0.40 U	0.40 U
D67603	RFETS	Uncategorized Metal	117	480	13.00 U	13.00 U	13.00 U
D67654	RFETS	Solidified Inorganics	111	800	0.27 U	0.27 U	0.53 U
D67657	RFETS	Solidified Inorganics	111	800	0.27 U	0.27 U	0.53 U
D67678	RFETS	Heterogeneous	116	825	0.43 U	0.43 U	0.43 U
D67698	RFETS	Heterogeneous	116	831	1.60 U	1.60 U	3.20 U
D67707	RFETS	Heterogeneous	116	831	0.50 U	0.50 U	1.00 U
D67734	RFETS	Heterogeneous	116	831	110.00 U	110.00 U	110.00 U
D67735	RFETS	Uncategorized Metal	117	480	1.80 U	1.80 U	1.80 U
D67759	RFETS	Heterogeneous	116	831	2.80 U	2.80 U	2.80 U
D67764	RFETS	Heterogeneous	116	831	2.00 U	2.00 U	4.00 U
D67766	RFETS	Heterogeneous	116	831	1.50 U	1.50 U	3.00 U
D67781	RFETS	Heterogeneous	116	831	0.30 U	0.30 U	0.30 U
D67908	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.10 U
D67929	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.20 U
D67989	RFETS	Heterogeneous	116	831	0.50 U	0.50 U	0.50 U
D67994	RFETS	Heterogeneous	116	831	2.67 U	2.67 U	5.33 U
D68044	RFETS	Heterogeneous	116	825	0.50 U	0.50 U	0.50 U
D68096	RFETS	Heterogeneous	116	821	0.20 U	0.20 U	0.20 U
D68247	RFETS	Solidified Inorganics	111	800	0.13 U	0.13 U	0.27 U
D68248	RFETS	Solidified Organics	112	801	150.00 U	150.00 U	150.00 U
D68250	RFETS	Solidified Organics	112	801	170.00 U	170.00 U	170.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D68254	RFETS	Solidified Inorganics	111	800	0.27 U	0.27 U	0.53 U
D68256	RFETS	Solidified Inorganics	111	800	0.40 U	0.40 U	0.80 U
D68276	RFETS	Heterogeneous	116	852	0.10 U	0.10 U	0.10 U
D68277	RFETS	Uncategorized Metal	117	480	0.50 U	0.50 U	0.50 U
D68377	RFETS	Uncategorized Metal	117	480	0.20 U	0.20 U	0.40 U
D68460	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.20 U
D68480	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D68486	RFETS	Solidified Organics	112	801	140.00 U	140.00 U	140.00 U
D68514	RFETS	Uncategorized Metal	117	480	0.10 U	0.10 U	0.10 U
D68538	RFETS	Lead/Cadmium Metal Waste	123	339	0.10 U	0.10 U	0.20 U
D68600	RFETS	Heterogeneous	116	825	18.00 U	18.00 U	18.00 U
D68601	RFETS	Heterogeneous	116	825	7.00 U	7.00 U	7.00 U
D68702	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D68724	RFETS	Heterogeneous	116	831	180.00 U	180.00 U	180.00 U
D68756	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.40 U
D68885	RFETS	Heterogeneous	116	831	40.00 U	40.00 U	40.00 U
D68896	RFETS	Heterogeneous	116	831	213.00 U	213.00 U	213.00 U
D68975	RFETS	Solidified Organics	112	801	540.00 U	540.00 U	540.00 U
D68999	RFETS	Heterogeneous	116	821	0.40 U	0.40 U	0.40 U
D69091	RFETS	Heterogeneous	116	825	0.50 U	0.50 U	0.50 U
D69095	RFETS	Heterogeneous	116	833	0.54 U	0.54 U	0.54 U
D69113	RFETS	Heterogeneous	116	831	48.00 U	48.00 U	48.00 U
D69250	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D69287	RFETS	Heterogeneous	116	821	138.00 U	138.00 U	138.00 U
D69306	RFETS	Solidified Organics	112	801	250.00 U	250.00 U	250.00 U
D69312	RFETS	Solidified Inorganics	111	800	0.40 U	0.40 U	0.80 U
D69364	RFETS	Heterogeneous	116	833	0.30 U	0.30 U	0.30 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D69400	RFETS	Heterogeneous	116	831	37.00 U	37.00 U	37.00 U
D69406	RFETS	Heterogeneous	116	831	50.00 U	50.00 U	50.00 U
D69413	RFETS	Heterogeneous	116	831	0.60 U	0.60 U	0.60 U
D69418	RFETS	Heterogeneous	116	831	73.40 U	73.40 U	73.40 U
D69431	RFETS	Heterogeneous	116	831	53.33 U	53.33 U	106.67 U
D69518	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D69602	RFETS	Heterogeneous	116	821	1.00 U	1.00 U	1.00 U
D69759	RFETS	Heterogeneous	116	833	0.30 U	0.30 U	0.30 U
D69855	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D69877	RFETS	Heterogeneous	116	825	0.50 U	0.50 U	0.50 U
D69883	RFETS	Heterogeneous	116	825	0.30 U	0.30 U	0.30 U
D69975	RFETS	Heterogeneous	116	821	0.70 U	0.70 U	0.70 U
D70063	RFETS	Heterogeneous	116	821	0.51 U	0.51 U	0.51 U
D70077	RFETS	Heterogeneous	116	831	60.00 U	60.00 U	60.00 U
D70229	RFETS	Heterogeneous	116	831	0.20 U	0.20 U	0.20 U
D70353	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D70370	RFETS	Heterogeneous	116	821	0.30 U	0.30 U	0.30 U
D70379	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D70383	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D70446	RFETS	Uncategorized Metal	117	480	1.00 U	1.00 U	2.00 U
D70448	RFETS	Heterogeneous	116	831	150.00 U	150.00 U	150.00 U
D70455	RFETS	Heterogeneous	116	831	0.70 U	0.70 U	0.70 U
D70543	RFETS	Solidified Organics	112	801	828.00 U	828.00 U	828.00 U
D70661	RFETS	Filter	0	331	0.60 U	0.60 U	1.20 U
D70669	RFETS	Uncategorized Metal	117	480	0.10 U	0.10 U	0.10 U
D70675	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D70682	RFETS	Heterogeneous	116	831	45.00 U	45.00 U	45.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D70696	RFETS	Heterogeneous	116	821	0.60 U	0.60 U	0.60 U
D70734	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.20 U
D70780	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.20 U
D70856	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D70882	RFETS	Heterogeneous	116	831	14.00 U	14.00 U	14.00 U
D70937	RFETS	Filter	0	331	0.50 U	0.50 U	1.00 U
D71019	RFETS	Solidified Organics	112	801	1.30 U	1.30 U	1.30 U
D71020	RFETS	Solidified Organics	112	801	911.50 U	911.50 U	911.50 U
D71022	RFETS	Solidified Organics	112	801	1200.00 U	1200.0 U	2400.0 U
D71241	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.20 U
D71351	RFETS	Uncategorized Metal	117	480	0.10 U	0.10 U	0.20 U
D71354	RFETS	Uncategorized Metal	117	480	0.10 U	0.10 U	0.20 U
D71385	RFETS	Heterogeneous	116	833	0.30 U	0.30 U	0.30 U
D71494	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D71504	RFETS	Solidified Organics	112	801	0.20 U	0.20 U	0.20 U
D71514	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D71521	RFETS	Heterogeneous	116	825	0.20 U	0.20 U	0.20 U
D71638	RFETS	Uncategorized Metal	117	480	1.00 U	1.00 U	2.00 U
D71804	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.20 U
D71829	RFETS	Heterogeneous	116	852	220.00 U	220.00 U	220.00 U
D71838	RFETS	Heterogeneous	116	831	7.60 U	7.60 U	7.60 U
D71921	RFETS	Heterogeneous	116	833	0.10 U	0.14 J	0.20 U
D71932	RFETS	Solidified Organics	112	801	4367.96 U	4367.9 U	4367.9 U
D71933	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.20 U
D71934	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.20 U
D71936	RFETS	Heterogeneous	116	833	21.67 U	21.67 U	21.67 U
D71937	RFETS	Heterogeneous	116	833	33.33 U	33.33 U	66.67 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D71938	RFETS	Heterogeneous	116	833	1.80 U	1.80 U	1.80 U
D71940	RFETS	Solidified Organics	112	801	1000.00 U	1000.0 U	1000.0 U
D71941	RFETS	Solidified Organics	112	801	1000.00 U	1000.0 U	1000.0 U
D72010	RFETS	Heterogeneous	116	832	0.30 U	0.30 U	0.60 U
D72079	RFETS	Uncategorized Metal	117	480	6.50 U	6.50 U	6.50 U
D72127	RFETS	Solidified Organics	112	801	0.40 U	0.40 U	0.40 U
D72128	RFETS	Solidified Organics	112	801	130.00 U	130.00 U	130.00 U
D72131	RFETS	Heterogeneous	116	833	0.27 U	0.27 U	0.53 U
D72132	RFETS	Solidified Organics	112	801	48.00 U	48.00 U	96.00 U
D72133	RFETS	Solidified Organics	112	801	0.20 U	0.20 U	0.20 U
D72136	RFETS	Solidified Organics	112	801	21.00 U	21.00 U	21.00 U
D72139	RFETS	Solidified Organics	112	801	1.90 U	1.90 U	1.90 U
D72178	RFETS	Heterogeneous	116	821	0.30 U	0.30 U	0.30 U
D72186	RFETS	Heterogeneous	116	821	0.20 U	0.20 U	0.20 U
D72195	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D72255	RFETS	Heterogeneous	116	833	0.30 U	0.30 U	0.30 U
D72267	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.10 U
D72293	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D72333	RFETS	Heterogeneous	116	831	0.30 U	0.37 J	0.30 U
D72339	RFETS	Heterogeneous	116	821	0.50 U	0.50 U	0.50 U
D72347	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D72375	RFETS	Heterogeneous	116	831	80.00 U	80.00 U	80.00 U
D72434	RFETS	Heterogeneous	116	831	210.00 U	210.00 U	210.00 U
D72436	RFETS	Uncategorized Metal	117	480	0.30 U	0.30 U	0.60 U
D72542	RFETS	Heterogeneous	116	832	10.00 U	10.00 U	20.00 U
D72545	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D72546	RFETS	Heterogeneous	116	832	15.00 U	15.00 U	30.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D72566	RFETS	Solidified Organics	112	801	0.80 U	0.80 U	0.80 U
D72598	RFETS	Heterogeneous	116	821	0.60 U	0.60 U	0.60 U
D72618	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D72619	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D72623	RFETS	Solidified Organics	112	801	0.50 U	0.50 U	1.00 U
D72631	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D72632	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D72673	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D72819	RFETS	Heterogeneous	116	833	0.40 U	0.40 U	0.40 U
D72822	RFETS	Heterogeneous	116	831	0.27 U	0.27 U	0.53 U
D72831	RFETS	Uncategorized Metal	117	480	4.00 U	4.00 U	8.00 U
D72887	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D72923	RFETS	Heterogeneous	116	833	0.40 U	0.40 U	0.40 U
D72932	RFETS	Heterogeneous	116	825	0.30 U	0.30 U	0.30 U
D73054	RFETS	Heterogeneous	0	336	113.33 U	113.33 U	226.67 U
D73074	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D73117	RFETS	Uncategorized Metal	117	480	0.40 U	0.40 U	0.80 U
D73123	RFETS	Heterogeneous	116	831	126.00 U	126.00 U	126.00 U
D73134	RFETS	Heterogeneous	116	831	72.00 U	72.00 U	144.00 U
D73136	RFETS	Solidified Inorganics	111	807	0.10 U	0.10 U	0.20 U
D73274	RFETS	Heterogeneous	116	831	50.00 U	50.00 U	50.00 U
D73285	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D73293	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D73295	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D73296	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D73301	RFETS	Solidified Organics	112	801	0.20 U	0.20 U	0.20 U
D73605	RFETS	Lead/Cadmium Metal Waste	123	339	0.10 U	0.10 U	0.20 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Trl methyl benzene	1,2,4-Trl methyl benzene
D73632	RFETS	Heterogeneous	116	825	0.70 U	0.70 U	0.70 U
D73667	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D73672	RFETS	Solidified Organics	112	801	0.10 U	0.10 U	0.10 U
D73745	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.20 U
D73828	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D73848	RFETS	Heterogeneous	116	821	0.13 U	0.13 U	0.13 U
D73987	RFETS	Lead/Cadmium Metal Waste	123	339	0.30 U	0.30 U	0.60 U
D74007	RFETS	Uncategorized Metal	117	480	0.30 U	0.30 U	0.60 U
D74110	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D74147	RFETS	Solidified Organics	112	801	0.80 U	0.80 U	0.80 U
D74156	RFETS	Solidified Organics	112	801	0.60 U	0.60 U	0.60 U
D74374	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.20 U
D74683	RFETS	Heterogeneous	116	821	1.50 U	1.50 U	1.50 U
D74904	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.20 U
D74913	RFETS	Heterogeneous	116	832	0.30 U	0.30 U	0.30 U
D75039	RFETS	Heterogeneous	116	832	3.47	10.55	16.31
D75265	RFETS	Heterogeneous	116	833	1.20 U	1.20 U	1.20 U
D75267	RFETS	Heterogeneous	116	832	0.20 U	0.20 U	0.20 U
D75278	RFETS	Heterogeneous	116	832	0.30 U	0.30 U	0.30 U
D75399	RFETS	Heterogeneous	116	833	0.40 U	0.40 U	0.40 U
D75564	RFETS	Heterogeneous	116	825	0.13 U	0.13 U	0.21 J
D75868	RFETS	Heterogeneous	116	825	0.60 U	0.60 U	0.60 U
D75888	RFETS	Heterogeneous	116	833	0.10 U	0.15 J	0.49 J
D75926	RFETS	Heterogeneous	116	832	0.40 U	0.40 U	0.40 U
D75930	RFETS	Heterogeneous	116	832	100.00 U	100.00 U	200.00 U
D75947	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.10 U
D75976	RFETS	Heterogeneous	116	833	0.13 U	0.13 U	0.27 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D76044	RFETS	Heterogeneous	116	831	0.27 U	0.27 U	0.27 U
D76050	RFETS	Heterogeneous	116	832	0.10 U	0.30 J	0.80 J
D76054	RFETS	Heterogeneous	116	831	0.30 U	0.30 U	0.30 U
D76098	RFETS	Heterogeneous	116	832	0.20 U	0.20 U	0.40 U
D76135	RFETS	Solidified Organics	112	801	26.67 U	26.67 U	53.33 U
D76136	RFETS	Solidified Inorganics	111	803	0.40 U	0.40 U	0.80 U
D76138	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D76142	RFETS	Solidified Inorganics	111	800	0.24 U	0.24 J	0.48 U
D76143	RFETS	Solidified Inorganics	111	803	0.30 U	0.30 U	0.60 U
D76144	RFETS	Solidified Inorganics	111	800	0.67 U	0.67 U	1.33 U
D76146	RFETS	Solidified Inorganics	0	292	0.10 U	0.10 U	0.20 U
D76147	RFETS	Solidified Inorganics	111	803	0.10 U	0.10 U	0.10 U
D76182	RFETS	Solidified Inorganics	111	800	1.02 J	0.70 U	0.70 U
D76183	RFETS	Solidified Inorganics	111	800	0.13 U	0.23 J	0.44 J
D76185	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D76187	RFETS	Solidified Inorganics	111	803	0.50 U	0.50 U	1.00 U
D76189	RFETS	Solidified Inorganics	111	803	2.00 U	2.00 U	4.00 U
D76192	RFETS	Solidified Inorganics	111	803	0.10 U	0.10 U	0.20 U
D76194	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D76195	RFETS	Solidified Organics	112	801	480.00 U	480.00 U	480.00 U
D76196	RFETS	Solidified Organics	112	801	166.67 U	166.67 U	333.33 U
D76199	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D76200	RFETS	Solidified Organics	112	801	633.33 U	633.33 U	1266.6 U
D76203	RFETS	Solidified Organics	112	801	223.33 U	223.33 U	446.67 U
D76205	RFETS	Solidified Inorganics	111	800	0.10 U	0.10 U	0.20 U
D76206	RFETS	Solidified Inorganics	111	803	0.40 U	0.40 U	0.80 U
D76217	RFETS	Heterogeneous	116	833	1.00 U	1.00 U	2.00 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D76282	RFETS	Solidified Inorganics	111	800	11.33 U	11.33 U	22.67 U
D76283	RFETS	Solidified Organics	112	801	90.00 U	90.00 U	180.00 U
D76287	RFETS	Solidified Inorganics	111	800	5.33 U	5.33 U	10.67 U
D76293	RFETS	Heterogeneous	116	833	0.40 U	0.40 U	0.40 U
D76302	RFETS	Solidified Inorganics	111	800	3.00 U	3.00 U	6.00 U
D76303	RFETS	Solidified Inorganics	111	803	0.27 U	0.27 U	0.53 U
D76305	RFETS	Solidified Inorganics	111	800	12.00 U	12.00 U	24.00 U
D76306	RFETS	Heterogeneous	116	833	0.80 U	0.80 U	0.80 U
D76362	RFETS	Heterogeneous	116	833	6.67 U	6.67 U	13.33 U
D76406	RFETS	Heterogeneous	116	831	0.10 U	0.10 U	0.10 U
D76437	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D76443	RFETS	Heterogeneous	116	825	0.30 U	0.30 U	0.33 J
D76452	RFETS	Heterogeneous	116	825	0.20 U	0.20 U	0.20 U
D76454	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.29 J
D76456	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.24 J
D76461	RFETS	Heterogeneous	116	825	0.30 U	0.30 U	0.30 U
D76463	RFETS	Heterogeneous	116	825	0.30 U	0.30 U	0.30 U
D76470	RFETS	Solidified Inorganics	111	803	0.10 U	0.10 U	0.20 U
D76587	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.10 U
D76596	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.10 U
D76627	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.10 U
D76630	RFETS	Heterogeneous	116	825	0.10 U	0.10 U	0.18 J
D76635	RFETS	Heterogeneous	116	825	0.20 U	0.20 U	0.59 J
D76652	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.20 U
D76677	RFETS	Solidified Inorganics	111	800	2.40 U	2.40 U	2.40 U
D76710	RFETS	Heterogeneous	116	833	2.00 U	2.00 U	2.00 U
D76712	RFETS	Heterogeneous	116	833	0.30 U	0.30 U	0.30 U

Table C2-4
WIPP WASTE CHARACTERIZATION DATA
Gas Chromotography/Mass Spectrometry Results
(all data in ppmv)

Drum #	Site	Waste Matrix Code Group	TruCon Code	IDC Code	1,1,2,2-Tetra chloro ethane	1,3,5-Tri methyl benzene	1,2,4-Tri methyl benzene
D76715	RFETS	Heterogeneous	116	832	0.20 U	0.20 U	0.20 U
D76811	RFETS	Heterogeneous	116	832	0.20 U	0.20 U	0.20 U
D76908	RFETS	Heterogeneous	116	833	0.10 U	0.10 U	0.10 U
D76911	RFETS	Heterogeneous	116	832	0.20 U	0.20 U	0.40 U
D77088	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.40 U
D77227	RFETS	Heterogeneous	116	833	0.40 U	0.40 U	0.80 U
D77285	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D77621	RFETS	Heterogeneous	0	336	0.27 U	0.27 U	0.53 U
D80765	RFETS	Heterogeneous	116	833	0.20 U	0.20 U	0.20 U
D80772	RFETS	Heterogeneous	116	833	1.00 U	1.00 U	1.00 U
D80774	RFETS	Heterogeneous	116	833	3.10 U	3.10 U	3.10 U
D80776	RFETS	Heterogeneous	116	832	0.10 U	0.10 U	0.10 U

APPENDIX C3

TOTALS ANALYSIS VERSUS TOXICITY CHARACTERISTIC LEACHING PROCEDURE

APPENDIX C3
TOTALS ANALYSIS VERSUS TOXICITY CHARACTERISTIC LEACHING PROCEDURE

Data from totals analyses (total organic compound analysis and total metals analysis) are compared to the Regulatory Toxicity Levels (RTL) expressed as total values. RTL values are obtained by calculating the weight/weight concentration (in the solid) of a Toxicity Characteristic (TC) analyte that would give the regulatory weight/volume concentration (in the extract), assuming 100 percent analyte dissolution. Table C3-1 lists the TC levels expressed as RTL values for toxicity characteristic leaching procedure (TCLP) and totals analysis.

To demonstrate the appropriateness and conservatism of using totals analysis rather than the TCLP, consider the following example. Assume that a solid sample contains 100 milligrams per kilogram (mg/kg) of lead (Pb). The current TCLP regulatory level for Pb is 5 milligrams per liter (mg/L). This is comparable to a concentration of 5 mg/kg as demonstrated by the following calculation:

$$\frac{5 \text{ mg Pb}}{1 \text{ L solution}} \times \frac{1 \text{ L solution}}{1000 \text{ milliliters (ml) solution}} \times \frac{1 \text{ ml solution}}{1 \text{ gram (g) solution}} \times \frac{1000 \text{ g solution}}{1 \text{ kg solution}} = 5 \text{ mg Pb/kg}$$

When one compares the predicted results of totals analysis and TCLP analysis on the same sample, the following is observed:

Totals Analysis

Analyzing a sample by totals analysis yields a result equal to the actual contaminant concentration in the sample (assuming that the instrument and the methodology are 100 percent accurate).

Predicted result = 100 mg Pb/kg sample

TCLP Analysis

Assuming that 5 grams [g] (0.2 ounces (oz)) of sample is extracted and analyzed, 100 g of extraction fluid must be used (TCLP requires that the weight of extraction fluid must be 20 times the weight of the solid sample). Assuming that 100 percent of the lead in the sample is leachable, and as a result, is extracted into the solution where it will be detected in the analysis, the predicted concentration of the TCLP solution will be 5 mg/kg, as demonstrated in the following calculation:

$$\frac{5 \text{ g sample} \times \frac{100 \text{ mg Pb}}{1 \text{ kg sample}} \times \frac{1 \text{ kg sample}}{1000 \text{ g sample}}}{100 \text{ g solution} \times \frac{1 \text{ kg solution}}{1000 \text{ g solution}}} = 5 \text{ mg Pb/kg solution}$$

These calculations demonstrate that, by conservatively assuming a 100 percent leaching efficiency, a concentration of 100 mg/kg obtained by totals analysis is comparable to a concentration of 5 mg/kg (or 5 mg/L) using TCLP (See Figure C3-1). As such, by using a regulatory level of 100 mg/kg for totals analysis for lead (i.e., 20 times the TCLP level), the U.S. Department of Energy (DOE) is taking a conservative approach to the regulation, because a leaching efficiency of 100 percent is improbable. A comparison of the regulatory levels used for TCLP versus totals analysis for all TC analytes is presented in Table C3-1.

This approach was also addressed by the U.S. Environmental Protection Agency (EPA) in the preamble to a proposed rule issued in the Federal Register (FR) on October 24, 1991. In this preamble, the EPA stated the following:

> One could compare the numerical value of a potential TCLP standard to a theoretical maximum leaching level derived from a total constituent standard. One would have to assume that the entire amount of the toxicity characteristic constituent (as represented by the total constituent concentration at the level of the standard) would be extracted into an aqueous leaching medium. One would then have to account for the 20-fold dilution inherent in the TCLP analytical procedure. A theoretical maximum leaching value could, thus be calculated by dividing the numerical value of the total constituent treatment standard by a factor of 20 (56 FR 55167).

TABLE C3-1
RTLS FOR TCLP ANALYSIS VS. RTLS FOR TOTALS ANALYSIS

Analyte	TCLP RTL Value (mg/kg)	Totals RTL Value (mg/kg)[a]
Metals and Semi-VOCs[b]		
Arsenic	5.0	100
Barium	100.0	2000
Cadmium	1.0	20
Chromium	5.0	100
Cresols	200.0	4000
1,4-Dichlorobenzene	7.5	150
2,4-Dinitrotoluene	0.13	2.6
Hexachlorobenzene	0.13	2.6
Hexachloroethane	3.0	60
Lead	5.0	100
Mercury	0.2	4
Nitrobenzene	2.0	40
Pentachlorophenol	100.0	2000
Pyridine	5.0	100
Selenium	1.0	20
Silver	5.0	100
VOCs[c]		
Benzene	0.5	10
Carbon tetrachloride	0.5	10
Chlorobenzene	100.0	2000
Chloroform	6.0	120
1,2-Dichloroethane	0.5	10
1,1-Dichloroethylene	0.7	14
Methyl ethyl ketone	200.0	4000
Pyridine	5.0	100
Tetrachloroethylene	0.7	14
Trichloroethylene	0.5	10
Vinyl chloride	0.2	4

[a]The calculations assume 1) the maximum amount of material suggested by the TCLP is used, 2) wastes are 100 percent solid (no liquid fraction), 3) the maximum amount of extraction fluid is used, and 4) all analytes are 100 percent soluble in the extraction fluid.
[b]For metals and semi-VOCs, RTL value (mg/kg) = (TC level, mg/L) (volume of extraction fluid, 2L)/(weight of sample, 0.100 kg)
[c]For VOCs, RTL value (mg/kg) = (TC level, mg/L) (volume of extraction fluid, 0.5 L)/(weight of sample, 0.025 kg)

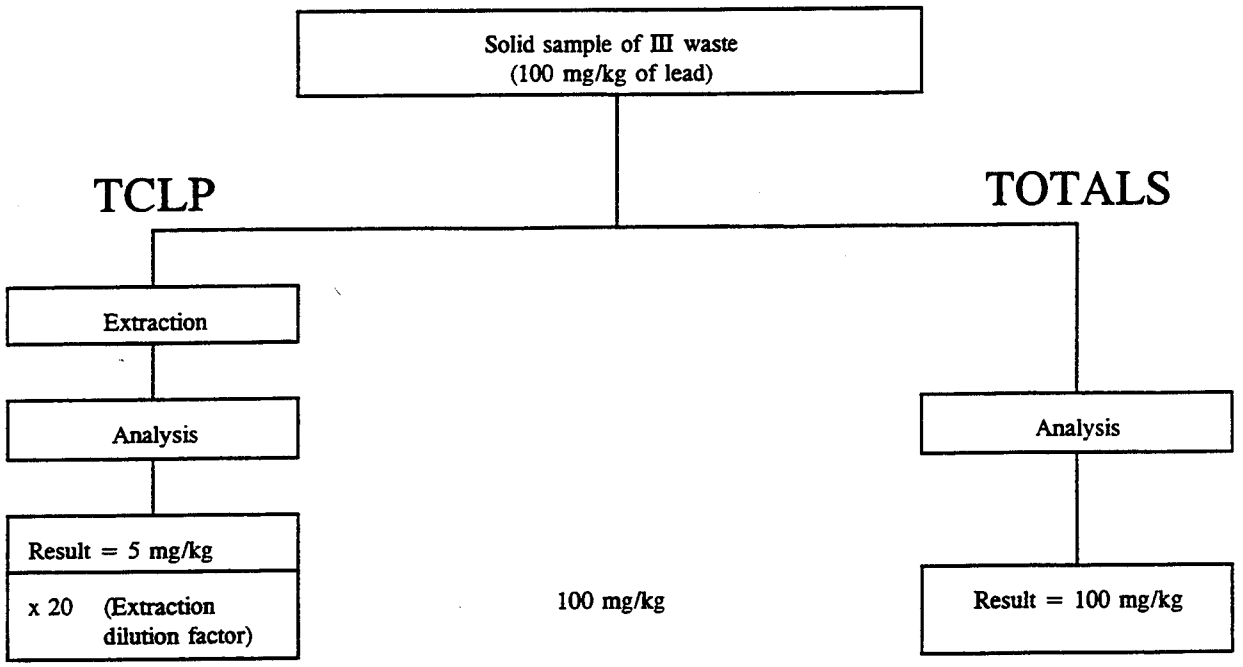

FIGURE C3-1
Comparison of TCLP and Totals Analyses for 100 mg/kg Lead Sample

APPENDIX C4
WASTE CHARACTERIZATION SAMPLING METHODS

APPENDIX C4
WASTE CHARACTERIZATION SAMPLING METHODS

C4-1 Headspace-Gas Sampling

C4-1a Method Requirements

All sampling must be accomplished within a radiation containment area (e.g., glovebox or hot/warm cell). The configuration of the containment area and remote-handling equipment at each sampling facility are expected to differ. A description of the containment area and remote-handling equipment must be provided in the site quality assurance project plan (QAPjP). Headspace-gas samples will be analyzed for the analytes listed in Table C8-2 of Appendix C8.

Sites may collect samples in SUMMA® canisters using the headspace gas sampling methods described in the Methods Manual. As an alternative, sites may use on-line integrated sampling/analysis systems. In this case, samples are immediately directed to an analytical instrument instead of being collected in SUMMA® canisters. The same sampling manifold and sampling heads are used with on-line integrated sampling/analysis systems and all of the requirements associated with sampling manifolds and sampling heads must be met. However, when using an on-line integrated sampling/analysis system, the sampling batch and analytical batch quality control (QC) samples are combined as on-line batch QC samples as outlined in Section C4-1b.

Manifold

This headspace gas sampling protocol employs a multiport manifold capable of collecting multiple simultaneous headspace samples for analysis and QC purposes. The manifold can be used to collect samples in SUMMA® canisters or as part of an on-line integrated sampling/analysis system. The sampling equipment must be leak checked and cleaned prior to first use and as needed thereafter. The manifold and sample canisters must be evacuated to 0.0039 inches (in.) (0.10 millimeters [mm]) mercury (Hg) prior to sample collection. Cleaned and evacuated sample canisters must be attached to the evacuated manifold before the manifold inlet valve is opened. The manifold inlet valve must be attached to a changeable filter connected to different sampling head(s), capable of punching through the metal lid of the drum or penetrating a carbon-composite filter.

The manifold must also be equipped with a purge assembly that allows applicable QC samples to be collected through the entire manifold, from the needle tip through all of the same manifold components that the drum headspace gas passes through. Field blanks shall be samples of room air collected in the sampling area in the immediate vicinity of the waste container to be sampled. If using SUMMA® canisters, field blanks are collected directly into the canister, without the use of the manifold.

The manifold, the associated sampling heads, and the headspace-gas sample volume requirements must be designed to ensure that a representative sample is collected. The

manifold internal volume must be calculated and documented in the field logbook. The total volume of headspace gases collected during each sampling operation can be determined by adding the combined volume of the canisters attached to the manifold to the internal volume of the manifold. When an estimate of the available headspace gas volume can be made, less than 10 percent of that volume should be withdrawn.

As illustrated in Figure C4-1, the sampling manifold must consist of a sample side and a standard side. The dotted line indicates how the sample side shall be connected to the standard side for cleaning and collecting equipment blanks and field reference standards. The sample side must consist of the following major components:

- An applicable sampling head that forms a leak-tight connection with the headspace sampling manifold.

- A flexible hose that allows movement of the sampling head from the purge assembly (standard side) to the waste container.

- A pressure sensor(s) that must be pneumatically connected to the manifold. This manifold pressure sensor(s) must be able to measure absolute pressure in the range from 0.002 in. (0.05 mm) Hg to 39.3 in. (1,000 mm) Hg. Resolution must be ±0.0002 in. (0.005 mm) Hg at 0.0020 in. (0.05 mm) of Hg. The manifold pressure sensor(s) must have an operating range from approximately 59°F (15°C) to 104°F (40°C).

- Ports for attaching sample canisters. If using canister-based sampling methods, a sufficient number of ports must be available to allow simultaneous collection of headspace-gas samples and duplicates for volatile organic compounds (VOC) analyses. If using an on-line integrated sampling/analysis system, only one port is necessary for the collection of comparison samples. Ports not occupied with sample canisters during cleaning or headspace-gas sampling activities require a plug to prevent ambient air from entering the system. In place of using plugs, sites may choose to install valves that can be closed to prevent intrusion of ambient air into the manifold. Ports must have VCR® fittings for connection to the sample canister(s) to prevent degradation of the fittings on the canisters and manifold.

- Sample canisters, as illustrated in Figure C4-2, that are leak-free, welded stainless steel pressure vessels, with a chromium-nickel oxide (Cr-NiO) SUMMA®-passivated interior surface, bellows valve, and a pressure/vacuum gauge. All sample canisters must have VCR® fittings for connection to sampling and analytical equipment. The pressure/vacuum gauge must be mounted on each canister. It must be helium-leak tested to 1.5×10^{-7} standard cubic centimeters per second (cc/s), have all stainless steel construction, and be capable of tolerating temperatures to 125°C. The gauge range must be capable of indicating leaks and sample collection.

- A dry vacuum pump with the ability to reduce the pressure in the manifold to 0.05 mm Hg. A vacuum pump that requires oil may be used, but precautions must be taken to prevent diffusion of oil vapors back to the manifold. Precautions may include the use of a molecular sieve and a cryogenic trap in series between the headspace sampling ports and the pump.

- A minimum distance between the tip of the needle and the valve that isolates the pump from the manifold in order to minimize the dead volume in the manifold. The outer diameter of the system's tubing must be 1/8 in. (3.1750 mm).

- If real-time blanks are not available, the manifold must be equipped with an organic vapor analyzer (OVA) that is capable of detecting all analytes listed in Table C8-2 of Appendix C8. The OVA must be capable of measuring total VOC concentrations as low as 0.1 parts per million (ppm). Detection of 1,1,2-trichloro-1,2,2-trifluoroethane may not be possible if a photoionization detector is used. The OVA measurement must be confirmed by the collection of equipment blanks at the frequency specified in Section C4-1 to check for manifold cleanliness.

The standard side must consist of the following major elements:

- A cylinder of compressed zero air, helium, nitrogen or hydrocarbon and carbon dioxide (CO_2)-free air to clean the manifold between samples and to provide gas for the collection of equipment blanks or on-line blanks. These high-purity gases must be certified by the manufacturer to contain less than one ppm total VOCs. The gases must be metered into the standard side of the manifold by two-stage stainless steel regulators. Alternatively, a zero air generator may be used, provided a sample of the zero air is collected and demonstrated to contain less than one ppm total VOCs. Zero air from a generator must be humidified.

- Cylinders of field-reference standard gases or on-line control sample gases. These cylinders provide gases for evaluating the accuracy of the headspace-gas sampling process. Each cylinder of field-reference gas or on-line control sample gas must have a flow-regulating device. The field-reference standard gases or on-line control sample gas must be certified by the manufacturer to contain known analytes at known concentrations.

- If using an analytical method other than Fourier Transform Infrared System (FTIRS) a humidifier filled with American Society for Testing and Materials (ASTM) Type II water, connected, and opened to the standard side of the manifold between the compressed gas cylinders and the purge assembly. Dry gases flowing to the purge assembly will pick up moisture from the humidifier. Moisture is added to the dry gases to condition the equipment blanks and field-reference standards and to assist with system cleaning between headspace-gas sample collection. If using FTIRS for analysis, the sample and sampling system must be kept dry.

NOTE: Caution should be exercised to isolate the humidifier during the evacuation of the system to prevent flooding the manifold. In lieu of the humidifier, the compressed gas cylinders (e.g., zero air and field-reference standard gas) may contain water vapor in the concentration range of 1,000 to 10,000 parts per million by volume (ppmv).

- A purge assembly that allows the sampling head (sample side) to be connected to the standard side of the manifold. The ability to make this connection is required to transfer gases from the compressed gas cylinders to the canisters or on-line analytical instrument. This connection is also required for system cleaning.

- A flow-indicating device that is connected downstream of the purge assembly to monitor the flow rate of gases through the purge assembly. The flow rate through the purge assembly must be monitored to assure that excess flow exists during cleaning activities and during QC sample collection. Maintaining excess flow will prevent ambient air from contaminating the QC samples and allow samples of gas from the compressed gas cylinders to be collected near ambient pressure.

In addition to a manifold consisting of a sample side and a standard side, the area in which the manifold is operated must contain sensors for measuring ambient pressure and ambient temperature, as follows:

- The ambient-pressure sensor must have a sufficient measurement range for the ambient barometric pressures expected at the sampling location. It must be kept in the sampling area during sampling operations. Its resolution must be 1.0 mm Hg or less, and calibration must be based on National Institute of Standards and Technology (NIST), or equivalent, standards.

- The temperature sensor must have a sufficient measurement range for the ambient temperatures expected at the sampling location. The temperature sensor calibration must be traceable to NIST, or equivalent, standards.

Direct Canister

This headspace gas sampling protocol employs a canister-sampling system to collect headspace-gas samples for analysis and QC purposes without the use of the manifold described above. Rather than attaching sampling heads to a manifold, in this method the sampling heads are attached directly to an evacuated sample canister as shown in Figure C4-3.

Canisters must be evacuated to 0.0039 in. (0.10 mm) Hg prior to use and attached to a changeable filter connected to the appropriate sampling head. The sampling head(s) must be capable of punching through the metal lid of the drums and the rigid 90-mil poly liner or penetrating a carbon-composite filter to obtain the drum headspace samples. Field duplicates must be collected at the same time, in the same manner, and using the same type of sampling apparatus as used for headspace-gas sample collection. Field blanks must be samples of room air collected in the immediate vicinity of the waste-drum sampling area prior to removal of the

drum lid. Equipment blanks and field-reference standards must be collected using a purge assembly equivalent to the standard side of the manifold described above. These samples must be collected from the needle tip through the same components (e.g., needle and filter) that the headspace-gas samples pass through.

The sample canisters, associated sampling heads, and the headspace-sample volume requirements ensure that a representative sample is collected. When an estimate of the available headspace-gas volume can be made, less than 10 percent of that volume should be withdrawn. A determination of the sampling head internal volume must be made and documented. The total volume of headspace gases collected during each headspace gas sampling operation can be determined by adding the volume of the sample canister(s) attached to the sampling head to the internal volume of the sampling head. Every effort must be made to minimize the internal volume of sampling heads.

Each sample canister used with the direct canister method must have a pressure/vacuum gauge capable of indicating leaks and sample collection. Canister gauges are intended to be gross leak-detection devices not vacuum-certification devices. If a canister pressure/vacuum gauge indicates an unexpected pressure change, determine if the change is a result of ambient temperature and pressure differences or a canister leak. Prior to sampling, canisters must be evacuated to 0.0039 in. (0.10 mm) Hg. This gauge must be helium-leak tested to 1.5×10^{-7} standard cc/s, have all stainless steel construction, and be capable of tolerating temperatures to 125°C.

The SUMMA® sample canisters must be used when sampling each drum. Three different sampling heads for attachment to the sample canister are described below. These heads must form a leak-tight connection with the canister and allow sampling through the drum-lid carbon-composite filter, or through the drum lid itself. Figure C4-3 illustrates the direct canister-sampling equipment.

Sampling Heads

A sample of the headspace gas directly under the drum lid must be collected from within the drum. Two methods, sampling through the carbon filter and sampling through the drum lid, have been developed for collecting a representative sample.

Sampling Through the Carbon Filter

To sample the drum-headspace gas through the drum's carbon-composite filter, a side-port needle (i.e., a hollow needle sealed at the tip with a small opening on its side close to the tip) must be pressed through the filter and into the headspace beneath the drum lid. This permits the gas to be drawn into the manifold or directly into the canister(s). This procedure is described in detail in the Methods Manual and is specific to a type of carbon-composite filter that permits insertion of the needle. To assure that the sample collected is representative, all of the general method requirements, sampling apparatus requirements, and QC requirements described in this section must be met in addition to the following requirements that are pertinent to drum headspace-gas sampling through the carbon filter:

- The lid of the drum's 90-mil poly liner must contain a hole for venting to the drum. If headspace-gas samples are collected prior to venting the 90-mil poly liner, a nonconformance report must be prepared, submitted, and resolved. Nonconformance procedures are outlined in Appendix C8 (Section C8-13).

- For sample collection, the drum's carbon-composite filter must be sealed as specified in the Methods Manual, or equivalent, to prevent outside air from entering the drum and diluting and/or contaminating the sample.

The sampling head for collecting drum headspace by penetrating the carbon-composite filter must consist of a side-port needle, a filter to prevent particles from contaminating the gas sample, and an adapter to connect the two. To prevent cross contamination, the sampling head must be cleaned or replaced after sample collection, after field-reference standard collection, and after field-blank collection. The following requirements must also be met:

- The housing of the carbon-composite filter must allow insertion of the sampling needle through the filter element into the drum headspace.

- The side-port needle must be used to reduce the potential for plugging.

- The purge assembly must be modified for compatibility with the side-port needle.

Sampling Through the Drum Lid

Sampling through the drum lid must be performed when the drum's carbon-composite filter does not permit insertion of the side-port needle. To sample the drum headspace-gas through the drum lid, the lid must be breached using a sparkless punch. The punch must form an airtight seal between the drum lid and the manifold or direct canister. To assure that the sample collected is representative, all of the general method requirements, sampling apparatus requirements, and QC requirements specified in Methods Manual Procedures 110.1 through 110.4, as appropriate, must be met in addition to the following requirements:

- The seal between the drum lid and sampling head must be designed to minimize intrusion of ambient air [See Methods Manual Procedure 110.4, Section 8.0].

- All components of the drum-punch sampling system that come into contact with sample gases must be purged with humidified zero air, nitrogen, or helium prior to sample collection [See Methods Manual Procedure 110.4, Section 8.0].

- Equipment blanks and field reference standards must be collected through all the components of the punch that contact the headspace-gas sample.

- Pressure must be applied to the sparkless punch until the drum lid has been breached. Then the punch must be backed out to expose the headspace gas.

- Provisions must be made to relieve potential drum pressure increases during drum-punch operations; pressure increases may occur during sealing of the drum punch to the drum lid.

- The lid of the drum's 90-mil poly liner must contain a hole for venting to the drum. If headspace-gas samples are collected prior to venting the 90-mil poly liner, a nonconformance report must be prepared, submitted, and resolved.

- During sampling, the drum's carbon-composite filter, if present, must be sealed to prevent outside air from entering the drum.

Sampling through the drum lid must be accomplished using the drum punch described in the Methods Manual (Procedure 110.4), or an equivalent. The same type of sampling head as used for the 55-gallon (208-liter) poly bag sampling must be pneumatically connected to the drum punch to provide a seal between the drum lid and the manifold or direct canister. The following requirements must also be met:

- A flow-indicating device to verify excess flow of QC gases (for system purge) must be pneumatically connected downstream of the drum punch and operated in the same manner as the flow-indicating device described in the "Manifold" section. A flowrate of approximately one liter per minute for approximately three minutes is required.

- Equipment must be used adequately to secure the drum-punch sampling system to the drum lid.

- Provisions must be made to prevent the punch from rotating as it is pressed through the drum lid.

C4-1b Quality Control

For manifold and direct canister sampling systems, field QC samples must be collected on a per sampling batch basis. A sampling batch is a suite of samples collected consecutively using the same sampling equipment within a specific time period. A sampling batch can be up to 20 samples (excluding QC samples), all of which must be collected within 14 days of the first sample in the batch. For on-line integrated sampling/analysis systems, QC samples must be collected and analyzed on a per on-line batch basis. An on-line batch is the number of headspace gas samples collected and analyzed within a 12-hour period using the same on-line integrated analysis system. Table C4-2 provides a summary of field QC sample collection requirements. Table C4-3 provides a summary of QC sample acceptance criteria.

For on-line integrated sampling analysis systems, the on-line batch QC samples serve as combined sampling batch/analytical batch QC samples as follows:

- The on-line blank replaces the equipment blank and laboratory blank

- The on-line control sample replaces the field reference standard and laboratory control sample

- The on-line duplicate replaces the field duplicate and laboratory duplicate

The acceptance criteria for on-line batch QC samples are the same as for the sampling batch and analytical batch QC samples they replace. Acceptance criteria are shown in Table C4-3. A separate field blank must still be collected and analyzed for each on-line batch. However, if the results of a field blank collected through the sampling manifold meets the acceptance criterion, a separate on-line blank need not be collected and analyzed.

The site project Quality Assurance (QA) officer shall have the responsibility to monitor and document field QC sample results and fill out a nonconformance report if acceptance criteria are not met. The site project manager shall have the responsibility to ensure appropriate corrective action is taken if acceptance criteria are not met.

Field Blanks

Field blanks must be collected to evaluate background levels of program-required analytes. Field blanks must be collected prior to sample collection, and at a frequency of one per sampling batch. The site project manager shall use the field blank data to assess impacts of ambient contamination, if any, on the sample results. A nonconformance report (Section C8-13) must be initiated and resolved if the final reported QC sample results do not meet the acceptance criteria.

Equipment Blanks

Equipment blanks must be collected to assess cleanliness prior to first use of all sampling equipment. After the initial cleanliness check, equipment blanks collected through the manifold must be collected at a frequency of one per sampling batch for VOC analysis. If the direct canister method is used, field blanks may be used in lieu of equipment blanks. The site project manager shall use the equipment blank data to assess impacts of potentially contaminated sampling equipment on the sample results. Equipment blank results determined by gas chromatography/mass spectrometry and gas chromatography/flame ionization detection shall be acceptable if the concentration of each VOC analyte is less than three times the method detection limit (MDL) listed in Table C8-2 in Appendix C8. Equipment blank results determined by FTIRS shall be acceptable if the concentration of each VOC analyte is less than the program required quantitation limit and listed in Table C8-2.

Field Reference Standards

Field reference standards shall be used to assess the accuracy with which the sampling equipment collects VOC samples into SUMMA® canisters prior to first use of the sampling equipment. Field reference standards must contain a minimum of six of the analytes listed in Table C8-2 in Appendix C8 at concentrations within a range of 0 to 100 ppmv. Field reference standards must have a known valid relationship to a nationally recognized standard (e.g., NIST). If commercial gases are used, a Certificate of Analysis from the manufacturer documenting

traceability is required. Commercial stock gases must not be used beyond their manufacturer-specified shelf life. After the initial accuracy check, field reference standards collected through the manifold must be collected at a frequency of one per sampling batch and submitted blind to the analytical laboratory. For the direct canister method, field reference standard collection may be discontinued if the field reference standard results demonstrate the quality assurance objectives (QAO) for accuracy specified in Appendix C8. Field reference standard results shall be acceptable if the accuracy is 70 to 130 percent recovery.

Field Duplicates

Field duplicate samples must be collected simultaneously and in accordance with Table C4-1 to assess the precision with which the sampling procedure can collect samples into SUMMA® canisters. Field duplicate results shall be acceptable if the relative percent difference is less than or equal to 25.

C4-1c Equipment Testing, Inspection and Maintenance

All sampling equipment components that come into contact with headspace sample gases must be constructed of relatively inert materials such as stainless steel or Teflon®. A passivated interior surface on the stainless steel components is recommended.

To minimize the potential for cross contamination of samples, the headspace sampling manifold and sample canisters must be properly cleaned and leak-checked prior to headspace gas sampling. Procedures for cleaning and preparing the manifold and sample canisters are provided in the Methods Manual (Procedures 110.1 and 110.2). Cleaning requirements are presented below.

Headspace Gas Sample Canister Cleaning

SUMMA® canisters used in these methods must be subjected to a rigorous cleaning and certification procedure prior to use in the collection of any samples. Guidance for the development of this procedure has been derived from Method TO-14 (EPA 1988a) and can be found in the Methods Manual (Procedure 210.1). Specific details must be provided in laboratory standard operating procedures (SOPs) for the cleaning and certification of canisters.

Canisters must be cleaned and certified on an equipment cleaning batch basis. An equipment cleaning batch is any number of canisters cleaned together at one time using the same cleaning method. A cleaning system, capable of processing multiple canisters at a time, composed of an oven (optional) and a cryogenic trap vacuum manifold must be used to clean SUMMA® canisters. Prior to cleaning, a 24-hour leak test must be performed on all canisters. For a positive pressure check, a canister passes if the pressure does not change by more than ± 2 psig in 24 hours. Any canister that fails must be checked for leaks, repaired, and reprocessed. One canister per equipment cleaning batch must be filled with humid zero air or humid high purity nitrogen and analyzed for VOCs. The equipment cleaning batch of canisters shall be considered clean if there are no VOCs above three times the MDLs listed in Table C8-2 of Appendix C8. After the canisters have been certified for leak-tightness and free of background contamination, they must be evacuated to 0.0039 in. (0.10 mm) Hg or less for storage prior to shipment. The

laboratory responsible for canister cleaning and certification shall maintain canister certification documentation and initiate the canister tags as described in Section 6.0 of the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP).

Sampling Equipment Initial Cleaning and Leak Check

The surfaces of all headspace gas sampling equipment components that will come into contact with headspace gas must be thoroughly inspected and cleaned prior to assembly, in accordance with Methods Manual Procedures 110.1 and 110.2, or equivalent. The manifold and associated sampling heads must be purged with humidified zero air, nitrogen, or helium, and leak checked after assembly. This cleaning must be repeated if the manifold and/or associated sampling heads are contaminated to the extent that the routine system cleaning is inadequate.

Sampling Equipment Routine Cleaning and Leak Check

The manifold and associated sampling heads which are reused must be cleaned and checked for leaks in accordance with the cleaning and leak check procedures described in Procedures 110.1 and 110.2 of the Methods Manual, or equivalent. The procedures must be conducted after headspace gas and field duplicate collection; after field blank collection, if the field blank is collected through the manifold; and after the additional cleaning required for field reference standard collection has been completed. The protocol for routine manifold cleaning and leak check requires that sample canisters be attached to the canister ports, or that the ports be capped or closed by valves, and requires that the sampling head be attached to the purge assembly. Humidified zero air, nitrogen, or helium, regulated through the purge assembly, must then be swept through the sample side of the sampling system.

VOCs must be removed from the internal surfaces of the headspace sampling manifold to levels that are less than three times the MDLs of the analytes listed in Table C8-2 of Appendix C8, as determined by analysis of an equipment blank or the OVA. This is achieved by sweeping the sample side of the sampling system. It is recommended that the headspace sampling manifold be heated and periodically evacuated and flushed with humidified zero air, nitrogen, or helium. When not in use, the manifold must be demonstrated clean before storage with a positive pressure of high purity gas (i.e., zero air, nitrogen, or helium) in both the standard and sample sides.

Sampling must be suspended and corrective actions must be taken when the analysis of an equipment blank indicates these limits have been exceeded. The site project manager must ensure that corrective action has been taken prior to resumption of sampling.

Manifold Cleaning After Field Reference Standard Collection

The sampling system must be specially cleaned after a field reference standard has been collected, because the field reference standard gases contaminate the standard side of the headspace sampling manifold when they are regulated through the purge assembly. This cleaning requires the installation of a gas-tight connector in place of the sampling head, between the flexible hose and the purge assembly. This configuration allows both the sample and standard sides of the sampling system to be flushed (evacuated and pressurized) with humidified

zero air, nitrogen, or helium which, combined with heating the pneumatic lines, should sweep and adequately clean the system's internal surfaces. After this protocol has been completed and prior to collecting another sample, the routine system cleaning and leak check (see previous section) must also be performed.

Sampling Head Cleaning

To prevent cross contamination, the needle, adapters, and filter of the sampling heads must be cleaned in accordance with the cleaning procedures described in Procedures 110.1 and 110.2 of the Methods Manual, or equivalent. After sample collection, a sampling head must be disposed of or cleaned in accordance with the Methods Manual procedures, or equivalent, prior to reuse. As a further QC measure, the needle and filter, after cleaning, should be purged with zero air, nitrogen, or helium and capped for storage to prevent sample contamination by VOCs potentially present in ambient air.

C4-1d Equipment Calibration and Frequency

The manifold pressure sensor must be certified prior to initial use, then annually, using NIST traceable, or equivalent, standards. If necessary, the pressure indicated by the pressure sensor(s) must be temperature compensated. The ambient air temperature sensor, if present, must be certified prior to initial use, then annually, to NIST traceable, or equivalent, temperature standards.

The OVA must be calibrated once per day, prior to first use, or as necessary according to the manufacturer's specifications. Calibration gases must be certified to contain known analytes at known concentrations. The balance of the OVA calibration gas must be consistent with the manifold purge gas when the OVA is used (i.e., zero air, nitrogen, or helium).

C4-2 Sampling of Homogenous Solids and Soil/Gravel

C4-2a Method Requirements

The methods used to collect samples of transuranic (TRU) waste, classified as homogenous solids and soil/gravel from waste containers, must be such that the samples are representative of the waste from which they were taken. To minimize the quantity of investigation-derived waste, laboratories conducting the analytical work may require no more sample than is required for the analysis, based on the analytical methods. Therefore, sampling must be conducted to collect samples in accordance with the QAO specifications as described below.

Core Collection

Coring tools must be used to collect cores of homogenous solids and soil/gravel from waste containers, when possible, in a manner that minimizes disturbance to the core. A rotational coring tool (i.e., a tool that is rotated longitudinally), similar to a drill bit, to cut, lift the waste cuttings, and collect a core from the bore hole, must be used to collect sample cores from containers of the waste. For homogenous solids and soil/gravel that are relatively soft, nonrotational coring tools may be used in lieu of a rotational coring tool.

To provide a basis for describing the requirements for core collection, diagrams of a rotational coring tool (i.e., a light weight auger) and a nonrotational coring tool (i.e., a thin-walled sampler) are provided in Figures C4-4 and C4-5, respectively. Each has been tested for its ability to collect a vertical core of simulated solidified waste contained in 55-gal (208-L) drums and 1-gal (3.8-L) poly bottles (EG&G 1994). The nonrotational coring tool has demonstrated core recoveries greater than 88 percent for soft simulated wastes. The rotational coring tool has demonstrated core recoveries greater than 75 percent for soft simulated wastes and greater than 94 percent for hard simulated wastes.

The following requirements apply to the use of coring tools:

- Each coring tool must contain a removable tube (liner) that is constructed of fairly rigid material unlikely to affect the composition and/or concentrations of target analytes in the sample core. Materials that are acceptable for use for coring device sleeves are polycarbonate, teflon, or glass for most samples, and stainless steel or brass if samples are not to be analyzed for metals (Methods Manual Procedure 120.1). Site QAPjPs must document that analytes of concern are not likely to be present in liner material. Sites must document that the materials are unlikely to affect sample results through the collection and analysis of equipment prior to first use as specified in the 'Equipment Blanks' section of this appendix. Liner outer diameter is recommended to be no more than 2 in. and no less than one in. Liner wall thickness is recommended to be no greater than 1/16 in. Before use, the liner must be cleaned in accordance the requirements in Section C4-2b. The liner must fit flush with the inner wall of the coring tool and must be of sufficient length to hold a core that is representative of the waste along the entire depth of the waste. The liner material must have sufficient transparency to allow visual examination of the core after sampling. If sub-sampling is not conducted immediately after core collection and liner extrusion, then end caps constructed of material unlikely to affect the composition and/or concentrations of target analytes in the core (e.g., Teflon®) must be placed over the ends of the liner. End caps must fit tightly to the ends of the liner.

- A spring retainer, similar to that illustrated in Figures C4-4 and C4-5, must be used with each coring tool when the physical properties of the waste are such that the waste may fall out of the coring tool's liner during sampling activities. The spring retainer must be constructed of relatively inert material (e.g., stainless steel or Teflon®) and its inner diameter must not be less than the inner diameter of the liner. Before use, spring retainers must be cleaned in accordance with the requirements in Section C4-2b.

- Coring tools must have an air-lock mechanism that opens to allow air inside the liners to escape as the tool is pressed into the waste (e.g., ball check valve). This air-lock mechanism must also close when the core is removed from the waste container.

- After disassembling the coring tool, a device (extruder) to forcefully extrude the liner from the coring tool must be used if the liner does not slide freely. All

surfaces of the extruder that may come into contact with the core must be cleaned in accordance with the requirements in Section C4-2(b) prior to use.

- Coring tools must be of sufficient length to hold the liner and must be constructed to allow placement of the liner leading edge as close as possible to the coring tools leading edge.

- All surfaces of the coring tool that have the potential to contact the sample core must be cleaned in accordance with the requirements in Section C4-2(b) prior to use.

- The leading edge of the coring tools must be sharpened and tapered to a diameter equivalent to, or slightly smaller than, the inner diameter of the liner. Based on tests conducted with the coring tools described in the Methods Manual, a diameter slightly smaller (e.g., 1/10 in.) has demonstrated a reduction in the drag of the homogenous solids and soil/gravel against the internal surfaces of the liner, thereby enhancing sample recovery.

- Rotational coring tools must have a mechanism to prevent the liner inside the coring tool from rotating with the coring tool during coring activities, thereby minimizing physical disturbance to the core.

- Rotational coring must be conducted in a manner that minimizes transfer of frictional heat to the core, thereby minimizing potential loss of VOCs.

- Nonrotational coring tools must be designed such that the tool's kerf width is minimized. Kerf width is defined as one-half of the difference between the outer diameter of the tool and the inner diameter of the tool's inlet.

Sample Collection

Sampling must be conducted in accordance with the following requirements:

- Sampling must be conducted as soon as possible after core collection. If a substantial delay (i.e., more than 60 minutes) is expected between core collection and sampling, the core must remain in the liner and the liner must be capped at each end. If the liner containing the core is not extruded from the coring tool and capped, then two alternatives are permissible: 1) the liner must be left in the coring tool and the coring tool must be capped at each end, or 2) the coring tool must remain in the waste container with the air-lock mechanism attached.

- Samples of homogenous solids and soil/gravel for VOC analyses must be collected prior to extruding the core from the liner. The sampling location must be randomly selected along the long axis of the liner and access to the waste must be gained by making a perpendicular cut through the liner and the core. Sites must develop procedures to select, and document the selection, of random sampling locations. True random sampling involves the proper use of random

numbers for identifying sampling locations. A sampling device such as the metal coring cylinder described in ASTM Designation: 4547-91 (ASTM 1991a), or modified disposable syringe described in Procedure 120.1 of the Methods Manual, or equivalent, must be immediately used to collect a 15-gram sample once the core has been exposed to air. Immediately after sample collection, the sample must be extruded into a 40-mL Volatile Organics Analysis (VOA) vial, the top rim of the vial visually inspected and wiped clean of any waste residue, and the vial cap secured. Sample handling requirements are outlined in Table C4-4. Additional guidance for this type of sampling can be found in *Soil Sampling and Analysis for Volatile Organic Compounds* (EPA, 1991).

- Samples of the homogenous solids and soil/gravel for semi-volatile organic compound, polychlorinated biphenyls, and metals analyses must be collected. These samples may be collected from the same location and in the same manner as the sample(s) collected for VOC analysis, or they may be collected by splitting or compositing a representative subsection of the core. The representative subsection is chosen by randomly selecting a location along the core. Sites must develop procedures to select, and document the selection, of random sampling locations. True random sampling involves the proper use of random numbers for identifying sampling locations. Guidance for splitting and compositing solid materials can be found in "Standard Practice for Reducing Field Samples of Aggregate to Testing Size" (ASTM, 1987). All surfaces of the sampling tools that have the potential to come into contact with the sample must be constructed of materials unlikely to affect the composition or concentrations of target analytes in the waste (e.g., Teflon®). Sample sizes and handling requirements are outlined in Table C4-4.

C4-2b Quality Control

QC requirements for sampling of homogenous solids and soil/gravel include collection of collocated cores to determine precision; equipment blanks to verify cleanliness of the coring tools and sampling equipment; and analysis of reagent blanks to ensure reagents, such as deionized or high pressure liquid chromatography (HPLC) water, are of sufficient quality. Coring and sampling of homogenous solids and soil/gravel must comply, at minimum, with the following QC requirements.

Co-located Cores

In accordance with the requirement to collect field duplicates required by Environmental Protection Agency (EPA) methods found in SW-846, co-located cores must be collected to determine the combined precision of the coring and sampling procedures. The co-located core methodology is a duplicate sample collection methodology intended to collect samples from approximately the same location within the drum. Cores must be collected side by side as close as feasible to one another, handled in the same manner, visually inspected through the transparent liner, and sampled in the same manner at the same randomly selected sample location. If the visual examination detects inconsistencies such as color, texture, or waste type in the waste at the sample location, another sampling location may be randomly selected, or the

cores may be invalidated and co-located cores may again be collected. Co-located cores must be collected at a frequency of one per sampling batch. A sampling batch is a suite of homogenous solids and soil/gravel samples collected consecutively using the same sampling equipment within a specific time period. A sampling batch can be up to 20 samples (excluding field QC samples), all of which must be collected within 14 days of the first sample in the batch. Because of the normally slow rate of core collection (1-2 cores per day), daily collection of field QC samples would result in numerous QC samples being collected for each field sample. This is inappropriate for sampling operations and is unnecessary for QC purposes. The collection of field QC samples on a "per sampling batch" basis provides adequate control for sampling operations.

Equipment Blanks

In accordance with SW-846, equipment blanks must be collected from fully assembled coring tools prior to first use at a frequency of one per equipment cleaning batch. An equipment cleaning batch is the number of sampling equipment items cleaned together at one time using the same cleaning method. The equipment blank must be collected from the fully assembled coring tool, in the area where the coring tools are cleaned, prior to covering with protective wrapping and storage. The equipment blank must be collected by pouring clean water (e.g., deionized water, HPLC water) down the inside of the liners of the assembled coring tool. The water must be collected in a clean sample container placed at the leading edge of the coring tool and analyzed for the analytes listed in Tables C8-4, C8-6, and C8-9 of Appendix C8. The results of the equipment blank will be considered acceptable if the analysis indicates no analyte at a concentration greater than three times the MDLs listed in Tables C8-4 and C8-6 or in the Program Required Detection Limits (PRDL) in Table C8-9 of Appendix C8. If analytes are detected at concentrations greater than three times the MDLs, then the associated equipment cleaning batch of coring tools must be cleaned again and another equipment blank collected.

Equipment blanks must be collected from liners that are cleaned separately from the coring tools. These equipment blanks must be collected at a frequency of one per equipment cleaning batch. The equipment blanks must be collected by randomly selecting a liner from the equipment cleaning batch, pouring clean water (e.g., deionized water or HPLC water) across its internal surface, collecting the water in a clean sample container, and analyzing the water for the analytes listed in Tables C8-4, C8-6, and the PRDLs in C8-9 of Appendix C8. The results of the equipment blank analysis will be considered acceptable if the results indicate no analyte at a concentration greater than three times the MDLs listed in Tables C8-4, C8-6, or C8-9 of Appendix C8. If analytes are detected at concentrations greater than three times the MDLs (or PRDLs for metals), then the associated equipment cleaning batch of liners must be cleaned again and another equipment blank collected.

Sampling equipment (e.g., bowls, spoons, chisel, VOC sub-sampler) must also be cleaned. Equipment blanks must be collected for the sampling equipment at a frequency of one per equipment cleaning batch. After the sampling equipment has been cleaned, one item from the equipment cleaning batch is randomly selected, water (e.g., deionized water, HPLC water) is passed over its surface, collected in a clean container, and analyzed for the analytes listed in Tables C8-4, C8-6, and C8-9 of Appendix C8. The results of the equipment blank will be considered acceptable if the results indicate no analyte present at a concentration greater than

three times the MDLs listed in Tables C8-4 and C8-6 and in the PRDLs in C8-9 of Appendix C8. If analytes are detected at concentrations greater than three times the MDLs (or PRDLs for metals), then the associated equipment cleaning batch of sampling equipment must be cleaned again and another equipment blank collected.

The results of equipment blanks must be traceable to the items in the equipment cleaning batch that the equipment blank represents. It is recommended that the equipment blank results for the coring tools, liners, and sampling equipment be reviewed prior to use. A sufficient quantity of these items should be maintained in storage to prevent disruption of sampling operations.

A site may choose to discard liners and sampling tools after one use. In this instance, cleaning and equipment blank collection is not required.

Coring Tool and Sampling Equipment Cleaning

Coring tools and sampling equipment must be cleaned in accordance with the following requirements:

- All surfaces of coring tools and sampling equipment that will come into contact with the core and the samples must be clean prior to use. All items of sampling equipment must be cleaned in the same manner. Immediately following cleaning, coring tools and sampling equipment must be assembled and sealed inside clean protective wrapping.

- Each coring tool must have a unique identification number. Each number must be referenced to the waste container on which it was used. This information must be recorded in the field records. One coring tool from the equipment cleaning batch must be tested for cleanliness in accordance with the requirements specified above. The identification number of the coring tool from which the equipment blank was collected must be recorded in the field records. The results of the equipment blank analysis for the equipment cleaning batch in which each coring tool was cleaned must be submitted to the sampling facility with the identification numbers of all coring tools in the equipment cleaning batch.

- Sample containers must be cleaned in accordance with the *Specifications and Guidance for Obtaining Contaminant-Free Sample Containers* (EPA, 1992).

C4-2c Equipment Testing, Inspection and Maintenance

Prior to initiation of coring activities, coring tools must be tested in accordance with manufacturer specifications to ensure operation within the manufacturer's tolerance limits. Other specifications specific to the sampling operations (e.g., operation of containment structure and safety systems) should also be tested and verified as operating properly prior to initiating coring activities. Coring tools must be assembled, including liners, and tested. Air-lock mechanisms and rotation mechanisms must be inspected for free movement of critical parts. Coring tools found to be malfunctioning must be repaired or replaced prior to use.

Coring tools and sample collection equipment must be maintained in accordance with manufacturer's specifications. Clean coring tools and sampling equipment must be sealed inside clean protective wrapping and maintained in a clean storage area prior to use. Sampling equipment must be properly maintained to avoid contamination. A sufficient supply of spare parts should be maintained to prevent delays in sampling activities due to equipment down time. Records of equipment maintenance and repair must be maintained in the field records in accordance with site SOPs.

Inspection of sampling equipment and work areas shall include the following:

- Sample collection equipment in the immediate area of sample collection must be inspected daily for cleanliness. Visible contamination on any equipment (e.g., waste on floor of sampling area, hydraulic fluid from hoses) that has the potential to contaminate a waste core or waste sample must be thoroughly cleaned upon its discovery.

- The waste coring and sampling work areas must be maintained in clean condition to minimize the potential for cross contamination between cores and samples.

- Expendable equipment (e.g., plastic sheeting, plastic gloves) must be visually inspected for cleanliness prior to use and properly discarded after each sample.

- Prior to removal of the protective wrapping from a coring tool designated for use, the condition of the protective wrapping must be visually assessed. Coring tools with torn protective wrapping should be returned for cleaning. Coring tools visibly contaminated after the protective wrapping has been removed must not be used and must be returned for cleaning or properly discarded.

- Sampling equipment must be visually inspected prior to use. All sampling equipment that comes into contact with waste samples must be stored in protective wrapping until use. Prior to removal of the protective wrapping from sampling equipment, the condition of the protective wrapping must be visually assessed. Sampling equipment with torn protective wrapping should be discarded or returned for cleaning. Sampling equipment visibly contaminated after the protective wrapping has been removed must not be used and must be returned for cleaning or properly discarded.

C4-2d Equipment Calibration and Frequency

The scale used for weighing sub-samples must be calibrated as necessary to maintain its operation within manufacturer's specification, and after repairs and routine maintenance. Weights used for calibration must be traceable to a nationally recognized standard. Calibration records must be maintained in the field records.

C4-3 Radiography

C4-3a Methods Requirements

Radiography has been developed by the Department of Energy (DOE) specifically to aid in the examination and identification of containerized waste. There is no equivalent or associated method found in EPA sampling and analysis guidance documents. All activities required to achieve the radiography objectives must be described in site QAPjPs and SOPs.

A radiography system normally consists of an X-ray-producing device, an imaging system, an enclosure for radiation protection, a waste container handling system, an audio/video recording system, and an operator control and data acquisition station. Although these six components are required, it is expected there will be some variation within a given component between sites. The X-ray-producing device must have controls which allow the operator to vary the voltage, thereby controlling image quality. It should be possible to vary the voltage, typically between 150 to 400 kilovolts (k), to provide an optimum degree of penetration through the waste. For example, high-density material should be examined with the X-ray device set on the maximum voltage. This ensures maximum penetration through the waste container. Low-density material should be examined at lower voltage settings to improve contrast and image definition. The imaging system typically utilizes a fluorescent screen and a low-light television camera.

To perform radiography, the waste container is scanned while the operator views the television screen. An audio/videotape is made of the waste container scan and is maintained as a permanent record. A radiography data form is also used to document the matrix parameter category and estimated waste material parameter weights of the waste. The estimated waste material parameter weights should be determined by compiling an inventory of waste items, residual materials, and packaging materials. The items on this inventory should be sorted by waste material parameter and combined with a standard weight look-up table to provide an estimate of waste material parameter weights.

C4-3b Quality Control

The radiography system involves qualitative and semiquantitative evaluations of visual displays. Operator training and experience are the most important considerations for assuring quality controls in regard to the operation of the radiography system and for interpretation and disposition of radiography results. Only trained personnel must be allowed to operate radiography equipment.

Standardized training requirements for radiography operators must be based upon existing industry standard training requirements and must comply with the training and qualification requirements of NQA-1, Element 2, except for Supplement 2S-2 (ASME, 1994). Supplement 2S-2 is associated with radiography used in verifying safety-related parameters, such as welding, where quantitative comparisons can be utilized. As such, it is not applicable to waste management operations and not considered necessary or appropriate for training radiography operators involved in TRU waste characterization activities.

Each site must develop a training program that provides radiography operators with both formal and on-the-job (OJT) training. Radiography operators must be instructed in the specific waste generating practices, typical packaging configurations, and associated waste material parameters expected to be found in each matrix parameter category at the site. The OJT and apprenticeship must be conducted by an experienced, qualified radiography operator prior to qualification of the training candidate. The training programs will be site-specific due to differences in equipment, waste configurations, and the level of waste characterization efforts. For example, certain sites use digital radiography equipment, which is more sensitive than real-time radiography equipment. In addition, the particular physical forms and packaging configurations at each site will vary; therefore, radiography operators must be trained on the types of waste that are generated, stored, and/or characterized at that particular site.

Although each site must develop its own training program, all of the radiography QC requirements specified in this Waste Analysis Plan (WAP) and the Methods Manual must be incorporated into the training programs and radiography operations. In this way data quality and comparability will not be affected.

Radiography training programs will be the subject of the Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C11).

Although the site-specific training programs will vary to some degree, each program will contain the following required elements based on NQA-1 requirements:

Formal Training

- Project Requirements
- State and Federal Regulations
- Basic Principles of Radiography
- Radiographic Image Quality
- Radiographic Scanning Techniques
- Application Techniques
- Radiography of Waste Forms
- Standards, Codes, and Procedures for Radiography
- Site-Specific Instruction

On-the-Job Training

- System Operation
- Identification of Packaging Configurations
- Identification of Waste Material Parameters
- Weight and Volume Estimation
- Identification of Prohibited Items

A radiography test drum will include items common to the waste streams to be generated/stored at the generator/storage site. The test drums must be divided into layers with varying packing densities or different drums may be used to represent different situations that may occur during

radiography examination at the site. The following is a list of required elements of a radiography test drum:

- Aerosol can with puncture
- Horsetail bag
- Pair of coveralls
- Empty bottle
- Irregular shaped pieces of wood
- Empty one gallon paint can
- Full container
- Aerosol can with fluid
- One gallon bottle with three tablespoons of fluid
- One gallon bottle with one cup of fluid (upside down)
- Leaded glove or leaded apron
- Wrench

These items must be successfully identified by the operator as part of the qualification process. Qualification of radiography operators must, at a minimum, encompass the following requirements:

- Successfully pass a comprehensive exam based upon training enabling objectives. This exam will be reviewed as part of the Generator/Storage Site Waste Screening and Acceptance Audit Program (Appendix C11)

- Perform practical capability demonstration in the presence of appointed site radiography subject matter expert. This person is an experienced radiography operator who is qualified as an OJT trainer.

Requalification of operators must be based upon evidence of continued satisfactory performance (primarily audio/videotape reviews) and must be done at least every two years. Unsatisfactory performance will result in disqualification. Unsatisfactory performance is defined as the misidentification of a prohibited item in a training drum or a score of less than 80% on the comprehensive exam. Retraining and demonstration of satisfactory performance are required before an operator is again allowed to operate the radiography system.

A training drum with various container sizes must be periodically scanned by each operator. The videotape must then be reviewed by a supervisor to ensure that operators' interpretations remain consistent and accurate. Imaging system characteristics must be verified on a routine basis.

Independent replicate scans and replicate observations of the video output of the radiography process must be performed under uniform conditions and procedures. Independent replicate scans must be performed on one waste container per day or once per testing batch, whichever is less frequent. Independent observations of one scan (not the replicate scan) must also be made once per day or once per testing batch, whichever is less frequent, by a qualified radiography operator other than the individual who performed the first examination. A testing batch is a suite of waste containers undergoing radiography using the same testing equipment. A testing batch can be up to 20 waste containers without regard to waste matrix.

Oversight functions include periodic audio/video tape reviews of accepted waste containers and must be performed by qualified radiography personnel other than the operator who dispositioned the waste container. The results of this verification must be available to the radiography operator. The site project QA officer shall be responsible for monitoring the quality of the radiography data and calling for corrective action, when necessary.

Visual Examination

As an additional QC check, the radiography results must be verified directly by visual examination of the waste container contents. Visual examination must be performed on a statistically determined portion of waste containers to verify the results of radiography. This verification must include the matrix parameter category and waste material parameter weights. The verification must be performed through a comparison of radiography and visual examination results. The results of the visual examination must be transmitted to the radiography facility.

The visual examination must consist of a semi-quantitative and/or qualitative evaluation of the waste container contents, and must be recorded on audio/videotape. The visual examination program has been developed by the DOE to provide an acceptable level of confidence in radiography. There is no equivalent method found in EPA sampling and analysis guidance documents. A detailed procedure that meets the requirements of this method can be found in the Methods Manual.

Standardized training for visual inspection must be developed to include both formal classroom and OJT. Visual inspectors must be instructed in the specific waste generating processes, typical packaging configurations, and expected waste material parameters expected to be found in each matrix parameter category at the site. The OJT and apprenticeship must be conducted by an operator experienced and qualified in visual examination prior to qualification of the candidate. The training must be site specific to include the various waste configurations generated/stored at the site. For example, the particular physical forms and packaging configurations at each site will vary so operators must be trained on types of waste that are generated, stored, and/or characterized at that particular site. Visual examination personnel must be requalified once every two years.

Although site-specific training programs will vary to some degree, each program will contain the following required elements based on NQA-1 requirements:

Formal Training

- Project Requirements
- State and Federal Regulations
- Application Techniques
- Site-Specific Instruction

On-the-Job Training

- Identification of Packaging Configurations
- Identification of Waste Material Parameters

- Weight and Volume Estimation
- Identification of Prohibited Items

Each visual examination facility must designate a visual examination expert. The visual examination expert must be familiar with the waste generating processes that have taken place at that site and also be familiar with all of the types of waste being characterized at that site. The visual examination expert shall be responsible for the overall direction and implementation of the visual examination at that facility. Site QAPjPs must specify the selection, qualification, and training requirements of the visual examination expert.

Figure C4-6 illustrates the overall programmatic approach to the visual examination of waste. If the waste is homogeneous, the expert may decide that a limited visual examination involving a confirmation of the radiography data is appropriate. If the waste is heterogeneous, the expert may decide a full visual examination by opening bags and segregating waste is warranted. Various degrees of segregation are possible based on the expert's judgment and availability of acceptable knowledge data. Site QAPjPs must specify decision-making criteria for the visual examination expert. In all cases, SOPs must be developed to support the visual examination process, and the basis for the expert's decisions must be documented.

A description of the waste container contents must be recorded on a data form as implemented in the site QAPjP. The description can be brief, but it must clearly identify the appropriate waste matrix parameters and provide enough information to estimate weights of waste material parameters. In cases where bags are not opened, a brief written description of the contents of the bags must contain an estimate of the amount of each waste type in the bags. The written records of visual examination must be supplemented with the audio/video recording.

C4-4 Sample Custody of Samples

Chain-of-Custody on field samples (including field QC samples) will be initiated immediately after sample collection or preparation. Sample custody will be maintained until the associated analyses are completed and the data have been validated at the project level. Sample custody will be maintained until the sample is expended or until the sample is removed from the sample analysis program. Site QAPjPs will include a copy of the sample chain-of-custody form; this form will include provisions for each of the following:

- Signature of individual initiating custody control, along with the date and time
- Documentation of sample numbers for each sample under custody
- Signatures of custodians relinquishing and receiving custody, along with date and time of the transfer
- Description of final waste container disposition, along with signature of individual removing waste container from custody
- Comment section

C4-5 Sample Packing and Shipping

In the event that the analytical facilities are not at the generator site, the samples must be packaged and shipped to an off-site laboratory. Sample containers must be packed to prevent any damage to the sampling container and maintain the preservation temperature, if necessary. Department of Transportation (DOT) regulations must be adhered to for shipment of the package.

When preparing SUMMA® canisters for shipment, special care must be taken with the pressure gauge and the associated connections. Metal boxes which have separate compartments, or cardboard boxes with foam inserts are standard shipping containers. The chosen shipping container may be required to meet selected DOT regulations. If temperatures must be maintained, cold packs can be added to the package.

Glass jars are wrapped in bubble wrap or another type of protection. The wrapped jar should be placed in a plastic bag inside of the shipping container, so that if the jar breaks, the inside of the shipping container and the other samples will not be contaminated. The plastic bag will enable the receiving analytical lab to prevent contamination of their shipping and receiving area. Plastic jars do not present a problem for shipping purposes. A DOT approved cooler, or similar package may be used as the shipping container. If temperatures must be maintained, cold packs can be added to the package. If a fill material is needed, compatibility between the samples and the fill should be considered.

Sample containers should be affixed with a tamper-proof seal so that it is apparent if the sample integrity has been compromised. A seal should also be placed on the outside of the shipping container for the same reason. Sample custody documentation must be placed inside of the shipping container, with the current custodian signing to release custody. The shipping documentation will serve as proof of custody during shipment, so the transporter does not need to sign the chain-of-custody documentation.

A Uniform Hazardous Waste Manifest is not required, since samples are exempted from the definition of hazardous waste. All other shipping documentation (i.e., bill of lading, site-specific shipping documentation) is required.

C4-6 List of References

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U.S. Environmental Protection Agency (EPA), 1988, "Compendium Method TO-14, The Determination of Volatile Organic Compounds (VOC) in Ambient Air Using SUMMA Passivated Canister Sampling and Gas Chromatographic Analyses." *Compendium of Methods for Determination of Toxic Organic Compounds in Ambient Air.* Research Triangle Part, North Carolina, Quality Assurance Division, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency.

TABLES

TABLE C4-1

GAS SAMPLE CONTAINERS AND HOLDING TIMES

Parameter	Container	Minimum Drum Headspace Sample Volume[a]	Holding Temperatures	Field Holding Time[b]	Shipping Allowance	Laboratory Holding Time[c]
VOCs	SUMMA® Canister	250 ml	0-40 °C	4 days	2 days	28 days

[a] Alternatively, if available headspace is limited, a single 100 ml sample may be collected for determination of VOCs.
[b] From the time of headspace sample collection to shipment.
[c] Programmatic-based maximum holding time. Holding time begins at VTSR.

TABLE C4-2
SUMMARY OF DRUM FIELD QC HEADSPACE SAMPLE FREQUENCIES

QC Samples	Manifold	Direct Canister	On-Line Systems
Field blanks[a]	1 per sampling batch[d]	1 per sampling batch[d]	1 per on-line batch[f]
Equipment blanks[b]	1 per sampling batch[d]	once[e]	1 per on-line batch[f]
Field reference standards[c]	1 per sampling batch[d]	once[e]	1 per on-line batch[f]
Field duplicates	1 per sampling batch[d]	1 per sampling batch[d]	1 per on-line batch[f]

[a]Analysis of field blanks for VOCs (Table C8-2 of Appendix C8), only, is required. For on-line integrated sampling/analysis systems, if field blank results meet the acceptance criterion, a separate on-line blank is not required.

[b]One equipment blank or on-line sample must be collected, analyzed for VOCs (Table C8-2), and demonstrated clean prior to first use of the headspace gas sampling equipment with each of the sampling heads, then at the specified frequency, for VOCs only thereafter. Daily, prior to work, the sampling manifold, if in use, must be verified clean using an OVA.

[c]One field reference standard or on-line control sample must be collected, analyzed, and demonstrated to meet the QAOs specified in Appendix C8 prior to first use, then at the specified frequency thereafter.

[d]A sampling batch is a suite of samples collected consecutively using the same sampling equipment within a specific time period. A sampling batch can be up to 20 samples (excluding field QC samples), all of which must be collected within 14 days of the first sample in the batch.

[e]One equipment blank and field reference standard must be collected after equipment purchase, cleaning, and assembly.

[f]An on-line batch is the number of samples collected and analyzed within a 12-hour period using the same on-line integrated sampling/analysis system.

TABLE C4-3
SUMMARY OF SAMPLING QUALITY CONTROL SAMPLE ACCEPTANCE CRITERIA

QC Sample	Acceptance Criteria	Corrective Action[a]
Field blanks	VOC amounts < 3 x MDLs in Table C8-2 of Appendix C8 for GC/MS and GC/FID; < PRQLs in Table C8-2 for FTIRS	Nonconformance if any VOC amount > 3 x MDLs in Table C8-2 of Appendix C8 for GC/MS and GC/FID; > PRQLs in Table C8-2 for FTIRS
Equipment blanks	VOC amounts < 3 x MDLs in Table C8-2 of Appendix C8 for GC/MS and GC/FID; < PRQLs in Table C8-2 for FTIRS	Nonconformance if any analyte amount > 3 x MDLs in Table C8-2 of Appendix C8 for GC/MS and GC/FID; > PRQLs in Table C8-2 for FTIRS
Field reference standards or on-line control sample	70 - 130 %R	Nonconformance if %R < 70 or > 130
Field duplicates or on-line duplicate	RPD ≤ 25	Nonconformance if RPD > 25

[a]Corrective action is only required if the final reported QC sample results do not meet the acceptance criteria.
MDL = Method detection limit
%R = Percent recovery
RPD = Relative percent difference

TABLE C4-4

SAMPLE HANDLING REQUIREMENTS FOR HOMOGENEOUS SOLIDS AND SOIL/GRAVEL

Parameter	Suggested Quantity[a]	Required Preservative	Suggested Container	Maximum Holding Time[b]
VOCs	15 grams	Cool to 4°C	Glass Vial[c]	14 Days Prep/ 40 Days Analyze[d]
SVOCs	50 grams	Cool to 4°C	Glass Jar[e]	14 Days Prep/ 40 Days Analyze[d]
Polychlorinated Biphenyls (PCBs)	50 grams	Cool to 4°C	Glass Jar[e]	14 Days Prep/ 40 Days Analyze[d]
Metals	10 grams	Cool to 4°C	Plastic Jar[g]	180 Days[h]

[a]Quantity may be increased or decreased according to the requirements of the analytical laboratory, as long as the QAOs are met.
[b]Holding time begins at sample collection (holding times are consistent with SW-846 requirements).
[c]VOA vial, must have septum cap.
[d]40-day holding time allowable only for methanol extract - 14-day holding time for non-extracted VOCs.
[e]Opaque glass container, must have Teflon® lined cap (example, amber jar).
[f]Analysis for PCBs is required only for waste streams in matrix parameter category S3220 (organics sludges).
[g]Polyethylene or polypropylene preferred, glass jar is allowable.
[h]Holding time for mercury analysis is 28 days.

FIGURES

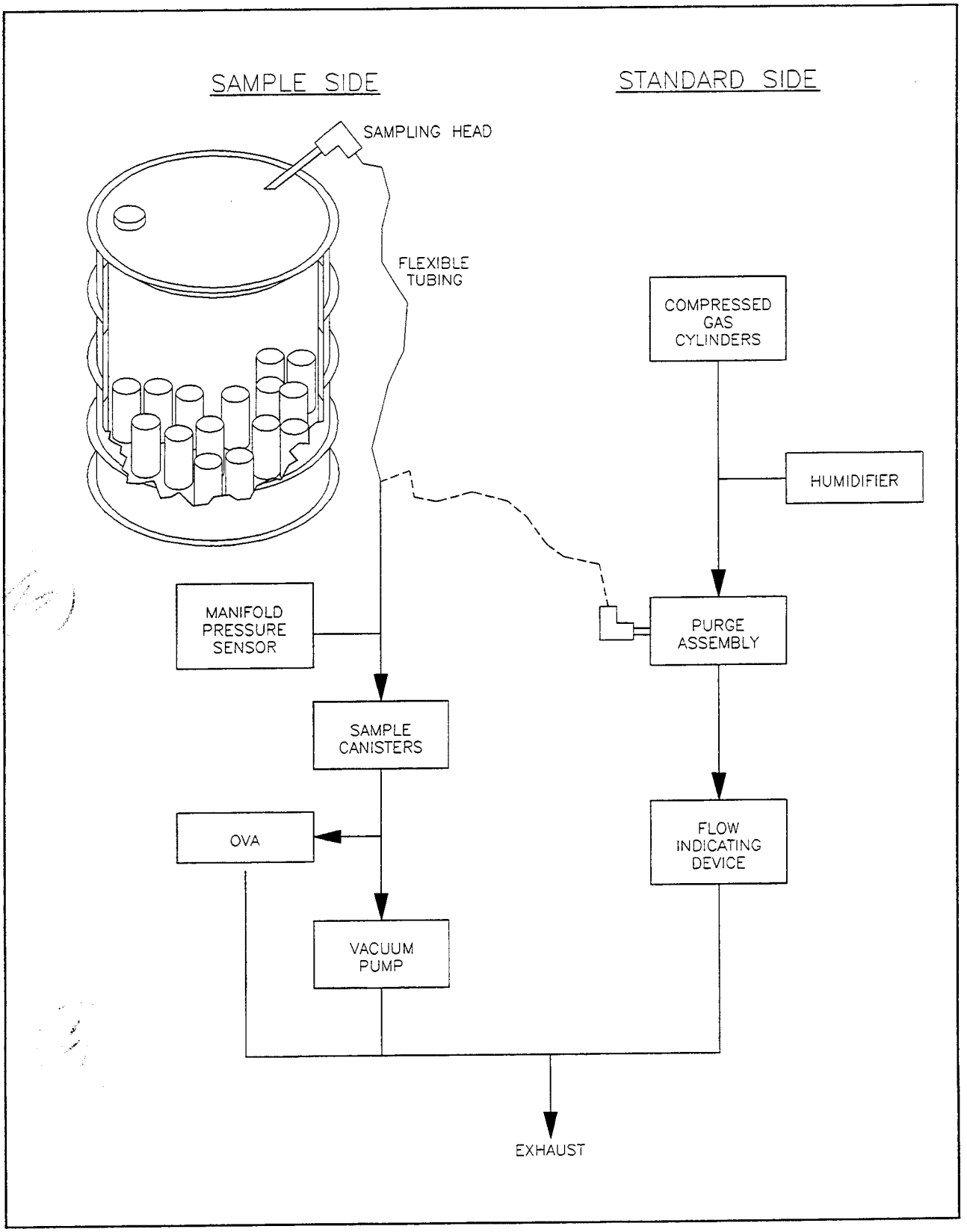


Figure C4-1
Headspace Sampling Manifold

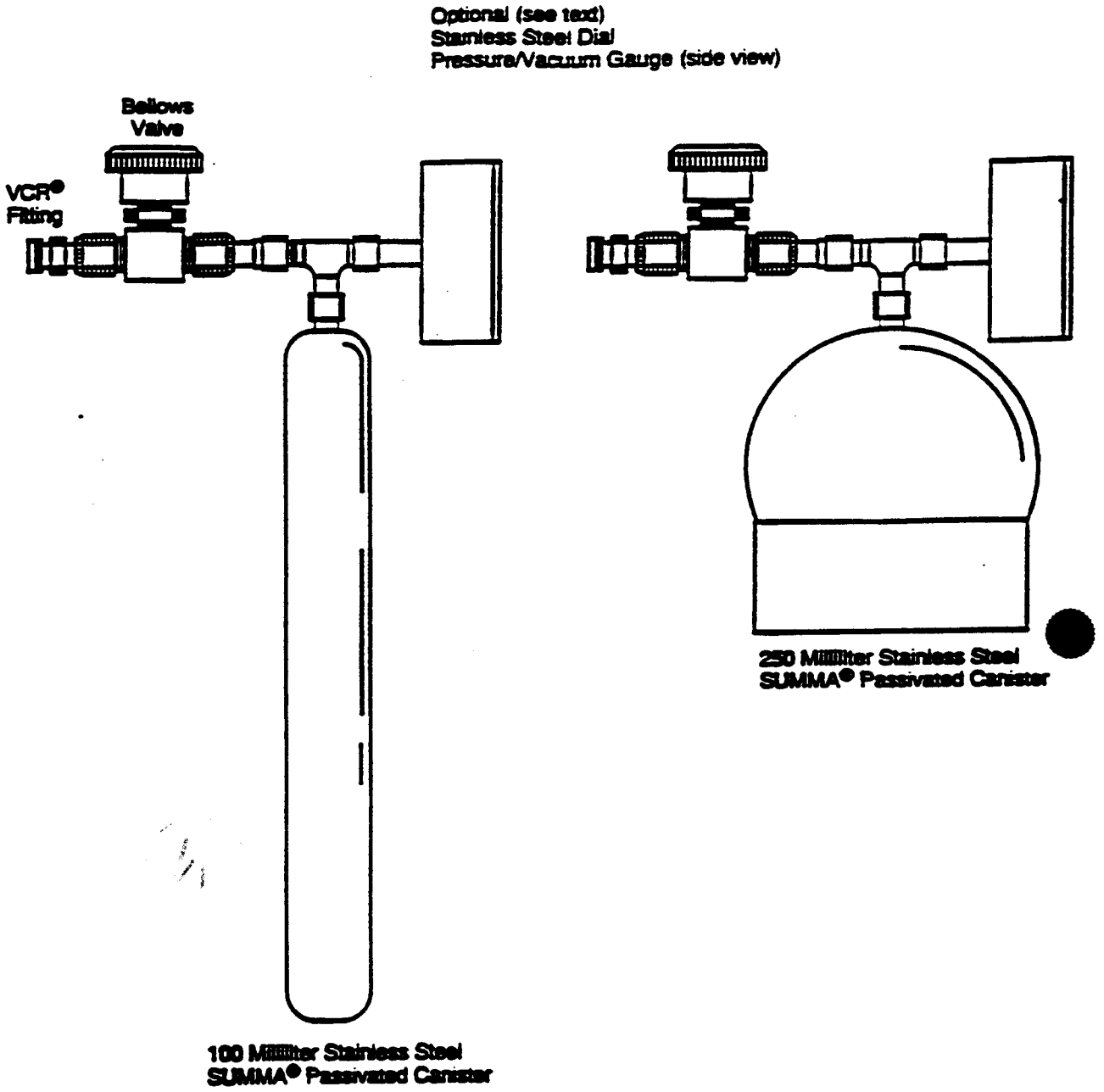


FIGURE C4-2
SUMMA® Canister Components Configuration
(Not to Scale)

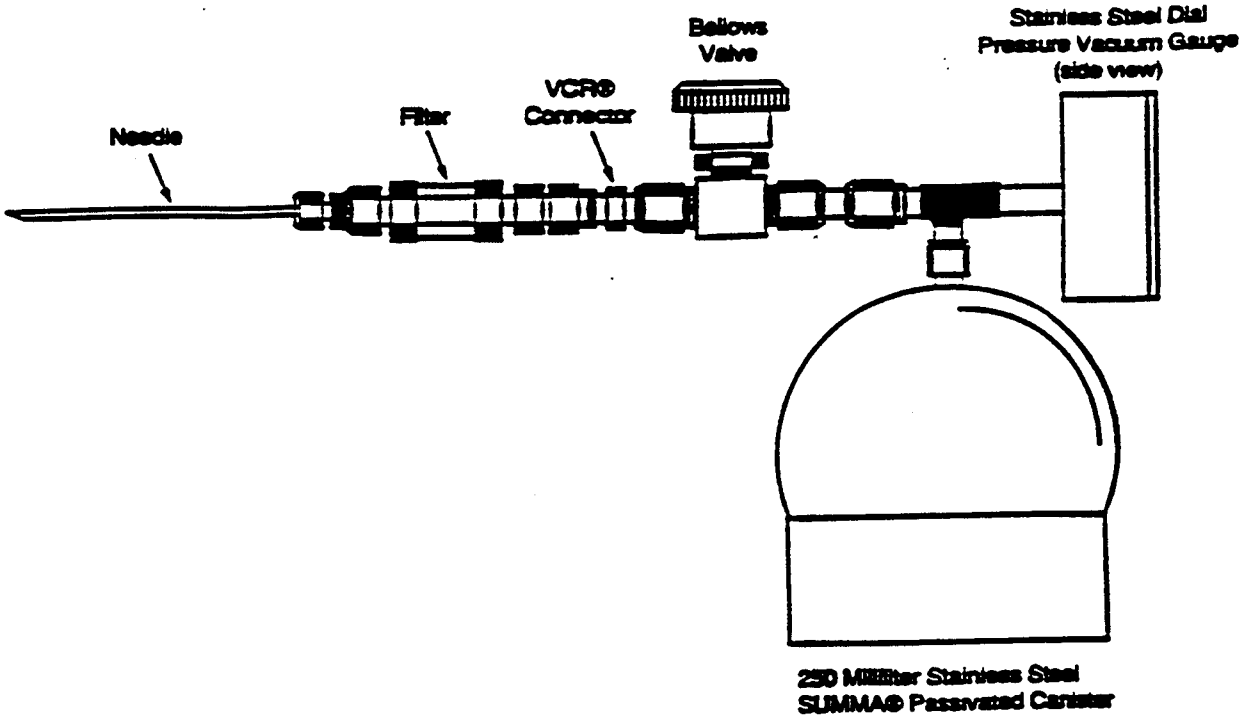
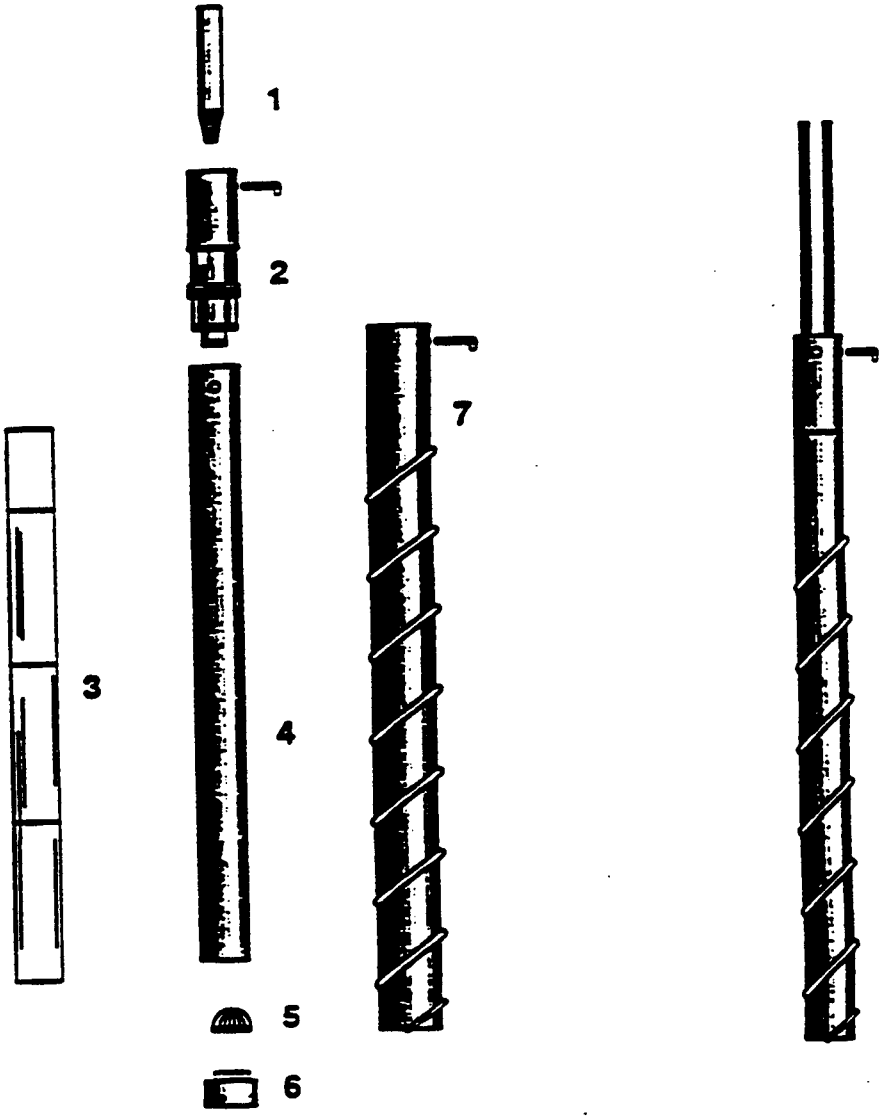
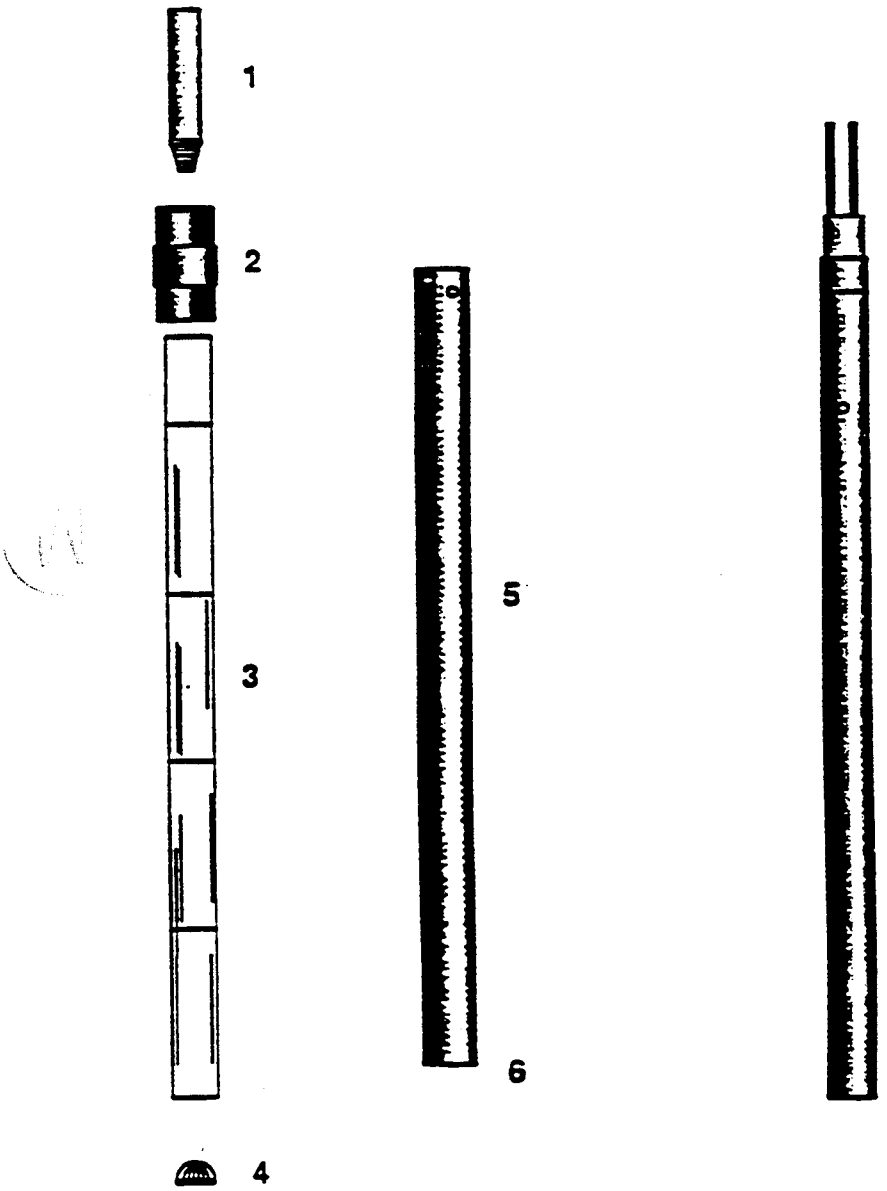


FIGURE C4-3
Schematic Diagram of Direct Canister with the Poly Bag Sampling Head



1 Drill Rod
2 Thrust Bearing Ball Check Valve
3 Clear Teflon® Liners
4 Core Barrel
5 Spring Retainer (optional)
6 Core Barrel Tip
7 Auger and Pin

FIGURE C4-4
Rotational Coring Tool
(Light Weight Auger)



1 Drill Rod
2. Ball Check Valve
3. Clear Teflon® Liners
4. Spring Retainer (optional)
5. Tube
6. Tapered Tip

FIGURE C4-5
Non-Rotational Coring Tool
(Thin Walled Sampler)

APPENDIX C5

APPLICABILITY OF REAL-TIME RADIOGRAPHY

APPENDIX C5
APPLICABILITY OF REAL-TIME RADIOGRAPHY (RTR) [a]

Summary Category Group	Waste Category	Applicable RTR Codes[b]	Waste Description
Homogeneous Solids S3000	Cation and Anion Exchange Resin	A, B, E, G	• Anion and cation exchange resins washed with hot HNO_3 and water then mixed with water and portland cement to form solid mass. Resins are a polystyrene and divinylbenzene copolymer.
Homogeneous Solids S3000	Inorganic Waste Water Treatment Sludge	A, B, E, G, H	• Solidified aqueous waste generated by vacuum filtration of precipitated solids from pretreated aqueous slurry. Filter medium is diatomaceous earth. Wet sludge is solidified with portland cement. • Wet sludge from chemical treatment and mixed with absorbents (i.e., portland cement and Oil-Dri® to absorb free liquid). • Sludges removed from tanks that collected liquid effluent from floor drains; sludge consists of dirt, sand, gravel, floor sweepings, and similar materials; sludges mixed with portland cement. • Sludges removed from tanks that collected liquid effluent from the laundry; sludge consists of lint, spent detergent, and dirt mixed with portland cement. • Cemented inorganic process solids; waste is filter sludge, grit, and firebrick fines, solidified in portland cement. • Cemented or solidified process solids (i.e., grit, firebrick fines, filter sludges, and resins).
Homogeneous Solids S3000	Organic Liquid and Sludge	A, B, E, G	• Waste organic liquid (oil and/or solvents) mixed with gypsum cement (Envirostone®); oils are machining oil and lathe coolant. • Waste organic liquid (oil and/or solvents) mixed with gypsum cement (Envirostone®); oils are machining oil and lathe coolant.

Refer to footnotes at end of table.

APPENDIX C5 (CONTINUED)
APPLICABILITY OF RTR[a]

Summary Category Group	Waste Category	Applicable RTR Codes[b]	Waste Description
Homogeneous Solids S3000	Pyrochemical Salt	A, B, E, G	• Spent chloride salt (combinations of cesium, calcium, magnesium, potassium, and NaCl) from pyrochemical operations.
		A, B, E, F	• Fused halide salt mixtures of NaCl, KCl, and/or $CaCl_2$; some salts also contain $MgCl_2$, CaF_2, CaO.
Homogeneous Solids S3000	Solidified Liquid	A, B, E, G	• Aqueous laboratory wastes that are not compatible with primary aqueous treatment system; waste contains organic acids. Wastes are pH adjusted and solidified by mixing with portland and magnesia cement.
		A, B, E, G, H	• Waste consists of solidified organics that contain plutonium complexing chemicals (i.e., alcohols, organic acids, and chelating agents (EDTA). Liquids mixed with portland cement and magnesia cement.
Solids/Gravel S4000	Soils/Gravel	A, B, C, E, G	• Soil and gravel waste that comprises more than 50% of the waste volume.
Debris Waste S5000	Benelex® and Plexiglas™	A, B, E, G	• Organic solid waste that is noncombustible. Benelex®/Plexiglas™ neutron shielding, black top, concrete, dirt, and sand. • Benelex® and Plexiglas™ glovebox windows. Benelex® (dense laminated, lignocellulose hardboard made from wood chips and particles). Benelex® usually coated with fire retardant paint sometimes had lead sheeting attached to it. Also, leaded glass may be present.
Debris Waste S5000	Combustibles	A, B, C, D	• Solid combustible waste, including paper, rags, cloth, coveralls, plastic, rubber, wood, and other similar material.

Refer to footnotes at end of table.

APPENDIX C5 (CONTINUED)
APPLICABILITY OF RTR[a]

Summary Category Group	Waste Category	Applicable RTR Codes[b]	Waste Description
Debris Waste S5000	Combustibles	A, B, C, E, F	• Combustible solids (dry, damp, or moist), including paper, rags, plastic, surgeon's gloves, coveralls and booties, cardboard, wood, plywood sheeting, filter frames, ladders, bottles, laundry lint, Kimwipes®, canvas, sample vials, respirator face masks, etc.; some waste coated with paint and some contain trace levels of HNO_3.
Debris Waste S5000	Combustibles and Noncombustibles	A, B, C, E, F	• Combustible and noncombustible solids, i.e., dissolved lab samples, absorbed in Oil-Dri®, uranium pellets, plutonium sources, glassware, gloves, Kimwipes®, and used equipment. • Piping, flanges, valves, tools, glasswares, filters, polyethylene bottles, glovebox gloves, paper, and plastics.
Debris Waste S5000	Filters	A, B, C, D OR A, B, E,G	• Frames of filters made of wood or metal and medium is fiberglass or Nomex®-type material. Fulflo® filter cartridges consist of polypropylene plastic. Some filter wastes are processed by the addition of portland cement.
		A, B, C, D	• Absolute filters, high-efficiency particulate air (HEPA) filters, chemical warfare service (CWS) filters, fiberglass and asbestos filter media, asbestos pipe insulation, and asbestos gloves and fire blankets. Filter frames are wood, particle board, or aluminum; filter media either fiberglass or asbestos.
Debris Waste S5000	Firebrick and Ceramic Crucibles	A, B, E, G	• Firebrick, clay absorbent (Oil-Dri®), and insulation. • Leco crucible waste: silicate-based ceramic crucibles and caps. Some contain an accelerator (Fe, Sn, Cu, Tl, stainless steel). • Firebrick wastes consisting of whole or broken pieces of construction bricks, cinderblocks, and incinerator firebrick. Firebrick (high-aluminum/high-strength) composition: Al_2O_3, CaO, Fe_2O_3, MgO, SiO_3, TiO_2, and alkalies.

Refer to footnotes at end of table.

APPENDIX C5 (CONTINUED)
APPLICABILITY OF RTR[a]

Summary Category Group	Waste Category	Applicable RTR Codes[b]	Waste Description
Debris Waste S5000	Glass	A, B, C, E, F	• Glass and ceramic waste including leached Raschig rings, ceramic crucibles, glovebox windows, lab glassware, process equipment, and empty containers.
Debris Waste S5000	Glass (Oil Residue)	A, B, C, E, F	• Unleached glass neutron-absorbing Raschig rings.
Debris Waste S5000	Graphite	A, B, C, E, F	• Broken graphite molds and graphite furnace equipment or graphite chunks and pieces from mold cleaning and declassification. Also discarded lab equipment.
Debris Waste S5000	Leaded Rubber	A, B, C, E, F	• Leaded gloves and aprons comprised of layers of Hypalon® rubber and PbO-impregnated neoprene. Limited amounts of unleaded gloves, lead bricks, and lead sheeting may be included.
Debris Waste S5000	Metal	A, B, C, E, F	• Nonpyrophoric waste metals (iron, copper, aluminum, stainless steel, tungsten, lead, and tantalum). • Beryllium chips. • Billets of Zn-Mg alloy. • Noncompressible and noncombustible items (i.e., filters, metal equipment, furnace brick, metal crucibles, and funnels). Metals are tantalum, tungsten, platinum, and lead. • Metals from small hand tools, valves, trays, clamps, pipes, gloveboxes, furnaces, tanks, respirator filters, control panels, etc.

[a]Remote-handled (RH) transuranic (TRU) waste characterization data requirements will provide the same types of information to the extent that this is consistent with RH TRU waste forms.
[b]Real-Time Radiography (RTR) codes:

A Verification of compliance with packaging requirements.

B Verification of physical waste form identification.

C Verification of Waste Matrix Code.

Refer to footnotes at end of table.

APPENDIX C5 (CONTINUED)
APPLICABILITY OF RTR[a]

D Verification of absence of noncompliant items, including free liquids and compressed gases throughout the volume of the container.

E Verification of absence of free liquids around the perimeter of the container (between drum/liner, liner/poly bag, and poly bag/waste).

F Verification of absence of noncompliant items, including free liquids and compressed gases throughout the volume of the container, conditional on the physical geometry of the waste and the resulting package density (variable void volume).

G Density of the waste may negate RTR examination of the entire container.

H Process knowledge is well defined and precludes introduction of extraneous materials, such as pressure vessels.

NOTE: The use of trade names or brand names in this table does not constitute endorsement by the DOE or its contractors.

APPENDIX C6
STATISTICAL METHODS USED IN SAMPLING AND ANALYSIS

APPENDIX C6
STATISTICAL METHODS USED IN SAMPLING AND ANALYSIS

C6-1 Approach for Statistically Selecting Waste Containers for Visual Inspection

As a Quality Control check on radiography, a statistically selected portion of the certified waste containers must be opened and visually examined. The data from visual examination must be used to verify the matrix parameter category and waste material parameter weights as determined by radiography.

The data obtained from the visual examination must also be used to determine, with acceptable confidence, the percentage of miscertified waste containers. Miscertified containers are those that radiography indicates meet the Waste Isolation Pilot Plant Waste Acceptance Criteria and Transuranic Package Transporter-II Authorized Methods for Payload Control but visual examination indicates do not meet these criteria.

Experience at the Idaho National Engineering Laboratory indicates that two-percent of the radiography-certified waste containers have been miscertified when compared to the results of visual examination (EG&G 1994). Participating sites must use this historical miscertification rate to calculate the number of waste containers that must be visually examined. The miscertification rate must be determined each year based on results of certification activities over a minimum of 12 months. Table C6-1 provides the number of waste containers that must be visually examined for several miscertification rates and waste container population sizes.

Table C6-1 has been developed with the use of an EG&G Idaho, Inc. engineering design file (EG&G 1994). The number of waste containers requiring visual examination will ensure the program is 80-percent confident that if the true miscertification rate is the same as the percent column heading of Table C6-1, and if the indicated number of waste containers is examined, the Upper Confidence Level of 90 percent (UCL_{90}) of the miscertification percentage will be less than 14 percent (i.e., there is only a 10-percent chance that the miscertification rate is greater than 14 percent). If the number of containers listed in Table C6-1 are visually examined, it is simply guaranteed that the UCL_{90} of the miscertification percentage will be less than 14 percent; 14 percent is a worst case. In actuality, when UCL_{90}s have been calculated from sample data, most of them will be much smaller than 14 percent.

For the hypergeometric approach to determining the number of containers to be visually examined, the acceptable level of uncertainty is the estimate of the proportion miscertified (along with the information on the previous percentage miscertified) determines the number of containers that must be examined. The rationale and details of this methodology are discussed below.

In a population of size N, there are M miscertified containers, so the true proportion of the miscertified containers in the population is $M/N = p_{true}$. Since p_{true} (or M) is not known, we wish to estimate it by randomly sampling some of the containers. If in a sample of n containers, x are found to be miscertified, the sample estimate ($\hat{p}$) of the true population proportion p_{true} is:

$$\hat{p} = \frac{x}{n} \tag{C6-1}$$

This value is only an estimate, and as such has some uncertainty associated with it. This uncertainty is quantified by calculating the upper one-sided (1-α) percent confidence limit for p, defined as p_{UCL}. This confidence limit gives the largest value the true proportion could take on and still have a "reasonable" chance (e.g., an $\alpha = 0.10$ probability) of producing x miscertified containers in a sample of n out of N. This upper confidence limit is calculated as:

$$p_{UCL} = \frac{M_{UCL}}{N} \tag{C6-2}$$

where M_{UCL} is the largest value of M such that the probability of observing x or fewer miscertified containers in a sample of size n is less than or equal to α. That is, it is the largest value of M such that the following inequality is true:

$$\sum_{k=0}^{x} \frac{\binom{M}{k}\binom{N-M}{n-k}}{\binom{N}{n}} \leq \alpha \tag{C6-3}$$

where each term in parentheses has the usual combinatorial interpretation. For example:

$$\binom{M}{k} = \frac{M!}{k!\,(M-k)!} \tag{C6-4}$$

Each term in the sum in Equation C6-3 is the hypogeometric probability of observing k miscertified containers in a sample size n from a population of size N in which there are M miscertified containers (and hence the population proportion of miscertified containers is p =M/N). The value M_{UCL} is obtained by substituting different values for M into Equation C6-3 until the largest value satisfying the inequality is found.

Note that in Equation C6-3, the upper confidence limit is dependent on x, the number of miscertifications observed in the sample, as well as on n, the sample size. So, to obtain the required sample size, the values of x that are likely to be seen also need to be considered. Sample size is thus determined by setting a desired upper confidence limit value and then manipulating x and n in Equation C6-3.

C6-2 Approach for Statistically Selecting Waste Containers for Totals Analysis

The statistical approach for characterizing retrievably stored homogeneous solids and soil/gravel waste using sampling and analysis relies on acceptable knowledge to segregate waste containers into relatively homogeneous waste streams. In this way it is reasonable to classify as hazardous or nonhazardous the entire waste stream rather than individual waste containers. Individual waste containers serve as convenient units for characterizing the combined mass of waste from the waste stream of interest. Once segregated by waste stream, random selection and sampling of the waste containers followed by analysis of the waste samples must be performed to ensure that the resulting mean contaminant concentration provides an unbiased representation of the true mean contaminant concentration for each waste stream. The site project manager shall verify that the samples collected from within a waste stream were selected randomly.

The end use of analytical results for retrievably stored homogeneous solids and soil/gravel is for determining the Environmental Protection Agency hazardous waste D-codes that apply to each waste stream. The D-codes are indicators that the waste exhibits the toxicity characteristic for specific contaminants under the Resource Conservation and Recovery Act (RCRA). The RCRA-toxicity determination is made on the basis of sampling and analysis of waste streams and on whether or not the waste stream carries F-codes. If a waste stream carries one or more RCRA F-codes, toxicity characteristic contaminants associated with the F-codes are not included in the RCRA-toxicity characteristic determination. That is, the F-codes take precedence over RCRA-toxicity D-code. Therefore, toxicity characteristics contaminants associated with F-codes(s) for a waste stream must be omitted from all calculations for determining the number of containers to sample. In addition, each toxicity characteristic contaminant associated with the F-code(s) must be excluded from evaluation of analytical results to determine D-codes. Contaminants of interest for the sampling, analysis, and RCRA-toxicity determination of a waste stream, then, excludes contaminants associated with F-codes that have been assigned to the waste stream.

The sampling and analysis strategy is illustrated in Figure C6-1. Preliminary estimates of the mean concentration and variance of each RCRA regulated contaminant in the waste will be used to determine the number of waste containers to select for sampling and analysis. The preliminary estimates will be made by obtaining a preliminary sample from the waste stream or from previous sampling from the waste stream. The applicability of the preliminary estimates to the waste stream to be sampled must be justified and documented. The estimates will be determined in accordance with the following equations:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad \text{(C6-5)}$$

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \qquad \text{(C6-6)}$$

where $\bar{x}$ is the calculated mean and s^2 is the calculated concentration variance, n is the number of samples analyzed, x_i is the concentration determined in the *ith* sample, and *I* is an index from 1 to n.

The ratio of the standard deviation, s, to the mean is called the coefficient of variation (CV); preliminary estimates for CV must be calculated for all contaminants of interest which are described above. The highest CV will be used in determining the number of samples to collect and analyze. Analysis results will then be summarized on a contaminant-specific basis. The calculations for the number of samples to collect and calculations for analysis summaries are described in subsequent paragraphs.

The preliminary estimated concentration mean and associated variance for the contamination with the highest CV among all contaminants of interest must then be used to calculate the number of samples required, n, in accordance with the procedure described in Cochran (1977). As a first approximation, take

$$n_0 = \frac{s^2}{\bar{x}^2 c} \qquad \text{(C6-7)}$$

where s^2 and $\bar{x}$ are the preliminary estimates for the variance and the mean, and

$$c = \frac{r^2}{t^2_{\alpha, n_0-1}} \qquad \text{(C6-8)}$$

where $t_{\alpha,n0-1}$ is the 90th percentile for a t distribution with n_0-1 degrees of freedom. The parameter r is taken as 1.0, which represents a relative error of 100 percent. This choice of r is made in order to obtain the Type I and Type II error rates. This reduces Equation C6-7 to

$$n_0 = \frac{t^2_{\alpha, n_0-1} s^2}{\bar{x}^2} \qquad \text{(C6-9)}$$

Because t_{α,n_0-1} is dependent on n_0, the calculation procedure is iterative. If the ratio of n_0 to the number of containers in the waste stream, N, is appreciable, the number of samples required may be reduced to

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \qquad \text{(C6-10)}$$

The effect of the ratio n_0/N on n in Equation C6-10 depends on n_0. Equation C6-10 should be used for cases where it results in a different number of samples from n_0. All calculations should be rounded up to the nearest integer. A minimum of five containers must be sampled and analyzed in each waste stream. If there are fewer than the minimum or required number of containers in a waste stream, one or more containers must be sampled more than once to obtain the samples of the waste. Otherwise any one container may be selected for sampling only once.

The calculated number of required waste containers will then be randomly sampled and analyzed. If waste container samples for the preliminary mean and variance estimates were randomly collected from the same waste stream lot being examined and were collected and analyzed in the manner required for characterization samples, then these samples may be counted toward meeting the required number. The number of waste containers that must be sampled is dependent on defined levels of acceptable error for the hazardous versus nonhazardous determination, as described below.

C6-3 Upper Confidence Limit

Upon completion of the required sampling, final mean and variance estimates and the UCL_{90} for the mean concentration for each contaminant must be determined. The UCL_{90} for the mean concentration of each contaminant will be calculated in accordance with the following equation:

$$UCL_{90} = \bar{x} + \frac{t_{\alpha,n-1}s}{\sqrt{n}} \qquad \text{(C6-11)}$$

The observed sample CV must be checked against the preliminary estimate for CV used in determining the number of samples to be collected before proceeding. If the observed sample CV is greater than the preliminary estimate for CV, the required number of samples must be recomputed using the observed CV. If the observed sample CV estimate results in greater than 20 percent more required samples, then additional sampling and analysis must occur. Once sufficient sampling and analysis has occurred, the determination of whether the waste stream is RCRA-hazardous or nonhazardous will proceed. The determination will be made with 90 percent confidence. If the UCL_{90} for the mean concentration is less than the regulatory threshold limit, the waste stream will be classified as nonhazardous for this contaminant. If the UCL_{90} is

greater than or equal to the regulatory threshold limit, the waste stream will be classified as hazardous for this contaminant.

C6-4 Justification for Use of the 90 Percent Confidence Limit for RCRA Characterization of Transuranic Waste

A 90 percent confidence limit was determined to be adequate and appropriate for the following reasons:

- The hazardous waste determination is made based on "Total Analysis" of waste as opposed to the Toxicity Characteristic Leaching Procedure. This approach uses the regulatory limits that incorporate assumptions that samples are 100 percent solid (i.e., no moisture content) and contaminants are 100 percent soluble in the extraction fluid. "Total Analysis" also uses a more aggressive extraction procedure (i.e., stronger acids) which more completely solubilize contaminants. This is an inherently conservative approach and waste analyzed by "Total Analysis" methods.

- Regardless of the hazardous or non-hazardous determination associated with any particular waste stream or individual waste container, all contact-handled waste will be handled in the same manner during transportation to and emplacement at the WIPP. All waste will be handled, stored, and disposed in a way that meets the requirements for hazardous waste.

- Waste will not be segregated on the basis of a RCRA hazardous determination for the purpose of handling or disposal, so safety related issues are not a concern for "mis-designated" waste. Emergency response personnel will be adequately equipped to mitigate health and safety concerns associated with hazardous waste.

Simulated hazardous waste determinations using both the 90 percent and 95 percent confidence limits indicate an approximate 60 percent increase in sampling and analysis costs to achieve a 95-percent confidence limit. The Department of Energy considered the consequence of increasing the confidence level from 90 to 95 percent for determining whether or not waste streams exhibit the toxicity characteristic. Calculations show that the number of containers to sample increases from 57 to 70 percent with the increase in confidence.

Calculations used Equation C6-9, which pertains to sampling of retrievably stored homogeneous solids and soil/gravel waste. The factor that changes with confidence level is $t^2_{\sigma, n-1}$, which also changes with the calculated number of containers to sample (n). Therefore, this factor is used to calculate the percent increase in n, for different possible values of n. The finite population factor (Equation C6-10) is not used in these calculations; however, it is not expected to significantly affect the results.

The results are given in Table C6-2. For the values of n between 5 and 500 at 90 percent confidence, increases the range from 57 to 70 percent. The values of n for both 90 and 95 percent confidence are given in the table so the number of containers required to be sampled can be directly compared. Because of the formulation for calculating the required number of containers to sample, the tabled values do not depend on the number of containers in the waste stream. The number of containers to sample reflects variabilities of constituent concentrations observed in the waste stream; in particular, it reflects the maximum ratio of standard deviation to mean concentration, which is the maximum coefficient of variation. For example, for a waste stream of any size that has a coefficient of variation of 0.918, the required number of containers to sample increases 60 percent from 5 for 90 percent confidence to 8 for 95 percent confidence.

C6-5 Control Charting for Newly Generated Waste Stream Sampling

Significant process changes and process fluctuations can be determined using statistical process control (SPC) charting techniques; these techniques require historical data for determining limits for indicator species, and subsequent periodic sampling to assess process behavior relative to historical limits. SPC may be performed on waste prior to solidification or packaging for ease of sampling. If the limits are exceeded, the waste stream must be recharacterized, and the characterization must be performed according to procedures required in the Transuranic Waste Characterization Quality Assurance Program Plan for retrievably stored waste.

A Shewhart control chart (Gilbert, 1987) is a control chart for means that can be used for checking whether current data are consistent with past data and whether shifts or trends in means have occurred. The control chart for means is constructed of a center line and upper and lower control limits that are based on the mean and standard deviation of historical data for the process. If a current sample mean from the process lies within the limits, the process is said to be "in control", or consistent with historical data. If the current mean exceeds the limits, the process has likely changed from historical periods.

Logical sets of historical data to be used for the construction of limits in this application are the data from the initial characterization of the waste stream, if available, from characterization of a different lot of the waste stream, or from a retrievably stored waste stream of the same type from the same process. The data used for construction of the limits must be justified. The underlying assumptions for control charts are that the data are independent and normally distributed with constant mean μ and constant variance σ^2. The statistical tests for normality must be conducted and data transformation to normality performed, if necessary. Transformations must take place prior to any calculations that use the data.

Each limit will be constructed such that there is a 90 percent confidence that the true mean does not exceed a limit. One-sided control limits are used because once a waste stream has been determined to be RCRA-hazardous, the limit exceedence of interest is on the lower side; that is when the process may become nonhazardous. Likewise, once a waste stream has been determined to be RCRA-hazardous, the limit exceedence of interest is on the upper side; that

is when the process may become RCRA-hazardous. Whether or not exceeding the limit would result in a change in the RCRA-hazardous nature of the waste stream depends on how close the limits are to RCRA limits.

Current process data will be collected and averaged for comparison to the control limit for the mean. The collection period and number of samples to be included in the average are dependent on the waste stream characteristics. A small number of samples will reflect more of the process variability and there will potentially be more limit exceedence. If two or three samples are collected for the mean in the required annual (or batch) sampling of a relatively homogeneous waste stream, limit exceedences may not occur. If the waste stream is more variable, it will be necessary to collect more samples to meet the required confidence limit.

Periodically it will be necessary to update the control limit for a process. An update is performed that includes all historical data if there is no evidence of a trend in the process or a shift in the mean for the process. If there has been a shift in the mean, only more recent data that reflects the shift is used. In general, control limits should be based on at least ten data points that are representative of the process and do not exhibit outliers or a trend with time.

REFERENCES

Cochran, William G. 1977. *Sampling Techniques.* New York, New York, John Wiley & Sons: pp.77-78.

EG&G. 1994. *Description of the SWEPP Certified Waste Sampling Program for FY-94.* Engineering Design File, RWMC-363, Revision 6, Idaho Falls, Idaho, EG&G - Idaho Inc., Idaho National Engineering Laboratory.

Gilbert, Richard O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* New York, Van Nostrand Reinhold.

TABLES

TABLE C6-1
NUMBER OF WASTE CONTAINERS REQUIRING VISUAL EXAMINATION

Annual Number of Waste Containers Undergoing Characterization	Number of Waste Containers Requiring Visual Examination Based on Percent of Waste Containers Miscertified to WIPP-WAC by Radiography in Previous Year(s)					
	1%	2%	3%	4%	5%	6%
50	22[a]	22	22[a]	22	29[a]	29
100	15	24	24	33	33	41
200	15	26	26	35	44	52
300	15	26	26	35	44	53
400	15	26	26	36	45	62
500	16	26	26	36	45	63

[a]Number of containers for the higher even-number percent of miscertified containers is used because an odd percent implies a noninteger number of containers are likely to be miscertified.

TABLE C6-2

PERCENT INCREASE IN NUMBER OF CONTAINERS (*n*) TO SAMPLE WITH INCREASE IN CONFIDENCE FROM 90 PERCENT TO 95 PERCENT

n for 90 Percent Confidence	n for 95 Percent Confidence	Approximate Percent Increase
5	8	60.00
6	10	66.67
7	11	57.14
8	13	62.50
9	15	66.67
10	17	70.00
25	41	64.00
100	165	65.00
500	824	64.80

Note: Finite population factor not accounted for.

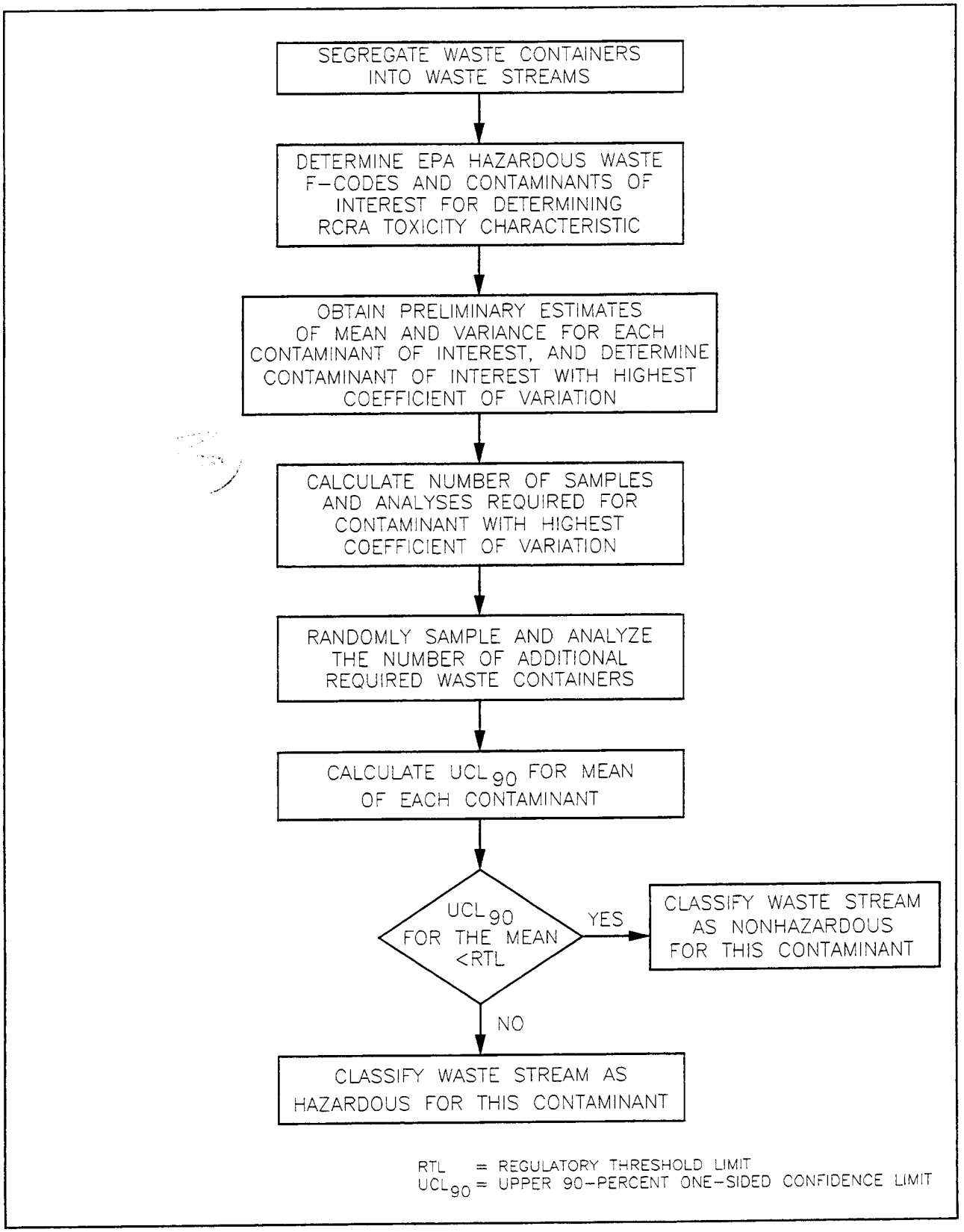


Figure C6-1

Statistical Approach to Sampling and Analysis of Waste Streams of Retrievably Stored Homogenous Solids and Soil/Gravel

APPENDIX C7
SUBMITTAL AND APPROVAL OF ALTERNATIVE TRU WASTE CHARACTERIZATION ANALYTICAL METHODS

APPENDIX C7

SUBMITTAL AND APPROVAL OF ALTERNATIVE TRU WASTE CHARACTERIZATION ANALYTICAL METHODS

C7-1 Purpose and Scope

The National Transuranic Program (NTP) Organization provides the *Transuranic Waste Characterization Sampling and Analysis Methods Manual* (Methods Manual) (DOE 1995a) for use when characterizing transuranic (TRU) waste. However, the NTP recognizes that new or modified techniques may be needed to meet performance objectives for specific wastes and to minimize waste generation associated with sampling and analysis. The NTP has developed a written procedure for guidance to the analytical laboratories at the generator site who want to submit an alternative analytical method for approval by the NTP.

The procedure provides an initial approval process, a list of minimum performance data required for approval of the alternative method verification, and the process of method acceptance. It includes method format specifications, documentation, and supporting data required as part of requests for alternative method approval.

The *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP) (DOE 1995b) establishes a performance based program where quality assurance objectives (QAO) are defined for all analytes. The Methods Manual contains approved methods with demonstrated performance data that meet the QAOs and should be used if possible. The TRU Waste Characterization Interface Working Group (WCIWG) is responsible for the review and recommendation of alternative methods to the NTP (DOE 1995c). Final approval of alternative methods will not be granted unless the QAOs described in the QAPP have been met.

C7-2 Preliminary Approval

The preliminary approval process is used to screen the number of alternative methods requiring review and approval. The approval must be obtained in the planning and initial testing stages of the method development process to avoid duplication of efforts and conserve time and resources. To obtain the preliminary approval, the author must submit a written description of the method, with justification and supporting documentation, to the NTP Waste Characterization Manager at the Department of Energy Carlsbad Area Office (DOE/CAO).

The method description must be complete enough so that the technical applicability can be assessed. Any limitations of the method must be clearly stated. Criteria for appropriate justifications are: 1) previous analytical data supporting the fact that existing or approved methods cannot be used (e.g., a radioisotope creates an interference), 2) data supporting the fact that an approved method cannot meet the QAOs for a specific matrix, or 3) information demonstrating that an alternative analytical method offers a distinct advantage over the approved methods, such as waste minimization, reduction of analytical time, or reducing worker radiation exposure.

When submitting justification statements in cases of waste matrix interferences that prohibit compliance with required QAOs, the author must demonstrate with supporting data that: 1) the laboratory personnel can satisfactorily analyze other less complex matrices (e.g., water) using an existing approved method, 2) the analyte or matrix interferences from the specific waste is the cause for nonconformance with the QAOs, and 3) there is sufficient evidence from literature or other studies that support the potential use of this alternative method for this waste.

A description of the method will be posted on the WCIWG bulletin board in the Analytical and Test Methods Development Forum to enable the review committee to seek input from other sites. In addition, other sites may comment with supporting data or additional information that will aid the review committee.

C7-3 Required Elements of Alternative Methods

When a method is submitted for approval, all twelve sections of the method, as presented in the Methods Manual, must be included. Tables, figures, flowcharts, equations, units, nomenclature, and references must be clearly labeled and follow the Methods Manual format. The performance criteria must apply to at least one matrix, and the actual method must have been successfully tested on simulated or actual waste samples.

Minimum performance data, demonstrating compliance with the requirements of the QAPP, must be provided for each waste matrix for which the method is to be used that consists of:

- A detection limit study including the statistical method for calculation (seven spiked replicates)
- A precision and bias study using spike and replicate samples of the matrix of interest or similar matrix
- A method blank study using reagents and equipment to ensure contamination will not be a problem
- Data demonstrating the QAPP QAOs are met for accuracy and precision (spike, duplicate, and replicate measurements)
- An interference study using waste matrix spikes

C7-4 Final Approval

A review committee for review and approval of proposed methods will be assembled by the WCIWG chairperson. The review committee will be composed of individuals with expertise in the field of the proposed method. The review process includes determining the applicability of the method; reviewing the performance data, quality control sample requirements, and acceptance criteria, bias and interferences; and checking the equations and calculations. The data that demonstrate results, sensitivity, and repeatability also will be reviewed and checked for accuracy and completeness.

A formal comment and response process will be documented to provide for the clarification of issues relating to the methods and performance data. This also ensures that methods undergo a comparable review process and obtain equal consideration. In some cases, additional performance information, Quality Control data, or more investigation will be required before approval. In other cases, the method may not be approved because the QAOs were not met. In either situation, the method author is allowed one written challenge to the WCIWG review committee's decision.

After the method has undergone WCIWG committee review, all reviewer's comments have been satisfactorily resolved, and the final changes have been made to the method, the method is submitted to the DOE/CAO Quality Assurance Manager for concurrence. After concurrence, the method will be submitted to the DOE/CAO Regulatory Compliance Manager for review and approval. The DOE/CAO Regulatory Compliance Manager will submit the proposed method to the New Mexico Environment Department (NMED) for concurrent review. Upon completion of its review of the proposed method, the NMED must provide a written statement that the method is acceptable, or written comments to the DOE/CAO Regulatory Compliance Manager. The DOE/CAO Regulatory Compliance Manager will notify in writing the WCIWG chairperson regarding whether the method can or cannot be used for TRU waste characterization. Methods approved by both the DOE/CAO Regulatory Compliance Manager and the NMED will be incorporated into the Methods Manual. Methods not approved by the DOE/CAO Regulatory Compliance Manager or found unacceptable by the NMED will not be incorporated into the Methods Manual until all comments have been resolved. Also, the availability of approved, alternative methods will be posted on the WCIWG electronic bulletin board in the TRU Waste Characterization Methods Manual Protocols Forum (DOE 1995d). As additional performance data are generated, these data are also made available through the bulletin board to ensure the most current information is available to the generator sites. Records associated with this review and approval process will be kept on file by the DOE/CAO and will be available for review.

C7-5 References

DOE. 1995a. *Transuranic Waste Characterization Sampling and Analysis Methods Manual.* DOE/WIPP-91-043, Current Revision, Carlsbad, New Mexico, Carlsbad Area Office, U.S. Department of Energy.

DOE. 1995b. *Transuranic Waste Characterization Quality Assurance Program Plan.* CAO-94-1010, Revision 0, Carlsbad, New Mexico, Carlsbad Area Office, U.S. Department of Energy.

DOE. 1995c. *Waste Characterization Interface Working Group Charter.* Carlsbad, New Mexico, Carlsbad Area Office National Transuranic Program, U.S. Department of Energy.

DOE. 1995d. *TRU Waste Characterization Interface Working Group Communications Plan.* May, 1995, Carlsbad, New Mexico, Carlsbad Area Office, U.S. Department of Energy.

APPENDIX C8

QUALITY ASSURANCE OBJECTIVES AND DATA VALIDATION TECHNIQUES FOR WASTE CHARACTERIZATION SAMPLING AND ANALYTICAL METHODS

APPENDIX C8
QUALITY ASSURANCE OBJECTIVES FOR WASTE CHARACTERIZATION SAMPLING AND ANALYTICAL METHODS

C8-1 Validation Methods

Validation of all data (qualitative as well as quantitative) shall be performed so that data used for Waste Isolation Pilot Plant (WIPP) compliance programs will be of known and acceptable quality. Validation includes a quantitative determination of precision, accuracy, completeness, comparability, and method detection limit (as appropriate) for analytical data (headspace Volatile Organics Compounds (VOC) and total VOCs, Semivolatile Organic Compounds (SVOC), and metals data). Quantitative data validations shall be performed by the data generation level Quality Assurance (QA) officer according to the conventional methods outlined below (equations C8-1 through C8-8). These quantitative determinations will be compared to the Quality Assurance Objectives (QAOs) specified in Sections C8-2 through C8-9. A qualitative determination of representativeness will also be performed.

The qualitative data or descriptive information generated by radiography is not amenable to statistical analysis. However, radiography and visual examination are complementary techniques yielding similar data for determining the waste matrix code and waste material parameter weights of waste present in a waste container. Therefore, visual examination results shall be used to verify the waste matrix code and waste material parameter weights determined by radiography.

Representativeness of waste containers from waste streams subjected to visual examination and homogeneous solids and soil/gravel sampling and analysis will be validated, through documentation, that a true random sample was collected. Since representativeness is a quality characteristic that expresses the degree to which a sample or group of samples represents the population being studied, the random selection of waste containers ensures representativeness on a Program level. The Site Project Manager shall document that the selected waste containers from within a waste stream were randomly selected. Sampling personnel shall verify that proper procedures are followed to ensure that samples are representative of the waste contained in a particular waste container or a waste stream.

Precision

Precision is a measure of the mutual agreement among multiple measurements of a single analyte, either by the same method or by different methods. Precision is either expressed as the relative percent difference (RPD) for duplicate measurements or as the percent relative standard deviation (%RSD) for three or more replicate measurements. For duplicate measurements, the precision expressed as the RPD is calculated as follows:

$$RPD = \frac{C_1 - C_2}{\frac{(C_1 + C_2)}{2}} \times 100 \qquad \text{(C8-1)}$$

where C_1 and C_2 are the two values obtained by analyzing the duplicate samples. C_1 is the larger of the two observed values.

For three or more replicate measurements, the precision expressed as the %RSD is calculated as follows:

$$\%RSD = \frac{s}{\bar{y}} \times 100 \qquad \text{(C8-2)}$$

where s is the standard deviation and $\bar{y}$ is the mean of the replicate sample analyses.

The standard deviation, s, is calculated as follows:

$$s = \sqrt{\sum_{i=1}^{n} \frac{(y_i - \bar{y})^2}{n - 1}} \qquad \text{(C8-3)}$$

where y_i is the measured value of the ith replicate sample analysis measurement, and n equals the number of replicate analyses.

Another aspect of precision is associated with analytical equipment calibration. In these instances, the percent difference (%D) between multiple measurements of an equipment calibration standard shall be calculated as follows:

$$\%D = \left|\frac{C_1 - C_2}{C_1}\right| \times 100 \qquad \text{(C8-4)}$$

where C_1 is the initial measurement and C_2 is the second or other additional measurement.

Accuracy

Accuracy is the degree of agreement between a measured analyte concentration (or the average of replicate measurements of a single analyte concentration) and the true or known concentration. Accuracy is determined as the percent recovery (%R).

For situations where a standard reference material is used, the %R is calculated as follows:

$$\%R = \frac{C_m}{C_{srm}} \times 100 \qquad \text{(C8-5)}$$

where C_m is the measured concentration value obtained by analyzing the sample and C_{srm} is the "true" or certified concentration of the analyte in the sample.

For measurements where matrix spikes are used, the %R is calculated as follows:

$$\%R = \frac{S - U}{C_{sc}} \times 100 \qquad \text{(C8-6)}$$

where S is the measured concentration in the spiked aliquot, U is the measured concentration in the unspiked aliquot, and C_{sc} is the actual concentration of the spike added.

Method Detection Limit

The method detection limit (MDL) is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. The MDL for all quantitative measurements (except for those using Fourier Transform Infared Spectroscopy [FTIRS]) is defined as follows:

$$MDL = t_{(n-1,1-\alpha=.99)} \times s \qquad \text{(C8-7)}$$

where $T_{(n-1,1-\alpha=.99)}$ is the t-distribution value appropriate to a 99 percent confidence level and a standard deviation estimate with n-1 degrees of freedom, n is the number of observations, and s is the standard deviation of replicate measurements.

For headspace-gas analysis using FTIRS, MDL is defined as follows:

$$\mathbf{MDL = 3s} \qquad \text{(C8-8)}$$

where s is the standard deviation. Initially, a minimum of seven samples of ambient air or seven blanks must be used to establish the MDLs. MDLs should be constantly updated using the results of the laboratory control sample or on-line control sample.

Completeness

Completeness is a measure of the amount of valid data (i.e., data that meets all Quality Assurance/Quality Control (QA/QC) requirements) obtained from the overall measurement system compared to the amount of data collected and submitted for analysis. Completeness must be expressed as the number of samples analyzed with valid results as a percent of the

total number of samples submitted for analysis. Completeness, expressed as the percent complete (%C), is calculated as follows:

$$\%C = \frac{V}{n} \times 100 \qquad \text{(C8-9)}$$

where V is the number of valid analytical results obtained and n is the number of samples submitted for analysis.

Comparability

Comparability is the degree to which one data set can be compared to another. Comparability of data generated at different sites will be assured through the use of standardized, approved testing, sampling, and analytical techniques and by meeting the QAOs specified in Sections C8-2 through C8-9. The techniques presented in Sections C8-2 through C8-9 are provided in detail in the Quality Assurance Program Plan (QAPP) and in the Transuranic Waste Characterization Sampling and Analysis Methods Manual (Methods Manual) (DOE,1995).

Representativeness

Representativeness is the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter that concerns the proper design of the sampling program.

C8-2 Headspace-Gas Sampling

Quality Assurance Objectives

Headspace-gas sampling may occur from three areas within drums of transuranic (TRU) waste (see Figure C6-1): 1) the drum headspace (i.e., the headspace directly under the drum lid), 2) the 55-gallon (gal) (208-liter [L]) polyethylene (poly) bag headspace, and 3) the headspace of the innermost layers of confinement. The precision and accuracy of the drum headspace-gas sampling operations must be assessed by analyzing field QC headspace-gas samples. These samples must include equipment blanks, field reference standards, field blanks, and field duplicates. If the QAOs described below are not met, a nonconformance report must be prepared, submitted, and resolved.

Precision

The precision of the headspace-gas sampling and analysis operation must be assessed by simultaneous collection of field duplicates for VOCs determination. Corrective actions must be taken if the RPD exceeds 25 percent.

Accuracy

A field reference standard must be collected using headspace-gas sampling equipment to assess the accuracy of the headspace-gas sampling operation. Corrective action must be taken if the %R of the field-reference standard is less than 70 or greater than 130.

Completeness

Sampling completeness shall be expressed as the number of valid samples collected as a percent of the total number of samples collected. Participating sampling facilities must achieve a minimum 90 percent completeness. The amount and type of data that may be lost during the headspace-gas sampling operation cannot be predicted in advance. The importance of any lost or contaminated headspace-gas samples must be evaluated by the Site Project QA Officer, and corrective action must be taken as appropriate.

Comparability

Consistent use and application of uniform procedures and equipment, as specified in the Methods Manual, should ensure that headspace gas sampling operations are comparable when sampling different layers of confinement and at the different sampling facilities.

Representativeness

Specific headspace-gas sampling steps to ensure samples are representative include:

- A sample canister cleaning and leak check
- Sampling equipment cleaning or disposal after use
- Sampling equipment leak check
- Use of sample canisters with passivated internal surfaces
- Use of low-internal-volume sampling equipment
- Collection of small-sample volume: low-sample volume to available headspace volume ratio
- Careful pressure regulation
- Performance audits
- Collection of equipment blanks, field reference standard, field blanks, and field duplicates

C8-3 Sampling of Homogenous Solids and Soils/Gravel

Quality Assurance Objectives

To ensure that sampling is conducted in a representative manner on a waste-stream basis for waste containers containing homogenous solids and soil/gravel, samples must be collected randomly in both the horizontal and vertical planes of each container's waste. For waste containers that contain homogenous solids and soil/gravel in smaller containers (e.g., 1 gal [4.0 L] poly bottles) within the waste container, one randomly chosen smaller container must be sampled.

Precision

Sampling precision must be determined by collecting and sampling field duplicates (e.g., co-located cores as described in Appendix C4-2.2) once per sampling batch or once per week during sampling operations, whichever is more frequent. A sampling batch is a suite of homogenous solids and soil/gravel samples collected consecutively using the same sampling equipment within a specific time period. A sampling batch can be up to 20 samples (excluding field QC samples), all of which must be collected within 14 days of the first sample in the batch. The RPD between co-located samples must be calculated and reported by the Site Project QA Officer.

The recommended method for establishing acceptance criteria for co-located cores is development of control charts for the RPD in the cores. Control charts will be developed for each constituent and for each waste matrix or waste type (e.g., pyrochemical salts or organic sludges), as needed, using historical analysis results. The historical analysis results currently do not exist, but would be collected over the course of future waste characterization activities. RPDs for at least 25 to 30 pairs of co-located cores would be used in the construction of the control charts. The limits for the control chart will be three standard deviations above or below the average RPD. Once constructed, RPDs for additional co-located pairs will be compared with the control chart to determine whether or not the co-located cores are acceptable. Periodically, the control charts will be updated using all available data.

In order to establish acceptance criteria to be used at the beginning of waste characterization activities, the variance between co-located cores will be compared to the variance measured within the waste stream (exclusive of containers with co-located core measurement) using a statistical test. The test will be performed for each constituent in each waste stream. The test is not considered sensitive and is presented as an interim method until the preferred method of control charting is established. Because of the expected difference between the co-located core variance and the waste stream variance, the test will rarely reject the hypothesis that the co-located core variance is less than the waste stream variance. However, without sufficient data to develop control charts and without established acceptance criteria for field duplicates (i.e., as specified by SW-846), the interim method is a reasonable approach for evaluating co-located cores.

The statistical test will involve calculating the variance for co-located cores by pooling the variances computed for each pair of co-located cores. The variance for the waste stream will be computed excluding any data from drums with co-located cores, because the test requires

the variance estimates to be independent. All data must be transformed to normality prior to computing variances and performing the test. The test hypothesis is evaluated using the F distribution and the method for testing the difference in variances. The method will be replaced with the control charting method once sufficient data are available.

Accuracy

Sampling accuracy shall not be measured. Because waste containers containing homogenous solids and soil/gravel with known quantities of analytes are not available, sampling accuracy cannot be determined. However, sampling methods and requirements described are designed to minimize sample degradation and hence maximize sampling accuracy.

Completeness

Sampling completeness shall be expressed as the number of valid samples collected as a percent of the total number of samples collected. Participating sampling facilities must achieve a minimum 90 percent completeness.

Comparability

Consistent use and application of uniform procedures, sampling equipment, and measurement units must ensure that sampling operations are comparable. The analysis results of field duplicates (samples taken of the same medium, under the same conditions, using the same procedures) are examined to determine the comparability. In addition, laboratories analyzing samples must participate in the Performance Demonstration Program (PDP).

Representativeness

Specific steps to ensure the representativeness of samples include the following for both waste containers and smaller containers:

- Coring tools and sampling equipment must be clean prior to sampling.
- The entire depth of the waste must be cored, and the core collected must have a length greater than or equal to 50 percent of the depth of the waste. This is called the core recovery and is calculated as follows:

$$\textit{Core recovery (percent)} = \frac{y}{x} * 100 \qquad \text{(C8-10)}$$

where

x = the depth of the waste in the container
y = the length of the core collected from the waste.

- Coring operations and tool selection should be designed to minimize alteration of the in-place waste characteristics. Minimal waste disturbance must be verified by visually examining the core and describing the observation (e.g., undisturbed, cracked, or pulverized) in the field logbook.

If core recovery is less than 50 percent of the depth of the waste, a second coring location shall be randomly selected. The core from the second location shall be used for sample collection regardless of the core recovery.

$$MDC = K_1 K_2 (2.71 + 4.65 * s_b) \qquad \text{C8-11}$$

C8-4 Radiography

Quality Assurance Objectives

The QAOs for radiography are detailed in this section. If the QAOs described below are not met, then corrective action, such as additional operator training must be taken. It should be noted that radiography does not have a specific MDL because it is primarily a qualitative determination. The objective of radiography for the program is to verify the waste matrix parameters for each waste container and to estimate each waste material parameter weight (Table C8-1). All activities required to achieve these objectives must be described in the site quality assurance project plan (QAPjP) and standard operating procedures (SOP).

Data to meet these objectives must be obtained from an audio/videotaped scan provided by trained radiography operators at the sites. Results must also be recorded on a radiography data form. The precision, accuracy, completeness, and comparability objectives for radiography data are presented below.

Precision

The qualitative determinations, such as verifying the waste matrix code, made during radiography do not lend themselves to statistical evaluation of precision. However, comparison of data derived from radiography and visual examination on the same waste containers at the Rocky Flats Environmental Technology Site and the Idaho National Engineering Laboratory indicates that radiography operators can provide estimated inventories and weights of waste items in a waste container. As a measure of precision, the Site Project QA Officer shall calculate and report the RPD between the estimated waste material parameter weights as determined by radiography and these same parameters as determined by visual examination.

Accuracy

The accuracy with which the waste matrix code and waste material parameter weights can be determined must be documented through visual examination of a randomly selected statistical portion of waste containers. The percentage of waste containers that require assignment to a

different waste matrix code after visual examination must be calculated and reported by the Site Project QA Officer as a measure of radiography accuracy.

Completeness

An audio/videotape of the radiography examination and a validated radiography data form will be obtained for 100 percent of the retrievably stored waste containers in the program.

Comparability

The comparability of radiography data from different sites shall be enhanced by using standardized radiography procedures and operator qualifications.

C8-5 Gas Volatile Organic Compound Analysis

Quality Assurance Objectives

The development of data quality objectives (DQO) specifically for this program has resulted in the QAOs listed in Table C8-2. The specified QAOs represent the required quality of data necessary to draw valid conclusions regarding program objectives. Program-required limits, such as the program required quantitation limits (PRQL) associated with VOC analysis, are specified to ensure that the analytical data collected satisfy the requirements of all data users. A summary of the Quality Control Samples and the associated acceptance criteria is included in Table C8-3. Key data-quality indicators for laboratory measurements are defined below.

Precision

Precision shall be assessed by analyzing laboratory duplicates and replicate analyses of laboratory-control samples and PDP blind-audit samples. Results from measurements on these samples must be compared to the criteria listed in Table C8-2. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Accuracy

Accuracy as %R shall be assessed for the laboratory operations by analyzing PDP blind audit samples and laboratory-control samples. Results from these measurements must be compared to the criteria listed in Table C8-2. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Method Detection Limit

MDLs shall be expressed in nanograms for VOCs and must be less than or equal to those listed in Table C8-2. MDLs shall be determined based on the method described in the QAPP. The detailed procedures for MDL determination shall be included in site SOPs.

Program Required Quantitation Limit

Laboratories must demonstrate the capability to quantitate analytes at or below the PRQLs given in Table C8-2. Laboratories shall set the concentration of at least one calibration standard below the PRQL. The detailed procedures for PRQL demonstration shall be included in laboratory SOPs.

Completeness

Laboratory completeness shall be expressed as the number of samples analyzed with valid results as a percent of the total number of samples submitted for analysis. Participating laboratories must meet the completeness specified in Table C8-2.

Comparability

For VOC analysis, data generated through analysis of samples from different sites shall be comparable. Comparability will be achieved by using standardized methods and traceable standards and by requiring all sites to participate in the PDP.

Representativeness

Representativeness for VOC analysis shall be achieved by collecting sufficient numbers of samples using clean sampling equipment that does not introduce sample bias. Samples must be collected as described in Appendix C4.

C8-6 Total Volatile Organic Compound Analysis

Quality Assurance Objectives

The development of DQOs specifically for this program has resulted in the QAOs listed in Table C8-4. The specified QAOs represent the required quality of data necessary to draw valid conclusions regarding program objectives. Program-required limits, such as the PRQL associated with VOC analysis, are specified to ensure that the analytical data collected satisfy the requirements of all data users. Key data-quality indicators for laboratory measurements are defined below.

Precision

Precision shall be assessed by analyzing laboratory duplicates, replicate analyses of laboratory-control samples, matrix-spike duplicates, and PDP blind-audit samples. Results from measurements on these samples must be compared to the criteria listed in Table C8-4. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Accuracy

Accuracy as %R shall be assessed for the laboratory operations by analyzing laboratory control samples, matrix spikes, surrogate compounds, and PDP blind-audit samples. Results from these

measurements must be compared to the criteria listed in Table C8-5. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Method Detection Limit

MDLs shall be expressed in milligrams per kilogram (mg/kg) for VOCs and must be less than or equal to those listed in Table C8-4. The detailed procedures for MDL determination shall be included in site SOPs.

Program Required Quantitation Limit

Laboratories must demonstrate the capability to quantitate analytes in samples at or below the PRQLs given in Table C8-4. Laboratories shall set the concentration of at least one calibration standard below the PRQL. The detailed procedures for PRQL demonstration shall be included in laboratory SOPs.

Completeness

Laboratory completeness shall be expressed as the number of samples analyzed with valid results as a percent of the total number of samples submitted for analysis. Participating laboratories must meet the completeness specified in Table C8-4.

Comparability

For VOC analysis, data generated through analysis of samples from different sites shall be comparable. Comparability will be achieved by using standardized methods and traceable standards and by requiring all sites to participate in the PDP.

Representativeness

Representativeness for VOC analysis shall be achieved by collecting unbiased samples. Samples must be collected as described in Appendix C4.

C8-7 Total Semivolatile Organic Compound Analysis

Quality Assurance Objectives

The development of DQOs specifically for this program has resulted in the QAOs listed in Table C8-6. The specified QAOs represent the required quality of data necessary to draw valid conclusions regarding program objectives. Program-required limits, such as the PRQLs, are specified to ensure that the analytical data collected satisfy the requirements of all data users. A summary of Quality Control Samples and associated acceptance criteria for this analysis is included in Table C8-7. Key data-quality indicators for laboratory measurements are defined below.

Precision

Precision shall be assessed by analyzing laboratory duplicates, replicate analyses of laboratory control samples, matrix spike duplicates, and PDP blind-audit samples. Results from measurements on these samples must be compared to the criteria listed in Table C8-7. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Accuracy

Accuracy, as %R, shall be assessed for the laboratory operations by analyzing laboratory-control samples, matrix spikes, surrogate compounds, and PDP blind-audit samples. Results from these measurements must be compared to the criteria listed in Table C8-7. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Method Detection Limit

MDLs shall be expressed in mg/kg for SVOCs and must be less than or equal to those listed in Table C8-6. The detailed procedures for MDL determination shall be included in site SOPs.

Program Required Quantitation Limit

Laboratories must demonstrate the capability to quantitate analytes in samples at or below the PRQLs given in Table C8-6. Laboratories shall set the concentration of at least one calibration standard below the PRQL. The detailed procedures for PRQL demonstration shall be included in laboratory SOPs.

Completeness

Laboratory completeness shall be expressed as the number of samples analyzed with valid results as a percent of the total number of samples submitted for analysis. Participating laboratories must meet the level of completeness specified in Table C8-6.

Comparability

For SVOC analysis, data generated through analysis of samples from different sites shall be comparable. Comparability will be achieved by using standardized methods and traceable standards and by requiring all sites to participate in the PDP.

Representativeness

Representativeness for SVOC analysis shall be achieved by collecting unbiased samples. Samples must be collected as described in Appendix C4.

C8-8 Total Metal Analysis

Quality Assurance Objectives

The development of DQOs for the program has resulted in the QAOs listed in Table C8-8. The specified QAOs represent the required quality of data necessary to draw valid conclusions regarding program objectives. Program-required limits, such as the PRQLs associated with metal analysis, are specified to ensure that the analytical data collected satisfy the requirements of all data users. A summary of Quality Control Samples and the associated acceptance criteria for this analysis is provided in Table C8-9. Key data-quality indicators for laboratory measurements are defined below.

Precision

Precision shall be assessed by analyzing laboratory matrix spike duplicates, replicate analyses of laboratory-control samples, and PDP blind-audit samples. Results from measurements on these samples must be compared to the criteria listed in Table C8-8. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Accuracy

Accuracy shall be assessed through the analysis of laboratory matrix spikes, PDP blind-audit samples, and laboratory-control samples. Results from these measurements must be compared to the criterion listed in Table C8-8. These QC measurements will be used to demonstrate acceptable method performance and to trigger corrective action when control limits are exceeded.

Program Required Detection Limits

PRDLs, expressed in units of micrograms per L (μg/L), are the maximum values for instrument detection limits (IDL) permissible for program support under the QAPP. IDLs must be less than or equal to the PRDL for the method used to quantitate a specific analyte. Any method listed in Table C-11 of the application may be used if the IDL meets this criteria. For high concentration samples, an exception to the above requirements may be made in cases where the sample concentration exceeds five times the IDL of the instrument being used. In this case, the analyte concentration may be reported even though the IDL may exceed the PRDL. IDLs shall be determined semiannually (i.e., every six months). Detailed procedures for IDL determination shall be included in laboratory SOPs.

Program Required Quantitation Limit

Laboratories must demonstrate the capability of analyte quantitation at or below the PRQLs in units of mg/kg dry weight (given in Table C8-8). The PRDLs are set an order of magnitude less than the PRQLs (assuming 100 percent solid sample diluted by a factor of 100 during preparation). Laboratories shall set the concentration of at least one QC or calibration standard

at or below the solution concentration equivalent of the PRQL. Detailed calibration procedures shall be included in site SOPs.

Completeness

Laboratory completeness shall be expressed as the number of samples analyzed with valid results as a percent of the total number of samples submitted for analysis. Participating laboratories must meet the completeness specified in Table C8-8.

Comparability

Data generated through analysis of samples from different sites shall be comparable. Comparability will be achieved by using standardized methods and traceable standards and by requiring all sites to participate in the PDP.

Representativeness

Representativeness for metals analysis shall be achieved by the collection of unbiased samples. Samples must be collected as described in Appendix C4.

C8-9 Acceptable Knowledge

Acceptable knowledge documentation provides primarily qualitative information that cannot be assessed according to specific data quality goals that are used for analytical techniques. QAOs for analytical results are described in terms of precision, accuracy, completeness, comparability, and representativeness. Analytical results will be used to confirm the characterization of wastes based on acceptable knowledge (Section C9-4). To ensure that the acceptable knowledge process is consistently applied, sites must comply with the following data quality requirements for acceptable knowledge documentation:

- Precision - Precision is the agreement among a set of replicate measurements without assumption of the knowledge of a true value. The qualitative determinations, such as compiling and assessing acceptable knowledge documentation, do not lend themselves to statistical evaluations of precision. However, the acceptable knowledge information will be addressed by the independent review of acceptable knowledge information during internal and external audits.

- Accuracy - Accuracy is the degree of agreement between an observed sample result and the true value. The percentage of waste containers which require reassignment to a new waste matrix code and/or designation of different hazardous waste codes based an the reevaluation of acceptable knowledge and sampling and analysis data will be reported as a measure of acceptable knowledge accuracy.

- Completeness - Completeness is an assessment of the number of waste streams or number of samples collected to the number of samples determined to be useable through the data validation process. The acceptable knowledge record

must contain 100 percent of the required information (Section C9-3). The useability of the acceptable knowledge information will be assessed for completeness during audits.

- Comparability - Data are considered comparable when one set of data can be compared to another set of data. Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for procedures that are used to implement the acceptable knowledge process. All sites must assign hazardous waste codes in accordance with Section C9-4 and provide this information regarding its waste to other sites who store or generate a similar waste stream.

- Representativeness - Representativeness expresses the degree to which sample data accurately and precisely represent characteristics of a population. Representativeness is a qualitative parameter that will be satisfied by ensuring that the process of obtaining, evaluating, and documenting acceptable knowledge information is performed in accordance with the minimum standards established in Section C9-4. Sites also must assess and document the limitations of the acceptable knowledge information used to assign hazardous waste codes (e.g., purpose and scope of information, date of publication, type and extent to which waste parameters are addressed).

Each site must address quality control by tracking its performance with regard to the use of acceptable knowledge by: 1) assessing the frequency of inconsistencies among information, and 2) documenting the results of acceptable knowledge confirmation through radiography, headspace-gas analyses, and solidified waste analyses. In addition, the acceptable knowledge process and waste stream documentation must be evaluated through internal assessments by quality assurance organizations and assessments by auditors external to the organization (i.e., DOE/CAO).

C8-10 Data Review, Validation, and Verification Requirements

Data review, validation, and verification requirements include procedures for the review, validation, and verification of data at the data generation level; the validation and verification of data at the project level; and the verification of data at the CAO level. Data review determines if raw data have been properly collected and ensures raw data are properly reduced. Requirements for data reduction are provided in Sections 9.0 through 15.0 of the QAPP, as appropriate, and in the Methods Manual. Data validation confirms that the data reported satisfy the requirements defined by the user and is accompanied by signature release. Data verification authenticates that data are in fact that which is claimed. The procedures presented in this section ensure that Program records furnish documentary evidence of quality.

Data Generation Level

The following are minimum requirements for raw data collection and management:

- All raw data shall be signed and dated in black ink by the person generating it.

- All data must be recorded clearly, legibly, and accurately in field and laboratory records (bench sheets, logbooks), and include applicable sample identification numbers.

- All changes to original data must be lined out, initialed, and dated by the individual making the change. A justification for changing the original data may also be included. Original data must not be obliterated or otherwise disfigured so as not to be readable.

- All data must be transferred and reduced from field and laboratory records completely and accurately.

- All field and laboratory records must be maintained in permanent files according to NEIC guidelines.

- Data must be organized into a standard format for reporting purposes (testing, sampling, analytical or on-line batch data report), as outlined in specific sampling and analytical techniques.

- All electronic and video data must be stored appropriately to ensure that waste container, sample, and associated QC data are readily retrievable.

Data review, validation, and verification at this level involves scrutiny and signature release from qualified independent technical reviewer(s), technical supervisors(s), and a QA officer, as specified below. Any nonconformance identified during this process shall be documented on a nonconformance report (Section C8-13). Facilities may combine the positions of independent technical reviewer and QA officer. Individuals conducting this data review, validation, and verification must use checklists that address all of the items included in this section. Checklists must contain tables showing the results of sampling, analytical or on-line batch QC samples, if applicable. Completed checklists must be forwarded with testing, sampling, analytical and on-line batch data reports to the project level.

- One hundred percent of the batch data reports must receive an independent technical review. This review shall be performed by an individual other than the data generator who is qualified to have performed the initial work. The reviewer(s) must release the data as evidenced by signature, and as a consequence ensure the following:

  - Data generation and reduction were conducted in a technically correct manner in accordance with the methods used. Data were reported in the proper units and correct number of significant figures.

  - Calculations have been verified by a valid calculation program, a spot check of verified calculation programs, and/or 100 percent check of all hand calculations.

  - All variances from an accepted method and the rationale for the variations have been documented and approved (Section C8-13).

- The data have been reviewed for transcription errors.

- The testing, sampling, or analytical data QA documentation (testing batch, sampling batch, analytical or on-line batch) is complete and includes raw data, calculation records, chain-of-custody (COC) forms, calibration records, QC sample results, and gas canister sample tags (if applicable).

- QC sample results are within established control limits, and if not, the data have been appropriately qualified.

- Reporting flags were assigned correctly.

- Sample holding time and preservation requirements were met, or exceptions documented.

- Radiography tapes have been reviewed, at a minimum for every tenth waste container, against the data reported on the radiography form to ensure that the data are correct and complete.

- Field sampling records are complete.

• One hundred percent of the batch data reports must receive technical supervisory signature release for each testing batch, sampling batch, analytical batch and on-line batch. This release must ensure the following:

  - The data are technically reasonable based on the technique used.

  - All data have received independent technical review with the exception of radiography tapes, which shall receive periodic technical review as specified above.

  - The testing, sampling, or analytical data QA documentation (testing batch, sampling batch, analytical batch or on-line batch) is complete and includes raw data, calculation records, COC forms, calibration records, QC sample results, and gas sample canister tags (if applicable).

  - Sample holding time requirements were met, or exceptions documented.

  - Field sampling records are complete.

• One hundred percent of the batch data reports must receive QA officer signature release. This release must ensure the following:

  - Independent technical and technical supervisory reviews have been performed as evidenced by the appropriate signature releases.

- The testing, sampling, or analytical data QA documentation (testing batch, sampling batch, analytical batch or on-line batch) is complete as appropriate for the point of data generation (i.e., radiography, RA, sampling, and analysis).

- Sampling and analytical QC checks have been properly performed. QC criteria that were not met are documented.

- QAOs have been met according to the methods outlined in Section C8-11.

Project Level

Data validation and verification at this level involves scrutiny and signature release from the Site Project Manager (or designee) and the Site Project QA Officer (or designee). This must be accomplished by meeting the following minimum requirements for each waste container. Any nonconformance identified during this process shall be documented on a nonconformance report (Section C8-13).

- One hundred percent of the testing, sampling, and analytical batch data reports must have Site Project Manager signature release. This signature release must ensure the following:

  - Data generation level independent technical, technical supervisory, and QA officer review, validation, and verification have been performed as evidenced by the appropriate signature releases.

  - Testing, sampling, analytical and on-line batch data review checklists are complete.

  - Testing, sampling, analytical and on-line batch data reports are complete and data are properly reported (e.g., data are reported in the correct units, with the correct number of significant figures, and with qualifying flags).

  - Reconciliation with the DQOs was performed (Section C8-12).

- One hundred percent of the testing, sampling, and analytical batch data reports must receive Site Project QA Officer signature release. This signature release must ensure the following:

  - Sampling batch QC checks (e.g., equipment blanks, field duplicates, field reference standards) were properly performed, and meet the established QAOs.

  - Testing batch QC checks (e.g., replicate scans, measurement system checks, replicate counts) were properly performed.

- Analytical batch QC checks (e.g., laboratory duplicates, laboratory blanks, matrix spikes, matrix spike duplicates, laboratory control samples) were properly performed and meet the established QAOs.

- On-line batch QC checks (e.g., field blanks, on-line blanks, on-line duplicates, on-line control samples) were properly performed and meet the established QAOs.

- Proper procedures were followed to ensure representative samples of headspace gas and homogenous solids and soil/gravel were taken.

- Radiography data are complete and acceptable based on the videotape review of one waste container per testing batch, at a minimum.

- RA data are complete and acceptable.

- The Site Project Manager and Site Project QA Officer shall ensure that a repeat of the data generation level review, validation, and verification is performed on the data for a minimum of one randomly chosen waste container quarterly (every three months). This exercise will document that the data generation level review, validation, and verification is being performed according to implementing procedures.

In association with the project-level validation and verification described above, the Site Project QA Officer (or designee) must prepare a Site Project QA Officer Summary and the Site Project Manager (or designee) must prepare a Data Validation Summary. The Site Project QA Officer Summary includes, on a per waste container basis, a validation checklist for each testing, sampling, analytical and on-line batch. Checklists for the Site Project QA Officer Summary must be sufficiently detailed to validate all aspects of a testing, sampling, analytical or on-line batch that affect data quality. The Data Validation Summary provides confirmation that, on a per waste container basis, all data have been validated in accordance with the site QAPjP. The Data Validation Summary must list each testing, sampling, analytical or on-line batch, describe how the validation was performed and whether or not problems were detected, and include a statement indicating that all data are acceptable.

Once the data have received project-level validation and verification, the Site Project Manager must ensure that the laboratory is notified. Samples must be retained by the laboratory until this notification is received. Gas sample canisters may then be released from storage for cleaning, recertification, and subsequent reuse. Sample tags must be removed and forwarded to the Site Project QA Officer before recycling the canisters. If the site project manager requests that samples or canisters be retained for future use (e.g., an experimental holding time study), the same sample identification and COC forms shall be used and cross-referenced to a document which specifies the purpose for sample or canister retention.

CAO Level

The third and final level of data verification occurs at CAO and must, at a minimum, consist of an inventory check of the data packages to verify completeness. The CAO Office of Regulatory Compliance manager is responsible for the verification that data packages include the following:

- Project-level signature releases
- Listing of all waste containers being reported in the package
- Listing of all testing, sampling, and analytical batch numbers associated with each waste container being reported in the package
- Data package case narrative
- Site Project QA Officer Summary
- Data Validation Summary
- Complete summarized qualitative and quantitative data for all waste containers

The CAO Office of Regulatory Compliance manager must verify that each data package is complete and notify the originating site in writing of the acceptance status of the data within two weeks of data package receipt. CAO will maintain the data as appropriate for use in the regulatory compliance programs.

C8-11 Reconciliation with Data Quality Objectives

Reconciling the results of waste testing and analysis with the DQOs provides a way to ensure that data will be of adequate quality to support the regulatory compliance programs. Reconciliation with the DQOs will take place at both the project level and the CAO level. At the project level, reconciliation will be performed by the Site Project Manager; at CAO, reconciliation will be performed by the CAO Office of Regulatory Compliance manager.

Reconciliation at the Project Level

The Site Project Manager will ensure that all data generated and used in decision making meet the DQOs provided in Section C-4d of the text of Chapter C. To do so, the Site Project Manager must assess whether data of sufficient type, quality, and quantity have been collected. The Site Project Manager must determine if the variability of the data set is small enough to provide the required confidence in the results. The Site Project Manager must also determine if, based on the desired error rates and confidence levels, a sufficient number of valid data points have been determined. In addition, the Site Project Manager must document that random sampling of containers was performed for the purposes of waste stream characterization.

For each waste stream characterized, the Site Project Manager must determine if sufficient data have been collected to determine the following Program-required waste parameters:

- Waste matrix code
- Waste material parameter weights
- Average mass and activity of each radionuclide of concern
- If each waste container of waste is TRU radioactive waste
- Average concentration of hydrogen, methane, and each VOC in the headspace gas of waste containers in the waste stream
- Total masses of VOCs, hydrogen, and methane in the headspace gas of the waste stream
- The potential flammability of TRU waste headspace gases
- Mean concentrations, UCL_{90} for the mean concentrations, standard deviations, and number of samples collected for VOCs, SVOCs, and metals in the waste stream
- Total masses of VOCs, SVOCs, and metals in the waste stream
- Whether the waste stream exhibits a toxicity characteristic (TC) under 40 CFR Part 261, Subpart C
- Whether the waste stream can be classified as hazardous or nonhazardous at the 90-percent confidence level
- Whether a sufficient number of waste containers have been visually examined to determine with a reasonable level of certainty that the UCL_{90} for the miscertification rate is less than 14 percent

If the Site Project Manager determines that insufficient data have been collected to make the determinations listed above, additional data collection efforts must be undertaken.

The statistical procedure presented in Appendix C6 shall be used by participating Site Project Managers to evaluate and report waste characterization data from the analysis of homogenous solids and soil/gravel. The procedure, which calculates UCL_{90} values, shall be used to assess compliance with the DQOs in Section 1.5 as well as with RCRA regulations. The procedure must be applied to all laboratory analytical data for total VOCs, total SVOCs, and total metals. For RCRA regulatory compliance (40 CFR § 261.24), data from the analysis of the appropriate metals and organic compounds shall be compared to the TC levels expressed as total values. These total values will be considered the regulatory threshold limit (RTL) values for the Program. RTL values are obtained by calculating the weight/weight concentration (in the solid) of a TC analyte that would give the regulatory weight/volume concentration (in the toxicity characteristic leaching procedure (TCLP) extract), assuming 100-percent analyte dissolution.

Reconciliation at the CAO Level

CAO must also ensure that data of sufficient type, quality, and quantity have been collected to meet Program DQOs. The CAO Office of Regulatory Compliance manager is responsible for determining if sufficient data have been collected to determine the following:

- The concentration of headspace gas VOCs in the total waste inventory to support a demonstration that VOCs will not migrate through the air beyond the WIPP unit boundary in concentrations greater than Environmental Protection Agency (EPA)-determined health-based limits during WIPP operations;

- The concentration of VOCs, SVOCs, and metals in the total waste inventory to support a demonstration that hazardous constituents will not migrate beyond the WIPP unit boundary in concentrations greater than EPA-determined health-based limits;

- The total curie, hydrogen, and methane concentrations in TRU waste to support revision of the thermal power restrictions for shipment of waste in the Transuranic Package Transporter (TRUPACT-II);

- An inventory of radioactive materials and physical waste forms to support an assessment of repository performance;

- Whether waste streams proposed for disposal in WIPP have been adequately characterized; and

- Whether data supports the preparation of the WIPP facility no-migration variance petition, the WIPP RCRA permit application, the WIPP facility 40 CFR Part 191 Certification Application, and a revised safety analysis report for the TRUPACT-II.

C8-12 Data Reporting Requirements

Data reporting requirements define the type of information and the method of transmittal for data transfer from the data generation level to the project level and from the project level to CAO.

Data Generation Level

Data shall be transmitted by hard copy from the data generation level to the project level. Transmitted data shall include all testing, sampling, and analytical batch data reports, and data review checklists. The report forms and checklists used must contain all of the information required by the testing, sampling, and analytical techniques described in Sections 7.0 through 15.0 of the QAPP, as well as the signature releases to document the review, validation, and verification as described in Section C8-10. All testing, sampling, and analytical batch data reports and checklists shall be on approved forms, as provided in site-specific documentation.

Testing, sampling, and analytical batch data reports shall be forwarded to the site project office. Site QAPjPs shall specify the individual at the site project office who will receive these reports. Testing batch data reports shall be forwarded to the site project office within 28 days of the

testing of the last waste container in a testing batch. Sampling batch data reports shall be forwarded to the site project office within 28 days of sample collection of the last sample in a sampling batch. Analytical batch data reports shall be forwarded to the site project office within 28 days of the VTSR of the last sample in an analytical batch. After review by the Site Project QA Officer, all batch data reports will be forwarded to the Site Project Manager. All testing, sampling, and analytical batch data reports shall be assigned serial numbers, and each page shall be numbered at the bottom. The serial number used for data reports can be the same as the testing, sampling, or analytical batch number.

QA documentation shall be maintained in either testing, sampling, and analytical facility files, or site project files for those facilities located on sites. Contract waste operation facilities shall forward testing, sampling, and analytical QA documentation along with testing, sampling, and analytical batch data reports to the site project office for inclusion in site central files.

Project Level

There are two aspects to project level reporting. First, summarized testing, sampling, and analytical data must be reported on a per-waste container basis. Second, summarized characterization information must be reported on a waste stream basis.

Summarized testing, sampling, and analytical data shall be transmitted by hard copy from the Site Project Manager to CAO when requested. Participating sites shall combine data from individual waste containers into data packages for reporting. Hard copy data packages shall consist of the following:

- Cover page with the site name, program identification, waste container numbers for containers included in the data package, and release signatures of the Site Project Manager and Site Project QA Officer
- Table of contents; and
- A concise narrative that summarizes the results of the project-level review and briefly describes any problems or other noteworthy items of interest associated with the data (i.e., nonconformance reports, operational variances). The narrative shall include separate sections which address results of duplicates/replicates and nonconformance reports associated with the waste containers being reported in the package.

For each waste container being reported in the data package, the following information shall be included:

- Cover page with the site name, program identification, waste container number, and approval/release signatures of the Site Project Manager and Site Project QA Officer
- A table that relates sample numbers (testing, sampling, and analytical) to waste container number

- Table of contents
- Site Project QA Officer Summary
- Data Validation Summary
- Radiography results
- Radioassay (RA) results
- Waste container headspace gas hydrogen, methane, and VOC analytical results
- Innermost layer of confinement headspace gas hydrogen, methane, and VOC analytical results for waste containers with inner layers of confinement (if applicable)
- Total VOC, SVOC, and metal analytical results for homogenous solids and soil/gravel (if applicable)

WIPP Waste Information System (WWIS) Data Reporting

The WWIS Data Dictionary (Appendix C13) contains all of the data fields, the field format and the limits associated with the data as established by various waste acceptance criteria. This data will be subjected to edit and limit checks that are performed automatically by the database.

WIPP will coordinate the data transmission with each generator site using the Internet and the TCP/IP transmission protocol. Actual data transmission will use DES encryption technology to ensure the integrity of the data transmissions. The sites with large waste inventories and large databases will populate a data structure provided by WIPP that contains the required data dictionary fields that are appropriate for the waste stream (or waste streams) at that site. For example, totals analysis data will not be requested from sites that do not have homogeneous solids or soil/gravel waste. WIPP will access this data via the Internet to ensure an efficient transfer of this data. Small quantity sites will be given a similar data structure that is tailored to their types of waste. Sites with very small quantities of waste will be provided with the ability to assemble the data interactively to this data structure on the WWIS.

C8-13 Nonconformances and Operational Variances

The status of work and the Program activities at participating sites shall be monitored and controlled by the Site Project Manager and Site Project QA Officer. This monitoring and control shall include: 1) nonconformance identification, documentation, and reporting; and 2) operational variance identification, documentation, and reporting.

Nonconformances

Nonconformances are uncontrolled and unapproved deviations from an approved plan, procedure, or expected result. Nonconforming items and activities are those that do not meet the Program requirements, procurement document criteria, or approved work procedures.

Nonconforming items shall be identified by marking, tagging, or segregating, and the affected organization(s) notified. Participating sites shall disposition nonconforming items as appropriate in accordance with the Quality Assurance Program Description (QAPD). Disposition of nonconforming items shall be identified and documented. The QAPjPs shall identify the person(s) responsible for evaluating and dispositioning nonconforming items and shall include referenced procedures for handling them.

Management at all levels shall foster a "no-fault" attitude to encourage the identification of nonconforming items and processes. Nonconformances may be detected and identified by anyone performing Program activities, including

- Project staff - during field operations, supervision of subcontractors, data validation and verification, and self-assessment
- Laboratory staff - during the preparation for and performance of laboratory testing; calibration of equipment; QC activities; laboratory data review, validation, and verification; and self-assessment
- QA personnel - during oversight activities or audits

A nonconformance report shall be prepared for each nonconformance identified. Each nonconformance report shall be initiated by the individual(s) identifying the nonconformance. The nonconformance report shall then be processed by knowledgeable and appropriate personnel. For this purpose, a nonconformance report including, or referencing as appropriate, results of laboratory analysis, QC tests, audit reports, internal memoranda, or letters shall be prepared. The nonconformance report must provide the following information:

- Identification of the individual(s) identifying or originating the nonconformance
- Description of the nonconformance
- Method(s) or suggestions for correcting the nonconformance (corrective action) or description of the variance granted
- Schedule for completing the corrective action
- An indication of the potential ramifications and overall useability the data, if applicable
- Any approval signatures specified in the QAPjPs

The Site Project QA Officer shall oversee the nonconformance report process and be responsible for developing a plan to identify and track all nonconformances and report this information to the DOE field office. Documentation of nonconformances shall be made available to the Site Project Manager, who in turn is responsible for notifying project personnel of the nonconformance. Completion of the corrective action for nonconformances must be verified by the Site Project QA Officer.

Operational Variances

Variances are approved and controlled changes to Program-related plans or procedures. The need for a variance is caused by the identification of improvement opportunities or unusual or nonroutine occurrences that affect operations but not the ability to achieve the performance standards or quality requirements specified in this QAPP or site QAPjPs. Each person performing Program activities is responsible for the quality of their work and adherence to the applicable requirements contained in this QAPP and site QAPjPs. When a need to deviate from established procedures is identified, it is the responsibility of the person performing the work to initiate a variance.

When a variance is required, the person identifying the need for the variation shall complete a Record of Variance and have a direct supervisor approve it. A Record of Variance must be completed and approved before initiation of the activity to document the variation from normal, approved procedures. The Site Project QA Officer shall assess the significance of the variance and determine if changes to the plans or procedures and further notifications are required.

A Record of Variance must contain at least the following information:

- Title or heading, "Record of Variance"
- Waste container or sample identification number
- Reason for the deviation from the requirements contained in the QAPjP or SOP
- A description of the variation from the accepted sampling, testing, or analytical procedure
- A description of special equipment or personnel required
- Initiator's signature and date
- Supervisor's signature and date
- Site Project Manager's signature and date
- Site Project QA Officer's signature and date

DOE/CAO Corrective Action Process

DOE/CAO initiates a corrective action process when internal nonconformances and nonconformances at the generator/storage sites are identified. Activities and processes that do not meet requirements are documented as deficiencies. All deficiencies regardless of type and origin are processed through the CAO corrective action process.

When a deficiency is identified by the CAO, the following process action steps are initiated:

- The condition is documented on a Corrective Action Report (CAR) by the individual identifying the problem.

- The CAO QA Manager and the National TRU Programs (NTP) Team Leader review the CAR, determine validity of the finding (determine that a requirement has been violated), classify the significance of the condition, assign a response due date, and issue the CAR to the responsible party.

- The responsible organization reviews the CAR, evaluates the extent and cause of the deficiency and provides a response to the CAO, indicating remedial actions and actions to preclude recurrence that will be taken.

- The CAO reviews the response from the responsible organization and, if acceptable, communicates the acceptance to the responsible organization.

- The responsible organization completes remedial actions and actions to preclude recurrence of the condition.

- After all corrective actions have been completed, the CAO schedules and performs a verification to assure that corrective actions have been completed and are effective. When all actions have been completed and verified as being effective, the CAR is closed by the CAO QA Manager and the NTP Team Leader.

- As part of the planning process for subsequent audits and surveillances, past deficiencies are reviewed and the previous deficient activity or process is subject to reassessment.

C8-14 Special Training Requirements and Certifications

Before performing activities that affect Program quality, all personnel are required to receive indoctrination into the scope, purpose, and objectives of the Program and the specific QAOs of the assigned task. Personnel assigned to perform activities for the Program shall have the education, experience, and training applicable to the functions associated with the work. Evidence of personnel proficiency and demonstration of competence in the task(s) assigned must be demonstrated and documented. All personnel designated to work on specific aspects of the Program shall maintain qualification (i.e., training and certification) throughout the duration of the work as specified in this QAPP and applicable QAPjPs. Job performance shall be evaluated and documented at periodic intervals, as specified in the QAPjPs.

Personnel involved in Program activities shall receive continuing training to ensure that job proficiency is maintained. Training includes both education in principles and enhancement of skills. Each participating site shall include in its QAPjP a description of the procedures for implementing personnel qualification and training in accordance with the QAPD and 10 CFR § 830.120. All training records that specify the scope of the training, the date of completion, and documentation of job proficiency shall be maintained in the site project file.

Analytical laboratory line management must ensure that analytical personnel are qualified to perform the analytical method(s) for which they are responsible. The minimum qualifications for certain specified positions for the Program are summarized in Table C8-10. QAPjPs, or their implementing SOPs, shall specify the site-specific titles and minimum training and qualification requirements for personnel performing Program activities. QAPjPs shall also contain the requirements for maintaining records of the qualification, training, and demonstrations of proficiency by these personnel.

An evaluation of personnel qualifications shall include comparing and evaluating the requirements specified in the job/position description and the skills, training, and experience included in the current resume of the person. This evaluation also must be performed for personnel who change positions because of a transfer or promotion as well as personnel assigned to short-term or temporary work assignments that may affect the quality of the Program. QAPjPs shall identify the responsible person(s) for ensuring that all personnel maintain proficiency in the work performed and identify any additional training that may be required.

C8-11 List of References

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TABLES

TABLE C8-1
WASTE MATERIAL PARAMETERS AND DESCRIPTIONS

Waste Material Parameter	Description
Iron-based Metals/Alloys	Iron and steel alloys in the waste; does not include the waste container materials
Aluminum-based Metals/Alloys	Aluminum or aluminum-based alloys in the waste materials
Other Metals	All other metals found in the waste materials
Other Inorganic Materials	Nonmetallic inorganic waste including concrete, glass, firebrick, ceramics, sand, and inorganic sorbents
Cellulosics	Materials generally derived from high-polymer plant carbohydrates; (e.g., paper, cardboard, wood, and cloth)
Rubber	Natural or man-made elastic latex materials; (e.g., surgeons' gloves, and leaded rubber gloves)
Plastics (waste materials)	Generally man-made materials, often derived from petroleum feedstock; (e.g., polyethylene and polyvinylchloride)
Organic Matrix	Cemented organic resins, solidified organic liquids and sludges
Inorganic Matrix	Any homogeneous materials consisting of sludge or aqueous-based liquids that are solidified with cement, calcium silicate, or other solidification agents; (e.g., wastewater treatment sludge, cemented aqueous liquids, and inorganic particulates)
Soils/gravel	Generally consists of naturally occurring soils that have been contaminated with inorganic waste materials
Steel (packaging materials)	55-gal (208-L) drums
Plastics (packaging materials)	90-mil polyethylene drum liner and plastic bags

TABLE C8-2
GAS VOLATILE ORGANIC COMPOUNDS TARGET ANALYTE LIST AND QUALITY ASSURANCE OBJECTIVES

Compound	CAS Number	Precision[a] (%RSD or RPD)	Accuracy[a] (%R)	MDL[b] (ng)	FTIRS MDL[b] (ppmv)	PRQL (ppmv)	Completeness (%)
Benzene	71-43-2	≤25	70-130	10	5	10	90
Bromoform	75-25-2	≤25	70-130	10	5	10	90
Carbon tetrachloride	56-23-5	≤25	70-130	10	5	10	90
Chlorobenzene	108-90-7	≤25	70-130	10	5	10	90
Chloroform	67-66-3	≤25	70-130	10	5	10	90
1,1-Dichloroethane	75-34-3	≤25	70-130	10	5	10	90
1,2-Dichloroethane	107-06-2	≤25	70-130	10	5	10	90
1,1-Dichloroethylene	75-35-4	≤25	70-130	10	5	10	90
cis-1,2-Dichloroethylene	156-59-2	≤25	70-130	10	5	10	90
Ethyl benzene	100-41-4	≤25	70-130	10	10	10	90
Ethyl ether	60-29-7	≤25	70-130	10	5	10	90
Formaldehyde[c]	50-00-0	≤25	70-130	10		10	90
Hydrazine[d]	302-01-2	≤25	70-130	10		10	90
Methylene chloride	75-09-2	≤25	70-130	10	5	10	90
1,1,2,2-Tetrachloroethane	79-34-5	≤25	70-130	10	5	10	90
Tetrachloroethylene	127-18-4	≤25	70-130	10	5	10	90
Toluene	108-88-3	≤25	70-130	10	5	10	90
1,1,1-Trichloroethane	71-55-6	≤25	70-130	10	5	10	90
Trichloroethylene	79-01-6	≤25	70-130	10	5	10	90
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	≤25	70-130	10	5	10	90
m-Xylene[e]	108-38-3	≤25	70-130	10	5	10	90
o-Xylene	95-47-6	≤25	70-130	10	5	10	90
p-Xylene[e]	106-42-3	≤25	70-130	10	5	10	90
Acetone	67-64-1	≤25	70-130	150	50	100	90
Butanol	71-36-3	≤25	70-130	150	50	100	90
Methanol	67-56-1	≤25	70-130	150	50	100	90
Methyl ethyl ketone	78-93-3	≤25	70-130	150	50	100	90
Methyl isobutyl ketone	108-10-1	≤25	70-130	150	50	100	90

[a]Criteria apply to PRQL concentrations.
[b]Values based on delivering 10 mL to the analytical system.
[c]Required only for homogenous solids and soil/gravel from Los Alamos National Laboratory.
[d]Required only for homogenous solids and soil/gravel from Oak Ridge National Laboratory and the Savannah River Site.
[e]These xylene isomers cannot be resolved by GC/MS.

CAS = Chemical Abstract Service
%RSD = Percent relative standard deviation
RPD = Relative percent difference
%R = Percent recovery
MDL = Method detection limit (maximum permissible value), for GC/MS and GC/FID; total number of nanograms delivered to the analytical system per sample (nanograms); for FTIRS based on 1m sample cell
PRQL = Program required quantitation limit (parts per million/volume basis)

TABLE C8-3
SUMMARY OF LABORATORY QUALITY CONTROL SAMPLES AND FREQUENCIES FOR GAS VOLATILE ORGANIC COMPOUND ANALYSIS

QC Sample	Minimum Frequency	Acceptance Criteria	Corrective Action[a]
Method performance samples	Seven (7) samples initially and four (4) semiannually	Meet method QAOs	Repeat until acceptable
Laboratory duplicates or on-line duplicates	One (1) per analytical batch for GC/MS and GC/FID. One (1) per analytical batch or on-line batch for FTIRS	RPD≤25[b]	Nonconformance if RPD >25
Laboratory blanks or on-line blanks	Daily prior to sample analysis for GC/MS and GC/FID. Daily prior to sample analysis and one (1) per analytical batch or on-line batch for FTIRS.	Analyte amounts <3 x MDLs for GC/MS and GC/FID; <PRQL for FTIRS	Nonconformance if analyte amounts > 3 x MDLs for GC/MS and GC/FID; >PRQL for FTIRS
Laboratory control samples or on-line control samples	One (1) per analytical batch for GC/MS and GC/FID. One (1) per analytical batch or on-line batch for FTIRS	70-130 %R	Nonconformance is %R <70 or >130
GC/MS comparison sample (for FTIRS only)	One (1) per analytical or on-line batch	RPD≤25	Nonconformance if RPD >25
Blind audit samples	Samples and frequency controlled by the Gas PDP Plan	Specified in the Gas PDP Plan	Specified in the Gas PDP Plan

[a]Corrective action per section C8-13 when final reported QC samples do not meet the acceptance criteria.
[b]Applies only to concentrations greater than the PRQLs listed in Table C8-2.

MDL = Method Detection Limit
QAO = Quality Assurance Objective
PDP = Performance Demonstration Program
PRQL = Program Required Quantitation Limit
%R = Percent Recovery
RPD = Relative Percent Difference

TABLE C8-4
TOTAL VOLATILE ORGANIC COMPOUNDS TARGET ANALYTE LIST AND QUALITY ASSURANCE OBJECTIVES

Compound	CAS Number	Precision[a] (%RSD or RPD)	Accuracy[a] (%R)	MDL (mg/kg)	PRQL (mg/kg)	Completeness (%)
Benzene	71-43-2	≤45	37-151	1	10	90
Bromoform	75-25-2	≤47	45-169	1	10	90
Carbon disulfide	75-15-0	≤50	60-150	1	10	90
Carbon tetrachloride	56-23-5	≤30	70-140	1	10	90
Chlorobenzene	108-90-7	≤38	37-160	1	10	90
Chloroform	67-66-3	≤44	51-138	1	10	90
1,4-Dichlorobenzene[b]	106-46-7	≤60	18-190	1	10	90
ortho-Dichlorobenzene[b]	95-50-1	≤60	18-190	1	10	90
1,2-Dichloroethane	107-06-2	≤42	49-155	1	10	90
1,1-Dichloroethylene	75-35-4	≤250	D-234[c]	1	10	90
Ethyl benzene	100-41-4	≤43	37-162	1	10	90
Methylene chloride	75-09-2	≤50	D-221[c]	1	10	90
1,1,2,2-Tetrachloroethane	79-34-5	≤55	46-157	1	10	90
Tetrachloroethylene	127-18-4	≤29	64-148	1	10	90
Toluene	108-88-3	≤29	47-150	1	10	90
1,1,1-Trichloroethane	71-55-6	≤33	52-162	1	10	90
1,1,2-Trichloroethane	79-00-5	≤38	52-150	1	10	90
Trichloroethylene	79-01-6	≤36	71-157	1	10	90
Trichlorofluoromethane	75-69-4	≤110	17-181	1	10	90
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	≤50	60-150	1	10	90
Vinyl chloride	75-01-4	≤200	D-251[c]	1	4	90
m-xylene	108-38-3	≤50	60-150	1	10	90
o-xylene	95-47-6	≤50	60-150	1	10	90
p-xylene	106-42-3	≤50	60-150	1	10	90
Acetone	67-64-1	≤50	60-150	10[d]	100	90
Butanol	71-36-3	≤50	60-150	10[d]	100	90
Ethyl ether	60-29-7	≤50	60-150	10[d]	100	90
Formaldehyde[e]	50-00-0	≤50	60-150	10[d]	100	90
Hydrazine[f]	302-01-2	≤50	60-150	10[d]	100	90
Isobutanol	78-83-1	≤50	60-150	10[d]	100	90
Methanol	67-56-1	≤50	60-150	10[d]	100	90
Methyl ethyl ketone	78-93-3	≤50	60-150	10[d]	100	90
Pyridine[b]	110-86-1	≤50	60-150	10[d]	100	90

[a]Criteria apply to PRQL concentrations.
[b]Can also be analyzed as a semi-volatile organic compound.
[c]Detected; result must be greater than zero.
[d]Estimate, to be determined.
[e]Required only for homogenous solids and soil/gravel from Los Alamos National Laboratory.
[f]Required only for homogenous solids and soil/gravel from Oak Ridge National Laboratory and Savannah River Site.

CAS = Chemical Abstract Service
%RSD = Percent relative standard deviation
RPD = Relative percent difference
%R = Percent recovery
MDL = Method detection limit (maximum permissible value) (milligrams per kilogram)
PRQL = Program required quantitation limit; calculated from the toxicity characteristic level for benzene assuming a 0.9 oz (25-gram [g]) sample, 0.1 gal (0.5 liter [L]) of extraction fluid, and 100 percent analyte extraction (milligrams per kilogram)

TABLE C8-5
SUMMARY OF LABORATORY QUALITY CONTROL SAMPLES AND FREQUENCIES FOR TOTAL VOLATILE ORGANIC COMPOUND ANALYSIS

QC Sample	Minimum Frequency	Acceptance Criteria	Corrective Action[a]
Method performance samples	Seven (7) samples initially and four (4) semiannually	Meet total VOC analysis QAOs	Repeat until acceptable
Laboratory duplicates[b]	One (1) per analytical batch	Meet total VOC analysis RPDs	Nonconformance if RPDs > values in Table C8-4
Laboratory blanks	One (1) per analytical batch	Analyte concentrations < 3 x MDLs	Nonconformance if analyte concentrations > 3 x MDLs
Matrix spikes	One (1) per analytical batch	Meet total VOC analysis %Rs in QAP	Nonconformance if %Rs are outside the range specified in QAPP
Matrix spike duplicates	One (1) per analytical batch	Meet total VOC analysis RPDs and %Rs	Nonconformance if RPDs and %Rs > values in Table C8-4
Laboratory control samples	One (1) per analytical batch	80 - 120 %R	Nonconformance if %R < 80 or > 120
Surrogate compounds	Each analytical sample	Average %R from minimum of 30 samples for a given matrix ±3 standard deviations	Nonconformance if %R < (average %R - 3 standard deviation) or > (average %R + 3 standard deviation)
Blind audit samples	Samples and frequency controlled by the Solid PDP Plan	Specified in the Solid PDP Plan	Specified in the Solid PDP Plan

[a]Corrective Action per section C8-13 when final reported QC samples do not meet the acceptance criteria.
[b]May be satisfied using matrix spike duplicate; acceptance criteria applies only to concentrations greater than the PRQLs listed in Table C8-4.

MDL = Method detection limit
QAO = Quality assurance objective
PDP = Performance Demonstration Program
%R = Percent recovery
RPD = Relative percent difference

TABLE C8-6
SEMI-VOLATILE ORGANIC COMPOUND TARGET ANALYTE LIST AND QUALITY ASSURANCE OBJECTIVES

Compound	CAS Number	Precision[a] (%RSD or RPD)	Accuracy [a] (%R)	MDL (mg/kg)	PRQL (mg/kg)	Completeness (%)
Cresols	1319-77-3	≤50	60-150	5	40	90
1,4-Dichlorobenzene[b]	106-46-7	≤86	20-124	5	40	90
ortho-Dichlorobenzene[b]	95-50-1	≤64	32-129	5	40	90
2,4-Dinitrophenol	51-28-5	≤119	D-172[d]	5	40	90
2,4-Dinitrotoluene	121-14-2	≤46	39-139	0.3	2.6	90
Hexachlorobenzene	118-74-1	≤319	D-152[d]	0.3	2.6	90
Hexachloroethane	67-72-1	≤44	40-113	5	40	90
Nitrobenzene	98-95-3	≤72	35-180	5	40	90
Polychlorinated Biphenyls				5	40	90
Aroclor 1016[c]	12674-11-2	≤33	50-114	5	40	90
Aroclor 1221[c]	11104-28-2	≤110	15-178	5	40	90
Aroclor 1232[c]	11141-16-5	≤128	10-215	5	40	90
Aroclor 1242[c]	53469-21-9	≤49	39-150	5	40	90
Aroclor 1248[c]	12672-29-6	≤55	38-158	5	40	90
Aroclor 1254[c]	11097-69-1	≤62	29-131	5	40	90
Aroclor 1260[c]	11096-82-5	≤56	8-127	5	40	90
Pentachlorophenol	87-86-5	≤128	14-176	5	40	90
Pyridine[b]	110-86-1	≤50	60-150	5	40	90

CAS = Chemical Abstract Service
%RSD = Percent relative standard deviation
RPD = Relative percent difference
%R = Percent recovery
MDL = Method detection limit (maximum permissible value) (milligrams per kilogram)
PRQL = Program required quantitation limit; calculated from the toxicity characteristic level for nitrobenzene assuming a 100-gram (g) sample, 0.5 gal (2 liter [L]) of extraction fluid, and 100 percent analyte extraction (milligrams per kilograms)

[a]Criteria apply to PRQL concentrations
[b]Can also be analyzed as a volatile organic compound
[c]Required only for waste matrix code S3220 (organic sludges)
[d]Detected; result must be greater than zero

TABLE C8-7
SUMMARY OF LABORATORY QUALITY CONTROL SAMPLES AND FREQUENCIES FOR TOTAL SEMI-VOLATILE ORGANIC COMPOUNDS ANALYSIS

QC Sample	Minimum Frequency	Acceptance Criteria	Corrective Action[a]
Method performance samples	Seven (7) samples initially and four (4) semiannually	Meet Table C8-7 QAOs	Repeat until acceptable
Laboratory duplicates[b]	One (1) per analytical batch	Meet Table C8-7 RPDs	Nonconformance if RPDs > Table C8-7
Laboratory blanks	One (1) per analytical batch	Analyte concentrations <3 x MDLs	Nonconformance if analyte concentrations > 3 x MDLs
Matrix spikes	One (1) per analytical batch	Meet Table C8-7 %Rs	Nonconformance if %Rs are outside the range specified in Table C8-7
Matrix spike duplicates	One (1) per analytical batch	Meet Table C8-7 RPDs and %Rs	Nonconformance if RPDs and %Rs > Table C8-7 values
Laboratory control samples	One (1) per analytical batch	80 - 120 %Rs	Nonconformance if %R < 80 or > 120
Surrogate compounds	Each analytical sample	Average %R from minimum of 30 samples from a given matrix ±3 standard deviations	Nonconformance if %R < (average %R - 3 standard deviations) or > (average %R + 3 standard deviations)
Blind audit samples	Samples and frequency controlled by the Solid PDP Plan	Specified in the Solid PDP Plan	Specified in the Solid PDP Plan

[a]Corrective action per section C8-13 when final reported QC samples do not meet the acceptance criteria

[b]May be satisfied by using matrix spike duplicate; acceptance criteria applies only to concentrations greater than the PQRLs listed in Table C8-6.

MDL = Method Detection Limit
QAO = Quality Assurance Objective
PDP = Performance Demonstration Program
%R = Percent Recovery
RPD = Relative Percent Difference

TABLE C8-8
TOTAL METALS TARGET ANALYTE LIST AND QUALITY ASSURANCE OBJECTIVES

Analyte	CAS Number	Precision (%RSD or RPD)[a]	Accuracy (%R)[b]	PRDL[c] (μg/L)	PRQL (mg/kg)	Completeness (%)
Antimony	7440-36-0	≤30	80-120	100	100	90
Arsenic	7440-38-2	≤30	80-120	100	100	90
Barium	7440-39-3	≤30	80-120	2000	2000	90
Beryllium	7440-41-7	≤30	80-120	100	100	90
Cadmium	7440-43-9	≤30	80-120	20	20	90
Chromium	7440-47-3	≤30	80-120	100	100	90
Lead	7439-92-1	≤30	80-120	100	100	90
Mercury	7439-97-6	≤30	80-120	4.0	4.0	90
Nickel	7440-02-0	≤30	80-120	100	100	90
Selenium	7782-49-2	≤30	80-120	20	20	90
Silver	7440-22-4	≤30	80-120	100	100	90
Thallium	7440-28-0	≤30	80-120	100	100	90
Vanadium	7440-62-2	≤30	80-120	100	100	90
Zinc	7440-66-6	≤30	80-120	100	100	90

[a]≤ 30 percent control limits apply when sample and duplicate concentrations are ≥ 10 x IDL for ICP-AES and AA techniques, and ≥ 100 x IDL for Inductively Coupled Plasma—Mass Spectrometry (ICP-MS) techniques. If less than these limits, the absolute difference between the two values shall be less than or equal to the PRDL.
[b]Applies to laboratory control samples, laboratory matrix spikes, and PDP blind audit samples. If a solid laboratory control sample material which has established statistical control limits is used, then the established control limits for that material should be used for accuracy requirements.
[c]PRDL set such that it is a factor of 10 below the PRQL for 100 percent solid samples, assuming a 100 x dilution during digestion.

CAS = Chemical Abstract Service
%RSD = Percent relative standard deviation
RPD = Relative percent difference
%R = Percent recovery
PRDL = Program required detection limit (i.e., maximum permissible value for IDL) (milligrams per liter)
PRQL = Program required quantitation limit (milligrams pre kilogram)

TABLE C8-9
SUMMARY OF LABORATORY QUALITY CONTROL SAMPLES AND FREQUENCIES FOR TOTAL METALS ANALYSIS

QC Sample	Minimum Frequency	Acceptance Criteria	Corrective Action[a]
Method performance samples	Seven (7) samples initially and four (4) semiannually	Meet Table C8-9 QAOs	Repeat until acceptable
Laboratory blanks	One (1) per analytical batch	≤ 3 x IDL (≤ 5 x IDL for ICP-MS)[b]	Redigest and reanalyze any samples with analyte concentrations which are ≤10 x blank value and ≥ 0.5 x PQRL
Matrix spikes	One (1) per analytical batch	80 - 120 %Rs	Nonconformance if %Rs are <80 or >120
Matrix spike duplicates	One (1) per analytical batch	RPD ≤ 30 80-120 %R	Nonconformance if RPD > 30 or if %R < 80 or > 120
Laboratory control samples	One (1) per analytical batch	80 - 120 %Rs	Redigest and reanalyze for affected analytes
Blind audit samples	Samples and frequency controlled by the Solid PDP Plan	Specified in the Solid PDP Plan	Specified in the Solid PDP Plan

[a]Corrective action per section C8-13 when final reported QC samples do not meet the acceptance criteria

[b] Applies only to concentrations greater than the PQRLs listed in Table C8-8.

IDL = Instrument Detection Limit
PDP = Performance Demonstration Program
PQRL = Program Required Detection Limit
%R = Percent Recovery
RPD = Relative Percent Difference

TABLE C8-10
MINIMUM TRAINING AND QUALIFICATIONS REQUIREMENTS[a]

Personnel	Requirements[a]
Radiography Operators[c]	Site-specific training based on waste matrix codes and waste material parameters; requalification every 2 years
Gas Chromatography Technical Supervisors[b] Gas Chromatography Operators[c]	B.S. or equivalent experience and 6 months previous applicable experience
Gas Chromatography/Mass Spectrometry Operators[c] Mass Spectrometry Operators[c]	B.S. or equivalent experience and 1 year independent spectral interpretation or demonstrated expertise
Gas Chromatography/Mass Spectrometry Technical Supervisors[b] Mass Spectrometry Technical Supervisors[b] Atomic Absorption Spectroscopy Technical Supervisors[b] Atomic Absorption Spectroscopy Operators[c] Atomic Mass Spectrometry Operators[c] Atomic Emission Spectroscopy Operators[c]	B.S. or equivalent experience and 1 year applicable experience
Atomic Mass Spectrometry Technical Supervisors[b]	B.S. and specialized training in Atomic Mass Spectrometry and 2 years applicable experience
Atomic Emission Spectroscopy Technical Supervisors[b]	B.S. and specialized training in Atomic Emission Spectroscopy and 2 years applicable experience.

[a]Based on requirements contained in *USEPA Contract Laboratory Program Statement of Work for Organics Analysis* (Document Number OLM 01.0) and *Statement of Work for Inorganics Analysis* (Document Number ILM 03.0).
[b]Technical Supervisors are those persons responsible for the overall technical operation and development of a specific laboratory technique. QAPjPs shall include the site-specific title for this position.
[c]Operators are those persons responsible for the actual operation of analytical equipment. QAPjPs shall include the site-specific title for this position.

FIGURES

1

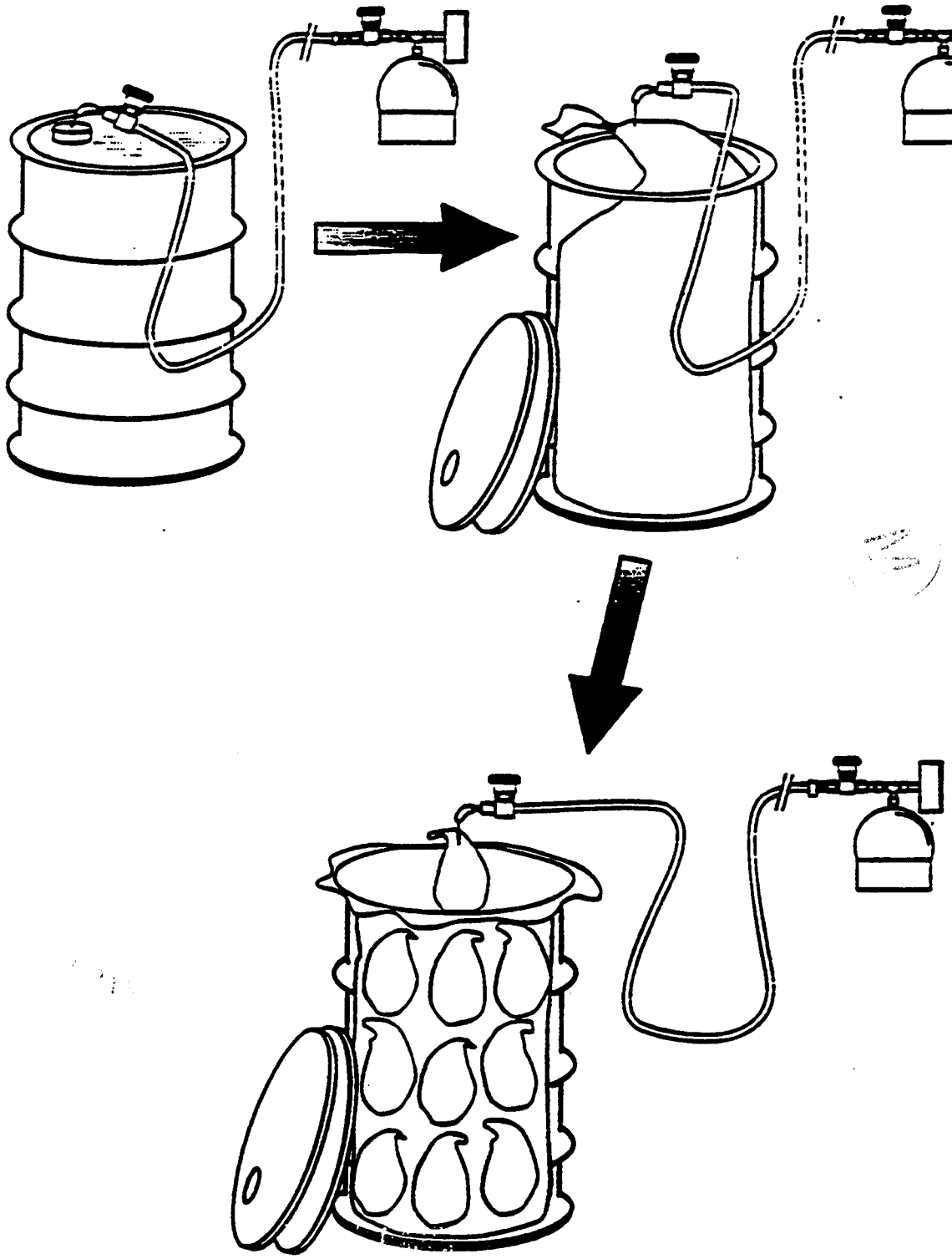

FIGURE C8-1
OVERALL HEADSPACE-GAS SAMPLING SCHEME ILLUSTRATING MANIFOLD SAMPLING

APPENDIX C9
TRU WASTE CHARACTERIZATION USING ACCEPTABLE KNOWLEDGE

APPENDIX C9
TRU WASTE CHARACTERIZATION USING ACCEPTABLE KNOWLEDGE

C9-1 Introduction

The Resource Conservation and Recovery Act (RCRA) regulations codified in 40 CFR Parts 260 through 265, 268, and 270, and the New Mexico Hazardous Waste Management Regulations in Title 20 New Mexico Administrative Code, Chapter 4, Part 1, (20 NMAC 4.1) Subparts I through VI, Subpart VIII, and Subpart IX, authorize the use of acceptable knowledge as a method which can be used in appropriate circumstances by waste generators, or treatment, storage, or disposal facilities to make hazardous waste determinations. Acceptable knowledge is defined in *Waste Analysis: EPA Guidance Manual for Facilities That Generate, Treat, Store and Dispose of Hazardous Waste* (EPA 1994) to include process knowledge, waste analysis data, and facility records of analysis performed before the effective date of RCRA regulations. Acceptable knowledge, as an alternative to sampling and analysis, can be used to meet all or part of the waste characterization requirements under the RCRA (EPA 1994).

Acceptable knowledge is one of a number of techniques used to characterize transuranic (TRU) waste. It is used in conjunction with radiography, headspace gas sampling and analysis, and solidified waste sampling and analysis to meet the requirements of the Waste Analysis Plan (WAP). Acceptable knowledge is used in TRU waste characterization activities in three ways:

- To delineate TRU waste streams
- To determine if TRU debris wastes exhibit a toxicity characteristic (40 CFR §261.24)
- To determine if TRU wastes are listed (40 CFR §261.31)

Acceptable knowledge is confirmed using nondestructive techniques and sampling and analysis.

C9-2 Reasons for Using of Acceptable Knowledge

The Environmental Protection Agency (EPA) (1994) describes four situations in which the use of acceptable knowledge is appropriate. Three of these situations are applicable to TRU waste characterization and are discussed below.

Waste Generating Processes are Well Documented

Waste generating processes from nonspecific sources are included in RCRA regulations at 40 CFR §261.31. The waste generated from these processes are known to contain certain hazardous constituents. Generators of these wastes are not required to perform sampling and analysis of their wastes; knowledge of the process used to generate the waste is required to make an accurate hazardous waste determination.

TRU wastes from nonspecific sources are spent solvent-contaminated wastes (i.e., EPA hazardous waste codes F001 through F005). Acceptable knowledge must be used to determine if these wastes meet the requirements for listing as a spent solvent. To be listed, it must be known if the solvent compound was used for its solvent properties, that is, to solubilize or mobilize other constituents. Examples of solvent use are degreasing, cleaning, use as diluents, extractants, and reaction and synthesis media. In addition, the solvent mixture must have originally contained more than 10 percent by volume of the solvents included under the F001 through F005 listings.

Because listed wastes (i.e., wastes from nonspecific sources under 40 CFR §261.31) are well defined and are based on knowledge of the materials and processes that generate the waste, sampling, and analysis is not required to make a hazardous waste determination. Generators of TRU waste that meets the criteria included in 40 CFR §261.31 (F-listed wastes) must use acceptable knowledge to characterize their TRU waste.

Health and Safety Risks

TRU waste presents serious health and safety risks to waste characterization personnel. Extensive measures are taken by the Department of Energy (DOE) to package this waste so that the potential for human exposure to ionizing radiation is limited. Packaging measures include multiple layers of plastic and shielding to reduce the potential exposure of alpha and gamma radiation, respectively. The breaching of confinement layers or increasing the potential for respirable particulates by size reduction (e.g., shredding or grinding) of TRU debris waste increases the health and safety risks associated with TRU waste management. The design of a data collection program that includes the use of acceptable knowledge allows characterization of TRU waste, while limiting radiation exposure to personnel and the environment.

Physical Nature of the Waste

The TRU waste characterization requirements have been established using the EPA's Data Quality Objectives (DQO) process. The DOE employed this process to establish a defensible, cost-effective program to generate data for regulatory decision making. To make defensible decisions based on sampling and analytical data, a representative sample must be collected. The physical nature of TRU debris wastes (e.g., glass, metal, or combustible waste forms) does not lend itself to the collection and analysis of a representative sample.

To collect a representative sample of TRU debris waste, size reduction and compositing, along with extensive handling of the waste, would be required. During the process of size reduction, target volatile organic compounds (VOC) would be lost so that the final sample would not be representative of the initial waste. Size reduction of alpha-contaminated materials is in direct conflict with DOE's health and safety protocols for the management of TRU waste. Because the greatest risk of exposure to alpha-radiation is by inhalation, TRU waste packaging and handling operations are designed to minimize the potential for airborne particulates. Size reduction of TRU waste would increase the quantities of respirable particulates and increase the potential for release of radionuclides and human exposure. Because of the limited use of data obtained from sampling TRU debris waste, the increase in potential human exposure and the costs associated with facilities to sample and contain TRU waste is not justified.

The EPA (1994) suggests that swiping the surface of waste materials (e.g., metals or glass) may be an alternative to sampling debris wastes. The DQO process requires that the end use of the data be considered in developing sampling and analytical protocols. Swiping the surfaces of TRU waste materials would not provide a representative sample that the DOE could use to make hazardous waste determinations. For example, if VOCs are not detected on the surface of materials, the DOE could not classify the waste as nonhazardous. Many TRU debris wastes contain spent solvents, which are listed according to how the wastes were generated and not whether they contain a listed constituent. In addition, the DOE cannot determine if a waste exhibits a toxicity characteristic based on the concentration of a particular constituent present on surfaces of materials. Therefore, collecting surface swipes is not justified in light of the potential increased exposure to radiation. Collection and preparation of surface swipe samples would not be representative of the waste for the purpose of waste characterization, would be very costly, and would increase the potential exposure of personnel to radiation.

C9-3 Acceptable Knowledge Documentation

It is the responsibility of each DOE TRU waste generator/storage site to develop a logical sequence of acceptable knowledge information that progresses from general facility information (TRU Waste Management Program Information) to more detailed waste-specific information (TRU Waste Stream Information). The consistent presentation of acceptable knowledge documentation among DOE sites in auditable records will allow Waste Isolation Pilot Plant (WIPP) personnel to verify the completeness and adequacy of acceptable knowledge for TRU waste characterization during the audit process.

The following sections include the minimum information that each site must have to characterize TRU waste using acceptable knowledge. Because waste generating processes are site-specific, DOE sites may supplement the minimum required acceptable knowledge records with additional information (Supplemental Acceptable Knowledge Documentation). If the mandatory information is not available for a particular waste, then this waste will not be accepted for disposal at the WIPP facility based on acceptable knowledge alone. Sites may submit additional sampling and analytical data that may provide the required waste characterization information.

TRU Waste Management Program Information

An overview of the TRU waste program provides an understanding of TRU waste management operations at each site. This overview, which will establish the basis for more detailed TRU waste stream information, must reveal an overall perspective of TRU waste management operations and serve as a guide to the waste stream-specific information.

TRU waste management program information must clearly define waste categorization schemes and terminology, provide a breakdown of the types and quantities of TRU waste that are generated and stored at the site, and describe how waste is tracked and managed at the site, including historical and current operations. Information related to TRU waste certification procedures and the types of documentation (e.g., waste profile forms) used to summarize acceptable knowledge must also be provided. The following information must be included as part of the acceptable knowledge record:

- Map of the site with the areas and facilities involved in TRU waste generation, treatment, and storage identified
- Facility mission description as related to TRU waste generation and management (e.g., nuclear weapons research may involve metallurgy, radiochemistry, and nuclear physics operations that result in specific waste streams)
- Description of the operations that generate TRU waste at the site (e.g., plutonium recovery, weapons design, or weapons fabrication)
- Waste identification or categorization schemes used at the facility (e.g., item description codes, content codes)
- Types and quantities of TRU waste generated, including historical generation through future projections
- Correlation of waste streams generated from the same building and process, as appropriate (e.g., sludge, combustibles, metals, and glass)
- Waste certification procedures for retrievably stored and newly generated wastes to be sent to the WIPP facility

TRU Waste Stream Information

For each TRU waste stream, sites must compile all process information and data that support the acceptable knowledge used to characterize that waste stream. The type and quantity of supporting documentation will vary by waste stream, depending on the process generating the waste and site-specific requirements imposed by DOE or state agencies. At a minimum, the waste process information must include:

- Area(s) and building(s) from which the waste stream was or is generated
- Waste stream volume and time period of generation (e.g., 100 standard waste boxes of retrievable stored waste generated from June 1977 through December 1977)
- Waste generating process described for each building (e.g., batch waste stream generated during decommissioning operations of glove boxes)
- Process flow diagrams (e.g., a diagram illustrating glove boxes from a specific building to a size reduction facility to a container storage area)
- Material inputs or other information that identifies the chemical and radionuclide content of the waste stream and the physical waste form (e.g., glove box materials, chemicals and radionuclides handled during glove box operations, if applicable)

A summary must identify all sources of information. The basis and rationale for defining each waste stream based on the parameters of interest must be clearly summarized and traceable to referenced documents. Assumptions made in defining each waste stream also must be identified and justified.

Supplemental Acceptable Knowledge Documentation

Examples of additional documentation that may be used for acceptable knowledge include, but are not limited to, the following:

- Process design documents (e.g., Title II Design)
- Standard operating procedures that may include a list of raw materials or reagents, a description of the process or experiment generating the waste, and a description of wastes generated and how the wastes are managed at the point of generation
- Preliminary and final safety analysis reports and technical safety requirements
- Waste packaging logs
- Test plans or research project reports that describe reagents and other raw materials used in experiments
- Site databases (e.g., chemical inventory database for Superfund Amendments and Reauthorization Act Title III requirements)
- Information from site personnel (e.g., documented interviews)
- Standard industry documents (e.g., vendor information)
- Previous analytical data relevant to the waste stream, including results from fingerprint analyses, spot checks, or routine verification sampling
- Material Safety Data Sheets, product labels, or other product package information
- Sampling and analysis data from comparable or surrogate waste streams (e.g., equivalent nonradioactive materials)
- Laboratory notebooks that detail the research processes and raw materials used in an experiment

The specific, relevant information must be identified and justification provided for its use (e.g., identification of a toxicity characteristic). Supplemental documentation is not required but may be used, if available, to further document the rationale for the hazardous waste designations. Similar to required information, if discrepancies exist between supplemental information and the required documentation, then sites must include all potential hazardous waste codes to the subject waste stream. For example, if personnel interviews indicate that lead was part of the

input materials, then D008 must be designated in spite of the fact that no records of the use of lead exist in the required documentation. Sites must prioritize the sources of information used to assign hazardous waste codes in terms of accuracy of the information. Published documents and controlled databases are considered the most reliable information. Second priority will be given to unpublished data, internal procedures, and notes. Correspondence, such as memoranda, letters, telephone logs, and interviews are considered the least defensible. The pages from large documents, such as safety analysis reports, must be flagged with the relevant information noted.

C9-4 Acceptable Knowledge Process

Consistency among DOE sites in using acceptable knowledge information to characterize TRU waste involves a three phase process: 1) compiling the minimum acceptable knowledge documentation in an auditable record, 2) confirming acceptable knowledge information using radiography and headspace-gas sampling and analysis and solidified waste sampling, and 3) auditing acceptable knowledge records. This section describes each phase of the process and specifies the procedures that sites must develop to implement the requirements for using acceptable knowledge.

Site personnel responsible for compiling, assessing, and resolving discrepancies associated with acceptable knowledge must have the following minimum qualifications and training:

- WIPP WAP, Waste Acceptance Criteria, and Quality Assurance Program Plan (QAPP) Requirements
- State and Federal RCRA regulations associated with solid and hazardous waste determinations
- Nonconformance process, including discrepancy resolution and reporting
- Site-specific procedures associated with waste characterization using acceptable knowledge

Assembling an Acceptable Knowledge Record

Figure C9-1 provides an overview of the process for assembling acceptable knowledge documentation into an auditable record. The first step is to assemble all of the mandatory acceptable knowledge information and any supplemental information regarding the materials and processes that generate a specific waste stream. DOE sites must ensure the following criteria are met in establishing acceptable knowledge records:

- Acceptable knowledge information must be compiled in an auditable record, including a road map for all applicable information.
- The overview of the facility and TRU waste management operations in the context of the facility's mission must be correlated to specific waste stream information.

- Correlations between waste streams, with regard to time of generation, waste generating processes, and site-specific facilities must be clearly described.

- A reference list must be provided that identifies documents, databases, Quality Assurance protocols, and other sources of information that support the acceptable knowledge information.

Container inventories for TRU waste currently in retrievable storage are then defined as waste streams by correlating the container identification to the mandatory acceptable knowledge information. For newly generated wastes, the rate and quantity of waste to be generated must be defined and procedures implemented to make hazardous waste determinations using acceptable knowledge prior to packaging the waste.

For all TRU wastes, sites must develop written procedures that describe how RCRA hazardous waste codes are assigned using acceptable knowledge information and how unacceptable wastes (e.g., reactive, ignitable, and corrosive RCRA-regulated hazardous wastes) are identified and segregated from certifiable TRU waste populations. Site-specific procedures must address the following elements:

- Sites must prepare a written procedure outlining the specific methodology used to assemble acceptable knowledge records, including the origin of the documentation, how it will be used, and any limitations associated with the information (e.g., identify the purpose and scope of a study that included limited sampling and analysis data).

- To compile the required acceptable knowledge record, sites must assemble and evaluate available documentation in the following priority: a) relevant information from published documents and controlled databases, b) unpublished data, c) internal procedures and notes, such as log books, and d) correspondence, such as memoranda, letters, telephone logs, and interviews.

- Sites must comply with Section C9-4 to identify hazardous wastes and assign the appropriate hazardous waste codes to each waste stream.

- Sites must describe the waste certification program and procedures that are used to ensure unacceptable wastes are identified and segregated.

- Sites must develop and implement a procedure(s) for the confirmation of acceptable knowledge in accordance with Section C9-4.

- Sites must provide a cross reference to the applicable waste summary category group (i.e., S3000, S4000, and S5000) to verify all of the required confirmation data has been evaluated and the proper hazardous waste codes have been assigned.

The waste certification procedure(s) must describe the administrative controls used by the site to ensure that nonconforming items are documented and managed in accordance with site-

specific certification plans. The following minimum elements must be addressed in site-specific documentation associated with administrative controls:

- Identify the organization(s) responsible for compliance with administrative controls.
- Identify the oversight procedures and frequency of actions to verify compliance with administrative controls.
- Develop on-the-job training specific to administrative control procedures.
- Ensure that personnel may stop work if noncompliance with administrative controls is identified.
- Develop a nonconformance process that complies with the requirements in Section C8-13 of the WAP to document and establish corrective actions.
- As part of the corrective action process, assess the potential time frame of the noncompliance, the potentially affected waste population(s), and the reassessment and recertification of those wastes.

Sites must develop procedures that describe how acceptable knowledge information is evaluated and any discrepancies in documentation resolved. If different sources of information indicate different hazardous wastes are present, then sites must include all sources of information in its records and conservatively assign all potential hazardous waste codes. Discrepancies in acceptable knowledge documentation must be resolved by including all available information in the auditable records and assigning all hazardous waste codes indicated by all of these records to the subject waste. For example, if one record indicates that solvents were not part of a process, while another record indicates that 1,1,1-trichloroethane was used for cleaning parts, then the F001 hazardous waste code must be applied to the waste. No judgements may be made regarding the quality of the required documentation,and the assignment of hazardous waste codes must be tracked to all required documentation.

Sites must compile adequate documentation to demonstrate consistency in assigning hazardous waste codes and to defend and justify the use of acceptable knowledge in making hazardous waste determinations to independent auditors. The following are minimum baseline requirements/standards that site-specific procedures must include to ensure comparable and consistent identification of hazardous waste:

- Compile all of the required information in an auditable record.
- Review the required information to determine if the waste is listed under 40 CFR Part 261, Subpart D. Assign all listed hazardous waste codes.
- Review the required information to determine if the waste may contain hazardous constituents included in the toxicity characteristics specified in 40 CFR Part 261, Subpart C. If a toxicity characteristic contaminant is identified and is not included as a listed waste, assign the toxicity characteristic code. Unless data is available from the sampling and analysis of a representative sample of the waste stream

that demonstrates that the concentration of the constituent in the waste is less than the toxicity characteristic regulatory level, no judgement may be made regarding the concentration of the constituent. When analytical data is not available, the toxicity characteristic hazardous waste code for the identified hazardous constituent must be applied to the waste stream.

- In the case of discrepancies in information, no judgement may be made regarding the quality of the information. Sites must ensure that all potential hazardous waste codes are assigned to the waste stream.

Confirmation of Acceptable Knowledge Information

Acceptable knowledge includes information regarding the physical form of the waste, the base materials composing the waste, and the process that generates the waste. Waste characterization (i.e., radiography, headspace-gas sampling and analysis, and solidified waste sampling and analysis) will be used to confirm acceptable knowledge information. Figure C-2 illustrates the process sites will use to confirm acceptable knowledge.

All retrievably stored waste must be characterized using radiography to confirm the waste matrix code and certify compliance with the RCRA Waste Analysis Plan. If a site must repackage its retrievably stored waste, then visual examination of the waste during repackaging is used to confirm acceptable knowledge information rather than radiography.

For newly generated wastes, sites must have written procedures to document the confirmation of acceptable knowledge information with visual examination prior to or during waste packaging. The following minimum requirements must be addressed in site-specific procedures: 1) scope (i.e., waste streams) and purpose, 2) responsible organization(s), 3) administrative process controls, 4) material inputs to process, 5) process controls and range of operation that affect final hazardous waste determinations, 6) rate and quantity of the hazardous waste generated, 7) list of applicable operating procedures relevant to the hazardous waste determination, 8) nonconformance reporting, 9) process knowledge verification sampling (i.e., headspace-gas sampling and/or solidified waste annual sample), and 10) reporting and records management.

Sites must establish procedures for reevaluating acceptable knowledge if radiography or visual examination results in the assignment of a different waste matrix code [e.g., Plastic/Rubber (S5310) versus Paper/Cloth (S5330)]. Site procedures must describe how the waste is reassigned, acceptable knowledge reevaluated, and appropriate hazardous waste codes assigned.

The base materials that compose TRU debris waste (e.g., lead, stainless steel, glass) are well established, and potential toxicity characteristics can be determined without destructive sampling and analysis. The waste matrix code is related to the base materials and waste generating process. In lieu of sampling and analytical data to the contrary, sites must assign the toxicity characteristic hazardous waste codes based on the presence of the constituent, regardless of the quantity or concentration. Radiography or visual examination must be used to confirm the waste matrix code identified using acceptable knowledge. Procedures must describe how discrepancies in the waste matrix code are recorded and changes to hazardous waste codes based on material composition are documented, as necessary. If a waste must be assigned to

a different waste matrix code based on radiography or visual examination, the following minimum steps must be taken to reevaluate acceptable knowledge:

- Review existing information based on the container identification number and document all differences in hazardous waste code assignments
- If differences exist in the hazardous waste codes that were assigned, reassess and document all required acceptable knowledge information (Section C9-3) associated with the new designation
- Reassess and document all sampling and analytical data associated with the waste
- Verify and document that the reassigned waste matrix code was generated within the specified time period, area and buildings, waste generating process, and that the process material inputs are consistent with the waste material parameters identified during radiography or visual examination
- Record all changes to acceptable knowledge records
- If discrepancies exist in the acceptable knowledge information for the reassigned waste matrix code, complete a nonconformance report (Appendix C8-13), document the segregation of this container, and define the corrective actions necessary to fully characterize the waste

Finally, radiography and visual examination procedures must include a list of nonconforming items that the operator must verify are not present in each container of waste (i.e., corrosives, ignitables, reactives, incompatible waste). Sites must establish and document administrative controls to ensure that nonconforming items or waste are segregated from certifiable populations.

Headspace-gas sampling and analysis must be conducted on all TRU waste to be sent to the WIPP facility. Headspace-gas data will be used to confirm the presence or absence of VOCs identified using acceptable knowledge.

Sites must use acceptable knowledge to identify spent solvents associated with each TRU waste stream or waste stream lot. Headspace-gas data will be used to confirm acceptable knowledge concerning the presence or absence of F-listed solvents. Headspace-gas data may be used to assist in confirming the characterization of waste contaminated with F-listed solvents by the "mixture rule" (e.g., solvent-contaminated rags mixed with other wastes materials). Sites must provide documentation to support any determination that organic constituents are associated with packaging materials or other uses not consistent with solvent use. If the source of the detected solvents can not be identified, the appropriate spent solvent hazardous waste code will be conservatively applied to the waste stream.

Hazardous wastes associated with S3000 and S4000 waste streams will be verified based on the results of the total analysis of a representative solidified waste sample. If discrepancies between the results obtained from solidified waste sampling and analysis and headspace-gas sampling and analysis exist (i.e., a VOC is detected in the solidified waste but not in the

headspace), the solidified waste data will be used to verify acceptable knowledge and assign hazardous waste codes.

Sites must confirm the assignment of spent solvent hazardous waste codes (40 CFR §261.31) by evaluating the average concentrations of each VOC detected in container headspace gas and/or solidified waste matrix using the upper 90 percent confidence limit (UCL_{90}). The UCL_{90} for the mean concentration must be compared to the program required quantitation limit (PRQL) for the constituent. If the UCL_{90} for the mean concentration exceeds the PRQL, sites must reevaluate their acceptable knowledge information and determine the potential source of the constituent.

If the source of the constituent is identified as a spent solvent used in the process or is determined to be the result of mixing a listed waste with a solid waste during waste packaging, then the site will either: 1) assign the applicable listed hazardous waste code to the entire waste stream, or 2) segregate the drums containing detectable concentrations of the solvent into a separate waste stream and assign applicable hazardous waste codes. Each site must document, justify, and consistently define waste streams and assign hazardous waste codes based on site-specific permit requirements and other state-enforced agreements.

To determine the mean concentration of solvent VOCs, all headspace-gas data and solidified waste data for a waste stream or waste stream lot (i.e., the portion of the waste stream that is characterized as a unit) will be used, including data qualified with a 'J' flag (i.e., less than the PRQL but greater than the method detection limit [MDL]) or qualified with a 'U' flag (i.e., undetected). For data qualified with a 'U' flag, sites must use one-half the MDL in calculating the mean concentration. Because listed wastes are not defined based on concentration, sites may not remove hazardous waste codes assigned using acceptable knowledge if hazardous constituents are not detected in the headspace.

In many cases, TRU headspace gases and solidified waste matrices contain one or two constituents (e.g., carbon tetrachloride and 1,1,1-trichloroethane) at concentrations that are orders of magnitude higher than the other target analytes. In these cases, samples must be diluted to remain within the instrument calibration range. Sample dilution results in elevated MDLs. Only the concentrations of detected constituents will be used to calculate the mean for the purpose of assigning F-listed hazardous waste codes. Because the presence or absence of F-listed solvents can not be confirmed based on the artificially high MDLs that are caused by sample dilution, data flagged as 'U' and showing an elevated MDL will not be used in calculating the mean concentration.

Acceptable knowledge documentation provides primarily qualitative information that cannot be assessed according to specific data quality goals that are used for analytical techniques. Quality assurance objectives for analytical results are described in terms of precision, accuracy, completeness, comparability, and representativeness. Analytical results will be used to confirm the characterization of wastes based on acceptable knowledge (Section C9-4).

The data quality objectives for sampling and analysis techniques are provided in Appendix C8. To ensure that the acceptable knowledge process is consistently applied, sites must comply with the following data quality requirements for acceptable knowledge documentation:

- Precision - Precision is the agreement among a set of replicate measurements without assumption of the knowledge of a true value. The qualitative determinations, such as compiling and assessing acceptable knowledge documentation, do not lend themselves to statistical evaluations of precision.

- Accuracy - Accuracy is the degree of agreement between an observed sample result and the true value. The percentage of waste containers which require reassignment to a new waste matrix code and/or designation of different hazardous waste codes based an the reevaluation of acceptable knowledge and sampling and analysis data will be reported as a measure of acceptable knowledge accuracy.

- Completeness - Completeness is an assessment of the number of waste streams or number of samples collected to the number of samples determined to be useable through the data validation process. The acceptable knowledge record must contain 100 percent of the required information (Section C9-3). The useability of the acceptable knowledge information will be assessed for completeness during audits.

- Comparability - Data are considered comparable when one set of data can be compared to another set of data. Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for procedures that are used to implement the acceptable knowledge process. All sites must assign hazardous waste codes in accordance with Section C9-4 and provide this information regarding its waste to other sites who store or generate a similar waste stream.

- Representativeness - Representativeness expresses the degree to which sample data accurately and precisely represent characteristics of a population. Representativeness is a qualitative parameter that will be satisfied by ensuring that the process of obtaining, evaluating, and documenting acceptable knowledge information is performed in accordance with the minimum standards established in Section C9-4. Sites also must assess and document the limitations of the acceptable knowledge information used to assign hazardous waste codes (e.g., purpose and scope of information, date of publication, type and extent to which waste parameters are addressed and limitations of information in identifying hazardous wastes).

Each site must address quality control by tracking its performance with regard to the use of acceptable knowledge by: 1) assessing the frequency of inconsistencies among information, and 2) documenting the results of acceptable knowledge confirmation through radiography, headspace-gas analyses, and solidified waste analyses. In addition, the acceptable knowledge process and waste stream documentation must be evaluated through internal assessments by quality assurance organizations and assessments by auditors external to the organization (i.e., DOE/Carlsbad Area Office (CAO).

DOE Site Audits of Acceptable Knowledge

The DOE/CAO will conduct an initial audit of each generator/storage site prior to certifying the site for shipment of TRU waste to the WIPP facility. This initial audit will establish an approved baseline that will be reassessed annually. The QAPP/RCRA portion of these audits will verify compliance with the requirements specified in the WAP and QAPP. The QAPP/RCRA audits will be used to ensure the consistent compilation, application, and interpretation of acceptable knowledge information throughout the DOE complex and to evaluate the completeness and defensibility of site-specific acceptable knowledge documentation related to hazardous waste determinations. Appendix C11 gives a description of the overall audit program and a sample checklist. Figure C9-3 includes the primary steps associated with the audit process of acceptable knowledge.

Audit plans will identify the scope of the audit, requirements to be assessed, participating personnel, activities to be audited, organizations to be notified, applicable documents, and schedule. Audits will be performed in accordance with written procedures and checklists. The audit checklists will include specific items associated with the compilation and evaluation of the required acceptable knowledge information.

Audit checklists must include all of the following elements for review during the audit:

- Documentation of the process used to compile, evaluate, and record acceptable knowledge is available and implemented;
- Personnel qualifications and training are documented;
- All of the required acceptable knowledge documentation specified in Section C9-3 has been compiled in an auditable record;
- A procedure exists for assigning hazardous waste codes to waste streams in accordance with Section C9-4;
- A procedure exists for resolving inconsistencies in acceptable knowledge documentation in accordance with Section C9-4;
- A procedure exists for confirming acceptable knowledge information through: a) radiography or visual examination, b)headspace gas sampling and analysis, and c) solidified waste sampling in accordance with Section C9-4; and
- Results of other audits of the TRU waste characterization programs at the site are available in site records.

Members of the audit team will be knowledgeable regarding the required acceptable knowledge information, RCRA regulations and EPA guidance regarding the use of acceptable knowledge for waste characterization, RCRA hazardous waste determinations, and the WAP and QAPP requirements. Audit team members will be independent of all TRU waste management operations at the site being audited.

Auditors will evaluate all documents associated with the evaluation of the acceptable knowledge documentation for at least one debris waste stream and one solidified waste stream during the audit. For these waste streams, auditors will review all procedures and associated processes developed by the site for documenting the process of compiling acceptable knowledge documentation; correlating information to specific waste inventories; assigning hazardous waste codes; and identifying, resolving, and documenting discrepancies in acceptable knowledge records. The adequacy of acceptable knowledge procedures and processes will be assessed and any deficiencies in procedures documented in the audit report.

Auditors will review the acceptable knowledge documentation for selected waste streams for logic, completeness, and defensibility. The criteria that will be used by auditors to evaluate the logic and defensibility of the acceptable knowledge documentation include completeness and traceability of the information, consistency of application of information, clarity of presentation, degree of compliance with Appendix C9 of the WAP with regard to acceptable knowledge confirmation data, nonconformance procedures, and oversight procedures. Auditors will evaluate compliance with written site procedures for developing the acceptable knowledge record. A completeness review will evaluate the availability of the minimum required TRU waste management and TRU waste stream information (Section C9-3). Records will be reviewed for correlation to specific waste streams and the basis for making hazardous waste determinations. Auditors will verify that sites include all required information and conservatively include all potential hazardous waste codes indicated by the acceptable knowledge records. All deficiencies in the acceptable knowledge documentation will be included in the audit report.

Auditors will verify and document that sites use administrative controls and follow written procedures to make hazardous waste determinations for newly-generated and retrievably stored wastes. Auditors will review procedures used by the sites to confirm acceptable knowledge information using radiography or visual examination and headspace gas sampling and analysis and solidified waste sampling and analysis. Procedures to document changes in acceptable knowledge documentation and hazardous waste code assignments to specific waste streams also will be evaluated for compliance with the WAP.

After the audit is complete, the DOE/CAO will provide the site with preliminary results at a close-out meeting. The DOE/CAO will prepare a final audit report that includes all observations and findings identified during the audit. Sites must respond to all audit findings and identify corrective actions. Audit results will be available at DOE/CAO for review by regulatory agencies, and copies will be provided upon request. If acceptable knowledge procedures do not exist, the minimum required information is not available, or findings of noncompliance are identified associated with hazardous waste determinations, the DOE/CAO will not grant the site waste characterization and certification authority for the subject waste. Waste stream characterization and certification authority may be revoked or suspended if findings during subsequent annual audits indicate a lack of compliance with approved acceptable knowledge procedures. Waste characterization and certification authority will not be reinstated until the site demonstrates all corrective actions have been implemented and the program is reassessed by the DOE/CAO.

The National TRU Program disseminates information regarding TRU waste characterization requirements and program status through the TRU Waste Characterization Interface Working Group. Sites use the CAO electronic bulletin board to disseminate information to other generator sites regarding TRU waste streams, RCRA compliance, and operational and programmatic

issues, methods development, and waste characterization information, including the application of acceptable knowledge. WIPP personnel are provided the required waste characterization information prior to waste acceptance at WIPP and also will conduct audits at least annually. WIPP will maintain an operating record for review during regulatory agency audits. Regulatory agencies may also review information during generator site audits. The NMED will be notified regarding any site's failure to implement corrective actions associated with hazardous waste determinations.

C9-5 Confirmation of Acceptable Knowledge

Prior to notifying a site that a waste stream can be shipped and accepted at the WIPP facility, the DOE/CAO will review the Waste Stream Profile Forms and associated data packages to ensure that radiography, headspace-gas data confirm hazardous waste determinations made using acceptable knowledge. Sites must provide all of the required data associated with waste stream characterization, including radiography or visual examination results, headspace gas sampling and analysis, and solidified waste sampling and analysis. In addition, sites will designate the assigned hazardous waste codes for the waste stream on the waste profile form. The data packages will be evaluated as illustrated in Figure C9-2 and compared to the hazardous waste codes specified on the waste profile form. The DOE/CAO will review information provided by the sites to ensure that changes to hazardous waste codes are identified and justified based on data and that hazardous waste codes are included in the Part A of the WIPP permit application. As part of the reconciliation of DQOs (Appendix C8, Section C8-11), sites are required to track and report changes to hazardous waste determinations. If data consistently indicates discrepancies with acceptable knowledge information, the DOE/CAO will require sites to increase sampling, reassess the materials and processes that generate the waste, and resubmit waste stream profile information. Until discrepancies are resolved, shipment of the waste stream to the WIPP will be prohibited. Consistent nonconformances by a site in implementing and documenting WAP and QAPP requirements will result in the termination of a site's waste characterization and waste certification authority.

Any drum with unresolved discrepancies associated with hazardous waste determinations will not be shipped to the WIPP facility until the discrepancies are resolved. Sites must reassess the materials and processes that generate the waste, including headspace-gas sampling and analysis, radiography or visual examination, and solidified waste sampling and analysis. All shipments of the subject waste stream will cease until the corrective action(s), as necessary, have been implemented and the discrepancy resolved. The DOE/CAO will notify the New Mexico Environment Department (NMED) when the certification status of a waste stream at a site is revoked. If the site does not comply with the corrective actions associated with the hazardous waste determination, which are specified during the nonconformance process, the DOE/CAO will notify the NMED prior to accepting the subject waste at the WIPP facility.

C9-6 Summary

Acceptable knowledge is used in conjunction with other waste characterization techniques to delineate waste streams, identify listed wastes from nonspecific and specific sources in accordance with 40 CFR §261.31, and determine the toxicity characteristics associated with TRU debris wastes. Acceptable knowledge is a key component in properly making hazardous waste determinations under RCRA. The physical form and the associated increased health and safety

risks associated with obtaining a representative sample of TRU debris wastes, clearly justify the use of acceptable knowledge to make hazardous waste determinations. Acceptable knowledge information is confirmed using nondestructive techniques and sampling and analysis.

The proper assignment of listed hazardous waste codes relies on knowledge of the materials and processes that generated the waste and not on the concentration of constituents. Nuclear weapons production resulted in a variety of wastes contaminated with spent solvents used for cleaning and degreasing (i.e., hazardous waste codes F001-F005). Acceptable knowledge documentation must be used to identify these TRU wastes.

To ensure consistency in the use and interpretation of acceptable knowledge information, sites must compile the minimum required information (Section C9-3) in an auditable record. Sites must develop and implement written procedures that describe the compilation, use, and confirmation of acceptable knowledge. In addition, sites must demonstrate through compliance with written procedures that discrepancies in information will be documented and that hazardous waste codes will be conservatively applied.

The DOE/CAO will audit DOE sites to initially grant TRU waste certification authority to each site. The DOE/CAO will conduct audits at least annually thereafter to verify compliance with approved plans and procedures. Sites will implement corrective action plans that address all audit findings. Waste stream characterization and certification authority will be revoked if trends of consistent noncompliance with the WAP and QAPP are identified by the DOE/CAO at a site.

The DOE/CAO will review waste stream profile forms and associated data packages to ensure that radiography and headspace gas data confirm acceptable knowledge and that the correct hazardous waste codes have been assigned to each waste stream. If complete and adequate information is not provided by the generator regarding the hazardous waste determinations, then the waste will not be authorized for shipment to and disposal at the WIPP facility.

FIGURES

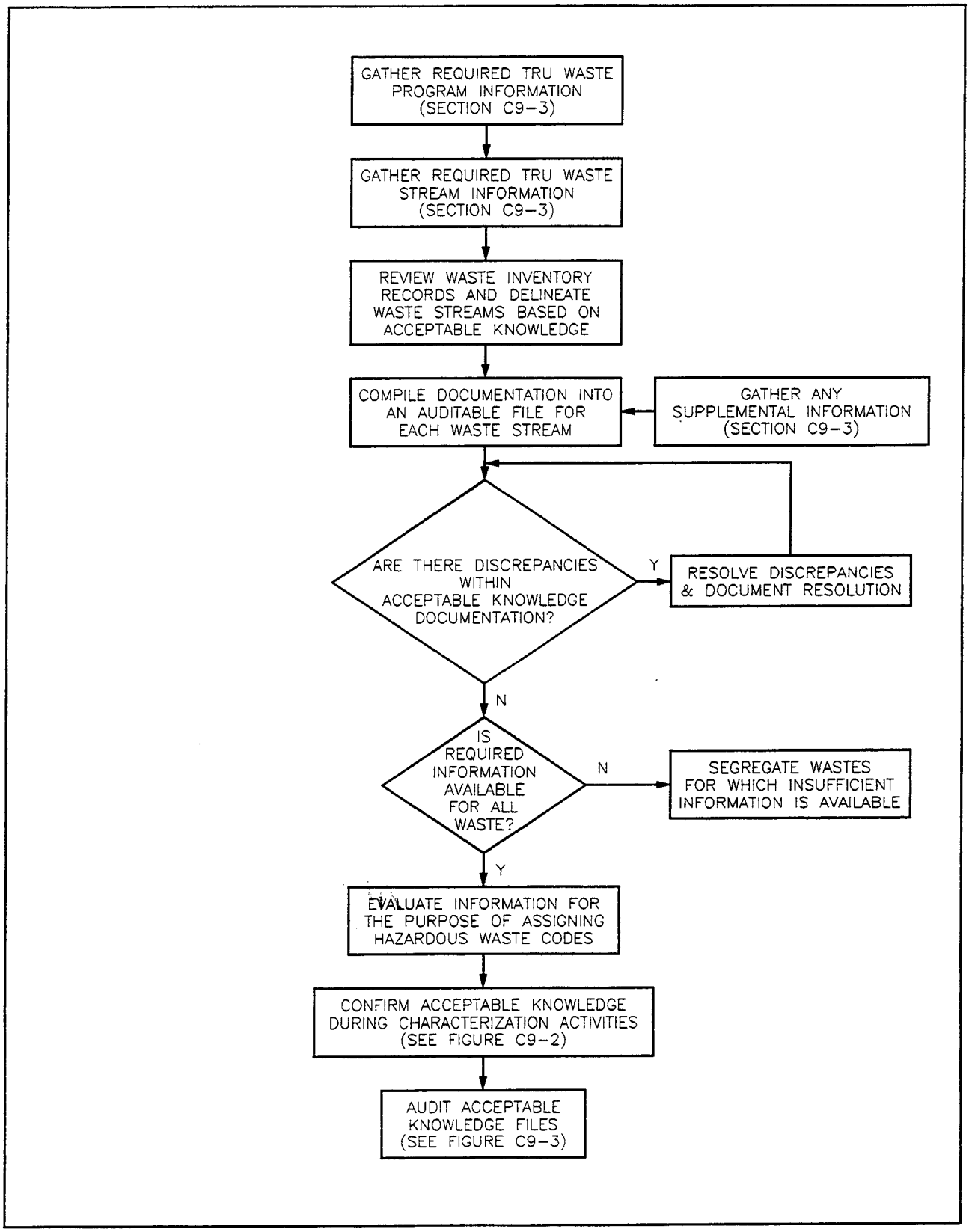

Figure C9-1
Compilation of Acceptable Knowledge Documentation

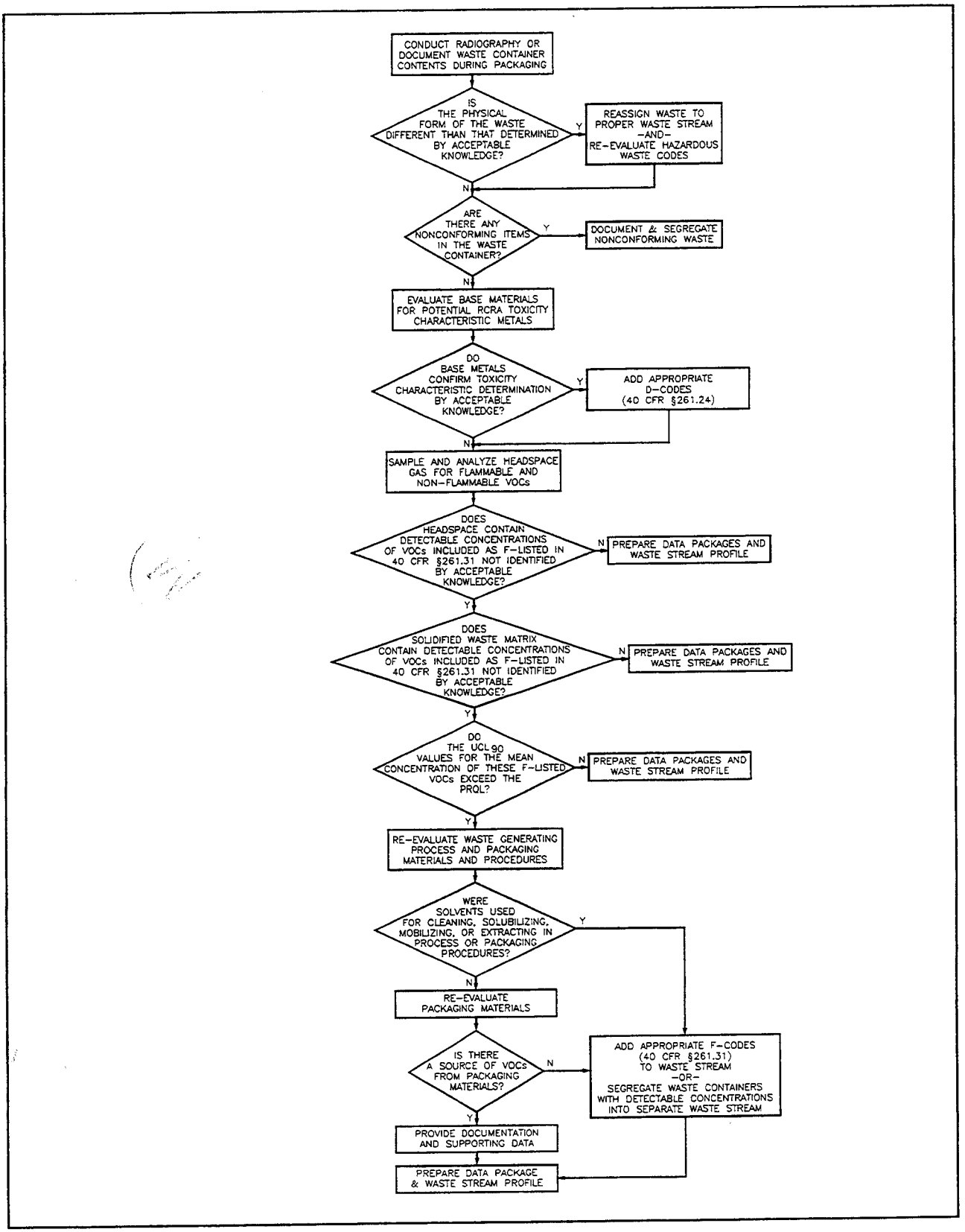

Figure C9-2
Confirmation of Acceptable Knowledge

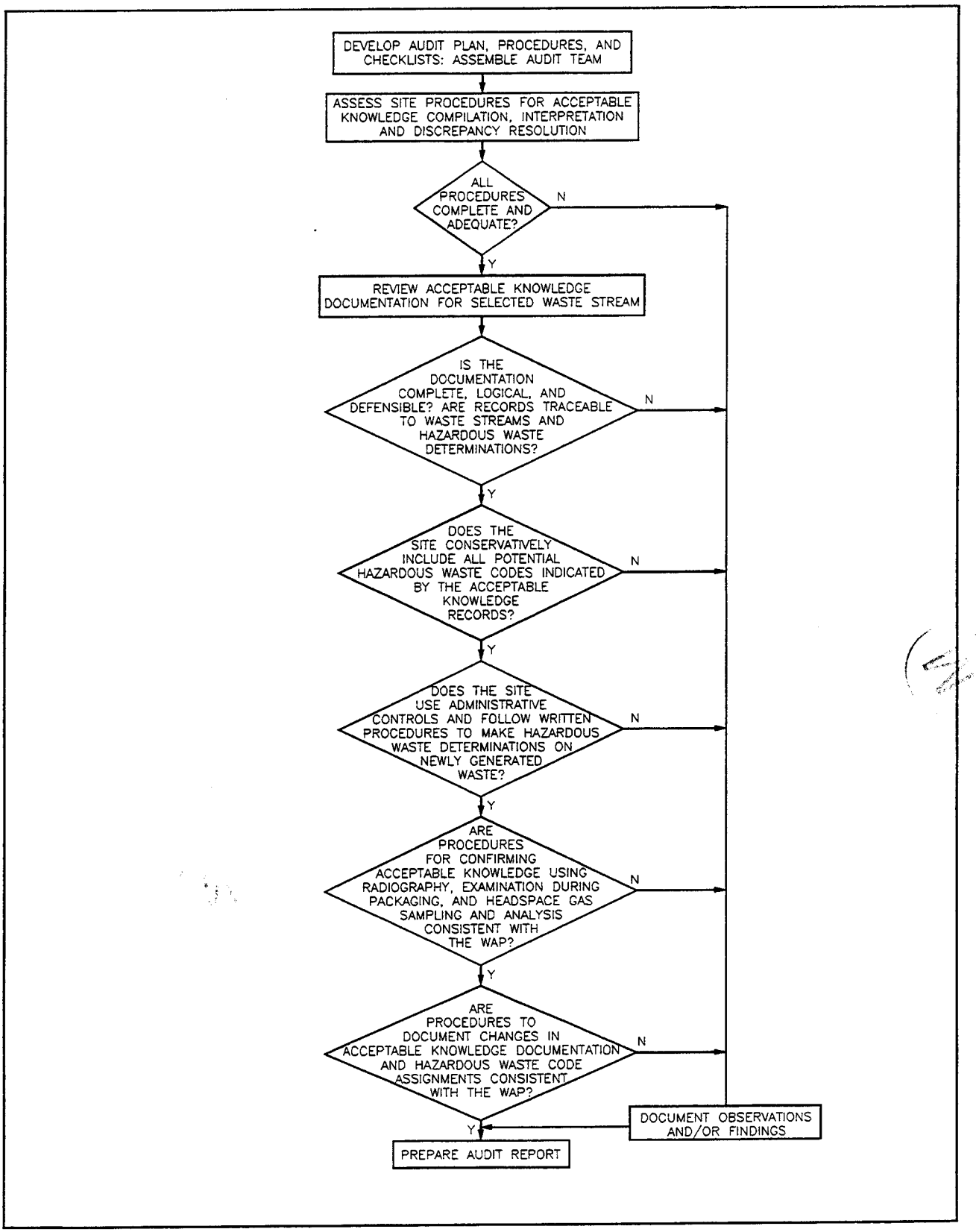

Figure C9-3
Acceptable Knowledge Auditing

APPENDIX C10
QUALITY ASSURANCE PROJECT PLAN REQUIREMENTS

APPENDIX C10
QUALITY ASSURANCE PROJECT PLAN REQUIREMENTS

C10-1 Quality Assurance Project Plans

Each participating site shall develop and implement a quality assurance project plan (QAPjP) that addresses all the requirements specified in Waste Isolation Pilot Plant waste analysis plan and implemented in the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP)(CAO-94-1010, April 30, 1995). These QAPjPs shall include or reference the appropriate management and technical criteria of the quality assurance program, as well as qualitative or quantitative criteria for determining that waste characterization program activities are being satisfactorily performed. QAPjPs shall identify the organization(s) and position(s) responsible for their implementation. The QAPjPs shall also reference site-specific documentation that details how each of the required elements of the characterization program will be performed.

Prior to the implementation of characterization activities at participating sites, standard operating procedures (SOP) will be developed for all activities affecting waste characterization program quality that require written instructions or procedures. For the purposes of the quality assurance program, the term SOP refers to any site-specific implementing document. Compliance with SOPs will ensure that tasks are performed in a consistent manner that results in achieving the quality required for the quality assurance program. The organization, format, content, and designation of SOPs must be described in the QAPjPs. Site-specific SOPs will be reviewed for consistency with the QAPjP during the Generator/Storage Site Waste Screening and Acceptance Audit Program.

C10-2 Document Review, Approval, and Control

The preparation, issue, and change to documents that specify quality requirements or prescribe activities affecting quality for the transuranic waste characterization program shall be controlled to assure that correct and current documents are used and referenced. The QAPjPs shall include the document control format implemented by the QAPP consisting of a unique document identification number in the upper left-hand corner of each page, and the section number, current revision number, date, and page number placed in the upper right-hand corner of each page. All quality documents for the waste characterization program shall be reviewed prior to approval and issuance by qualified and independent individuals. This review shall consider, as appropriate, the technical adequacy, completeness, and correctness of the documents and the inclusion of appropriate quality requirements. Approval shall be indicated by a signature and date page included in the front of each document. Table C10-1 shows the parties responsible for document review, review/approval, implementation, change approval, and change control. Whenever the quality assurance (QA) documents are revised, review and approval of the revision shall be conducted by the same level of approval authority and in accordance with the requirements of review as the original documents.

At a minimum, revisions to QA documents shall be denoted by including the current revision number on the document title page, the revised signature page, and each page that has been revised. Only revised pages need to be reissued. A vertical bar, indicating the change to the

text, shall be included along the left-hand margin of the page. Revised document submittals shall also identify the changes, the reason for the changes, and the justification for concluding that the revised contents continue to satisfy the requirements of the quality assurance program.

The QAPP shall be controlled by the U.S. Department of Energy Carlsbad Area Office National Transuranic Program (NTP) team leader and distributed by this position to the applicable DOE field offices. A distribution list for the QAPP shall be used to control the issuance of revisions and shall be maintained by the NTP team leader.

The QAPP shall be initially reviewed, approved, and concurred with by those positions indicated in Table C10-1, and thereafter reviewed by the NTP team leader at least annually to ensure it addresses the current needs of the waste characterization quality assurance program. If changes to the QAPP are required, the NTP team leader shall be responsible for scheduling and coordinating the review and approval of the revised document. Changes shall be reported by the NTP team leader to the DOE field office managers for notification to the sites. Each site project manager shall be responsible for the revision of the QAPjP and SOPs in accordance with the approved changes to the QAPP.

Each site must have a document control system to control the review and approval of controlled documents. The NTP team leader, the applicable DOE field office, the site project manager, and the site project QA officer are responsible for the initial review and approval of the QAPjPs. Thereafter, the QAPjPs shall be reviewed at least annually by the site project manager. If changes to the QAPjP are required, the site project manager shall be responsible for scheduling and coordinating the review and approval of the revised document. The QAPjPs shall include a description of the organization(s) or person(s) responsible for distributing revisions to those plans.

The QAPjPs shall include a detailed description of the reporting and approval requirements for changes to approved QA documents and SOPs, including procedures for implementing changes to these documents. All members of the site project staff are responsible for reporting any obsolete or superseded information to the site project manager. All site-specific changes shall be evaluated and approved by the site project manager and the site project QA officer before implementation. The site project manager shall notify the appropriate personnel and the affected documents shall be revised as necessary. The site project manager shall also be responsible for notifying the DOE field office of the changes. No changes that affect performance criteria or data quality; such as sample handling and custody requirements, sampling, and analytical procedures, quality assurance objectives, calibration requirements, or QC sample acceptance criteria; shall be made without prior approval of the DOE field office and the NTP team leader. However, minor changes to QAPjPs and SOPs that do not affect the transuranic waste characterization quality assurance program performance criteria or data quality may be made without prior notification of the DOE field office and the NTP team leader.

TABLE C10-1
REQUIREMENTS FOR REVIEW, APPROVAL, IMPLEMENTATION, AND CONTROL OF THE QAPP AND QAPjPs

	Responsible Party							
	Deputy Assistant Secretary, EM-30	Manager, CAO	Manager, Office of Regulatory Compliance	Manager, CAO Quality Assurance	Team Leader, National TRU Program	DOE Field Office	Site Project Manager	Site Project QA Officer
QAPP								
Review	X							
Review/Concurrence			X	X	X			
Review/Approval		X						
Implementation					X			
Change Approval		X	X	X	X			
Change Control					X			
QAPjPs								
Review/Approval				X	X	X	X	X
Implementation							X	
Change Approval				X		X	X	X
Change Control							X	

APPENDIX C11

WASTE ISOLATION PILOT PLANT GENERATOR/STORAGE SITE WASTE SCREENING AND ACCEPTANCE AUDIT PROGRAM

APPENDIX C11
WASTE ISOLATION PILOT PLANT GENERATOR/STORAGE SITE WASTE SCREENING AND ACCEPTANCE AUDIT PROGRAM

The Waste Isolation Pilot Plant (WIPP) Generator Site Waste Screening and Acceptance Audit Program ensures that: 1) the operators of generator/storage sites that plan to transport transuranic (TRU) mixed waste to the WIPP facility conduct sampling and analysis of wastes in accordance with the current WIPP Waste Analysis Plan (WAP), and 2) the information supplied by each generator/storage site to satisfy the waste screening and acceptability requirements of Section C-5 of the WAP is being managed properly. WIPP (meaning both the U.S. Department of Energy Carlsbad Area Office [DOE/CAO] and Westinghouse Waste Isolation Division [WID] personnel) will conduct these audits at the generator sites in accordance with a standard operating procedure. This procedure will contain steps for selecting audit personnel, reviewing applicable background information, preparing an audit plan, preparing audit checklists, conducting the audit, developing an audit report, and following up audit deficiencies. The checklists used in the audit are tailored for each site to be audited, based on the approved site quality assurance project plan (QAPjP), which is the site-specific implementation of the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP).

Audit procedures incorporate the applicable requirements (e.g., auditor and technical specialist qualifications, lead auditor certification) of 10 Code of Federal Regulations 830.120 (Quality Assurance), and the American Society of Mechanical Engineers NQA-1, part 2.7 of NQA-2, NQA-3, and incorporate requirements of DOE Order 5700.6C (Quality Assurance). It further establishes the responsibilities and methodology for planning, scheduling, performing, reporting, verifying, and closing announced and unannounced audits of TRU mixed waste generator and storage sites. Records of all audit activities are part of the WIPP Operating Record and will be maintained at the WIPP facility until closure.

Approved procedures are used to describe audit activities and requirements. Procedures define the responsibilities of specific positions necessary to manage this audit program. The manager who oversees this program must perform the following:

- Schedule audits, including initial audits prior to approval of waste stream profile forms
- Designate lead auditor(s)
- Appoint auditor and lead auditor trainees
- Maintain auditor training and qualification records
- Assure that all auditors have been given appropriate training, including training on the WAP
- Assign auditors and lead auditors to perform annual certification audits

- Review and approve final audit reports

- Track and close all deficiencies and any observations requiring action

- Assure records are entered into the WIPP Operating Record and are properly maintained until facility closure

The DOE will approve lead auditors, auditors, and technical specialists based upon the expertise required for the functions being examined according to the audit scope, including personnel available from WID. The WID will supply auditors/technical specialists with expertise in the Resource Conservation and Recovery Act (RCRA) requirements and knowledge of the analysis and documentation methods required to verify the hazardous determinations made by the generator sites.

Lead auditors must meet the established experience and education requirements and pass a qualification exam. The lead auditor who is assigned to be the audit team leader must perform the following tasks:

- Concur that assigned auditors and technical specialists have the collective experience and training commensurate with the scope, complexity, or special nature of the activities to be audited

- Develop an audit plan and coordinate the preparation of an overall checklist to cover the scope of the audit, with consideration given to previous audit results from that site

- Assign specific audit areas to individual auditors and technical specialists within their particular specialty and provide guidance on checklist development

- Review individual auditor checklists to assure complete coverage of assigned scope, and approve the checklists

- Conduct the audit at the generator site, with entrance meetings, daily team meetings, daily management update, and exit meetings, ensuring that the site is kept fully apprised of the audit progress and results

- Encourage observers to participate according to the protocol established by the DOE/CAO

- Communicate audit results at the conclusion of the audit, including any deficiencies and observations

- Prepare and sign the audit report

- Maintain complete records of each audit and transfer them to the manager when the audit report is issued

Auditors and technical specialists assigned to the specific audit will report to the audit team leader for supervision and perform the following tasks:

- Attend any required specific training and team orientation and planning meetings as directed by the audit team leader.
- Prepare specific audit checklists to verify that the QAPP Quality Assurance Objectives (QAO) are met for the areas being audited.
- Obtain audit team leader approval of checklist.
- Review acceptable knowledge documentation packages, test report data, and documentation of data verification activities.
- Obtain and evaluate objective evidence by means of observation, document reviews, or the conduct of interviews with operators, analysts, technicians, and others necessary to determine the adequacy and effective implementation of the QAPP programs and this WAP.
- Conduct inspection tours of waste generating stations, analytical laboratories, calibration facilities, administrative, and document control/record facility.
- Complete checklist during the audit indicating the objective evidence observed verifies that the generator site has met the QAOs for the program elements, methods, and the activities being audited. Add other items to the checklist as they are observed or as needed during the audit.
- Prepare narrative statements for all deficiencies, and observations that clearly and concisely identify the conditions involved.
- Prepare any portion of the final audit report assigned by the lead auditor.

Audits will be conducted at least annually for each generator site involved in the waste characterization program. Both announced and unannounced audits address the following:

- Results of previous audits
- Changes in programs or operations
- New programs or activities being implemented
- Changes in key personnel

The conduct of the audit commences with an entrance meeting, conducted by the audit team leader, with site or facility management. At this meeting, the audit objectives and scope, the specific areas to be audited, the processes or functions to be observed, and the site-participation required, including site interfaces, will be identified. The purpose of this meeting is to confirm

the audit scope, discuss the audit sequence, establish channels of communication, and confirm the daily and exit meeting. The audit is performed using the approved audit checklist. Audit checklists are tailored for each site to provide an assessment of the specific activities at that generator site. Consistency of evaluation is ensured before the audit through the generator site QAPjP approval. The QAPjPs for the generator sites must incorporate the same requirements from the QAPP. Objective evidence is examined (to the depth necessary) to determine if the identified activities, procedures, or QAOs are adequate and are being effectively implemented.

Audit conduct is accomplished through site personnel interviews, document and record reviews, observations of operations, and any other activities deemed necessary by the auditors to meet the objectives of the audit. Observations or deficiencies identified during the audit will be investigated or evaluated, as necessary, to determine if they are isolated conditions or represent a general breakdown of the waste characterization quality assurance program. During audit interviews or during the daily management meetings, site personnel will be advised of deficiencies identified within their areas of responsibility to establish a clear understanding of the identified condition.

The site personnel will be given the opportunity to correct any condition that can be corrected during the audit period. Deficiencies and observations will be documented and included as part of the final audit report. Those items that can be resolved during the audit (isolated conditions that do not require a root cause determination or actions to preclude recurrence), will be verified prior to the end of the audit, and so noted in the audit report. Those items that affect the quality of the program, and/or the data generated by that program, will be documented on a Corrective Action Report (CAR) and included as a part of the audit report. The CAR will be entered into the DOE/CAO CAR tracking system and tracked until closure. Also, WID will track RCRA-related items on the systematic tracking and action reporting system.

When a deficiency is identified by the audit team, the condition is documented on a CAR by the audit team leader. The DOE/CAO Quality Assurance (QA) Manager and the National Transuranic Program (NTP) Team Leader review the CAR, determine validity (assures that a requirement has really been violated), classify the significance of the condition, assign a response due date, and issue the CAR to the generator site. The generator site reviews the CAR, evaluates the extent and cause of the deficiency, and provides a response to the WIPP indicating the remedial actions and actions taken to preclude recurrence. The WIPP reviews the response from the generator site and, if acceptable, communicates the acceptance to the generator site. The generator site completes remedial actions and actions to preclude recurrence. After all corrective actions have been completed, the WIPP schedules and performs a verification visit to assure that corrective actions have been completed and are effective. When all actions have been completed and verified as being effective, the CAR is closed by the DOE/CAO QA Manager and the NTP Team Leader. As part of the planning process for subsequent audits and surveillances, past deficiencies are reviewed and the previous deficient activity or process is subject to reassessment.

The generator site management will be required to submit a corrective action plan to eliminate the adverse condition stated on the CAR including a resolution of the acceptability of any data generated prior to the resolution of the corrective action.

The corrective action response will include a discussion of the investigation performed to determine the extent and impact of the deficiency, a description of the remedial actions taken, determination of root cause, and actions to preclude recurrence.

An exit meeting will be conducted by the lead auditor prior to departure of the audit team from the site. This meeting will be with site management personnel, including DOE personnel. All draft audit results will be presented to the generator site management.

The formal audit report will be prepared, approved, and issued to the site within 30 days of the completion of the audit by the WIPP facility. The report will include, as a minimum, sections describing the scope, purpose, summary of deficiencies, and observations in narrative format, as well as an identification of the organization audited, the dates of the audit, and the requested response date. The audited site will respond to any deficiencies and observations within 30 days after receipt of any CARs and indicate the corrective action taken or to be taken. If the corrective action has not been completed, the response must indicate the expected date the action will be completed. Subsequent audits or specific verifications, announced or unannounced, will determine if the corrective action has been satisfactorily implemented. Deficiencies, observations, and CARs will be tracked to completion according to established procedure(s). In addition, all audit items will be trended to determine if similar situations exist system wide. Trend reports will be issued as necessary to provide a "lessons learned" announcement to other generator sites who might benefit from program improvements implemented as a result of resolutions to the specific situations discovered at the performance of these audits.

If a generator/storage site fails to implement a corrective action that directly affects the waste characterization activities at the site, the site will have their certification authority suspended and waste shipments to the WIPP will be suspended until the corrective action is completed.

The audit records will be maintained at WIPP as a part of the Operating Record. These records will be included on the Record Inventory and Disposition Schedule and maintained on-site until closure of the WIPP facility.

TABLE C11-1
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
Quality Assurance Objectives			
A. Radiography Does documentation exist to verify the performance of the radiography analyses? Does documentation exist to verify the use of specific training drums? Does documentation exist to verify independent replicate scans by another qualified operator for each batch of containers scanned? Does documentation exist to require the use of test screens for routine equipment checks? Are radiography operator qualifications current? Has radiography been conducted on all retrievably stored drums planned for disposal at the Waste Isolation Pilot Plant (WIPP) facility? Have periodic audio/video tape reviews been performed? Have corrective actions, if needed, been implemented per the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
B. Drum-Headspace Sampling Does documentation exist to verify the precision and accuracy of drum-headspace sampling and analysis? Have field duplicates been collected for drum-headspace sampling? Does the precision of field duplicate analyses meet the quality assurance objective (QAO) specified in the Quality Assurance Program Plan (QAPP)? Have field reference standards been collected for drum-headspace sampling? Does the accuracy of field reference standards meet the QAO specified in the QAPP? Have measures listed in the QAPP been taken to ensure that drum-headspace samples are representative? Have corrective actions, if needed, been implemented per the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
C. Homogeneous Solids and Soils/Gravel Sampling Does documentation exist to verify precision and accuracy of homogeneous solids and soils/gravel sampling? Have co-located cores been collected for each sampling batch? Does the precision of the co-located cores analyses meet the QAO? Have measures listed in the QAPP been taken to ensure that homogeneous solids and soils/gravel samples are representative? Have corrective actions, if needed, been implemented per the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
D. Visual Examination Does documentation exist to verify the precision and accuracy of the visual examination analyses? Are visual examination operator qualifications current? Has visual examination been conducted on the required sample of drums planned for disposal at and currently awaiting shipment to the WIPP facility? Does documentation exist to confirm that visual examination has been performed on a statistical portion of waste containers? Does documentation exist to indicate that the QA Officer has determined the Relative Percent Difference of radiography visual examination? Have corrective actions, if needed, been implemented per the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
E. Gas and Volatile Organic Compound Analyses			
Does documentation exist to verify the precision and accuracy of headspace analyses?			
Have duplicate or replicate measurements been conducted for headspace analyses?			
Does the precision of duplicate or replicate analyses meet the quality assurance objective specified in the QAPP?			
Does the accuracy of U.S. Environmental Protection Agency blind samples and laboratory control standards meet the quality assurance objectives specified in the QAPP?			
Does the instrument meet the method detection limits specified in the QAPP?			
Have corrective actions, if needed, been implemented per the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
F. Totals Analyses Does documentation exist to verify the precision and accuracy of totals analyses? Have duplicate and replicate measurements been conducted for totals analyses? Does the precision and duplicate or replicate analyses meet the quality assurance objective specified in the QAPP? Does the accuracy of the U.S. Environmental Protection Agency blind samples and laboratory control standards meet the quality assurance objectives specified in the QAPP? Do the instruments meet the method detection limits specified in the QAPP? Have corrective actions, if needed, been implemented per the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
Acceptable Knowledge			
A. Acceptable Knowledge Record Is the acceptance knowledge documentation assembled into an auditable record? Have resolutions between document discrepancies been documented? Are the required documents included in the acceptable knowledge record? Does the acceptable knowledge documentation support the waste stream hazardous waste code assignment? Is the logic behind the assignment of the hazardous waste codes documented and kept as part of the acceptable knowledge record? Are results of other audits of the TRU Waste Characterization Programs at the site available in site records?			
B. Verification Has the acceptable knowledge been verified? Have discrepancies and resolutions been documented?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
C. Acceptable Knowledge Procedures Does a procedure exist for assigning hazardous waste codes to waste streams in accordance with the WAP? Does a procedure exist for resolving inconsistencies in acceptable knowledge documentation in accordance with the WAP? Does a procedure exist for confirming acceptable knowledge information through a) radiography or visual examination, b) headspace gas sampling and analysis, and c) solidified waste sampling in accordance with the WAP?			
D. Acceptable Knowledge Training Are the people using acceptable knowledge to make hazardous waste determinations trained per the requirements in the WAP? Are personnel qualifications and training documented? Does the acceptable knowledge training program contain the elements outlined in the WAP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
Sample Custody			
A. Waste Containers (Drums) Have Chain of Custody (COC) Forms been completed and maintained (per the QAPP) for waste containers, from the time they are removed from inventory until their contents are placed in a shipping container?			
B. Samples Have COC Forms been completed and maintained (per the QAPP) for samples?			
Calibration			
A. Radiography Has radiography equipment been qualified to meet the performance criteria specified in the site Quality Assurance Project Plan (QAPjP) and Standard Operating Procedures?			
B. Headspace Sampling Have the headspace sampling equipment and instrumentation been calibrated per the requirements of the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
C. Visual Examination Has the weighing system used during the visual examination process been calibrated per the requirements of the QAPP?			
D. Determination of Headspace Gases Have the instruments used for the analysis of headspace gases been calibrated per the requirements of the QAPP?			
E. Determination of Headspace Organic Gases Have the instruments used for the analysis of headspace organic gases been calibrated per the requirements of the QAPP?			
F. Determination of Total Metals Have the instruments used for total metals analysis been calibrated per the requirements of the QAPP?			
G. Determination of Total VOCs Have the instruments used for total VOCs analysis been calibrated per the requirements of the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
H. Determination of Total SVOCs Have the instruments used for total SVOCs analysis been calibrated per the requirements of the QAPP?			
Data Reduction, Validation, and Reporting			
A. Data Reduction Is data reduction being conducted at the data generation level per the requirements of the QAPP? Is data reduction being conducted at the project level per the requirements of the QAPP?			
B. Data Validation Is data validation being conducted at the data generation level per the requirements of the QAPP? Is data validation being conducted at the project level per the requirements of the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
C. Data Reporting Is data reporting being conducted at the data generation level per the requirements of the QAPP? Is data reporting being conducted at the project level per the requirements of the QAPP?			
Other Quality Control Checks			
A. Radiography Are radiography QC checks (e.g., replicate radiography examinations by a different qualified operator) conducted per the requirements and at the frequency specified in the QAPP?			
B. Drum Headspace Sampling Are field blanks, sampling equipment blanks, field-reference standards, and field sample duplicates taken per the requirements and at the frequency specified in the QAPP?			
C. Visual Examination Are visual examination quality control (QC) checks conducted per the requirements and at the frequency specified in the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
D. Gas Analysis Are laboratory control standards, sampling manifold blanks, equipment blanks, laboratory blanks, and duplicates analyzed per the requirements and at the frequency specified in the QAPP?			
E. Organic Gas Analysis Are laboratory control standards, sampling manifold blanks, equipment blanks, laboratory blanks, laboratory duplicates, and internal standards analyzed per the requirements and at the frequency specified in the QAPP?			
F. Total Metals Analysis Are laboratory blanks, matrix spikes, matrix spike duplicates and laboratory control samples analyzed per the requirements and the frequency specified in the QAPP?			
G. Total VOCs Analysis Are laboratory duplicates, laboratory blanks, matrix spikes, matrix spike duplicates, laboratory control samples and surrogate compounds analyzed per the requirements and the frequency specified in the QAPP?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

TABLE C11-1 (CONTINUED)
EXAMPLE OF WIPP GENERATOR/STORAGE SITE AUDIT CHECKLIST

AUDIT NO. _____ FACILITY/SITE: _____ DATE: _____

Compliance Requirement	Compliance Document	Objective Evidence	Comments
H. Total SVOCs Analysis Are laboratory duplicates, laboratory blanks, matrix spikes, matrix spike duplicates, laboratory control samples, and surrogate compounds analyzed per the requirements and the frequency specified in the QAPP?			
Procedures			
A. Waste Generating Process Procedures Does each waste generating process procedure follow the format specified in the WAP? Does each waste generating process procedure have a section which lists the process controls and range of operation that affect final hazardous waste determinations? Does the procedure specify what actions are to be taken if the parameters do not remain within the specified range and how it is verified that the parameters stay within the given range?			

_____ _____ _____ _____
Auditor Date Lead Auditor Date

APPENDIX C12
COMPARISON OF TRANSURANIC WASTE CHARACTERIZATION PROCEDURES WITH EPA-APPROVED WASTE CHARACTERIZATION METHODS

APPENDIX C12
COMPARISON OF TRANSURANIC (TRU) WASTE CHARACTERIZATION PROCEDURES WITH EPA-APPROVED WASTE CHARACTERIZATION METHODS

The Department of Energy (DOE) sites characterize waste in accordance with this Waste Analysis Plan (WAP) and the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP), which specify waste characterization procedures found in the *Transuranic Waste Characterization Sampling and Analysis Methods Manual* (Methods Manual). The Methods Manual provides a unified source of information on the testing, sampling, and analytical techniques that enable sites to comply with this WAP. The Methods Manual includes all of the testing, sampling, and analytical methodologies accepted by DOE for use in transuranic (TRU) waste characterization requirements.

Many of the analytical procedures found in the Methods Manual are based on methods found in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* SW-846, Third Edition, Final Update I, and Final Update II. Specifically, analytical procedures for solid phase waste in the Methods Manual are based on SW-846 methods. In these instances, the analyst is referred directly to the SW-846 method for the requirements of the procedure. Only information unique to the Program (e.g., target analytes, quality assurance objectives, quality control requirements) is included in the Methods Manual. The testing and sampling procedures included in the Methods Manual were developed specifically for characterizing TRU waste and equivalent methods are not found in SW-846.

The DOE has examined the consequence of modifying SW-846 methods for use in TRU waste characterization to ensure program specific changes do not compromise the integrity of the original SW-846 methods. This examination considered program-specific modifications (i.e., target analysis, quality assurance objectives, quality control requirements) to ensure: 1) these modifications could be met by the SW-846 method being referenced, and 2) these modifications do not compromise the integrity of the SW-846 method being referenced. DOE examined the following elements of each method:

- Scope and Application
- Summary of Procedure
- Interferences
- Safety
- Apparatus and Materials
- Reagents
- Sample Collection, Preservation, and Handling
- Procedure
- Calculations
- Quality Control
- Procedure Performance
- References

For each element, a comparison was made between the Methods Manual and the SW-846 method. Often, the Methods Manual procedure referred directly, and only, to the SW-846

method. In instances where this is not the case, the Methods Manual procedure requirements were evaluated for applicability and compliance with the requirements of the SW-846 method.

A comparison is made in Table C12-1 which indicates which Methods Manual procedures are based on SW-846 methods, and specifies the appropriate SW-846 method. Tables C12-2 through C12-16 are specific comparisons between SW-846 methods and Method Manual procedures. The "comments" column of Tables C12-2 through C12-16 includes reasoning as to why the differences in the SW-846 method and the Methods Manual procedure are non-impactive.

TABLES

TABLE C12-1
CORRELATION BETWEEN SW-846 METHODS AND METHODS MANUAL METHODS

Methods Manual Procedure	SW-846 Method
Procedure 110.1: Sampling Manifold Method to Collect Headspace Gas Samples From a TRU Waste Drum	Program specific procedure, no equivalent SW-846 method
Procedure 110.2: Direct Canister Method to Collect Headspace Gas Samples From a TRU Waste Drum	Program specific procedure, no equivalent SW-846 method
Procedure 110.3: Using a Side-Port Needle to Collect Headspace Gas Samples Through a TRU Waste Drum's Carbon Composite Filter	Program specific procedure, no equivalent SW-846 method
Procedure 110.4: Punching the Drum Lid to Collect Headspace Gas Samples from a TRU Waste Drum	Program specific procedure, no equivalent SW-846 method
Procedure 120.1: Collecting Samples from TRU Waste Drums Containing Homogenous Solids and Soil/Gravel (Sludge)	Program specific procedure, no equivalent SW-846 method
Procedure 210.1: SUMMA® Passivated Stainless Steel Canister Certification and Cleaning	Program specific procedure, no equivalent SW-846 method
Procedure 310.1: Physical Waste Form Characterization Using Radiography	Program specific procedure, no equivalent SW-846 method
Procedure 310.2: Physical Waste Form Characterization Using Visual Examination	Program specific procedure, no equivalent SW-846 method
Procedure 430.1: Modified Method TO-14 for the Gas Chromatography/Mass Spectrometry Determination of Volatile Organic Compounds in Waste Container Headspace	Program specific procedure, no equivalent SW-846 method
Procedure 430.2: Modified Method 8240/8260 for the Determination of Volatile Organic Compounds in Waste Container Headspace	Program specific procedure, no equivalent SW-846 method

TABLE C12-1 (CONTINUED)
CORRELATION BETWEEN SW-846 METHODS AND METHODS MANUAL METHODS

Methods Manual Procedure	SW-846 Method
Procedure 430.3: Method 8240B for the Determination of Total Volatile Organic Compounds in Homogenous Solids and Soil/Gravel	SW-846 Method 8240B: Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS) – See Table C12-2
Procedure 430.4: Method 8260A for the Determination of Total Volatile Organic Compounds in Homogenous Solids and Soil/Gravel	SW-846 Method 8260A: Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS): Capillary Column Technique – See Table C12-3
Procedure 430.5: Method 8250A for the Determination of Total Semi-Volatile Organic Compounds in Homogenous Solids and Soil/Gravel	SW-846 Method 8250A: Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS) – See Table C12-4
Procedure 430.6: Method 8270B for the Determination of Total Semi-Volatile Organic Compounds in Homogenous Solids and Soil/Gravel	SW-846 Method 8270B: Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS): Capillary Column Technique – See Table C12-5
Procedure 440.1: Gas Chromatography/Flame Ionization Detector Determination of Alcohols and Ketones in Waste Container Headspace	Program specific procedure, no equivalent SW-846 method
Procedure 440.2: Direct Injection Gas Chromatography/Flame Ionization Detector Determination of Nonhalogenated Volatile Organic Compounds in Homogenous Solids and Soil/Gravel	Program specific procedure, no equivalent SW-846 method
Procedure 440.3: Gas Chromatography/Electron Capture Detection Determination of PCBs in Organic Sludge	SW-846 Method 8081: Organochlorine Pesticides and PCBs as Aroclors by Gas Chromatography: Capillary Column Technique; SW-846 Method 3550: Ultrasonic Extraction; SW-846 Method 3620: Florisil Column Cleanup. These methods have been optimized for the determination of PCBs only in TRU waste – See Table C-12-6

TABLE C12-1 (CONTINUED)
CORRELATION BETWEEN SW-846 METHODS AND METHODS MANUAL METHODS

Methods Manual Procedure	SW-846 Method
Procedure 510.1: Mass Spectrometry Determination of Hydrogen and Methane in Waste Container Headspace	Program specific procedure, no equivalent SW-846 method
Procedure 520.1: Gas Chromatography Determination of Hydrogen and Methane in Waste Container Headspace	Program specific procedure, no equivalent SW-846 method
Procedure 610.1: Microwave Assisted Acid Digestion of Homogenous Solids and Soil/Gravel	SW-846 Method 3051: Microwave Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils – See Table C-12-7
Procedure 620.1: Extraction Chromatography Cleanup of Homogenous Solids and Soil/Gravel Samples Undergoing Total Metals Analysis	Program specific procedure, no equivalent SW-846 method
Procedure 630.1: Method 6020 for the Inductively Coupled Plasma-Mass Spectrometry Determination of Total Metals in Homogenous Solids and Soil/Gravel	SW-846 Method 6020: Inductively Coupled Plasma-Mass Spectrometry – See Table C-12-8
Procedure 640.1: Method 6010A for the Inductively Coupled Plasma-Atomic Emission Spectroscopy Determination of Total Metals in Homogenous Solids and Soil/Gravel	SW-846 Method 6010A: Inductively Coupled Plasma-Atomic Emission Spectroscopy – See Table C-12-9
Procedure 650.1: Flame Atomic Absorption Spectroscopy Determination of Total Metals in Homogenous Solids and Soil/Gravel	Various SW-846 Direct Aspiration Atomic Absorption Methods, including 7040 (antimony), 7080A (barium), 7090 (beryllium), 7130 (cadmium), 7190 (chromium), 7420 (lead), 7520 (nickel), 7760A (silver), 7840 (thallium), 7910 (vanadium), 7950 (zinc) – See Table C12-10

TABLE C12-1 (CONTINUED)
CORRELATION BETWEEN SW-846 METHODS AND METHODS MANUAL METHODS

Methods Manual Procedure	SW-846 Method
Procedure 650.2: Graphite Furnace Atomic Absorption Spectroscopy Determination of Total Metals in Homogenous Solids and Soil/Gravel	Various SW-846 Graphite Furnace Atomic Absorption Methods, including 7041 (antimony), 7081 (barium), 7091 (beryllium), 7131A (cadmium), 7191 (chromium), 7421 (lead), 7761 (silver), 7841 (thallium), 7911 (vanadium), 7951 (zinc) -- See Table C12-11
Procedure 650.3: Cold Vapor Atomic Absorption Spectroscopy Determination of Total Mercury in Homogenous Solids and Soil/Gravel	SW-846 Method 7471A Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique) -- See Table C12-12
Procedure 650.4: Hydride Generation Atomic Absorption Spectroscopy Determination of Total Arsenic in Homogenous Solids and Soil/Gravel	SW-846 Method 7061A Arsenic (AA, Gaseous Hydride) -- See Table C12-13
Procedure 650.5: Borohydride Generation Atomic Absorption Spectroscopy Determination of Total Antimony and Arsenic in Homogenous Solids and Soil/Gravel	SW-846 Method 7062 Antimony and Arsenic (AA, Borohydride Reduction) -- See Table C12-14
Procedure 650.6: Hydride Generation Atomic Absorption Spectroscopy Determination of Total Selenium in Homogenous Solids and Soil/Gravel	SW-846 Method 7741A Selenium (AA, Gaseous Hydride) -- See Table C12-15
Procedure 650.7: Borohydride Generation Atomic Absorption Spectroscopy Determination of Total Selenium in Homogenous Solids and Soil/Gravel	SW-846 Method 7742 Selenium (AA, Borohydride Reduction) -- See Table C12-16

TABLE C12-2
COMPARISON OF SW-846 METHOD 8240B AND METHODS MANUAL PROCEDURE 430.3

Methods Manual Procedure 430.3 Section	Corresponding SW-846 Method 8240B Section	Comments
Section 1.0 Scope and Application • Program analyte list and quality assurance objectives (QAOs) included in Table 1 • Analyte list is a subset of SW-846 Method 8240B analyte list except for 1,4-dichlorobenzene, ortho-dichlorobenzene, and 1,1,2-trichloro-1,2,2-trifluoroethane • Refers directly and only to SW-846 Method 8240B • Method detection limit of 1 mg/kg • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Analyte list does not include 1,4-dichlorobenzene, ortho-dichlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) and specifies total xylenes • Estimated quantitation limit for soil/sediment samples is 0.5 mg/kg • Batch not to exceed 20 samples as per SW-846 Chapter One	• SW-846 Method 8240B allows analysis of most volatile organic compounds with boiling points below 200 degrees C and are insoluble or slightly soluble in water. • Dichlorobenzenes can be analyzed as semivolatile organic compound as per Table 1 in the Methods Manual procedure. • Freon 113 is very similar to other freon compound included on the analyte list of SW-846 Method 8240B. • Program QAOs are derived based on SW-846 Method 8240B Table 6 calibration and quality control acceptance criteria (precision and accuracy) and regulatory requirements (MDL and PRQL) • SW-846 Method is capable of quantitating at Procedure 430.3 method detection limit.
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 8240B	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 8240B	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training.	No equivalent section in SW-846 Method 8240B	

TABLE C12-2 (CONTINUED)
COMPARISON OF SW-846 METHOD 8240B AND METHODS MANUAL PROCEDURE 430.3

Methods Manual Procedure 430.3 Section	Corresponding SW-846 Method 8240B Section	Comments
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 8240B	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 8240B	Section 5.0 Reagents	
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to Chapter Four, Section 4.1 of SW-846	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for VOC samples included in SW-846, Chapter Four, Section 4.1.
Section 8.0 Procedure • Allows analyst to determine appropriate preparation techniques based on SW-846 or other nationally recognized standard methods • Refers directly and only to SW-846 Method 8240B for initial calibration • Refers directly and only to SW-846 Method 8240B continuing calibration • All calibration requirements are summarized in Table 2 • Refers directly and only to SW-846 Method 8240B for analytical steps	Section 7.0 Procedure • Subsection 7.2 addresses initial calibration • Subsection 7.3 addresses continuing calibration • Subsection 7.4.3 addresses the analysis of sediment/soil and waste samples	• Calibration requirements in Procedure 430.3 are the same as found in SW-846 Method 8240B except for the response factor for bromoform listed in Table 2 of Procedure 430.3. This error in Procedure 430.3 will be corrected.

TABLE C12-2 (CONTINUED)
COMPARISON OF SW-846 METHOD 8240B AND METHODS MANUAL PROCEDURE 430.3

Methods Manual Procedure 430.3 Section	Corresponding SW-846 Method 8240B Section	Comments
Section 9.0 Calculations • Refers directly and only to SW-846 Method 8240B • Specifies results reported in mg/kg wet-weight basis	Section 7.5 Data Interpretation • Specifies waste reported in ug/kg wet-weight basis	• Conversion from ug/kg to mg/kg is a simple multiplication step.

TABLE C12-2 (CONTINUED)
COMPARISON OF SW-846 METHOD 8240B AND METHODS MANUAL PROCEDURE 430.3

Methods Manual Procedure 430.3 Section	Corresponding SW-846 Method 8240B Section	Comments
Section 10.0 Quality Control • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs. • Laboratory duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision • Laboratory blanks must be run once per batch, acceptance criteria is <3 x MDLs in Table 1 • Matrix spikes must be run once per batch, acceptance criteria are the Table 1 QAOs for accuracy • Matrix spike duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision and accuracy • Laboratory control samples must be run once per batch, acceptance criteria are 80-120 %R • Surrogate compounds required in each sample, acceptance criteria are average %R from at least 30 samples ±3 standard deviations • Blind audit samples are distributed, analyzed and reported as part of the	Section 8.0 Quality Control • SW-846 Method 8000A requires each laboratory to operate a formal quality control program • Requires demonstration of acceptable accuracy and precision through the analysis of quality control reference sample • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Laboratory duplicates required once per batch in SW-846 Method 8000A, acceptance criteria not addressed • Method blanks required initially and once per batch in SW-846 Method 8000A and Chapter One, various acceptance criteria are recommended • Matrix spikes required once per batch, no acceptance criteria specified for solid samples • Matrix spike duplicates not required in addition to laboratory duplicates • Laboratory control samples required once per batch in SW-846 Chapter One, minimum acceptance criteria 70-140 %R as indicated in Table 6 of SW-846 Method 8240B • Surrogate compounds required in each	• Procedure 430.3 quality control requirements meet or exceed SW-846 Method 8240B quality control requirements • Procedure 430.3 provides a better defined quality control program than SW-846 Method 8240B

TABLE C12-2 (CONTINUED)
COMPARISON OF SW-846 METHOD 8240B AND METHODS MANUAL PROCEDURE 430.3

Methods Manual Procedure 430.3 Section	Corresponding SW-846 Method 8240B Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 8240B	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 8240B	

TABLE C12-3
COMPARISON OF SW-846 METHOD 8260A AND METHODS MANUAL PROCEDURE 430.4

Methods Manual Procedure 430.4 Section	Corresponding SW-846 Method 8260A Section	Comments
Section 1.0 Scope and Application • Program analyte list and quality assurance objectives (QAOs) included in Table 1 • Analyte list is a subset of SW-846 Method 8260A analyte list except for 1,1,2-trichloro-1,2,2-trifluoroethane • Refers directly and only to SW-846 Method 8260A • Method detection limit of 1 mg/kg • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Analyte list does not include 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) • Estimated quantitation limit for soil/sediment samples is 0.5 mg/kg • Batch not to exceed 20 samples as per SW-846 Chapter One	• SW-846 Method 8260A allows analysis of most volatile organic compounds with boiling points below 200 degrees C and are insoluble or slightly soluble in water. • Freon 113 is very similar to other freon compounds included in the analyte list of SW-846 Method 8260A • Program QAOs are derived based on SW-846 Method 8240B Table 6 calibration and quality control acceptance criteria (precision and accuracy) and regulatory requirements (MDL and PRQL) • SW-846 Method 8260A is capable of quantitating at Procedure 430.4 method detection limit.
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 8260A	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 8260A	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training.	No equivalent section in SW-846 Method 8260A	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 8260A	Section 4.0 Apparatus and Materials	

TABLE C12-3 (CONTINUED)
COMPARISON OF SW-846 METHOD 8260A AND METHODS MANUAL PROCEDURE 430.4

Methods Manual Procedure 430.4 Section	Corresponding SW-846 Method 8260A Section	Comments
Section 6.0 Reagents • Refers directly and only to SW-846 Method 8260A	Section 5.0 Reagents	
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to Chapter Four, Section 4.1 of SW-846	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for VOC samples included in SW-846, Chapter Four, Section 4.1.
Section 8.0 Procedure • Allows analyst to determine appropriate preparation techniques based on SW-846 or other nationally recognized standard methods • Refers directly and only to SW-846 Method 8260A for initial calibration • Refers directly and only to SW-846 Method 8260A continuing calibration • All calibration requirements are summarized in Table 2 • Refers directly and only to SW-846 Method 8260A for analytical steps	Section 7.0 Procedure • Subsection 7.3 addresses initial calibration • Subsection 7.4 addresses continuing calibration • Subsections 7.1, 7.2, and 7.5 address the analysis of sediment/soil and waste samples	• Calibration requirements in Procedure 430.4 are the same as found in SW-846 Method 8260A except for the response factor for bromoform listed in Table 2 of Procedure 430.4. This error in Procedure 430.4 will be corrected.

TABLE C12-3 (CONTINUED)
COMPARISON OF SW-846 METHOD 8260A AND METHODS MANUAL PROCEDURE 430.4

Methods Manual Procedure 430.4 Section	Corresponding SW-846 Method 8260A Section	Comments
Section 9.0 Calculations • Refers directly and only to SW-846 Method 8260A • Specifies results reported in mg/kg wet-weight basis	Section 7.5 Data Interpretation • Specifies waste reported in ug/kg wet-weight basis	• Conversion from ug/kg to mg/kg is a simple multiplication step.

TABLE C12-3 (CONTINUED)
COMPARISON OF SW-846 METHOD 8260A AND METHODS MANUAL PROCEDURE 430.4

Methods Manual Procedure 430.4 Section	Corresponding SW-846 Method 8260A Section	Comments
Section 10.0 Quality Control • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs. • Laboratory duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision • Laboratory blanks must be run once per batch, acceptance criteria is <3 x MDLs in Table 1 • Matrix spikes must be run once per batch, acceptance criteria are the Table 1 QAOs for accuracy • Matrix spike duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision and accuracy • Laboratory control samples must be run once per batch, acceptance criteria is 80-120 %R • Surrogate compounds required in each sample, acceptance criteria are average %R from at least 30 samples ±3 standard deviations • Blind audit samples are distributed, analyzed and reported as part of the	Section 8.0 Quality Control • SW-846 Method 8000A requires each laboratory to operate a formal quality control program • Requires demonstration of acceptable accuracy and precision through the analysis of quality control reference sample • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Laboratory duplicates required once per batch in SW-846 Method 8000A, acceptance criteria not addressed • Method blanks required initially and once per batch in SW-846 Method 8000A and Chapter One, various acceptance criteria are recommended • Matrix spikes required once per batch in SW-846 Method 8000A, no acceptance criteria specified for solid samples • Matrix spike duplicates not required in addition to laboratory duplicates • Laboratory control samples required once per batch in SW-846 Chapter One, minimum acceptance criteria 70-140 %R as indicated in Table 6 of SW-846 Method 8240B	• Procedure 430.4 quality control requirements meet or exceed SW-846 Method 8260A quality control requirements • Procedure 430.4 provides a better defined quality control program than SW-846 Method 8260A

TABLE C12-3 (CONTINUED)
COMPARISON OF SW-846 METHOD 8260A AND METHODS MANUAL PROCEDURE 430.4

Methods Manual Procedure 430.4 Section	Corresponding SW-846 Method 8260A Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 8260A	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 8260A	

TABLE C12-4
COMPARISON OF SW-846 METHOD 8250A AND METHODS MANUAL PROCEDURE 430.5

Methods Manual Procedure 430.5 Section	Corresponding SW-846 Method 8250A Section	Comments

Section 1.0 Scope and Application
• Program analyte list and quality assurance objectives (QAOs) included as Table 1, which includes:
  • cresols (a mixture of all isomers of cresol [o, m, p])
  • ortho-dichlorobenzene
  • pyridine
• Analyte list is a subset of SW-846 Method 8250A analyte list, except pyridine
• Refers directly and only to SW-846 Method 8250A
• Requires samples to be analyzed in batches not to exceed 20 samples
	Section 1.0 Scope and Application
	• The table in Subsection 1.1 lists the applicable analytes, including:
	  • 2-methylphenol and 4-methylphenol
	  • 1,2-dichlorobenzene
	• Subsection 1.2 includes pyridines as compounds that can be quantitated
	• Batch not to exceed 20 samples as per SW-846 Chapter One
		• The Methods Manual list is a subset of that in SW-846. Cresols are the same as methylphenols and ortho-dichlorobenzene is the same as 1,2-dichlorobenzene. The Methods Manual includes m-cresol (3-methylphenol) in its list (under cresols), which is not included in SW-846. SW-846 does not include pyridine in the analyte list, but allows for it in Subsection 1.2.
		• Program QAOs are derived based on SW-846 Method 8250A Table 6 (accuracy and precision) and regulatory requirements (MDL and PRQL)

Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 8250A	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 8250A	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 8250A	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 8250A	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 8250A	Section 5.0 Reagents	

TABLE C12-4 (CONTINUED)
COMPARISON OF SW-846 METHOD 8250A AND METHODS MANUAL PROCEDURE 430.5

Methods Manual Procedure 430.5 Section	Corresponding SW-846 Method 8250A Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter 4, Section 4.1	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapter 4, Section 4.1.
Section 8.0 Procedure • Refers directly and only to SW-846 Method 8250A for sample preparation and cleanup. • Refers directly and only to SW-846 Method 8250A for GC/MS operating conditions • Refers directly and only to SW-846 Method 8250A for initial calibration • Refers directly and only to SW-846 Method 8250A for continuing calibration • All calibration requirements are summarized in Table 2 • Refers directly and only to SW-846 Method 8250A for analytical steps	Section 7.0 Procedure • Subsections 7.1 and 7.2 refer to other SW-846 methods for sample preparation and cleanup • Subsection 7.3 addresses recommended GC/MS operating conditions • Subsection 7.4 addresses initial calibration • Subsection 7.5 addresses continuing (daily) calibration • Subsection 7.6 addresses the analytical procedure	• Calibration requirements in Procedure 430.5 are the same as found in SW-846 Method 8250A, except for the %RSD for CCCs listed in Table 2 of Procedure 430.5. This error in Procedure 430.5 will be corrected. • Procedure 430.5 includes accuracy criteria for surrogate compounds in its continuing calibration criteria; SW-846 Method 8250A provides this criteria in Subsection 8.9 and Table 8.

TABLE C12-4 (CONTINUED)
COMPARISON OF SW-846 METHOD 8250A AND METHODS MANUAL PROCEDURE 430.5

Methods Manual Procedure 430.5 Section	Corresponding SW-846 Method 8250A Section	Comments
Section 9.0 Calculations • Refers directly and only to SW-846 Method 8250A • Specifies results reported in mg/kg wet-weight basis	Subsection 7.7 Data Interpretation • Specifies waste reported in µg/kg wet-weight basis	• Conversion from µg/kg to mg/kg is a simple multiplication step.

TABLE C12-4 (CONTINUED)
COMPARISON OF SW-846 METHOD 8250A AND METHODS MANUAL PROCEDURE 430.5

Methods Manual Procedure 430.5 Section	Corresponding SW-846 Method 8250A Section	Comments
Section 10.0 Quality Control • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision • Laboratory blanks must be run once per batch, acceptance criteria is <3 x MDLs in Table 1 • Matrix spikes must be run once per batch, acceptance criteria are the Table 1 QAOs for accuracy • Matrix spike duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision and accuracy • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Surrogate compounds must be included in every sample, acceptance criteria are average %R from at least 30 samples ±3 standard deviations • Blind audit samples are distributed,	Section 8.0 Quality Control • Requires each laboratory to operate a formal quality control program • Requires demonstration of acceptable precision and accuracy through the analysis of quality control check standard • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Laboratory duplicates not addressed • Method blanks required initially and once per batch in SW-846 Method 8000A and Chapter One, various acceptance criteria are recommended • Matrix spikes required once per batch, acceptance criteria are the accuracy ranges provided in Method 8250A Table 6 • Matrix spike duplicates required once per batch, acceptance criteria are not addressed • Laboratory control samples required once per batch in SW-846 Chapter One, acceptance criteria are not addressed • Surrogate compounds required in each sample, acceptance criteria are average	• Procedure 430.5 quality control requirements meet or exceed SW-846 Method 8250A quality control requirements • Procedure 430.5 provides a better defined quality control program than SW-846 Method 8250A

TABLE C12-4 (CONTINUED)
COMPARISON OF SW-846 METHOD 8250A AND METHODS MANUAL PROCEDURE 430.5

Methods Manual Procedure 430.5 Section	Corresponding SW-846 Method 8250A Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 8250A	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 8250A	

TABLE C12-5
COMPARISON OF SW-846 METHOD 8270B AND METHODS MANUAL PROCEDURE 430.6

Methods Manual Procedure 430.6 Section	Corresponding SW-846 Method 8270B Section	Comments

Section 1.0 Scope and Application
• Program analyte list and quality assurance objectives (QAOs) included as Table 1, which includes:
  • cresols (a mixture of all isomers of cresol [o, m, p])
  • ortho-dichlorobenzene
  • pyridine
• Analyte list is a subset of SW-846 Method 8270B analyte list, except pyridine
• Refers directly an only to SW-846 Method 8270B
• Requires samples to be analyzed in batches not to exceed 20 samples
	Section 1.0 Scope and Application
	• The table in Subsection 1.1 lists the applicable analytes, including:
	  • 2-methylphenol, 3-methylphenol, and 4-methylphenol
	  • 1,2-dichlorobenzene
	• Subsection 1.2 includes pyridines as compounds that can be quantitated
	• Batch not to exceed 20 samples as per SW-846 Chapter One
		• The Methods Manual list is a subset of that in SW-846. Cresols is the same as methylphenols and ortho-dichlorobenzene is the same as 1,2-dichlorobenzene. SW-846 does not include pyridine in the analyte list, but allows for it in Subsection 1.2.
		• Program QAOs are derived based on SW-846 Method 8270B Table 6 quality control criteria (accuracy and precision) and regulatory requirements (MDL and PRQL)

Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 8270B	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 8270B	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 8270B	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 8270B	Section 4.0 Apparatus and Materials	

TABLE C12-5 (CONTINUED)
COMPARISON OF SW-846 METHOD 8270B AND METHODS MANUAL PROCEDURE 430.6

Methods Manual Procedure 430.6 Section	Corresponding SW-846 Method 8270B Section	Comments
Section 6.0 Reagents • Refers directly and only to SW-846 Method 8270B	Section 5.0 Reagents	
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter 4, Section 4.1	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapter 4, Section 4.1.
Section 8.0 Procedure • Refers directly and only to SW-846 Method 8270B for sample preparation and cleanup • Refers directly and only to SW-846 Method 8270B for initial calibration • Refers directly and only to SW-846 Method 8270B for continuing calibration • All calibration requirements are summarized in Table 2 • Refers directly and only to SW-846 Method 8270B for analytical steps	Section 7.0 Procedure • Subsections 7.1 and 7.2 refer to other SW-846 methods for sample preparation and cleanup • Subsection 7.3 addresses initial calibration • Subsection 7.4 addresses continuing (daily) calibration • Subsection 7.5 addresses the analytical procedure	• Calibration requirements in Procedure 430.6 are the same as found in SW-846 Method 8270B, except for the %RSD for CCCs listed in Table 2 of Procedure 430.6. This error in Procedure 430.6 will be corrected. • Procedure 430.6 includes accuracy criteria for surrogate compounds in its continuing calibration criteria; SW-846 Method 8270B provides this criteria in Subsection 8.9 and Table 8.

TABLE C12-5 (CONTINUED)
COMPARISON OF SW-846 METHOD 8270B AND METHODS MANUAL PROCEDURE 430.6

Methods Manual Procedure 430.6 Section	Corresponding SW-846 Method 8270B Section	Comments
Section 9.0 Calculations • Refers directly and only to SW-846 Method 8270B • Specifies results reported in mg/kg wet-weight basis	Subsection 7.6 Data Interpretation • Specifies waste reported in µg/kg wet-weight basis	• Conversion from µg/kg to mg/kg is a simple multiplication step.

TABLE C12-5 (CONTINUED)
COMPARISON OF SW-846 METHOD 8270B AND METHODS MANUAL PROCEDURE 430.6

Methods Manual Procedure 430.6 Section	Corresponding SW-846 Method 8270B Section	Comments
Section 10.0 Quality Control • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision • Laboratory blanks must be run once per batch, acceptance criteria is <3 x MDLs in Table 1 • Matrix spikes must be run once per batch, acceptance criteria are the Table 1 QAOs for accuracy • Matrix spike duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision and accuracy • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Surrogate compounds must be included in every sample, acceptance criteria are average %R from at least 30 samples ±3 standard deviations • Blind audit samples are distributed, analyzed and reported as part of the	Section 8.0 Quality Control • Requires each laboratory to operate a formal quality control program • Requires demonstration of acceptable precision and accuracy through the analysis of quality control reference standard • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Laboratory duplicates required once per batch, acceptance criteria are not addressed • Method blanks required initially and once per batch in SW-846 Method 8000A and Chapter One, various acceptance criteria are recommended • Matrix spikes required once per batch, acceptance criteria are not addressed for solid samples • Matrix spike duplicates not required in addition to laboratory duplicates • Laboratory control samples required once per batch in SW-846 Chapter One, acceptance criteria are not addressed • Surrogate compounds required in each sample, acceptance criteria are average %R from at least 30 samples ± 3	• Procedure 430.6 quality control requirements meet or exceed SW-846 Method 8270B quality control requirements • Procedure 430.6 provides a better defined quality control program than SW-846 Method 8270B

TABLE C12-5 (CONTINUED)
COMPARISON OF SW-846 METHOD 8270B AND METHODS MANUAL PROCEDURE 430.6

Methods Manual Procedure 430.6 Section	Corresponding SW-846 Method 8270B Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 8270B	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 8270B	

TABLE C12-6
COMPARISON OF COMBINED SW-846 METHODS (8081, 3550, 3620) AND METHODS MANUAL PROCEDURE 440.3

Methods Manual Procedure 440.3 Section	Corresponding SW-846 Method(s) Section	Comments
Section 1.0 Scope and Application • Program analyte list (limited to 7 PCB Aroclors) and quality assurance objectives (QAOs) included as Table 1 • Analyte list is a subset of SW-846 Method 8081 analyte list • Refers directly SW-846 Methods 8000A, 8081, 3550, and 3620 • Requires samples to be analyzed in batches not to exceed 20 samples • Method detection limit set at 5 mg/kg	Section 1.0 Scope and Application • SW-846 Method 8081 analyte list includes numerous pesticides and PCB aroclors • Batch not to exceed 20 samples as per SW-846 Chapter One • Minimum reported method detection limits are 0.057-0.070 mg/kg for PCB aroclors	• Procedure 440.3 has been optimized for the determination of PCBs in TRU waste sludge • Procedure 440.3 analyte list is a subset of SW-846 Method 8081 analyte list • Program QAOs are derived based on SW-846 Method 8081 Tables 15 and 16 and procedure development work (precision and accuracy) and regulatory requirements (MDL and PRQL) • SW-846 Method 8081 capable of quantitating at Procedure 440.3 method detection limit
Section 2.0 Summary of Procedure • Sample preparation, hexane extraction with vortex mixing, Florisil cleanup, and quantitation by GC/ECD is summarized	Section 2.0 Summary of Method • SW-846 Method 8081 requires appropriate extraction method, hexane-acetone extraction according to SW-846 Method 3550 allowed • SW-846 Method 8081 allows for a variety of cleanup steps as discussed in Section 3.0 • SW-846 Method 8081 allows quantitation with GC/ECD	
Section 3.0 Interferences • General discussion of possible interferences • Requires Florisil cleanup for spindle oil • Refers directly to SW-846 Method 8081	Section 3.0 Interferences • SW-846 allows for a variety of cleanup methods, including Florisil cleanup according to SW-846 Method 3620	

TABLE C12-6 (CONTINUED)
COMPARISON OF COMBINED SW-846 METHODS (8081, 3550, 3620) AND METHODS MANUAL PROCEDURE 440.3

Methods Manual Procedure 440.3 Section	Corresponding SW-846 Method(s) Section	Comments
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Methods	
Section 5.0 Apparatus and Materials • Refers directly to SW-846 Method 8081 • Specifies extraction and cleanup equipment and materials	Section 4.0 Apparatus and Materials • Equivalent equipment specified in SW-846 Methods 3550 and 3620	
Section 6.0 Reagents • Refers directly to SW-846 Method 8081 • Requires certified standard solutions • Stock standards limited to 6 months shelf life, or as required for purity • Calibration standards must include all aroclors, individually and as mixes • 5 standards required that encompass 5-500 ppm range • Calibration standards limited to 2 months shelf life • Surrogate standards are DCBP as primary, TCMX as secondary • Surrogate final concentration in cleaned extract to be 0.05 ppm • Refers to SW-846 Method 8081, Section 8.3 for corrective action for out-of-control surrogate recovery	Section 5.0 Reagents • Stock standards limited to 1 year shelf life, or as required for purity • Calibration standards to encompass expected concentration range of samples • Calibration standards limited to 6 months shelf life, or as required for purity • Surrogate standards are DCBP as primary, TCMX as secondary	• Procedure 440.3 should refer to SW-846 Method 8081, Section 8.2.2 for corrective action of out-of-control surrogate standards. This error will be corrected.

TABLE C12-6 (CONTINUED)
COMPARISON OF COMBINED SW-846 METHODS (8081, 3550, 3620) AND METHODS MANUAL PROCEDURE 440.3

Methods Manual Procedure 440.3 Section	Corresponding SW-846 Method(s) Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Requires sample extracts to be stored under refrigeration and in dark and must be analyzed within 40 days of extraction • Refers to SW-846 Chapter Four	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846 Method 8081 and Chapter Four.
Section 8.0 Procedure • Requires hexane extraction and vortex mixing of 2.0 gram sample; surrogate must be added to each sample and blank • Requires Florisil cleanup of all samples • Refers directly to SW-846 Method 8000A for initial and continuing calibration • Requires a 3 point calibration curve • All calibration requirements are summarized in Table 2 • Refers directly to SW-846 Methods 8000A and 8081 for analytical steps	Section 7.0 Procedure • SW-846 Method 8000A, Subsection 7.4.2 addresses calibration requirements and requires a 5 point calibration curve • SW-846 Method 8000A, Subsection 7.6, and Method 8081, Subsection 7.5 addresses analysis	• Because Procedure 440.3 was developed to analyze PCBs in samples of radioactive organic sludge, extraction and cleanup steps are modified from SW-846 Methods 3550 and 3620. Extensive procedure performance documentation is included in Section 11.0 to support and justify modified techniques. • Procedure 440.3 requires a 3 point calibration curve. Extensive procedure performance documentation is included in Section 11.0 to support and justify this calibration.
Section 9.0 Calculations • Requires quantitation by summing 3-5 peaks associated with appropriate Aroclor(s)	Section 7.6.4 Quantitation of PCBs • Allows quantitation by summing areas of 3-5 peaks associated with appropriate Aroclor	

TABLE C12-6 (CONTINUED)
COMPARISON OF COMBINED SW-846 METHODS (8081, 3550, 3620) AND METHODS MANUAL PROCEDURE 440.3

Methods Manual Procedure 440.3 Section	Corresponding SW-846 Method(s) Section	Comments
Section 10.0 Quality Control • Refers directly to SW-846 Method 8081, Subsections 8.4 (GC/MS confirmation) and 8.5 (Florisil cleanup) • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision • Laboratory blanks must be run once per batch, acceptance criteria is <3 x MDLs in Table 1 • Matrix spikes must be run once per batch, acceptance criteria are the Table 1 QAOs for accuracy • Matrix spike duplicates must be run once per batch, acceptance criteria are the Table 1 QAOs for precision and accuracy • Laboratory control samples must be run once per batch, acceptance criteria are 80-120 %R • Surrogate compounds must be included in every sample, acceptance criteria are	Section 8.0 Quality Control • SW-846 Method 8000A requires each laboratory to operate a formal quality control program • Recommends demonstration of acceptable accuracy through the analysis of quality control reference standard once per batch, acceptance criteria is 80-120 %R • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Laboratory duplicates required once per batch in SW-846 Method 8000A and Chapter One, acceptance criteria are not addressed • Method blanks required initially and once per batch in SW-846 Method 8000A and Chapter One, various acceptance criteria are recommended • Matrix spikes required once per batch in SW-846 Method 8000A, no acceptance criteria specified for solid samples • Matrix spike duplicates not required in addition to laboratory duplicates • Laboratory control samples not addressed	• The laboratory control sample required by Procedure 440.3 fulfills the quality control reference standard recommended by SW-846 Method 8081 • Procedure 440.3 quality control requirements meet or exceed SW-846 Method 8081 quality control requirements • Procedure 440.3 provides a better defined quality control program than SW-846 Method 8081

TABLE C12-6 (CONTINUED)
COMPARISON OF COMBINED SW-846 METHODS (8081, 3550, 3620) AND METHODS MANUAL PROCEDURE 440.3

Methods Manual Procedure 440.3 Section	Corresponding SW-846 Method(s) Section	Comments
Section 11.0 Procedure Performance • Extensive documentation of performance of the optimized extraction, cleanup, and analytical procedure developed by Argonne National Laboratory	Section 9.0 Method Performance • References extensive method performance work performed by Oak Ridge National Laboratory	• Because Procedure 440.3 was developed to analyze PCBs in samples of radioactive organic sludge, extraction and cleanup steps are modified from SW-846 Methods 3550 and 3620. Extensive procedure performance documentation is included in Section 11.0 of Procedure 440.3 to support and justify modified techniques.
Section 12.0 References • *Determination of PCBs in Rocky Flats Type IV Waste Sludge by Gas Chromatography/Electron Capture Detection* (ANL 1993) • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 8081	

TABLE C12-7
COMPARISON OF SW-846 METHOD 3051 AND METHODS MANUAL PROCEDURE 610.1

Methods Manual Procedure 610.1 Section	Corresponding SW-846 Method 3051 Section	Comments
Section 1.0 Scope and Application • Program analyte indicated (subset of analytes allowed by SW-846 Method 3051) • List of analytical methods applicable to this preparation procedure • Refers directly to SW-846 Method 3051 • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Section 1.1, analyte list • Section 1.2, addresses analytical methods applicable to this preparation procedure • Batch not to exceed 20 samples as per SW-846 Chapter One	• Procedure 610.1 analyte list is a subset of the analyte list in SW-846 Method 3051 • The acceptable analytical procedures to be used for the digestates generated by this procedure are identical
Section 2.0 Summary of Procedure • Refers directly and only to SW-846, Method 3051	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846, Method 3051	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 3051	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846, Method 3051	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846, Method 3051	Section 5.0 Reagents	

TABLE C12-7 (CONTINUED)
COMPARISON OF SW-846 METHOD 3051 AND METHODS MANUAL PROCEDURE 610.1

Methods Manual Procedure 610.1 Section	Corresponding SW-846 Method 3051 Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody procedures in Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation, and Handling • Samples collected following sampling plan in SW-846 Chapter Nine • Sample containers must be prewashed in SW-846 Chapter Three • Samples must be refrigerated and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements in SW-846 Method 3051, Chapter Nine, and Chapter Three
Section 8.0 Procedure • Refers to SW-846 Method 3051 for procedural requirements. • Final acid concentration of digestate should be 4 M nitric acid if using Procedure 620.1 for transuranic element cleanup.	Section 7.0 Procedure	• Procedure 620.1 does not have an equivalent method in SW-846 because it is used to preferentially extract transuranic elements from the sample matrix to reduce interferences.
Section 9.0 Calculations • Does not apply to procedure	Section 7.0 Procedure • Section 7.0 of SW-846, Method 3051 includes all required calculations	• Procedure 610.1 will be revised to refer to Section 7.0 of SW-846, Method 3051

TABLE C12-7 (CONTINUED)
COMPARISON OF SW-846 METHOD 3051 AND METHODS MANUAL PROCEDURE 610.1

Methods Manual Procedure 610.1 Section	Corresponding SW-846 Method 3051 Section	Comments
Section 10.0 Quality Control • Laboratory blank must be included in analytical batch. • Matrix spike must be included in analytical batch. • Matrix spike duplicate must be included in analytical batch. • Laboratory control sample must be included in analytical batch. • Refers analyst to quality control section of the analytical procedure used for any additional requirements.	Section 8.0 Quality Control • Method blank required once per batch in SW-846 Chapter One, various acceptance criteria are recommended • Matrix spike required once per batch in SW-846 Method 3051, Section 8.3, acceptance criteria are not addressed • Matrix spike duplicate or duplicate recommended once per batch in SW-846 Method 3051, Section 8.2, acceptance criteria are not addressed • Laboratory control samples required once per batch in SW-846 Chapter One	• No acceptance criteria given in Procedure 610.1 for quality control samples. Acceptance criteria are found in the analytical methods • Procedure 610.1 quality control requirements (as included in analytical procedures) meet or exceed SW-846 quality control requirements • Methods Manual procedure provide a better defined quality control program than SW-846
Section 11.0 Procedure Performance • Refers directly and only to SW-846, Method 3051	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 3051	

TABLE C12-8
COMPARISON OF SW-846 METHOD 6020 AND METHODS MANUAL PROCEDURE 630.1

Methods Manual Procedure 630.1 Section	Corresponding SW-846 Method 6020 Section	Comments
Section 1.0 Scope and Application • Program analyte list and quality assurance objectives (QAOs) included in Table 1 • Analyte list is a subset of SW-846 Method 6020 analyte list • Refers directly to SW-846 Method 6020 • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Analyte list included as Table 1 • Batch not to exceed 20 samples per SW-846 Chapter One	• Program QAOs are derived from SW-846 Method 6020 (precision and accuracy) and regulatory requirements (MDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 6020	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 6020	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 6020	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 6020	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 6020	Section 5.0 Reagents	

TABLE C12-8 (CONTINUED)
COMPARISON OF SW-846 METHOD 6020 AND METHODS MANUAL PROCEDURE 630.1

Methods Manual Procedure 630.1 Section	Corresponding SW-846 Method 6020 Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Samples collected following SW-846 Chapter Nine • Reference to SW-846 Chapter Three, Section 3.1.3 for sample handling and preservation	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846 Chapter Three and Chapter Nine
Section 8.0 Procedure • Sample preparation procedures must follow Procedure 610.1 of Methods Manual • Sample cleanup Procedure 620.1 of the Methods Manual may be used • Refers directly and only to SW-846 Method 6020 for initial and continuing calibration • All calibration requirements are summarized in Table 2 • Refers directly and only to SW-846 Method 6020 for analytical steps	Section 7.0 Procedure • Subsection 7.1 references sample preparation methods, SW-846 Method 3051, microwave assisted digestion, allowed • Subsections 7.2 through 7.10 address calibration and analytical requirements	• Procedure 610.1 is based on SW-846 Method 3051 (see Table C-12-7)

TABLE C12-8 (CONTINUED)
COMPARISON OF SW-846 METHOD 6020 AND METHODS MANUAL PROCEDURE 630.1

Methods Manual Procedure 630.1 Section	Corresponding SW-846 Method 6020 Section	Comments
Section 9.0 Calculations • Refers to Section 7.12 of SW-846 Method 6020 for required calculations. • Sample dilution must be taken into account • Results reported in mg/kg (wet weight basis) • Percent solid content must be determined on a separate sample aliquot to convert analytical results into mg/kg dry weight	Section 7.0 Procedure • Section 7.11 of SW-846 Method 6020 addresses required calculations	• Procedure 630.1 will be revised to reference Section 7.11 of SW-846 Method 6020

TABLE C12-8 (CONTINUED)
COMPARISON OF SW-846 METHOD 6020 AND METHODS MANUAL PROCEDURE 630.1

Methods Manual Procedure 630.1 Section	Corresponding SW-846 Method 6020 Section	Comments
Section 10.0 Quality Control • Refers to Section 8.1 through 8.5 of SW-846 Method 6020 and states that all quality control requirements are mandatory • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • IDL must be at or below PRDL • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criteria are ≤5 x IDL • Matrix spikes must be run once per batch, acceptance criteria are 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are 80-120 %R and ≤30 RPD • Laboratory control samples must be run once per batch, acceptance criteria are 80-120 %R • Blind audit samples are distributed, analyzed, and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Subsection 8.1 requires the laboratory to establish a formal quality control program • SW-846 Chapter One includes equations for calculating precision, accuracy and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • SW-846 Chapter One and SW-846 6020, Subsection 5.5 lists three blanks that must be included (calibration blank, preparation blank, and rinse blank), acceptance criteria is programmatic • Matrix spike required once per batch, acceptance criteria are not addressed • One duplicate (may be matrix spike duplicate) is required per batch, recommended acceptance criteria are ≤20 RPD for concentrations >100 x IDL • Laboratory control sample recommended once per batch, acceptance criteria are not addressed • Blind audit samples not addressed, however participation in an external performance evaluation program is addressed in SW-846 Chapter One	• Procedure 630.1 quality control requirements meet or exceed SW-846 Method 6020 quality control requirements • Procedure 630.1 provides a better defined quality control program than SW-846 Method 6020

TABLE C12-8 (CONTINUED)
COMPARISON OF SW-846 METHOD 6020 AND METHODS MANUAL PROCEDURE 630.1

Methods Manual Procedure 630.1 Section	Corresponding SW-846 Method 6020 Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 6020	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 6020	

TABLE C12-9
COMPARISON OF SW-846 METHOD 6010A AND METHODS MANUAL PROCEDURE 640.1

Methods Manual Procedure 640.1 Section	Corresponding SW-846 Method 6010A Section	Comments
Section 1.0 Scope and Application • Program analyte list and quality assurance objectives (QAOs) included as Table 1 • Analyte list is a subset of SW-846 Method 6010A analyte list • Refers directly SW-846 Method 6010A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Analyte list included as Table 1 • Batch not to exceed 20 samples as per SW-846 Chapter One	• Program QAOs are derived from SW-846 Method 6010A (precision and accuracy) and regulatory requirements (MDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 6010A	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 6010A	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 6010A	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 6010A	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 6010A	Section 5.0 Reagents	

TABLE C12-9 (CONTINUED)
COMPARISON OF SW-846 METHOD 6010A AND METHODS MANUAL PROCEDURE 640.1

Methods Manual Procedure 640.1 Section	Corresponding SW-846 Method 6010A Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Three, Section 3.1 through 3.3 for sample handling and preservation	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapters Three and Nine
Section 8.0 Procedure • Procedure 610.1 of the Methods Manual must be followed • Procedure 620.1 of the Methods Manual may be used if cleanup is required • Refers directly and only to SW-846 Method 6010A for initial calibration • Refers directly and only to SW-846 Method 6010A for continuing calibration • All calibration requirements are summarized in Table 2 • Refers directly and only to SW-846 Method 6010A for analytical steps	Section 7.0 Procedure • Subsection 7.1 references sample preparation methods, SW-846 Method 3051, microwave assisted digestion, allowed • Subsections 7.2 through 7.5 address initial calibration, continuing calibration, and analytical steps	• Procedure 610.1 is based on SW-846 Method 3051 (see Table C-12-7)
Section 9.0 Calculations • Specifies results reported in mg/kg wet-weight basis • Use the calibration curve to determine analyte concentration	• Section 7.0 addresses quantitation	

TABLE C12-9 (CONTINUED)
COMPARISON OF SW-846 METHOD 6010A AND METHODS MANUAL PROCEDURE 640.1

Methods Manual Procedure 640.1 Section	Corresponding SW-846 Method 6010A Section	Comments
Section 10.0 Quality Control • Refers to Section 8.1 through 8.5 of SW-846, Method 6010A and requires that all quality control requirements are mandatory • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, method detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criteria are ≤3 x IDL • Matrix spikes required once per batch, acceptance criteria are 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are 80-120 %R and ≤30 RPD • Laboratory control samples must be run once per batch, acceptance criteria are 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • SW-846 Chapter One requires each laboratory to operate a formal quality control program • SW-846 Chapter One requires demonstration of acceptable precision and accuracy through the analysis of quality control reference standard • SW-846 Chapter One includes equations used for calculating accuracy, precision, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • SW-846 Chapter One and SW-846 Method 6010A requires the method blank be run once per batch, acceptance criteria are ±3 standard deviations of mean blank value • Matrix spikes required once per batch, acceptance criteria 80-120 %R • Matrix spike duplicates required once per batch, acceptance criteria is ≤20 RPD and 80-120 %R • Laboratory control samples required once per batch in SW-846 Chapter One, acceptance criteria are not addressed • Blind audit samples not addressed, however participation in an external	• Procedure 640.1 quality control requirements meet or exceed SW-846 Method 6010A quality control requirements • Procedure 640.1 provides a better defined quality control program than SW-846 Method 6010A

TABLE C12-9 (CONTINUED)
COMPARISON OF SW-846 METHOD 6010A AND METHODS MANUAL PROCEDURE 640.1

Methods Manual Procedure 640.1 Section	Corresponding SW-846 Method 6010A Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 6010A	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 6010A	

TABLE C12-10
COMPARISON OF SW-846 METHODS 7000A, 7040, 7080A, 7090, 7130, 7190, 7420, 7520, 7760A, 7840, 7910, AND 7950 AND METHODS MANUAL PROCEDURE 650.1

Methods Manual Procedure 650.1 Section	Corresponding SW-846 Methods Section	Comments
Section 1.0 Scope and Application • Program analyte list and quality assurance objectives (QAOs) included as Table 2 • Analyte list is correlated directly to appropriate SW-846 Method • Refers directly to SW-846 Methods listed in Table 1 and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Table 1 analyte list, no specified QAOs in SW-846 Method 7000A • Batch not to exceed 20 samples as per SW-846 Chapter One	• Each individual method refers to SW-846 Method 7000A for general requirements. However each method for a specific analyte may have additional requirements unique to the analyte • Program QAOs are derived based on SW-846 Methods (precision and accuracy) and regulatory requirements (PRDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Methods listed in Table 1	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Methods listed in Table 1	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Methods	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Methods listed in Table 1	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Methods listed in Table 1	Section 5.0 Reagents	

TABLE C12-10 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7040, 7080A, 7090, 7130, 7190, 7420, 7520, 7760A, 7840, 7910, AND 7950 AND METHODS MANUAL PROCEDURE 650.1

Methods Manual Procedure 650.1 Section	Corresponding SW-846 Methods Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846 Chapter Nine
Section 8.0 Procedure • Procedure 610.1 of the Methods Manual must be followed • Procedure 620.1 of the Methods Manual may be used if cleanup is required • Refers directly to SW-846 Methods listed in Table 1 for analytical steps except for silver which refers to Section 7.4 through 7.6 of SW-846 Method 7760A • Use of proven matrix modifiers other than those specified in SW-846 is acceptable • All calibration requirements are summarized in Table 3	Section 7.0 Procedure • Subsection 7.1 addresses sample preparation, Section 5.0 addresses standard preparation Section 7.0 addresses analysis • Calibration criteria are provided in SW-846 Method 7000A Subsections • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.1 are the same as found in SW-846 Method 7000A. • Procedure 650.1 requires 3 standards in the initial calibration; Method 7000A requires a minimum of three standards.

TABLE C12-10 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7040, 7080A, 7090, 7130, 7190, 7420, 7520, 7760A, 7840, 7910, AND 7950 AND METHODS MANUAL PROCEDURE 650.1

Methods Manual Procedure 650.1 Section	Corresponding SW-846 Methods Section	Comments
Section 9.0 Calculations • Allows for reading analyte concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	Subsection 7.4 • Subsection 7.4 in SW-846 Method 7000A addresses concentration determination calculations including sample dilution calculations	

TABLE C12-10 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7040, 7080A, 7090, 7130, 7190, 7420, 7520, 7760A, 7840, 7910, AND 7950 AND METHODS MANUAL PROCEDURE 650.1

Methods Manual Procedure 650.1 Section	Corresponding SW-846 Methods Section	Comments
Section 10.0 Quality Control • Refers to Subsection 8.6 and 8.7 of SW-846 Method 7000A and requires that all quality control requirements are mandatory • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 2 QAOs • Laboratory blanks must be run once per batch, acceptance criteria is ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criteria is 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80-120 %R • Laboratory control samples must be run once per batch, acceptance criteria is 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000A Section 8.0 • SW-846 Method 7000A Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommeded • Matrix spikes required once per batch in SW-846 Method 7000A Section 8.0, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000A Section 8.0, acceptance criteria not addressed • Laboratory control samples (reference standard) required once per batch in SW-846 Method 7000A Section 8.0, acceptance criteria not addressed • Blind audit samples not addressed, however participation in an external performance evaluation program is addressed in SW-846 Chapter One	• Procedure 650.1 quality control requirements meet or exceed SW-846 Methods quality control requirements • Procedure 650.1 provides a better defined quality control program than the SW-846 Methods

TABLE C12-10 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7040, 7080A, 7090, 7130, 7190, 7420, 7520, 7760A, 7840, 7910, AND 7950 AND METHODS MANUAL PROCEDURE 650.1

Methods Manual Procedure 650.1 Section	Corresponding SW-846 Methods Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Methods listed in Table 1	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Methods 7000A, 7040, 7080, 7090,7130, 7190, 7420, 7520, 7760A, 7840, 7910, and 7950	

TABLE C12-11
COMPARISON OF SW-846 METHODS 7000A, 7041, 7081, 7091, 7131A, 7191, 7421, 7761, 7841, 7911, AND 7951 AND METHODS MANUAL PROCEDURE 650.2

Methods Manual Procedure 650.2 Section	Corresponding SW-846 Methods Section	Comments
Section 1.0 Scope and Application • Program analyte list and quality assurance objectives (QAOs) included as Table 2 (Nickel is listed as an analyte for analysis by GFAA) • Refers directly to SW-846 Methods listed in Table 1 and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • SW-846 Method 7000A, Table 1 analyte list • SW-846 does not list a GFAA method for nickel • Batch not to exceed 20 samples as per SW-846 Chapter One	• Each individual method refers to SW-846 Method 7000A for general requirements. However each method for a specific analyte may have additional requirements unique to the analyte • Program QAOs are derived based on SW-846 Methods (precision and accuracy) and regulatory requirements (PRDL and PRQL) • Table 1 in Procedure 650.2 will be revised to reflect the correct SW-846 method numbers • Analyte list for Procedure 650.2 will be revised to exclude nickel
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Methods listed in Table 1	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Methods listed in Table 1	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Methods	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Methods listed in Table 1	Section 4.0 Apparatus and Materials	

TABLE C12-11 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7041, 7081, 7091, 7131A, 7191, 7421, 7761, 7841, 7911, AND 7951 AND METHODS MANUAL PROCEDURES 650.2

Methods Manual Procedure 650.2 Section	Corresponding SW-846 Methods Section	Comments
Section 6.0 Reagents • Refers directly and only to SW-846 Methods listed in Table 1	Section 5.0 Reagents	
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846 Chapter Nine

TABLE C12-11 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7041, 7081, 7091, 7131A, 7191, 7421, 7761, 7841, 7911, AND 7951 AND METHODS MANUAL PROCEDURES 650.2

Methods Manual Procedure 650.2 Section	Corresponding SW-846 Methods Section	Comments
Section 8.0 Procedure • Procedure 610.1 of the Methods Manual must be followed • Procedure 620.1 of the Methods Manual may be used if cleanup is required • Refers directly to SW-846 Methods listed in Table 1 for analytical steps except for arsenic, selenium, and silver which refer to Sections of SW-846 Methods 7061, 7741, and 7761 respectively • Use of proven matrix modifiers other than those specified in SW-846 is acceptable • All calibration requirements are summarized in Table 3	Section 7.0 Procedure • Subsection 7.1 addresses sample preparation, Section 5.0 addresses standard preparation Section 7.0 addresses analysis • Calibration criteria are provided in SW-846 Method 7000A Subsections • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.1 are the same as found in SW-846 Method 7000A. • Procedure 650.1 requires 3 standards in the initial calibration; Method 7000A requires a minimum of three standards.
Section 9.0 Calculations • Allows for reading analyte concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	Subsection 7.4 • Subsection 7.4 in SW-846 Method 7000A addresses concentration determination calculations including sample dilution calculations	

TABLE C12-11 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7041, 7081, 7091, 7131A, 7191, 7421, 7761, 7841, 7911, AND 7951 AND METHODS MANUAL PROCEDURES 650.2

Methods Manual Procedure 650.2 Section	Corresponding SW-846 Methods Section	Comments
Section 10.0 Quality Control • Refers to Subsection 8.6 and 8.7 of SW-846 Method 7000A and requires that all quality control requirements are mandatory • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 2 QAOs • Laboratory blanks must be run once per batch, acceptance criteria are ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criteria are 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80-120 %R • Laboratory control samples must be run once per batch, acceptance criteria are 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000A Section 8.0 • SW-846 Method 7000A Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field sample analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommended • Matrix spikes required once per batch in SW-846 Method 7000A Section 8.0, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000A Section 8.0, acceptance criteria not addressed • Laboratory control samples (reference standard) required once per batch in SW-846 Method 7000A Section 8.0, acceptance criteria not addressed • Blind audit samples not addressed, however participation in an external performance evaluation program is	• Procedure 650.2 quality control requirements meet or exceed SW-846 Methods quality control requirements • Procedure 650.2 provides a better defined quality control program than SW-846 Methods

TABLE C12-11 (CONTINUED)
COMPARISON OF SW-846 METHODS 7000A, 7041, 7081, 7091, 7131A, 7191, 7421, 7761, 7841, 7911, AND 7951 AND METHODS MANUAL PROCEDURES 650.2

Methods Manual Procedure 650.2 Section	Corresponding SW-846 Methods Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Methods listed in Table 1	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Methods 7000A, 7041, 7081, 7091, 7131A, 7191, 7421, 7761, 7841, 7911, and 7951	

TABLE C12-12
COMPARISON OF SW-846 METHOD 7471A AND METHODS MANUAL PROCEDURE 650.3

Methods Manual Procedure 650.3 Section	Corresponding SW-846 Method 7471A Section	Comments
Section 1.0 Scope and Application • Program quality assurance objectives (QAOs) for mercury included as Table 1 • Refers directly to SW-846 Methods 7471A and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Method 7471A is approved for measuring total mercury • Batch not to exceed 20 samples as per SW-846 Chapter One	• Program QAOs are derived based on SW-846 Method 7471A (precision and accuracy) and regulatory requirements (PRDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 7471A	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 7471A	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 7471A	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 7471A	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 7471A	Section 5.0 Reagents	

TABLE C12-12 (CONTINUED)
COMPARISON OF SW-846 METHOD 7471A AND METHODS MANUAL PROCEDURE 650.3

Methods Manual Procedure 650.3 Section	Corresponding SW-846 Method 7471A Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846 Chapter Nine
Section 8.0 Procedure • Refers directly and only to SW-846 Method 7471A for sample and standard preparation and analysis • Allows for use of fluorescence detection instead of absorption as long as all other method requirements are met • All calibration requirements are summarized in Table 2	Section 7.0 Procedure • Subsections 7.1 through 7.4 address sample and standard preparation and analysis • Calibration criteria are provided in SW-846 Method 7000A Subsections 8.2 and 8.3 • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.3 are the same as found in SW-846 Method 7000A. • Procedure 650.3 requires 5 standards in the initial calibration; SW-846 Method 7000A requires a minimum of three standards.
Section 9.0 Calculations • Allows for reading mercury concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	Subsections 7.5 and 7.6 • Subsections 7.5 and 7.6 address constructing a calibration curve and determining mercury concentration • Subsection 7.6 requires sample dilution taken into account and concentrations appropriately qualified (e.g., dry weight)	

TABLE C12-12 (CONTINUED)
COMPARISON OF SW-846 METHOD 7471A AND METHODS MANUAL PROCEDURE 650.3

Methods Manual Procedure 650.3 Section	Corresponding SW-846 Method 7471A Section	Comments
Section 10.0 Quality Control • Refers to Subsections 8.5, 8.6, and 8.7 of SW-846 Method 7000A • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criterion is ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criterion is 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80-120 %R • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000 Section 8.0 • SW-846 Method 7000 Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommended • Matrix spikes required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Laboratory control samples required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Blind audit samples not addressed, however participation on an external performance demonstration program is addressed in SW-846 Chapter One	• Procedure 650.3 quality control requirement meet or exceed SW-846 7471A quality control requirements • Procedure 650.3 provides a better defined quality control program than SW-846 Method 7471A

TABLE C12-12 (CONTINUED)
COMPARISON OF SW-846 METHOD 7471A AND METHODS MANUAL PROCEDURE 650.3

Methods Manual Procedure 650.3 Section	Corresponding SW-846 Method 7471A Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 7471A	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 7471A	

TABLE C12-13
COMPARISON OF SW-846 METHOD 7061A AND METHODS MANUAL PROCEDURE 650.4

Methods Manual Procedure 650.4 Section	Corresponding SW-846 Method 7061A Section	Comments
Section 1.0 Scope and Application • Program quality assurance objectives (QAOs) for arsenic included as Table 1 • Refers directly to SW-846 Methods 7061A and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Method 7061A is approved for determining the concentration of arsenic in waste • Batch not to exceed 20 samples as per SW-846 Chapter One	• Program QAOs are derived based on SW-846 Method 7061A (precision and accuracy) and regulatory requirements (PRDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 7061A	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 7061A	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 7061A	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 7061A	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 7061A	Section 5.0 Reagents	

TABLE C12-13 (CONTINUED)
COMPARISON OF SW-846 METHOD 7061A AND METHODS MANUAL PROCEDURE 650.4

Methods Manual Procedure 650.4 Section	Corresponding SW-846 Method 7061A Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapter Nine
Section 8.0 Procedure • Refers directly and only to SW-846 Method 7061A for procedural requirements • All calibration requirements are summarized in Table 2	Section 7.0 Procedure • Provides sample and standard preparation and analytical procedures • Calibration criteria are provided in SW-846 Method 7000A Subsections 8.2 and 8.3 • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.4 are the same as found in SW-846 Method 7000A. • Procedure 650.4 requires 5 standards in the initial calibration; SW-846 Method 7000A requires a minimum of three standards.
Section 9.0 Calculations • Allows for reading arsenic concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	• SW-846 Method 7061A does not address determining the concentration of arsenic • SW-846 Method 7000A Subsection 7.4 addresses determining metal concentration	

TABLE C12-13 (CONTINUED)
COMPARISON OF SW-846 METHOD 7061A AND METHODS MANUAL PROCEDURE 650.4

Methods Manual Procedure 650.4 Section	Corresponding SW-846 Method 7061A Section	Comments
Section 10.0 Quality Control • Refers to SW-846 Method 7000A Subsections 8.5, 8.6, and 8.7 • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criterion is ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criterion is 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80-120 %R • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000 Section 8.0 • SW-846 Method 7000 Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however, SW-846 Chapter One requires demonstration of method performance prior to field analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommended • Matrix spikes required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Laboratory control samples required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Blind audit samples not addressed, however participation on an external performance demonstration program is addressed in SW-846 Chapter One	• Procedure 650.4 quality control requirements meet or exceed SW-846 Method 7061A quality control requirements • Procedure 650.4 provides a better defined quality control program than SW-846 Method 7061A

TABLE C12-13 (CONTINUED)
COMPARISON OF SW-846 METHOD 7061A AND METHODS MANUAL PROCEDURE 650.4

Methods Manual Procedure 650.4 Section	Corresponding SW-846 Method 7061A Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 7061A	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 7061A	

TABLE C12-14
COMPARISON OF SW-846 METHOD 7062 AND METHODS MANUAL PROCEDURE 650.5

Methods Manual Procedure 650.5 Section	Corresponding SW-846 Method 7062 Section	Comments
Section 1.0 Scope and Application • Program quality assurance objectives (QAOs) for antimony and arsenic included as Table 1 • Refers directly to SW-846 Methods 7062 and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Method 7062 is approved for determining 1 μg/L to 400 μg/L of antimony and arsenic in waste • Batch not to exceed 20 samples as per SW-846 Chapter One	• Program QAOs are derived based on SW-846 Method 7062 (precision and accuracy) and regulatory requirements (PRDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly to SW-846 Method 7062 • Requires sample preparation according to Methods Manual Procedure 610.1 before evaporating the samples to near dryness at the end of the digestion	Section 2.0 Summary of Method • Refers to SW-846 Method 3050 for digestion	• SW-846 Method 3051 is provided as an alternative to Method 3050 • Procedure 610.1 is based on SW-846 Method 3051 (see Table C-12-7)
Section 3.0 Interferences • Refers directly and only to SW-846 Method 7062	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 7062	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 7062	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 7062	Section 5.0 Reagents	

TABLE C12-14 (CONTINUED)
COMPARISON OF SW-846 METHOD 7062 AND METHODS MANUAL PROCEDURE 650-5

Methods Manual Procedure 650.5 Section	Corresponding SW-846 Method 7062 Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapter Nine
Section 8.0 Procedure • Refers directly and only to SW-846 Method 7062 for procedural requirements • All calibration requirements are summarized in Table 2	Section 7.0 Procedure • Provides analytical procedures • Calibration criteria are provided in SW-846 Method 7000A Subsections 8.2 and 8.3 • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.5 are the same as found in SW-846 Method 7000A. • Procedure 650.5 requires 5 standards in the initial calibration; Method 7000A requires a minimum of three standards.
Section 9.0 Calculations • Allows for reading antimony and arsenic concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	Subsections 7.6 and 7.7 • Addresses reading the concentration of antimony and arsenic from the calibration curve and using method of standard additions	

TABLE C12-14 (CONTINUED)
COMPARISON OF SW-846 METHOD 7062 AND METHODS MANUAL PROCEDURE 650-5

Methods Manual Procedure 650.5 Section	Corresponding SW-846 Method 7062 Section	Comments
Section 10.0 Quality Control • Refers to SW-846 Method 7000A Subsections 8.5, 8.6, and 8.7 • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criterion is ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criterion is 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80-120 %R • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000 Section 8.0 • SW-846 Method 7000 Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommended • Matrix spikes required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Laboratory control samples required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Blind audit samples not addressed, however participation on an external performance demonstration program is addressed in SW-846 Chapter One	• Procedure 650.5 quality control requirements meet or exceed SW-846 Method 7062 quality control requirements • Procedure 650.5 provides a better defined quality control program than SW-846 Method 7062

TABLE C12-14 (CONTINUED)
COMPARISON OF SW-846 METHOD 7062 AND METHODS MANUAL PROCEDURE 650-5

Methods Manual Procedure 650.5 Section	Corresponding SW-846 Method 7062 Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 7062	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 7062	

TABLE C12-15
COMPARISON OF SW-846 METHOD 7741A AND METHODS MANUAL PROCEDURE 650.6

Methods Manual Procedure 650.6 Section	Corresponding SW-846 Method 7741A Section	Comments
Section 1.0 Scope and Application • Program quality assurance objectives (QAOs) for selenium included as Table 1 • Refers directly to SW-846 Methods 7741A and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Method 7741A is approved for determining the concentration of selenium in waste • Batch not to exceed 20 samples as per SW-846 Chapter One	• Program QAOs are derived based on SW-846 Method 7741A (precision and accuracy) and regulatory requirements (PRDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly and only to SW-846 Method 7741A	Section 2.0 Summary of Method	
Section 3.0 Interferences • Refers directly and only to SW-846 Method 7741A	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 7741A	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 7741A	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 7741A	Section 5.0 Reagents	

TABLE C12-15 (CONTINUED)
COMPARISON OF SW-846 METHOD 7741A AND METHODS MANUAL PROCEDURE 650.6

Methods Manual Procedure 650.6 Section	Corresponding SW-846 Method 7741A Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapter Nine
Section 8.0 Procedure • Refers directly and only to SW-846 Method 7741A for procedural requirements • All calibration requirements are summarized in Table 2	Section 7.0 Procedure • Provides sample and standard preparation and analytical procedures • Calibration criteria are provided in SW-846 Method 7000A Subsections 8.2 and 8.3 • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.6 are the same as found in SW-846 Method 7000A. • Procedure 650.6 requires 5 standards in the initial calibration; SW-846 Method 7000A requires a minimum of three standards.
Section 9.0 Calculations • Allows for reading selenium concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	• SW-846 Method 7741A does not address determining the concentration of selenium • SW-846 Method 7000A Subsection 7.4 addresses determining metal concentration	

TABLE C12-15 (CONTINUED)
COMPARISON OF SW-846 METHOD 7741A AND METHODS MANUAL PROCEDURE 650.6

Methods Manual Procedure 650.6 Section	Corresponding SW-846 Method 7741A Section	Comments
Section 10.0 Quality Control • Refers to SW-846 Method 7000A Subsections 8.5, 8.6, and 8.7 • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criterion is ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criterion is 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80- 120 %R • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000 Section 8.0 • SW-846 Method 7000 Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommended • Matrix spikes required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Laboratory control samples required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Blind audit samples not addressed, however participation on an external performance demonstration program is addressed in SW-846 Chapter One	• Procedure 650.6 quality control requirements meet or exceed SW-846 Method 7741A quality control requirements • Procedure 650.6 provides a better defined quality control program than SW-846 Method 7741A

TABLE C12-15 (CONTINUED)
COMPARISON OF SW-846 METHOD 7741A AND METHODS MANUAL PROCEDURE 650.6

Methods Manual Procedure 650.6 Section	Corresponding SW-846 Method 7741A Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 7741A	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 7741A	

TABLE C12-16
COMPARISON OF SW-846 METHOD 7742 AND METHODS MANUAL PROCEDURE 650.7

Methods Manual Procedure 650.7 Section	Corresponding SW-846 Method 7742 Section	Comments
Section 1.0 Scope and Application • Program quality assurance objectives (QAOs) for selenium included as Table 1 • Refers directly to SW-846 Methods 7742 and 7000A • Requires samples to be analyzed in batches not to exceed 20 samples	Section 1.0 Scope and Application • Method 7742 is approved for determining 3 μg/L to 750 μg/L of selenium in waste • Batch not to exceed 20 samples as per SW-846 Chapter One	• Program QAOs are derived based on SW-846 Method 7742 (precision and accuracy) and regulatory requirements (PRDL and PRQL)
Section 2.0 Summary of Procedure • Refers directly to SW-846 Method 7742 • Requires sample preparation according to Methods Manual Procedure 610.1 before evaporating the samples to near dryness at the end of the digestion	Section 2.0 Summary of Method • Refers to SW-846 Method 3050 for digestion	• SW-846 Method 3051 is provided as an alternative to Method 3050 • Procedure 610.1 is based on SW-846 Method 3051 (see Table C-12-7)
Section 3.0 Interferences • Refers directly and only to SW-846 Method 7742	Section 3.0 Interferences	
Section 4.0 Safety • Responsibilities for safety and health and training	No equivalent section in SW-846 Method 7742	
Section 5.0 Apparatus and Materials • Refers directly and only to SW-846 Method 7742	Section 4.0 Apparatus and Materials	
Section 6.0 Reagents • Refers directly and only to SW-846 Method 7742	Section 5.0 Reagents	

TABLE C12-16 (CONTINUED)
COMPARISON OF SW-846 METHOD 7742 AND METHODS MANUAL PROCEDURE 650.7

Methods Manual Procedure 650.7 Section	Corresponding SW-846 Method 7742 Section	Comments
Section 7.0 Sample Collection, Preservation and Handling • Requires sample collection according to Methods Manual Procedure 120.1 • Requires sample handling and chain-of-custody according to Section 6.0 of the QAPP	Section 6.0 Sample Collection, Preservation and Handling • Refers to SW-846 Chapter Nine for sampling plan considerations • Requires all sample containers prewashed with detergents, acids, and reagents • Allows for both glass and plastic containers • Requires nonaqueous samples to be refrigerated (when possible) and analyzed as soon as possible	• Procedure 120.1 is a program specific procedure developed specifically for the collection of samples from containers of TRU waste through coring and subsampling. Procedure 120.1 refers to SW-846 for guidance and requirements for sampling. • Section 6.0 of the QAPP incorporates applicable sample handling and preservation requirements for samples included in SW-846, Chapter Nine
Section 8.0 Procedure • Refers directly and only to SW-846 Method 7742 for procedural requirements • All calibration requirements are summarized in Table 2	Section 7.0 Procedure • Provides analytical procedures • Calibration criteria are provided in SW-846 Method 7000A Subsections 8.2 and 8.3 • Serial dilution and post-digestion spike criteria are provided in SW-846 Method 7000A Subsection 8.6	• Calibration requirements in Procedure 650.7 are the same as found in SW-846 Method 7000A. • Procedure 650.7 requires 5 standards in the initial calibration; Method 7000A requires a minimum of three standards.
Section 9.0 Calculations • Allows for reading selenium concentration from calibration curve or directly from instrument readout • Requires sample dilution taken into account • Specifies results reported in mg/kg wet weight basis • Provides for conversion to mg/kg dry weight	Subsections 7.6 and 7.7 • Addresses reading the concentration of selenium from the calibration curve and using method of standard additions	

TABLE C12-16 (CONTINUED)
COMPARISON OF SW-846 METHOD 7742 AND METHODS MANUAL PROCEDURE 650.7

Methods Manual Procedure 650.7 Section	Corresponding SW-846 Method 7742 Section	Comments
Section 10.0 Quality Control • Refers to SW-846 Method 7000A Subsections 8.5, 8.6, and 8.7 • Requires formal quality control program • Requires demonstration of acceptable performance prior to analyzing program samples • Specifies equations for calculating analytical precision, accuracy, instrument detection limit, and percent recovery for quality control samples • Method performance samples must be run initially and semiannually, acceptance criteria are Table 1 QAOs • Laboratory blanks must be run once per batch, acceptance criterion is ≤3 x IDL • Matrix spikes must be run once per batch, acceptance criterion is 80-120 %R • Matrix spike duplicates must be run once per batch, acceptance criteria are ≤30 RPD and 80-120 %R • Laboratory control samples must be run once per batch, acceptance criterion is 80-120 %R • Blind audit samples are distributed, analyzed and reported as part of the DOE Performance Demonstration Program	Section 8.0 Quality Control • Refers to SW-846 Method 7000 Section 8.0 • SW-846 Method 7000 Section 8.0 recommends quality control data be maintained and available for easy reference or inspection • SW-846 Chapter One includes equations for calculating precision, accuracy, and method detection limit • Method performance samples not addressed, however SW-846 Chapter One requires demonstration of method performance prior to field analysis • Method blanks required once per batch per SW-846 Chapter One, various acceptance criteria recommended • Matrix spikes required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Matrix spike duplicates required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Laboratory control samples required once per batch in SW-846 Method 7000 Subsection 8.4, acceptance criteria not addressed • Blind audit samples not addressed, however participation on an external performance demonstration program is addressed in SW-846 Chapter One	• Procedure 650.7 quality control requirements meet or exceed SW-846 Method 7742 quality control requirements • Procedure 650.7 provides a better defined quality control program than SW-846 Method 7742

TABLE C12-16 (CONTINUED)
COMPARISON OF SW-846 METHOD 7742 AND METHODS MANUAL PROCEDURE 650.7

Methods Manual Procedure 650.7 Section	Corresponding SW-846 Method 7742 Section	Comments
Section 11.0 Procedure Performance • Refers directly and only to SW-846 Method 7742	Section 9.0 Method Performance	
Section 12.0 References • *Performance Demonstration Program Plan for the Analysis of Solidified Wastes for the Transuranic Waste Characterization Program* (DOE 1995a) • *Transuranic Waste Characterization Quality Assurance Program Plan* (DOE 1995b) • *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846* (EPA 1995)	Section 10.0 References • See SW-846 Method 7742	

APPENDIX C13

WIPP WASTE INFORMATION SYSTEM DATA DICTIONARY

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
I.	Aspiration Method	None	Method used for aspirating the container prior to shipment per Appendix 1.3.7 of the TRUPACT-II Safety Analysis Report. Method is to be identified as either Option 1, 2, or 3.	A1	Edit check of either 1, 2, or 3. No Blanks	No
II.	Aspiration Period	Days	Time that the container must be aspirated based on the aspiration method selected per Appendix 3.6.11 of the TRUPACT-II Safety Analysis Report	999	Look-up table of container aspiration periods	No
III.	Assay Characterization Method	None	Identifies the site-specific approved characterization method(s) or system(s) that was used to identify and quantify the radionuclide masses	A4	Look-up table listing approved methods	No
IV.	Assay Date	None	The date when the assay was completed at the certification site	Date	None	No
V.	Assembly Identification Number	None	A unique number assigned by the shipper to an assembly. The number consists of the 2-letter site identification code followed by the last two digits of the year and the 4-digit package assembly number.	AAYY9999	Unique number Each container in an assembly (e.g. a seven pack) must be of the same shipping category	No
VI.	Bore Hole Number	None	Disposal location within the WIPP where a remote handled waste canister is disposed.	A6	None	No
VII.	Characterization Methods	None	Identifies the approved EPA characterization methods or systems that were used to obtain the waste characterization data.	A20	Look-up table of characterization techniques	No
VIII.	Column Height	None	The column height within a room/drift at the WIPP which designates the location within the height of the room/drift where the container is emplaced	9	None	No
IX.	Column Number	None	The column number within a room/drift at the WIPP which designates the location within the width of the room/drift where the container is emplaced	9	None	No
X.	Comments	None	Data field to be used to provide additional information	A200	None	No
XI.	Contact Dose Rate of Container (Beta/Gamma)	mrem/hr	Beta/gamma contact dose rate at the surface of the Type A container	9999999	≤ 200 mrem/hr for CH ≤ 1000 rem/hr for RH	No
XII.	Contact Dose Rate of Container (Neutron)	mrem/hr	Neutron contact dose rate at the surface of the Type A container	9999999	≤ 270 mrem/hr for RH	No
XIII.	Contact Dose Rate of Container (Total)	mrem/hr	Total contact dose rate at the surface of the Type A container	9999999	≤ 200 mrem/hr for CH ≤ 1000 rem/hr for RH	Yes

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
XIV.	Contact Dose Rate of Package (Total at Surface)	mrem/hr	Total contact dose rate at the surface of the Type B packaging (TRUPACT-II and RH Cask)	9999999	≤ 200 mrem/hr	No
XV.	Contact Phone	None	Phone number of the shipper technical contact. Number to be listed is to include area code + prefix + number	A12	None	No
XVI.	Container Closure Date	None	Date the container was closed	Date	None	No
XVII.	Container Identification Number	None	A unique identification number assigned to each container	AA999999999 99	Unique number	No
XVIII.	Container Liner Punctured	None	Identifies whether the container liner was punctured (if applicable)	Logical (yes/no)	If field 16 had identified the use of a liner, reject if "no"	No
XIX.	Container Liner Type	None	Identifies the type of container liner (if applicable)	A3	Look-up table of standard liners. Look-up table is also to contain the option of "no liner".	No
XX.	Container Type Code	None	A 3-digit container type code	A3	Look-up table of approved container type codes 001 55-gallon drum 002 SWB 003 TDOP 004 Pipe component (6") 005 Pipe component (12") 101 RH-TRU 72-B canister 102 RH-TRU drum canister	No
XXI.	Decay Heat	Watts	The rate of deposition of thermal energy within the container associated with the decay of radionuclides. The terms "decay heat" and "thermal power" are synonymous.	9.99E+99	None	Yes
XXII.	Decay Heat of Package	Watts	Sum of decay heats of containers within the package	9.99E+99	≤ 40 watts per TRUPACT-II package	Yes
XXIII.	Decay Heat Uncertainty	Watts	Uncertainty in the decay heat	9.99E+99	None	Yes
XXIV.	Decay Heat Uncertainty of Package	Watts	Square root of the sum of the squares of the container decay heat uncertainties	9.99E+99	None	Yes
XXV.	Decay Heat (Maximum)	Watts	Sum of the decay heat and decay heat uncertainty for a container	9.99E+99	Look-up table containing decay heat limits for each shipping category	Yes
XXVI.	Disposal Date	None	The date when the container is emplaced in the underground of the WIPP	Date	Date equal to or later than the shipment receipt date	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
XXVII.	Dose Rate of Package at 1 Meter	mrem/hr	Total dose rate at 1 meter from the surface of the Type B packaging (required to assign a transport index)	9999999	None	No
XXVIII.	Dose Rate of Package at 2 Meters	mrem/hr	Total dose rate at 2 meters from the surface of the Type B packaging (TRUPACT-II and RH Cask)	9999999	≤ 10 mrem/hr	No
XXIX.	DOT Description	None	U.S. Department of Transportation description for the Uniform Hazardous Waste Manifest	Memo	None	No
XXX.	Drift Number	None	The geotechnical location within the WIPP where a container is emplaced	A6	None	No
XXXI.	EPA ID	None	U.S. Environmental Protection Agency's number for the waste site having responsibility for shipment of the waste	A15	Look-up table containing the corresponding name and address of the generator	No
XXXII.	Filter Install Date	None	The date the filter was installed in the container	Date	None	No
XXXIII.	Filter Model	None	Vendor model number of the filter used to vent a container	A6	Look-up table listing approved filters	No
XXXIV.	Gas Generation Completion Date	None	The date of test completion for a container shipping category	Date	None	No
XXXV.	Gas Generation Rate - Measured H_2 + CH_4	moles/s	Measured hydrogen and methane gas generation rate for a container shipping category	9.9E+99	Look-up table containing hydrogen and methane gas generation rate limits as a function of packaging layers, content code, and radionuclide activity	No
XXXVI.	Gas Generation Rate - Measured Total	moles/s	Measured total gas generation rate for a container shipping category	9.9E+99	Look-up table containing total gas generation rate limits as a function of packaging layers, content code, and radionuclide activity	No
XXXVII.	Hazardous ID Code	None	Hazardous waste EPA codes listed for the container. This is a multiple occurring field.	A4	Look-up table listing the codes	No
XXXVIII.	Headspace Gas Innermost Layer: Analyte Name	None	The element, ion, or compound an analysis seeks to determine; the element of interest	A20	Look-up table containing the 29 targeted analytes (this is a multiple occurring data field)	No
XXXIX.	Headspace Gas Innermost Layer: Characterization Method	None	Identifies the characterization method or system that was used to obtain the innermost layer gas data.	A30	Look-up table listing approved methods	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
XL.	Headspace Gas Innermost Layer: Date Analyzed	None	Date gas of innermost layer was analyzed	Date	≤ 34 days from date sampled	No
XLI.	Headspace Gas Innermost Layer: Date Sampled	None	Date gas of innermost layer was sampled	Date	None	No
XLII.	Headspace Gas Innermost Layer: Flammable Gas Concentrations	Volume Percent	Concentrations of flammable gases in the innermost layer including but not limited to H_2 and CH_4	999	≤ 5% (H_2 + CH_4)	No
XLIII.	Headspace Gas Innermost Layer: Identification	None	Innermost layers of confinement must be consecutively numbered and labeled starting with 1 as they are sampled and removed from the waste container during visual examination. The sample collected from each innermost layer of confinement must be referenced to that particular inner most layer of confinement and to the waste container.	99	None	No
XLIV.	Headspace Gas Innermost Layer: VOC Concentrations	ppmv	Concentrations of the 29 target VOCs in the innermost layer	999999	This is a multiple occurring data field	No
XLV.	Headspace Gas: Analyte Name	None	The element, ion, or compound an analysis seeks to determine; the element of interest. This is a multiple occurring field.	A20	Look-up table containing the 29 targeted VOC analytes	No
XLVI.	Headspace Gas: Characterization Method	None	Identifies the characterization method or system used to obtain the headspace gas data.	A30	Look-up table listing approved methods	No
XLVII.	Headspace Gas: Date Analyzed	None	Date headspace gas was analyzed	Date	≤ 34 days after sampling date	No
XLVIII.	Headspace Gas: Date Sampled	None	Date headspace gas was sampled	Date	None	No
XLIX.	Headspace Gas: Flammable Gas Concentrations	Volume Percent	Concentrations of H_2 plus CH_4 flammable gases in the headspace	A20	≤ 5% (H_2 + CH_4)	No
L.	Headspace Gas: Total Flammable VOC Concentration	ppmv	Total concentration of target flammable VOCs in the headspace.	999999	≤ 500 ppm total flammable VOCs	Yes

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
LI.	Headspace Gas: VOC Concentrations	ppmv	Concentrations of the 29 target VOCs in the headspace. This is a multiple occurring field.	999999	No limits for the target VOCs except for the following: carbon tetrachoride ≤ 7510 chloroform ≤ 6325 1,1-dichloroethene ≤ 28750 1,2-dichloroethane ≤ 9100 methylene chloride ≤ 368500	Yes
LII.	ICV Closure Date	None	The date when the inner containment vessel was closed	Date	None	No
LIII.	Item Description Code	None	A site specific numerical code applied to individual waste forms to identify their source	A4	Look-up table listing approved item description codes taken from the site's certification plan	No
LIV.	Layers of Packaging	None	Identifies the number of layers of plastic confinement within a container	9	None	No
LV.	Manifest Document Number	None	Identifies the manifest number assigned to the waste shipment	A5	None	No
LVI.	Nondestructive Examination	None	The radiometric examination of retrievably stored waste	Logical (yes/no)	100% sampling of retrievably stored waste	No
LVII.	Packaging Serial Number	None	The TRUPACT-II , cask, or other Type B shipping container number	A3	None	No
LVIII.	Panel Number	None	The panel number in which the container is disposed	A2	None	No
LIX.	PCB Concentration	ppm	The concentration of polychlorinated biphenyls (PCBs) in the container	9999	≤ 50 ppm No blanks	No
LX.	Plutonium-239 Equivalent Activity	PE-Ci	The plutonium-239 equivalent activity per container	9.9E+99	≤ 80 PE-Ci per drum ≤ 130 PE-Ci per SWB ≤ 1000 PE-Ci per canister	Yes
LXI.	Plutonium-239 FGE per Type B RH-TRU 72-B Waste Shipping Package (Total)	FGE	The Plutonium-239 FGE plus the Plutonium-239 FGE uncertainty per RH-TRU 72-B waste shipping package	9.9E+99	≤ 325 FGE	Yes
LXII.	Plutonium-239 Fissile Gram Equivalent	FGE	The Plutonium-239 fissile gram equivalent per container	9.9E+99	≤ 200 FGE per drum ≤ 325 FGE per SWB ≤ 325 FGE per canister ≤ 200 FGE per pipe overpack package	Yes

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
LXIII.	Plutonium-239 Fissile Gram Equivalent (Total)	FGE	The Plutonium-239 FGE plus twice the Plutonium-239 FGE uncertainty per container	9.9E+99	≤ 200 FGE per drum ≤ 325 FGE per SWB ≤ 325 FGE per canister ≤ 200 FGE per pipe overpack package	Yes
LXIV.	Plutonium-239 Fissile Gram Equivalent per Type B Package	FGE	Sum of the Plutonium-239 fissile gram equivalent per container per Type B package	9.9E+99	≤ 325 FGE ≤ 2800 FGE for pipe overpack packages	Yes
LXV.	Plutonium-239 Fissile Gram Equivalent per Type B Package for CH-TRU (Total)	FGE	The Plutonium-239 FGE plus twice the Plutonium-239 FGE uncertainty per Type B package for CH-TRU	9.9E+99	≤ 325 FGE ≤ 2800 FGE for pipe overpack packages	Yes
LXVI.	Plutonium-239 Fissile Gram Equivalent Uncertainty	FGE	The Plutonium-239 fissile gram equivalent uncertainty per container	9.9E+99	None	Yes
LXVII.	Plutonium-239 Fissile Gram Equivalent Uncertainty per Type B Package	FGE	Square root of the sum of the squares of the Plutonium-239 fissile gram equivalent uncertainties per container per Type B package	9.9E+99	None	Yes
LXVIII.	Radionuclide Activity	Curies	Activity of the individual radionuclides	9.9E+99	None	No
LXIX.	Radionuclide Activity Uncertainty	Curies	Uncertainty in the activity of the individual radionuclides	9.9E+99	None	No
LXX.	Radionuclide Activity Uncertainty (Total)	Curies	Uncertainty in the summation of activities of the individual radionuclides within a container	9.9E+99	None	Yes
LXXI.	Radionuclide Highway Route Controlled Quantity	None	A highway route controlled quantity is that quantity of normal form material in a type B package which exceeds 3000 times the A2 value of the radionuclides as specified in 49 CFR 173.443 or 30,000 curies, whichever is least	Logical (yes/no)	yes if > 1 no if ≤ 1	Yes
LXXII.	Radionuclide Mass	Grams	Mass of the individual radionuclides	9.9E+99	None	Yes
LXXIII.	Radionuclide Mass Uncertainty	Grams	Uncertainty in the mass of the individual radionuclides	9.9E+99	None	Yes
LXXIV.	Radionuclide Reportable Quantity	None	A reportable quantity is that quantity of material in a type B package which equals or exceeds the quantity listed in the Appendix to 49 CFR 172.101	Logical (yes/no)	None	Yes
LXXV.	Radionuclide Symbol	None	The radionuclide the analysis seeks to determine	A7	Look-up table containing the predominant radionuclides (this is a multiple occurring data field)	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
LXXVI.	Reporting Flag	None	Designator which is used by the analytical laboratory to identify detection levels of the various analytes within a sample	A2	Coded to indicate appropriate flag per QAPP requirements	No
LXXVII.	Room Number	None	The room number within a panel in which the container is emplaced	A1	None	No
LXXVIII.	Row Number	None	The row number within a room/drift at the WIPP which designates the location within the length of the room/drift where the container is emplaced	A4	None	No
LXXIX.	Shipment Certification Date	None	The date when the shipment was certified for transport to the WIPP	Date	Shipment certification date ≥ WAC certification date	No
LXXX.	Shipment Number	None	Number assigned to the shipment	A12	Unique	No
LXXXI.	Shipment Receipt Date	None	The date the waste shipment was received at the WIPP	Date	Shipment receipt date ≥ shipment send date	No
LXXXII.	Shipment Send Date	None	The date the waste shipment left the shipper site (to be entered at the time of receipt at the WIPP using date on manifest)	Date	Shipment send date ≥ shipment certification date	No
LXXXIII.	Shipping Category	None	A category under which a content code is shipped	A8	All containers within a package must be of the same shipping category	No
LXXXIV.	Site Address	None	Address of the waste site having responsibility for shipment of the waste	A50	None	No
LXXXV.	Site Name	None	Name of the site which shipped the waste	A30	None	No
LXXXVI.	Solid Waste Metals: Analyte Name	None	The element, ion, or compound an analysis seeks to determine; the element of interest	A50	Look-up table of target solid waste metal analytes (this is a multiple occurring field)	No
LXXXVII.	Solid Waste Metals: Concentration	mg/kg	The concentration of the solid waste metal analytes the analysis seeks to determine	9.99E+99	None	No
LXXXVIII.	Solid Waste Metals: Date Analyzed	None	The date solid waste metals were analyzed	Date	≤ 180 days after sampling date ≤ 28 days for mercury	No
LXXXIX.	Solid Waste Metals: Date Sampled	None	The date solid waste metals were sampled	Date	None	No
XC.	Solid Waste Semi-VOC: Analyte Name	None	The element, ion, or compound an analysis seeks to determine; the element of interest	A50	Look-up table of target solid waste semi-VOC analytes (this is a multiple occurring field)	No
XCI.	Solid Waste Semi-VOC: Concentration	mg/kg	The concentration of the solid waste semi-VOC analytes the analysis seeks to determine	9.99E+99	Look-up table of target solid waste semi-VOC analytes	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
XCII.	Solid Waste Semi-VOC: Date Analyzed	None	The date solid waste semi-VOCs were analyzed	Date	≤ 180 days after sampling date	No
XCIII.	Solid Waste Semi-VOC: Date Sampled	None	The date solid waste semi-VOCs were sampled	Date	None	No
XCIV.	Solid Waste VOC: Analyte Name	None	The element, ion, or compound an analysis seeks to determine; the element of interest	A50	Look-up table of target solid waste VOC analytes (this is a multiple occurring field)	No
XCV.	Solid Waste VOC: Concentration	mg/kg	The concentration of the solid waste VOC analytes the analysis seeks to determine	9.99E+99	Look-up table of target solid waste VOC analytes	No
XCVI.	Solid Waste VOC: Date Analyzed	None	The date solid waste VOCs were analyzed	Date	≤ 54 days after sampling date	No
XCVII.	Solid Waste VOC: Date Sampled	None	The date solid waste VOCs were sampled	Date	None	No
XCVIII.	Surface Contamination of Container (Alpha)	dpm/cm^2	The removable alpha emitting radionuclide surface contamination on waste containers	9.9E+99	≤ 20 $dpm/100\ cm^2$ (alpha)	No
XCIX.	Surface Contamination of Container (Beta/Gamma)	dpm/cm^2	The removable beta/gamma emitting radionuclide surface contamination on waste containers	9.99E+99	≤ 200 $dpm/100\ cm^2$ (beta/gamma)	No
C.	Technical Contact	None	Name of the person at the shipper site who is the technical contact for the site. Information is to be recorded based on the last name, first name, and middle initial (if available)	A20	None	No
CI.	Tentatively Identified Compounds (TICs): Date Analyzed	None	The date the TICs were analyzed	Date	See limits in fields 36, 77, 80, and 83	No
CII.	Tentatively Identified Compounds (TICs): Date Sampled	None	The date the TICs were sampled	Date	None	No
CIII.	Tentatively Identified Compounds: Analyte Name	None	Compounds not intiailly anticipated to be in the waste stream but subsequently identified in either the headspace gas or solid waste analysis	A30	Look-up table of TICs identified in 40 CFR 264, Appendix IX	No
CIV.	Tentatively Identified Compounds: Concentration (mg/kg)	mg/kg	If applicable, the concentrations of compounds not initially anticipated to be in the waste stream but subsequently identified in either the headspace gas or solid waste analysis	9.99E+99	None	No
CV.	Tentatively Identified Compounds: Concentration (ppmv)	ppmv	If applicable, the concentrations of compounds not initially anticipated to be in the waste stream but subsequently identified in either the headspace gas or solid waste analysis	9.99E+99	None	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
CVI.	Thermal Power Density	Watts/ft^3	The thermal power per unit volume of the container	9.9E+99	A flag is to be raised ≥ 0.1 watt/ft3 when averaged over the container	Yes
CVII.	Transporter EPA ID	None	U.S. Environmental Protection Agency identification number for the transporter of the waste shipment	A15	Look-up table containing the corresponding name and address of the transporter	No
CVIII.	Transporter Name	None	The name of the transporter of the waste shipment	A25	None	No
CIX.	TRU Alpha Activity	Curies	Summation of the alpha activities of the transuranic (TRU) isotopes within a container	9.9E+99	None	Yes
CX.	TRU Alpha Activity Concentration	Curies per gram	Summation of the alpha activities of the transuranic isotopes divided by the mass of the waste within a container (excluding the masses of the container, liner (if applicable), and shielding (if applicable))	9.9E+99	> 100 nCi/gram	Yes
CXI.	TRU Alpha Activity Concentration Uncertainty	Curies per gram	Uncertainty in the TRU waste alpha activity concentration	9.9E+99	None	
CXII.	TRU Alpha Activity Uncertainty	Curies	Uncertainty in the TRU waste alpha activity	9.9E+99	None	Yes
CXIII.	TRUCON Content Code	None	The TRUCON content code which describes the contents of the container based on the site Item Description Code.	A6	Look-up table of approved content codes	No
CXIV.	TRUPACT-II OCA Lid Number	None	The TRUPACT-II OCA lid number	A8	None	No
CXV.	Vehicle Type	None	The type of vehicle used to transport the waste.	A1	Look-up table containing either "R" for railcar or "T" for truck	No
CXVI.	Vent/Puncture Date	None	The date when the container was vented and, if applicable, the liner punctured	Date	None	No
CXVII.	Verification Date	None	The date when the radiography or visual inspection was completed at the certification site	Date	None	No
CXVIII.	Verification Method	None	Identifies if radiography or visual inspection was used to identify and quantify the radionuclide masses	A4	Radiography or Visual Inspedtion	No
CXIX.	Visual Examination of Container	None	A statistical sample of retrievably stored waste streams must be examined visually. This field serves to identify whether visual examination was performed.	Logical (yes/no)	None	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
CXX.	WAC Certification Date	None	The date when the certifying official signed the certification statement for the container	Date	None	No
CXXI.	WAC Certification Site	None	The site where the container was certified shall be identified by the 2-character site code as in Table B-3 of the WIPP WAC	A2	Look-up table of site identification codes	No
CXXII.	WAC Exception Number	None	A number granted to the shipper for an exception to the WAC. The number consists of a 2-character site code plus the last two numbers of the year the request was made plus a sequential number beginning with one each year.	AAYYXXX	Look-up table containing approved WAC exception numbers	No
CXXIII.	WAC Revision Number	None	Revision number of the WIPP-WAC to which the waste was certified	A2	≥ Revision 4	No
CXXIV.	Waste Container Fill Factor	Percentage	Estimated percentage of the waste container volume occupied by the waste (zero percent is interpreted as dunnage)	999	Lower bound = 0 Upper bound = 100	No
CXXV.	Waste Handling Code	None	The code is "CH" for contact-handled TRU waste or "RH" for remote-handled TRU waste	A2	None	No
CXXVI.	Waste Material Parameters	None	Waste materials having the potential of impacting performance assessment	A40	Look-up table of waste material parameters	No
CXXVII.	Waste Matrix Code	None	Numerical codes used to classify mixed waste at DOE facilities	A4	Look-up table of waste matrix codes	No
CXXVIII.	Waste Matrix Code Date	None	The date the site Project review of the waste matrix code has been completed	Date	None	No
CXXIX.	Waste Matrix Code Group	None	The group identification taken from the Baseline Inventory Report	A2	None	No
CXXX.	Waste Stream MWIR ID	None	The waste stream MWIR identification number	A6	None	No
CXXXI.	Waste Stream Profile Form Number	None	The waste stream profile form number	9999	Look-up table of approved waste stream profile form numbers	No
CXXXII.	Waste Stream WIPP ID	None	The waste stream WIPP identification number	A6	None	No
CXXXIII.	Waste Type Code	None	The code is "TRU" for non-mixed waste and "MTRU" for mixed waste	A4	None	No
CXXXIV.	Weight (empty container, liner, and shielding)	kg	The weight of the empty container including liner & shielding if applicable	999999.9	None	No
CXXXV.	Weight (Gross)	kg	The gross weight of a container	999999.9	≤ 1000 lbs per drum ≤ 4000 lbs per SWB ≤ 6450 lbs per TDOP ≤ 8000 lbs per canister	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

NO	FIELD	UNITS	DEFINITION	FORMAT	LIMITS, EDITS, & RANGE CHECKS	CALCULATED
CXXXVI.	Weight of a TRUPACT-II Shipment	kg	The weight of the TRUPACT-II packages including their payloads per railcar or truck	999999.9	The sum of the weights of the TRUPACT-II packages (unique for each serial number) including their payloads per railcar or truck	Yes
CXXXVII.	Weight of Payload Assembly	kg	The weight of a seven pack payload assembly	999999.9	Equal to the sum of the gross weights of the seven drums contained in the payload assembly	Yes
CXXXVIII.	Weight of TRUPACT-II	kg	The weight of a TRUPACT-II package (unique per serial number) including its payload	999999.9	The sum of the weights of the TRUPACT-II (using a look-up table of TRUPACT-II weights per serial number) and the payload.	Yes
CXXXIX.	Weight of Waste	kg	The weight of the waste inside a container	999999.9	None	Yes
CXL.	Weight of Waste Material Parameters	kg	The estimated weight of the waste material parameters	999999.9	Sum of the estimated waste material parameter weights should equal the weight of the waste	Yes
CXLI.	Weight of Waste Uncertainty	kg	The uncertainty in the weight of the waste inside a container	999999.9	None	Yes
CXLII.	Weight Uncertainty (empty container, liner, and shielding)	kg	The uncertainty in the weight of the empty container including liner & shielding if applicable	999999.9	None	No
CXLIII.	Weight Uncertainty (Gross)	kg	The uncertainty in the gross weight of a container	999999.9	None	No

WWIS DATA DICTIONARY (DRAFT Version 0.1)

* NOTES - FIELD SPECIFIC

III. The method used for this designator is to be determined.

IV. Data field will include a list of acronyms for the characterization equipment used.

X. No more than 5% of the RH canisters received at the WIPP are allowed to have dose rates > 100 rem/hr. This requirement necessitates that a running calculation of the percentage be performed in the background. If the percentage exceeds 5%, a flag will be raised. Prior approval by the WIPP is required before RH canisters having dose rates > 100 rem/hr but ≤ 1000 rem/hr may be shipped to the WIPP.

XVI. The look-up table used for this field will also include the internal volume of each container listed. This volume is required for the calculation of thermal power density (see field #90).

XVIII. Reporting of thermal power per container will be made using the calculated value of the container's decay heat.

XXIX. A unique generator name and address corresponds to each generator EPA ID.

XXXVIa. The 11 flammable VOCs, a subset of the 29 target VOC analytes, need to be identified in order to calculate the total flammable VOC concentration required by field #39a.

XXXIX. A flag will be raised if any of the VOC headspace gas concentration limits are exceeded. Based on a running average of these concentrations, a determination will be made whether to accept the container with the outerlying VOC(s).

XXXIXa. A flag will be raised if any of the flammable VOC headspace gas concentration limits are exceeded. Based on a running average of these concentrations, a determination will be made whether to accept the container with the outerlying VOC(s).

LXIV. A running total of RH activity needs to be performed. Total activity of RH waste cannot exceed 5,100,000 curies.

XCI. A unique transporter name and address corresponds to each transporter EPA ID.

CVII. A running total of TRU waste volume, in ft^3 and m^3, needs to be performed. Total volume of TRU waste (CH & RH) cannot exceed 6.2E+6 cubic feet.

NOTES - GENERIC

- Since SI units will be used in all reports, conversion constants need to be identified for the purpose of implementing this requirement. This includes curies to becquerels, pounds to kilograms, grams to kilograms, feet to meters, centimeters to meters, etc.
- Approved project plans are required before waste characterization data will be accepted for waste certification. Interim QAPjPs will suffice.
- Data calculated by the sites will be verified in the background; i.e., the data (whether measured or calculated) is the property of the sites, any calculations performed by the WWIS are for purposes of verification only.

Solid Sample Analysis Data

Solidified Waste Analyses (INEL)						
	Drum # 000593 Date: 06/05/95		Drum # 001437 Date: 06/09/95		Drum # 003121 Date: 06/11/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	9.03	U	8.30	U	8.50	U
Freon	0.96	U	0.91	U	0.95	U
Acetone	9.03	U	8.30	U	8.50	U
Methylene Chloride	0.96	U	0.91	U	0.95	U
2-Butanone	9.03	U	8.30	U	8.50	U
Chloroform	0.96	U	0.91	U	0.95	U
1,1,1-Trichloroethane	0.96	U	0.91	U	0.95	U
Cyclohexane	0.96	U	0.91	U	0.95	U
Carbon Tetrachloride	0.96	U	0.91	U	0.95	U
Benzene	0.96	U	0.91	U	0.95	U
1,2-Dichloroethane	0.96	U	0.91	U	0.95	U
1-Butanol	9.03	U	8.30	U	8.50	U
Trichloroethylene	0.96	U	0.91	U	0.95	U
Chlorobenzene	0.96	U	0.91	U	0.95	U
Ethyl Benzene	0.96	U	0.91	U	0.95	U
m,p-Xylene	0.96	U	0.91	U	0.95	U
0-xylene	0.96	U	0.91	U	0.95	U
Bromoform	0.96	U	0.91	U	0.95	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
E - Analyte exceeds calibration curve
J - Analyte less than PRQL, but greater than or equal to MDL
U - Analyte was undetected (MDL reported)
D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 000593 Date: 06/05/95		Drum # 001437 Date: 06/09/95		Drum # 003121 Date: 06/11/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
1,1,2,2-Tetrachloroethane	0.96	U	0.91	U	0.95	U
Vinyl Chloride	0.96	U	0.91	U	0.95	U
Trichlorofluoromethane	0.96	U	0.91	U	0.95	U
l,l-Dichloroethylene	0.96	U	0.91	U	0.95	U
Carbon Disulfide	0.96	U	0.91	U	0.95	U
2-Nitropropane	0.96	U	-	-	0.95	U
1,1,2-Trichloroethane	0.96	U	-	-	0.95	U
Toluene	0.96	U	0.91	U	0.95	U
Tetrachlroethylene	0.96	U	0.91	U	0.95	U
1,4-Dichlorobenzene	0.96	U	0.91	U	0.95	U
ortho-Dichlorobenzene	0.96	U	0.91	U	0.95	U
Bromomethane	2.25	JB	3.65	JB	2.45	JB
Ethyl Ether	9.03	U	8.30	U	8.50	U
Isobutanol	9.03	U	8.30	U	8.50	U
Pyridine	9.03	U	8.30	U	8.50	U
2-Methylphenol	50	UD	50	UD	50	UD
Hexachloroethane	50	UD	50	UD	50	UD
4-Methylphenol	50	UD	50	UD	50	UD

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Solidified Waste Analyses (INEL)						
	Drum # 000593 Date: 06/05/95		Drum # 001437 Date: 06/09/95		Drum # 003121 Date: 06/11/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Nitrobenzene	50	UD	50	UD	50	UD
2,4-Dinitrotoluene	3	UD	3	UD	3	UD
Hexachlorobenzene	3	UD	3	UD	3	UD
Pentachlorophenol	50	UD	50	UD	50	UD
2,4-Dinitrophenol	50	UD	50	UD	50	UD
Phenol	1.65	JD	2.7	JD	6.6	JD
Di-n-butylphthalate	2.1	JBD	9.4	JBD	2.1	JBD
Bis(2-ethylhexyl)phthalate	17	JD	6.4	JD	34	JBD
Furan, Tetrahydro	-	-	0.92	J	-	-
1 Hexanol, 2 Ethyl	-	-	-	-	1.25	J
Fluoranthene	-	-	-	-	15	JD
METALS						
Silver	8.75	U	-	-	-	-
Arsenic	3	-	4.5	J	1.5	U
Barium	7.55	J	150	-	23	J
Beryllium	22	J	290	-	35	-
Cadmium	6.05	U	27	J	8.6	J
Chromium	450	-	1200	-	800	-

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 000593 Date: 06/05/95		Drum # 001437 Date: 06/09/95		Drum # 003121 Date: 06/11/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Mercury	3.45	JB	3.7	J	4.2	J
Nickel	67.5	-	100	-	75	-
Lead	200	U	69	-	36	-
Selenium	0.51	U	5	U	4.9	U
Titanium	0.51	U	5	U	4.9	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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E - Analyte exceeds calibration curve
J - Analyte less than PRQL, but greater than or equal to MDL
U - Analyte was undetected (MDL reported)
D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 003129 Date: 06/15/95		Drum # 003130 Date: 06/17/95		Drum # 003173 Date: 06/19/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	9.85	J	10.50	J	9.70	J
Freon	0.95	U	0.95	U	0.79	U
Acetone	9.85	U	8.10	U	9.33	U
Methylene Chloride	0.95	U	0.95	U	0.79	U
2-Butanone	9.85	U	8.10	U	9.33	U
Chloroform	0.95	U	0.95	U	0.79	U
1,1,1-Trichloroethane	0.95	U	0.95	U	0.79	U
Cyclohexane	0.95	U	0.95	U	0.79	U
Carbon Tetrachloride	0.95	U	0.95	U	0.79	U
Benzene	0.95	U	0.95	U	0.79	U
1,2-Dichloroethane	0.95	U	0.95	U	0.79	U
1-Butanol	9.85	U	8.10	U	9.33	U
Trichloroethylene	0.95	U	0.95	U	0.79	U
Chlorobenzene	0.95	U	0.95	U	0.79	U
Ethyl Benzene	0.95	U	0.95	U	0.79	U
m,p-Xylene	0.95	U	0.95	U	0.79	U
0-xylene	0.95	U	0.95	U	0.79	U
Bromoform	0.95	U	0.95	U	0.79	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
E - Analyte exceeds calibration curve
J - Analyte less than PRQL, but greater than or equal to MDL
U - Analyte was undetected (MDL reported)
D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 003129 Date: 06/15/95		Drum # 003130 Date: 06/17/95		Drum # 003173 Date: 06/19/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
1,1,2,2-Tetrachloroethane	0.95	U	0.95	U	0.79	U
Vinyl Chloride	0.95	U	0.95	U	0.79	U
Trichlorofluoromethane	0.95	U	0.95	U	0.79	U
I,I-Dichloroethylene	0.95	U	0.95	U	0.79	U
Carbon Disulfide	0.95	U	0.95	U	0.79	U
2-Nitropropane	0.95	U	0.95	U	0.79	U
1,1,2-Trichloroethane	0.95	U	0.95	U	0.79	U
Toluene	0.95	U	0.95	U	0.79	U
Tetrachlroethylene	0.95	U	0.95	U	0.79	U
1,4-Dichlorobenzene	0.95	U	0.95	U	0.79	U
ortho-Dichlorobenzene	0.95	U	0.95	U	0.79	U
Bromomethane	2.33	JB	1.8	JB	1.3	JB
Ethyl Ether	9.85	U	8.10	U	9.33	U
Isobutanol	9.85	U	8.10	U	9.33	U
Pyridine	9.85	U	8.10	U	9.33	U
2-Methylphenol	50	UD	50	UD	50	UD
Hexachloroethane	50	UD	50	UD	50	UD
4-Methylphenol	50	UD	50	UD	50	UD

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
E - Analyte exceeds calibration curve
J - Analyte less than PRQL, but greater than or equal to MDL
U - Analyte was undetected (MDL reported)
D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 003129 Date: 06/15/95		Drum # 003130 Date: 06/17/95		Drum # 003173 Date: 06/19/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Nitrobenzene	50	UD	50	UD	50	UD
2,4-Dinitrotoluene	3	UD	3	UD	3	UD
Hexachlorobenzene	3	UD	3	UD	3	UD
Pentachlorophenol	50	UD	50	UD	50	UD
2,4-Dinitrophenol	50	UD	50	UD	50	UD
Phenol	8.95	JD	5.7	JD	-	-
Di-n-butylphthalate	3.3	JBD	1.8	JBD	2.05	JBD
Bis(2-ethylhexyl)phthalate	8.75	JBD	13	JBD	43.5	JBD
1-Hexanol,2-ethyl	1.1	J	1.04	J	-	-
1-Nonanol	1.13	J	1.8	J	1.9	J
Fluoranthene	6.9	JD	7.1	JD	1.35	JD
Dodecylcyclohexane	-	-	-	-	4.8	JD
Di-n-octylphthalate	-	-	-	-	1.2	JD
METALS						
Arsenic	1.6	J	1.5	J	3.15	J
Barium	19	J	28	-	43.5	-
Beryllium	48.5	-	35	-	53	-
Cadmium	7.7	J	8.4	J	9.85	J

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 003129 Date: 06/15/95		Drum # 003130 Date: 06/17/95		Drum # 003173 Date: 06/19/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Chromium	760	-	750	-	480	-
Mercury	5.15	-	5.3	-	5.8	-
Nickel	64	-	81	-	120	-
Lead	36.5	-	42	-	45	-
Selenium	4.55	U	4.2	U	4.95	U
Titanium	4.55	U	4.2	U	4.95	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
E - Analyte exceeds calibration curve
J - Analyte less than PRQL, but greater than or equal to MDL
U - Analyte was undetected (MDL reported)
D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 004283 Date: 05/22/95		Drum # 009006 Date: 05/18/95		Drum # 014009 Date: 05/31/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	10.13	U	8.20	U	10.25	U
Freon	1.01	U	0.81	U	0.97	U
Acetone	10.13	U	8.20	U	10.25	U
Methylene Chloride	1.01	U	0.81	U	0.97	U
2-Butanone	10.13	U	8.20	U	10.25	U
Chloroform	1.01	U	0.81	U	0.97	U
1,1,1-Trichloroethane	1.01	U	0.81	J	0.97	U
Cyclohexane	1.01	U	0.81	U	0.97	U
Carbon Tetrachloride	1.01	U	0.81	U	0.97	U
Benzene	1.01	U	0.81	U	0.97	U
1,2-Dichloroethane	1.01	U	0.81	U	0.97	U
1-Butanol	10.13	U	8.20	U	10.25	U
Trichloroethylene	1.01	U	0.81	U	0.97	U
Chlorobenzene	1.01	U	0.81	U	0.97	U
Ethyl Benzene	1.01	U	0.81	U	0.97	U
m,p-Xylene	1.01	U	0.81	U	0.97	U
0-xylene	1.01	U	0.81	U	0.97	U
Bromoform	1.01	U	0.81	U	0.97	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
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D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 004283 Date: 05/22/95		Drum # 009006 Date: 05/18/95		Drum # 014009 Date: 05/31/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
1,1,2,2-Tetrachloroethane	1.01	U	0.81	U	0.97	U
Vinyl Chloride	1.01	U	0.81	U	0.97	U
Trichlorofluoromethane	1.01	U	0.81	U	0.97	U
I,I-Dichloroethylene	1.01	U	0.89	JB	0.97	U
Carbon Disulfide	1.01	U	0.81	U	0.97	U
2-Nitropropane	1.01	U	0.81	U	0.97	U
1,1,2-Trichloroethane	1.01	U	0.81	U	0.97	U
Toluene	1.01	U	0.81	U	0.97	U
Tetrachlroethylene	1.01	U	0.81	U	0.97	U
1,4-Dichlorobenzene	1.01	U	0.81	U	0.97	U
ortho-Dichlorobenzene	1.01	U	0.81	U	0.97	U
Bromomethane	2.13	JB	1.95	JB	2.3	JB
Ethyl Ether	10.13	U	8.20	U	10.25	U
Isobutanol	10.13	U	8.20	U	10.25	U
Pyridine	10.13	U	8.20	U	10.25	U
2-Methylphenol	5	U	50	UD	50	UD
Hexachloroethane	5	U	50	UD	50	UD
4-Methylphenol	5	U	50	UD	50	UD

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
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Solidified Waste Analyses (INEL)						
	Drum # 004283 Date: 05/22/95		Drum # 009006 Date: 05/18/95		Drum # 014009 Date: 05/31/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Nitrobenzene	5	U	50	UD	50	UD
2,4-Dinitrotoluene	0.3	U	3	UD	3	UD
Hexachlorobenzene	0.3	U	3	UD	3	UD
Pentachlorophenol	5	U	50	UD	50	UD
2,4-Dinitrophenol	5	U	50	UD	50	UD
Phenol	-	-	3.1	JD	2.2	JD
Di-n-butylphthalate	-	-	-	-	1.6	JBD
Bis(2-ethylhexyl)phthalate	-	-	12	JD	23	JD
Fluoranthene	-	-	-	-	1.1	JD
METALS						
Silver	8.71	U	8.75	U	8.6	U
Arsenic	3.71	-	3.36	-	5.2	-
Barium	23.55	J	18.4	J	16	J
Beryllium	81.7	-	16.3	J	21	J
Cadmium	6.55	U	6.58	U	6	U
Chromium	489.5	-	108	-	320	-
Mercury	4.01	U	5.01	J	5.3	-
Nickel	110.4	-	127	-	140	-

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 004283 Date: 05/22/95		Drum # 009006 Date: 05/18/95		Drum # 014009 Date: 05/31/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Lead	50.65	-	32.8	-	190	U
Selenium	0.51	J	0.89	J	0.63	J
Titanium	0.5	U	0.5	U	0.5	U

Solidified Waste Analyses (INEL)						
	Drum # 014387 Date: 04/22/95		Drum # 015655 Date: 06/02/95		Drum # 015786 Date: 05/08/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	8.60	U	10.05	U	10.20	U
Freon	0.96	U	0.87	U	0.78	U
Acetone	8.60	U	10.05	U	10.20	U
Methylene Chloride	0.96	U	0.87	U	0.78	U
2-Butanone	8.60	U	10.05	U	10.20	U
Chloroform	0.96	U	0.87	U	0.78	U
1,1,1-Trichloroethane	0.96	U	0.87	U	0.78	U
Cyclohexane	0.96	U	0.87	U	0.78	U
Carbon Tetrachloride	0.96	U	0.87	U	0.78	U
Benzene	0.96	U	0.87	U	0.78	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
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Solidified Waste Analyses (INEL)						
	Drum # 014387 Date: 04/22/95		Drum # 015655 Date: 06/02/95		Drum # 015786 Date: 05/08/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
1,2-Dichloroethane	0.96	U	0.87	U	0.78	U
1-Butanol	8.60	U	10.05	U	10.20	U
Trichloroethylene	0.96	U	0.87	U	0.78	U
Chlorobenzene	0.96	U	0.87	U	0.78	U
Ethyl Benzene	0.96	U	0.87	U	0.78	U
m,p-Xylene	0.96	U	0.87	U	0.78	U
0-xylene	0.96	U	0.87	U	0.78	U
Bromoform	0.96	U	0.87	U	0.78	U
1,1,2,2-Tetrachloroethane	0.96	U	0.87	U	0.78	U
Vinyl Chloride	0.96	U	0.87	U	0.78	U
Trichlorofluoromethane	0.96	U	0.87	U	0.78	U
l,l-Dichloroethylene	0.96	U	0.87	U	0.78	U
Carbon Disulfide	0.96	U	0.87	U	0.78	U
2-Nitropropane	0.96	U	0.87	U	0.78	U
1,1,2-Trichloroethane	0.96	U	0.87	U	0.78	U
Toluene	0.96	U	0.87	U	0.78	U
Tetrachlroethylene	0.96	U	0.87	U	0.78	U
1,4-Dichlorobenzene	0.96	U	0.87	U	0.78	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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Solidified Waste Analyses (INEL)						
	Drum # 014387 Date: 04/22/95		Drum # 015655 Date: 06/02/95		Drum # 015786 Date: 05/08/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
ortho-Dichlorobenzene	0.96	U	0.87	U	0.78	U
Bromomethane	3.63	JB	2.2	JB	2	JB
Ethyl Ether	8.60	U	10.05	U	10.20	U
Isobutanol	8.60	U	10.05	U	10.20	U
Pyridine	8.60	U	10.05	U	10.20	U
2-Methylphenol	49.5	UD	50	UD	4.9	U
Hexachloroethane	49.5	UD	50	UD	4.9	U
4-Methylphenol	49.5	UD	50	UD	4.9	U
Nitrobenzene	49.5	UD	50	UD	4.9	U
2,4-Dinitrotoluene	3	UD	3	UD	0.3	U
Hexachlorobenzene	3	UD	3	UD	0.3	U
Pentachlorophenol	49.5	UD	50	UD	4.9	U
2,4-Dinitrophenol	49.5	UD	50	UD	4.9	U
Phenol	3.1	JD	4.8	JD	-	-
Di-n-butylphthalate	1.5	JBD	-	-	5.7	JB
Bis(2-ethylhexyl)phthalate	17	JD	56	JD	2.4	J
1-Hexanol,2-ethyl	-	-	1	J	-	-
Isooctanol	-	-	1.23	J	-	-

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
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Solidified Waste Analyses (INEL)						
	Drum # 014387 Date: 04/22/95		Drum # 015655 Date: 06/02/95		Drum # 015786 Date: 05/08/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Fluoranthene	1.4	JD	1.7	JD	-	-
METALS						
Silver	29.6	J	8.7	U	8.7	U
Arsenic	3.83	-	3.6	-	1.78	J
Barium	45.4	-	23	J	5.61	U
Beryllium	6.61	J	21	J	19.8	J
Cadmium	26.55	U	6	U	6.54	U
Chromium	122	-	230	-	100	-
Mercury	3.63	-	6.1	-	4	U
Nickel	34.4	-	530	-	49.8	-
Lead	27.15	-	200	U	49	-
Selenium	0.88	J	1.1	J	1.08	J
Titanium	0.5	U	0.5	U	0.5	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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Metals Analysis

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U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 016869 Date: 05/14/95		Drum # 017788 Date: 03/29/95		Drum # 021565 Date: 04/06/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	9.28	U	14.33	J	11.67	J
Freon	0.92	U	1.02	U	0.83	U
1,1-Dichloroethene	-	-	1.09	J	8.77	U
Acetone	9.28	U	1.1	U	-	-
Methylene Chloride	0.92	U	1.42	J	0.83	U
cis-1,2-dichloroethylene	-	-	-	-	1.49	J
2-Butanone	9.28	U	11	U	8.77	U
Chloroform	0.92	U	1.02	U	0.83	U
1,1,1-Trichloroethane	1.17	J	24.67	-	0.83	U
Cyclohexane	-	-	1.02	U	0.83	U
Carbon Tetrachloride	0.92	U	1.02	U	0.83	U
Benzene	0.92	U	1.02	U	0.83	U
1,2-Dichloroethane	0.92	U	-	-	3.73	J
1-Butanol	9.88	J	11	U	8.77	U
Trichloroethylene	0.92	U	1.20	JB	0.83	U
Chlorobenzene	0.92	U	1.02	U	0.83	U
Ethyl Benzene	0.92	U	1.02	U	0.83	U
m,p-Xylene	0.92	U	1.02	U	0.83	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
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Metals Analysis

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Solidified Waste Analyses (INEL)						
	Drum # 016869 Date: 05/14/95		Drum # 017788 Date: 03/29/95		Drum # 021565 Date: 04/06/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
0-xylene	0.92	U	1.02	U	0.83	U
Bromoform	0.92	U	1.02	U	0.83	U
1,1,2,2-Tetrachloroethane	0.92	U	1.02	U	0.83	U
Vinyl Chloride	0.92	U	1.02	U	0.83	U
Trichlorofluoromethane	0.92	U	1.02	U	0.83	U
I,I-Dichloroethylene	0.92	U	-	-	-	-
Carbon Disulfide	0.92	U	1.42	U	0.83	U
2-Nitropropane	0.92	U	1.02	U	0.83	U
1,1,2-Trichloroethane	0.92	U	1.02	U	0.83	U
Toluene	0.92	U	1.02	U	0.83	U
Tetrachlroethylene	0.92	U	1.02	U	0.83	U
1,4-Dichlorobenzene	0.92	U	1.02	U	0.83	U
ortho-Dichlorobenzene	0.92	-	1.02	U	0.83	U
Bromomethane	0.92	JB	6.20	JB	1.32	JB
Ethyl Ether	9.28	U	11	U	8.77	U
Isobutanol	9.28	U	11	U	8.77	U
Pyridine	9.28	U	300	U	8.77	U
2-Methylphenol	48.5	UD	300	UD	99.33	UD

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

B - Analyte detected in blank
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Metals Analysis

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J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
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Solidified Waste Analyses (INEL)						
	Drum # 016869 Date: 05/14/95		Drum # 017788 Date: 03/29/95		Drum # 021565 Date: 04/06/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Hexachloroethane	48.5	UD	300	UD	9.33	UD
4-Methylphenol	48.5	UD	300	UD	99.33	UD
Nitrobenzene	48.5	UD	300	UD	99.33	UD
2,4-Dinitrotoluene	2.95	UD	18	UD	99.33	UD
Hexachlorobenzene	2.95	UD	18	UD	6.00	UD
Pentachlorophenol	48.5	UD	300	UD	6.00	UD
2,4-Dinitrophenol	48.5	UD	300	UD	99.33	UD
Phenol	1.5	JD	13.25	JD	4.37	JD
Di-n-butylphthalate	4.55	JD	-	-	10.10	JD
Bis(2-ethylhexyl)phthalate	9.7	JD	98	JBD	16.33	JD
1-Hexanol, 2-ethyl	-	-	-	-	0.81	J
METALS						
Silver	8.59	U	135	-	2.92	U
Arsenic	1.44	J	1.65	J	4.07	-
Barium	17.15	J	38.1	-	33.77	-
Beryllium	18.95	J	54.03	-	33.47	-
Cadmium	6.46	U	19.87	U	26.63	U
Chromium	205.5	-	482.33	-	311.3	-

FLAGS

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J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
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Solidified Waste Analyses (INEL)						
	Drum # 016869 Date: 05/14/95		Drum # 017788 Date: 03/29/95		Drum # 021565 Date: 04/06/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Mercury	4.65	J	12.43	-	7.32	-
Nickel	191.5	-	193	-	63.43	-
Lead	53.25	-	58.43	-	111.97	J
Selenium	1.41	J	0.92	J	0.60	J
Titanium	0.5	U	0.37	U	0.5	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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E - Analyte exceeds calibration curve
J - Analyte less than PRQL, but greater than or equal to MDL
U - Analyte was undetected (MDL reported)
D - Analyte was quantitated from a secondary dilution, or reduced volume sample aliquot

Metals Analysis

B - Analyte blank concentration greater than or equal to 20 percent of the sample concentration prior to dilution
J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 022121 Date: 04/25/95		Drum # 022811 Date: 06/07/95		Drum # 022833 Date: 04/16/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	10.50	J	17.5	J	23	J
Freon	4.25	J	1.16	J	.91	U
Acetone	9.50	U	10.5	U	8.7	U
Methylene Chloride	1.1	U	.83	U	1.06	J
2-Butanone	9.5	U	10.5	U	8.7	U
Chloroform	1.1	U	.83	U	-	-
1,1,1-Trichloroethane	13.9	-	11.85	-	34	-
Cyclohexane	1.1	U	.83	U	.91	U
Carbon Tetrachloride	1.1	U	.83	U	.91	U
Benzene	1.1	U	.83	U	.91	U
1,2-Dichloroethane	1.1	U	.83	U	.91	U
1-Butanol	9.5	U	-	-	8.7	U
Trichloroethylene	1.1	U	0.83	U	0.91	U
Chlorobenzene	1.1	U	0.83	U	0.91	U
Ethyl Benzene	1.1	U	0.83	U	0.91	U
m,p-Xylene	1.1	U	0.83	U	0.91	U
0-xylene	1.1	U	0.83	U	.91	U
Bromoform	1.1	U	0.83	U	.91	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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Metals Analysis

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J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
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Solidified Waste Analyses (INEL)						
	Drum # 022121 Date: 04/25/95		Drum # 022811 Date: 06/07/95		Drum # 022833 Date: 04/16/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
1,1,2,2-Tetrachloroethane	1.1	U	.83	U	.91	U
Vinyl Chloride	1.1	U	.83	U	.91	U
Trichlorofluoromethane	1.1	U	.83	U	.91	U
I,I-Dichloroethylene	1.1	U	.83	U	1.16	J
Carbon Disulfide	1.1	U	.83	U	.91	U
2-Nitropropane	1.1	U	.83	U	.91	U
1,1,2-Trichloroethane	1.1	U	.83	U	.91	U
Toluene	1.1	J	.83	U	.91	U
Tetrachlroethylene	1.3	UJU	.83	U	.91	U
1,4-Dichlorobenzene	1.1	U	.83	U	.91	U
ortho-Dichlorobenzene	1.1	U	.83	U	.91	U
Bromomethane	4.95	JB	1.1	JB	4.8	JB
Ethyl Ether	9.5	U	10.5	U	8.7	U
Isobutanol	9.5	U	10.5	U	8.7	U
Pyridine	9.5	U	10.5	U	8.7	U
2-Methylphenol	49	UD	50	UD	98	UD
Hexachloroethane	49	UD	-	-	98	UD
4-Methylphenol	49	UD	50	UD	98	UD

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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Solidified Waste Analyses (INEL)						
	Drum # 022121 Date: 04/25/95		Drum # 022811 Date: 06/07/95		Drum # 022833 Date: 04/16/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Nitrobenzene	49	UD	50	UD	98	UD
2,4-Dinitrotoluene	3	UD	3	UD	5.9	UD
Hexachlorobenzene	3	UD	3	UD	5.9	UD
Pentachlorophenol	49	UD	3	UD	98	UD
2,4-Dinitrophenol	49	UD	50	UD	98	UD
Phenol	10	JD	5.8	JD	15	JD
Di-n-butylphthalate	14	JBD	-	-	2.9	JBD
Bis(2-ethylhexyl)phthalate	43	JD	1.9	JD	47	JD
Fluoranthene	16	JD	9.8	JD	7.1	JD
2 Methylnaphthalene	2	JD	1.9	JD	-	-
1-Hexanol, 2-Ethyl	-	-	5.3	J	-	-
METALS						
Silver	15.3	J	8.8	U	18.1	J
Arsenic	.9	J	1.3	J	3.94	-
Barium	78.1	-	68	-	37.2	-
Beryllium	63.7	-	61	-	131	-
Cadmium	26.5	U	6.1	U	26.7	U
Chromium	551	-	580	-	208	-

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Solidified Waste Analyses (INEL)						
	Drum # 022121 Date: 04/25/95		Drum # 022811 Date: 06/07/95		Drum # 022833 Date: 04/16/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Mercury	26.8	-	22	-	12.5	-
Nickel	510	-	610	-	422	-
Lead	60.1	-	200	U	65.7	-
Selenium	.71	J	.8	J	1.37	J
Titanium	.5	U	.51	U	.5	U

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J - Analyte less than or equal to IDL but less than 5 x IDL before dilution correction
U - Analyte was undetected (IDL reported)

Solidified Waste Analyses (INEL)						
	Drum # 022841 Date: 04/18/95		Drum # 022850 Date: 04/17/95		Drum # 022894 Date: 05/29/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	32	J	11.4	J	11.43	U
Freon	.99	U	4.29	J	1.03	U
Acetone	7.35	-	7.6	U	11.43	U
Methylene Chloride	2.03	J	1.1	J	1.03	U
2-Butanone	7.35	U	7.6	U	11.43	U
Chloroform	.99	U	.94	U	1.03	U
1,1,1-Trichloroethane	44.75	-	37	-	1.03	U
Cyclohexane	.99	U	.94	U	1.03	U
Carbon Tetrachloride	.99	U	.94	U	1.03	U
Benzene	.99	U	.94	U	1.03	U
1,2-Dichloroethane	.99	U	.94	U	1.03	U
1-Butanol	-	-	-	-	11.43	U
Trichloroethylene	.99	U	.94	U	1.03	U
Chlorobenzene	.99	U	.94	U	1.03	U
Ethyl Benzene	.99	U	-	-	1.03	U
m,p-Xylene	.99	U	.94	U	1.03	U
0-xylene	.99	U	.94	U	1.03	U
Bromoform	.99	U	.94	U	1.03	U

FLAGS

Total Volatile and Semi-Volatile Organic Compound Analyses

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Solidified Waste Analyses (INEL)						
	Drum # 022841 Date: 04/18/95		Drum # 022850 Date: 04/17/95		Drum # 022894 Date: 05/29/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
1,1,2,2-Tetrachloroethane	.99	U	.94	U	1.03	U
Vinyl Chloride	.99	U	.94	U	1.03	U
Trichlorofluoromethane	.99	U	.94	U	1.03	U
I,I-Dichloroethylene	.99	U	1.2	J	1.58	J
Carbon Disulfide	.99	U	.94	U	1.03	U
2-Nitropropane	.99	U	.94	U	1.03	U
1,1,2-Trichloroethane	.99	U	.94	U	1.03	U
Toluene	1.23	J	1.14	J	1.03	U
Tetrachlroethylene	-	-	-	-	1.03	U
1,4-Dichlorobenzene	.99	U	.94	U	1.03	U
ortho-Dichlorobenzene	.99	U	.94	U	1.03	U
Bromomethane	4.98	JB	5.2	JB	2.2	JB
Ethyl Ether	7.35	U	7.6	U	11.43	U
Isobutanol	7.35	U	7.6	U	-	-
Pyridine	7.35	U	7.6	U	11.43	U
2-Methylphenol	99	UD	99	UD	50	UD
Hexachloroethane	99	UD	99	UD	50	UD
4-Methylphenol	99	UD	99	UD	50	UD

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Solidified Waste Analyses (INEL)						
	Drum # 022841 Date: 04/18/95		Drum # 022850 Date: 04/17/95		Drum # 022894 Date: 05/29/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Nitrobenzene	99	UD	99	UD	50	UD
2,4-Dinitrotoluene	5.9	UD	5.9	UD	3	UD
Hexachlorobenzene	5.9	UD	5.9	UD	3	UD
Pentachlorophenol	99	UD	99	UD	50	UD
2,4-Dinitrophenol	99	UD	99	UD	50	UD
Phenol	11.5	JD	6.7	JD	50	UD
Di-n-butylphthalate	2.1	JBD	-	-	1.35	JD
Bis(2-ethylhexyl)phthalate	43.5	JD	309	JD	1.35	JBD
Tetrachloroethene	.99	U	-	-	-	-
Fluoranthene	8	JD	12	JD	-	-
Trichloroethene	-	-	1.39	J	-	-
Chloromethane	-	-	1	-	-	-
2-Newthylnaphthalene	-	-	2.1	JD	-	-
METALS						
Silver	10.65	J	8.99	J	8.65	U
Arsenic	2.41	J	1.76	J	2.25	J
Barium	37.4	-	72.8	-	32.5	-
Beryllium	142	-	85.1	-	780	-

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Solidified Waste Analyses (INEL)						
	Drum # 022841 Date: 04/18/95		Drum # 022850 Date: 04/17/95		Drum # 022894 Date: 05/29/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Cadmium	26.5	U	26.5	U	36.5	-
Chromium	295	-	553	-	76	-
Mercury	18.95	-	27.4	-	1.7	JB
Nickel	559	-	602	-	55	-
Lead	60.1	-	59.1	-	865	-
Selenium	.99	J	.58	J	.84	J
Titanium	.5	U	.5	U	.5	U

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Solidified Waste Analyses (INEL)						
	Drum # 023535 Date: 04/14/95		Drum # 016807 Date: 05/26/95		Drum # 021572 Date: 04/12/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Methanol	8.2	U	7.15	U	13	J
Freon	.92	U	0.91	U	.89	U
1,1-Dichloroethene	-	-	1.10	J	-	-
Acetone	8.2	U	7.15	U	9.70	U
Methylene Chloride	.92	U	0.91	U	.89	U
cis-1,2-dichloroethylene	-	-	-	-	.89	U
2-Butanone	8.2	U	7.15	U	9.70	U
Chloroform	.92	U	0.91	U	.89	U
1,1,1-Trichloroethane	16.5	-	0.91	U	9.27	-
Cyclohexane	.92	U	0.91	U	.89	U
Carbon Tetrachloride	.92	U	0.91	U	.89	U
Benzene	.92	U	0.91	U	.89	U
1,2-Dichloroethane	.92	U	0.91	U	.89	U
1-Butanol	8.2	U	7.15	U	9.70	U
Trichloroethylene	.92	U	-	-	.89	U
Chlorobenzene	.92	U	0.91	U	.89	U
Ethyl Benzene	.92	U	0.91	U	.89	U
m,p-Xylene	.92	U	0.91	U	.89	U

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Solidified Waste Analyses (INEL)						
	Drum # 023535 Date: 04/14/95		Drum # 016807 Date: 05/26/95		Drum # 021572 Date: 04/12/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
0-xylene	-	-	0.91	U	.89	U
Bromoform	.92	U	0.91	U	.89	U
1,1,2,2-Tetrachloroethane	.92	U	0.91	U	.89	U
Vinyl Chloride	.92	U	0.91	U	.89	U
Trichlorofluoromethane	.92	U	0.91	U	.89	U
I,I-Dichloroethylene	.92	U	-	-	-	-
Carbon Disulfide	.92	U	0.91	U	.89	U
2-Nitropropane	.92	U	0.91	U	-	-
1,1,2-Trichloroethane	.92	U	0.91	U	.89	U
Toluene	.92	U	0.91	U	.89	U
Tetrachlroethylene	-	-	.091	U	.89	U
1,4-Dichlorobenzene	.92	U	0.91	U	.89	U
ortho-Dichlorobenzene	.92	U	0.91	U	.89	U
Bromomethane	5.15	JB	2.2	JB	13.67	JB
Ethyl Ether	8.2	U	7.15	U	9.70	U
Isobutanol	8.2	U	7.15	U	9.70	U
Pyridine	8.2	U	7.15	U	9.70	U
2-Methylphenol	98	UD	50	UD	99	UD

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	Drum # 023535 Date: 04/14/95		Drum # 016807 Date: 05/26/95		Drum # 021572 Date: 04/12/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Hexachloroethane	98	UD	50	UD	99	UD
4-Methylphenol	98	UD	50	UD	99	UD
Nitrobenzene	98	UD	50	UD	99	UD
2,4-Dinitrotoluene	5.9	UD	3	UD	6	UD
Hexachlorobenzene	5.9	UD	3	UD	6	UD
Pentachlorophenol	98	UD	3	UD	99	UD
2,4-Dinitrophenol	98	UD	50	UD	99	UD
Phenol	7.2	JD	-	-	49	JD
Di-n-butylphthalate	6.6	JBD	-	-	3.6	JBD
Bis(2-ethylhexyl)phthalate	29	JD	14	JD	15	JD
Fluoranthene	4.3	JD	-	-	-	-
Chloromethane	-	-	-	-	1.77	JB
1-Heptanol	-	-	-	-	1.6	J
METALS						
Silver	8.76	U	8.6	U	29.6	J
Arsenic	2.93	-	3	-	3.8	-
Barium	30.5	-	6.5	J	30.5	-
Beryllium	48	-	23	-	34.4	-

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Solidified Waste Analyses (INEL)						
	Drum # 023535 Date: 04/14/95		Drum # 016807 Date: 05/26/95		Drum # 021572 Date: 04/12/95	
Compound	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag	Concentration (mg/kg)	Flag
Cadmium	26.7	U	5.9	U	26.4	U
Chromium	375	-	48	-	360	-
Mercury	37.7	-	1.3	JB	9.59	-
Nickel	215	-	8.1	U	76.3	-
Lead	62.1	-	190	U	81.7	-
Selenium	.68	J	0.58	J	0.72	J
Titanium	.5	U	0.49	U	.5	U

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To: ALL CHAPTER LEADERS
Larry Madl
Rick Schroeder
Ross Kirkes
Bill Weston

Memorandum

To: Long-Term Regulatory Compliance

cc: B. A. Howard
R. J. Leonard

From: Bryan Howard

Date: June 25, 1996

Subject: CCA Action Plan

Please review those portions of the attached CCA action plan and make any appropriate additions, deletions, and changes. You may note that some of the newly added appendices do not have draft and/or final due dates. Please fill in these blanks as well.

Please provide your input to me by noon on Friday, June 28, 1996.

COMPLIANCE CERTIFICATION APPLICATION

ACTION PLAN

CH.	LEAD	SUPPORT	DRAFT DUE	FINAL DUE	COMMENTS
Preface	J. Maes	Kirkes	7/26/96	8/9/96	(Insert DOE legalese here)
Ex. Sum.	Kirkes	Wagner	7/26/96	8/9/96	Final task for CCA.
1	Kirkes	Wagner	7/26/96	8/9/96	Underway.
2	Wagner	Kirkes	2/5/96	3/8/96	Complete, currently under EPA review.
3	Madl	Wagner Johns	5/31/96 Complete	6/17/96 Complete	Complete
4	Weston	Johns	Complete	Complete	Complete
5	Weston	Johns Cannon (WID) Brown (CAO)	Complete	Complete	Complete
6	Wagner	Kirkes	2 of 3 phases of production completed.	9/13/96	70% of Ch. 6 has been developed, reviewed, and finalized. Final portion is pending PA results.
7	Schroeder	Rodriguez	6/24/96	7/15/96	Underway
8	Madl	Kirkes	7/22/96	8/12/96	Chapter hinges on modelling results.
9	Weston	Kirkes	8/6/96	9/30/96	Cannot be finalized until all peer reviews have been documented.
Reference Expansions and Acquisition	McMillian	Johns	Ongoing	Ongoing	Leads MUST provide WDM all draft and final chapters.
CD ROM Interface	McMillian	ALL	Ongoing	Ongoing	Leads will review and verify CD links as provided by CTAC.
APPENDIX	**LEAD**	**SUPPORT**	**DRAFT**	**FINAL**	**TO CD-ROM**
1. AIC	Schroeder	Rodriguez	6/10/96	6/22/96	6/28/96 to CD-ROM
2. AUD	Weston		7/15/96	8/15/96	8/23/96 to CD-ROM
3. BACK	Madl				

4. BECR	Madl	Kirkes	10/20/96	10/20/96	10/20/96 to CD-ROM
5. BH	Madl	Johns	6/25/96	7/12/96	7/26/96 to CD-ROM
6. BIR	Weston		6/28/96	6/28/96	7/15/96 to CD-ROM
7. BRAGFLO	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
8. CCDFGF	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
9. CLI	Kirkes		6/7/96	6/7/96	6/15/96 to CD-ROM
10. CODELINK	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
11. CUTTINGS	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
12. DEF	Wagner		6/18/96 Complete	6/18/96 Complete	6/28/96 to CD-ROM Complete
13. DEL	Madl		7/19/96	8/9/96	8/16/96 to CD-ROM
14. EBS	Wagner		7/19/96	8/16/96	9/30/96 to CD-ROM
15. EMP	Schroeder		Complete	Complete	6/28/96 to CD-ROM
16. EPIC	Schroeder		6/28/96		
17. FAC	Wagner		Complete	Complete	Complete
18. GCR	Wagner		Complete	Complete	Complete
19. GTMP	Schroeder		unknown	unknown	unknown
20. GWMP	Schroeder		Complete	Complete	6/28/96 to CD-ROM
21. HYDRO	Wagner		Complete	Complete	Complete
22. IRD	Schroeder		Complete	Complete	6/28/96 to CD-ROM
23. IRES	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
24. MASS	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
25. MON	Schroeder		7/29/96	8/15/96	9/30/96 to CD-ROM
26. NUTS	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
27. PANEL	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
28. PAR	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
29. PEER	Weston	Wagner	8/6/96	9/30/96	9/30/96 to CD-ROM
30. PICs	Schroeder		5/17/96	5/23/96	6/7/96 to CD-ROM
31. PORSURF	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
32. QAPD	Weston		5/17/96	5/17/96	6/14/96 to CD-ROM

33. RBP	Wagner		Complete	Complete	Complete
34. SA	Kirkes	Weston	8/13/96	9/30/96	9/30/96 to CD-ROM
35. SCHED	Weston				
36. SCR	Kirkes		6/24/96	7/19/96	8/2/96 to CD-ROM
37. SEAL	Madl		9/30/96	9/30/96	9/30/96 to CD-ROM
38. SECOFL2D	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
39. SECOTP2D	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
40. SER	Wagner		5/31/96	5/31/96	6/14/96 to CD-ROM
41. SOTERM	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
42. SUM	Wagner		Complete	Complete	Complete
43. TFIELD	Kirkes		7/12/96	8/6/96	9/30/96 to CD-ROM
44. USDW	Madl		6/28/96	7/19/96	7/26/96 to CD-ROM
45. VCMP	Schroeder		Complete	Complete	6/28/96 to CD-ROM
46. WAP	Weston		6/21/96	6/21/96	6/28/86 to CD-ROM
47. WCA	Weston		6/28/96	8/12/96	9/1/96 to CD-ROM
48. WRAC	Schroeder		6/27/96	7/12/96	7/26/96 to CD-ROM

Appendix	Description
WCL	In calculating the performance of the disposal system, the DOE has to set bounding values for the waste components. Within these values, the analyses are valid, and the WIPP can be reasonably expected to comply with the disposal standards. These bounds are presented in this appendix.
WRAC	This appendix contains a feasibility study for the removal of most of the waste from the disposal system at some time in the future as discussed in Section 7.6. Conventional mining techniques, coupled with remote-handled (RH) technology, are discussed to show that, even with today's technology, such removal would be possible at any time after facility closure.

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Sandia National Laboratories

Albuquerque, New Mexico 87185

date: June 24, 1996

to: Bill Weston, Westinghouse, WIPP MS 090

JUL - 9 1996

Christine L. Northrop-Salazar

from: Christine L. Northrop-Salazar, 6841, SNL MS 1395

subject: Memo of Understanding

Upon request, a hardcopy and an electronic file of the Sandia National Laboratories' (SNL) Waste Isolation Pilot Plant (WIPP) Quality Assurance Program Description (QAPD), Revision R, are being provided for inclusion in the appendix of the Compliance Certification Application (CCA). Both the hardcopy and the electronic file provided are UNCONTROLLED COPIES. SNL personnel have verified their accuracy. Note, if the SNL's QAPD is revised after today by SNL, SNL is not responsible for notifying you of the change because you are not on controlled distribution for this document. In addition, it is not SNL's responsibility if the electronic file is altered, accidentally or intentionally, after its delivery to Westinghouse.

Bill, it has been a pleasure working with you. I am looking forward to when our paths cross again in the future.

cc: Bill McMillan, WIPP MS 260
Les Shephard, SNL MS 1395
Susan Pickering, SNL MS 1395
Amy Martinez, SNL MS 1330
SWCF-C: 1.4.03.3.1:NQ:QAPD;CCA

I received copy of SNL/WIPP QAPD on 6/27/96.

Bill Weston

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Acronyms

from chapter list

DOE	
WIPP	
USDW	Underground Source of Drinking Water
WQSP	Water Quality Sampling Program
LWA	Land Withdrawal Act
TDS	total dissolved solids
MCL	maximum contamination level
ERDA	Energy Research and Development Administration

Contaminant

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APPENDIX USDW

USDW.1 Executive Summary

The U.S. Department of Energy (DOE) must demonstrate that the Waste Isolation Pilot Plant (WIPP) may be operated and closed in compliance with the provisions and requirements of applicable U.S. Environmental Protection Agency (EPA) environmental radiation protection standards. The applicable regulations are in 40 CFR Part 191, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes.* This report has been prepared to support the DOE's documentation of compliance with the requirements of 40 CFR Part 191, Subpart C, which provides environmental standards for groundwater. It focuses on the question of whether any underground source of drinking water (USDW), as defined in Subpart C of 40 CFR Part 191, is located at or near the WIPP site. A USDW, for the purposes of 40 CFR Part 191, Subpart C, is essentially an aquifer that adequately supplies water that is fit for human consumption (see Section USDW.2).

The disposal standards in §191.24(a)(1) require that

> Disposal systems for waste and any associated radioactive material shall be designed to provide a reasonable expectation that 10,000 years of undisturbed performance after disposal shall not cause the levels of radioactivity in any underground source of drinking water, in the accessible environment, to exceed the limits specified in 40 CFR part 141 as they exist on January 19, 1994.

The National Primary Drinking Water Standards are contained in 40 CFR Part 141.

The study area, for the purposes of this report, is defined as the 10,240 acres withdrawn for the WIPP Project under the Waste Isolation Pilot Plant Land Withdrawal Act of 1992 (Pub. L. 102-579) and an area bounded by T21S through T24S, and R29E through R32E, as shown in Figure USDW-1. The study area is based on the area used for the collection of groundwater data under the WIPP Water Quality Sampling Program (WQSP). WQSP data are partially relied upon in this study to determine the potential presence of USDWs.

In addition, although any USDW located within the WIPP controlled area (the area within the WIPP site boundary as shown on Figure USDW-1) is excluded from the requirements of 40 CFR Part 191, Subpart C, WQSP data from the land withdrawal area are used in this study because the land withdrawal area has been more highly characterized during the WQSP than outlying areas. These data are considered relevant for determining groundwater characteristics of geologic units in the study area.

To assess the presence of a USDW, it is necessary for the DOE to establish mapping criteria to be applied to water quantity and quality data from wells in the study area. These DOE criteria and their bases are described in Section USDW.2. This evaluation also includes a review and summary of relevant literature pertaining to groundwater quality and quantity in the study area. The results of this review are provided in Section USDW.3.

Observation wells completed in the five water-bearing geologic units in the study area were evaluated for this study. The geologic units are

1. the Santa Rosa Sandstone of the Dockum Group (hereafter referred to as the Santa Rosa),
2. the Dewey Lake Formation (hereafter referred to as the Dewey Lake), and
3. the Culebra Dolomite Member of the Rustler Formation (hereafter referred to as the Culebra),
4. the Magenta Dolomite Member of the Rustler Formation (hereafter referred to as the Magenta), and
5. the Capitan Aquifer of the Guadalupian Reef Complex (hereafter referred to as the Capitan Aquifer).

The DOE's approach for the determination of potential USDWs in the study area is based on the establishment of mapping criteria related to groundwater quantity and quality. According to the DOE's approach, USDWs subject to the requirements of 40 CFR Part 191, Subpart C are identified in the Culebra, and, because of inconclusive groundwater production data, possible USDWs are present in the Dewey Lake and the Santa Rosa. However, as reported in Chapter 8 of this application, even if a release from the repository were to occur, maximum contaminant levels (MCLs) would not be exceeded in any USDW.

USDW.2 Criteria for the Definition of Underground Sources of Drinking Water

To determine if groundwater in the study area qualifies as a USDW, the DOE evaluated the available groundwater data relative to the applicable regulations. To complete this task, it is necessary for the DOE to establish mapping criteria so that available data can be directly evaluated relative to the regulation. The regulatory requirements and the DOE's mapping criteria for groundwater quantity and quality are addressed in this section.

USDW.2.1 Applicable Regulations

The regulatory citations that apply to the determination of a USDW are 40 CFR § 191.22 and 40 CFR § 191.23. A USDW is defined in 40 CFR § 191.22 to mean an aquifer or its portion[1] that:

> (1) Supplies any public water system; or
> (2) Contains a sufficient quantity of groundwater to supply a public water system; and
> (i) Currently supplies drinking water for human consumption; or
> (ii) Contains fewer than 10,000 milligrams of total dissolved solids per liter.
>
> "Public water system" means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Such term includes:

[1] All subsequent text of this report will use the term "aquifer" to denote an aquifer or its portion.

Figure USDW-1. Generalized Stratigraphic Cross-Section at the WIPP Site

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(1) Any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system; and

(2) Any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.

"Total dissolved solids" means the total dissolved (filterable) solids in water as determined by use of the method specified in 40 CFR Part 136.

General provisions in 40 CFR §191.23 require that:

(a) Determination of compliance with this subpart shall be based upon underground sources of drinking water which have been identified on the date the implementing agency determines compliance with subpart C of this part.

USDW.2.2 DOE's USDW Mapping Criteria

Figure USDW-1 is a decision matrix showing the DOE's systematic approach for evaluating the existing data relative to 40 CFR § 191.22. To answer the questions indicated on Figure USDW-1, the DOE established mapping criteria that can be applied to the regulatory definition of a USDW. Two general mapping criteria apply: (1) groundwater quantity and (2) groundwater quality.

USDW.2.2.1 Groundwater Quantity

The term "sufficient quantity" in 40 CFR § 191.22 (2) is not strictly defined. The components that must be considered to determine sufficient quantity include groundwater production, and duration. The DOE has established two mapping sub-criteria to be applied to these components of the groundwater quantity determination:

1. an aquifer must be capable of producing water at an adequate rate, and

2. an aquifer must be capable of producing water for a sufficient duration.

USDW.2.2.1.1 Groundwater Production

The DOE uses water-consumption information to define the first sub-criterion for mapping potential USDWs. To be conservative in the definition of a USDW, the lower of the following two values is assigned to the sub-criterion:

1. The rate, over a 24-hour period, at which water would be consumed by 15 service connections.

2. The rate, over a 24-hour period, at which water would be consumed by 25 individuals.

The rate of consumption by 15 service connections is calculated using the data provided in Table USDW-1. These are U.S. Bureau of the Census data for the number of persons per household in communities in southeastern New Mexico and water-consumption data for the

Table USDW-1. Persons Per Household and Water Consumption

Community	Persons Per Household, 1990	Gallons Per Capita Per Day
Artesia	2.69	285
Carlsbad	2.63	307
Hobbs	2.81	267
Lovington	2.96	264
Roswell	2.66	285
Average	2.75	282

Sources: U.S. Bureau of the Census 1990; Wilson 1992.

same communities. The water-consumption data are from a report prepared by the New Mexico State Engineer's Office (Wilson 1992).

The average water usage in these communities is 282 gallons per person per day. The 1990 census statistics for these communities show an average of 2.75 people per household. One household equals one service connection.

Therefore:

2.75 people × 282 gallons per person per day = 775.5 gallons per service connection per day
775.5 gallons per day per service connection × 15 connections =11,633 gallons per day
11,633 gallons per day/1,440 minutes per day = 8.08 gallons per minute.

The rate of consumption by 15 service connections is calculated to be 8.08 gallons per minute.

The rate over a 24-hour period at which water would be consumed by 25 individuals may be calculated using these same data. The average water usage is 282 gallons per person per day in area communities. The consumption of water by 25 people equals:

282 gallons per person per day × 25 people = 7050 gallons per day
7050 gallons per day/1,440 minutes per day = 4.89 gallons per minute

Based on these two calculations, the quantity consumed by 25 individuals (4.89 gallons per minute; nominally 5 gallons per minute) is smaller than the quantity consumed by 15 service connections (8.08 gallons per minute). To be conservative in the determination of the quantity derived from a well that meets the DOE's first quantity sub-criterion, the 5 gallons per minute value is applied.

Figure USDW-1. **Decision Matrix for Evaluating Existing Data Relative to 40 CFR § 191.22 to Determine USDW**

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The DOE's application of the second quantity sub-criterion (the acceptable production duration from a well) is more subjective. Because the creation of a public water supply system involves considerable capital expense, it is reasonable to assume that such a water system would not be constructed unless the water source would continue to be available for some time, at least long enough to recover the capital expense.

USDW.2.2.1.2 Duration of Groundwater Production

If a USDW were available for appropriation, a determination of the duration of the supply would be necessary for planning appropriate use. According to a representative of the New Mexico State Engineer's Office, Albuquerque District, a water appropriation is generally considered permanent (Personal Communication 1996a). Exceptions would be the short-term appropriation of a water supply for temporary use such as for a road construction project. Therefore, a USDW appropriated for a public water supply system is generally considered to be a permanent use of the resource (Personal Communication 1996a).

According to a representative of the Rural Utility Service of the U.S. Department of Agriculture (Personal Communication 1996b), loan periods for funding new rural water supplies are generally 40 years ~~long~~. Appropriation and water rights issues must be resolved with the State Engineer prior to loan approval. Based on this reasoning and the State Engineer's policy of permanent appropriations, a duration of 40 years would be appropriate for a presumed permanent source. This duration is selected for the second quantity sub-criterion; however, in performing this study it was not necessary to actually apply this sub-criterion.

USDW.2.2.2 Groundwater Quality

A criterion of 10,000 milligrams per liter of total dissolved solids (TDS) is specified in the regulations. Any aquifer producing water ~~having~~ with TDS concentrations below this level will be determined to be producing water that meets the quality criterion for a USDW. Any aquifer producing water ~~having~~ with TDS concentrations at or above this level will be determined to be producing water that does not meet the quality criterion.

USDW.2.2.2.1 Groundwater Quality Variability

In some situations groundwater quality is variable within an aquifer, and TDS concentrations may range both above and below the criterion of 10,000 milligrams per liter of TDS. In this case, TDS concentrations in groundwater obtained from a single well in the aquifer may fluctuate because of pumping. Groundwater released from storage in response to pumping may be replaced by water consisting of a different TDS concentration derived farther ~~away~~ from the pumping source. Therefore, the application of the criterion of 10,000 milligrams per liter of TDS is not straightforward and the effect of pumping on changes in groundwater quality in the aquifer must be considered. Although not used in this assessment as a defining criterion, variable groundwater chemistry is discussed where relevant.

USDW.2.2.2.2 Safe Drinking Water Act Requirements

An additional groundwater quality issue is the application of maximum contamination levels (MCLs) under the Safe Drinking Water Act (40 CFR Part 141). All drinking water supplies must comply with the established MCLs under the Primary Drinking Water Regulations. Wells in the study area that meet the 40 CFR Part 191 USDW water-quality criterion of 10,000 milligrams per liter of TDS may not meet MCLs for other constituents under the Safe Drinking Water Act. The National Secondary Drinking Water Regulations (40 CFR Part 143), although not mandatory, deal with the aesthetics of drinking water and indicate at what levels of contamination treatment may be required to make the potential source palatable for drinking water. Because the MCLs are maximum levels at the tap after treatment, the viability and economics of treatment of the groundwater for development as a USDW must be considered. Although not used in this assessment as a defining criterion, MCLs are discussed where relevant.

USDW.2.3 General History and Limitations of Groundwater Use in the Carlsbad Basin

According to the New Mexico State Engineer, water shortages have occurred in the Pecos River drainage basin since the first major irrigation projects began in the mid-1870s (New Mexico State Engineer 1991). The Pecos River drainage basin includes the following declared groundwater basins: Carlsbad, Capitan, Roswell, Hondo, Peñasco, Fort Sumner, and Upper Pecos (Personal Communication 1996f; New Mexico State Engineer 1986). The WIPP site is located within the Carlsbad Basin (New Mexico State Engineer 1995).

By the late 1920s and early 1930s, Carlsbad irrigators began an effort to obtain additional water storage in a new reservoir (Alamogordo Reservoir). At about the same time, Roswell and Artesia farmers began to drill wells into the region's aquifers. By the late 1920s, groundwater development in the area had begun to adversely affect the volume of flow in the Pecos River. This caused the State Engineer to seek new legislation and adopt a groundwater code. The Roswell Artesian Basin was declared as the State's first groundwater basin shortly afterward (New Mexico State Engineer 1991).

Portions of the Carlsbad Basin and the study area were first declared by the State Engineer in 1947. The entire Carlsbad Basin and study area became declared with the addition of new areas on June 4, 1975 (New Mexico State Engineer 1995). In 1948, the Pecos River Compact was signed by New Mexico and Texas to apportion the water of the Pecos River equitably between the two states. In 1974, Texas submitted a complaint to the U.S. Supreme Court ~~that~~ asserting that New Mexico violated the Pecos River Compact by under-delivering water at the Texas State line. In 1988, the U.S. Supreme Court adopted an amended decree that required New Mexico to make up any shortfall in annual deliveries within a six-month period.

Continued water shortages in the Carlsbad Basin and other basins associated with the Pecos River have caused the State Engineer to evaluate methods to meet the requirements of the Pecos River Compact. If the shortfall cannot be met in the future, the State Engineer will consider taking back junior rights.

According to the State Engineer records (New Mexico State Engineer 1996), no current appropriations are used for public water systems in the study area.

USDW.3 Determination of USDWs in the Study Area

Five geologic units within the study area possess groundwater that could potentially meet the definition of a USDW under Subpart C of 40 CFR 191: (a) the Capitan Aquifer of the Guadalupian reef complex; (b) the Culebra Dolomite Member (Culebra) of the Rustler Formations; (c) the Magenta Dolomite Member (Magenta) of the Rustler Formation; (d) the Dewey Lake Formation (Dewey Lake); and (e) the Santa Rosa Sandstone (Santa Rosa) of the Dockum Group. A generalized stratigraphic cross-section of the study area shows the locations of these units with respect to the WIPP site (Figure USDW-2). The Capitan Aquifer does not appear in Figure USDW-2 because it occurs approximately 10 miles north of the WIPP site boundary, outside of the cross-sectional area. The areal extent of the Capitan Aquifer is shown in Figure USDW-3.

This section describes the investigations conducted to characterize the hydrology of these formations. Important sources of relevant information are identified and findings or conclusions related to the presence of USDWs are summarized. Relevant information from personal communication conducted during this evaluation is provided in Attachment USDW-A. The study area and the locations of boreholes and wells used in this study are shown in Figure USDW-1.

USDW.3.1 Water-Bearing Formations

The Capitan Aquifer consists of a reef margin that was deposited in a continuous, narrow, arcuate-trending belt during Permian Guadalupe time (Hiss 1976). It includes the Capitan and Goat Seep Limestones and most or all of the Carlsbad facies (Mercer 1983). The Capitan Aquifer also includes the upper part of the San Andres Limestone where it cannot be readily distinguished from the Carlsbad facies and the Goat Seep Limestone (Mercer 1983).

The two rock units of Permian Age within the Ochoan Series are the Rustler Formation and the overlying Dewey Lake. The Rustler in the study area is characterized by a variable lithology consisting of interbedded sulfates, carbonates, clastics, and halite. Holt and Powers (1988) concluded that the Rustler was the depositional product of repeated transgressive and subsequent dessication events over low-relief salt pan and mud flat environments. The transgressive events produced lagoonal conditions favorable to the subaqueous deposition of clastics, carbonates (Culebra and Magenta), and sulfates (anhydrite beds) (Holt and Powers 1990).

The Culebra and Magenta dolomite members of the Rustler Formation are regionally extensive carbonate beds. Both units are generally fluid-bearing in the study area (Mercer 1983). The Culebra is an argillaceous dolomicrite containing abundant open and gypsum-filled porosity (Holt and Powers 1990). Portions of the Culebra are extensively fractured. The Culebra is generally 18- to 28-feet (5- to 9-meter) thick (Mercer 1983). The Magenta is a moderately well-indurated, arenaceous, and gypsiferous dolomite (Holt and Powers 1990).

During mapping by Holt and Powers (1990), the Magenta produced only a limited amount of fluid. The Magenta is generally 23- to 27-feet (7- to 8-meters) thick (Mercer 1983).

The Dewey Lake in the study area consists of interbedded siltstone, fine sandstone, mudstone, and claystone. Gypsum-filled fractures are abundant throughout most of the Dewey Lake. The Dewey Lake represents a transition from the marine-influenced evaporite deposition of the Rustler to fluvial deposition on a broad, low-relief, fluvial plain (Holt and Powers 1990).

The Santa Rosa is part of the Late Triassic Dockum Group. Some authors (for example, Bachman 1987) believe that there is little basis for subdividing rocks of Triassic age in southeastern New Mexico, and refer to Triassic rocks as the Dockum Group (undivided) (Holt and Powers 1990). For consistency across the study area, the term Santa Rosa is used to describe rocks of Triassic age. The Santa Rosa is only present in the eastern one-half of the WIPP site (Figure USDW-2), having been removed by erosion in the west. Where present at the WIPP site, the Santa Rosa consists of medium- to coarse-grained, micaceous sandstone and conglomerate with interbeds of siltstone and mudstone. It overlies the Dewey Lake (Figure USDW-2) and ranges in thickness from a featheredge west of test hole ERDA-9 to 176 feet (54 meters) in test hole H-10 (Figure USDW-4) (Mercer 1983).

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Figure USDW-3. Areal Extent of the Capitan Aquifer near Carlsbad, New Mexico

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Figure USDW-4. Locations of Boreholes and Wells Used for this Study

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USDW.3.2 Available Groundwater Data

Data regarding the quality and quantity of groundwater from the water bearing units in the study area was obtained from the State Engineer, numerous investigation reports, and the WIPP WQSP. The WQSP began in January 1985 to establish water quality background characterization at the site. The WQSP sampled 28 separate WIPP monitoring wells and then identified 24 of these wells for repeated sampling to establish the baseline data.

The WIPP Site Environmental Report for Calendar Year 1991 (DOE 1992) presents the results of the baseline study in which all 24 wells had been sampled at least three times. In addition to the WIPP monitor wells, the WQSP sampled 11 privately owned wells in the study area. Ten of these wells provide water for livestock and one well, the Barn Well, provides water for human consumption (DOE 1992).

Subsequent to the completion of the WIPP Site Environmental Report for Calendar Year 1991, wells have been sampled annually as part of the WQSP. In 1992 and 1993, ten well locations were sampled: eight locations in the Culebra and two privately owned wells completed in the Dewey Lake (DOE 1993, 1994). The 1994 sampling year included nine locations in the Culebra. In 1994, DOE installed six new wells in the Culebra (WQSP-1 through 6) and one well in the Dewey Lake (WQSP-6a) to assist in meeting the requirements of site characterization (DOE 1995). During 1995, sampling for groundwater quality was performed at 11 well sites, including the new WQSP locations (DOE 1996).

USDW.3.3 Underground Sources of Drinking Water

This section addresses the potential for groundwater in the study area to meet the definition of a USDW. The USDW determinations are based on the available data, including some data that were developed many years ago.

USDW.3.3.1 Determination of Potential USDWs in the Capitan Aquifer

The Capitan Aquifer occurs in a long, narrow arcuate belt that ranges from 10 miles (16 kilometers) to more than 14 miles (23 kilometers) wide. The unit is reported to be more than 1,500 feet thick in many locations in New Mexico. The Capitan is not present at the WIPP site, but is located within the study area approximately ten miles north of the WIPP (Figure USDW-3) (Mercer 1983). The determination of potential USDWs in the Capitan Aquifer is described below.

Where present, the Capitan is capable of producing a significant quantity of water. The Capitan is a USDW in the City of Carlsbad where it supplies water for most of the city, irrigation, potash refining, and livestock. Water in the Capitan is under water-table conditions southwest of the Pecos River at Carlsbad. North and east of Carlsbad, the aquifer is under artesian conditions (Mercer 1983).

Motts (1968) reported that yields from developed wells are from 1,000 to 4,000 gallons per minute. Records from City of Carlsbad wells indicate rated capacities ranging from 700 to

3,000 gallons per minute (Hendrickson and Jones 1952). These data indicate that the Capitan Aquifer meets the sub-criteria for rate of production of 5 gallons per minute.

Hiss (1973) reported the chemical quality of water in 12 observation wells located along the areal extent of the Capitan aquifer. TDS concentrations ranged from 603 milligrams per liter (City of Carlsbad Well 13; T21S, R26E, Sec.36) to 191,024 milligrams per liter (Hackberry Deep Unit 1; T19S, R31E, Sec.31).

Of the 12 observation wells tested, TDS concentrations in the City of Carlsbad Well 13 were the only analyses that met the 40 CFR Part 191 TDS criterion (Hiss 1973). Well 13 is approximately 26 miles west of the WIPP site. Wells outside the study area, approximately 16 miles north of the WIPP (Figure 3-2), had TDS concentrations ranging from 25,800 to 28,740 milligrams per liter (Middleton Federal B 1; T19S, R32E, Sec. 31) and 184,227 to 191,024 milligrams per liter (Hackberry Deep Unit 1; T19S, R31E, Sec.31). Therefore, the closest Capitan wells have TDS concentrations above the USDW water-quality criterion of 10,000 milligrams per liter and water in the Capitan Aquifer at those locations does not meet the USDW definition of a USDW.

USDW.3.3.2 Determination of Potential USDWs in the Culebra

DOE has applied the available groundwater data for the Culebra to the decision matrix in Figure USDW-1 to determine the potential presence of a USDW in the Culebra in the study area. The results of the analysis are described below.

Groundwater data from the WQSP and private wells in the study area are used to determine the potential for USDWs to occur in the Culebra (Table USDW-2). Applying the decision matrix requires evaluating groundwater production and quality data. Because the groundwater quality criterion is in the final position in the decision matrix, it can be readily used to screen data that must meet both the groundwater quality criterion and the DOE's sub-criteria for groundwater quantity.

Determining whether the groundwater is being used for human consumption is the decision matrix question linking the groundwater quantity and quality questions (Figure USDW-1). Because WIPP wells in the study area are used for environmental monitoring, no one is currently drinking from these wells. Groundwater from the private wells—Engle, Poker Trap, Mobley Well, and USGS-1—is used for livestock. Therefore, because the answer to the matrix question regarding current use for human consumption is no, a direct analysis for the matrix questions for quality and quantity can be applied. The wells that have TDS values less than 10,000 milligrams per liter are identified and then the data from this subset of wells are evaluated to determine whether these wells can produce a sufficient quantity of water.

Table USDW-2. Groundwater Data from the WQSP and Private Wells in the Study Area Used for Determining Potential USDWs in the Culebra

Well	TDS (milligrams per liter)	Sample Date	Controlled Area	USDW Subject to Part 191 Subpart C
DOE-1	130,000 130,000 130,000	4/25/85 7/3/86 7/28/87	Yes	No
DOE-2	58,000 54,000 57,500	3/12/85 8/27/86 5/19/88	No	No
H-01[1]	97,300	3/17/77	Yes	No
H-02a	13,000 11,000 10,400	4/21/86 8/12/87 1/19/89	Yes	No
H-02b[1]	8,890	2/22/77	Yes	No
H-02c[1]	12,500	3/15/77	Yes	No
H-03b3	55,000 54,000 54,000 53,400 55,000	2/4/85 5/5/86 8/24/87 3/2/89 8/15/90	Yes	No
H-04b	20,000 23,000 16,000 20,700 21,000	7/20/85 11/13/86 9/25/87 4/6/89 9/11/90	No	No
H-05b	144,000 150,000 153,000 154,000 160,000	8/27/85 5/21/86 2/24/88 8/23/89 5/2/90	Yes	No
H-06b	58,000 59,000 60,300 59,600 66,000	9/15/85 7/28/86 11/16/87 7/24/89 2/12/90	Yes	No

Table USDW-2. Groundwater Data from the WQSP and Private Wells in the Study Area Used for Determining Potential USDWs in the Culebra (Continued)

Well	TDS (milligrams per liter)	Sample Date	Controlled Area[7]	USDW Subject to Part 191, Subpart C
H-07b1	3,400	3/27/86	No	Yes[5]
	3,500	2/25/87		
	3,400	4/25/88		
	3,500	5/19/89		
	3,500	11/9/90		
H-08b	3,100	1/22/86	No	Yes[5]
	3,100	2/11/87		
	2,900	6/8/88		
H-9b	3,300	11/14/85	No	Yes[5]
	3,300	1/28/87		
	3,100	6/21/88		
	3,300	1/19/90		
H-11b3	122,000	6/4/85	Yes	No
	121,000	6/4/86		
	120,000	9/15/87		
	116,000	10/25/89		
	113,000	10/17/90		
H-12	143,000	8/9/85	No	No
	140,000	1/16/87		
	130,000	12/14/88		
H-14	18,000	5/26/87	Yes	No
	17,200	1/27/88		
	16,500	4/21/89		
H-15	230,000	5/11/87	Yes	No
	230,00	1/13/88		
	246,000	11/7/88		
H-17[2]	151,000	10/27/87	No	No
H-18	24,000	11/10/87	Yes	No
	27,900	4/7/88		
	31,000	4/10/90		
P-14	26,000	2/27/86	No	No
	29,000	6/18/87		
	29,400	3/16/88		
P-15[1]	23,700	5/10/77	Yes	No

Table USDW-2. Groundwater Data from the WQSP and Private Wells in the Study Area Used for Determining Potential USDWs in the Culebra (Continued)

Well	TDS (milligrams per liter)	Sample Date	Controlled Area[7]	USDW Subject to Part 191, Subpart C
P-17	88,000 90,000 84,000	3/17/86 12/18/86 10/21/87	No	No
P-18[1]	118,000	5/10/77	No	No
WIPP-13[2]	67,000	2/16/87	Yes	No
WIPP-19	110,000 85,400 79,000 80,000 77,200	7/14/87 2/12/88 8/29/88 11/3/89 6/13/90	Yes	No
WIPP-25	14,000 14,000 14,800 14,500	2/12/86 4/15/87 3/28/88 6/27/89	No	No
WIPP-29[2]	290,000	3/11/87	No	No
WQSP-1	77,400 66,300	8/17/95 4/11/96	Yes	No
WQSP-2	67,600 70,400	8/31/95 4/25/96	Yes	No
WQSP-3	218,000 214,000	9/19/95 5/9/96	Yes	No
WQSP-4	108,000 106,000	9/28/95 5/23/96	Yes	No
WQSP-5	43,800 33,300	11/20/95 3/12/96	Yes	No
WQSP-6	21,600 16,500	10/16/95 3/12/96	Yes	No
WIPP-26	18,000 13,000 12,800	11/25/85 4/1/87 4/14/88	No	No

Table USDW-2. Groundwater Data from the WQSP and Private Wells in the Study Area Used for Determining Potential USDWs in the Culebra (Continued)

Well	TDS (milligrams per liter)	Sample Date	Controlled Area[7]	USDW Subject to Part 191, Subpart C
Private Wells				
Engle	3,450 4,000 3,600	3/4/85 12/8/87 1/31/90	No	Possible[6]
Poker Trap[3]	2,200	7/7/88	No	Possible[6]
Mobley Well[3]	3,800	4/14/88	No	Possible[6]
USGS-1[3]	2,100 4,000	4/12/88 7/7/88	No	Possible[6]
James Brothers[4]	3,940	4/30/50	No	Possible[6]

Sources: [1] Mercer and Orr 1979, [2] DOE 1988, [3] DOE 1989, [4] Hendrickson, G.E. and R.S. Jones 1952, all others DOE 1992.

Notes: [5] Groundwater meets both the quantity (>5 gallons per minute) and quality (<10,000 milligrams per liter, TDS) criteria. Production rates for these wells: H-07b (5 and 6 gallons per minute) ,H-08b (6 gallons per minute), and H-9b (9.6 to 10.5 gallons per minute).

[6] Groundwater meets the quality criterion (<10,000 milligrams per liter, TDS), but groundwater quantity data are not available, therefore, these are possible USDWs.

[7] USDWs located within the controlled area are not subject to the requirements of Subpart C of Part 191.

Using this approach, eight wells in the Culebra produce water meeting the groundwater quality criterion of less than 10,000 milligrams per liter of TDS: H-02b, H-07b1, H-08b, H-09b, Engle, Poker Trap, Mobley Well, and USGS-1. Groundwater samples from these locations have yielded TDS values ranging from 2,100 milligrams per liter to 8,890 milligrams per liter. The application of the DOE's sub-criterion for groundwater quantity in these wells is discussed below.

Hydraulic testing of well H-02b was conducted in 1977 by bailing liquid from the cored interval in the well (Mercer and Orr 1979). The hole was bailed nearly dry during two tests and took several days to recover, indicating that the production rate and duration of production of this well would be very low. Based on this information, the well would not meet the USDW quantity criterion of 5 gallons per minute.

The pumping rate for well H-07b1 was reported to range between 5 and 6 gallons per minute when it was purged for sampling (DOE 1988). Pumping rates during purging may be greater

than long-term pumping rates. In addition, the mean sulfate concentration in the well (1,960 milligrams per liter) is nearly eight times the MCL (250 milligrams per liter). Two other wells in the Culebra have sustained pumping rates greater than the USDW quantity sub-criterion of 5 gallons per minute. The pumping rates for wells H-08b and H-09b were reported to be 6 gallons per minute, and 9.6 to 10.5 gallons per minute, respectively. Groundwater in H-07b1, H-08b, and H-09b meets both the quality criterion and the groundwater production sub-criterion. Therefore, groundwater in the Culebra at the locations of these wells is considered to be USDWs. The cost of treating water from well H-07b1 and whether it could ever be used as a USDW was not addressed but could be if further analyses are warranted.

Long-term pump tests are not routinely performed on private wells. Therefore, production rates for the private wells are not available. Because groundwater production rates from the private wells may or may not exceed the DOE quantity sub-criterion of 5 gallons per minute, the sources for Engle, Poker Trap, Mobley Well and USGS-1 are determined to be possible USDWs.

Hendrickson and Jones (1952) report TDS concentrations for an additional well in the study area. The well belongs to the James Brothers and is located southwest of the WIPP in T23S, R30E, Sec 2. Reported TDS concentrations are 3,940 milligrams per liter. No pumping information is provided. According to State Engineer records, a well located in T23S, R30E, Sec. 2 is listed under the name Brothers James, but is not a permitted or declared well (the spelling of this listing appears to represent a typographical error in the record). Because water from this well meets the quality criterion and may or may not meet the groundwater production sub-criterion, the Culebra at this location is also considered a possible USDW.

USDW.3.3.3 Determination of Potential USDWs in the Magenta

The DOE has applied the available groundwater data for the Magenta to the decision matrix in Figure USDW-1 to determine the potential presence of a USDW in the Magenta in the study area. The results of the analysis are described below.

USDW.2.2.

Groundwater data from the WQSP wells in the study area are used for determining potential USDWs in the Magenta. The data evaluation for the Magenta is applied consistently with the method described in Section USDW.3.3.3.2. This approach requires an evaluation of groundwater production and quality data. Three wells have produced water with TDS concentrations below 10,000 milligrams per liter: H-03b1, H-05c, and H-06c. Table USDW-3 presents the water quality data and pumping rates for wells completed in the Magenta in the study area.

Well H-03b1 was completed in the Magenta. Water collected from this well had TDS values ranging from 8,100 to 9,300 milligrams per liter. When water was collected for analysis, the well discharge rate was approximately 0.5 gallons per minute.

Well H-04c was also completed as a Magenta water quality monitoring well. The DOE (1992) indicates that the TDS concentrations varied from 22,000 to 24,600 milligrams per

liter. It is concluded that the Magenta, at this location, would not meet the water quality criterion of less than 10,000 milligrams per liter. does

Water collected from Well H-05c had a TDS concentration ranging from 6,800 to 7,200 milligrams per liter. The pumping rate for purging was low. The pump test rate was maintained at approximately 0.23 gallons per minute (Sandia National Laboratories 1985).

Well H-06c was originally completed in the Culebra and was recompleted by plugging the well to the Magenta as a water quality monitoring well. Water collected from this well had TDS values ranging from 4,600 to 4,800 milligrams per liter. The purging rate for this well was 27 gallons per hour or 0.45 gallons per minute. Because sustained production rates are long term, hydrogeologic experience has shown that they would generally be lower than the short-term measured purge rates; pressures tend to drop as the well is left open for longer periods.

Table USDW-3. Groundwater Data from the WQSP Wells in the Study Area Used for Determining Potential USDWs in the Magenta

Well	TDS (milligrams per liter)	Sample Date	Pumping Rate (gallons per minute)[1]	Controlled Area	USDW Subject to Part 191, Subpart C
H-03b1	8,800	7/1/85	0.25	Yes	No
	8,500	9/16/86			
	8,100	9/2/87			
	8,800	3/16/89			
	9,300	8/28/90			
H-04c	22,000	11/4/86	0.09	No	No
	24,000	10/5/87			
	23,500	7/19/88			
	24,400	4/21/89			
	24,600	10/2/90			
H-05c	6,800	10/24/86	0.23	Yes	No
	6,900	3/3/88			
	7,000	8/18/88			
	7,100	9/14/89			
	7,200	5/16/90			
H-06c	4,600	10/1/86	0.45	Yes	No
	4,800	11/4/87			
	4,800	7/26/88			
	4,800	8/4/89			
	4,800	3/15/90			

Sources: DOE 1992, DOE 1991.

[1] Notes: None of the Magenta wells meet the quantity criterion of 5 gallons per minute.

Because there's only one note, change footnote

Most of the Magenta wells yield fluids that ~~would~~ meet the water quality definition in the study area. However, the Magenta ~~would~~ not meet the sustained pumping rate of 5 gallons per minute, and consequently is not a USDW in the study area.

USDW.3.3.4 Determination of Potential USDWs in the Dewey Lake

The DOE has applied the available groundwater data for the Dewey Lake to the decision matrix in Figure USDW-1. The results of the analysis to determine the potential presence of a USDW in the Dewey Lake in the study area are described below.

Groundwater data from the WQSP and private wells in the study area ~~are~~ used for determining potential USDWs in the Dewey Lake. The data evaluation for the Dewey Lake is applied consistent with the method described in Section USDW.3.3.3.2. Six wells have produced water with TDS concentrations below 10,000 milligrams per liter: WQSP-6a, Barn Well, Ranch Well, Twin Wells, Fairview Well and Unger Well. Table USDW-4 presents the water quality data and pumping rates for wells completed in the Dewey Lake in the study area.

Several authors indicate the low potential for the Dewey Lake to contain significant amounts of groundwater. In general, the formation appears to have low permeabilities that would not be expected to sustain pumping for long durations. The description of the Dewey Lake as containing mostly low-permeability sediments has been noted by Brokaw et al. (1972), Cooper and Glanzman (1971), Griswold (1977), Mercer and Orr (1977, 1979), Mercer (1983), and Sandia National Laboratories (1979a, b, 1980, 1981, 1982, 1983).

Beauheim (1986) summarizes the results of an 11-zone hydraulic test performed in well DOE-2 that indicated the low permeability of the Dewey Lake. The Dewey Lake zone testing was conducted on September 13 and 14, 1985. The test method was a constant-head, borehole-infiltration test. The initial test idea was to inject water at a rate of 0.25 gallons per minute, which was near the lower threshold of the flow meter used, consistent with the low permeability of the Dewey Lake sediments. After observing that the interval would not take the fluids, the test was converted to a constant-head test. This test was ended for two reasons:

> (1) at an apparent inflow rate of approximately 1 ml/min, even a very small leak somewhere in the system could introduce a very large error in the flow measurement; and (2) because of the low infiltration rate observed, continuing the test until reaching steady state conditions was deemed impractical, especially considering that an unknown volume of rock had to be saturated, and the infiltration would decrease further as saturation was approached (Beauheim 1986, 33).

Table USDW-4. Groundwater Data from the WQSP and Private Wells in the Study Area Used for Determining Potential USDWs in the Dewey Lake

Well	TDS (milligrams per liter)	Sample Date	Pumping Rate (gallons per minute)	Controlled Area[7]	USDW Subject to Part 191, Subpart C
H-04c	Not Tested	-	12-15	No	Possible
WQSP-6a	4,238[1] 3,920	7/13/95 3/28/96	12[2]	Yes	No
Private Wells					
Barn Well[3]	670 720 630 650	11/4/87 4/20/88 7/27/89 6/21/90	Not Tested	No	Possible[6]
Ranch Well[3]	3,300 3,200 2,900 2,800 3,000	6/18/86 12/20/87 4/20/88 7/27/89 6/20/90	Not Tested	No	Possible[6]
Twin Wells-(Pasture Well[3])	400 390 400 410	1/30/86 8/3/88 10/20/89 5/30/90	Not Tested	No	Possible[6]
Fairview Well[3,4,5]	3,400 3,300	11/16/87 7/6/88	Not Tested	No	Possible[6]
Unger Well[3,4,5]	3,300 3,200	11/18/87 7/6/88	Not Tested	No	Possible[6]

Sources: [1] Personal Communication 1996e, [2] Personal Communication 1996f, [3] DOE 1992, [4] DOE 1988, [5] DOE 1989.

Notes: [6] Groundwater meets quality criterion (<10,000 milligrams per liter, TDS), but groundwater quantity data are not available, therefore, the wells are possible USDWs.

[7] USDWs located within the controlled area are not subject to the requirements of Subpart C of Part 191.

Mercer and Orr (1979) summarize data collection in ten wells at the WIPP site. These wells are H-01, H-03, H-03 complex (H-03a, H-03b, and H-03c), P-14, P-15, P-17, P-18, and AEC-8. The data include geology, construction details, geophysical data, and hydrologic testing data. The general discussion on important shallow geologic units suggests that "the siltstones and mudstone of the Dewey Lake Formation limit liquid transmission capability"

(Mercer and Orr 1979) (1). The zones noted in the drilling program were tested with the result of "no appreciable liquid flows were found" (Mercer and Orr 1979, 11).

The Dewey Lake was encountered during the drilling of H-04c, a WQSP well completed in the Magenta. According to a borehole data sheet (Fenix & Scisson, Inc. 1978), the borehole produced water at 190 feet (58 meters) at 12 to 15 gallons per minute. Groundwater quality data for the Dewey Lake were not obtained from the well. The well meets the groundwater quantity production criterion of 5 gallons per minute, but may or may not meet the quality criterion. Therefore, the Dewey Lake at this location is considered a possible USDW.

Well WQSP-6a was completed in the Dewey Lake and first sampled on July 13, 1995 (Personal Communication 1996d). The TDS concentration was reported by the laboratory at 11,000 milligrams per liter. However, based on the sum of the detected anions and cations in the sample, these data indicate a TDS value of approximately 4,238 milligrams per liter (Personal Communication 1996e). This is consistent with the sampling results from March 28, 1996, that indicate a TDS concentration of 3,920 milligrams per liter.

WQSP-6a had a pumping rate of 12 gallons per minute during pump testing. Initial results of the pump test indicate that the well can sustain up to 30 gallons per minute (Personal Communication 1996f). Based on initial information, it appears that the Dewey Lake, at this location, meets the water quality criterion of less than 10,000 milligrams per liter and the quantity sub-criterion of 5 gallons per minute. This indicates that the Dewey Lake meets the USDW definition at this location but, since the location is within the WIPP controlled area, this portion of the Dewey Lake is not subject to the requirements of 40 CFR Part 191, Subpart C.

Long-term pump tests are not routinely performed on private wells. Therefore, production rates for the private wells are not available. Because groundwater production rates from the private wells may or may not exceed the DOE quantity sub-criterion of 5 gallons per minute, the sources of Barn Well, Ranch Well, Twin Wells, Fairview Well, and Unger Well are determined to be possible USDWs. The Barn Well is the only private well identified in the study area that is used to supply drinking water to a single residence. The well is approximately 3.4 miles (5.5 kilometers) southwest of the WIPP. It does not currently supply 25 individuals or 15 service connections.

Hendrickson and Jones (1952) report TDS concentrations for an additional well in the study area. The James Headquarters Well (T23S, R31E, Sec. 7) southwest of the WIPP site had a TDS concentration of 3,330 milligrams per liter and an estimated yield of 10 gallons per minute. Hendrickson and Jones (1952) indicate that this well is 180 feet (55 meters) deep, screened in the Dockum Redbeds. State Engineer records indicate that a well located in T23S, R31E, Sec. 7 is listed under the name James Brothers, but that the well is not permitted or declared. The State Engineer database designates that the well is located in the Triassic (Chinle) Formation Aquifer. According to Holt and Powers (1990), the Dewey Lake is the geologic unit present at a depth of 180 feet (55 meters) in this area. Therefore, it is assumed that this well is screened in the Dewey Lake, not the Triassic units. Because this well may

meet both the quality criterion and the groundwater production sub-criterion, the Dewey Lake at this location is also considered a possible USDW.

USDW.3.3.5 Determination of Potential USDWs in the Santa Rosa

The DOE has applied the available groundwater data for the Santa Rosa to the decision matrix in Figure USDW-12 to determine the potential presence of a USDW in the Santa Rosa in the study area. The results of the analysis are described below.

Groundwater data from the WQSP and private wells in the study area are used for determining potential USDWs in the Santa Rosa. The data evaluation for the Santa Rosa is applied consistent with the method described in Section USDW.3.3.3.2. Three wells have been shown to produce water with TDS concentrations below 10,000 milligrams per liter: H-05c, Comanche Well, and Clifton Well. Table USDW-5 presents the water quality data and pumping rates for wells completed in the Santa Rosa in the study area.

Several wells east of the WIPP have been reported to be obtaining water from the Santa Rosa, but yields are reported to be small (Mercer 1983). Groundwater was present only in the lower part of the Santa Rosa in test hole H-05c. The water was under water-table conditions and was present in a sandstone immediately overlying the Dewey Lake Formation. The TDS concentration in water from H-05c was reported at 1,200 milligrams per liter, which meets the 40 CFR Part 191 USDW water-quality criterion of 10,000 milligrams per liter. Mercer (1983) indicates that other hydraulic tests were not successful, implying that lack of water in the formation at H-05c prohibited testing.

The Comanche Well is approximately nine miles east of the WIPP site and is used to supply water to livestock. Groundwater from the Comanche Well has been analyzed on two occasions (DOE 1988, 1989). TDS concentrations were reported to be 340 milligrams per liter during both sampling periods.

The Clifton Well is approximately 7.7 miles (12.4 kilometers) east of the WIPP site and is used to supply water to livestock. Groundwater from the Clifton Well has also been analyzed on two occasions (DOE 1988, 1989). TDS concentrations were reported to be 780 milligrams per liter during both sampling periods.

Groundwater quantity data for the Comanche, Clifton, and H-05c wells are not available. Because groundwater production rates from the private wells may or may not exceed the DOE quantity sub-criterion of 5 gallons per minute, these wells are determined to be located in possible USDWs.

Table USDW-5. Groundwater Data from the WQSP and Private Wells in the Study Area Used for Determining Potential USDWs in the Santa Rosa

Well	TDS (milligrams per liter)	Sample Date	Pumping Rate (gallons per minute)	Controlled Area[5]	USDW
H-05c[1]	1,200	5/24/78	Unable to test	Yes	No
Private Wells					
Comanche Well[2,3]	340 340	10/26/87 6/28/88	Not Tested	No	Possible[4]
Clifton Well[2,3]	780 780	10/28/87 6/29/88	Not Tested	No	Possible[4]

Sources: [1] Mercer 1983, [2]DOE 1988, [3]DOE 1989.

Notes: [4] Groundwater meets quality criterion (<10,000 milligrams per liter, TDS), but groundwater quantity data are not available, therefore, the wells are possible USDWs.

[5] USDWs located within the controlled area are not subject to the requirements of Subpart C of Part 191.

USDW.4 Conclusions

Five water-bearing geologic units in the study area were evaluated for determination as USDWs under Subpart C of 40 CFR Part 191: the Santa Rosa, the Dewey Lake, the Culebra, the Magenta, and the Capitan Aquifer. The DOE's approach for determining potential USDWs in the study area is based on establishing mapping criteria related to groundwater quantity and quality. According to the DOE's approach, USDWs are identified in the Culebra and the Dewey Lake. The USDW located within the Dewey Lake is within the WIPP controlled area and is therefore not subject to the requirements of Subpart C of 40 CFR Part 191. In addition, due to inconclusive groundwater production data, possible USDWs are present outside the WIPP controlled area in the Dewey Lake and the Santa Rosa.

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Personal Communication, 1996d, Ron G. Richardson, Westinghouse Electric Corporation, Carlsbad, New Mexico, and Barbara Graves, John Hart and Associates, P.A., June 6, 1996.

Personal Communication, 1996e, Richard L. Beauheim, Sandia National Laboratories, Albuquerque, New Mexico, and Barbara Graves, John Hart and Associates, P.A., July 17, 1996.

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Attachment A

Relevant Information from Personal Communications Conducted During this Study

Reference: Personal Communication, 1996a, Wayne G. Canon, Supervisor, State Engineer, Albuquerque District, and Barbara J. Graves, John Hart and Associates, P.A., May 30, 1996.

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Meeting Notes:

Barbara J. Graves, of John Hart and Associates, P.A., met with Wayne Canon , Supervisor, State Engineer, Albuquerque District, on May 30, 1996. The purpose of the meeting was to discuss the duration of appropriations for groundwater use.

Mr. Canon stated that a water appropriation is generally considered permanent. Exceptions would be the short term appropriation of a water supply for temporary use such as a road construction project.

Once a water right is obtained by a party, it is permanent unless otherwise specified. Therefore, an underground source of drinking water appropriated for a public water supply system is generally considered a permanent use of the resource.

Reference: Personal Communication, 1996b, Martha Torrez, Rural Utility Service, U.S. Department of Agriculture, and Barbara J. Graves, John Hart and Associates, P.A., June 4, 1996.

Conversation Notes:

Barbara J. Graves, of John Hart and Associates, P.A., communicated by telephone with Martha Torrez, Rural Utility Service, U.S. Department of Agriculture, on June 4, 1996. The purpose of the conversation was to discuss the funding period for development of rural water supplies.

Ms. Torrez stated that loan periods for funding of new water supplies are generally 40 years in duration. Prior to loan approval, appropriation and water rights issues must be resolved by the loan applicant with the State Engineer.

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Reference: Personal Communication, 1996c, Ron G. Richardson, Westinghouse Electric Corporation, Carlsbad, New Mexico, and William A. Trippet II, John Hart and Associates, P.A., January 8, 1996.

Meeting Notes:

William A. Trippet II, of John Hart and Associates, P.A., met with Mr. Ron Richardson of the Westinghouse Waste Isolation Division at the WIPP site on January 8, 1996. The purpose of the meeting was to obtain data from the wells WQSP-6a, H-2a, H-3b1, H-5c, and H-6c. The following discussions occurred in the meeting:

- WQSP-6a was completed in the Dewey Lake Formation. It was sampled on July 13, 1995; the concentration of TDS was measured at 11,000 milligrams per liter. The well, reportedly, had a fairly good pumping rate; INTERA Inc. has recently conducted a pump test and is now in the process of reducing the data.

- Well H-2a has a TDS that is variable, but generally over 10,000 milligrams per liter. Mr. Richardson said that the pumping rate ranges between 15 and 20 gallons per hour. This is equivalent to 0.25 to 0.33 gallons per minute. If the well has a purge rate of 15 to 20 gallons per hour, the production rate to supply water over an extended period (that is, years) would be less than the purge rate

- H-3b1 was completed in the Magenta. When water was collected for analysis, the well discharge rate was approximately 0.5 gallons per minute.

- Well H-5c was completed in the Magenta. The pumping rate for purging was low. The pump test rate was maintained at approximately 0.23 gallons per minute (Sandia National Laboratories 1985). It was concluded that the Magenta Dolomite Member, at this location, does not meet the USDW quantity criterion of 5 gallons per minute over an extended period.

- Well H-6c was originally completed in the Culebra Dolomite Member and was recompleted by plugging back into a Magenta water-quality monitoring well. The well was last sampled on May 2, 1991, and the TDS value was 4,800 milligrams per liter. The substantial purging rate for this well was 27 gallons per hour or 0.45 gallons per minute. It was concluded that the Magenta Dolomite Member, at this location, does not meet the USDW quantity criterion of 5 gallons per minute over an extended period.

The H-4c well, which was completed as a Magenta water-quality monitoring well, was not discussed. Report DOE/WIPP 92-007 indicates that the TDS varied from 22,660 to 24,720 milligrams per liter at the 95% confidence level. It was concluded that the Magenta Dolomite Member, at this location, would not meet the USDW quality criterion of less than 10,000 milligrams per liter TDS.

Reference: Personal Communication, 1996d, Ron G. Richardson, Westinghouse Electric Corporation, Carlsbad, New Mexico, and Barbara Graves, John Hart and Associates, P.A., June 6, 1996.

Meeting Notes:

Barbara J. Graves, of John Hart and Associates, P.A., met with Mr. Ron Richardson of the Westinghouse Waste Isolation Division at the WIPP site on June 6, 1996. The purpose of the meeting was to obtain data regarding the WQSP.

The following discussions occurred in the meeting:

According to Ron Richardson, well WQSP-6a was completed in the Dewey Lake Formation and first sampled on July 13, 1995. The TDS was reported by the laboratory at 11,000 milligrams per liter. However, Mr. Richardson found that the reported value is inaccurate, based on the sum of the detected anion and cations in the sample. These data indicate a TDS value of approximately 4,238 milligrams per liter. This is consistent with the sampling results from March 28, 1996, that indicate a TDS concentration of 3,920 milligrams per liter.

WQSP-6a reportedly had a fairly substantial pumping rate during development. INTERA Inc. recently conducted a pump test and is currently reducing the data. Based on initial information, it appears that the Dewey Lake Formation, at this location, meets the water quality criterion of less than 10,000 milligrams per liter of TDS and may meet the quantity sub-criterion of 5 gallons per minute. The well is designed and used only for groundwater monitoring within the controlled area and would, therefore, be excluded from determination as a USDW.

Reference: Personal Communication, 1996e, Richard L. Beauheim, Sandia National Laboratories, Albuquerque, New Mexico and Barbara Graves, John Hart and Associates, P.A., July 17, 1996.

Conversation Notes:

Richard L. Beauheim provided information via telephone to a representative of WIPP who then provided Barbara J. Graves, John Hart and Associates, P.A., with written documentation of the conversation. This communication occurred during a comment resolution meeting held at Sandia National Laboratories Offices, Carlsbad, New Mexico, on July 17, 1996.

The following information was provided regarding WQSP-6a:

Transmissivity = 400 ft^2/day

Maintained pump rate - 12 gallon/minute during pump test

- 4 psi draw down, but fracture production makes interpretation difficult (12, 16, or 20 psi draw down?),

- 23 ft producing thickness (185 to 207 ft.), and

- Believes 30 gallon/minute can be sustained.

Reference: Personal Communication, 1996f, Kenneth Fresquez, Water Resource Engineering Specialist, State Engineer, Roswell District, and Barbara J. Graves, John Hart and Associates, P.A., July 31, 1996.

Conversation Notes:

Mr. Fresquez provided the information that the Capitan Basin is included in the Pecos River drainage basin. The basin also includes the following declared groundwater basins: Carlsbad, Roswell, Hondo, Penasco, Fort Sumner, and Upper Pecos (New Mexico State Engineer, 1986). The WIPP site lies within the Carlsbad Basin (New Mexico State Engineer 1995).

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APPENDICES

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Appendix AIC – Active Institutional Controls
Appendix AUDIT – Program Audits
Appendix BACK – Control of the Chemical Environment Through Implementation of an MgO Backfill Materia
Appendix BECR – Waste Isolation Pilot Plant Biennial Environmental Compliance Report DOE/WIPP 94-021(
Appendix BH – Waste Isolation Pilot Plant Borehole Data Report DOE/WIPP 95-2092 Rev. 1, (July 1996
Appendix BIR – Transuranic Waste Baseline Inventory Report DOE/CAO-95-1121 Rev 2+3 (Dec 95, June 96
Appendix BRAGFLO – WIPP PA User's Manual for BRAGFLO, Version 4.00 Docmat version 1.01 WPO# 30703 Jan 3
Appendix CCDFGF – Design Document for CCDFGF + GRIDFLO WPO# 31235 July 7th File design.doc (3 files)
Appendix CLI – Long-Term Climate Variability at the Waste Isolation Pilot Plant, Southeastern New Mexico, USA SAND91-7
Appendix CODELINK – The WIPP 1996 Performance Assessment Code and Their Linkages, Aug 12, 1996
Appendix CUTTINGS – WIPP PA User's Manual for CUTTINGS_S, Version 5.03, Docmat Version 1.00 WPO# 37765.
Appendix D&D – Conceptual Decontamination and Decommissioning Plan for the Waste Isolation Pilot Plant, DOE/WIPP-95-207
Appendix DEF – Deformation
Appendix DEL – Delaware Basin Study
Appendix EBS – ~~EBS~~ Engineered Alternatives Cost/Benefit Study, DOE/WIPP 95-2135, Sept 1995
Appendix EPIC – Effectiveness of Passive Institutional Controls in Reducing Inadvertent Human Intrusion into the WIPP
Appendix FAC – Facies Variability and Post-Depositional Alteration within the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant, Southeastern, New Mexico, DOE/WIPP 88-004
Appendix GCR – Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Aug 1998
Appendix GENII – WIPP PA User's manual for PREGEN II, Version 6.21, Docmat Version 4.00 WPO# 37763, WPP PA Users Manual for GENII-A, Version 2.10 Docmat version 1.00, WPO # 27751, Nov 13, 1995.
Appendix GWMP – Groundwater Hydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medaños Area, Southeastern New Mexico
Appendix HYDRO – Implementation of the Resource Disincentive in 40CFR Part 191.14(e) at the Waste Isolation Pilot Plant
Appendix IRD – Intermediate Results, August 12, 1996.
Appendix IRES – Supplementary Information on Modeling Assumptions, August 12, 1996
Appendix MASS – Pre-Closure and Long-Term Monitoring – August 12, 1996
Appendix MON – WIPP PA User's Manual for NUTS, Version 2.02, Docmat Version 1.00, WPO# 37727, May 29, 1996
Appendix NUTS – WIPP PA User's Manual for PANEL, Version 3.60 Docmat Version 1.00, WPO# 37361, Aug 10, 1996
Appendix PANEL – ~~Panel Closure System~~ Detailed Design Report for an Operational Phase Panel Closure System, DOE/WIPP 95-2
Appendix PCS – Parameters
Appendix PAR – Poor Review
Appendix PEER – Passive Institutional Controls Conceptual Design Report, Revision 0, May 1996
Appendix PICS – Porosity Surface Method
Appendix PORSURF – US DOE Carlsbad Area Office Quality Assurance Program Document, Revision 1, 4/22-96, WID Quality Assurance Program Description, WP 13-1, Revision 16, May 3, 1996.
Appendix QAPD – Statistical Summary of the Radiological Baseline Program for the Waste Isolation Pilot Plant, DOE/WIPP 92-03
Appendix RBP – ~~Appendix RE~~
Appendix SA – Sensitivity Analysis, Aug 12, 1996
Appendix SCR – FEPs Screening, Aug 12, 1996
Appendix SEAL – Waste Isolation Pilot Plant Shaft Sealing System Compliance Submittal Design Report, SAND96-1326 Aug 1996
Appendix SECOFL2D – WIPP PA User's Manual for SECOFL2D, Version 3.03, Docmat Version 1.01, WPO# 37
Appendix SECOTP2D – WIPP PA Users Manual for SECOTP2D, Version 1.30, Docmat Version 1.01 WPO# 36675, A
Appendix SER – Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1995, DOE/WIPP 96-2184
Appendix SOTERM – Source Term, Aug 12, 1996

*Appendix SUM Summary of Site-Characterization Studies Conducted from 1983 through 1987 at the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 88-0157

✓Appendix TFIELD Generation of an Ensemble of Cuebra Transmissivity Fields Conditioned to Steady-State and Transient Pressure Data Using GRASP-INV, August 12, 1996

Appendix USDW - Underground Sources of Drinking Water, August 12, 1996

*Appendix VCMP - Volatile Organic Compound (VOC) Monitoring Plan

Appendix WAP - Waste Analysis Plan (DOE/WIPP 91-005)

Appendix WCA - Waste Characterization Analysis, August 12, 1996

Appendix WCL - Waste Component limits, August 12, 1996

Appendix WRAC - Post-Disposal TRU Waste Removal Feasibility Analysis

Appendix XRE - Reference Expansion, August 12, 1996

✓* Appendix LMP - Land Management Plan

✓* Appendix DUR - Design Validation Report DOE-WIPP-86-010

✓* Appendix GTMP - Geotechnical Monitoring Plan

✓ Appendix SMP - Subsidence Monitoring Plan

✓ Appendix DMP - Drilling Monitoring Plan

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✓ [redacted] GRASP-INV - attachment to [redacted] TFIELD

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Chapter 1
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The following appendices are included in the application:

Appendix	Description
BH	Numerous boreholes have been drilled around the WIPP site for characterization purposes and for monitoring. These include holes for geological, hydrological, potash and soil investigations. Information and data from many of these holes were used in the preparation of Chapter 2.0. A compendium of these holes, along with summary physical and geological information is provided in Appendix BH. In addition, reference tables for non-WIPP holes (such as oil wells) that have been used in both site and regional studies by various investigators are provided in Appendix BH.
AIC	This appendix includes the DOE's plans for active institutional controls that will be used immediately following facility closure. The appendix provides the rationale for the design and the details of the various measures that the DOE intends to take for active institutional control. Active institutional controls are summarized in Section 7.1.
AUD	The CAO QAPD requires that the WIPP participants undergo independent QA assessments (audits and surveillances) to ensure compliance to the requirements of NQA-1, NQA-2, Part 2.7, and NQA-3. This appendix documents audits and surveillances conducted recently that were not included in Chapter 5.0 directly.
BACK	A backfill consisting of MgO has been defined for the WIPP facility as an engineered barrier. It substantially delays the movement of radionuclides by limiting their solubility. Its configuration is defined in Chapter 3.0. This appendix contains background information on its purpose and distribution. Backfill fulfills the requirement for implementing the concept of multiple barriers in Section 7.4.
BECR	The Biennial Environmental Compliance Report is required by the WIPP LWA. It summarizes the DOE's compliance with applicable environmental protection standards.
BIR	The DOE has assembled a database of waste information that serves to define the waste-related parameter values for the performance assessment. These data are tabulated in Chapter 4.0. This database covers existing waste and estimates of future waste. The most recent version of this database is in this appendix.
BRAGFLO	BRAGFLO estimates brine and gas flow everywhere within the controlled area and beyond from the Castile to the surface. Conceptual models implemented in BRAGFLO are discussed in Section 6.4. BRAGFLO couples the flow of brine and gas to other important repository processes such as creep closure and gas generation. The resulting brine-phase, transient flow fields are used by NUTS to simulate radionuclide transport in these flow fields.
CCDFGF	CCDFGF is used to calculate and present statistical performance assessment results. CCDFGF scales BRAGFLO and SECOTP2D results to match radionuclide outputs calculated by NUTS and PANEL. It combines all the calculated release data to simulate many different repository histories, generating random sequences of future events, calculating the probabilities associated with those random sequences, and preparing the data required to produce the CCDF plots that summarize the WIPP's predicted performance as presented in Section 6.5.
CLI	Appendix CLI is a technical study that was performed to determine climate changes in the recent past as a means of anticipating further changes in the next 10,000 years. Climate variation is modeled as described in Section 6.4.9 and Appendix MASS.
CODELINK	This appendix presents overviews of and backgrounds for (1) the principal codes, and (2) the principal code-linkage sequences that support the 1996 performance assessment as reported in Chapter 6.0. Detailed user's manuals, one for each performance assessment code, have been compiled and archived as part of the QA procedure for the performance assessment, and functional descriptions of each modeling code are included elsewhere as appendices.
CUTTINGS	This appendix describes the CUTTINGS_S code. This code estimates the direct removal of radionuclides from the repository as the result of penetration by a borehole inadvertently drilled into the disposal system at some time in the future. The word direct refers to the fact that CUTTINGS_S releases to the surface occur at the time of drilling. The conceptual models for direct release are discussed in Section 6.4.7.
D&D	The DOE has prepared an initial decommissioning and decontamination (D&D) plan for the facility. This plan is in this appendix. A final plan will be prepared just prior to final closure and will reflect the condition of the facility at the time of closure. Documents and regulations applicable to D&D are included in this appendix. This activity precedes active institutional controls as discussed in Section 7.1.
DEF	The DOE conducted numerous investigations to resolve the issues surrounding deformation of the evaporites and dissolution of salt. This appendix summarizes those investigations and the conclusions reached as the result. This supplements the summary information in Chapter 2.0.

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Appendix	Description
DEL	The DOE has compiled information regarding drilling in the Delaware Basin. This appendix includes a summary of current drilling practices, current well-plugging practices, presents an inventory of deep and shallow wells, and proposes assumptions for the inadvertent human intrusion scenarios in the performance assessment. These data are used in the performance assessment. Section 6.4 contains the conceptual model of drilling.
DMP	This appendix contains the Delaware Basin drilling activity surveillance program as described in Section 7.2. This program will focus on those drilling activities whose changes over time may impact the disposal system. These may include drilling rates, drill diameters, and borehole plugging practices.
DVR	The Design Validation Report discusses the analysis used in the design of the disposal system.
EBS	The DOE performed a study of engineered barriers in accordance with the criteria in 40 CFR Part 194. The final report of this study is contained in this appendix. This study was peer reviewed and those results are summarized in Chapter 9.0 and Appendix PEER. This supports the concept of multiple barriers in Section 7.4.
EMP	The WIPP Environmental Monitoring Plan (EMP) is included in Appendix EMP. It describes the ongoing environmental sampling activities at the WIPP. Results are reported annually. The EMP encompasses all possible environmental pathways along which humans may be exposed to radionuclides. Media sampled include groundwater, surface water, soil, air, airborne particulate, penetrating radiation, vegetation and other biota. The EMP is relevant to the background environmental conditions discussed in Chapter 2.0.
EPIC	This appendix provides the DOE's rationale for taking credit for 700 years of passive institutional controls in the calculation of the performance of the disposal system. This means that the likelihood of an inadvertent intrusion during this period of time is significantly diminished by active and passive institutional controls. This appendix supports the discussion of passive institutional controls in Section 7.3.
FAC	The WIPP shafts provided an excellent opportunity to study the sediments and evaporites at the WIPP site. This report provides in-depth interpretations of the geological evidence in the shafts and proposes depositional theories for the rocks of the site region. This report is the source of some of the detailed lithological information in Chapter 2.0.
GCR	Much of Chapter 2.0 was prepared based on the 1978 Geological Characterization Report prepared by Sandia National Laboratories (SNL) as a summary of the investigations performed for the WIPP. It includes a summary of work performed in the area by numerous other scientists as well as specific studies funded by the federal government specifically for selecting a radioactive waste disposal facility site. The basic geological features such as stratigraphy, lithology, geomorphology, physiography are established in this report. Discussions of regional features such as dissolution and deformation are included; however, conclusions regarding many of these features are reserved for later studies (see, for example, Appendices SUM and DEF).
GENII	This appendix contains the code manuals for the numerical codes used to calculate the doses to human receptors as the result of releases to the accessible environment.
GTMP	This appendix contains the geotechnical surveillance program that the DOE currently operates at the WIPP site and plans to continue to operate as part of the preclosure monitoring system as discussed in Section 7.2. The program will focus on observations of excavation effects such as creep closure and stresses that are useful in detecting deviations in expectations for near-term disturbed rock zone development.
GWMP	This appendix contains the groundwater surveillance program that the DOE currently operates at the WIPP site and plans to continue to operate as part of the pre- and postclosure monitoring system as discussed in Section 7.2. The program will focus on those characteristics of the Culebra, Magenta Member of the Rustler, and Dewey Lake whose changes over time may be diagnostic of changes in the disposal system. These include water salinity and water levels.
HYDRO	The USGS performed investigations and offered interpretations of the hydrological regime in the region around the WIPP site. Much of the subsequent hydrological testing and modeling are the results of the initial observations reported in Appendix HYDRO. Significant portions of the hydrological data in Chapter 2.0 are derived from this report.
IRD	This appendix supports the discussion in Section 7.5 and documents that the DOE considered natural resources and their impact during site selection and characterization. This discussion, along with the analysis of disposal system performance in Chapter 6.0, shows that the favorable features of the WIPP compensate for any increased risk from the presence of resources.
IRES	This appendix contains intermediate results calculated during the performance assessment including Latin hypercube sampling (LHS) output for each of the three replicates, time dependent shaft-seal permeabilities used in BRAGFLO, and actinide concentrations as discussed in Chapter 6.0.
MASS	Numerous modeling assumptions are used to simplify the calculations when such simplifications are justified. This appendix discusses the major modeling assumptions that are used in the WIPP performance assessment and attaches appropriate supportive information. Numerous references to Appendix MASS occur in Chapter 6.0. The appendix also discusses some alternative approaches that were considered by the DOE in developing the conceptual model.

Appendix	Description
MON	The DOE has conducted an analysis of the significant performance assessment parameters to determine which, if any, are candidates for monitoring. This analysis is included in this appendix along with the details of how the DOE has selected the parameters that will be subject to monitoring and the rationale for the monitoring methods that are planned as discussed in Section 7.2.
NUTS	NUTS is a radioisotope transport code that is used for the analysis in Chapter 6.0. Its principal capabilities are (1) to decay the inventory, using Bateman's equations, and (2) to transport radionuclide through porous or fractured media. NUTS is capable of resolving and tracking many individual radioisotopes.
PANEL	PANEL is a radionuclide mobilization and decay code that is used for the analysis in Chapter 6.0. Its principal functions are (1) to decay the inventory, using Bateman's equations, and (2) to use the decayed inventory together with the repository brine volume and outflow rate, and the dissolved and colloidal actinide source terms, to estimate the quantity of all modeled radionuclides that are transported up the intrusion borehole.
PAR	Specific parameters are identified in Section 6.4 as necessary to describe the geological system, the hydrological system, engineered systems, and the waste for the purposes of numerical modeling. The parameter values, listed as either ranges or constants, are included in Appendix PAR. Parameter values in Appendix PAR go directly into the performance assessment.
PCS	Chapter 3.0 discusses the closure of filled waste panels. This appendix contains the design of the Panel Closure System that will be used to close waste panels after they are filled. This closure contains conventional cement and block components to ensure that ventilation air will not enter a closed panel, thereby limiting the amount of volatile organic compounds that may be in the mine air at any given time.
PEER	This appendix includes the details of the peer reviews that are discussed in Chapter 9.0. Included are the results of the peer panels deliberations, comments, and DOE responses.
PIC	This appendix contains the DOE's design for passive institutional controls as discussed in Section 7.3. This involves a defense in depth approach that includes monuments, markers, records and archives in addition to continued federal control of the land. The details of the designs and messages to be used are provided.
PORSURF	Creep closure of the excavation and the presence of either brine or gas in the waste disposal region both influence the time-dependent changes in void volume in the waste disposal region. In order to vary them in a calculationally efficient manner, a porosity surface is generated. This surface is used by the BRAGFLO code to indirectly couple mechanical closure of the excavation and gas generation to the two-phase fluid flow calculations. This appendix discusses how the porosity surface is generated.
QAPD	The CAO QAPD defines the QA requirements that are applicable to WIPP quality affecting activities. DOE contractors, specifically Westinghouse Electric Corporation and SNL, have prepared QAPDs that are tiered to the CAO's QAPD. All three are provided in this appendix. The QAPDs are an integral part of the Quality Assurance Program described in Chapter 5.0.
RBP	The first three years of environmental sampling that were conducted at the WIPP site were designed to compile the radiological baseline described in Chapter 2.0 against which future sampling will be compared. These comparisons will allow the DOE to identify instances where the environmental conditions are deteriorating. The DOE investigates all deteriorating environmental conditions to determine if WIPP activities are the cause. Mitigative actions can be taken based on ongoing observations to ensure no irreparable damage results from WIPP activities.
SA	The final step in a Monte Carlo study is sensitivity analysis, which provides information about the sensitivity of the modeling system to uncertainty in specific input parameters. Appendix SA is the sensitivity analysis for the performance assessment described in Chapter 6.0.
SCR	The natural FEPs that have been identified for the WIPP site region and are discussed in Chapter 2.0 are screened for inclusion in the performance analysis. Appendix SCR documents the screening process and decisions.
SEAL	The final design for repository seals is described in Chapter 3.0. This appendix provides the details of the design, including component descriptions, performance predictions, and materials selections. Seal parameters are an input to Chapter 6.0. The seal conceptual model is discussed in Section 6.4.4.

Appendix	Description
SECOFL2D	The SECOFL2D code calculates a groundwater flow field. The two-dimensional groundwater flow is governed by Darcy's Law. Different hydrological transmissivities are specified in the code for every node throughout the region because they vary from node to node. Direct measurements of Culebra transmissivities exist at a number of locations throughout the WIPP region. The DOE used those data to generate an ensemble of fields that define transmissivity values at each node in the computational domain.
SECOTP2D	For each flow field, SECOTP2D (1) combines the flow results with material and transport parameters that affect radionuclide transport in the Culebra, (2) calculates the concentration of radionuclides everywhere in the local domain as a function of time, and (3) calculates the integrated discharge across user-defined boundaries. The conceptual model implemented by SECOTP2D for the performance assessment is discussed in Section 6.4.6.2.
SER	The DOE reports environmental conditions at the WIPP and in the vicinity as far away as Hobbs and Carlsbad in an annual site environmental report. The most current report, summarizing environmental measurements made during 1995, is included as Appendix SER to augment the summary background environmental conditions in Chapter 2.0.
SMP	This appendix contains the subsidence surveillance program that the DOE plans to operate as the postclosure monitoring system as discussed in Section 7.2. This program monitors subsidence. Subsidence predictions will be compared to actual measurements to investigate any potential deviations that may indicate a change in repository performance.
SOTERM	This appendix describes the actinide source term for the WIPP performance calculations in Chapter 6.0. The source term is defined by the sum of dissolved actinide species and mobile colloidal actinide species. Appendix SOTERM establishes the mobile concentration of actinides that may be released from the repository in brine.
SUM	Following the final selection of the site in 1980 and a review by the NAS and the EEG, numerous additional studies were identified to resolve specific site-related issues. These included regional studies, site studies, and underground tests. These were, for the most part, to a point of completion in 1988 that the DOE could prepare a summary of the findings and offer revised interpretations of geological relationships. These results were definitive in developing conceptual models for the FEPs that were expected to act on the WIPP disposal system. This report is the source of some of the detailed information in Chapter 2.0.
TFIELD	GRASP-INV is used outside of the performance assessment. It generates a field of transmissivities in the Culebra for a regional scale for each of the *n* input vectors. The conceptual model implemented by these codes for the performance assessment is described in Section 6.4.6.2.
USDW	The criteria in 40 CFR Part 194 mandate a map showing the location of any underground source of drinking water within the vicinity of the controlled area as discussed in Chapter 8.0. This appendix includes an analysis of the available groundwater information and concludes, based on limited information, that there are three possible underground sources of drinking water near the WIPP controlled area. One is in the Dewey Lake Redbeds, another is in the Santa Rosa Formation, and the other is in the Culebra Member of the Rustler Formation.
VCMP	This appendix describes the volatile organic compound confirmatory monitoring plan that will be used to evaluate the efficacy of panel closures. The DOE believes that these measurements may provide information regarding the gas generation process and creep closure processes in closed panels as discussed in Section 7.2.
WAP	The DOE has prepared a comprehensive plan for determining the physical and chemical characteristics of the waste as required by the RCRA. This plan (referred to as the Waste Analysis Plan or WAP) specifies acceptable sampling and analysis techniques and establishes data quality objectives for characterization. In addition, it defines the methodology for collecting and using acceptable knowledge in the characterization process.
WCA	The certification criteria state that the DOE shall perform an analysis of the TRU waste to determine the components that are important to disposal system performance. This analysis, which supports the description of waste components in Chapter 4.0, is presented in this appendix.